Testing strategy for new ocean sensors

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***Abstract*— The definition of a sensor monitoring strategy is based on the location for water monitoring, sensor performances, data storage and transmission. For any new sensor, available instruments currently used in oceanographic studies are identified to perform comparisons. Suitable transmission technology is selected according to the test conditions: open sea, coastal areas, remote locations, etc. Sensitivity and stress tests are designed to establish confidence limits under different environmental situations, so that the results obtained in planned testing exercises are enabled to certify the performance of the new instruments. In this paper, we will address three key phases to test and certify the performance of new sensors: (1) RD basis for cost-effective sensor development, (2) sensor development, sensor web platform and integration, and (3) field testing**

***Keywords*— sensor, ocean, test, validation**

I. INTRODUCTION

The Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 [1], establishes a framework for Community action in the field of water policy. Water pollution has been a problem that has accompanied human development and the greatest human achievements [2, 3]. New strategies and new radical approaches are needed to improve the management of water bodies, in terms of increasing the quality, also at sea, and working with local government to identify options and new technologies to assess the chemical and ecological status of water bodies and to develop best practice. New and efficient methods are needed for monitoring the implementation of various EU agreements and national programmes on reduction of water contamination. Relatively recent advancements in the field of sensing technologies have brought new trends in environmental controls. In micro-electronics and micro-fabrication technologies, that has allowed a miniaturization of sensors and devices, thus opening a series of new and exciting possibilities for environment monitoring [4, 5]. Moreover, robotics and advanced ICT-based technology (in particular, the extensive use of remote sensing and telemetry) is dramatically improving the detection and prediction of risk/crisis situations related to water environment, providing new unmanned tools for control. The COMMON SENSE project [6] aimed to support the implementation of European Union marine policies such as the Marine Strategy Framework Directive (MSFD) [7], the Common Fisheries Policy (CFP) [8], and the Water Framework Directive (WFD) [10] that highlight the common request to assess the chemical and ecological status of the water bodies involved (either sea or fresh). The project was designed to directly respond to requests for integrated and effective data acquisition systems by developing innovative sensors that can contribute to our understanding of how the marine environment functions. The core project focused on increasing the availability of standardised data on: eutrophication, concentrations of heavy metal compounds, microplastic fraction within marine litter, underwater noise, and other reference parameters such as temperature and pressure, pCO_2 and pH [9]. After an up-to-date state of the art of existing sensors, this project has first provided a working basis on "new generation" technologies to develop cost-effective sensors suitable for large-scale production and compatible with standard requirements such as the MSFD [7, 10], the INSPIRE directive, the GMES/COPERNICUS [11] and GOOS/GEOSS [12, 13]. To fulfil the above requirements, sea testing of the new instruments is crucial to ensure their capability for monitoring ocean waters under different environmental conditions [14]. The objective of the present paper is to bring basic rules for sensor certification after sea testing. Specific adjustments or additional steps may be necessary for specific new sensors. Due to this, we provide general information on how sensors should be field tested and how their behaviour has to be monitored and sensor performance be certified. More precisely on what kind of sensitivity and stress tests should be applied to analyse the sensor behaviour; what reference sensors or analytical methods for every parameter can be used; how sensor response has to be analysed; how testing sensor integration in instrumented arrays has to be addressed; what communications are required for data transmission and how their efficiency has to be analysed; which criteria have to be retained for sensor certification after tests. General procedures for sensor testing can be found in the specialised literature but the methodology described here, although general, is focused specifically to sensors developed within the COMMON SENSE project:

inorganic **nutrien**t concentrations (NO_2, NO_3, PO_4 and NH_4), **microplastics**, **heavy metals** (Cu, Pb, Hg and Cd), **underwater noise**, plus new sensors for innovative piro- and piezo-resistive polymeric **temperature** and **pressure**, and nanosensors for **pH** and pCO_2 measurements. If not otherwise specified sensors are always treated in the above mentioned groups (in bold). Instrumented arrays, that incorporate the above-mentioned new sensors, exhibit a wide variety of behaviours, ranging from those that are long lived and completely autonomous to those that require manual operation or for a limited time or number of samples. Then testing methodologies must be carefully chosen to be addressed to such instruments, thus avoiding too general considerations. The conditions, under which sensors were tested, were selected according to: the information about the sensors and their behaviour acquired during the project and proposed by sensor developers. The platforms where sensors were to be used, their range of operability and environmental working conditions under which sensors were expected to correctly perform, were under focus for stressing and transmission issues. Additionally, other essential background information for reference were previously collected like the existence of international agreements and regulations, implementation efforts, projects having influence on sensor design, relevant problems, technical issues and deficiencies in currently existing sensors, information on standards for managing/accessing sensor data and observations, and on standards for data communication.

