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1. EXECUTIVE SUMMARY

The coastal EGIM (cEGIM) is a module designed for the JERICO community to ease and foster the observation of coastal parameters in an interoperable fashion. A prototype was built in order to demonstrate its concept through a demonstration that will take place at a Coast-HF site offshore Luc-sur-Mer, part of the English Channel Pilot Super Site. The prototype is fitted with four sensors (NKE MP6, BBE Moldaenke Fluoroprobe, Hydroptic / LOV UVP6 and SATLANTIC ISUS) lent by JERICO-S3 partners. It is designed to sit on the seabed. A pre-demonstration of the prototype implementation and its associated data access chain took place from 16 December 2022 to 9 February 2023. The module was installed at the shallow-water site of Sainte-Anne du Portzic, where it could export its measurement data to a dedicated web server conforming to the Sensor Web Enablement OGC framework. The cEGIM embeds a bloom detection algorithm that could be fine-tuned during the pre-demonstration. After this pre-demonstration, some lessons were learnt, the cEGIM prototype was reconditioned and is deemed ready for the demonstration.

2. INTRODUCTION

In the framework of Jerico-S3, the need was expressed that the JERICO community can use a module for measuring a set of common variables in a number of locations in an interoperable fashion. Furthermore, this module should be able to host specific sensors or samplers, while respecting JERICO data flow and interoperability principles and being able to host the intelligent services planned within the Jerico-S3 objectives. Considering that a convergence with EMSO technology would benefit both the EMSO and JERICO communities, it was decided that this module, named coastal EGIM or cEGIM, would be derived from the EGIM: the EMSO Generic Instrument Module, developed in the framework of EMSOdev project (Grant agreement N°676555) and exploited by the EMSO ERIC.

However, it was found at the beginning of JERICO-S3 that the EGIM concept for open ocean was not fully transposable to coastal observation, where:

- the measurand range may greatly vary from one site to another, preventing the prescription of the same sensor reference everywhere, as the EGIM does,
- the environmental and implementation conditions may greatly vary from one site to another, preventing the use of a common mechanical design of the instrument module, as it was done for the EGIM.

Therefore, the main benefits expected from the coastal EGIM do not lie in the standardization of its sensors or mechanical setting but mainly in the use of its core electronic unit, which brings:

- A high TRL and high reliability solution for interfacing sensors and communication systems,
- Versatility as it can operate in a variety of coastal environments: underwater (benthic or water column), at the sea surface (buoys) or on jetties, pontoons etc, either autonomously or linked to an energy/communication link,
- Access to a wide library of existing sensor drivers, inherited from coastal and open ocean applications,
- Openness: easy integration of new sensors and functions, that will in turn benefit the whole cEGIM user community,
- Possibility of adaptive sampling based on innovative data science algorithms,
- Technical convergence with EMSO Generic Instrument Module,
- Interoperability.

This common core electronic unit is named COSTOF2 (Communication and Storage Front-end, 2nd generation), a marine sensor data acquisition device designed by Ifremer and widely used in coastal as well as open ocean applications.

3. MAIN REPORT

3.1. cEGIM prototype description

The project budget would not allow for the purchase of the sensor payload of the cEGIM prototype. Therefore, a call for available sensors was launched among Jerico-S3 partners, that resulted in the provision of the following sensors for the sake of the pre-demonstration and demonstration:

Manufacturer	Reference	Main measurands	Lending partner
NKE	MP6	Temperature, Conductivity, Depth, Dissolved Oxygen, Turbidity, Fluorescence	IFREMER
BBE Moldaenke	Fluoroprobe	Chlorophyll	IFREMER
Hydroptic / LOV	UVP6	Pictures	LOV
SATLANTIC	MBARI-ISUS	Nitrate concentration	IFREMER

In other respects, the knowledge of the demonstration site was essential to design an instrument module that would meet its specific implementation constraints. After a rigorous selection process, the demonstration site turned out to be under the SMILE buoy (of the COAST-HF French National Observation Service) of the English Channel Pilot Super Site, on an 18 m water depth sandy seabed.

Then, the cEGIM prototype would comprise:
- a mechanical frame able to be brought and sit on the seabed while hosting:
- 1 energy container supplying power to a COSTOF2 and the sensors listed above,
- 1 COSTOF2 rated 200 m and hosting an Odroid HC4 board inside its pressure housing,
- the sensor payload defined above,
- the set of cables/connectors necessary to interconnect the above-mentioned subsets.

The electrical diagram of the cEGIM prototype is shown below:

