iFADO Best Practice:
Fisheries Observing Systems (FOS): low cost-effective devices for monitoring pelagic habitats.

Background

The high costs derived from research surveys means that exploring the vast ocean with the necessary spatial and temporal resolution to characterise key oceanographic processes is unaffordable. Consequently, different technologies and platforms are employed as an alternative to R/V surveys for sustained monitoring ocean physics and biogeochemistry, producing data for operational usage available in near real-time. For instance, fishing vessels can be used as vessels of opportunity by being equipped with sensors and data loggers to record data on fishing efforts and physical parameters, such as sea temperature and salinity (Leblond *et al*., 2010). Thus, gaps between areas surveyed by research vessels can be filled with data obtained with this type of platform, providing a more sustainable model for collecting high-resolution data at a significantly lower cost. Furthermore, understanding the relationship between fish stocks abundance and environmental parameters represents a crucial point towards improving models and forecasting.

Incorporating sensors into fishing gears and sending the recorded data to data centres has been shown to be a feasible way of improving our ocean monitoring capacity (Van Vranken *et al*., 2020). For instance, about 300 fishing vessels have been instrumented since 2004 in France as part of the program RECOPESCA (https://archimer.ifremer.fr/doc/00024/13500/). The data provided increased spatial and temporal coverage, resulting in an improved description of the physical environment, and allowing the optimization of models through validation and data assimilation. A similar system has been established in the Adriatic Fisheries Observing System (http://www.ismar.cnr.it/infrastructures/observational-systems/adri-fishery-observing-system/index_html).

Case study

One NKE WiSens CTD (Conductivity-Temperature-Pressure) sensor and one WiSens TD (Temperature-Pressure) sensor, developed by NKE (France, https://nke-instrumentation.com), were purchased by IEO-CSIC to the Spanish company Casco Antiguo (Spain, www.cascoantiguopro.com). These autonomous data loggers measure and record temperature and pressure (TD) plus conductivity (CTD) down to 6000 m and 300 m depth, respectively. According to the manufacturer company's technical description, their lithium batteries should allow recording data for long-term use, up to several years.

Figure 1. *The NKE WiSens sensor can be accessed and configured with any device with Wi-Fi connectivity.*

The full specification sheets for the TD and CTD sensors are available here, respectively:

https://nke-instrumentation.com/wp-content/uploads/2019/04/WiSens-TD_UK6.pdf

https://nke-instrumentation.com/wp-content/uploads/2019/05/Datasheet_WiSens-CTDS.pdf

