Optodes and smart sensors suitable for gliders and floats: experiences and new developments

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EGO-2011 Workshop and glider School

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Smart sensors

Internal Digital Signal Processor (DSP) gives higher accuracy and stability

Multitasking (several parameters measured with the same sensor)

Calibration coefficients & ID included

Low power consumption

1s sampling

Multiple Output:

- **Cond: Cond,Sal,Temp,Sound speed,Raw**
- **Pres: Pres,Temp,Raw**
- **Oxygen: O_2,O_2%,Temp,Raw**
- **Wave & Tide: Wave,Tide,Temp,Raw**
- **CO_2: pCO_2,Temp,Raw**
- **Currents: Currents,Temp,Signal Strength,Raw**

Communication:

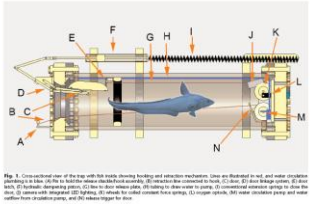
- **RS232/RS422**
- **Aanderaa SR10 (10 bit)**
- **CAN bus AiCaP (20 sensors plug and play)**
- **Analog 0-5 V, 4-20 mA (with adaptor)**

Oxygen Optodes

Experiences with AADI O_2 Optodes (more than 4000 in use)

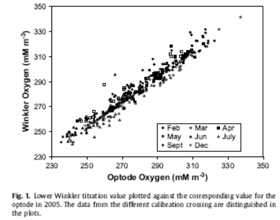
The basic technique and an evaluation of its functioning in aquatic environments Tengberg et al (2006)

Fauna Incubators



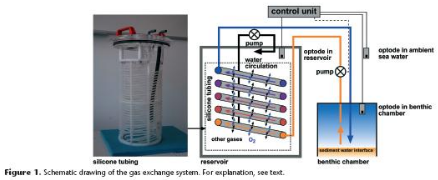
Optodes have played a central role in fauna incubators in deep sea applications. Drazen et al (2005) developed a hyperbaric fish incubator.

Ferry boxes



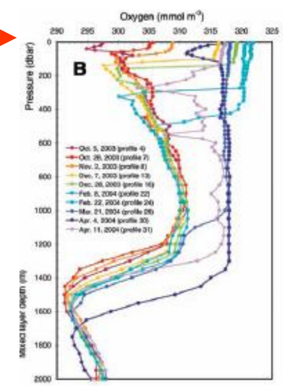
Hydes et al (2009) demonstrated the performance of optodes to measure oxygen on ferry box systems. No sensor drift was detected in any of the data series.

Gas Exchange Chamber



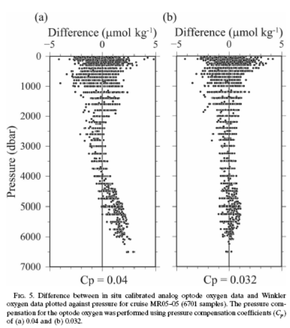
Sommer et al (2008) described an automatic system to regulate oxygen levels and to measure sediment-water fluxes during in-situ sediment incubation at vent sites

Argo floats, ~400 with O_2



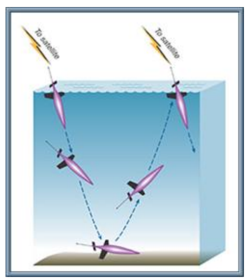
Körtzinger et al (2004, Nature) used autonomous Argo floats to measure the ventilation of the Labrador Sea. Since this paper optodes on Argo floats have shown stabilities of 4+ years. Other recent papers Johnson et al (2010, Nature) on Nitrate & O2 in the North Pacific subtropical gyre.

Cabled CTD



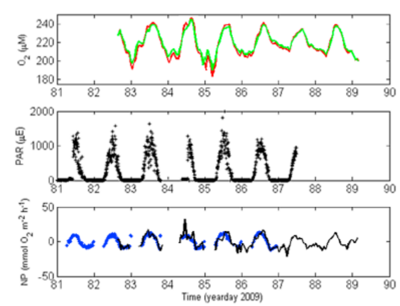
Uchida et al (2008) compared eleven optodes with several thousand Winkler data on cabled CTD instruments for profiling down to 6000 m. The work includes suggestions for improved calibrations, pressure effect and compensation for slow response.