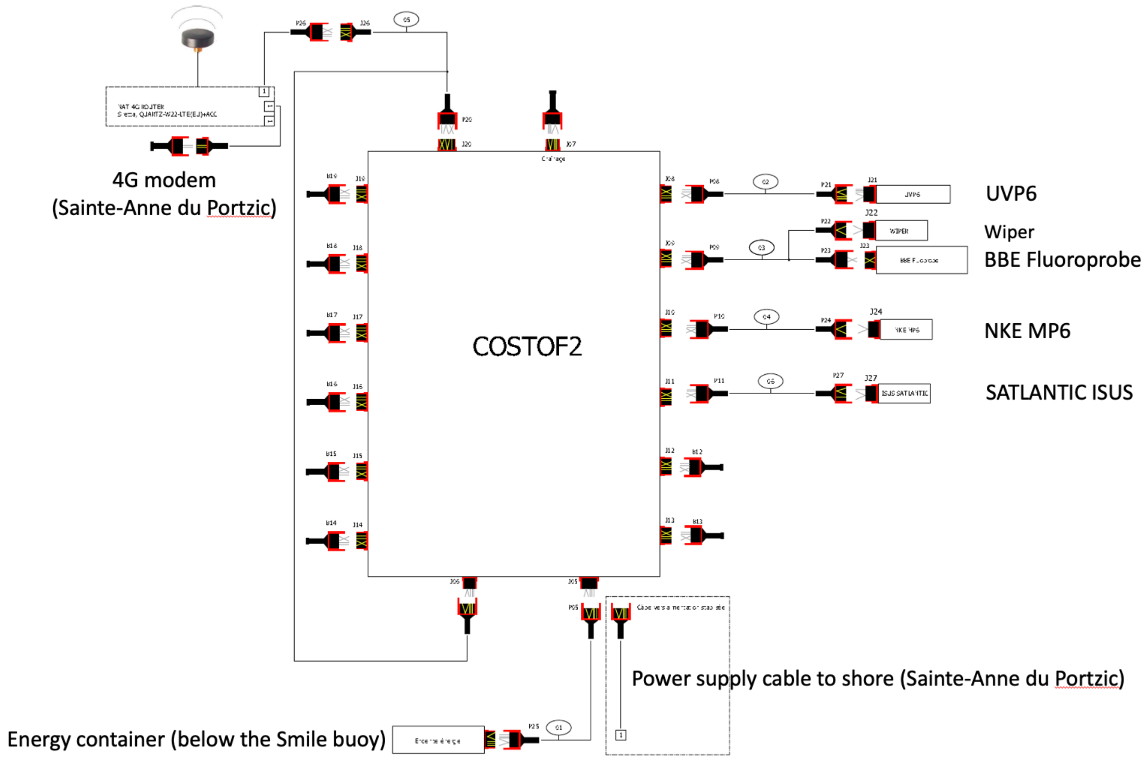


Figure 1 – Electrical diagram of the cEGIM

Two different electrical settings are foreseen:
- for the pre-demonstration at Sainte-Anne du Portzic, the module is powered from shore and able to communicate with the shore thanks to a 4G-modem,
- for the demonstration under the Smile buoy, the module will be fitted with a 4-kWh energy container and will not be able to communicate with the shore.

Figure 2 – cEGIM at the end of its assembly. The frame dimensions are 1200 x 800 x h915 mm. ©Ifremer / Tanguy Bescond

The JERICO-S3 project is funded by the European Commission's H2020 Framework Programme under grant agreement No. 871153. Project coordinator: Ifremer, France.

3.2. cEGIM prototype main building and test steps

26/07/2021	COSTOF2 delivered to IFREMER (first 200 m version manufactured). Reception tests.
21/03/2022	final sensor list available. Launch of the mechanical and electrical design detailed study (IFREMER).
31/05/2022	MP6, ISUS and BBE delivered to the development team. Launch of the sensor drivers development (IFREMER and UPC). First communication tests between sensors and COSTOF2.
07/06/2022	start of energy container design.
06/10/2022	UVP6 delivered to IFREMER. Hardware failure discovered on BBE, requiring a return to the manufacturer.
20/10/2022	first tests of UVP6. Development and fine-tuning of its driver. Start of cable assemblies fabrication.
03/11/2022	mechanical subparts delivered. Start of frame mounting and welding (IFREMER). Electrical integration of the COSTOF2, BBE wiper driving board and ODROID board (IFREMER).
07/11/2022	discussion and implementation of the bloom detection algorithm in the COSTOF2.
22/11/2022	BBE fixed and delivered to IFREMER. Lab tests.
07/12 □ 09/12/2022	COSTOF2, sensors and cables assembly on the mechanical frame. 12/12/2022 □ 15/12/2022: end of assembly. Last tests in the workshop.
16/12/2022	deployment at Sainte-Anne du Portzic. Start of pre-demo, cEGIM powered from shore and communicating via 4G.
23/01/2023	hyperbaric qualification of the energy container manufactured for the demo.
09/02/2023	Recovery from Sainte-Anne du Portzic. Start of conditioning for the demo on the Smile buoy site.

3.3. cEGIM pre-demonstration

3.3.1 Pre-demo objectives

The final demonstration will take place on a site where no communication will be possible between the cEGIM and the shore. Therefore, it was judged important to first deploy the cEGIM at sea with a real-time communication link, in order to

i) monitor its overall functioning in a representative shallow water site,

ii) check its compatibility with the onshore segment of the data acquisition chain.

This pre-demo was also the place for fine-tuning the bloom detection algorithm.

3.3.2 Site of Sainte-Anne du Portzic

The site of Sainte-Anne du Portzic (48°21.536'N 004°33.128'W) was chosen as the pre-demo site for its proximity with IFREMER premises of Plouzané and the possibility of simply setting up a communication link between seabed and shore. Sainte-Anne du Portzic is a cove on the northern side of the narrows that control the entrance of the Bay of Brest. The cove is protected on the SW by a jetty, beside which stands a tidal tower. The deployment location is on the seabed at the foot of the tidal tower, at a water depth of 8 m.

Figure 3 – Sainte-Anne du Portzic jetty and its tidal tower (midway left). Ifremer campus and premises in the background. ©Ifremer

Sainte-Anne du Portzic jetty is used for various experiments by Ifremer and partnering companies. A 20' container used by several teams, sheltering a dry lab and connected to the electricity network, is sitting on the jetty, next to the tidal tower footbridge.

3.3.3 cEGIM configuration

During the pre-demo, the cEGIM is powered from shore by a cable providing 28 Vdc delivered by a power supply unit installed in the 20' container. The cEGIM is connected to the internet thanks to a 4G-modem/antenna installed on top of the tidal tower.