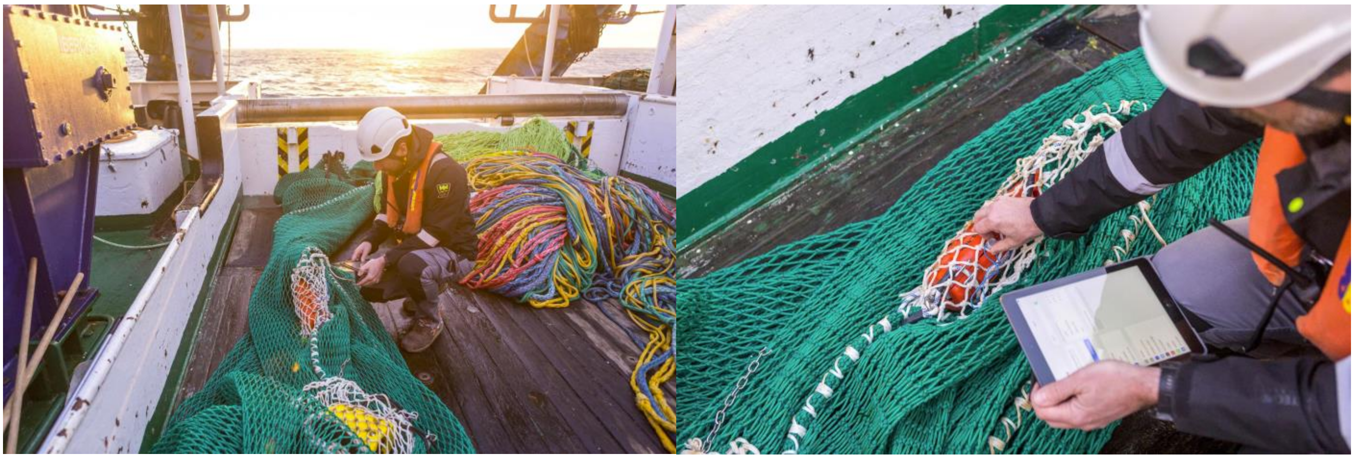

Figure 2. *WiSens sensor, within the orange case attached to a fishing net, being activated with a magnetic clip and configured via Wi-Fi before its deployment.*

Besides the sensor, the FOS system requires other devices and web tools to complete the process of data acquisition and management (Figure 3):

- any device with Wi-Fi connectivity (tablet, laptop, mobile phone, etc.) which allows wireless access to the sensor to perform the initial configuration;
- a MobCo "concentrator", the on-board data receiver, which receives data from the WiSens sensor via Wi-Fi and contains the GPS system for data geolocation. This device can be accessed quasi real-time from land, once the vessel is within range of 3G/4G network, allowing access to data.
- the BlueCherry.io, a cloud platform developed by the company Rovin (Belgium, https://www.rovin.eu), allows the access to the concentrator from land and manually downloading data;

Figure 3. *Scheme of the FOS connectivity and data management: 1) activation of the WiSens sensor with a magnetic clip and configuration via Wi-Fi; 2) data transferring to the on-board receiver (MobCo) via Wi-Fi; 3) MobCo connection with the BlueCherry.io service via 4G network; 4) MobCo can be accessed and thus data downloaded in two different ways: i) manually, through BlueCherry.io service, and ii) automatically (as in the experiences presented in this report) by means of an Application Programming Interface (API) (in our case, developed by IEO-CSIC technical staff).*

Previous FOS versions (as those employed both in the RECOPESCA project and in the Adriatic Sea) used a radio device for transferring the data to the on-board concentrator, which then sent data to the central database in land by GPRS. Now, **these sensors have been evolved so that the FOS system is easier to use,** as well as **faster and more accessible for data transferring**, thanks to some **new features** which, however, **remain to be tested on the field on real experiences**:

i) they are provided with a magnetic activating clip, which activates Wi-Fi when placed on a specified spot outside the carcase containing the sensor. This enables accessing to the WiSens embedded interface via any device with Wi-Fi connectivity (Figure 2, and Figure 3, step 1), allowing for a fast and easy wireless configuration.

ii) once the WiSens sensor is on-board after a deployment, the sensor and the on-board *MobCo* concentrator can now communicate via Wi-Fi (Figure 3, step 2), which represents several advantages with respect to previous versions of the FOS system: it is a more standard and low-cost solution, connection can be achieved from any device with Wi-Fi connectivity, it can take advantage of IoT (Internet of Things) developments, etc. On the other hand, one potential limiting factor for Wi-Fi communication could be the distance between the sensor and the *MobCo*. However, we have not experienced this problem during our tests, even in the large research vessel (R/V Vizconde de Eza), where the distance between the two devices was about 30 m (Figure 7).

iii) the connectivity of the *MobCo* with land is now possible via 4G network (Figure 3, step 3) instead of GPRS, without any involvement of the ship's crew nor specific devices

iv) Bluecherry.io (Cloud platform): as long as the *MobCo* is connected to 3G/4G network, data is accessible from land via this storage platform (Figure 3, step 4) to be manually downloaded.

Field experiences

Methods

Demonstrations of FOS functionality and performance tests were carried out on several monitoring configurations in different research cruises in the Iberian upwelling system and the Bay of Biscay, off the Iberian Peninsula (Figure 4).

