Overview of existing instrumentation relevant for ocean observatories

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Introduction

Man induced climate change and increasing exploitation of the world's oceans has increased the need for monitoring and management of the marine environment. Just as in meteorological modeling and forecasting marine models have to be supplied and calibrated with field data of sufficient quality and quantity to work reliably. For decades marine waters have been monitored from specialized ships at regular sampling schemes. It becomes increasingly clear that the spatial and temporal coverage of these data is insufficient. Continuous monitoring with instruments and sensors is needed and the technology is there to do it.

The main focus of the paper is to give an introduction to modern advanced instrumentation for monitoring of the marine environment which is mature enough to be deployed on ocean observatories. The main criteria for these sensors to be judged suitable is that the technology is well proven and has demonstrated to be long-term (at least 6 months) stable.

Ocean Observatories and criteria for the used sensors

The term *ocean observatory* is interpreted differently depending on which investigator is asked. The users of profiling Argo floats (http://www.argo.ucsd.edu/) will often refer to their instruments as the world's biggest array of ocean observatories including more than 3000 units.

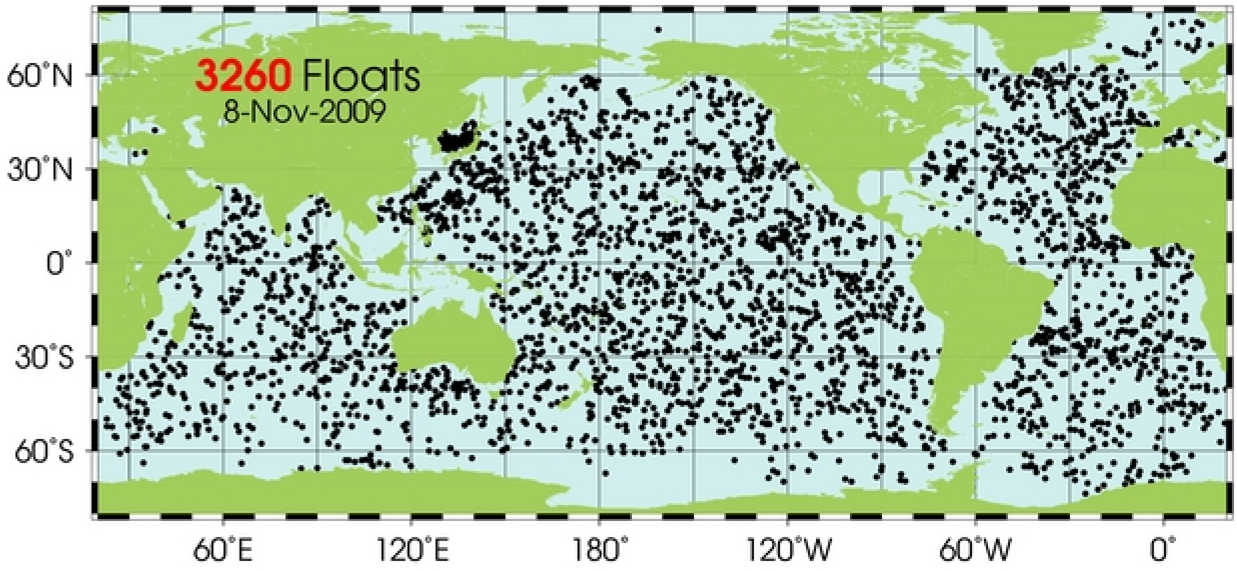

Fig 1: Number of Argo floats in operation as of November 8, 2009 (from http://www.argo.ucsd.edu/).

The core mission of the Argo float project is to measures Temperature and Salinity. Today numerous floats are also equipped with Oxygen sensors. More than 100 scientific publications are published every year using Argo float data.

Environmental buoy based monitoring systems with real time transfer of data have been established in various parts see e.g. http://www.poseidon.ncmr.gr/; http://www.gomoos.org/; http://www.pmel.noaa.gov/tao/; http://www.puertos.es/index.jsp and http://tabs.gerg.tamu.edu/Tglo/. Also many ports and harbors operate on-line installations, mainly used for navigational safety, which could be regarded as combined Oceanographic/Meteorological observatories e.g. http://on-line.msi.ttu.ee/tallinn/?eng and http://www.azti.es/ingles/estation.asp.

More recently large and expensive cabled observatories with high measurement and experimental capabilities have been installed. The first was set-up in Sagami bay off Japan (http://www.jamstec.go.jp/jamstec/station.html) . Others have been installed off the Canadian west coast (http://www.venus.uvic.ca/), off the French Mediterranean coast (http://antares.in2p3.fr/), off Oman (http://www.lighthousehouston.com/technology/lori/video) and off the US west coast (http://www.mbari.org/mars/).