3.3.4 COSTOF2 configuration

The COSTOF2 is connected to each of the four sensors listed in §3.1. For the sake of WP7, it has been specially adapted in order to host an Odroid HC4 board with a processing power able to meet the need of advanced signal processing imposed by the bloom detection algorithm. The COSTOF2 runs in autonomous mode and periodically sends out the measurement data of every sensor through the 4G-modem, using a binary data-format protocol. The default acquisition period is set to 1 hour. When a bloom is detected, the acquisition frequency is tripled (period = 20'), until the end of the bloom detection.

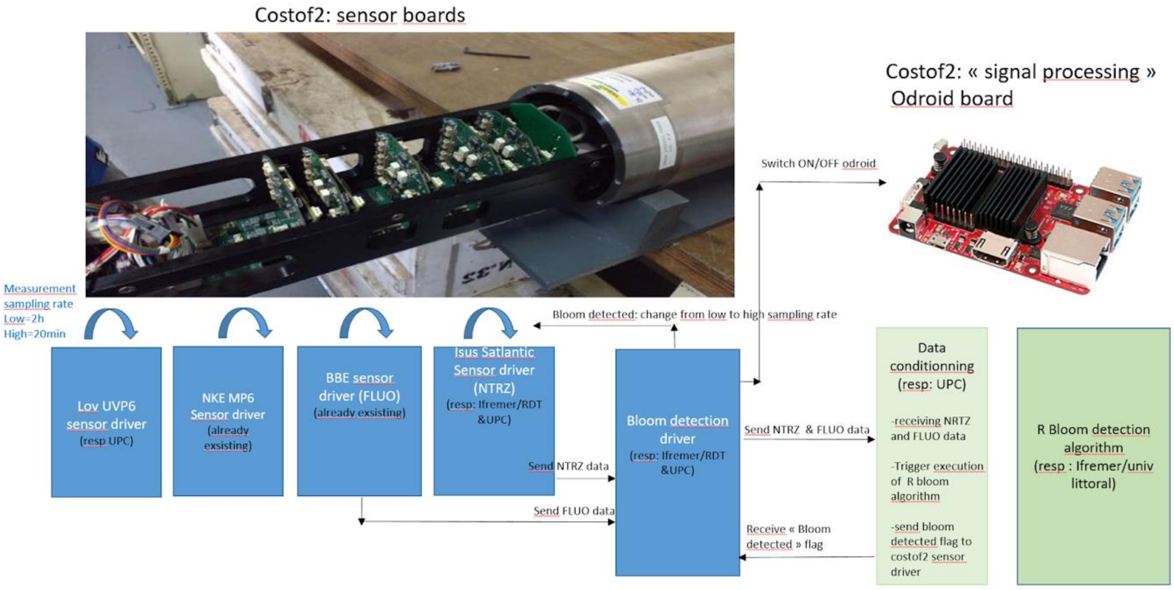


Figure 4 – COSTOF2 processing architecture for Jerico-S3

3.3.5 Configuration of data servers

A dedicated server hosted by Ifremer is in charge of decoding the binary flow and generates JSON files compliant with SensorThings format. This server is managed by UPC and Ifremer development teams. JSON files are sent through HTTP to a SensorThings API which is hosted and managed by 52 North.

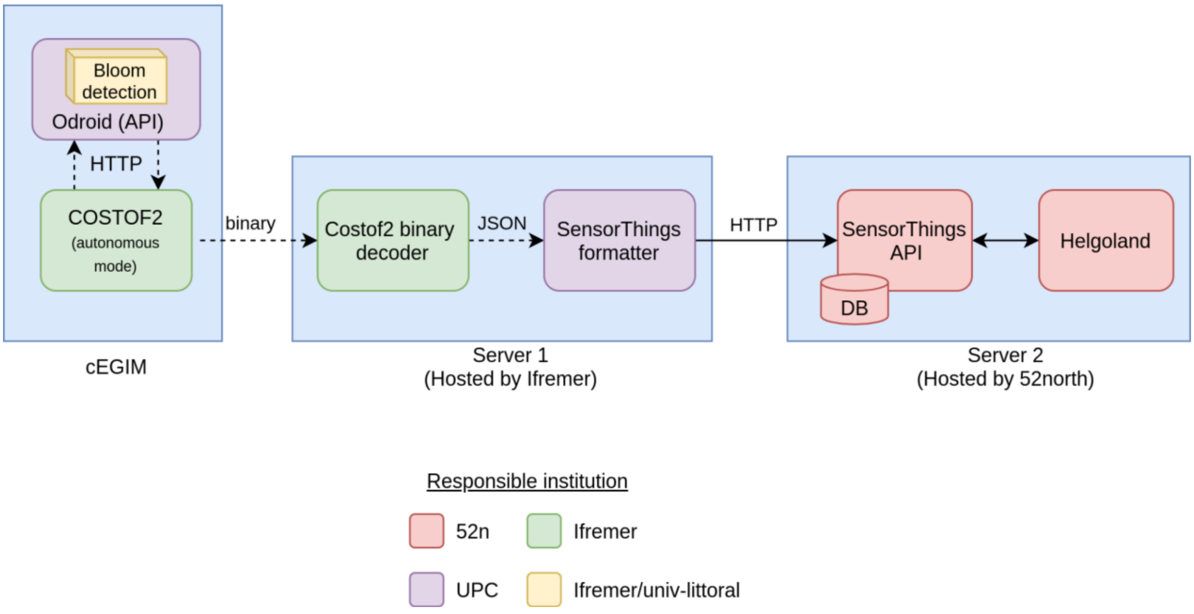


Figure 5 – Measurement data flow, from seabed to users

3.3.6 Deployment - Procedure and pictures

The deployment took place on 16th December 2022, taking advantage of a low tidal coefficient and quiet weather.
The 4G modem/antenna was installed on top of the tidal tower.
A boat with divers came to the tower.
The cEGIM cables to shore were prepared:

- power cable from the power supply in the 20' container, along the footbridge, to the top of the tidal tower then downward inside the tower, where it was tied to a wet messenger crossing the foot of the tower and going up to the divers' boat,
- modem cable from the modem, inside the tower then tied to a second messenger following the same way as the first one,
- divers on their boat pulled the messengers until finding and securing the cables extremities.

