



SUNA150511

Submersible Ultraviolet Nitrate Analyzer (SUNA)

User manual

05/2015, Edition 1

Section 1 Specifications	3
1.1 Mechanical	3
1.1.1 Bulkhead connector	3
1.1.2 Dimensions	3
1.2 Electrical	5
1.3 Optical	5
1.4 Analytical	5
1.4.1 Nitrate measurement accuracy	5
1.4.2 Nitrate measurement precision	6
Section 2 Operation	7
2.1 Install software	7
2.2 Verify sensor operation	8
2.3 Set up sensor for deployment	9
2.4 Use software to set up sensor for deployment	10
2.4.1 Set up for autonomous deployment	10
2.4.2 Set up for SDI-12 deployment	11
2.5 Monitor data collection	12
2.5.1 Monitor data in spectra graph	14
2.5.2 Monitor data in time series graph	14
2.5.3 Monitor data in absorbance graph	15
2.6 Get data from sensor	15
Section 3 Maintenance	17
3.1 Sensor maintenance	17
3.2 Maintenance for bulkhead connectors and cables	17
3.3 Update reference spectrum	18
3.4 Update firmware	21
Section 4 Reference	23
4.1 Software settings	23
4.1.1 Communication	23
4.1.1.1 File types	24
4.1.2 Continuous and fixed-time operation	26
4.1.3 Periodic operation	26
4.1.4 Polled operation	27
4.1.5 Other general settings	28
4.1.6 Compare reference spectrum files	28
4.1.7 Data acquisition monitor	29
4.1.8 Files necessary to process data	30
4.1.8.1 Convert raw data	30
4.1.8.2 Replay logged data	31
4.1.8.3 Reprocess SUNA data	32
4.2 SDI-12 commands	34
4.3 Terminal program	38
4.3.1 Input-output configuration values	39
4.3.2 Data collection setup values	39
4.3.3 Update firmware	41
4.4 Theory of operation	43
4.4.1 Background	43
4.4.2 Description of nutrient units	43
4.4.3 Nitrate concentration	44
4.4.4 Description of adaptive sampling	44
4.4.5 Sensor calibration from manufacturer	44

Table of Contents

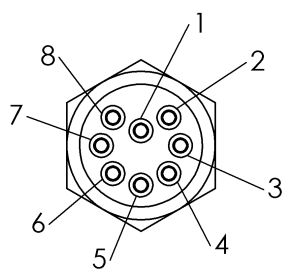
4.5 Interferences and mitigation.....	44
4.5.1 Uncharacterized species in sample.....	44
4.5.2 Optically dense constituents.....	44
4.5.3 Sample temperature.....	44
4.5.4 Identification of interfering species.....	45
4.5.5 Sensor function.....	45
4.6 CDOM absorption.....	46
4.7 Optional equipment.....	47
4.7.1 Wiper.....	47
4.7.2 Anti-fouling guard.....	47
4.7.3 Flow cell.....	48
Section 5 Troubleshooting.....	49
5.1 SUNA general troubleshooting.....	49
5.2 SUNA operation troubleshooting.....	49
5.3 SUNA communication troubleshooting.....	50
5.4 SUNA warnings and error messages.....	50
Section 6 General information.....	53
6.1 Warranty.....	53
6.2 Service and support.....	53
6.3 Waste electrical and electronic equipment.....	53

Section 1 Specifications

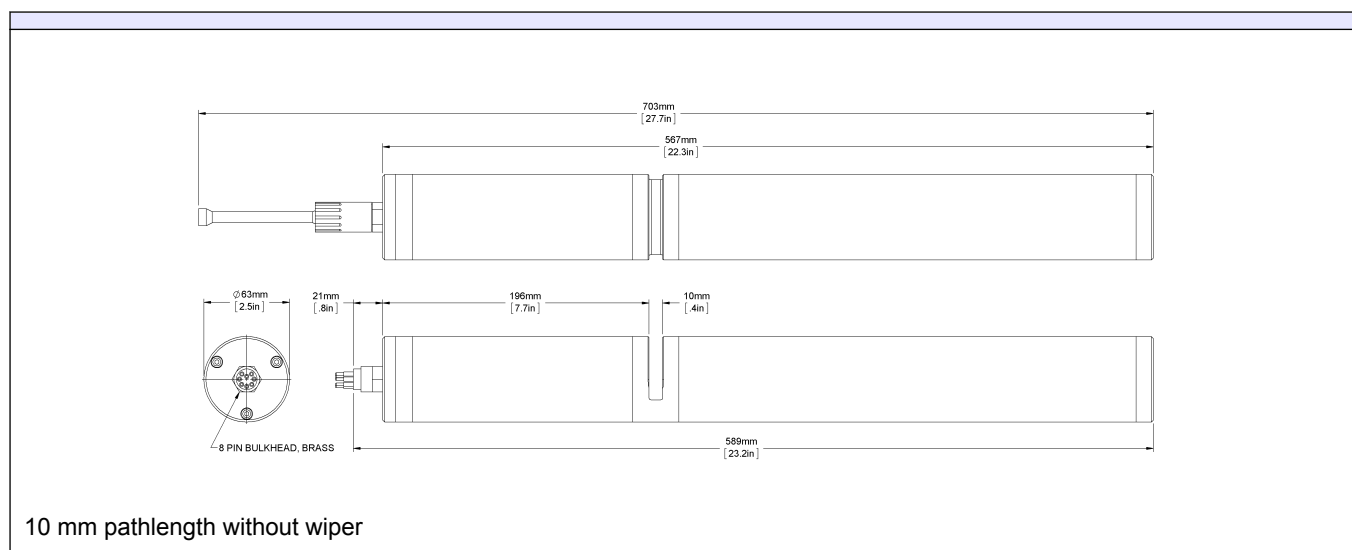
1.1 Mechanical

	SUNA with optional wiper		Standard SUNA	
Rated depth	100 m		500 m	
Weight (in air)	3.1 kg		2.5 kg	
Pathlength	10 mm	5 mm	10 mm	5 mm
Displacement	2092 cm ³	2084 cm ³	1749 cm ³	1745 cm ³
Length	588 mm	583 mm	567 mm	562 mm
Diameter	63 mm			
Material	Acetal			
Temperature range, operation	0–35 °C			
Temperature range, dry storage	-20–50 °C			

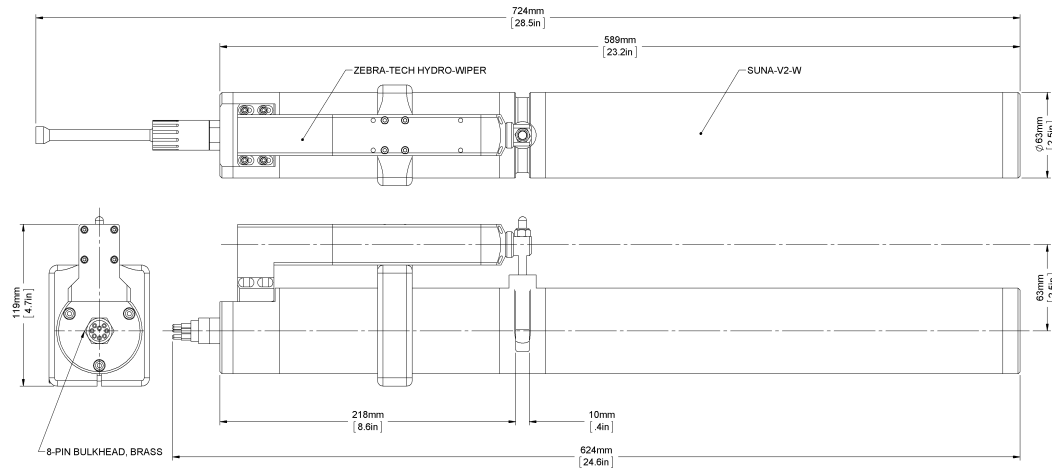
1.1.1 Bulkhead connector

Contact	Standard	Optional (USB/SDI-12)	
1	Voltage in 8–18 VDC (15 VDC for sensors with wiper)		
2	Ground		
3	—	USB 5 V power	
4	—	SDI-12	
5	RS232 TX	RS232 TX/USB D+	
6	RS232 RX	RS232 RX/USB D-	
7	—	Analog V out	
8	—	Analog current out	

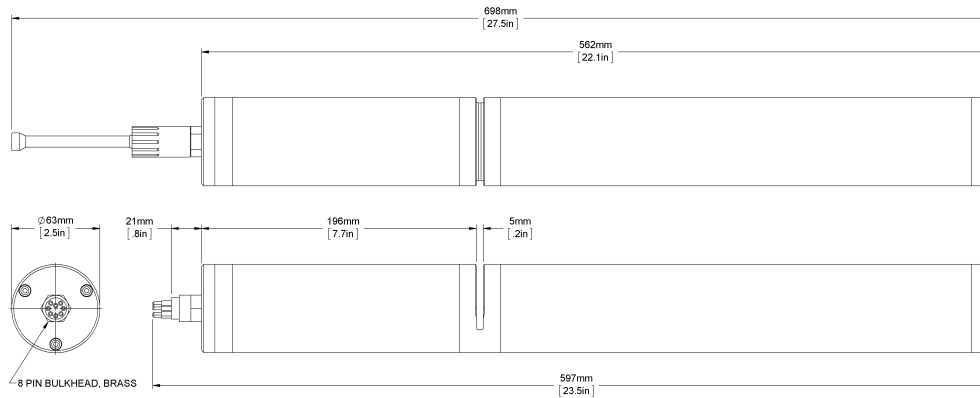
1.1.2 Dimensions



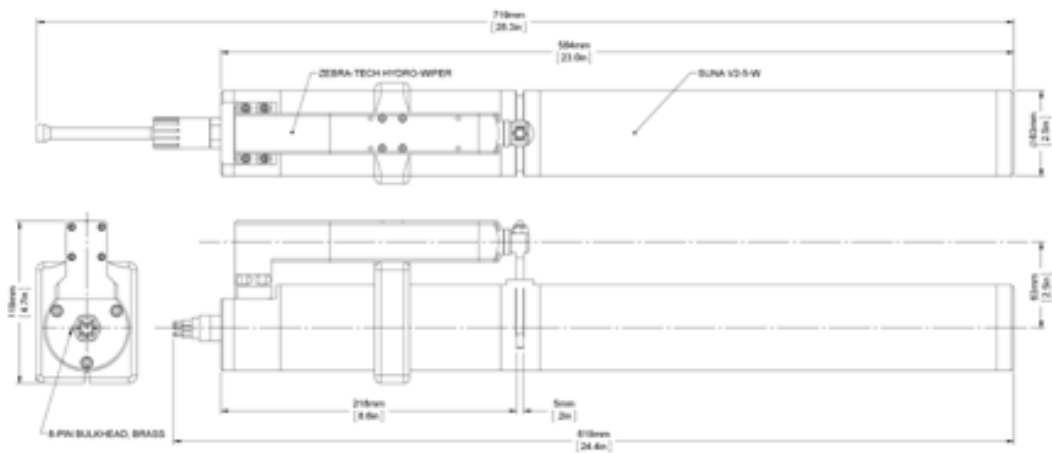
Specifications



10 mm pathlength with wiper



5 mm pathlength without wiper



5 mm pathlength with wiper

1.2 Electrical

Input	8–18 VDC
Input, sensor with wiper	8–15 VDC
Current draw, operation	~625 mA at 12 V (nominal)
Current draw, supervised low power (Periodic mode)	< 30 μ A
Current draw, processor low power (Polled mode)	< 3 mA polled
Current draw, standby (SDI-12 mode)	~20 mA at 12 V
Baud rate	57600 (9600, 19200, 38400, and 115200 available)
Communication interface	RS232 (USB and SDI-12 optional)
Data storage	2 GB (optional)

