

## Multi-parameter observations from coastal waters to the deep sea: focus on quality control and sensor stability

Anders Tengberg<sup>1,2</sup>, Per Hall<sup>2</sup>, Dariia Atamanchuk<sup>2</sup>, Mikhail Kononets<sup>2</sup> and Christoph Waldmann<sup>3</sup>

<sup>1</sup>Aanderaa Data Instruments AS, Bergen, Norway

<sup>2</sup>Department of Chemistry and Molecular Biology  
University of Gothenburg, Sweden

<sup>3</sup>Marum, University of Bremen, Germany  
E-mail of presenter: anderste@chem.gu.se

**Abstract:** Decades of technical development in electronics, telecommunication, optics and acoustics measuring techniques have opened new possibilities for multi-parameter monitoring of the marine environment. This conference paper will give examples on how fixed multi-parameter platforms are used in different applications. Focus will be on long-term (years) stability and the challenge to maintain satisfactory quality control throughout the deployments.

**Keywords:** observatories, sensors, quality control

### INTRODUCTION

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.

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. 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/>). 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>

<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>. Regardless of which platform serve as support for the measurements they all carry sensors which are more or less mature for long term deployments on observatories. In this conference paper the performance (accuracy and long-term stability) of a selection of chemical, physical and biological sensors will be addressed and exemplified with data. Immersing sensor technologies will also be discussed.

### ACOUSTIC CURRENT MEASUREMENTS

The use of acoustic Doppler Technology to measure currents is an accepted well-established method which is used from shallow water streams see (Fig. 1) down into the oceans deepest trenches (Fig. 2).



Fig 1. Sontek IQ compact acoustic doppler profiler installed in an irrigation canal to monitor flow.

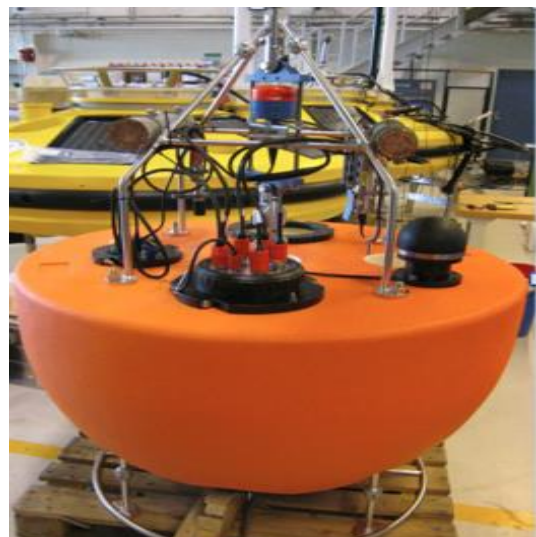


Fig 2. Deep sea observatory (Aanderaa Smart Sub) with multiple sensors: O<sub>2</sub>, pCO<sub>2</sub>, CH<sub>4</sub>, Salinity, Temp, Pressure and Doppler Currents Sensor (orange sensor on top) and with acoustic modem (Develogic) for on-line data transfer.

An independent technique to verify the accuracy of single point acoustic doppler sensors is to tow them in test tanks where the precise speed of a moving platform, trolley, serve as an absolute reference (Fig. 3 and Fig. 4).



Fig. 3. Example of a tow tank facility with the trolley towing an instrument at accurate speed in the middle of the tank.

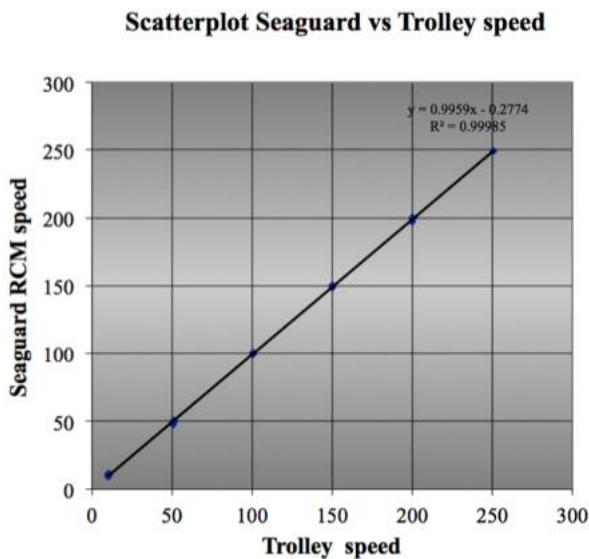


Fig. 4. Example of tow tank data from Aanderaa Seaguard recording current meters

Acoustic Doppler profilers that are measuring in several layers above or below the instrument itself, are difficult to verify in tow tanks, mainly because of noise coming from acoustic reflections in the tank walls.

