Sea Technology Magazine

WQM: New Instrumentation For Coastal Monitoring

Extending Deployments and Reducing Cost by Preserving Long-Term Accuracy

By Dr. Carol Janzen
Physical Oceanographer
Dr. Nordeen Larson
President
Sea-Bird Electronics Inc.
Bellevue, Washington
and
Casey Moore
President
WET Labs Inc.
Philomath, Oregon

Making high-accuracy water quality measurements for seasonal or longer periods in coastal marine environments requires instruments with high initial (calibration) accuracy, inherent stability and effective defenses against fouling. A new instrument, the water quality monitor (WQM), codeveloped by WET Labs and Sea-Bird Electronics, integrates high-accuracy sensors to measure pressure, temperature, salinity, dissolved oxygen, chlorophyll fluorescence and turbidity. Its design also focuses several synergistic antifoulant strategies for maximum effectiveness in the coastal application.

The WQM was specifically developed to meet the measurement challenges of observatory monitoring in coastal and estuarine regions and to substantially reduce operational and maintenance costs. Its performance has been demonstrated in six years of coastal field trials at two locations, each lasting more than four months.

Accuracy and Stability

In coastal ocean observing, measurements must capture the high variability inherent to coastal waters over short time scales (hours to months), but just as importantly, they must accurately reveal decadal changes, which tend to be one to two orders of magnitude smaller. In an interesting example, researchers analyzed a 35-year temperature and salinity record made at the mouth of Resurrection Bay (Seward, Alaska), a region of high freshwater discharge and biological activity.[1] Between 1970 and 2005, temperature increased between 0.84 and 1.09° C in the upper and lower water column, respectively (measurement accuracy ±0.01° C), and salinity freshened by 0.14 practical salinity units in the upper water column, coincident with increased salinity in the lower layer by 0.09 practical salinity units (measurement accuracy ±0.02 practical salinity units). The observed long-term trends have significant implications for regional circulation, nutrient fluxes and shifts in frontal boundaries critical to fisheries and biological dependencies. Had the accuracy of these measurements been reduced, the annual to decadal trends would have remained obscured and the change in that coastal environment could not be understood or ultimately forecast as required for management. The accuracy required to register trends in long-term measurements and to make predictions informs the general question of accuracy requirements for *in-situ* observations and upcoming observatory programs.

The WQM.

Ecosystem managers face particular challenges in obtaining sufficient knowledge to work effectively. The coastal environment is vast and complex, and the instrumentation and manpower to monitor it are always in short supply. Managers rely on chronically sparse measurements to understand present conditions. In an analogy with weather observations, managers increasingly rely on models to augment their knowledge of complex spatial patterns from discrete measurements. And, as with weather, predictions about the evolution of conditions from hour-to-season time scales forward are impossible without models. To be effective for managers, such models need accurate data inputs to reproduce the circulation patterns that occur beneath the tidal oscillations. The development and spread of harmful algal blooms, hypoxia/anoxia events and movements of water masses carrying biological or chemical constituents occur within these physical processes and are what ecosystem managers need to track and predict. This model requirement is another component advising the accuracy requirements for coastal measurements.

Reprinted from **Sea Technology** *magazine.*
For more information about the magazine, visit www.sea-technology.com

During a 1998 workshop focused on defining the national need for coastal salinity, an *in-situ* practical salinity accuracy goal of 0.01, maintainable for a minimum of six-month deployments for coastal ocean programs, was recommended for both observational and modeling work.[2] Though sensors exist that can meet this accuracy level initially, the six-month stability requirement is challenging, largely due to interference caused by biofouling.

WQM Technology

The WQM is designed for long-term moored applications in regions where high biofouling is expected. It tightly integrates technologies proven to perform well in blue water, including Sea-Bird's conductivity, temperature, depth (pressure) and dissolved oxygen sensors (CTD-DO), and WET Labs' combined chlorophyll fluorescence and turbidity sensor (ECO-FLNTUS).

