RBR AND OPTODE INFORMATION SHEET

Last updated 12 March 2019 by Ken Sandilands

Draft

This information sheet describes the method used in operating the RBR logger and Aanderaa Optodes used for Lake Sampling at the ELA.

Related information sheets:

Lake Sampling Observations and Water Sampling Methods

Background

In 2009 one RBR XRX620 profiling logger (Serial No. 18018) was purchased in an attempt to upgrade the sampling equipment used for Lake Sampling at ELA, and to replace the Flett Research Mark II digital telethermometers which were starting to fail. In 2010, a second RBR XRX620 (Serial No. 18033) was purchased. These loggers were chosen because they have a fast temperature sensor, and can sample at a high frequency (6Hz). These loggers can also accommodate additional sensors, such as an optical oxygen sensor, fluorometer, and PAR sensor. The RBR used with an Aanderaa Optode allows more detailed oxygen profiles (eg. each metre) than by taking few water samples for Winkler titration.

Data collected:

Date & Time
Depth (m)
Temperature* (°C)
Conductivity (uS/cm^2)
Dissolved Oxygen (mg/l)
Chlorophyll *a* (µg/l)

* The data is an average of 10 seconds worth of data, however, temperature profile data from the Physical Limnology section of the ELA Data retriever are instantaneous manual readings from the keypad display, so RBR temperature data won't be the same as the temperature profile data.

Data Collection

The RBR logger allows real-time data collection in the field. Data is stored in the logger for later retrieval, and also transmitted via cable to the surface, where it is collected with a CR1000 Campbell Scientific datalogger.
The CR1000 with keypad allows the user to view real-time data which is necessary for determining sampling depths (see Lake Sampling Observations and Water Sampling Methods Information Sheet).
The CR1000 is programmed to store data each second, and to store one data record once the sensors have stabilized when sampling a new depth. Note: The CR1000 logger stores data each second, even though the RBR is producing data 6 times a second (6Hz). Upon returning from the field, data from both the CR1000 and RBR loggers are read out and stored.

Data Processing performed by the CR1000

In addition to storing the raw RBR data each second, the CR1000 is programmed to store one data record for each depth once the sensors have stabilized. Since the Aanderaa Optode is the slowest sensor, the oxygen data is used to determine when the data is stable. The logger compares the current oxygen and depth values to the values 8 seconds previous, and if the absolute difference is less than 0.1 mg/L and 0.1m respectively the data is considered 'stable'. Once 10 seconds of continuously stable data are collected the average is calculated over the 10 seconds and stored. The logger is also programmed to send a signal to a beeper and an LED to signal the user that stable data has been collected for that depth, and the user can lower the RBR to the next desired depth. All data is obtained on the downcast. Any data collected on the upcast is discarded.

Specific conductivity is calculated by the CR1000 as follows:

$$\text{Specific Conductivity} = \frac{\text{Conductivity}}{1+(0.0191 \times (\text{Temperature} - 25))}$$

Specific conductivity is standardized to 25°C to match the conductivity as measured by the ELA chem lab.

Depth measurements

The RBR measures depth with a pressure sensor. Depth is calculated as follows:

$$\text{Depth (m)} = \frac{\text{measured pressure} - \text{atmospheric pressure}}{\text{water density} \times 0.980665}$$

Where atmospheric pressure is entered in the settings of the Ruskin software, and density of water is 1.0 for freshwater.
Since atmospheric pressure is always changing, the depth must be zeroed each time the RBR is used. To do this, the user holds the RBR so that the pressure sensor is out of the water, and uses the keypad to have the CR1000 logger set the atmospheric pressure equal to the current pressure reading.
The logger then uses the formula above to calculate depth, which has now been zeroed to the current atmospheric pressure.

> Note that because the atmospheric pressure is not set in the software preferences when the RBR logger is started each day, the depths recorded on the RBR logger are incorrect. If you are using the raw 6hz data from the RBR, you must take this into account.