Sea Gliders



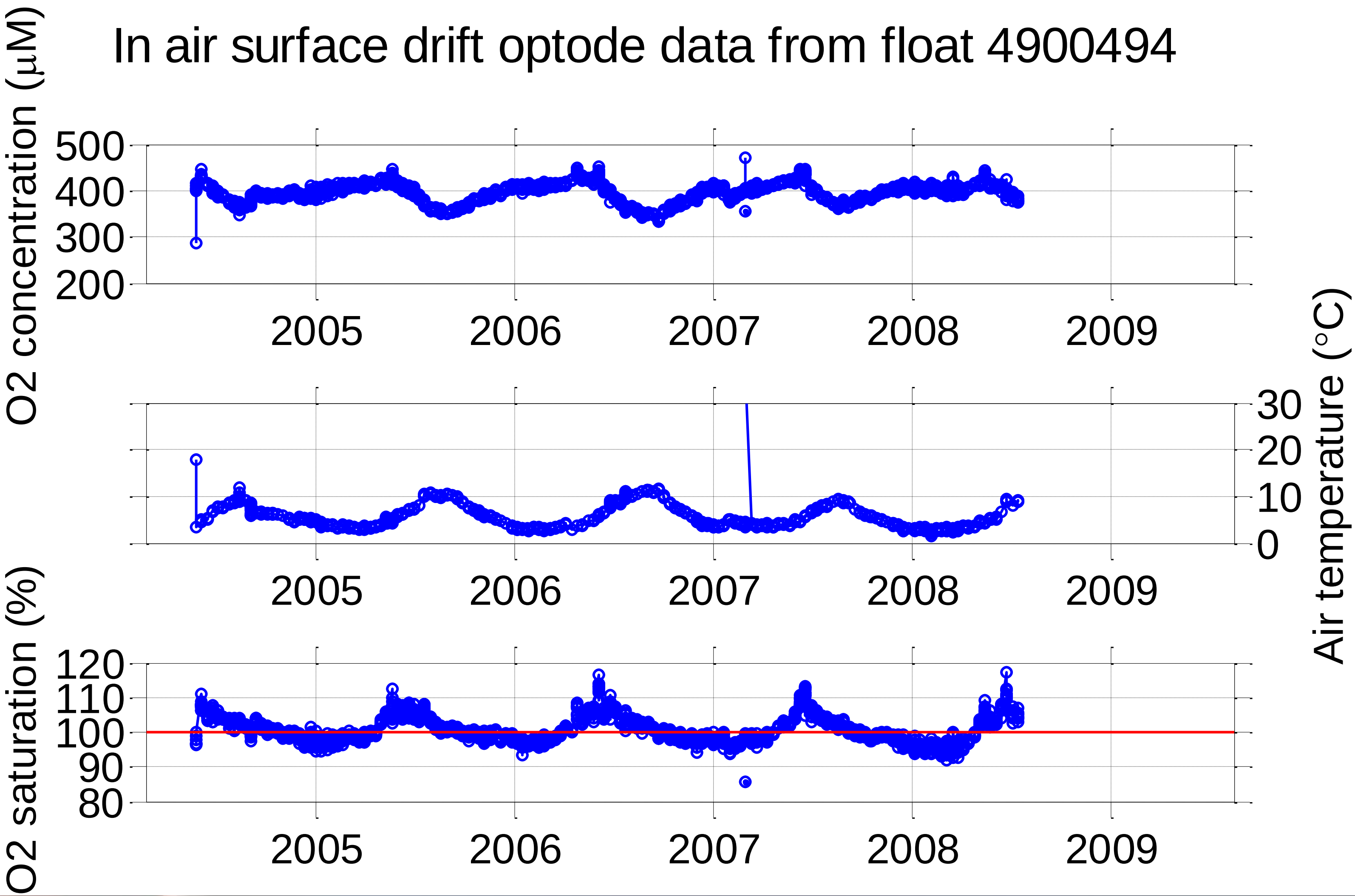
Nicholson et al (2008) deployed Seagliders (http://www.seaglider.washington.edu) in the subtropical North Pacific gyre and made measurements to quantify net community production. Optodes showed no signs of drift over the 9 month deployment period. Methods are suggested to compensate for slow response of the sensor.

Gradients



McGillis et al (2011) studied the metabolism of Cayo Enrique Reef, using in situ methods including the boundary layer gradient and enclosure techniques.

Field stability 4+years



Data from float in Labarador Sea
Denis Gilbert et al., Argo Science Workshop 3, Hangzhou, China, March 27, 2009

Quality Control of Profiling Float Oxygen Data

Yuichiro Takeshita [1] (ytakeshi@ucsd.edu), Todd R. Martz[1], Kenneth S. Johnson[2] , Josh Plant[2], Denis Gilbert[3], and Stephen C. Riser[4] 1. Scripps Institution of Oceanography, UCSD, La Jolla, CA, United States. 2. Monterey Bay Aquarium Research Institute, Moss Landing, CA, United States. 3. Maurice-Lamontagne Institute Mont-Joli, Québec, Canada 4. University of Washington, Seattle, WA, United States

Conclusions

- The optode exhibited lower drift than the SBE43.
- Slow response time of the optode may be responsible for larger deviations from the WOA near the oxycline suggesting that an "advance time" correction may improve optode data (Uchida et al., 2008)
- The accuracy of the oxygen measurements does not seem to be improving with time for either sensor.
- Poor documentation of metadata (e.g. sensor type, oxygen concentration units, post-deployment calibration) increases the uncertainty involved in using the float oxygen dataset.
- Applying an offset correction based on deep ΔO_2 shifts the average surface oxygen % saturation towards 100% (96±10% to 101±7%).

