Is the Hidroboya™ a suitable system to read water parameters?

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Abstract

Hidroboya (or Hidro-Buoy) is a new platform for water monitorization that introduces a new concept: keeping sensors dry and away from water inside an internal chamber that is filled with fresh water when necessary. This special arrangement makes it almost impossible for a sensor to be contaminated by fouling (marine particles accumulation that makes measurements to be incorrect).

This paper focuses on analyzing data retrieved by the Hidroboya system to demonstrate data validity and also for discussing Hidroboya limitations.
Keywords: buoy, marine sensors, fouling, large time series of data, water parameters.

1 Introduction

1.1 Hidroboya general overview

The buoy main part is a strong hosepipe hanging from a floating body (figure 1). The hose contains several sampling catheters which are used to get water from different depths (as these tubes go out from the main hose and finish at the desired sampling depths). The main hose is securely bound to the anchoring chain in one or more points to avoid excessive hose movement.

The sampled water will go through a "sampling chamber" located inside the floating body. Sensors inside the chamber will get the desired data. As we are

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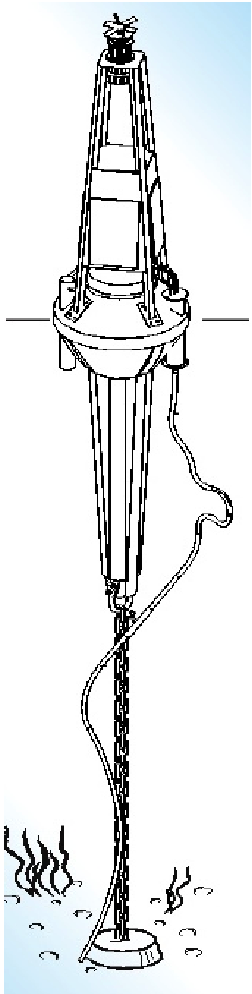

Figure 1: Buoy design.

keeping sensors away from sea water (or sweet water) most of the time we get a "fouling free" buoy.

The collected data will be transmitted o an "on land" station that will save them on a database system so that they will be available to all authorized users through a Web application. This Web page was named "Pagina Continuata Sensorum" a Latin phrase that emphasizes that with this system we get a continuous feed of water data over the internet.

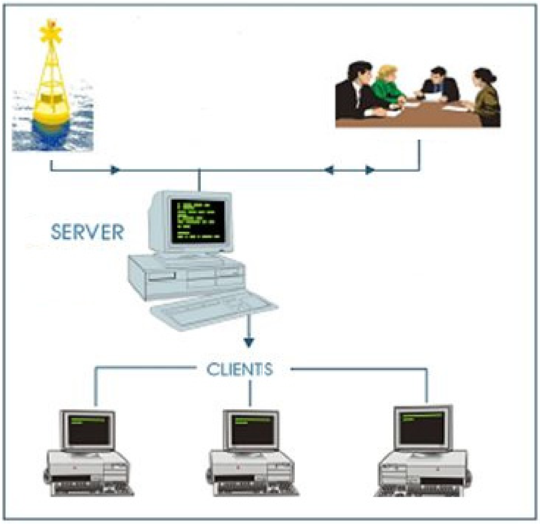

Figure 2: Data handling.

1.2 The fouling problem

Fouling can be defined as:

> "The accumulation of unwanted material on solid surfaces, most often in an aquatic environment. The fouling material can consist of either living organisms (bio-fouling) or a non-living substance (inorganic or organic). Fouling is usually distinguished from other surface-growth phenomena in that it occurs on a surface of a component, system or plant performing a defined and useful function, and that the fouling process avoids or interferes with this function."

In sensor fouling, the problem consists of alterations of the obtained measurements. A fouled sensor gives bad data and so becomes useless. Fouling is classified into visible (macro) fouling and invisible (micro) fouling.

Macro-fouling is caused by coarse matter of either biological or inorganic origin. In the case of sensors in a buoy macro-fouling does mainly apply in turbidimeters (nephelometers). Other kind of macro-fouling could be if water contains a great amount of oil. That oil will become attached to the sensors. This is not usual because great amounts of oil are always in the water surface.