Regardless off which platform serve as support for the measurements they all carry sensors which are more or less mature for long term deployments on observatories. Some criteria which have to be met for standardized high quality measurements from observatories are:

- LONG TERM STABILITY (most important)
- Detailed knowledge about sensor behavior
- Detailed knowledge about the measured parameter
- Parallel sensors (different makes)
- Mass produced with industrial quality control
- Based on modern industrial standards
- Traceability (sensor registry)
- Established reference methods
- Detailed knowledge about the quality of reference methods

To be successful quality control of the data is crucial and experience on how to do this in a systematic way can be gained from existing programs. E.g. in the Argo float program (see above) post data quality check is essential and is done by 5-10 persons at the Coriolois data center at Ifremer (http://www.coriolis.eu.org/) and at Scripps (http://www.argo.ucsd.edu/). For salinity and temperature high resolution CTD profiles obtained from nearby ships are used.

Overview over sensors:

More than two decades of technical development in electronics, telecommunication, optics and acoustics measuring techniques have opened new possibilities for on-line monitoring of the marine environment. Increasing computing and filtering capacity of instruments and sensors have increased the measurement accuracy at the same time as the equipment has been made smaller, long-term stable and consume less energy. Advances in telephone and satellite communications have increased the capacity to transfer data in real time, or close to, from any part of the world to the home office.

Today some technologies are clearly more mature and consequently better suited as sensors for ocean observatories than technologies which are still in the phase of development. In European project ESONET (http://www.esonet-noe.org/) which deals with the development of cabled observatories around Europe a “generic sensor package” has been proposed. This package consists of mature sensors which should give standard background information on all observatories. The suggested sensor package include: Conductivity, Temperature, Pressure, Turbidity, Currents, Passive acoustics, Acoustic backscatter and Oxygen.

In figure 2 below an attempt has been done to list and classify different sensor technologies according to if their track record is such that they can be considered ready for use on sea floor observatories.

To improve the quality and functioning of existing sensors and to boost the development of new technologies independent testing and evaluations are needed. The only organization which is doing this in a consistent and independent way by involving users and manufacturers is the Alliance for Coastal Technologies (http://www.act-us.info/). At this internet site information about different sensor technologies and manufacturers can be found as well as reports from comparative field tests.