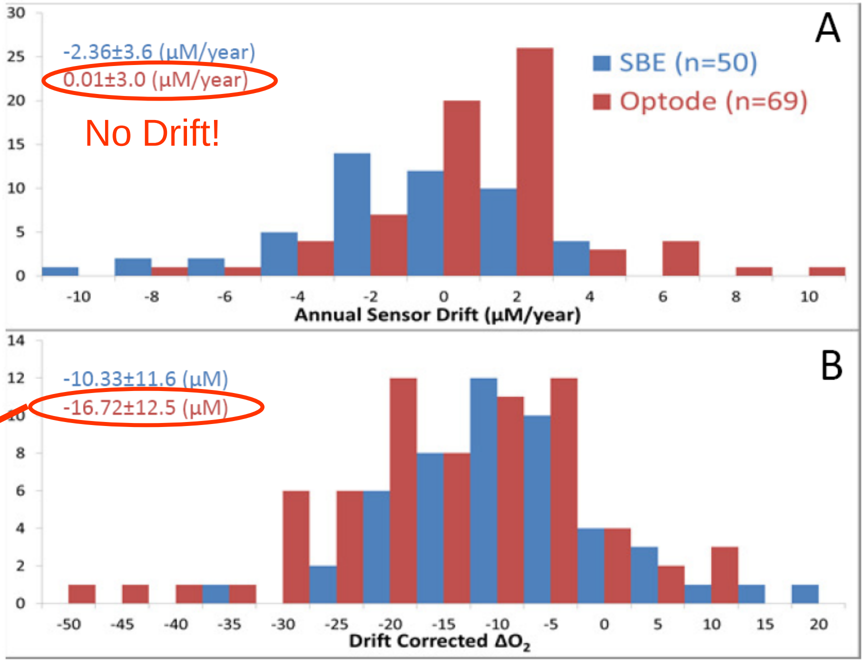
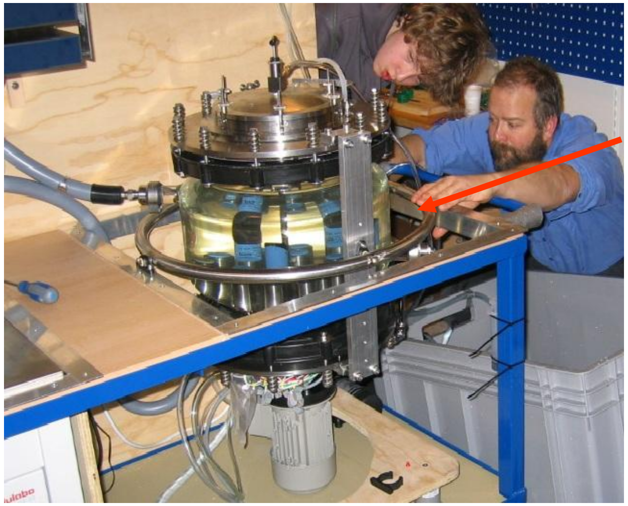