In most sensors, the micro-fouling, more in concretely: bio-fouling (micro-organisms, algae and diatoms, plants, and animals) is the main fouling type to avoid. Fouling in sensor surface alters the sensor itself (sensor loses its sensing surface and begins producing bad data).

In so short time as a week a submerged sensor can get completely fouled. In figure 3 it is shown how the real turbidity of the water is corrupted by fouling in one month (April 23 to May 22).

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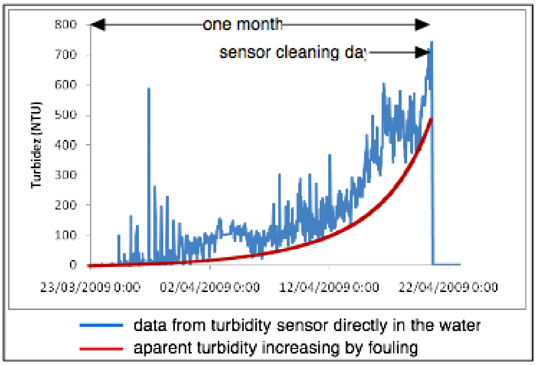

Figure 3: Turbidity data affected by fouling.

A good reference about classical techniques to avoid fouling can be found in [2] but basically there are:

1. Active systems: they try to clean fouling, for example: injecting bleach that avoids bio-fouling sedimentation.
2. Passive systems: they consist of physical protections for sensors that are made of materials that are harmful for bio-fouling. The most used material is copper.

Surveying product information from leading companies devoted to this market, it can be observed that all the available solutions are traditional systems that in no case avoid fouling [3, 4].

Hidroboya is a new technique that tries to minimize the time the sensor is in contact with the water. As we already said this technique is based on a new sensor arrangement and it could be classified as an active technique although it goes far beyond than any other known method.

1.3 Operational Oceanography

Operational Oceanography is a developing area that needs to be fed with oceanic data, in order to produce continuous information. These data can be obtained from Remote Sensing Satellites (CREPAD [5]: "Centro de Recepción, Proceso, Archivo y Distribución", Spanish for "Reception, Processing, Archiving and Distribution Center") but these data need to be combined with water column measurements taken directly from sea. Infrastructures such as CREPAD can help the whole society to have a better knowledge about the ocean and continental waters state. It will help in a more efficient use of our waters and coastal profitability.

Hidroboya has been created as a powerful tool to integrate with this operational oceanography systems. The development of the Hidroboya has been done looking for an effective way to avoid the fouling in the directly exposed sensors to the water. Overcoming the fouling problem lets Hidroboya to have very large maintenance intervals. Sensors are protected on board of the buoy. This brings the possibility of self calibration of sensors, enlarging even more the maintenance intervals. These facts make Hidroboya perfect for being used to feed data for the numerous projects of sea observation and for continental waters control [5, 6].

We firmly believe that the Hidroboya can suppose a “before and after” in the systems for direct water measurement.

2 Sensing design

Main originality of this buoy is the special sensor arrangement (figure 4). In classical systems sensors are directly contacting sea water and they soon became polluted (fouled) by particle sedimentation. Nevertheless our buoy keeps sensors dry when they are not being used so that they are not affected by fouling (figure 5). Due to this we have longer sensor life and less maintenance needs.

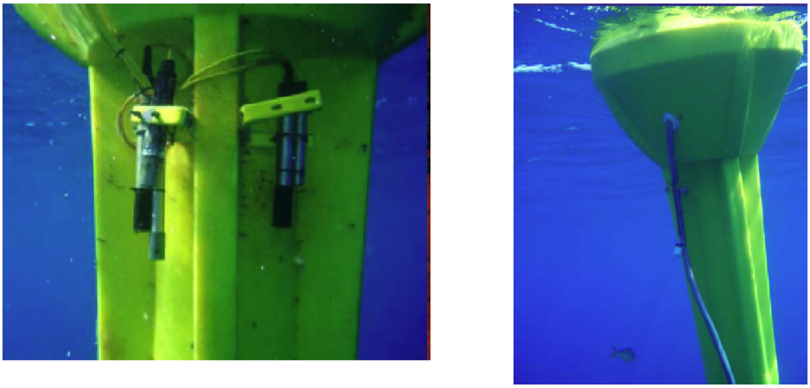

Figure 4: Sensor arrangement: classical buoy (above), Hidroboya (below).