II. INSTRUMENTS AND SENSORS FOR TESTING

A first important step to design a testing strategy for the sensors developed within the COMMON SENSE project is to classify them according to several other aspects in addition to their purpose (parameter observed), the methodology used (physical, chemical, etc) or the properties of each of the sensors. **Errore. L'origine riferimento non è stata trovata.** presents a list of those aspects for a sensor classification, some in a binary way (Y/N), and the results are included in **Errore. L'origine riferimento non è stata trovata.**. Such a procedure is very useful for testing methodologies, and is easy to expand if a new aspect would be included or for testing any new sensor, if needed.

Another aspect not previously mentioned involves the possibility of including a sensor in an instrumented sensor array that may include other commercially available sensors. Instrumented arrays are also convenient for testing purposes when including both the sensor objective and one or many reference sensors for contrast. Testing instrumented arrays should include testing data transmission and data storage if required. Another important aspect to be taken into account is the adaptation of a sensor to a platform.

Testing strategy involves a comparison among sensor output and another, widely acknowledged, reliable information on the sensed parameter. This is the so-called validation process. The reference data may be obtained either from a commercial sensor, being widely used in marine monitoring, and well calibrated, or from a standard analytical protocol on water samples. In many sensor descriptions produced from sensor developers, there are references to these suitable sensors or analytical protocols. In most cases they are being used in the first laboratory tests.

Sensors must be tested according to the real sea conditions that could be found during real monitoring. Sea conditions may exert important stresses on sensors and instrumented arrays, especially in unmanned and extended duration monitoring.

TABLE I. ASPECTS OF MEASURED PARAMETERS, METHODOLOGY USED OR SENSOR CHARACTERISTICS RELEVANT FOR TESTING

Acronym	Characteristic	related to	Details
SV	Single value	Parameter	Observation can be expressed as SV
CV	Complex value		Observation can be expressed as CV
CD	Continuous		Property is continuously distributed in water
DD	Discrete		Property is discretely distributed in water
PD	Point		Property can be associated to a single point at a time
ED	Extended		Property can be associated to an extended volume at a time
AM	Automatic	Method	Analysis is fully automatic
SM	Semiautomatic		Analysis requires periodic human intervention
MM	Manual		Analysis requires human intervention
CS	Continuous sampling		Delivered data can be continuous in time
DS	Discrete sampling		Delivered data is always discrete in time
LD	Low data		Information depends on few data points
HD	High data		Information depends on many data points
PP	Pre process		Pre process is always required before sending data
SS	Small	Sensor	Sensor and installation are small
LS	Large		Sensor and installation are large
AR	Auxiliary		Sensor requires auxiliary material (reagents, standards, etc)
RS	Replacement		Sensor is disposable and has to be replaced after some samples

TABLE II. ITEMS OF TABLE I RELATED TO EACH ONE OF THE SENSORS

Acronym	**Temperature**	**Pressure**	**pH**	**Nutrients**	**Microplasitcs**	**Heavy Metals**	**Underwater Noise**
SV/CV	SV	SV	SV	SV	SV	SV	CV
CD/DD	CD	CD	CD	CD	DD	CD	CD
PD/ED	PD	PD	PD	PD	PD	PD	ED
AM/SM/MM	AM	AM	MM	SM	SM	MM	AM
CS/DS	CS	CS	DS	DS	DS	DS	CS
LD/HD	LD	LD	LD	LD	HD	LD	HD
PP	*N*	*N*	*N*	*N*	*Y*	*N*	*Y*
SS/LS	SS	SS	SS	SS	LS	SS	LS
AR	*N*	*N*	*Y*	*Y*	*N*	*Y*	*N*
RS	*N*	*N*	*Y*	*Y*	*N*	*Y*	*N*

Taking into account that none of the developed sensors inside COMMON SENSE was supposed to work below 10 m depth, the stressor "depth (pressure)" has been removed from the list. In addition, according to sensors' developers it appears that none of the sensors was susceptible to be affected by environmental light.