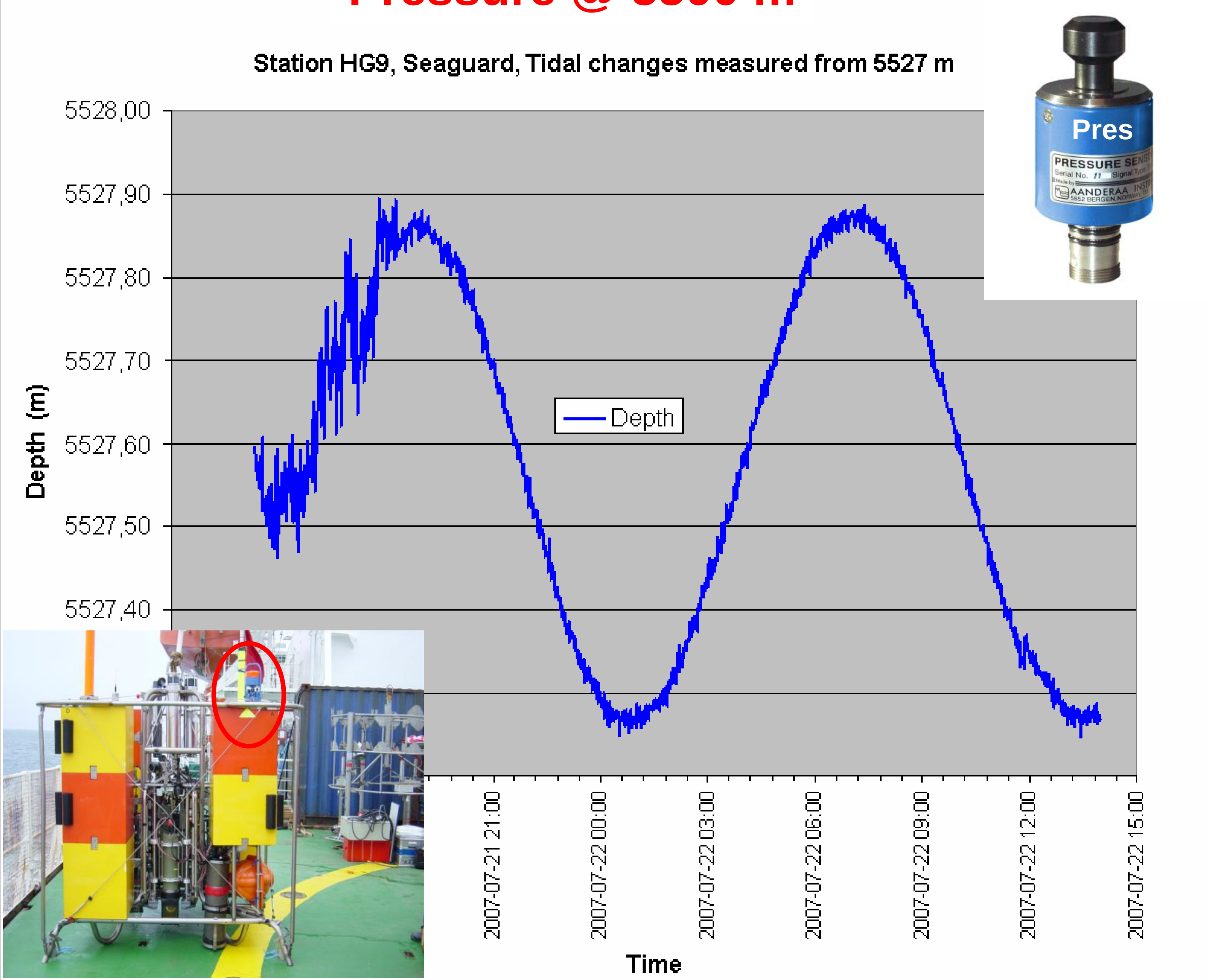
Figure 2. Histogram of sensor drift (A) and the Drift Corrected Average Deep ΔO_2 (B) for the two different types of oxygen sensors. The mean±std. dev. is labeled on the plot with its corresponding color.