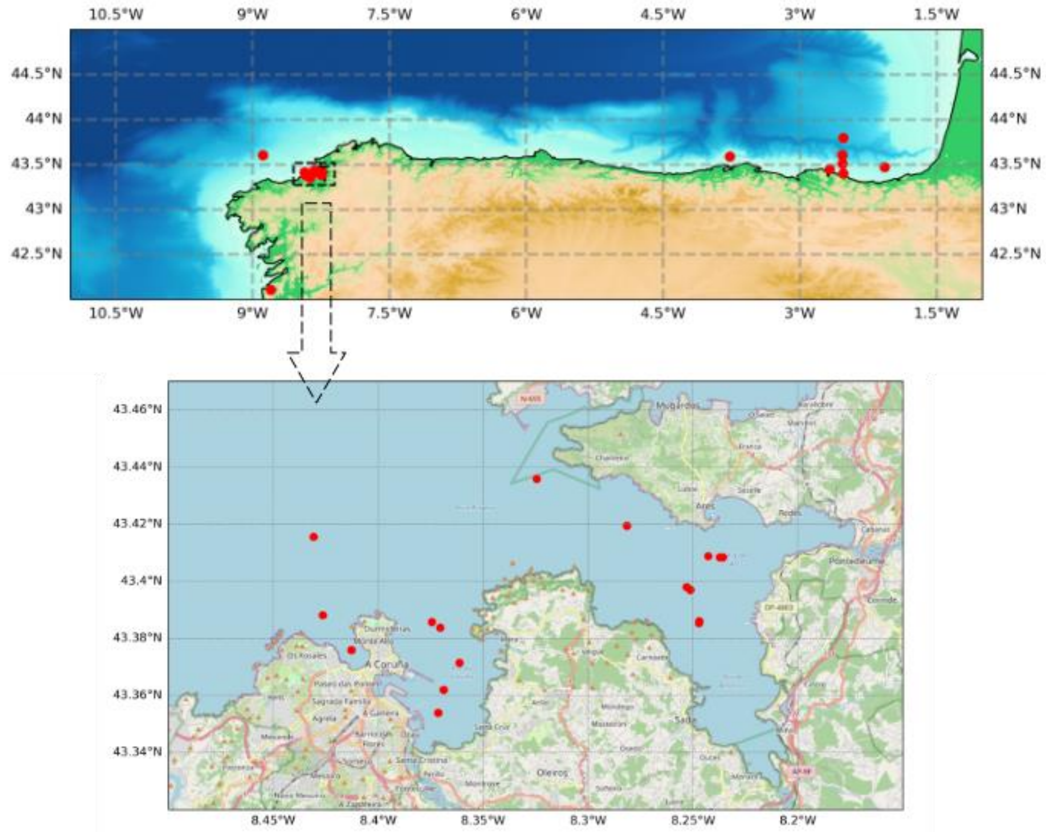

Figure 4. *Location of FOS deployments in the Iberian upwelling system and the Bay of Biscay, off the Iberian Peninsula.*

The NKE sensor is deployed within a waterproof case (orange case, Figure 2), which can be attached to different platforms. It was attached to fishing gears (Figure 5) both in oceanographic campaigns to assess fishery resources (PELACUS0422, SAREVA2023 and Biga-Project cruises), as well as on commercial vessels (pair-trawlers). Likewise, the sensors have been operated in conjunction with other oceanographic samplers, such as a rosette-CTD device (during Radiales time-series monitoring) and plankton nets (during the PELACUS0422 and SAREVA23 cruises).

The sensor can be easily switched on by a magnetic activating clip, which activates the Wi-Fi when placed on the middle part of the sensor. At this step, some parameters must be configured. For example, activation and deactivation of data acquisition could be done manually before and after deployment. However, in a real scenario it would imply the participation of the fishing ship's crew, which is not desirable for our objective. Alternatively, data logging start and stop can be configured to be triggered as a function of the values of one of the different variables measured by the sensor, such as pressure (depth), temperature, conductivity, and salinity, or at a given time after the beginning of the deployment (e.g., 30s after deployment).