III. COMMUNICATION

For data retrieved in real time (RT), communications have a key role in monitoring since they are necessary to get data available and must be carefully tested. Testing strategies should then be designed to include a review of the communication methods, their suitability according to monitoring circumstances and their strengths and weaknesses. The main goal of communications is to get data from a source (sensor/instrument) from a more or less remote location. Communications can also be required to trigger sampling or modify the working conditions of the instrument. Communications, then, can be uni- or bi-directional and data sent through a communication channel will be referred to as a signal. As convention, we refer the direction of the communication from the point of view of the instrument in charge of the monitoring, thus to send (output) or receive (input) signals. Data sent from the instrument have strict rules according to the OGC (Open Geospatial Consortium) Sensor Web Enablement (SWE) protocols to be assimilated through the Sensor Observation Service (SOS) and have to be taken into account when dealing with the different communication channels. In all cases, however, data transferred is digital, thus the present paragraph only deals on digital signal transmission disregarding analog signals.

A. *Communication channels*

A communication channel is a link between the source of a signal and the receiver. Communication may involve a real physical connection between source and receiver (physical link) or it can be established through electromagnetic or acoustic waves (telemetry). Physical links are based on cable or optical fibre and telemetry methods will depend on the transmitting medium: acoustic telemetry through water and electromagnetic telemetry through the atmosphere or space. A first step to select a communication channel involves the distance between source and receiver and the available infrastructure. For instance, if the source is moving (ship, drifting buoy) or in a remote location, there is no possibility to use a physical link. However, the reciprocal is not true since fixed locations near the coast cannot always be physically linked. Since we are considering only digital signals, the channel capacity for data transfer will be measured in bits per second (bps) and its multiples (Kbps, Mbps and so on). A second step to select a communication channel involves the capacity required. Other important conditions to be taken into account for the channel choice are: power requirements, reliability and costs, both for installation and transmission (recurring costs). Telemetry through electromagnetic waves is the most universal communication channel, except inside water.

TABLE III. SUMMARY OF COMMUNICATION CHANNELS AND THEIR CHARACTERISTICS.

Transmission Channel	Initial Cost	Recurring costs	Distance	Power	Platform	Capacity	Advantages
Undersea optical fibre	Very high	Maintenance / Insurance	No limit	irrelevant	B,C	The highest (10 Gbps)	Highest capacity
Cable	Medium	Maintenance	No limit	irrelevant	B,C	Very high	Very high capacity
Acoustic	High	Maintenance/ Insurance	2-3 km	high	none	Low (up to 2 Kbps)	for moving underwater sensors
Direct radio link	Low	Maintenance	<30 km (more if receiver is elevated)	low	C,F	High (50 Mbps)	Low cost equipment, high capacity, high reliability
Troposcatter	Medium	Maintenance	< 250 km	very high	none	Medium (up to 22 Mbps)	High capacity, high reliability, no delay, IP based system, no recurring monthly costs
Mobile GSM: 3G,4G, 5G	Low	Monthly. based on capacity and total monthly bytes	Short. Dependent of operator node network availability	low	A,C,F	Medium (up to 20 Mbps)	Low cost equipment, high capacity, high reliability, network implemented in land
Satellite link GEO	Low	Monthly. based on capacity and total monthly bytes	irrelevant	very high	none	Low: 256 bps to 8 Mbps	Low equipment cost (for very low capacity <512 bps)
Satellite link LEO	Low	Monthly. based on capacity and total monthly bytes	irrelevant	low	A,C,D,E,F	Low: 256 bps to 8 Mbps	Low equipment cost (for low capacity <7.2 Kbps)

Communication can be established directly between source and receiver or through an intermediate device. There are several choices depending on the kind of wave within the electromagnetic spectrum and the intermediate: direct radio links (microwaves without intermediates), mobile telephonic links (microwaves with intermediate) and satellite links (VHF, UHF with intermediates). The first two based on microwaves require the source be "at sight" from the receiver (in the same Line of Sight; LoS), thus they cannot work for long distances because of the Earth curvature. The next sections are devoted to a more detailed description of each one of the channels and the main relevant results are summarized in Table III (here platforms A, B, C, D, E, F stand for research vessel, fixed platforms, buoys and moorings, ocean racing yachts, drifting buoys and fishing vessels, respectively, available for sensors' testing inside the COMMON SENSE project).