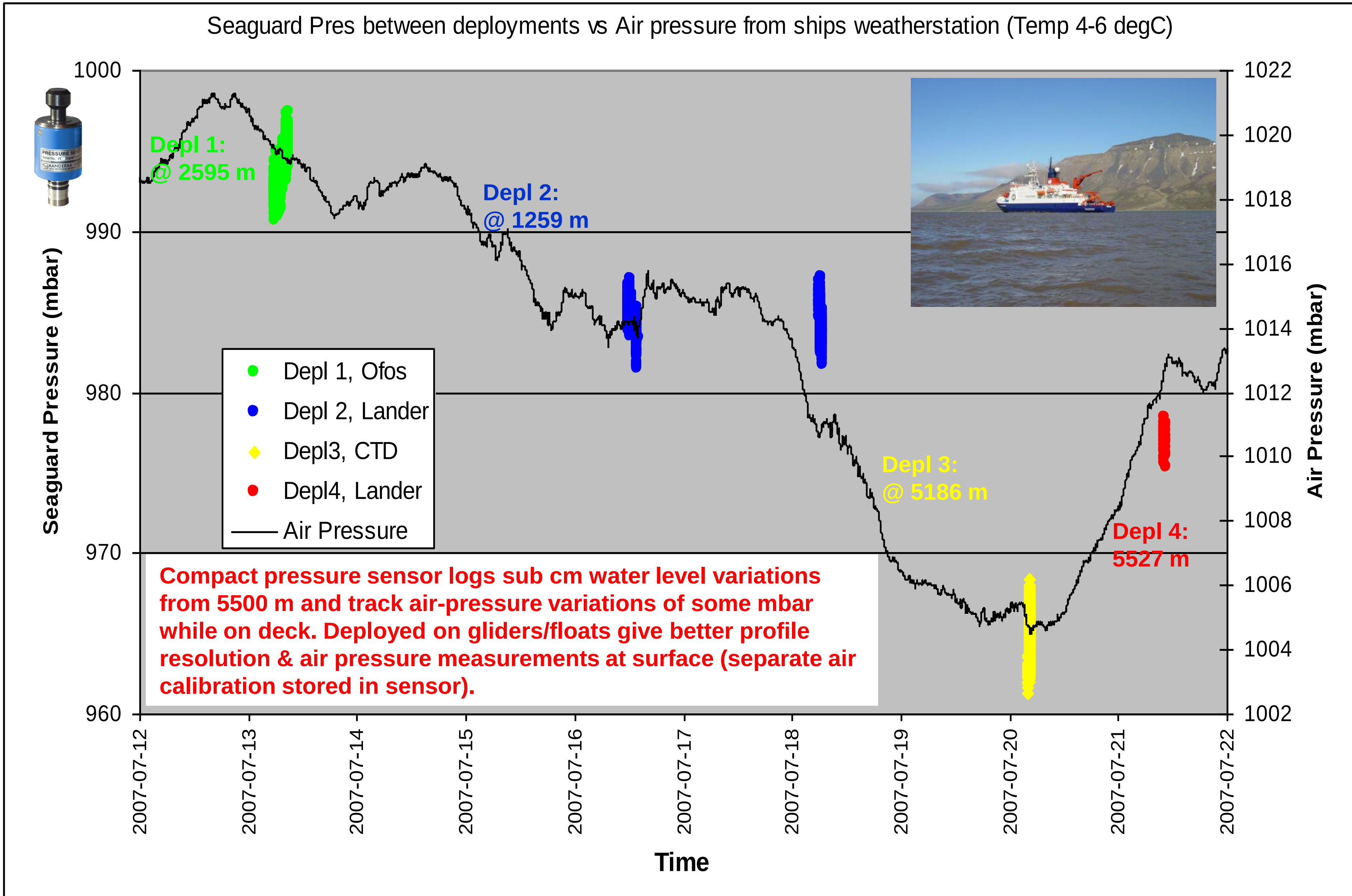


New multipoint calibration system for O_2 & CO_2 operational in August 2011, O_2 accuracy ±1.5 %

Poster presented at AGU fall meeting, San Francisco, Dec 2010

Pressure @ 5500 m




Seaguard Pres between deployments vs Air pressure from ships weatherstation (Temp 4-6 degC)
Seaguard Pressure (mbar)
Air Pressure (mbar)
Time
1000
990
980
970
960
1022
1020
1018
1016
1014
1012
1010
1008
1006
1004
1002
2007-07-12
2007-07-13
2007-07-14
2007-07-15
2007-07-16
2007-07-17
2007-07-18
2007-07-19
2007-07-20
2007-07-21
2007-07-22
Depl 1: @ 2595 m
Depl 2: @ 1259 m
Depl 3: @ 5186 m
Depl 4: 5527 m
Depl 1, Ofos
Depl 2, Lander
Depl3, CTD
Depl4, Lander
Air Pressure
Compact pressure sensor logs sub cm water level variations from 5500 m and track air-pressure variations of some mbar while on deck. Deployed on gliders/floats give better profile resolution & air pressure measurements at surface (separate air calibration stored in sensor).

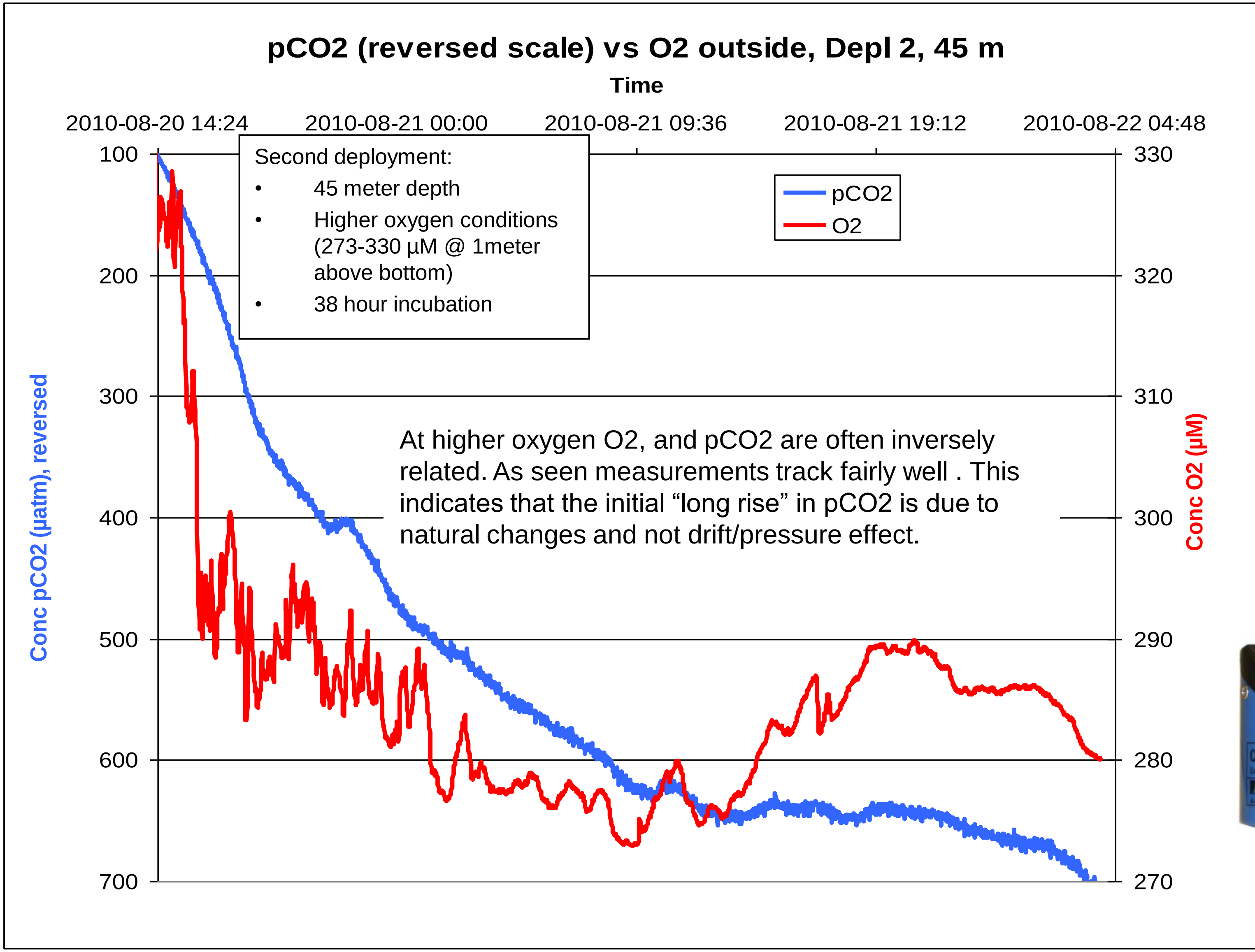
CO_2 Optodes (in test phase)