The cEGIM was brought to the top of the tidal tower, tied to a winch cable under a small crane and lowered to the divers' boat. There, the divers plugged the cEGIM to its two shore cables, before diving. The cEGIM was then lowered to the seabed under the divers' supervision, while the cable length in excess was pulled back and stored inside the tower.
The divers tied the cEGIM to a heavy metallic frame lying on the seabed.

Figure 6 – Lowering the cEGIM along the tidal tower
Ⓒlfremer / Michel Répécaud

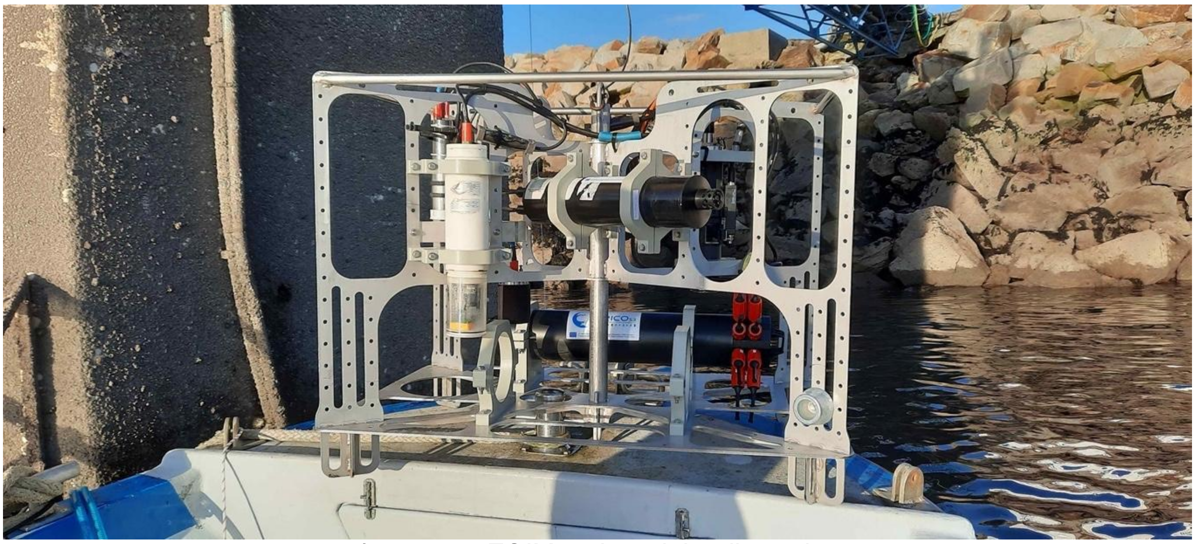


Figure 7 – cEGIM on board the divers' boat
©Ifremer / Michel Répécaud

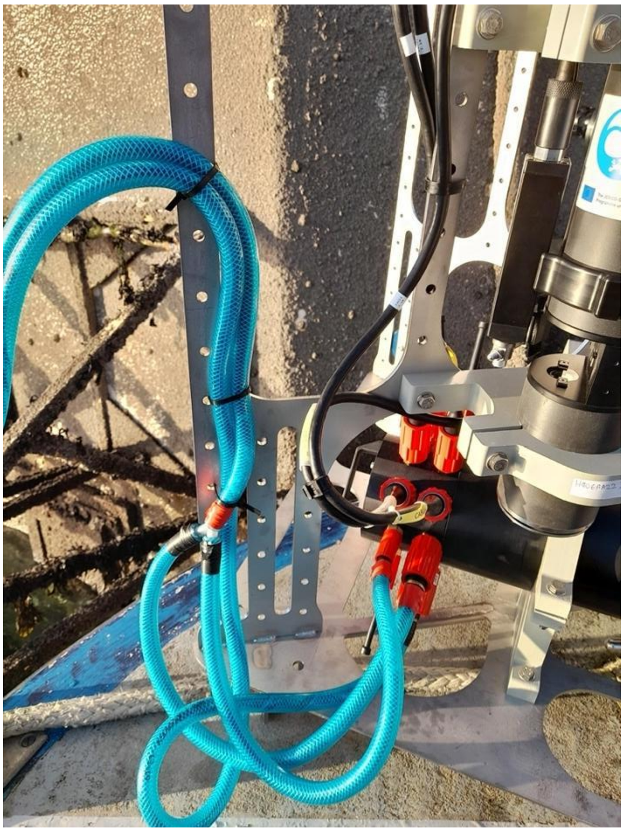


Figure 8 – Shore cables (modem & power supply) plugged to the cEGIM
©Ifremer / Michel Répécaud