B. *Physical direct links*

Physical direct links are the most efficient, quick and high capacity communication channels. The method consists of connecting the source and the receiver through a cable. Traditionally, a signal was transmitted through a metallic (Cu) cable, because it has an excellent conductivity, until the optical fibre is progressively expanding. As a communication channel, optical fibre has a much higher capacity (up to 10 Gbps compared with the 0.1 Gbps of the copper cable). The disadvantages are the high cost of installation, only justified for a really huge volume of data such as that generated by underwater noise sensors (in our case), or image transmission. This technology also requires the sensor be located in a fixed platform close to the receiver (mainly in coastal region) and easily serviced as for example OBSEA.

C. *Acoustic links*

Acoustic links are based on the transmission of sound through water. Since electromagnetic waves cannot propagate through the water, telemetry within this medium can be achieved through sound waves. In comparison with the propagation of the electromagnetic waves in the air, sound propagates much slower, at around 1500 m/s, and the attenuation of the signal depends on the frequency. The lower the frequencies, the longer is the transmission distance. Typical acoustic links consist of a transducer with a hydrophone and a receiver. Distances covered can reach some km in best conditions and the capacity of acoustic channels is fairly low (up to 2 kbps). In addition, the power required and cost used to be quite high. They are used for low-rate real-time communications with instruments deployed without cable connections (e.g. Scanmar sensors used in fishing boats).

D. *Direct radio links*

This kind of channel is conceptually similar to a direct physical link but through radio telemetry. It is also named as point-to-point radio link and the basic requirement is that source and receiver must share a LoS, without any obstacle between them. It is a dedicated channel and transmissions can be at no cost (see below). The source and reception communicate in the microwave band of the spectrum. The suitable frequencies for our purposes would lie within the ISM (Industrial, Scientific and Medical) radio band. Although these must be restricted to medical and scientific use, they are broadly used because no license is required for this band and this causes a risk of interference. The counterpart is that almost everywhere it is unlicensed so that instruments and receivers can be used almost everywhere within this band. Several environmental factors such as mist, rain and clouds can attenuate the signal in direct radio links. This is relevant for testing purposes so that any test for this communication channel should consider the additional power requirements to compensate the environmental attenuation. Higher frequencies also involve more attenuation. Radio links can be used for coastal regions, even if they are in remote inhabited areas since the receiver can be installed in a car, a house or even a provisional settlement such as a camp. This is the preferred option for the fixed buoy in front of Barcelona. Point-to-point transmission can be enhanced in coverage taking advantage of the tropospheric scattering of electromagnetic waves. In this case some of the scattered radiation emitted by the source can reach a receiver not being in a LoS. This kind of channel is named Troposcatter and is used for transmission between points well below 1000 km apart with good efficiency and relatively high capacity. The problem however is that high power for transmission is required since only a small fraction of the total emission can actually reach the receiver,

E. *Mobile phone webs*

The unprecedented widespread mobile communication systems from the early 2000's, has promoted a communication web based on terrestrial nodes with a large coverage on land. The system is based on a bidirectional microwave channel from the "user" to one of the nodes. Nodes are usually connected by cable or by direct radio links. Mobile webs are rapidly evolving and changing fast their protocols, from GSM-2G (2nd generation of Global System for Mobile communications) to UTMS-3G (3rd generation of Universal Mobile Telecommunications System) up to the 4G and the recent 5G. Those systems can be used as communication channels using the standard 2G, which is the most widespread, at low price but there are some important problems to be taken into account as shown below. The mobile systems are designed and suitable for land but their marine coverage is very limited to the very coastal areas. There are many companies operating using different frequencies and not always compatible. The protocols for data transmission now are evolving. The standard 2G for communications is now starting to be removed (within 2025), therefore for fixed coastal stations direct radio links are preferred.