Immediately after each monitoring event (e.g., after a fishing haul, Figure 6), once the WiSens sensor is out of water, it transmits data through the Wi-Fi connection to the *MobCo*, located in a safe place, for example, in the ship's bridge (Figure 7). On-board, this GPS concentrator allows the connection of any device with Wi-Fi connectivity. However, with the objective of the FOS implementation, a remote connection thanks to its 4G connection via the IoT platform Bluecherry.io. is much more useful (Figure 8). In this way, when the FOS is working on a commercial fishery vessel and connected, different types of queries can be made (both on-board and remotely):

- view and download data;
- check the status and quality of the GPS connection;
- check the latest GPS data and visualise them on a map;

Figure 5. *Fishing haul for pelagic species assessment during Pelacus0422 cruise.*

Figure 6. *Fishing net on-board after a fishing haul, with the WiSens CTD sensor attached (within the orange case), during Pelacus0422 cruise.*

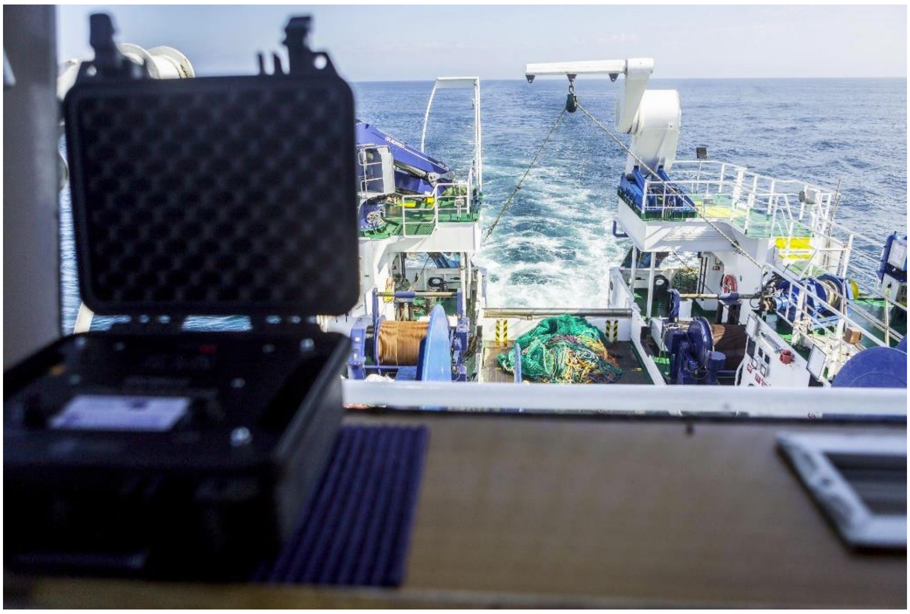

Figure 7. *MobCo concentrator*, placed on the B/O Vizconde de Eza's bridge during PELACUS0422 cruise.

Figure 8. *Screenshot of the MOBCO's data visualization web interface.*

However, two important limitations of this access systems have been revealed from our tests:

- data must be downloaded manually;

- remote access through BlueCherry.io does not allow for the remote configuration of the sensors, which is a very important limitation.

With the aim of achieving an operational data processing system, several improvements to the basic FOS system were developed by IEO-CSIC technical staff:

- On the one hand, an API programmed in Python was developed to interact with the BlueCherry.io storage platform. As no documentation was available for querying this platform, it was necessary to use reverse engineering for its development. The API routinely queries the platform for new data. When a new data release is detected, it is downloaded, processed, and stored in a local PostgreSQL database.

- In parallel, an alert system based on a Telegram bot was implemented. This system communicates the most relevant events of the different steps of the data processing as well as any error event. If so, alerts are sent both to the person responsible for data processing and to any other interested user (Figure 9).

- Finally, with the objective of being able to request the data quickly, a web application was developed that is fed directly from the local database. This application makes it possible to visualise the position of the hauls, the profiles, and the time series of the data (Figure 10).