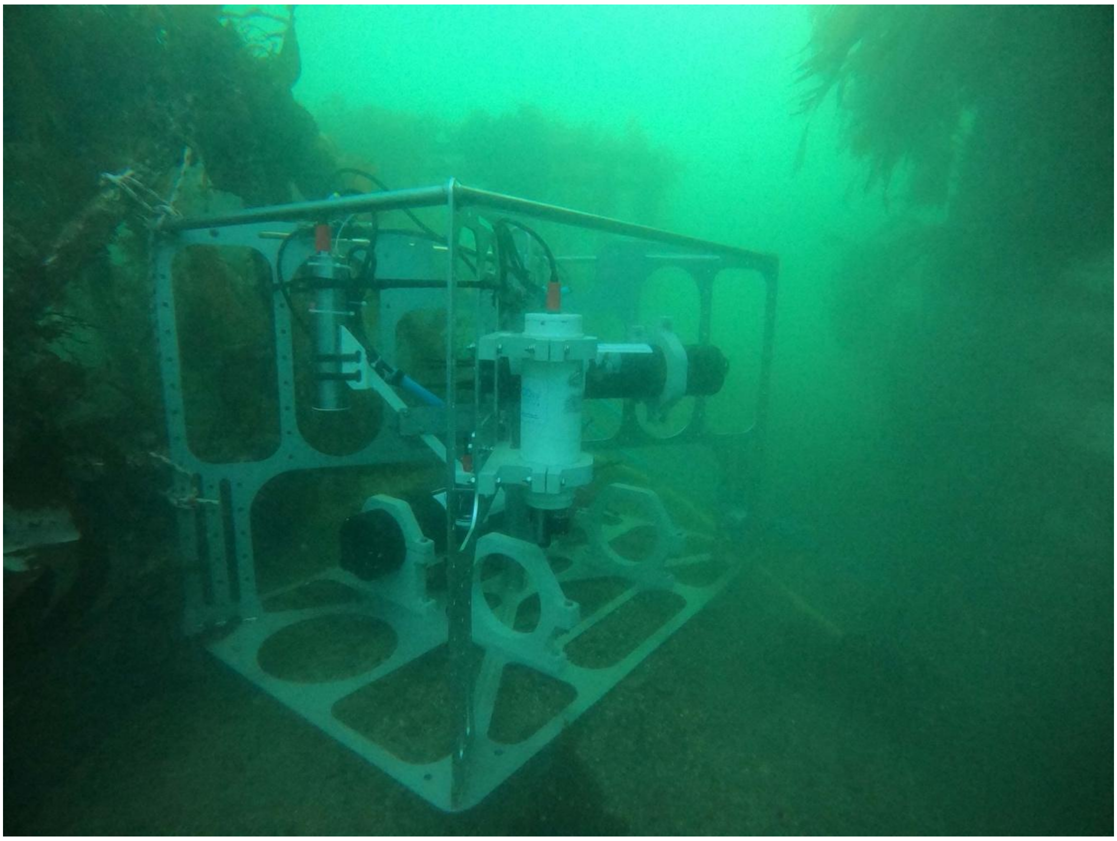


Figure 9 – cEGIM installed on the seabed
©Ifremer / Michel Répécaud

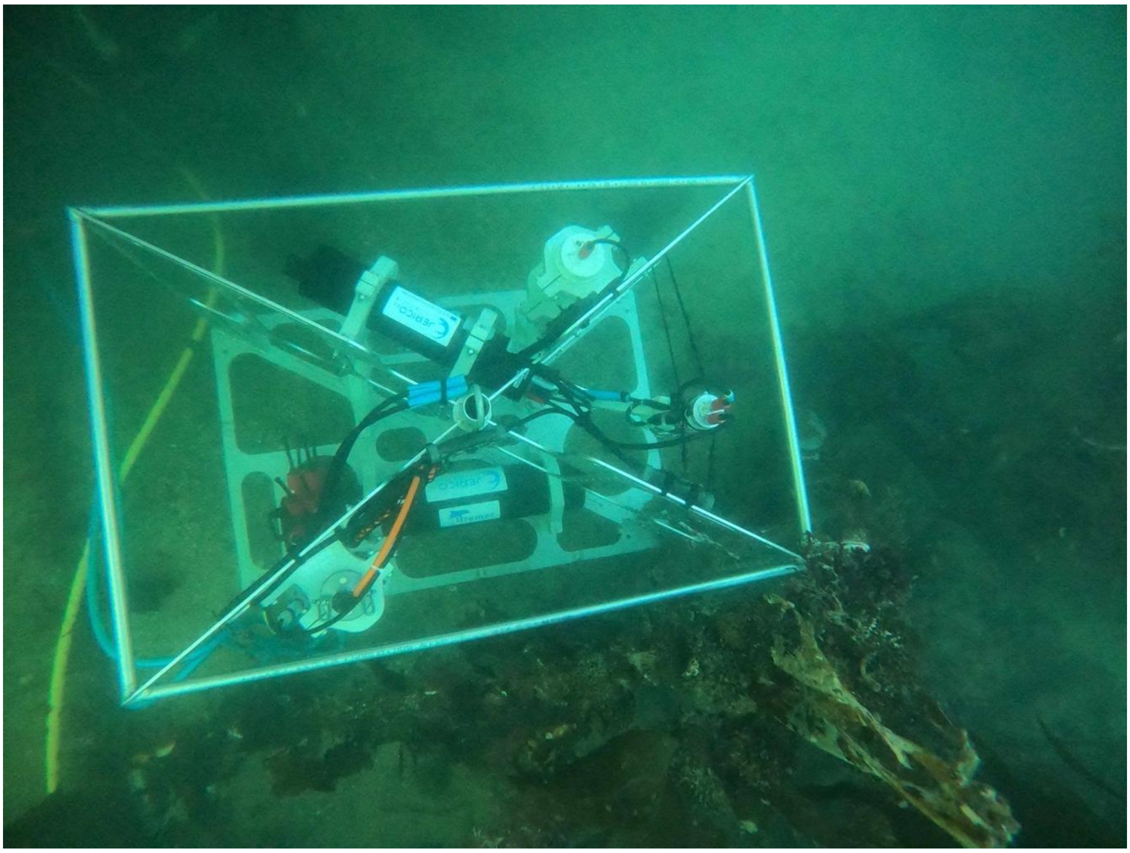


Figure 10 – Top view of the cEGIM sitting on the seabed
©Ifremer / Michel Répécaud