1.3 Optical

Spectral range	190–370 nm
Light source	UV deuterium lamp (900 hr lifetime)

1.4 Analytical

1.4.1 Nitrate measurement accuracy

Concentration range	Seawater and fresh water calibrations, 10 mm pathlength		Seawater and fresh water calibrations, 5 mm pathlength	
	Sensor-specific	Class-based	Sensor-specific	Class-based
Best accuracy	2 μ M (0.028 mgN/L)	2.5 μ M (0.035 mgN/L)	4 μ M (0.056 mgN/L)	4.5 μ M (0.063 mgN/L)
up to 1000 μ M (14 mgN/L)	10%	20%	10%	20%
up to 2000 μ M (28 mgN/L)	15%	25%	15%	25%
up to 3000 μ M (42 mgN/L)	20%	30%	15%	25%
up to 4000 μ M (0.056 mgN/L)				25%

- The specified accuracy is best accuracy or a percentage, whichever is more.
- A sensor-specific calibration uses extinction coefficients from the sensor itself.
- A class-based calibration uses extinction coefficients that are the average of many sensors.

Specifications

1.4.2 Nitrate measurement precision

Processing configuration	Seawater or fresh water with T-S correction	Seawater (0–40 psu)
Short-term precision (3 sigma) and limit of detection	0.3 μM (0.004 mgN/L)	2.4 μM (0.034 mgN/L)
Change ("drift") per hour of lamp time	< 0.3 μM (< 0.004 mgN/L)	< 1.0 μM (< 0.014 mgN/L)
Limit of quantification	1.0 μM (0.014 mgN/L)	8.0 μM (0.112 mgN/L)

Section 2 Operation

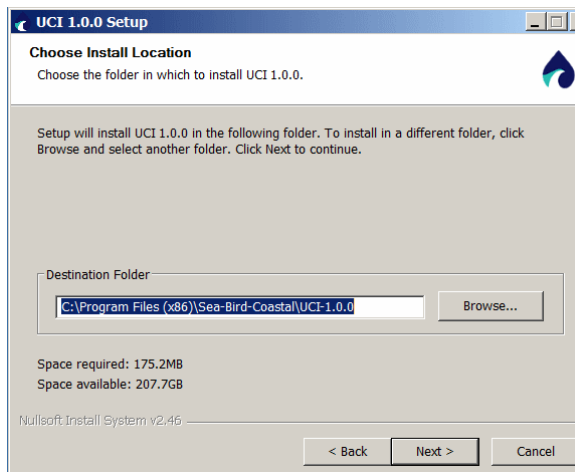
2.1 Install software

The Universal Coastal Interface (UCI) software communicates with a number of sensors. Refer to the sea-birdcoastal.com website for the current list of sensors that use this software.

1. Get the software from the sea-birdcoastal.com website or the manufacturer-supplied CD.
2. Double-click on the file with ".exe" appended to the name.
3. Push **Run** in the new window.
The setup wizard starts.
4. Push **Next**.



5. Push **Agree** in the next window to agree with the terms of the software.
6. Install the software at the default location or push **Browse** to go to another location to install the software.
7. Push **Next**.



8. Put a check in the boxes next to the "Install USB-Serial Driver" and "Show Readme."
9. Push **Finish**.



The software is ready to use.

2.2 Verify sensor operation

⚠ WARNING

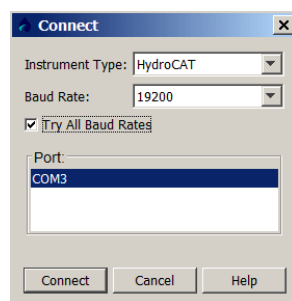
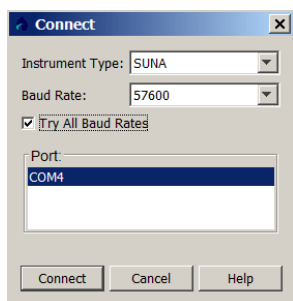
Nitrate sensors use an ultraviolet (UV) light. Do not look directly at a UV light when it is on. It can damage the eyes. Keep products that have UV light away from children, pets, and other living organisms. Wear polycarbonate UV-resistant safety glasses to protect the eyes when a UV light is on.

⚠ CAUTION

Do not supply more than 15 VDC to the sensor. More than 15 VDC will damage the wiper.

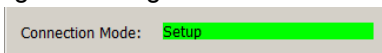
Do the steps below to make sure that the sensor operates before further setup and deployment.

1. Connect the connectors on the cable to the bulkhead connector on the sensor and to the PC.
2. Connect the USB or RS232 cable to the PC.
For RS232: connect the power connectors on the cable to a 8–15 VDC power supply.
For USB: a DC power supply is only necessary for data collection. If the sensor is equipped with internal memory, the file system will show as a USB mass storage device on the PC.
3. If necessary, start the software.
4. RS232: turn on the power supply.
5. Push **Connect** in the UCI Dashboard area.
6. If necessary, change the "Sensor Type" to the connected sensor.
7. Put a check in the "Try All Baud Rates" box.
The software automatically finds the correct baud rate.
8. If necessary, select the communication port.



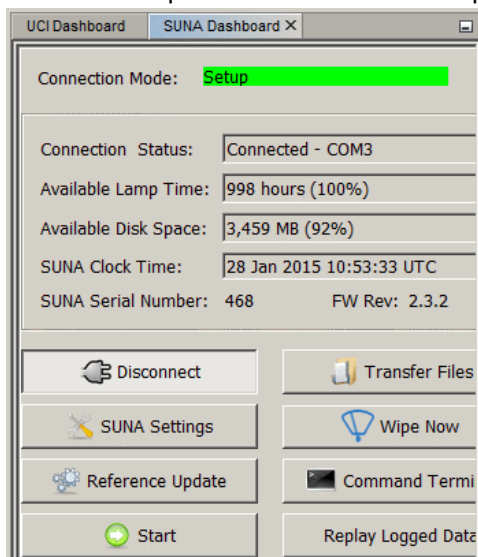
9. Push **Connect**.

The "Connection Mode" shows "Transition" on a yellow background, and then shows "Setup" on a green background.



10. Push **SUNA Settings** in the SUNA Dashboard area.

Make sure that the "Operational Mode" at the top of the new window is "Continuous."



11. Push **Start** in the SUNA Dashboard area.

The sensor collects data that shows in the *Spectra Graph* and *Time Series Graph* tabs.

12. For sensors that are not equipped with internal memory: Select the **View** menu, then *Data Logging*. Push **Start Log** to save data to the PC.

13. Let the sensor collect data for a minute or two.

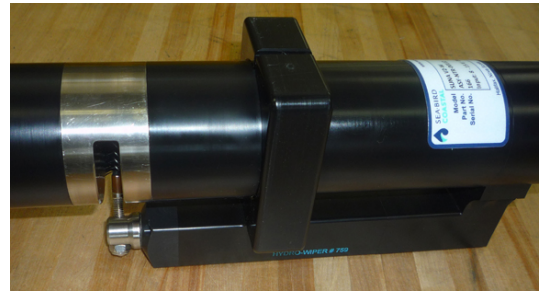
14. Push **Stop**.

15. Make sure that the collected data is saved.

- Sensors with internal memory: select **Transfer Files** in the SUNA Dashboard. Look at the files on the right for the file that was most recently saved.
- Sensors without internal memory: Go to the directory on the PC to see the file that was most recently saved.

2.3 Set up sensor for deployment

The sensor can be attached to a cage or pipe for deployment. Make sure that the sensor is attached correctly or the sensor may be damaged. The manufacturer recommends that the sensor operates in a horizontal orientation.



SUNA optical area pointed sideways, and down, to reduce the collection of sediment and bio-fouling.

- Do not use the wiper as a handle.
 - Do not attach the sensor to a cage or pipe at the wiper.
 - Do not attach the sensor so tightly that the sensor is out-of-round. Failure of the pressure seals can occur.
 - Do not let the wiper touch any part of a cage or pipe.
1. Use cradle clamps to attach the sensor to a flat surface such as a cage.
 2. Make sure that both ends of the sensor are attached to a cage or pipe. Do not leave one end unattached, such as at the end of a pipe.
 3. The user can attach the sensor to a cage with hose clamps:
 - a. Put several layers of electrical tape around the sensor to protect the pressure housing.
 - b. Put clamps over the electrical tape.

2.4 Use software to set up sensor for deployment

The user can deploy the sensor in an autonomous or a logger-controlled mode.

Autonomous modes

- *Continuous operation*—when started, the sensor operates until the user removes power or pushes **Stop** in the [SUNA Dashboard](#).
- *Fixed-time operation*—the sensor operates for a user-specified period of time or number of measurements.
- *Periodic operation*—the sensor operates at user-specified intervals. Data collection begins at a user-specified date and time and stops when the user removes power or pushes **Stop** in the [SUNA Dashboard](#).
Example: a sensor set up at 8:00 with a "Sample Interval" of 2 hours and an offset of 900 seconds (15 minutes) will operate at 10:15, 12:15, 2:15, etc.

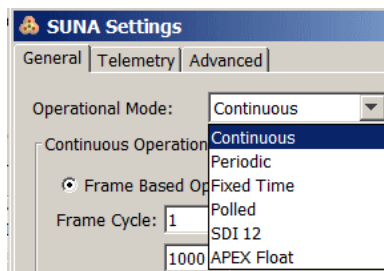
Logger-controlled modes

- *Polled operation*—the sensor communicates through and is controlled by an RS232 terminal program.
- *SDI-12*—The sensor communicates through and is controlled by an SDI-12 controller.

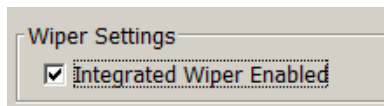
2.4.1 Set up for autonomous deployment

1. Make sure that the sensor is connected to a power supply and PC (RS232 or USB cable) and is on.
2. Make sure that the software is open and in communication with the sensor.
3. Push **SUNA Settings** in the [SUNA Dashboard](#) area.
4. Select the "Operational Mode" for the planned deployment.