Figure 5: Sensors affected by fouling (above). Hidroboya keeps sensors clean (below).

The fouling problem is really a very big one as long as a fouled sensor is producing incorrect data. What’s more, we normally have no idea about the speed of fouling sedimentation, so we do not know when received data are beginning to be erroneous.

This special arrangement has another important advantage: due to the fact that sensor are dry most of the time, we can integrate some sensors that are not feasible to be used in the classical mode. Examples of this are nutrient components meters, hydrocarbon meters, particle counters, plankton classifiers…

Nevertheless, the special sensor arrangement has some disadvantages. These are the following:

- Data are measured over a sampled portion of water that is always at 1 atmosphere of pressure. This is an intrinsic characteristic of the water pumping system. Design of a system that preserves original pressure is possible but difficult. This fact makes totally different some measurements (like solubilized gases concentration). Nevertheless until now it has not been necessary to improve the pumping system.
- Water temperature will be modified by measurement chamber temperature. This effect is minimized pumping water at high speed and putting measurement chamber under water level. Also catheters are made of a thermal insulated material.

Between measurements, sensors are kept dry but in a wet and dark atmosphere. They should also be at a similar temperature as the water that is going to be measured, that can be achieved maintaining the chamber inside the buoy but below sea level (instead of a chamber inside the buoy castle that was our first option). These conditions are optimal for sensor conservation.

3 Analysis of collected data

The first Hidroboya prototype was installed in Santa Cruz de Tenerife (Spain) from September, 2009 until June, 2010. This buoy had installed a multi-parametric sensor that measures: temperature, pH, electrical conductivity, redox, turbidity and solubilized oxygen concentration. It was making samples on three depths: 1 meter, 7 meters and 14 meters. In a test performed three months after installation, sensors were checked to be absolutely fouling free. We also tested that data acquisition, processing and sending to the Web server were correct. We also discovered that the inner face of catheters was affected by fouling. Although this is not so serious as if it were on the sensors, we decided to have the catheter always dry injecting compressed air into them.

The first commercial buoy was installed in Granadilla, Tenerife (Canary Islands, Spain) where a harbor will be constructed. The buoy is retrieving data from October 2010 until now. Data from the buoy can be accessed in real time in [7].

Having this practical experience we are going to analyze now data collected by Hidroboya buoys. We start by examining temporal graphs of data obtained by the sensors (figure 6).

In the curves we can see that data are suitable to be read only when the sensor has been reached by the water. See the strong discontinuity on data curves that corresponds to the beginning of correct measurements. To take this into account, the control system allows us to establish a priori the sampling instant to be used. This simple method is possible because chamber flooding speed is always the same for the same buoy (obviously sampling time is different at different depths). Sometimes we will have to wait some extra time to allow sensors to stabilize.