3.3.7 System functioning during deployment (16/12/2022 – 09/02/2023)

3.3.7.1 Power break sequence

During the deployment period, a faulty electrical device of the tidal tower triggered several power outages of the 20' container, interrupting the power supply of the cEGIM. Power restoration required a human intervention. It sometimes took several days before somebody realized the cEGIM power was off and requested its restoration. This is the sequence of power on and off:

Power state	Start date/time	End date/time
ON	16/12/2022, 17:00	29/12/2022, 22:00
OFF	29/12/2022, 22:00	03/01/2023, 11:00
ON	03/01/2023, 11:00	05/01/2023, 10:00
OFF	05/01/2023, 10:00	14/01/2023, 14:00
ON	14/01/2023, 14:00	06/02/2023, 19:00
OFF	06/02/2023, 19:00	07/02/2023, 10:00
ON	07/02/2023, 10:00	09/02/2023, 13:00

3.3.7.2 COSTOF2 functioning

COSTOF2 is the latest generation front-end for marine sensors enabling their long-term operation on any observation platform from seabed to surface. COSTOF2 provides most sensors with the following services:

- Energy supply and control,
- Communication with the external world,
- Measurement sequencing and local data storage,
- Precision time-stamping,
- Protection against biofouling.

The housing of this 200 meters COSTOF2 version is watertight and is corrosion-free. The housing is composed by a bottom end-cap without any connector, a cylindrical housing and a top end-cap on which all connectors are concentrated.

COSTOF2 is a multi-core system based on a backplane board connecting four application boards (for up to 12 sensors maximum). All the boards are built around the Ifremer Alees board, developed from a 32 bit microcontroller (Cortex M3 core).

For some sensors or for some specific purposes, algorithms and data can also be stored on a NAS associated with a Solid State Disk. In this case, a specific NAS board has to be plugged on the COSTOF2 backbone.

COSTOF2 has been designed to optimize its electrical consumption and its electronic architecture has been designed as modular as possible to increase its reliability and facilitate the interfacing of new sensors. Each board runs independently from each other and manages its own sensors.

COSTOF2 software is built around a real time operating system and provides 2 operating modes: acquisition and maintenance. The Acquisition mode is the autonomous mode allowing the COSTOF2 to manage the sensors following the configured parameters. The Maintenance mode is used to configure the system, to update its firmware, to retrieve data and to execute transparent mode to sensors.

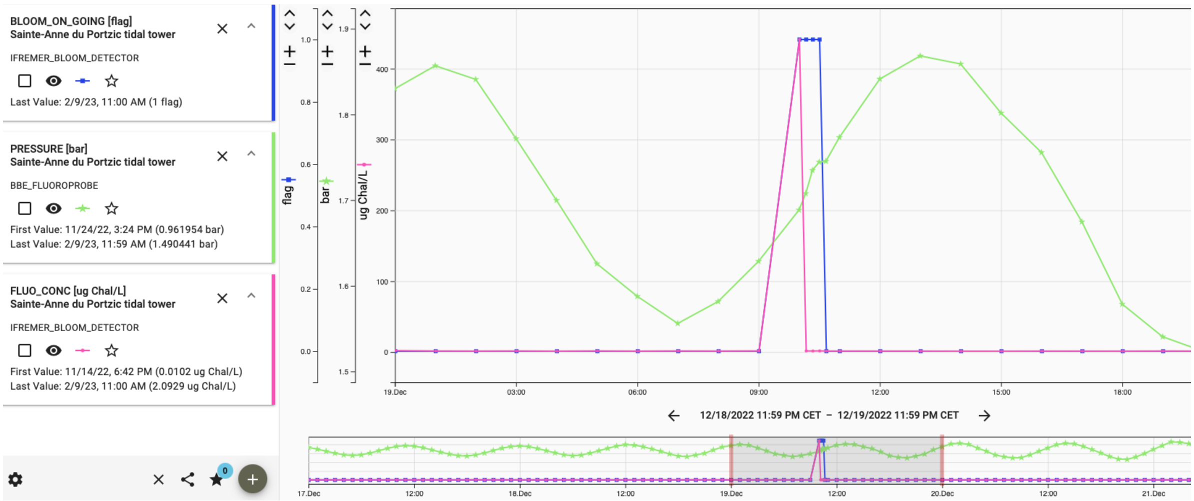
During the pre-demo, the COSTOF2 performed satisfactorily in Acquisition mode and periodically delivered its data to the server.