5. Use the manufacturer-set values for that operation mode or change them as necessary.

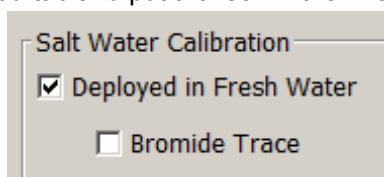


6. If the sensor has an integrated wiper, put a check in the "Integrated Wiper Enabled" box.

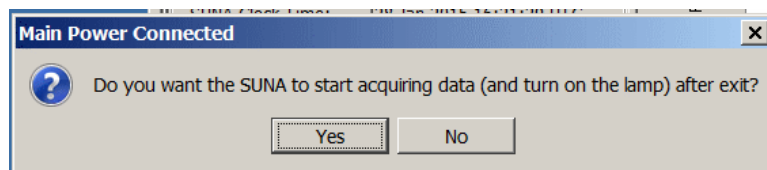


The wiper operates one time data is collected, but no more than once per hour.

7. If the sensor is to be deployed in fresh water but has a calibration for seawater, select the *Advanced* tab and put a check in the "Deployed in Fresh Water" box.



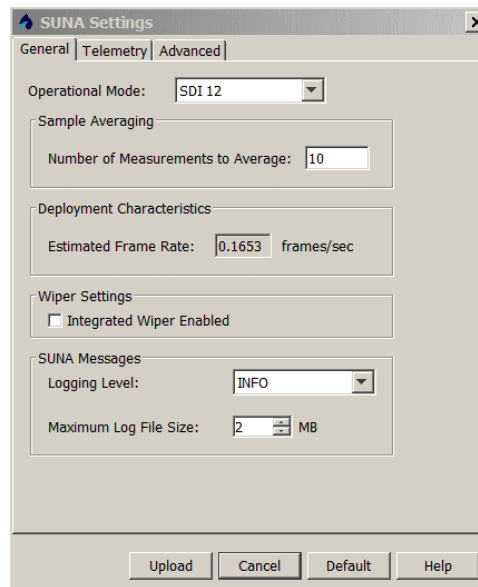
8. Push **Upload** to save the settings in the sensor.
9. Push **OK** to save any changes, or push **Cancel** to close the window with no changes.
10. Go to the **UCI** menu at the top of the software window and select *Exit* (Ctrl-e).
11. Exit the software:
 - Push **No** to close the software. Turn off the sensor, remove from the power supply and attach the protective dummy connector and lock collar.
 - Push **Yes** to close the software and start the sensor. The sensor will collect data immediately if the user selected "Continuous" or "Fixed-time" or at the user-specified time if "Periodic" was selected.



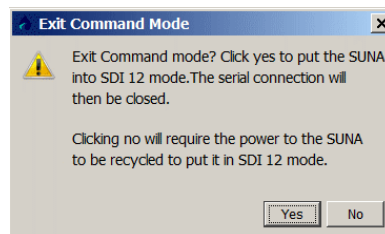
2.4.2 Set up for SDI-12 deployment

The user can deploy the sensor in a logger-controlled mode with an SDI-12 controller.

1. Set up the sensor in SDI-12 mode to operate with a controller.
2. Make sure that the sensor is connected to and in communication with the software.
3. Push **SUNA Settings** in the SUNA Dashboard.
4. At the *General* tab, select the "SDI 12 Operational Mode."



5. If necessary, change the "Number of Measurements per Frame."
The sensor calculates the average of the value entered. For example, if "5" is entered, 5 measurements will be averaged and will show as one measurement in the data.
6. If the sensor is so equipped, put a check in the "Integrated Wiper Enabled" box.
The wiper operates before each measurement.
7. The default "Logging Level" is INFO.
8. Push **Upload**.



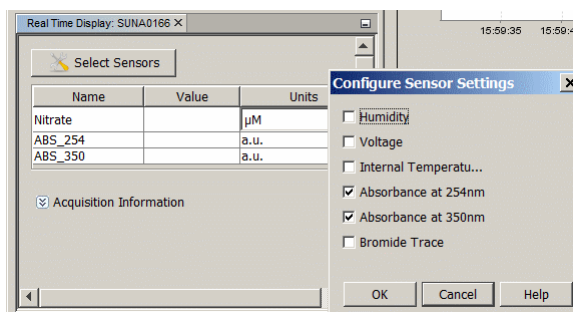
A new window shows.

9. Push **Yes** to put the SUNA into SDI-12 mode.
The sensor is ready to connect to an SDI-12 data logger.

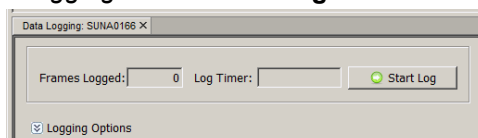
2.5 Monitor data collection

Use the software to monitor data as it is collected, or to look at it after a deployment, if the sensor is equipped with internal memory. If the sensor does not have internal memory, make sure to use the *Data Logging* tab to save collected data to a PC.

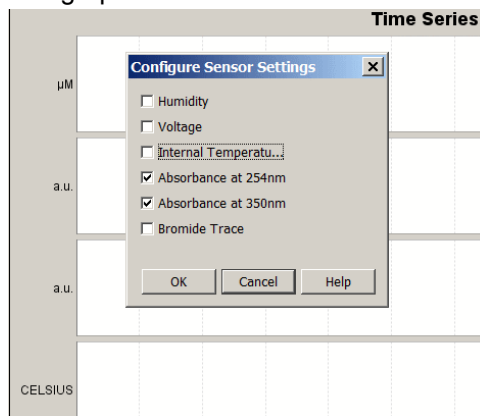
1. Push **Start** in the SUNA Dashboard area.
2. From the **View** menu, select the options to see the data:
 - *Real Time Data*—shows the most current data from the selected sensors.



- **Data Logging**—Push **Start Log** to save the collected data to the PC.



- **Time Series, Spectra, and Total Absorbance** graphs.
3. Push **Select Sensors** to see a list of parameters that can show in the *Time Series* tab.
 4. Put a check in the box next to any additional parameters so that they will show in the *Time Series* graph.

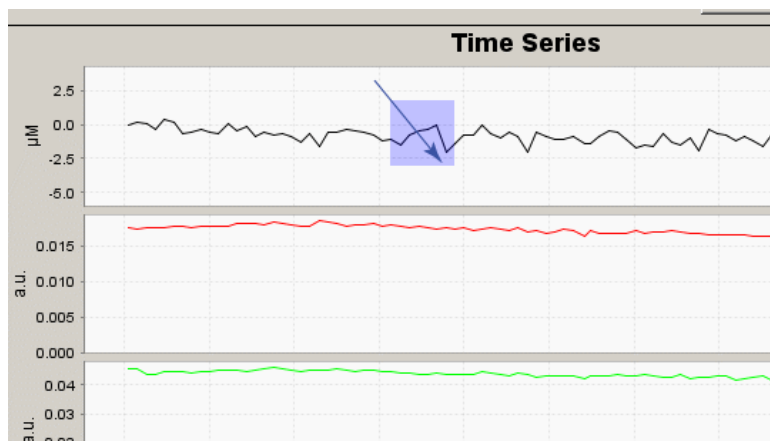


5. Look at the data in the *Time Series* tab.



- Put a check in the box next to "Time Axis" to push **Zoom In** and **Zoom Out** to change the scale of time.
- Put a check in the box next to "Range Axis" to push **Zoom In** and **Zoom Out** to change the scale of the data.

- To move the data in any direction, push the "Ctrl" key on the PC keyboard and the left button of the mouse pointer at the same time.
- To select a specific part of the data to zoom in on, pull the mouse pointer diagonally (refer to the arrow in the graph below).



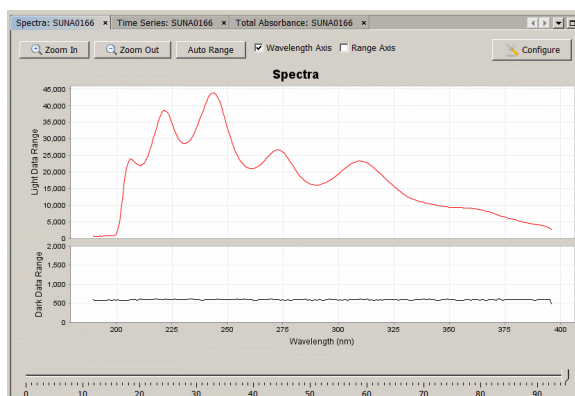
2.5.1 Monitor data in spectra graph

The *Spectra* graph shows both the dark and light data in raw counts.

The dark counts are from thermal noise. The light counts are the measured output minus the dark counts.

The measured spectrum is always flat below 200 nm, and then has four or five peaks.

The peaks are approximately 25 nm apart in the lower wavelength range and up to 50 nm apart in the upper range.



1. Put a check in the box next to either or both the "Wavelength Axis" or the "Range Axis" to enable the **Zoom In** or **Zoom Out** options.
The user can change the values for the axis with a check in the box.
2. Push **Select Sensors** either in the *Time Series* graph or in the *Real Time Display* tab to select the parameters to see on the graph.
3. Push **Configure** to put a limit on or to remove the limit to the "Time Axis Range."

2.5.2 Monitor data in time series graph

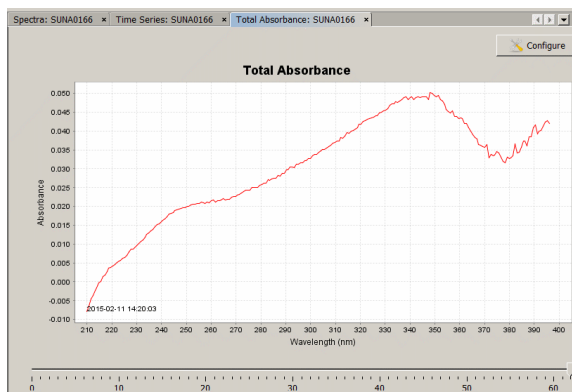
The *Time Series* graph shows the nitrate concentration and any selected optional values. Use this graph to replay data that is stored in the sensor.



1. Put a check in the box next to either or both the "Time Axis" or the "Range Axis" to enable the **Zoom In** or **Zoom Out** options.
2. Push **Select Sensors** either in the *Spectra* graph or in the *Real Time Display* tab to select the parameters to see on the graph.
3. Push **Configure** to put a limit on or to remove the limit to the "Graph History."

2.5.3 Monitor data in absorbance graph

The *Total Absorbance* graph shows the calculated absorbance from 210 to 370 nm. This graph is an alternative to the *Spectra* graph. The absorbance graph should be flat when a sample of DI water is collected. The absorbance increases as absorbing species such as nitrate and bromide are added to samples.