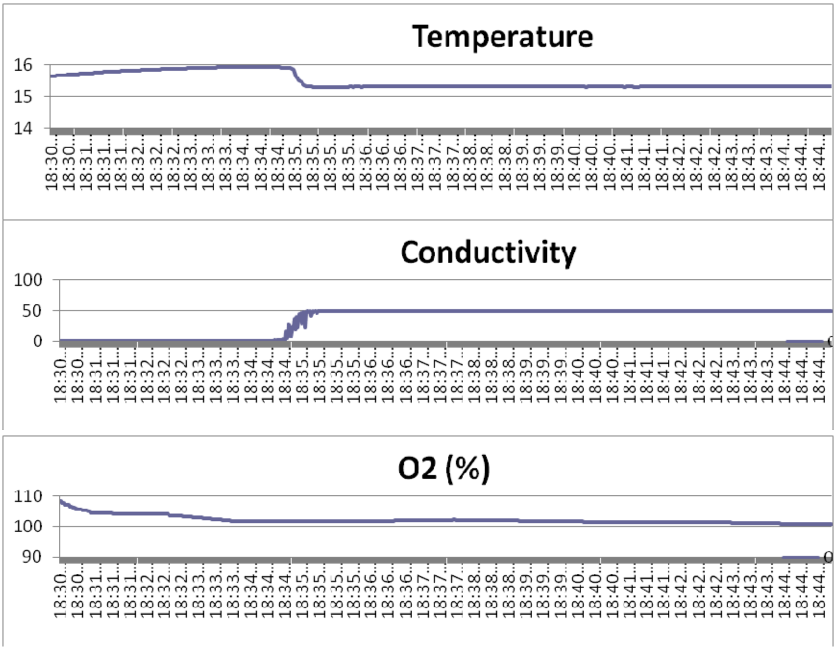

Figure 6: Data curves from buoy sensors (5 meter depth).

An important detail is that water continues to flow during the measuring process; this characteristic makes sensors to work at the best possible conditions because they are usually designed for moving (not still) water.

In some sensors (like redox potential) there will be noise fluctuations that never end. In this case we should define not a sampling instant but a sampling interval and we would keep the median of all collected samples (we started using the statistical mode but median is more robust).

As we commented above in section 2, temperature is also affected by the measuring process. Nevertheless temperature can be measured exactly because temperature sensors are not affected by fouling and they can be submerged directly in the water. In fact we use a thermistor chain to measure the exact temperature in the sampling points.

We also must know that oxygen concentration will be affected by the measurement system (oxygen concentration is affected by air pressure according to Henry's Law), being probably the less accurate measurement. System usually reads less concentration than real. Until now we have not needed to correct this detail but it is listed as a future line.

Our conclusion is that Hidroboya measurements are correct provided that operator configures properly the sampling times. These times can be determined previously in laboratory tests on each buoy. Most of the times, detecting parameter changes is more important than getting absolute values. And this is the main advantage of Hidroboya because its sensors are not affected by fouling. We care more on getting large (several years) complete time series. Getting large amounts of periodical data of the water conditions is the greatest advantages of Hidroboya that is hardly accomplished by other systems.

4 Work protocol

With this experience in mind we have established a “defensive” protocol for installation and maintenance of buoys:

- First: when installing a buoy, obtained values from the closed sampling chamber must be compared to those obtained by other sensors put directly into the sea (at the same depths). These sensors are used only for this test and are obviously free of fouling for this brief period.
- Second: each buoy must be checked for maintenance periodically with a standalone working period of about three months. Each sensor must be cleaned and calibrated. If it is found necessary to substitute sensors inside a buoy, measurements of the old sensor and the new one must be taken and saved for further study.

5 Conclusions

We have devoted this paper to demonstrate Hidroboya suitability for collecting water data at sea or continental waters. Hidroboya is right in the line pointed by the Water Framework Directive [8], about controlling different waters quality (bath, rivers, marine environment and coasts, drinking water, water pollution, etc). It uses the technologies pointed by [9] to construct the framework for marine environmental observation and control.

According to the results of this paper Hidroboya is suitable for reading data parameters with an adequate configuration of the sampling time for each sensor. The ability of Hidroboya to obtain large time series of water parameters (up to several years) makes Hidroboya a completely singular measurement system.

Some sensors (such as oxygen concentration) may have bigger errors and this could require another treatment. In any case, Hidroboya is superior to other systems that loose rapidly their precision due to fouling attack.

The U.S. Patent with definite number US 8312768 B2 and title “Autonomous and Remote-Controlled Multi-Parametric Buoy for Multi-Depth Water Sampling, Monitoring, Data Collection, Transmission and Analysis” has been granted for this system.

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