3.3.7.3 Bloom detection algorithm functioning

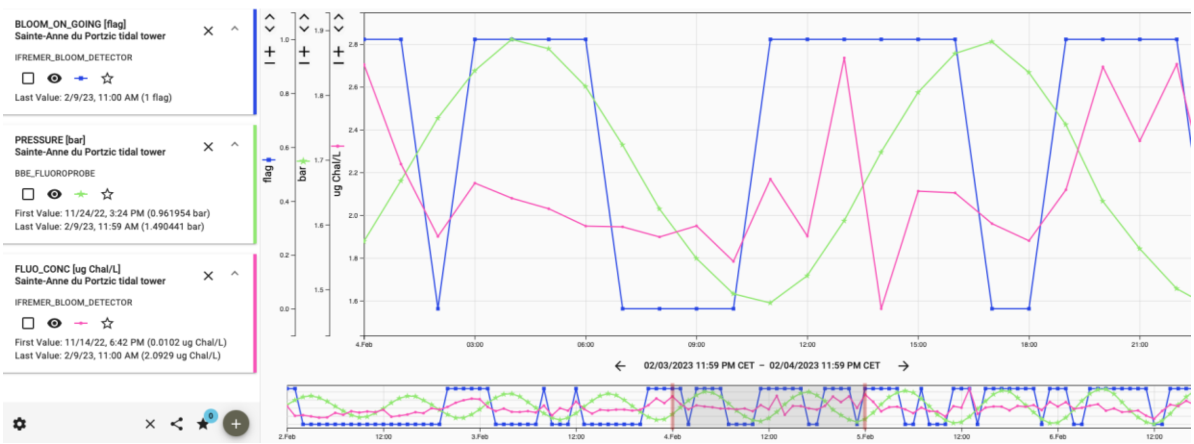
At the time of writing this report, the data internally recorded by the COSTOF2 were not retrieved. This will only be done in early March. Therefore, the functioning report below is based on an analysis of the cEGIM data available on the Helgoland data viewer.

Fluorescence threshold values:
Initial value (16/12/2022 → 04/01/2023, 12:00 CET): 1 µg/L
Final value (04/01/2023, 12:00 CET → 09/02/2023): 2 µg/L

Bloom detections:



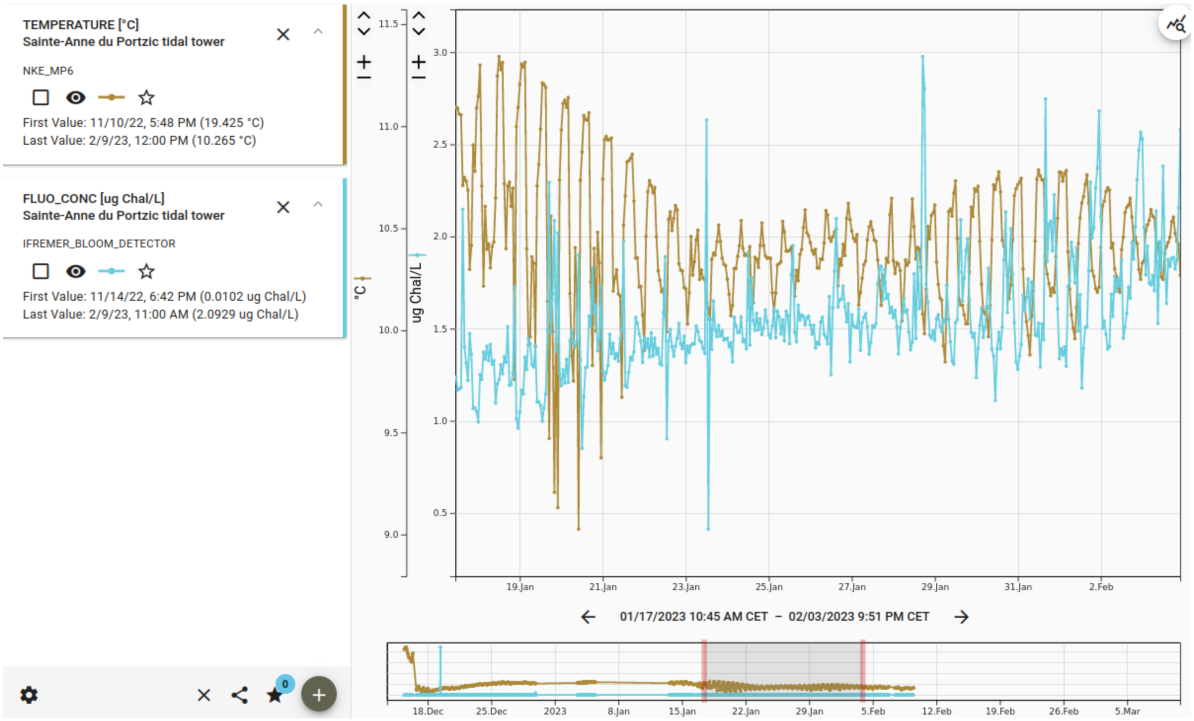
The screenshot above shows the flag "BLOOM_ON_GOING" going from 0 to 1 on 19/12/2022, 10:00 am, until 19/12/2022, 10:40, following a rise in the value of FLUO_CONC above the threshold. During this duration, the sampling period was 10', then returned to 60', as expected.



The above screenshot shows several occurrences of bloom detection that did not trigger the expected oversampling. This has to be investigated further by downloading the data recorded on the COSTOF2.

3.3.7.4 Data access and display

The data, transmitted in real-time using SWE components, was stored within a SensorThings service where it is accessible through its standard API. Then, the data can be integrated with any tool compatible with the STA standard. In this particular demo the 52°North Helgoland data viewer was used:



The API can be accessed at: https://jerico-s3.demo.52north.org/v1.1/

This Helgoland data viewer can be accessed at: https://jerico-s3.demo.52north.org/helgoland/

3.3.8 Recovery

The recovery took place on 9th February 2023.

The recovery procedure was the exact reverse sequence of 16th December operations.

The frame and instruments were found very clean, due to the winter conditions that prevailed during the deployment duration. The Al-Indium anode was found entirely consumed.