F. *Satellite communications*

This is the most "universal" communication link (a brief history at https://www.britannica.com/technology/satellite-communication and [15, 16]). The intermediate for communication is a satellite in orbit of the Earth which redirects the signal from the source to the receiver. The orbit characteristics are according to the distance from the Earth surface and such distance determines the coverage but also the power required by the sender to reach the satellite. Communications through satellite do not rely on a single one but require several of them (a constellation) to have a reasonable coverage without causing strong delays in data transfer. Geostationary (GEO) satellites are orbiting the Earth over the Equatorial plane and its period exactly coincides with the Earth rotation thus remaining at a fixed point in the sky from the point of view of any observer lying on the Earth surface. To reach this period, the radius of the orbit is very large so is its altitude (a distance of around

36000 km from the Earth surface). Since the altitude is almost 3 times the Earth diameter, its coverage is almost half of the total Earth surface, although from near the boundary of this coverage the satellite is seen at the horizon. For that reason, three satellites are required to cover the whole Earth instead of two. This coverage then is such as from any point on the Earth surface there is one of these three satellites at least 30° over the horizon, except obviously those points located at latitudes higher than 60°. This is a very good coverage for the whole ocean except some Arctic regions (with latitudes higher than 80°N where those satellites would be seen less than 10° over the horizon). The main problem with these satellites is the high power required for transmission to such a long distance that makes them not suitable for our purposes. VSAT [15, 16] are the most commonly used communication satellites for marine communication purposes. The lower the altitude of the satellite, the smaller is the coverage and shorter the orbit period. This means that more satellites are required in the constellation to ensure a simultaneous good coverage. Among those, there are the MEO (Medium Elliptic Orbit) and LEO (Low Earth Orbit) with altitudes from 4000 to 15000 km for MEO and around 900 km for LEO. Since MEO satellites are still too high thus requiring too much power for communications, we will focus on the LEO constellations. LEO satellite constellations are close enough to the Earth surface to ensure good communication quality without exaggerated power consumption (typically around 1 W or less) but a high number (40 to 60) of satellites are required to ensure a reasonable good Earth coverage. Although many of these constellations are designed for land communications, they can ensure a reasonable good global cover without important delays. Among those constellations, there are two categories of satellites: Big LEO and Little LEO according to their size and performances. Little LEO satellites are cheaper but they have low capacity (always below 1kbps). Some Little LEO constellations are: Orbcomm, VITASAT, STARNET, etc. One of the oldest LEO satellite transmission systems is known as ARGOS, based on the NOAA Earth observation satellites [15, 16]. This constellation has been used since the 1980's to follow wild animals such as migratory birds or marine turtles but also to track drifting buoys and ARGO profilers. The system has a wide coverage but there are very few satellites which mean that there can be gaps in transmission. Before the advent of the GPS coverage for positioning, they were used (and still are in some cases) to find the position of the target (bird or buoy) through a Doppler estimate, and get some information such as temperature, etc. Nowadays drifting buoys and ARGO profilers have a GPS antenna and they transmit the position to the satellite in addition to the other data requested. The ARGOS system is unidirectional, from source to receiver, good for low frequency short data strings but quite expensive for systematic use since nowadays there are other alternatives as described below. Big LEO satellite constellations appear to be the most suitable to be used for their large capacity while still having a reasonable cost. Some Big LEO constellations are: Globalstar, Iridium, Tedellesic, Ellipso, ICO (INMARSAT-P), etc.

IV. TESTING PROCEDURES

The goal of testing is to verify and certify the behaviour of an instrument under real conditions. The process involves: to verify (1) in situ operability, (2) to validate the data against a known reference, and (3) to look for vulnerabilities from different sources.

1. Operability is the first step of any testing process although not always taken into account. Frequently the design of an instrument involves many specialists in several disciplines that while working as a team each one has its own point of view. After laboratory tests, many problems are discovered and can be corrected but those tests are not performed in "real" conditions. Therefore, the first step in a field test of a brand new instrument is to verify its operability. This includes but is not restricted to handling, installation, connections, protection and communications. In particular, for those instruments powered by batteries it is advisable to control the real power consumptions at sea, to ensure enough battery capacity. The objective of a testing step thus was to find as many failures as possible in the above terms that can be solved with changes in the design. Handling and installation are the mostly ignored problems in some designs because in many cases those who are in charge of these did not participate nor had a secondary role in design process. For this step, it is strongly recommended to include the participation of the whole team involved in the design and building of the instrument.