Use fluorescent dual lifetime detection of pH. When CO_2 diffuses through a gas permeable matrix pH will change gives possibility to detect pCO_2.

Preliminary Specifications:

- Range: 0-50 000 µAtm (typically 100-5000 µAtm in Seawater)
- Resolution: ±10 µAtm
- Response time: 5 min (63 % response)
- Drift less than 1 % month
- Pressure dependence about 4 % lower signal per 1000 m

pCO_2 and O_2, Baltic Sea



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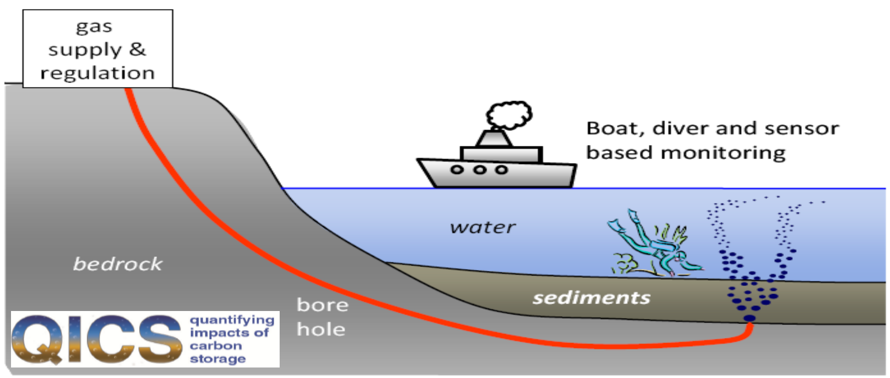
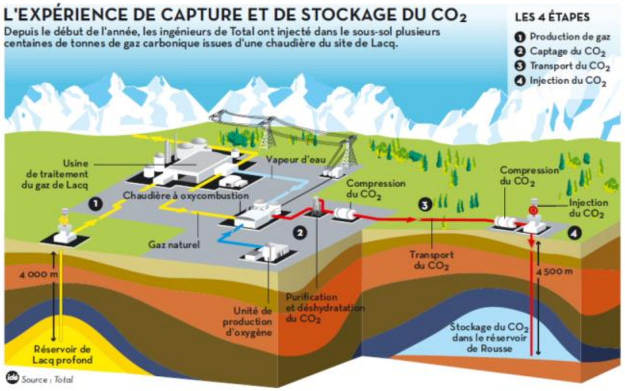
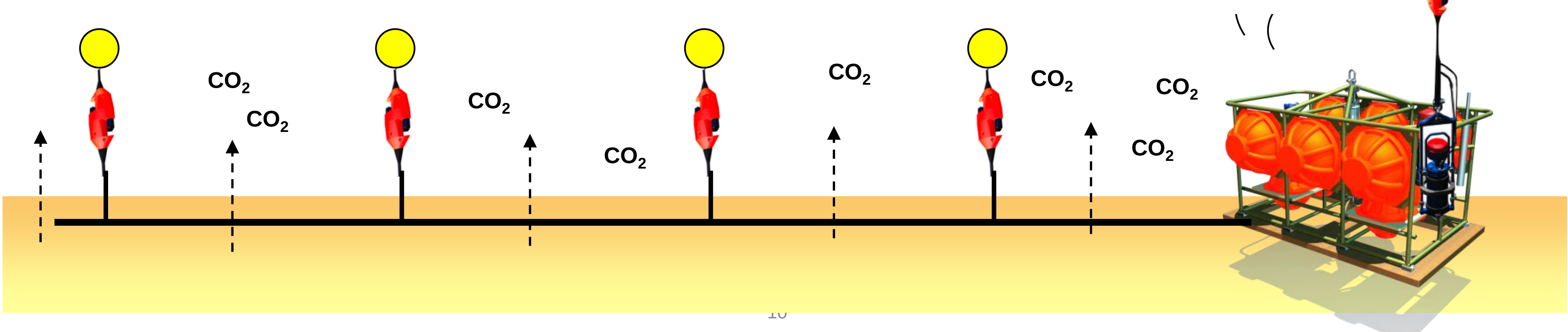
CO_2 optode applications