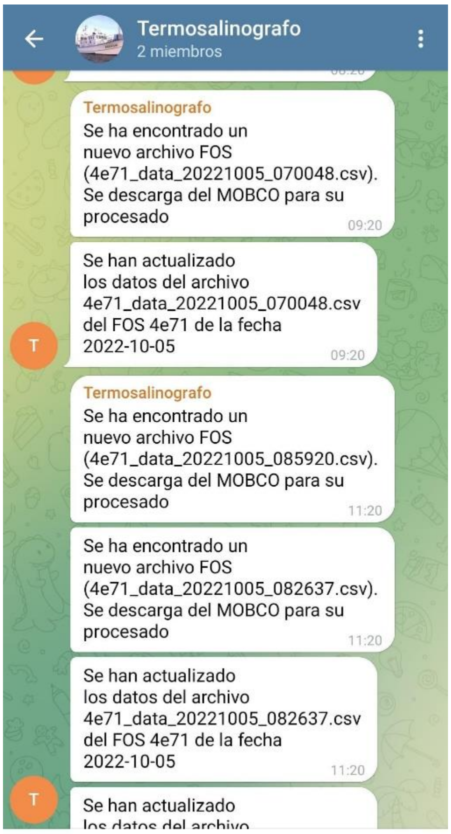

Figure 9: *Screenshot of the Telegram channel with the notifications of the FOS data processing events.*

Results and keys to success

Performance assessment

In all the field experiences, connectivity with the sensors and the *MobCo* have been relatively easy thanks to the system's Wi-Fi and 4G connections. The batteries used are long-lasting and can withstand high sampling demands for several months. Once the sensors have been configured to operate automatically, the system can work without any human intervention by recording data and making it available through the Bluecherry.io cloud platform. Furthermore, the web interface is intuitive and easy to use from land.

Although the overall performance was satisfactory, our tests have identified some aspects to improve:

- Documentation: in general, the documentation provided by the developer for both WiSens sensors and *MobCo* is sufficiently complete to allow the final user to perform basic operations. However, we identified some aspects for what further information would be desired:
  - How, where, and how often are GPS data stored?
  - Are recorded data deleted if the *MobCo* is switched off during a cruise?
  - How is the data dump process from the CTD to the *MobCo*?