Dissolved Oxygen Saturation

Percent saturation of oxygen is calculated using the following formula:
Where P is 0.95657atm (ELA is at 391m above sea level. That works out to 727mmHg or 0.95657atm)

$$C_p = C^* \times P \left[\frac{(1-P_{wv}/P)(1-\theta P)}{(1-P_{wv})(1-\theta)} \right]$$

C_p = equilibrium oxygen concentration at nonstandard pressure, mg/L

C^* = equilibrium oxygen concentration at standard pressure of 1 atm, mg/L

P = nonstandard pressure, atm

P_{wv} = partial pressure of water vapor, atm, computed from:

$\ln P_{wv} = 11.8571 - (3840.70/T) - (216,961/T^2)$

T = temperature, °K

$\theta = 0.000975 - (1.426 \times 10^{-5}\, t) + (6.436 \times 10^{-8}\, t^2)$

t = temperature, °C

Equation from http://www.waterontheweb.org/under/waterquality/oxygen.html
Results from this calculation match oxygen solubility tables such as
http://water.usgs.gov/owq/FieldManual/Chapter6/6.2.4.pdf

Reporting of data

The data is an average of 10 seconds worth of data, however, temperature profile data from the Physical Limnology section of the ELA Data retrivier are manual readings from the keypad display after a beep, so RBR temperature data won't be the same as the temperature profile data.

Data can be queried from the ELA data retriever in two formats:

All of the data

or

Averages based on the data being grouped in depth bins.

The first option gives you all of the data collected when the Campbell Logger detected stable oxygen data (Averages of 10 seconds of data once the oxygen data is stable). However, sometimes if the RBR was held at the same depth for a period of time, this process could happen multiple times, giving multiple data records for the same depth. Also, even though the user tried to hold the RBR at depths either at the whole metre or quarter metre intervals, data was recorded at other depths around these depths (eg. during windy days it is difficult to hold the RBR at exactly 6.25m until it stabilized).
Since there are many depths that do not match the intended sampling depths exactly, the depth-bin field was created so that depths within 10cm of the intended depth are binned into pre-determined depth intervals. For example, a depth of 3.40m would be put in the 3.5 depth bin, 3.39 would not fall into a depth bin as it is not within 10cm of either 3.25 or 3.50m. Depths bins for less than 10 m are in 0.25m increments, and 1m increments for greater than 10 m.

YSI

Occasionally a YSI dissolved oxygen meter was used to obtain temperature and oxygen profiles (eg. during the winter when it was not practical to use the RBR). In this case "YSI" is indicated in the

Methods field instead of “RBR”. This YSI (model 550A) uses the older membrane style probe to measure oxygen.

Fluorometer

The Seapoint Chlorophyll Fluorometer (Model SCF serial 3209) was purchased in September 2010 which allowed real-time *in situ* measurements to be added to the RBR dataset. The RBR is supposed run the fluorometer in auto-ranging mode which is supposed to adjust the gain depending on chlorophyll levels, however this often didn’t work, and chlorophyll values reached the maximum range at about 5ug/L. When this happened it was noted in the “comments” field of the data.

Below is a description of the fluorometer from Seapoint:

> “The Seapoint Chlorophyll Fluorometer (SCF) is a high-performance, low power instrument for in situ measurements of chlorophyll. Its small size, very low power consumption, high sensitivity, wide dynamic range, 6000 meter depth capability, and open or pump-through sample volume options provide the power and flexibility to measure chlorophyll in a wide variety of conditions. The SCF uses modulated blue LED lamps and a blue excitation filter to excite chlorophyll. The fluorescent light emitted by the chlorophyll passes through a red emission filter and is detected by a silicon photodiode. The low level signal is then processed using synchronous demodulation circuitry which generates an output voltage proportional to chlorophyll concentration. The SCF may be operated with or without a pump. The sensing volume may be left open to the surrounding water, or, with the use of the supplied cap, can have water pumped through it. Two control lines allow the user to set the range to one of four options. These lines may be hardwired or microprocessor controlled to provide a suitable range and resolution for a given application. The sensor is easily interfaced with data acquisition packages; a 5 ft. pigtail is supplied. Custom configurations are available.”