- Aquaculture
- In climate/ocean acidification
- CO_2 storage in the ground on land or in the sea







On-going developments and tests

Chamber for pressure testing

Elaborate calibration facility for O_2 and pCO_2 under construction

Seaguard String, water column data

Seaguard with 20 m string.

- Currents at one level
- Measurements at 8 levels
- Space for 18 sensors

Aquarius Coral Reef Observatory

Figure 2. Aquarius underwater habitat located on Conch Reef along the Florida Keys outer reef tract (Photo by Chris Martens, UNC-Chapel Hill).

AADI SEAGUARD® Sensor String System

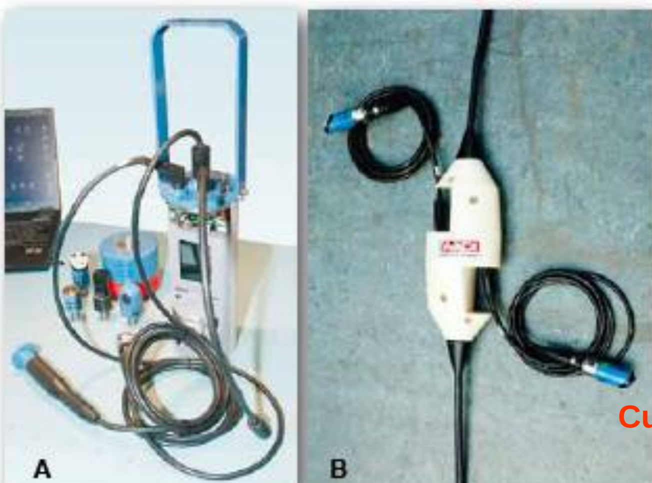
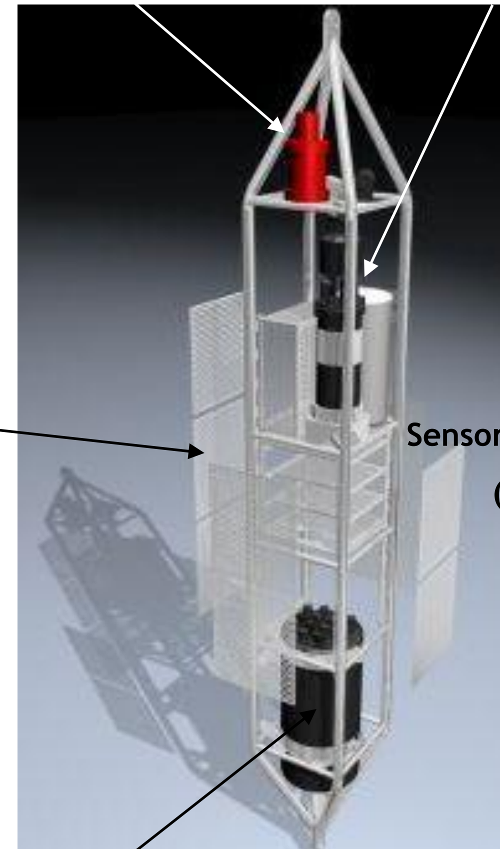


Figure 3. Aanderaa Data Instruments Seaguard sensor system designed for UNC-Chapel Hill's coral reef project. A, Seaguard base unit with current meter, optode O_2 sensor, CTD and turbidity sensors. B, wet mateable Optode sensors on 3 meter length fly leads. C, 170 meter optode sensor string with Seaguard base unit, .