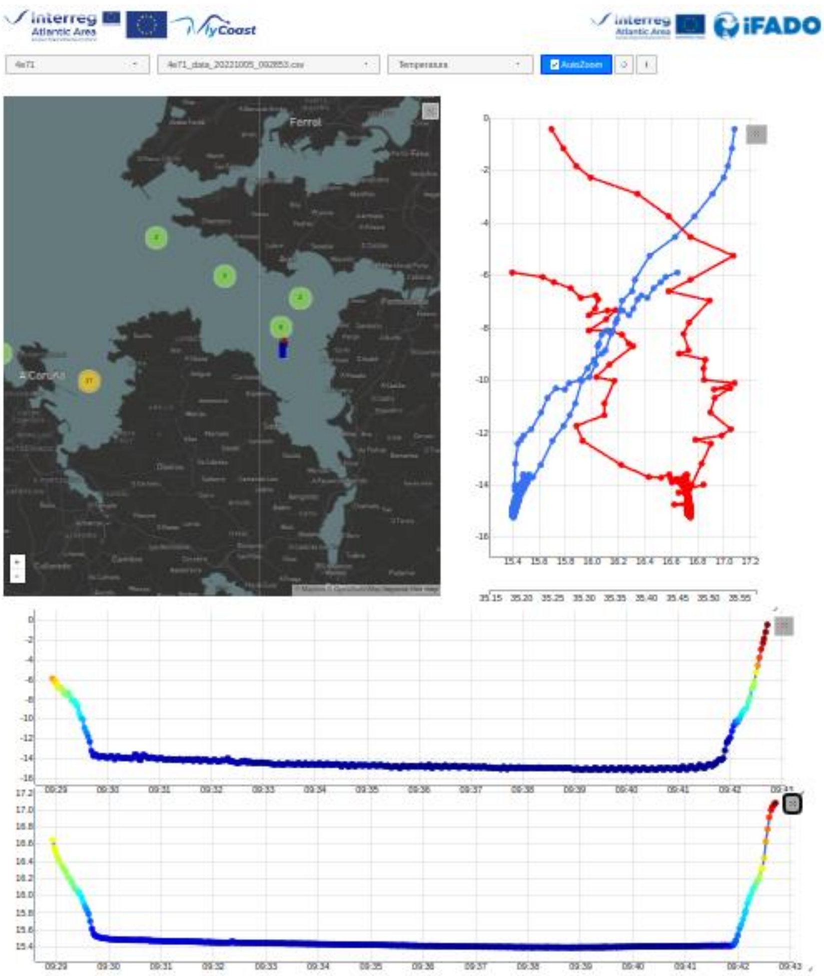

Figure 10: *Screenshot of the FOS data viewer web app.*

- Connectivity:
  - Once the Wi-Fi of the WiSens is activated with the magnetic clip and the CTD operation is configured, there is no way to know if the sensor is successively activated and ready to work. During these field experiences, sometimes the sensor was configured correctly but it was not activated, so that the sensor was idle for a full day.
  - In some situations, it was not possible to connect to the sensor for a long period of time. It is assumed that this could be related to the communication between the WiSens and the *MobCo* and to the data synchronisation process. However, there is no way of knowing the cause of this problem.
  - When the sensor is completely frozen, we have only managed to recover its activity by disassembling it and disconnecting the battery for a while.
  - Activation limits
    - If the activation/deactivation limits are configured upside down (i.e., the activation depth is deeper than the deactivation depth), the FOS does not provide any warning alert and the profiles will not be recorded.
    - Salinity: We have not achieved automatic profiles using salinity as a trigger, maybe because it is a derived variable from conductivity and temperature. The best performance was achieved when using depth as the activation trigger.

- GPS:
  - There have been some quite severe position fix problems, with the system being out of position for several hours, after several resets.
  - When the GPS freezes, it is not recovered until a *MobCo* reset is performed.

Data quality control

Preliminary analyses of both temperature and salinity data have been satisfactory. The comparisons with other measurement systems showed good results. Pending further intercomparison, we can say that **data generated by the FOS are of good quality**.

Some of the problems encountered have been related to measuring salinity in conditions where the temperature changes abruptly, in situations of marked pycnoclines or fronts between water masses (i.e., river plumes) (e.g., Figure 11). Although this kind of problems are inherent to any profiler, other commercial brands usually provide post-processing software to correct them.

Another sampling artefact is related to the temperature sensor tempering. As a system designed to work automatically following the rhythms of fishing operations, in some tests the WiSens CTD started to profile before it was completely tempered, generating wrong surface temperature and salinity data. Considering that the fishing operation in most cases is slow and the net is held for some time on the surface both at the start and the end of the haul, this is likely to be less of a problem in real sampling conditions on a commercial vessel.

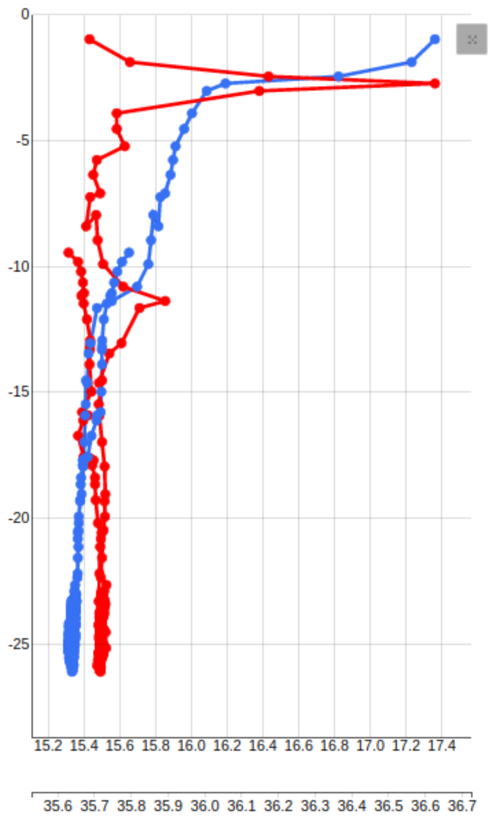

Figure 11: *Example of a profile (23-09-2022) where the presence of a significant temperature (blue) gradient leads to an error in the salinity (red) estimation.*

A piece of advice for future developments

After these experiences, we are in condition of coming up with some suggestions for the improvement of the FOS system performance and its ease of use:

1) To include a “ready-to-work” indicator: On a commercial vessel, where intervention on the sensor will be limited or almost absent, all data from a fishing campaign will be lost in case the sensor is configured but not properly activated.