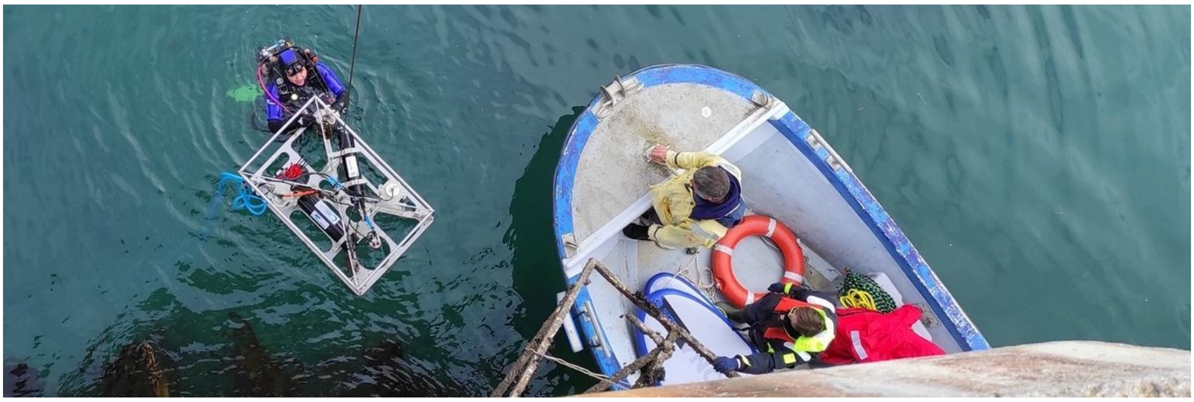


Figure 11 – cEGIM brought back to the surface
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Figure 12 – Unplugging the shore cables on the divers' boat
©Ifremer / Michel Répécaud

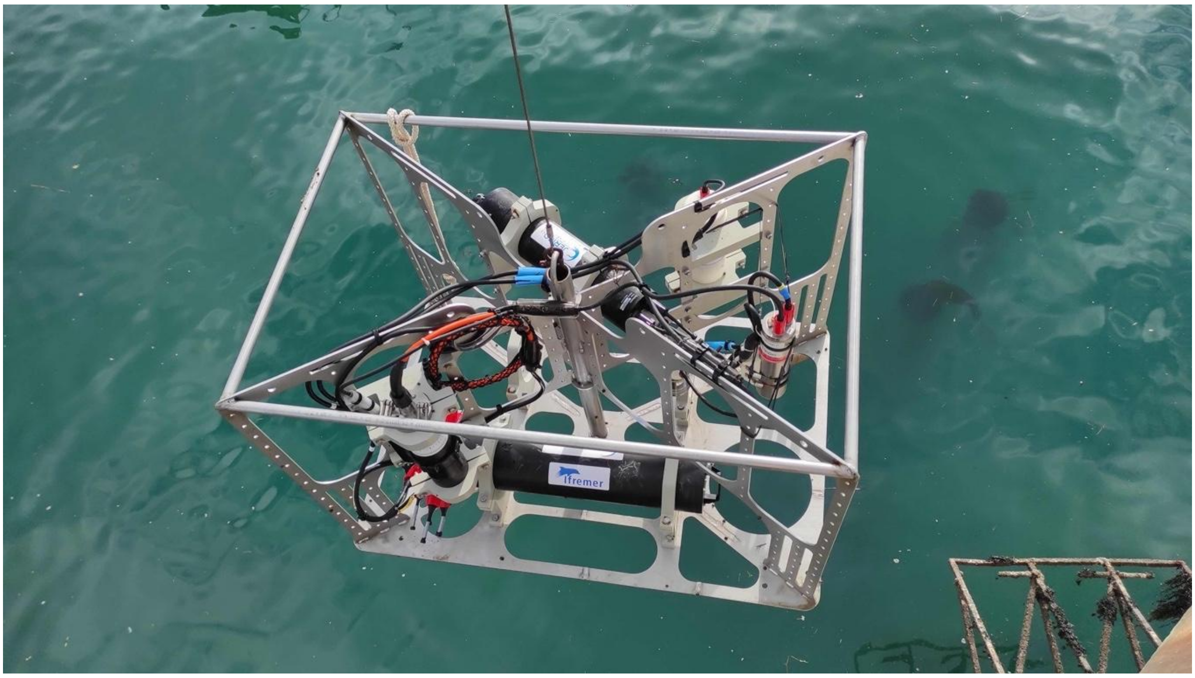

Figure 13 – cEGIM brought back to the top of the tidal tower
©Ifremer / Tanguy Bescond

Figure 14 – The anode was entirely consumed
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Figure 15 – UVP6 light. The optical surfaces are exempt from biofouling
©Ifremer / Tanguy Bescond

After thorough examination of all its subparts, the cEGIM was carefully rinsed, the instruments protected with end caps and stored in a dry place.

4. CONCLUSIONS

Overall, the cEGIM behaved well during the pre-demonstration.
As lessons learnt from this pre-demo, the following items will be corrected before the demo:
- 3 Al-Indium anodes plus 1 Zinc anode will be installed on the frame
- the lack of oversampling following a bloom detection must be investigated by analyzing COSTOF2 internal data
- the Fluo threshold value for bloom detection will be set to xx µg/L Alain?

Regarding the hardware necessary to execute the bloom detection algorithm, we now know that the COSTOF2 native boards could have done the job.

Acknowledgement
The authors wish to thank the Laboratoire d'Océanographie de Villefranche-sur-Mer for the lending of their Underwater Vision Profiler 6 (UVP6) and their kind and valuable support related to its implementation.