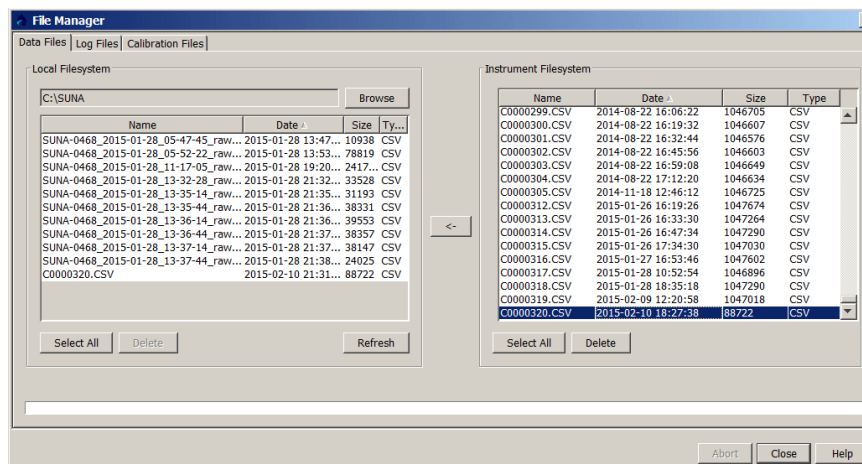
2.6 Get data from sensor

⚠ CAUTION

Do data transfers away from harsh environments such as strong electric fields or electrostatic discharge sources. Electrostatic Discharge (ESD) sources may temporarily disrupt data transfer. If this occurs, move the sensor away from the ESD source. Turn the power off and then on and continue operation.

If the sensor is equipped with internal memory, the collected data is saved in the sensor.

1. Push **Transfer Files** in the SUNA Dashboard area.
The files saved on the sensor show on the right side of the new **File Manager** window.



2. Select one or more files to copy to the PC.
The manufacturer recommends that the user use a USB connection to move the files because it is much faster.
3. Push the <- arrow to start the move.
The status shows at the bottom of the **File Manager** window.
4. Open the file on the PC to make sure it has all of the collected data.

Section 3 Maintenance

3.1 Sensor maintenance

Although the sensor is built for deployment in severe conditions, it is important to clean the sensor before each deployment and weekly (if deployed frequently) or monthly to prevent fouling.

After every deployment:

1. Attach a clean and lubricated dummy plug and a lock collar to the sensor.
2. Rinse the sensor with fresh clean water.
3. Flush the optical area with fresh clean water.
4. Dry the sensor.
Use a soft towel or blow with air.
5. Put the sensor in the manufacturer-supplied case for transport or storage.

3.2 Maintenance for bulkhead connectors and cables

⚠ WARNING

If the user thinks that a sensor has water in the pressure housing: Put on safety glasses and make sure that the sensor is pointed away from the body. Use the purge port (if the sensor is so equipped), or very SLOWLY loosen a bulkhead connector to allow the pressure to escape.

NOTICE

Connectors that have corrosion can cause a loss of data and increase the costs for service.

- Connectors that have corrosion can cause irreparable damage to the sensor.
- Do not use cleaners that contain petroleum or ketones.
- Do not use the cable to lift the sensor. The cable, cable splices, and bulkhead connectors can be damaged.
- Attach cleaned and lubricated dummy connectors to the sensor immediately after each deployment to prevent the bulkhead connector from damage
- Do not connect or disconnect connectors under water.

Examine, clean, and lubricate bulkhead connectors each time they are connected. Connectors that are not lubricated cause wear and tear on the rubber that seals the connector contacts.

1. Clean the connector contacts with isopropyl alcohol. Apply as a spray or with a nylon brush or lint-free swabs or wipes.
2. Flush the contacts with de-ionized or distilled water. Use a wash bottle with a nozzle to flush inside the sockets.
3. Shake the socket ends and wipe the pins of the connectors to remove water.
4. Examine the sockets and the rubber on the pins to make sure there are no problems.
 - a. Use a flashlight and magnifying glass.
 - b. Look for cracks, frayed scores, and delamination of the rubber on the pins and inside the sockets.

Table 1 Examples of damaged connectors



Corroded connector



Damaged contact



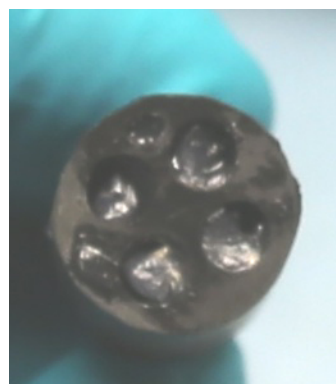
Damaged socket face

5. Use a finger to place a small quantity, approximately 1.5 cm in diameter of Dow Corning® 4 Electrical Insulating Compound on the socket end of the connector.

Table 2 Lubricant on connector sockets



Lubricant on socket end of the connector



Lubricant pushed into the sockets of the connector

6. Use a finger to push as much of the lubricant as possible into the sockets.
7. Connect the connectors.
There should be a small quantity of lubricant pushed to the sides of the connectors.
8. Clean the unwanted lubricant from the sides of the connectors.
The connectors are now lubricated and the connection is waterproof.

3.3 Update reference spectrum

The user needs to update the reference spectrum of the SUNA at regular intervals so that the data that the sensor collects is accurate. It may also be necessary to update the firmware, although that is not required very frequently.

A calibration file contains the data required to convert a spectral measurement into a nitrate concentration. The calibration data are the wavelengths of the spectrum, the extinction coefficients of chemical species and a reference spectrum relative to which the measurement is interpreted. The sensor can store many calibration files, but only the active file has a green background. Push **Transfer Files > File Manager**, then select the *Calibration Files* tab to see the list of calibration files stored in the sensor.

Make sure to clean the sensor and the sensor windows at regular intervals and before and after every deployment. Monitor the spectral intensity of the lamp. Although the intensity will decrease over time, make sure there are no sudden changes.

Necessary supplies:

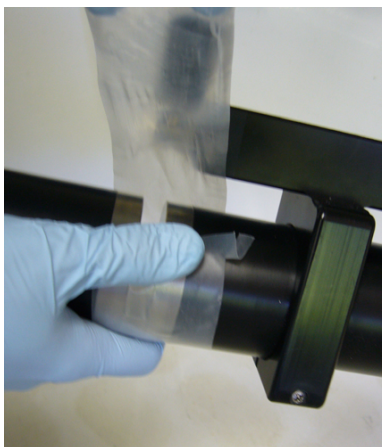
- Power supply
- PC with software
- Connector cable for sensor–PC–power supply
- Clean de-ionized (DI) water
- Lint-free tissues
- Cotton swabs
- Isopropyl alcohol (IPA)
- Parafilm® wrap

Notes

- Use only lint-free tissues, OPTO-WIPES™, or cotton swabs to clean the optical windows.
 - Use the software to update the reference spectrum.
 - Use only clean DI water that has been stored in clean glassware.
 - Use Parafilm® wrap to capture DI water in the optical area of the sensor. Do not use cups, a bucket, or a tank to collect a reference sample.
1. Clean the sensor:
 - a. Flush the sensor and the optical area with clean water to remove debris and saltwater.
 - b. Clean the metal parts external to the optical area so that the Parafilm® will seal.
 2. If the sensor has a wiper, carefully move it away from the optical area.

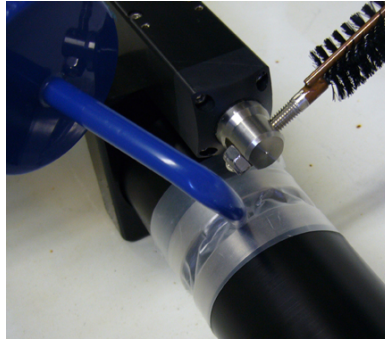
Figure 1 Wiper moved from optical area

3. Cut and stretch a length of approximately 40 cm (16 in.) of Parafilm®.
4. Wind the Parafilm® around the metal near the optical area.

Figure 2 Parafilm® on optical area

5. Break a small hole in the top of the Parafilm® and fill the optical area with DI water.

Figure 3 Optical area filled with DI water



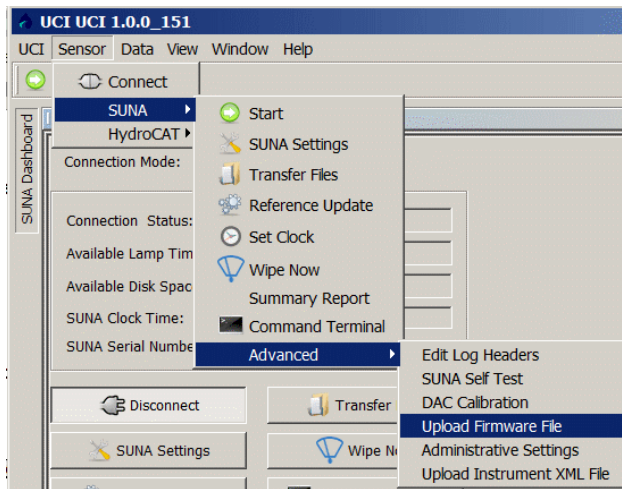
6. Supply power to the sensor and use the software to operate the sensor in "Continuous" mode.
7. Start the sensor and collect 1 minute of data.
8. Record the measurement value.
This is a "dirty" measurement to record the value when there are biofouling and blockages in the optical area.
9. Stop the sensor.
10. Remove the Parafilm® and drain the water from the optical area.
11. Clean the optical area:
 - a. Use DI water or IPA and cotton swabs and lint-free tissues to clean the windows.
 - b. Use vinegar to clean debris such as barnacles. Be careful that the windows do not get scratches.
12. Flush the optical area with DI water to remove any remaining IPA or vinegar.
13. Wind Parafilm® around the metal near the optical area.
14. Break a small hole in the top of the Parafilm® and fill the optical area with fresh DI water.
15. Supply power to the sensor and use the software to operate the sensor in "Continuous" mode.
16. Start the sensor and collect 1 minute of data.
17. Record the measurement value.
This measurement shows any sensor "drift" or change in the lamp output.
18. Stop the sensor.
19. Remove the Parafilm® and drain the water from the optical area.
20. Flush the optical area with DI water.
21. Wind Parafilm® around the metal near the optical area.
22. Break a small hole in the top of the Parafilm® and fill the optical area with fresh DI water.
23. Supply power to the sensor and use the software to operate the sensor in "Continuous" mode.
24. Start the sensor and collect 1 minute of data.
25. Record the measurement value.
26. Use the software to update the reference spectrum.
 - a. Go to the **Sensor** menu, then select *Update Calibration*.

- b. Do the steps in the **Calibration Wizard** to update the reference spectrum.
27. If the measurement is $\pm 2 \mu\text{M}$ (0.028 mgN/L) from the manufacturer-supplied reference ($\pm 5 \mu\text{M}$ [0.056 mgN/L] for a 5 mm pathlength sensor), the sensor is within the specification.
If the measurement is not within these specifications, do this procedure from step 9 until the measurement is within specification.

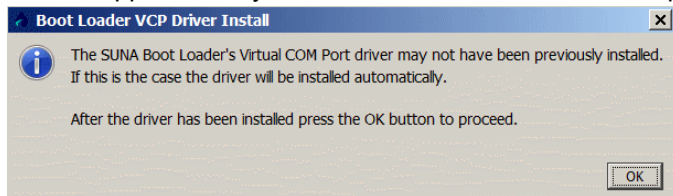
3.4 Update firmware

At regular intervals, make sure that the current firmware is installed in the SUNA. Go to the seabird-coastal.com web site to get the current firmware for the sensor.

1. Save the firmware to the PC.
The firmware is an ".sfw" file.
2. Make sure that the sensor is connected to the PC and a power supply.
3. Push **Connect**.
4. Go to the **Sensor** menu, then select *SUNA*, then *Advanced*, then *Upload Firmware File*.