2) To improve the capacity of remote configuration and interaction: Although the system allows remote interaction with the *MobCo* via the Bluecherry.io service, its functionalities are quite limited. For example, regarding the *MobCo* configuration:

   - Only the data downloaded from the sensors and the latest GPS positions can be consulted. It would be desirable to have access to GPS data all along the fishing track.
   - Even something as basic as the configuration of the 4G SIM card had to be done remotely by the company. It would be desirable to transfer this competence to the user.
   - It should be possible to reset the system or the GPS remotely.

   Additionally, in relation to the sensor configuration:

   - In case of error or any required change in the initial configuration of the WiSens, it can only be modified via Wi-Fi when the sensor is on-board, using a device with Wi-Fi connectivity (tablet, laptop, mobile, etc.). It would be very useful to change the configuration via the *MobCo*, either directly on the sensor or by loading the new configuration during the next connection with it.
   - To better monitor and control the system, it would be necessary to implement a more detailed log of the operations performed by the WiSens and the *MobCo* in terms of sampling, configuration, and interaction. Currently, the system only records when the *MobCo* is switched on and off. The development of a more elaborate notification system would facilitate the tracking and detection of operation errors.
3) To develop a data API for interaction with the data service (Bluecherry.io): The data generated by the sensors are remotely accessible. The query interface is quite intuitive and allows the user both to browse the measurements graphically and download them manually. However, the FOS does not provide an automatic data processing way. In the context of the iFADO project, we have developed a system for querying and downloading data in order to automate this process, but it would be desirable to develop a more functional API.
4) To develop a post-processing and quality control software: Considering the problems of sensor time response (thermal lag) especially in conditions of strong vertical (and horizontal) gradients, it would be necessary to develop a quality control software that could minimise these problems.
5) To improve GPS connectivity and logging (*MobCo*): GPS logging is very important in a sampling system like this, where data must be geolocated or they become completely useless. During some operations, the GPS coordinates were not registered. Therefore, it is necessary to improve both the recording hardware of the controller board and antenna and to add a system that monitors performance and notifies malfunction to prevent the loss of GPS information during the operations, ensuring that data is properly geolocated.

Is the FOS robust enough for its operation on commercial fishing vessels?

Based on the results from the tests carried out in our field experiences, although some of the problems detected could be critical to some extent and should be improved in future developments of the FOS system, we conclude that **the FOS measurement system is sufficiently mature to be implemented in commercial fishing vessels**. The remote connectivity via 4G that allows the routine monitoring of the system's performance, together with the collaboration of the ship's crew, would allow dealing with any potential operational problem of the current system. Hence, what we learned from these field experiences will enable us to move towards an observation system in Spanish Atlantic waters like that of RECOPESCA and FOOS (Fishery and Oceanography Observing System)(Patti *et al*., 2016), and even with improved data transferring capacity.

References

Leblond E, Lazure P, Laurans M, Rioual C, Woerther P, Quemener L, Berthou P. The Recopesca Project: a new example of participative approach to collect fisheries and in situ environmental data. *Mercator Ocean-Quarterly Newsletter*. 2010; (37), 40-48. https://archimer.ifremer.fr/doc/00024/13500/10514.pdf

Patti B, Martinelli M, Aronica S, Belardinelli A, Penna P, Bonanno A, Basilone G, Fontana I, Giacalone G, Gabriele Gallì N, Sorgente R, Angileri IVM, Croci C, Domenichetti F, Bonura D, Santojanni A, Sparnocchia S, D'Adamo R, Marini M, Fiorentino F, Mazzola S. The Fishery and Oceanography Observing System (FOOS): a tool for oceanography and fisheries science. *Journal of Operational Oceanography*. 2016; 9:sup1, s99-s118, DOI: 10.1080/1755876X.2015.1120961

Van Vranken C, Vastenhoud BMJ, Manning JP, Plet-Hansen KS, Jakoboski J, Gorringe P, Martinelli M. Fishing gear as a data collection platform: opportunities to fill spatial and temporal gaps in operational sub-Surface observation networks. *Front. Mar. Sci.* 2020; 7:485512. doi: 10.3389/fmars.2020.485512.