One method of on-line quality verification that has been used on the Koljoeffjord observatory is to place a single point tow tank tested current sensor in the water column above the profiler. Current speed and direction data from the single point sensor is compared with data from the corresponding level of the acoustic profiler. If data corresponds well there is reason to believe that current

measurements below the single point sensor are of high quality (Fig. 5).

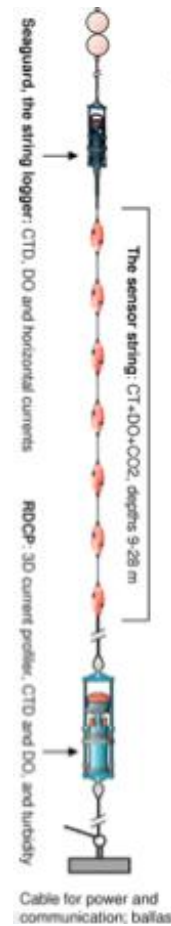
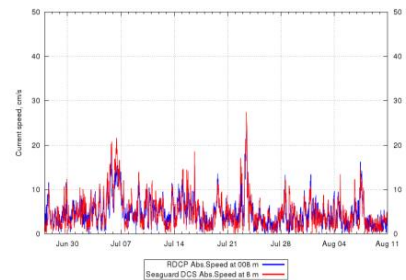


Fig. 5. To the left set-up of the Koljoeffjord observatory with Seaguard Single point current meter placed 32 m above an RDGP-600 acoustic profiler. Below is an example of comparative current speed data (Seaguard=red and RDGP=blue) where the single point sensor confirms the data quality of the current profile.



### KOLJOEFJORD OBSERVATORY

Most aquatic life depends on oxygen. It is, thus, an alarming finding that the occurrence of hypoxic (low oxygen) conditions is increasing worldwide. This is mainly thought to be a consequence of anthropogenic eutrophication (nutrient input) and climate change.

In the Koljoeffjord an on-line observatory was installed in April 2011 to assess and model the dynamics of a system of fjords on the Swedish west coast. The observatory also serves as a test facility of new sensors and technology. When installed one monitoring node with approximately 30 sensors was connected. Later the observatory has been updated with approximately 20 more sensors.

Data are stored internally in the instruments and the node, and are also available online and retrieved in real-time. Remote control over the main hub is implemented and has been used for adjusting measurement system parameters over the Internet. A web display is developed for checking, plotting and quality control of the data coming in: <http://mkononets.dyndns-home.com:8080/>.

The observatory is deployed very close to a sampling station of a monthly survey program run by SMHI (Swedish Meteorological and Hydrological Institution). All the reference data are available online and retrieved for displaying automatically from the web databases. Tidal oscillations result in strong variations in the intermediate layer. Within a few hours temperature can vary with up to 10 deg C, salinity with up to 5 PSU, oxygen with up to 70% air saturation (Fig. 6). This and because the depth of sensors and reference water sampling are not always the same, differences occur frequently between observatory and reference data. Outside the intermediate layer (close to surface and deeper) agreement to reference data is generally good.

A source of errors appears at low oxygen where reference Winkler data gave higher values due to contamination during sampling. The contamination can be introduced both when taking water samples with Winkler bottles, where the plastic dissolves oxygen and when emptying the bottles on deck.

Biofouling effects were observed for O<sub>2</sub> and Conductivity sensor data measured close to surface (result in lower readings) in July-September 2011. Reference data are invaluable in helping to identify this type of interference and to plan how frequently sensors should be cleaned.

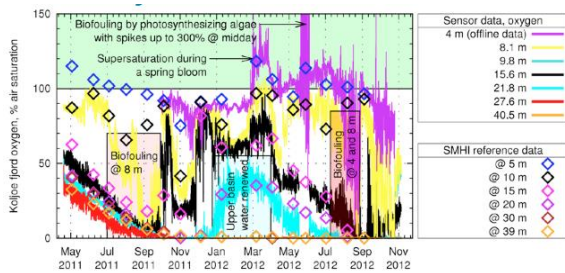


Fig. 6. 18 months of oxygen variation in the Koljoeffjord measured at 7 levels (lines) compared with monthly reference data from SMHI (diamonds). Note that at oxygen levels below 50 % values from water samples are consistently higher than what sensors on the observatory are giving.

Today oxygen is measured at 10 levels with 14 optical oxygen sensors. At some levels two sensors are placed in parallel to evaluate new technological developments. The majority of the oxygen sensors used come from Aanderaa. This type of sensors have been described and used in a wide variety of projects during the past decade e.g. [1-4]. The longest field deployments without any detectable drift have so far been more than 6 years. If sensors are affected by biofouling methods have been developed to lift and clean the observatory using dredging lines. This procedure is performed 2-3 times per year during the summer season and normally takes no more than one hour. No divers or ROVs are required for the operation.

After cleaning sensors return to correct reading. No signs of drift has been detected during the more that two years that the observatory has been operational.