5. Push **Browse** to find the firmware file that is saved on the PC.
6. Push **Open**.
7. Push **Upload**.
It takes approximately 2 minutes for the software to complete the upload.



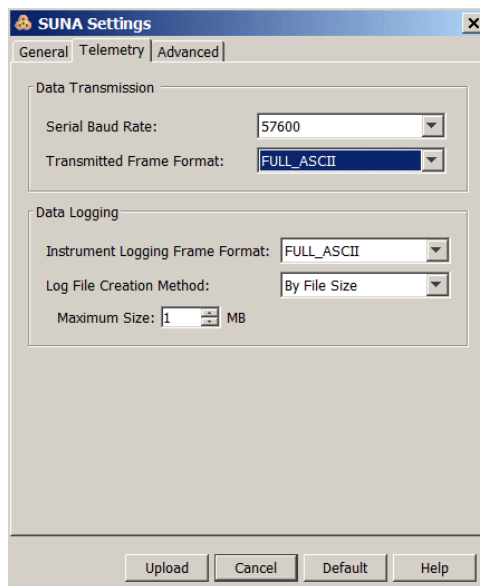
8. The firmware is updated.
The software disconnects the sensor.

4.1 Software settings

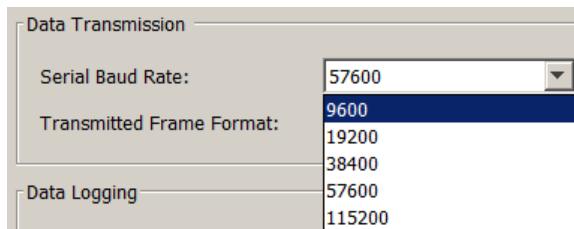
This section has information about configuration values and modes of operation that apply to all deployments.

4.1.1 Communication

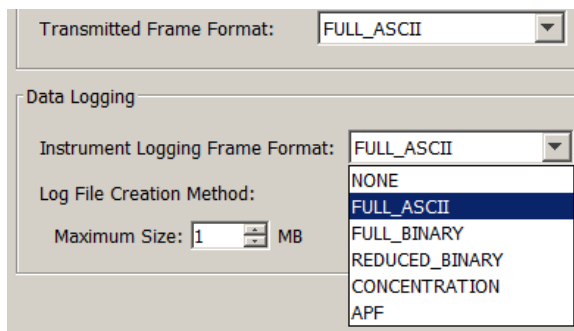
Go to the *Telemetry* tab in **SUNA Settings** to set up communication and data file types.



The default serial baud rate is 57600. Others are available.



The default for "Transmitted Frame Format" and "Instrument Logging Frame Format" is "FULL_ASCII."

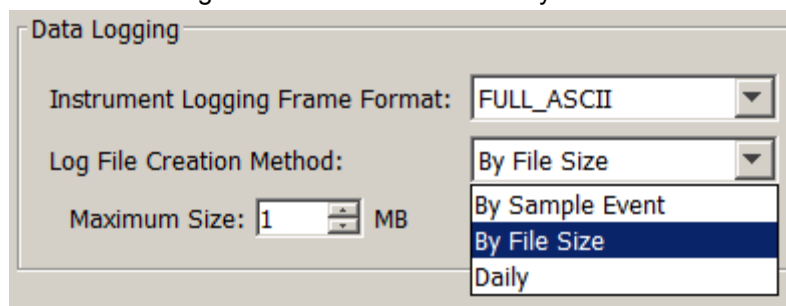


- **FULL_ASCII**—Contains all collected data in comma-separated fields. The file extension is **.csv**. The frame size is typically 1600–1800 bytes. Use this format so that data can be reprocessed.
- **NONE**—For "Transmitted Frame Format" data output is turned off. For "Sensor Logging Frame Format" sensor data storage is turned off.

Other available formats:

- **FULL_BINARY**—Contains all collected data. The file extension is **.bin**. The frame size is 632 bytes. Use this format so that data can be reprocessed.
- **REDUCED_BINARY**—Contains data from part of the spectrum and data from some auxiliary sensors. The file extension is **.bin**. The frame size is 144 bytes. Use this format so that seawater data can be reprocessed.
- **CONCENTRATION ASCII**—Contains a time-stamp, nitrate concentration, absorbance at 254 and 300 nm and Root Mean Square Error (RMSE) to measure the quality of the data. The file extension is **.csv**.
- **APF**—Used for APEX floats. Contains the user-selected parts of the spectrum and other auxiliary sensors. The frame size is typically 300–400 bytes.
- The user can set the "Transmitted Frame Format" to "NONE" to turn off data output. This increases the rate at which data is collected, and uses 10–30% less power.
- The user can set the "Instrument Logging Frame Format" to NONE to turn off internal data collection.

The default "Log File Creation Method" is "By File Size." Others are available.



- **By File Size**—The software makes a new file when the data file in use gets to the user-selected maximum size. The file name starts with "C" ("Continuous" file).
- **By Sample Event**—The software makes a new file when data collection starts for the first time after the power has been turned off, then on. The manufacturer recommends that the user select this for testing only. Use of this setting can result in so many stored files that the sensor operates slowly or incorrectly. The file name starts with "A" ("Acquisition" file). **Daily**—All data that is collected during a calendar day is put into a single file. This file name is a seven-digit number that is the year and the day of the year, for example, D2015142.csv. The file name starts with "D" ("Date-stamped" file).

The default "Maximum File Size" is 2 MB when the "Mode of Operation" is set to "Continuous." It is user-selected from 1–65 MB. The "Daily" and "Sample Event" files contain all of the data that is collected during the day or during one cycle of operation.

4.1.1.1 File types

The sensor uses three types of files:

- Data—either ASCII (**.csv**), or binary (**.bin**).
- Calibration—reference spectrum updates from the manufacturer (**.cal**).
- Log—information about the sensor (**.log**)

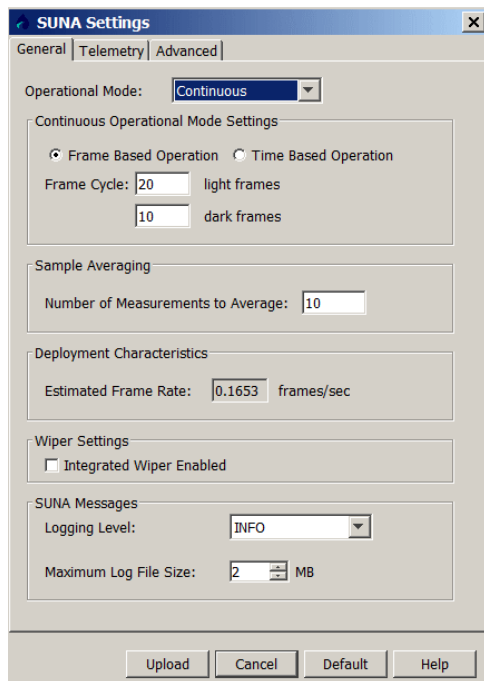
Table 3 Information in data files

Column	Data type	Full ASCII	Full Binary
1	Date, yyyy-mm-dd		
2	Header and serial number	N/A	
3	Date, year and day-of-year	AI7	BS 4
4	Time, hours of day	AF	BD 8

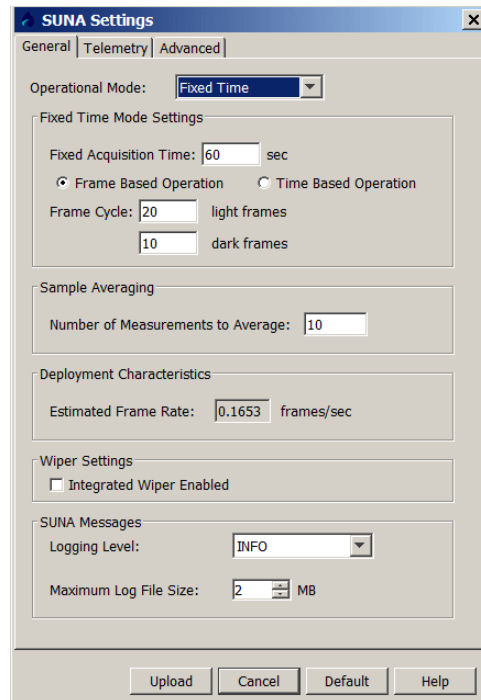
Table 3 Information in data files (continued)

5	Nitrate concentration, μM	AF	BF 4
6	Nitrogen in nitrate, mgN/L	AF	BF 4
7	Absorbance, 254 nm	AF	BF 4
8	Absorbance, 350 nm	AF	BF 4
9	Bromide trace, mg/L	AF	BF 4
10	Spectrum average	AI	BU 2
11	Dark value used for fit	AI	BU 2
12	Integration time factor	AI	BU 1
13–268	Spectrum channels	256 x AI	256 x BU 2
269	Internal temperature, $^{\circ}\text{C}$	AF	BF 4
270	Spectrometer temperature, $^{\circ}\text{C}$	AF	BF 4
271	Lamp temperature, $^{\circ}\text{C}$	AF	BF 4
272	Cumulative lamp on-time, secs	AI	BU 4
273	Relative humidity, %	AF	BF 4
274	Main voltage, V	AF	BF 4
275	Lamp voltage, V	AF	BF 4
276	Internal voltage, V	AF	BF 4
277	Main current, mA	AF	BF 4
278	Fit aux 1	AF	BF 4
279	Fit aux 2	AF	BF 4
280	Fit base 1	AF	BF 4
281	Fit base 2	AF	BF 4
282	Fit RMSE	AF	BF 4
283	if CTD: Time, secs	AI	BU 4
284	if CTD: Salinity, PSU	AF	BF 4
285	if CTD: Temperature, $^{\circ}\text{C}$	AF	BF 4
286	if CTD: Pressure, dBar	AF	BF 4
287	Check sum	AI	BU 1
	Terminator	<CR><LF>	—

4.1.2 Continuous and fixed-time operation



The SUNA Settings dialog box is shown with the 'Continuous' operational mode selected. The 'Continuous Operational Mode Settings' section includes radio buttons for 'Frame Based Operation' (selected) and 'Time Based Operation'. Below these are input fields for 'Frame Cycle' (20) for light frames and (10) for dark frames. The 'Sample Averaging' section has a 'Number of Measurements to Average' set to 10. The 'Deployment Characteristics' section shows an 'Estimated Frame Rate' of 0.1653 frames/sec. The 'Wiper Settings' section has 'Integrated Wiper Enabled' unchecked. The 'SUNA Messages' section has 'Logging Level' set to INFO and 'Maximum Log File Size' set to 2 MB. At the bottom are buttons for 'Upload', 'Cancel', 'Default', and 'Help'.