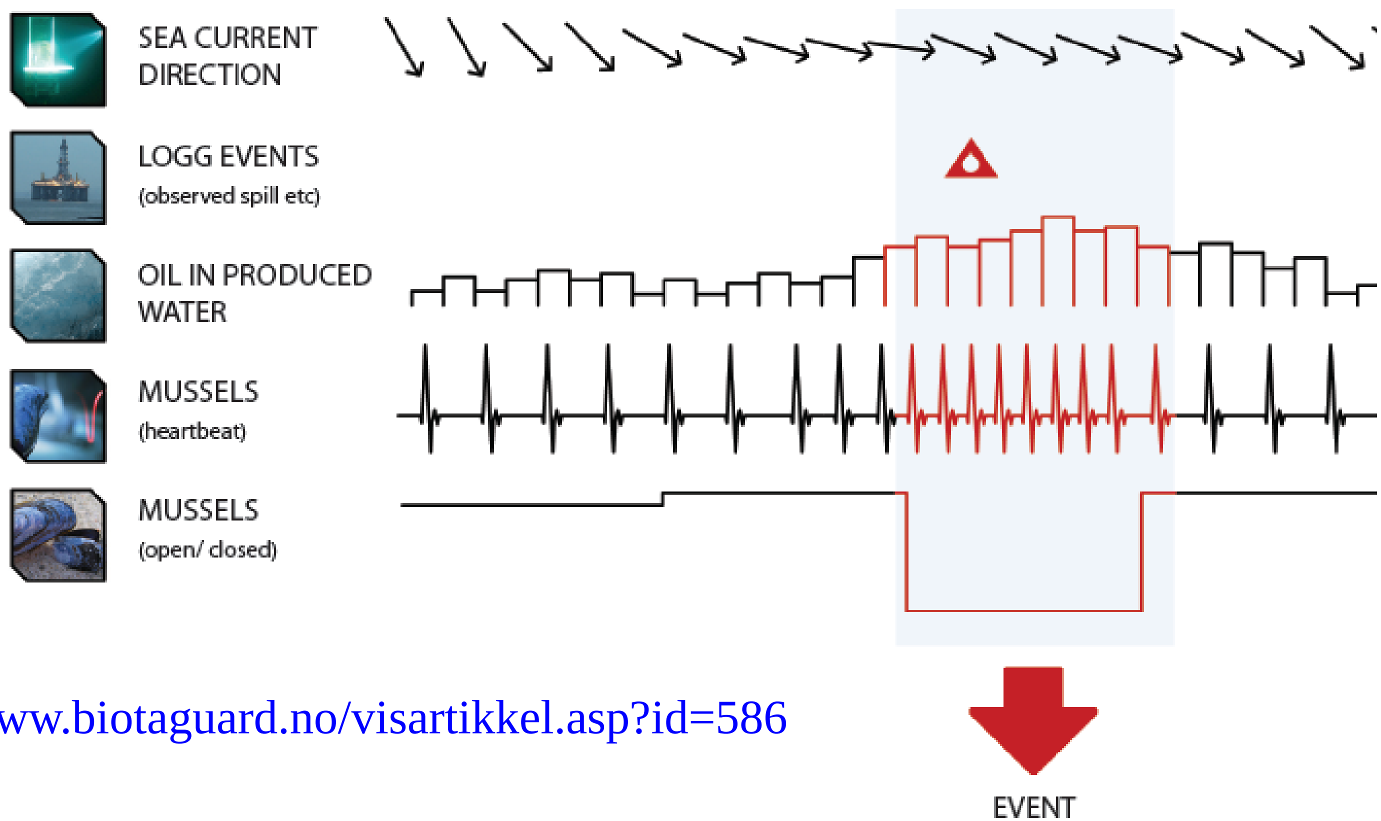
Combining Biosensors with ”traditional measurements”

Biological sensors (instrumented organisms)



http://www.biotaguard.no/visartikkel.asp?id=586

Method – ”Holistic approach”



http://www.biotaguard.no/visartikkel.asp?id=586

GLIDER/FLOATS SENSORS, MAIN FEATURES DEMANDED

Attribute	Yes/No	AADI sensors
Small Size, easy to accommodate in limited spaces.	✓	D x H < 90 mm x 39 mm
Low power demanding	✓	Max : 10-100 mA Quiescent mode: 0,16-0.25 mA
Robust and very low maintenance	✓	- No mobile parts - Monolithic architecture - Housing made in Ti, SS or POM - Calibration Interval ≥ 1 year
Reliable, no significative drift in time and with pressure changes	✓	Proven stability along years; Optodes ≥ 4 years
Standard signal ouput	✓	RS 232C, RS 422, CAN bus

SMARTGUARD

The next generation is more than a data logger

- Tailored for smart Hyd/Met stations
- Flexible and easy configuration and setup
- Fits all AADI sensors as well as serial and analog 3rd-party sensors
- Output to serial ports and LAN utilizing AADI Real-Time Protocols (XML)
- Remote data collection and operation through AADI Real-Time System
- Low power consumption
- The versatile data logger for future

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