The CTD-DO sensors are enclosed in a small-volume plumbing path that ingests a fresh sample by a controlled flow pump at the time of a measurement. This unique plumbing protects the CTD-DO sensors from continuous exposure to the surrounding environment, acting as a first line of defense against biofouling. Two cartridges installed within the plumbing passively diffuse a broad-spectrum antifoulant into the trapped water to neutralize biota that may have entered during a previous sample. A novel bleach injection system (BLIS) pumps a small volume of bleach directly into the DO sensor chamber at preprogrammed intervals when the pump and sensor are not running. This allows the user to ramp up the anti-fouling treatment as needed during periods of extreme fouling pressure (e.g., aquaculture monitoring). A copper guard is installed over the CTD sensors to prevent fouling of the plumbing intake and exhaust and to protect the external components of these sensors from biological settlements, making servicing and turnaround simple. Should the DO sensor experience fouling, there is a potent and simple method for *in-situ* correction of oxygen calibration drift and consequent extension of data accuracy and service interval.[3]

To prevent biological buildup on the WQM's optical windows, the ECO-FLNTUS is made with a copper anti-fouling faceplate and activates a copper Bio-wiper™ to sweep over the optical window when the sensor is on and cover the window when the sensor is not in use. Performance results of these specific sensors can be found in sensor validation reports prepared by the Alliance for Coastal Technologies (ACT).

WQM Coastal Trials

Two WQM trials lasting a minimum of four months were conducted in both Shilshole Bay Marina, Seattle, Washington, and Yaquina Bay, Oregon. Both locations experience moderate to high biofouling year-round.

Multiple WQMs were co-deployed at a depth of two meters simultaneously at each site and left in the water undisturbed for the duration of the deployment.

The results were used to evaluate longevity of the sensors during different environmental conditions with various WQM anti-fouling methods applied.

Results

Results focus on the accuracy and stability of the temperature and salinity measurements over a six-month calibration period, based on pre- and post-deployment factory calibration data. The longevity in accuracy of dissolved oxygen measurements to within five percent of initial calibration accuracy is based on *in-situ* validation samples collected biweekly at the mooring sites.[4]

	Initial calibration accuracy	*Drift*
Temperature	0.002 ° C	< 0.002 °C / 6 months
Salinity	0.005 psu	< 0.02 psu / 6 months
Oxygen	1 µmol or 2% of reading	< 5% for periods longer than 3 months

WQM ID & Location	Copper Guards & Cartridges & Bleach Injection	Copper Guards & Bleach Injection	Copper Guards & Cartridges	CONDUCTIVTY Period Between Factory Calibrations	Number of Months Between Conductivity Calibrations	Total Salinity Drift	Estimated Salinity Drift Rate per 6 months	DISSOLVED OXYGEN Deployment Period	Months DO Sensor Measured Within 5% of Reference	Percent of 3-months DO Sensor Within 5% of Reference
5001 Yaquina	X			3/4/06 – 2/23/07	12	0.025	0.013	9/14/06 – 1/23/07	3.5 of 4	100%
5001 Yaquina	X			3/21/07 – 11/2/07	7	0.001	0.001	5/4/07 – 11/2/07	2.7 of 6	90%
5004 Shilshole	X			8/15/06 – 1/17/07	5	0.002	0.002	8/15/06 – 1/17/07	5 of 5	100%
5004 Shilshole	X			3/24/2007-7/31/2007	NA	NA	NA	3/24/2007-7/31/2007	3 of 4	100%
5006 Shilshole		X		8/15/06 – 1/17/07	5	0.005	0.006	8/15/06 – 1/17/07	4 of 5	100%
5006 Shilshole		X		3/24/2007-7/31/2007	NA	NA	NA	6/5/2007-10/25/2007	4.5 of 4.5	100%
5003 Shilshole			X	8/15/06 – 1/17/07	5	0.01	0.012	8/15/06 – 1/17/07	5 of 5	100%
5003 Shilshole			X	3/24/2007-7/31/2007	NA	NA	NA	3/24/2007-7/31/2007	3 of 4	100%
0011 Yaquina			X †	9/19/05 – 2/23/07	17	0.05	0.018	9/14/06 – 1/23/07	2 of 4	67%
* 0011 Yaquina				3/21/07 – 11/2/07	7	0.05	0.038	5/4/07 – 11/2/07	1 of 6	33%

(Above) Results of WQM field trials.