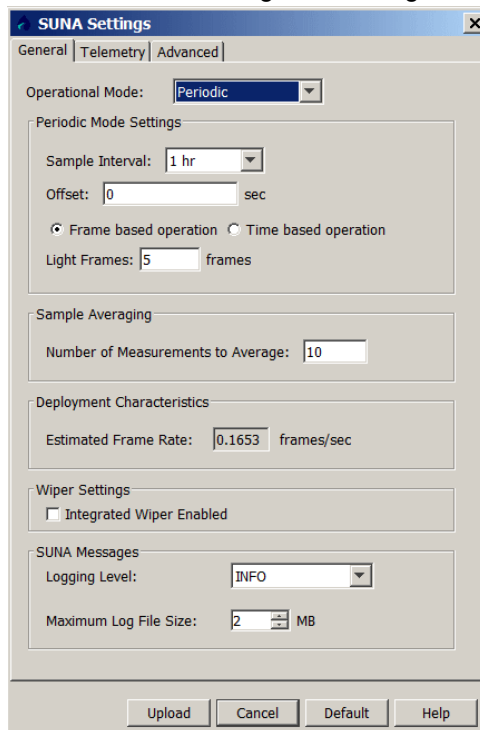
The SUNA Settings dialog box is shown with the 'Fixed Time' operational mode selected. The 'Fixed Time Mode Settings' section includes a 'Fixed Acquisition Time' set to 60 sec and radio buttons for 'Frame Based Operation' (selected) and 'Time Based Operation'. Below these are input fields for 'Frame Cycle' (20) for light frames and (10) for dark frames. The 'Sample Averaging' section has a 'Number of Measurements to Average' set to 10. The 'Deployment Characteristics' section shows an 'Estimated Frame Rate' of 0.1653 frames/sec. The 'Wiper Settings' section has 'Integrated Wiper Enabled' unchecked. The 'SUNA Messages' section has 'Logging Level' set to INFO and 'Maximum Log File Size' set to 2 MB. At the bottom are buttons for 'Upload', 'Cancel', 'Default', and 'Help'.

The sensor must regularly collect a dark spectrum measurement so that it has a baseline correction for changes in time or "drift" in the output of the spectrometer.

The user can set up the sensor to collect a dark spectrum measurement on a time-based or measurement-based schedule. A typical setup is a 1-second dark spectrum measurement for each 20–30 seconds (20–30 measurements) of the light spectrum.

4.1.3 Periodic operation

Use the software to see and change the settings for this mode of operation.



The SUNA Settings dialog box is shown with the 'Periodic' operational mode selected. The 'Periodic Mode Settings' section includes a 'Sample Interval' set to 1 hr, an 'Offset' set to 0 sec, radio buttons for 'Frame based operation' (selected) and 'Time based operation', and 'Light Frames' set to 5 frames. The 'Sample Averaging' section has a 'Number of Measurements to Average' set to 10. The 'Deployment Characteristics' section shows an 'Estimated Frame Rate' of 0.1653 frames/sec. The 'Wiper Settings' section has 'Integrated Wiper Enabled' unchecked. The 'SUNA Messages' section has 'Logging Level' set to INFO and 'Maximum Log File Size' set to 2 MB. At the bottom are buttons for 'Upload', 'Cancel', 'Default', and 'Help'.

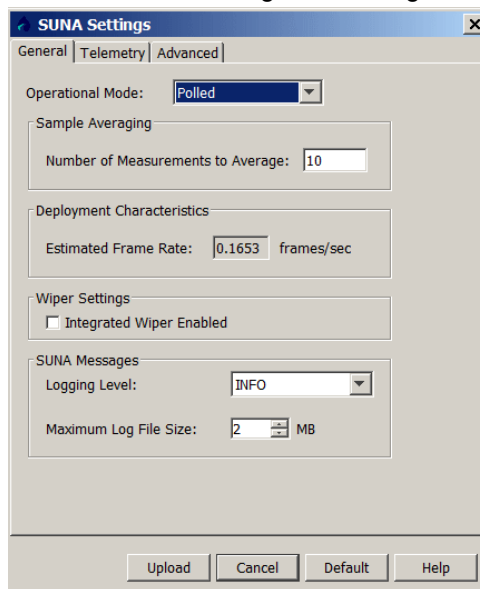
1. Select a "Sample Interval" from the drop-down menu.
2. Look at the "Offset" value. An offset value of 300 (5 min) changes the start time by five minutes, for example, from 06:00 to 06:05.
3. The "Light Frames" value is **0–255**.

Data is collected for either a user-selected quantity of time or a user-selected number of measurements.

Note: "Periodic" and "Autonomous" are both terms for the same mode of operation.

4.1.4 Polled operation

Use the software to see and change the settings for this mode of operation.



Use the commands below to communicate with the sensor in RS232.

Command	Result
Start	Start continuous data collection.
\$	Stops the sensor data collection.
Measure N	The sensor gets "n" light data frames. If "n" is zero, the sensor gets one dark data frame.
Timed N	The sensor gets light data frames for "n" seconds.
CTD	The sensor sends CTD data to be corrected for temperature and salinity. The sensor must be set up to do the correction and to process it.
Status	Print the status of the sensor.
Sleep	The sensor goes to low power standby mode.

Data files are saved in "FULL_ASCII."

Note: "Polled" and "Logger-controlled" are both terms for the same mode of operation.

4.1.5 Other general settings

Sample Averaging, Deployment Characteristics—The average of the number of frames selected. The higher the value, the more time it takes to make a measurement. The "Estimated Frame Rate" is directly related to the "Number of Measurements per Frame." The manufacturer recommends a value of 10–15 as the "Number of Measurements per Frame" to increase precision in a stable water sample. Use a lower value for unstable water samples.

Wiper Settings—If the sensor is equipped with a wiper, the user can put a check in this box so that the wiper will operate before each measurement.

SUNA Messages—The sensor gives information about the sensor operation and collected data. The default is "Info."

- "Error" gives the least information.
- "Debug" and "Trace" give the most information and are used only for troubleshooting.

Set the "Maximum Log File Size" to "0" to turn off the messages.

Options to monitor data

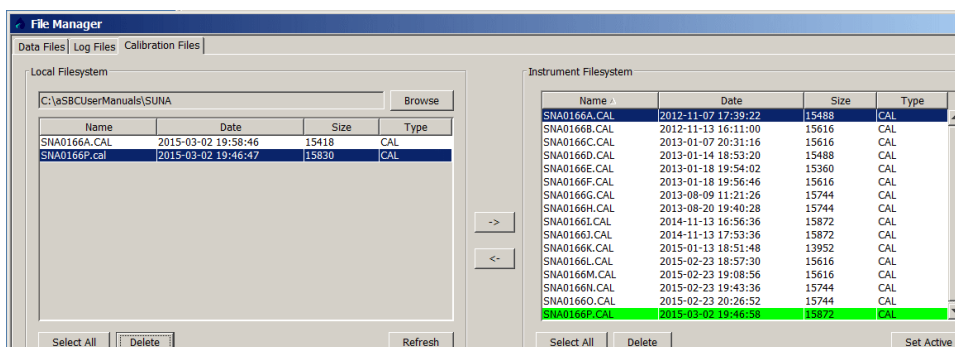
The user can select additional parameters to look at from the *Real Time Display* tab in the main window of the software. Push **Select Sensors** and put a check in the box next to the parameter to measure.

4.1.6 Compare reference spectrum files

Compare the change between two reference spectrum files. The amount of change is related to the time interval between the updates and the amount of lamp use during that time.

Note that this procedure is done automatically by the software when the user updates the reference spectrum for the sensor. Refer to [Update reference spectrum](#) on page 18 for more information.

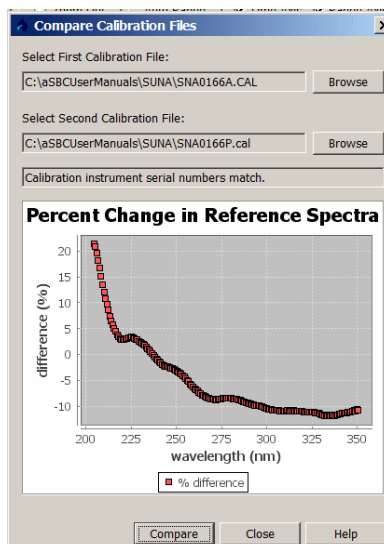
1. Find the two files to compare:



- Push **Transfer Files** in the SUNA Dashboard area.
- Select the *Calibration Files* tab.
- Select the first file under Instrument filesystem.
- Select the directory in the Local filesystem to save the file in.
- Push the <-- to move the first file.
- Do steps d and e to move the second file.
- Push **Close**.

Note that the date of the files changes to the current date.

- Select the **Data > SUNA > Compare Calibration** menu
- Push **Browse** to find to the first reference, or calibration, file on the PC to compare.
- Push **Browse** to find to the second reference, or calibration, file on the PC to compare.
- Push **Compare**.



A typical update interval of 3–6 months with no more than 100 hours of lamp use should cause a change of no more than 10% in the 215–240 nm interval.

Below 215 nm, larger relative changes are normal.

Above 240 nm, the change is smaller than at the 215–240 nm range.

If there is a large change, do several reference updates 12–24 hours apart to monitor the stability of the reference spectrum.

4.1.7 Data acquisition monitor

The software monitors the data collected by the sensor and shows any errors in this window. The error counters are reset each time the sensor starts a new data collection file. All information is transmitted during data collection, in real-time.

To see this tab, go to the **View** menu and select *Acquisition Monitor*.

Data Acquisition Monitor X

Data Logging: SUNA0166

Frame Statistics

Frame Id	Read	Errors	Checksum Err...	Counter Errors	Status Errors	Fitting Errors
SATSDf0166	1	0	0	0	0	0
SATSDC0166	0	0	0	0	0	0
SATSLC0166	0	0	0	0	0	0
SATSLF0166	78	0	0	0	0	0
SATSDR0166	0	0	0	0	0	0
SATSLB0166	0	0	0	0	0	0
SATSDb0166	0	0	0	0	0	0
SATSLR0166	0	0	0	0	0	0

- Frame Id—the unique frame number.
- Read—The number of frames accepted.
- Errors—The number of frames discarded.
- Checksum Errors—There may be a problem with the data that is transmitted. Examine the cabling and connectors. If the value in such a frame is wrong, it is discarded. If the collected data is saved to the internal memory of the sensor, that data is correct and can be copied to the PC at a later time.
- Counter, Status, and Fitting Errors—always zero.

4.1.8 Files necessary to process data

Go to the **Data** menu to select how data is processed. The HydroCAT can only replay data.

- Use *Convert Raw Data* to change binary files into ASCII files.
- Use *Replay Logged Data* to show a graph of saved data.
- Use *Reprocess Data* to apply a different reference value or change the settings to process the data.