SPECIFICATIONS

• Power Requirements:	8-20 VDC, 15mA avg., 27mA pk.		
• Output	0-5.0 VDC		
• Output Time Constant	0.1 sec.		
• Power-up Transient	< 1 sec.		
Period	470 nm CWL, 30 nm FWHM		
• Excitation Wavelength	685 nm CWL, 30 nm FWHM		
• Emission Wavelength	340 mm^3		
• Sensing Volume	0.02 µg/l		
• Minimum Detectable			
Level	Gain	Sensitivity, V/µg/l	Range, µg/l
	30x	1.0	5
Sensitivity/Range	10x	0.33	15
	3x	0.1	50
	1x	0.033	150
	< 0.2%/°C		
	6000 m (19,685 ft)		
• Temperature Coefficient	1000 g (2.2 lbs)		
• Depth Capability	0°C to 65°C (32°F to 149°F)		
• Weight (dry)	Rigid polyurethane		
• Operating Temperature	Impulse AG-306/206 (others available on request)		
• Material			
• Underwater Connector			

Aanderra Optodes

Dissolved oxygen data from the optodes (Model 4330F, Serial 249 & 138) begins the same time as the RBR data. Optodes foils and calibration is checked before each field season, and foils are changed and recalibrated is necessary.

Optode data from 2011 was compared to Winkler Titration results. These samples were collected at the same depth and time. These two methods agreed much better than when data was compared in 2010 when the water samples were not necessarily taken at the exact same depth and time.

4330F Specifications: (from Aanderra website)

Oxygen: O_2-Concentration Air Saturation

Measurement Range: 0 – 500 μM1) 0 - 150%

Resolution: < 1 μM 0.4 %

Accuracy: <8 μM or 5%2) <5 %3) whichever is greater

Response Time (63%): 4330F (with fast response foil) <8 sec

Temperature:

Range: -5 to +40°C (23 - 104˚F)

Resolution: 0.01°C (0.018°F)

Accuracy: ±0.03°C (0.18°F)4)

Response Time (63%): <2 sec

Output format: AiCaP CANbus, RS-232

Output Parameters: O_2-Concentration in μM, Air Saturation in %, Temperature in °C, Oxygen raw data and Temperature raw data

Sampling interval: 2s – 255 minutes

Supply voltage: 5 to 14Vdc

Current drain:

Average: 0.16 +48mA/S where S is sampling interval in seconds

Maximum: 100mA

Quiescent: 0.16mA

Operating depth: SW: 0-300 meters (0 - 984ft)

IW: 0 – 2000 meters (0 – 6,560ft)

DW: 0 - 6000 meter (0 - 19,690ft)

Elec. connection: 10-pin receptacle mating plug CSP

Dimensions (WxDxH): Ø36 x 86mm (Ø1.4"x 3.4")

Weight: 175g (6.17oz)

Materials: Epoxy coated Titanium, PA

Accessories: Foil Service Kit 4733(standard)/

(not included): 4794(fast)

AiCap extension cable with CSP 4793

CSP to free end cable 4762

CSP to PC cable 4865

Setup and confi g Cable

3855(5)/3855A(5)

(1) O_2 concentration in μM = μmol/l. To obtain mg/l, divide by 31.25

(2) requires salinity compensation for salinity variations > 1mS/cm, and pressure compensation for pressure > 100meter

(3) within calibrated range 0 - 120%

(4) within calibrated range 0 - 36°C

(5) only for laboratory use

Operating Principle

The sensing foil is excited by modulated blue light; the sensor measures the phase of the returned red light.

For improved stability the optode also performes a reference phase reading by use of a red LED that do not produce fluorescence in the foil. The sensor has an incorporated temperature thermistor which enables linearization and temperature compensation of the phase measurements to provide the absolute O_2-concentration.