Salinity/Conductivity is measured at 7 levels in the fjord (Fig. 7). As for the oxygen optodes, fouling is affecting the sensors during the summer season. Typically fouling effects are first seen on the Salinity/Conductivity sensors after 1-2 months while oxygen optodes are affected after the double amount of time.

For verification if conductivity sensors have been effected by fouling, and to what extent we have used profiling CTD instrument along the string of sensors just at the moment when the observatory is measuring. The compact CastAway CTD has turned out to be ideal for this purpose Fig. 8.

All sensors on the observatory have in built high quality temperature sensors. This means that temperature is measured at 10 levels with more than 20 sensors. Fouling has no effect on the temperature measurements.

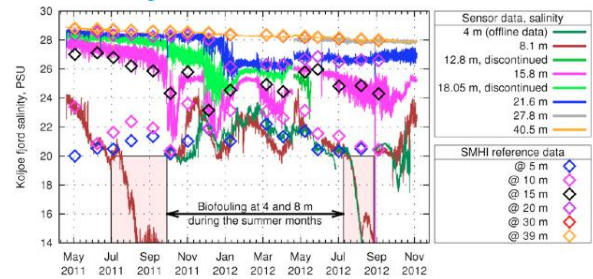


Fig. 7. 18 months of salinity variation in the Koljoeffjord measured at 7 levels (lines) compared with monthly reference data from SMHI (diamonds). Note that the salinity in the bottom of the fjord is slowly decreasing due to diffusion.



Fig.8. CastAway CTD (YSI) gives high-resolution Sal/Temp profiles in the water column while free falling. It has in-built GPS for positioning and accurate time. About 30 CTD casts are performed per hour without disturbing the structure of the water column. Data are stored on-board until automatically downloaded via Bluetooth to a PC.

#### TESTING OF NEW TECHNOLOGY

The Koljoeffjord observatory has been used as a test bed of new technology. For the past two years optical pCO<sub>2</sub> sensors in combination with other parameters have been giving interesting data on the primary production, organic matter degradation and on air-sea gas exchange (Fig. 9).

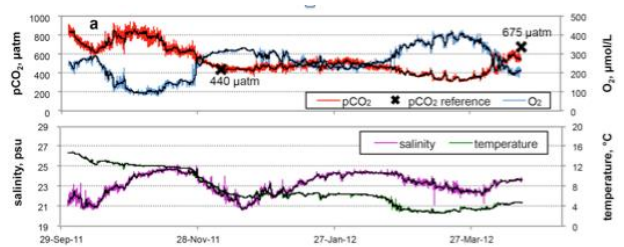


Fig. 9. Negative correlation between pCO<sub>2</sub> and oxygen time-series (upper panel), and measured/calculated temperature and salinity time-series (lower panel) for October 2011-April 2012. Black line represents a 12 hours averaging of the data; crosses indicate reference pCO<sub>2</sub> data analyzed from collected water samples. The figure was copied from [5].

During 2012-2013 a shallow water offline mooring with more than 20 sensors was deployed at the site focusing on pelagic algae production and air-sea exchange (Fig. 10). Data from this installation and from the observatory is presented in [5].



Fig. 10: One Seaguard (Aanderaa) and one EXO2 (YSI) deployed back to back during 2012-2013. The two instruments are carrying the following sensors: Cond/Sal (2), Temp (6), Pressure (2), Wave/Tide, O<sub>2</sub> (2), pCO<sub>2</sub> (2), FDOM, ChlA-Blue green-Total algae, pH/ORP and Currents (speed and direction). Copper coverage and a wiper provide Antifouling.

## REFERENCES

- [1] Körtzinger, A., J. Schimanski, U. Send, and D.W.R. Wallace (2004). The ocean takes a deep breath. *Science*, 306: 1337.
- [2] Tengberg A., J. Hovdenes, J. H. Andersson, O. Brocandel, R. Diaz, D. Hebert, T. Arnerich, C. Huber, A. Körtzinger, A. Khripounoff, F. Rey, C. Rønning, S. Sommer and A. Stangelmayer (2006). Evaluation of a life time based optode to measure oxygen in aquatic systems. *Limnology and Oceanography, Methods*, 4: 7-17.
- [3] Hydes D.J., M.C. Hartman, J. Kaiser and J.M. Campbell (2009) Measurement of dissolved oxygen using optodes in a FerryBox system. *Estuarine, Coastal and Shelf Science*, 83: 485-490.
- [4] Champenois W. and A. V. Borges (2012) Seasonal and interannual variations of community metabolism rates of a *Posidonia oceanica* seagrass meadow. *Limnology and Oceanography*, 57(1), 347-361.
- [5] Atamanchuk D., M. Kononets, P. Thomas, J. Hovdenes, A. Tengberg and P.O.J. Hall (2013) Continuous long-term observations of the carbonate system dynamics in the water column of a temperate fjord. Submitted to *Marine Chemistry*.