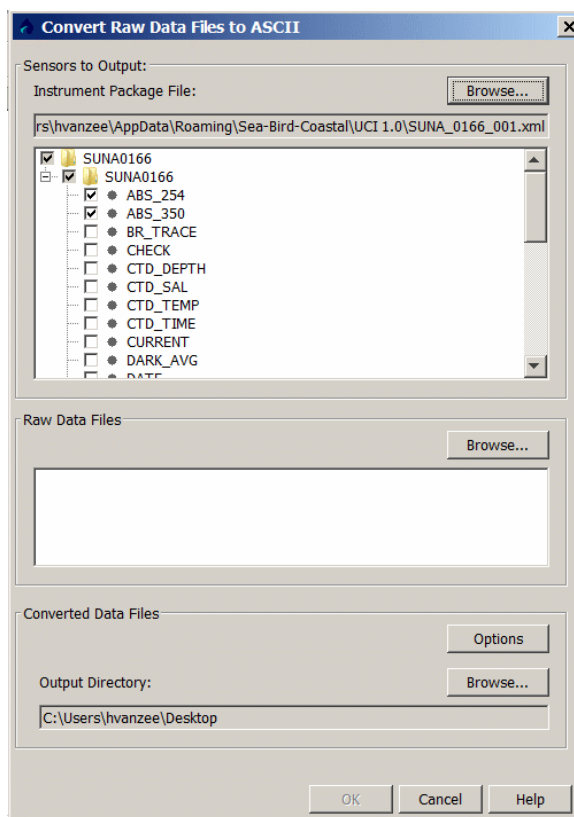
The SUNA uses the three files below to process data:

1. The .xml package file that is stored in C:\users\%username%\AppData\Roaming\Sea-Bird-Coastal\UCI 1.0\SUNA_%SN%.xml.
2. The raw data file to process.
3. The reference spectrum file (optional for *Replay Logged Data*).

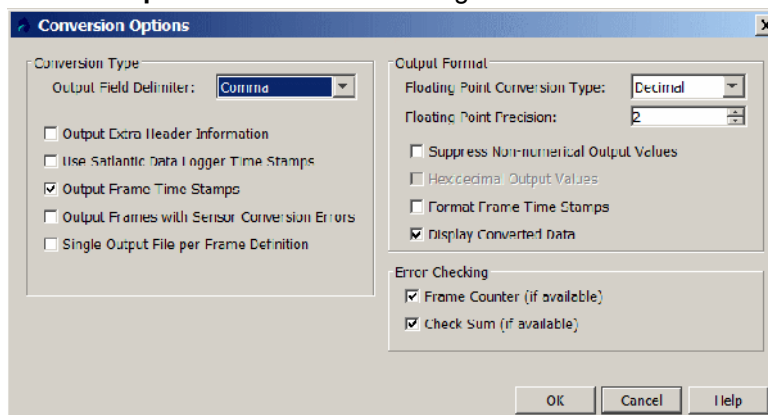
4.1.8.1 Convert raw data

Use the Convert Raw Data option to change binary data to ASCII.

1. Go to the **Data** menu, then *SUNA*, then *Convert Raw Data*.
2. Find the "Instrument Package File" that is stored on the PC.
3. Put a check in the boxes next to the parameters to convert from binary to ASCII.



4. Select the data file to process in the Raw Data Files area.
5. If necessary, change the "Output Directory" in the Converted Data Files area. Push **Options** to look at the settings to convert files.

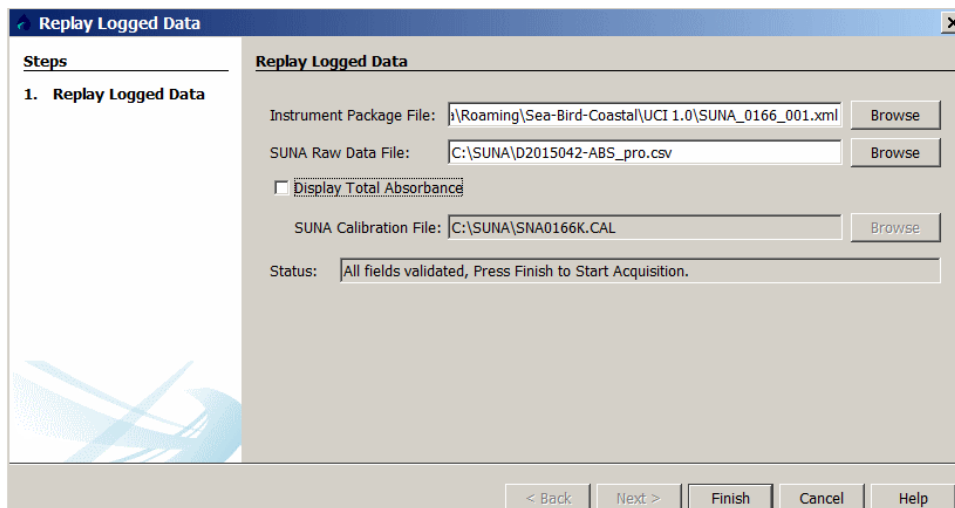


6. Push **OK**.
The converted file shows in a new tab in the software. It is also saved on the PC in the directory selected above.

4.1.8.2 Replay logged data

Use *Replay Logged Data* to look at graphs of the selected data. Data shows in the *Time Series*, the *Spectra*, and the *Total Absorbance* (if selected) graph tabs.

1. Push **Replay Logged Data** in the SUNA Dashboard, or go to the **Data** menu, then *SUNA*, then *Replay Logged Data*.
2. Make sure that the package file, the data file to replay, and the reference spectra ("calibration") files are selected.



3. Push **Finish**.
The saved data shows in the graph tabs.
4. Push **Stop** to stop the data.

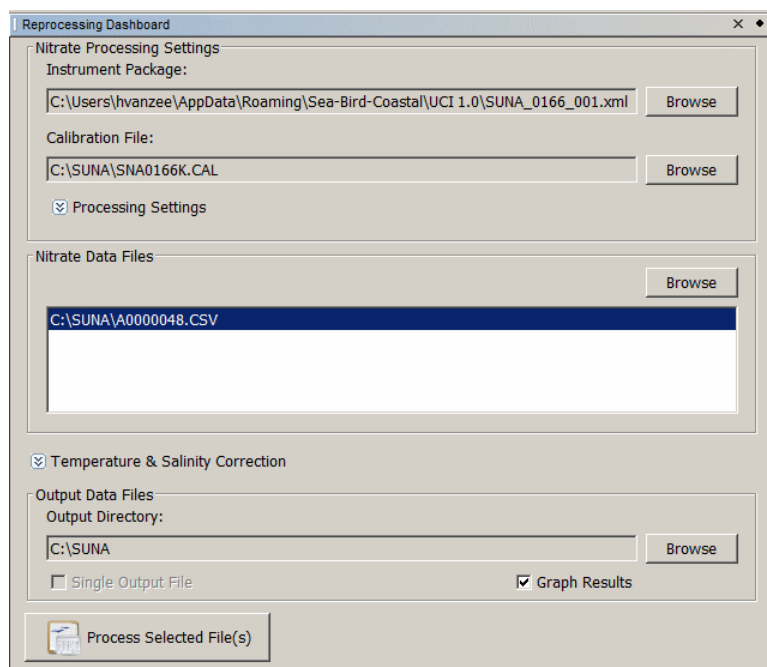
4.1.8.3 Reprocess SUNA data

The user may find that it helps to use the *Reprocess Data* option under some conditions.

- The settings for the sensor were incorrect. Use the Reprocess option to correct for this, such as when a sensor was deployed in seawater, but set up for fresh water.
- The data that is collected has changed over an extended deployment. Data is processed with an updated reference spectrum file, and compared to the original reference.
- Water temperature and salinity data are collected. These can be put together with the spectral data from the sensor to get more accurate nitrate data (Sakamoto et al. 2009).

Note that the data files collected with SDI-12 do not contain spectral data and cannot be reprocessed.

1. Start the software.
2. Go to the **Data** menu, then select *SUNA*, then *Reprocess Data*.



The Reprocessing Dashboard shows.

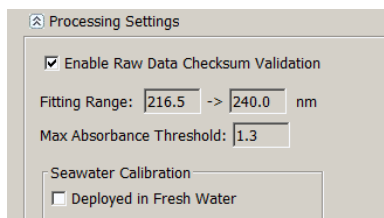
3. Push **Browse** to find the package file, the reference file, and the data file required to reprocess the data.
4. "Processing Settings" are set by the manufacturer and usually do not need to be changed.
5. Push **Process Selected File(s)**.

The software starts to reprocess the data.

4.1.8.3.1 Nitrate reprocessing details

Settings in "Processing Settings" and the "Temperature & Salinity Correction" areas do not show until selected by the user. The user can change these settings as necessary to get better quality data.

Processing settings



- The default "Enable Raw Data Checksum Validation" is on, with a check in the box. If it is turned off, raw data can be processed even when the checksum values have changed after data is collected.
- The default "Fitting Range" is 216.5–240 nm. If the wavelength is shorter, seawater typically causes extinction, and a poor signal-to-noise ratio. If the wavelength is longer non-characterized materials can be absorbed, which causes a bias in the processed concentrations.
- The default "Max Absorbance Threshold" is 1.3. The precision of the measured absorbance starts to decline at this value. At 2.5 absorbance units, the precision is at the "noise floor." The precision of the processed data is better when the low-quality parts of the "fitting range" are not processed.
- The default Seawater Calibration has no check in the box at "Deployed in Fresh Water." Put a check in this box if the sensor was calibrated for seawater but deployed

in fresh water. Data that was collected in seawater with a check in the "Deployed in Fresh Water" box gives incorrect nitrate concentrations.

Temperature and salinity correction

- The default "Activate Temperature & Salinity Correction" has no check in the box. Put a check in this box to add temperature and salinity correction information.
- "Temperature and Salinity Correction" is available if the sensor is calibrated for seawater, and if there is temperature and salinity data available in an ASCII format of "YYYY-MM-DD hh:mm:ss, Temperature (c), Salinity (PSU)." Push Browse to find the file to process.

4.2 SDI-12 commands

Note: "Polled" and "Logger-controlled" are both terms for the same mode of operation. The sensor supports all basic SDI-12 commands. Refer to the SDI-12 specification at www.sdi-12.org for details of the command protocol. For any command not described below, the sensor will respond according to the SDI-12 v1.3 specification.

The manufacturer-set address of the SDI-12 is numerical value 48 (ASCII character 0). The SDI controller uses this address to interface with the sensor in an SDI-12 mode of operation. The user can change this value in the SDI controller.

Definitions:

- "a" is the SDI-12 address of the sensor (default is "0")
- <CRC> is the 3-character Cyclic Redundancy Check
- <CR> is a Carriage Return character
- <LF> is a Line Feed character

Acknowledge Active (a!)	
Response	a<CR><LF>
Purpose	verifies the SDI-12 address
Example	address = 0
	SDI recorder sends 0!
	sensor sends 0<CR><LF>

Address query (?!)	
Response	a<CR><LF>
Purpose	shows the SDI-12 address
Example	address = a
	SDI recorder sends ?!
	sensor sends a<CR><LF>

Change address (aAb!)	
Response	b<CR><LF>
Purpose	changes SDI-12 address to "b". The default address is 0.
Example	address = 0
	SDI recorder sends 0A1!
	sensor sends 1<CR><LF>
	address now = 1

Verify (V!)	
Response	attn<CR><LF>
Purpose	The sensor always responds with a0000<CR><LF> . No diagnostic information is supported.