2. In situ data validation is the most important step in testing any instrument. It is assumed that sensors have been fully tested in the laboratory before starting field testing. This is an important remark to avoid confusions because at this point, we are dealing with validation, not calibration. Thus, when we talk about data delivered by an instrument/data source, we will not refer to the direct output from the sensors but to the information on the measured parameter values, expressed in their corresponding units. For example, when talking about data from a nutrient sensor, we are referring to the nutrient concentration (e.g. μmol/L), not to light transmission or absorption, measured by the colorimeter. According to the above considerations, we assume that when facing data validation, we already know the resolution and accuracy of the sensor, the precision of the measurement and no offset, since all this was already corrected in laboratory calibration and included in the process from raw data. Then we look for other aspects affecting the data quality such as long-time drifts, changes in resolution or any other problem caused by the environmental conditions in the field. The validation to be carried out thus essentially consists of an analysis of the data source versus the values produced by the reference sensors or analytical tools, by means of statistical tools. There are many choices for statistical tools, but the choice has to be consistent with the nature of the data source and the sampling strategy. These relevant concepts are reflected in Table II, as previously mentioned. The nature of the data concept refers to the physical properties of the measured magnitude. For example, it may act as a concentration of a dissolved matter (e.g. temperature, nutrients, heavy metals, and pH), strength, pressure (e.g. noise, pressure) or particulate matter (e.g. micro-plastics). Sampling strategy is a wide concept involving both time and spatial distribution of the measures including data acquisition frequencies and spatial resolution but also space and time span of the validation experiment. Data acquisition frequencies may vary from tens of Hz, in the case of marine underwater noise, to a few data points per day, in some of the manually operated sensors such as those for heavy metals or pH. Spatial resolution is directly related to the frequency through the speed of the platform holding the instrument.

Sampling strategy also involves the length of the time-series of data either when they are collected at a fixed position (mooring) or if the point is moving along a path (vessel track or vertical profile).

3. Testing of vulnerabilities is the last but not the least step in the testing process. Every instrument is designed to work under certain conditions. It must be tested under the foreseen stressors to reveal the impacts on data and operation (see the above sections) including the electronics and communications. Testing some of the stresses, such as sea-state, involve especially devoted exercises in suitable locations where the selected stresses are frequent. In addition, some of the stressors may act after long time exposure such as corrosion or fouling. This also involves a careful selection of locations for testing: high salinity and temperature or highly productive areas that would respectively accelerate the processes of corrosion and fouling. Some locations and conditions must be identified as suitable ones to test the sensors. Note that locations: (i) are under the previously identified stressors, (ii) are relevant according to the variables measured and, if possible, (iii) are being or can be currently monitored in for data validation and (iv) cover different transmission conditions. For a robust sensor testing it would be advisable that at least two different locations and conditions could be identified for every sensor+stressor to have more chances in case of any problem or failure.

The final goal of field testing is to certify the behaviour of each one of the sensors; therefore, present strategy must end up with a certificate design. Since sensors to be developed in this project are quite diverse, it is not advisable to prepare a "general testing certificate" covering all possible situations, so we propose a list of several items to include in a certificate and see which apply to every sensor, according to the previous information. These items have been classified in different categories, according to the methodology and sensors on which they will apply.

V. CONCLUSIONS

In its overall strategy of testing new sensors to certify their performance, the path for the development of a new ocean sensor can be grouped into three key phases: (1) R&D basis for cost-effective sensor development, (2) sensor development, sensor web platform and integration, and (3) field testing. In phase 1, a general understanding and integrated basis for a cost-effective sensors' development is provided. In phase 2, the new sensors are created to be integrated into instruments for the different previously identified platforms and it is planned how data produced will be processed, organised and saved. During phase 3, precompetitive prototypes at chosen platforms (e.g., research vessels, oil platforms, buoys and submerged moorings, ocean racing yachts, drifting buoys) are deployed to test the adaptability and performance of the in-situ sensors, then verified if the transmission of data is properly made and observed deviations are corrected. This paper uses what was obtained from the COMMON SENSE project where new robust, easy-to-use, multi-platform compatible, cost-effective, and multi-functional sensors have been provided focusing on eutrophication, marine litter, contaminants, underwater noise and other parameters (e.g. temperature, pressure, pH and pCO_2) according to the MSFD descriptors. However this approach intends to be feasible for any new sensor realized for marine research.

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