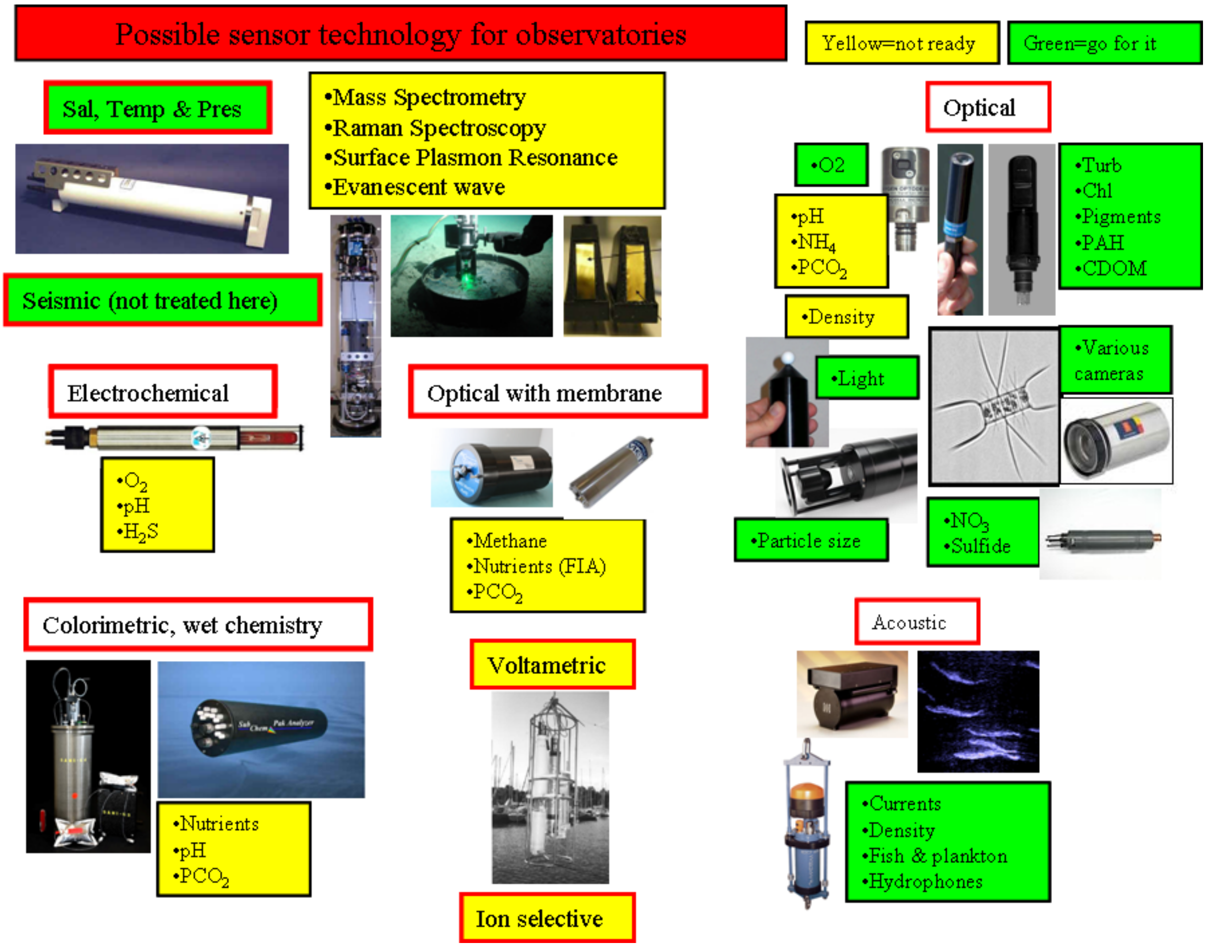

Figure 2: Classification of various existing sensor technologies into if they are suitable (green) for use on observatories of if more development would be needed (yellow).

Combined systems:

The real interest in cabled observatories is not to measure with a couple of sensors, which might as well be done with a traditional self contained instrument with internal power and data storage. Cabled observatories provide communication and power suitable for advanced systems. Some examples of immerging combined systems include the combination of biological and more traditional sensors. Biotaguard (Figure 3) is a system that combines heart frequency and shell opening measurements of mussels with the collection of physical and chemical information. Such systems are today deployed in Norway on-line for industrial leak detection. The mussels have the advantage of filtering large amount of water concentrating any persistent toxic substances which may be present in the water.

The image shows mussels which have been equipped with sensors for heart frequency and shell opening measurements.

Other combined systems include the Seaguard string logger equipped with sensors to measures respiration rates of giant reef sponges over time periods of several months (Figure 4).

Pairs of sensitive optode oxygen sensors spaced at 30 meter intervals along the main trunk cable or “string”, are placed at Giant Reef Sponge water intake and outflow (excurrent) locations to directly determine dissolved oxygen consumption by concentration difference. Responsible scientist is Dr. Chris Martens, University of North Carolina at Chappel Hill (USA). So called Planar Optodes (Figure 5) is a technique that permits to take two dimensional photos of the oxygen distributions in the sediment and at the sediment-water interface.

This technology has been developed for autonomous operation on landers.

Figure 3: The Biotaguard system (http://www.biotaguard.no/visartikkel.asp?id=586) combines biological (mussels), physical and chemical sensors into a powerful assembly for environmental monitoring.

. It has also been used on a Japanese cabled observatory in Sagami bay. On a cabled observatory it should be possible to move the Planar Optode from spot to spot to do mapping of greater areas using an instrument like the MBARI rover (http://www.mbari.org/news/news_releases/2009/rover/rover-release.html.

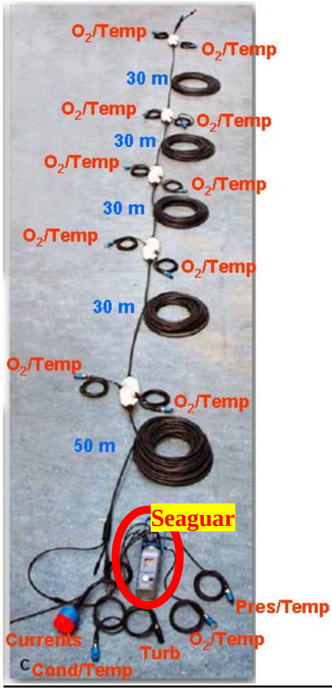

Figure 4: Seaguard string logger designed for use at the Aquarius underwater observatory off Florida Keys.

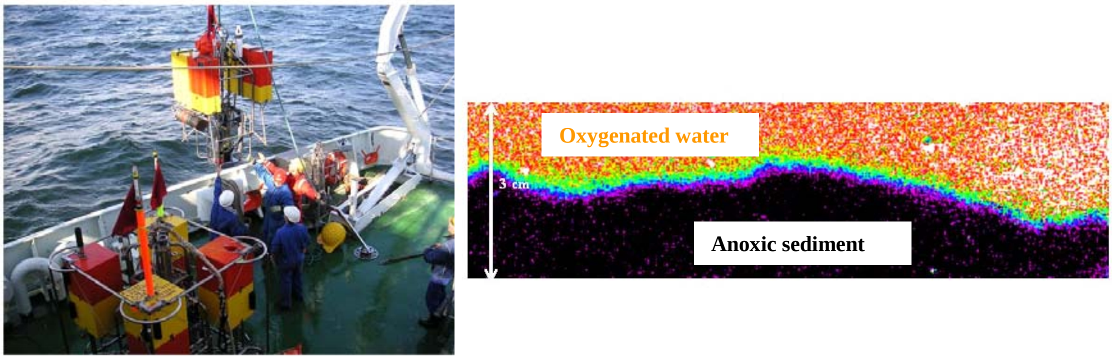

Figure 5: Left, the Göteborg minilander equipped with an autonomous planar optode being recovered in the Gulf of Finland (Baltic Sea). Right, example of oxygen image of the sediment-water interface.