*(Right) WQM stability test results for salinity and DO sensors. Colors identify the anti-foulant protections supplied. †Perforated copper guard only. *No anti-foulant protection provided.*

> ***"In coastal ocean observing, measurements...must accurately reveal decadal changes..."***

Temperature. Temperature calibrations for all the WQMs were stable within one to two millidegrees over five to 17 months between factory calibrations and during the course of the trials.

This result is expected, as it is the same sensor measurement methodology employed on Argo floats that maintain an accuracy of better than two millidegrees in five years.

Salinity. Of the ten WQM tests, the average six-month salinity drift rate was less than 0.02 practical salinity units with one exception—a WQM deployed in Yaquina Bay in 2007 with limited anti-foulant protection. The unprotected conductivity cell on this instrument still exhibited a calibration shift of only 0.038 practical salinity units.

The WQMs deployed with the various combinations of active and passive anti-fouling methods experienced significantly reduced salinity drift, between 0.001 to 0.018 practical salinity units.

Dissolved Oxygen. Seven of the ten WQM dissolved oxygen sensor tests provided accurate *in-situ* DO concentrations within five percent of reference samples for at least three months. Five of the 10 tests remained within five percent for up to five months. Two sensor tests without the full anti-foulant protection still measured DO within five percent of initial calibration for up to two months. The WQMs' DO data in all the trials exceed measurement expectations typical of coastal DO observing (e.g., ACT Dissolved Oxygen Sensor Verifications).

Conclusions

The WQM can remain unattended in harsh fouling coastal environments for several months while maintaining accurate, multiparameter water quality data important to scientists and resource managers.

The WQM's long-term sustainable accuracy has essential operational significance in reducing the costs of data collection through reducing instrument maintenance, calibration requirements and the effort necessary for data quality assurance. /st/

References

1. Royer, T.C. and C.E. Grosch, "Ocean Warming and Freshening in the Northern Gulf of Alaska," *Geophysical Research Letters*, vol. 33, 2006.
2. Woody, C., E. Shih, J. Miller, T. Royer, L.P. Atkinson and R. Moody, "Measurement of Salinity in the Coastal Ocean: A Review of Requirements and Technologies," *Marine Technology Society Journal*, vol. 34, no. 2, pp. 26-33, 2000.
3. Janzen, C., D. Murphy and N. Larson, "Getting More Mileage Out of Dissolved Oxygen Sensors in Long-Term Moored Applications," *Proceedings of the Oceans 2007 Marine Technology Society/IEEE Conference and Exhibition*, 2007.
4. Orrico, C.M., C. Moore, D. Romanko, A. Derr, A.H. Barnard, C. Janzen, N. Larson, D. Murphy, R. Johnson and J. Bauman, "WQM: A New Integrated Water Quality Monitoring Package for Long-Term *In Situ* Observation of Physical and Biogeochemical Parameters," *Proceedings of the Oceans 2007 Marine Technology Society/IEEE Conference and Exhibition*, 2007.

Visit our Web site at www.sea-technology.com, and click on the title of this article in the Table of Contents to be linked to the respective company's Web site.

Dr. Carol Janzen is an oceanographer with Sea-Bird Electronics Inc. She has a Ph.D. in physical oceanography and 24 years of experience conducting interdisciplinary observational research in coastal/estuarine environments. Janzen conducts performance assessments for new sensors and assists oceanographers with data analysis and instrumentation applications.

Dr. Nordeen Larson is the president of Sea-Bird Electronics Inc. He has a Ph.D. in physical oceanography and 30 years of experience developing oceanographic instruments and calibration systems.

Casey Moore is the president of WET Labs Inc. He has an M.S. in scientific instrumentation and a B.S. in physics.