Send identification (a!!) ("a, capital I, !)	
Response	allccccccmmmmmmvvvxxxxxxxxxx<CR><LF>
	a = sensor address
	ll (lowercase "l") = 2-character SDI-12 version. For example, "13" for version 1.3
	ccccccc = 8-character manufacturer identification. For example, "SATLANTC"
	mmmmm = 6-character sensor model. For example, "SUNA"
	vvv = 3-character sensor version. For example, "v2"
	xxxxxxxxxxxx = up to 13-character optional field. Format: F<MAJOR>.<MINOR>.<PATCH> Used for firmware by the manufacturer.
Example	013SATLANTC SUNA v2 0002F2.1.2<CR><LF>

Start Measurement (aM!)	
Start Measurement and Request CRC (aMC!)	
Start Concurrent Measurement (aC!)	
Start Concurrent Measurement and Request CRC (aCC!)	
Response	attn<CR><LF> attnn<CR><LF>
Purpose	starts a measurement. starts a concurrent measurement.
Notes	a = address = (0–9)
	ttt = measurement time in seconds. The sensor typically responds in less than 30 seconds.
	n or nn. The number of measurement values the sensor makes and returns after subsequent Send Data commands. Value = 4.
Example	00104<CR><LF> measurement 001004<CR><LF> concurrent measurement
	The sensor reports that 10 seconds are required to do the measurement. Typically it will complete sooner and send a service request to the controller.
	In subsequent data commands, the four values are— nitrate concentration μM nitrogen in nitrate concentration mgN/L light spectrum average dark spectrum average

Reference

Additional Measurement (aM1!) Additional Measurement and Request CRC (aMC1!) Additional Concurrent Measurement (aC1!) Additional Concurrent Measurement and Request CRC (aCC1!)	
Response	atttn<CR><LF> atttnn<CR><LF>
Purpose	starts a measurement. starts a concurrent measurement.
Notes	a = address = (0–9)
	ttn = measurement time in seconds. The sensor typically responds in less than 30 seconds.
	n or nn. The number of measurement values the sensor makes and returns after subsequent Send Data commands. Value = 7.
Example	00067<CR><LF> measurement 000607<CR><LF> concurrent measurement <i>where 00067 is the address (0), the measurement time (006), and the number of measurements (7).</i>
Example output from the controller:	
00M1! 0D0! 0D1!	00067 <CR><LF> 0+22.7+22.5+141779+46.8<CR><LF> 0+12.0+5.0+14.0<CR><LF>
	Example output from the controller for the seven values— <i>Example output values in parentheses:</i> lamp temperature, °C (22.7) spectrometer temperature, °C (22.5) lamp time, seconds (141779) relative humidity, % (46.8) internal voltage, V (12.0) regulated voltage, V (5.0) supplied voltage, V (14.0)

Additional Measurements (aM2!) Additional Measurements and Request CRC (aMC2!) Additional Concurrent Measurement (aC2!) Additional Concurrent Measurement and Request CRC (aCC2!)	
Response	atttn<CR><LF> atttnn<CR><LF>
Purpose	starts a measurement. starts a concurrent measurement.
Notes	ttn = measurement time in seconds. The sensor typically responds in less than 30 seconds.
	n or nn. The number of measurement values the sensor makes and returns after subsequent Send Data commands. Value = 7.
Example	00099<CR><LF> measurement 000913<CR><LF> concurrent measurement

Example output from the controller:	
00M2! 0D0! 0D1! 0D2!	00099 <CR><LF> 0+3.26+0.0457+15501+721<CR><LF> 0+2015033+20.57608<CR><LF> 0+0.132+0.0672+0<CR><LF>
	<p>Example output from the output for the nine (or 13 for concurrent) values— <i>Example output values in parentheses:</i></p> <p>nitrate concentration, μM (3.26) nitrogen in nitrate concentration, mgN/L (0.0457) light spectrum average (15501) dark spectrum average (721) measurement date (2015033) measurement time (20.57608) absorbance at 254 nm (0.132) absorbance at 350 nm (0.672) bromide trace (0) lamp temperature, $^{\circ}\text{C}$ (concurrent measurement only) spectrometer temperature, $^{\circ}\text{C}$ (concurrent measurement only) relative humidity, % (concurrent measurement only) rmse of nitrate processing (concurrent measurement only)</p>

Additional Measurements (aM3–aM9!) Additional Measurements and Request CRC (aMC3!–aMC9!) Additional Concurrent Measurement (aC3!–aC9!) Additional Concurrent Measurement and Request CRC (aCC3!–aCC9!)	
Response	atttn<CR><LF> atttnn<CR><LF>
Purpose	starts a measurement. starts a concurrent measurement.
Notes	The sensor supports 2 additional measurements. ttn = 000 n = 0 nn = 00

"Send Data" commands that come after the aM! or aMC! commands:

Send Data (aD0!–aD9!)	
Response	a<values><CR><LF> a<values><CRC><CR><LF>
Purpose	sends data to the SDI controller after a measurement or verification command. The response depends on the previous measurement command.
Note	after the M! or C! command the sensor responds with nitrate concentration in two units, and the light and dark spectrum average.
Example	0+1039.040+14.8434+22799+671<CR><LF>
Note	after the MC! or CC! command the sensor responds the same as M! or C! but with a CRC value attached.
Example	0+1038.188+14.8350+22683+672NtW<CR><LF>
Note	after the MC! or CC! command the sensor responds to the aD0! command temperature in two units, lamp time, and humidity.

Reference

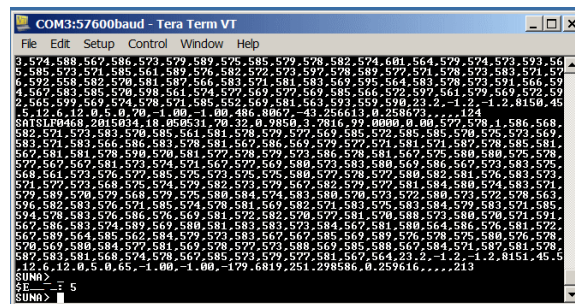
Example	0+33.188+23.500+3356+23.2AsF<CR><LF>
Note	The sensor responds to the aD1! command with three voltage units.
Example	0+11.92+5.43+13.68<CR><LF>
	after the MC1! command the sensor responds as in the M!! command, but with a CRC value attached.
Example	0+33.813+23.500+3356+23.2AsF<CR><LF> followed by: 0+11.92+5.43+13.62EyF<CR><LF>
	The response to the aC1!, aCC1!, aM2!, aMC2!, aC2!, aCC2! commands is similar.

Continuous Measurement (aR0!–aR9!) Continuous Measurement and Request CRC (aRC0!–aRC9!)	
Response	a<values><CR><LF> or a<values><CRC><CR><LF>
note	the Continuous Measurement command is not supported due to the limited life of the lamp. The sensor reports a0<CR><LF> or a0<CRC><CR><LF>

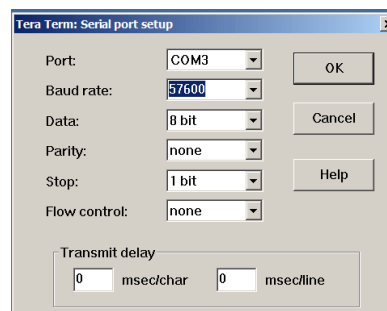
4.3 Terminal program

The user can communicate with the sensor through the manufacturer-supplied software, or by use of a terminal program through the serial port on a PC. Examples of terminal programs include Putty, Tera Term, and Bray's Terminal. When power is supplied to the sensor, the sensor goes into a low-power "standby" mode. Any activity on the input line puts the sensor to the "SUNA>" command interface within three seconds. The sensor returns to low-power standby after a user-selected period of time with no communication.

1. Connect the serial cable to the sensor and the PC.
2. Connect the serial cable to an 8–15 VDC, 1 A minimum, power supply.
3. Start a terminal program.
 - a. Set up the communication values if necessary: 8 bit, no parity, 1 stop bit, no flow control.



- b. Go to **Setup**, then *Serial Port*.
- c. If necessary, change the baud rate to 57600. Push **OK**.



4. Turn on the power supply.
5. Send one or more "\$" commands to the sensor to see a prompt at the command line. The sensor shows "SUNA>" when it is ready to accept commands.
6. Type "get opermode" to see the current mode of operation for the sensor. The default value is Fixed Time. It shows as "fixedtime." Refer to [Data collection setup values](#) on page 39 for other values for modes of operation.

Table 4 Status commands

Description	Command	Result
Selftest	selftest	Makes sure the sensor operates correctly, does measurements, and sends those measurements as the last line of output. \$Ok—the sensor operates correctly. !—A sensor component did not operate correctly. \$Error—A sensor component did not pass the test.
Used lamp time	get lamptime	The total time the lamp has operated, in seconds.
Wiper test	special swipewiper	The wiper operates one time.
Current configuration	get config	The sensor shows the current setup configuration.
Get mode of operation	get opermode	The sensor shows the current mode of operation.
Set mode of operation	set opermode	Changes the mode of operation

7. To change the mode of operation to SDI-12:
 - a. Make sure that the sensor is so equipped. Type "getopermodesdi12brd" The response is "available." If the response is "missing", the sensor is not equipped with SDI-12.
 - b. Type "set opermode sdi12" to change the mode of operation to SDI-12.

```
SUNA> set opermode sdi12
$Ok
SUNA> get opermode
$Ok SDI12
SUNA>
```

- c. Type "get opermode" to make sure that the sensor is in SDI-12 mode.
8. Use the SDI-12 controller to communicate with the sensor when it is in SDI-12 mode.

4.3.1 Input-output configuration values

Parameter	Possible values	Default value	Short name
Baud rate	9600, 19200, 38400, 57600, 115200	57600	baudrate
Message level	Error, Warn, Info, Debug	Info	msglevel
Message file size (MB)	0–65	2	msgfsize
Data file size (MB)	1–65	5	datfsize
Log file type	acquisition, continuous, daily	acquisition	logftype
Acquisition file duration (min)	0–1440	60	afiledur
Data wavelength, low (nm)	210–350	217	wdat_low
Data wavelength, high (nm)	210–350	250	wdat_hgh

4.3.2 Data collection setup values

Parameter	Possible values	Default value	Short name
Operation mode	continuous, fixedtime, periodic, polled, SDI12	fixedtime	opermode
Operation control	duration, samples	samples	operctrl

Reference

Countdown (sec)	0–3600	3	countdwn
Fixed time duration (sec)	1–1000000	10	fixddura
Periodic interval	1, 2, 5, 6, 10, 15, 20, 30 (min); 1, 2, 3, 4, 6, 8, 12, 24 (hr)	1 hr	perdival
Periodic offset (sec)	any value	0	perdooffs
Periodic duration (sec)	0–255	10	perddura
Periodic samples (# light frames)	0–255	10	perdsmpl
Polled timeout (sec)	0–65535	10	polltout
Skip sleep at startup	on, off	off	skpsleep
Lamp stability time (ds) ?	0–255	5	stbltime
Lamp switch-off temperature (°C)	* (see note below)	35	lamptoff
Spectrometer integration period (msec)	5–60000	N/A	spintper
Dark averages	1–200	1	drkavers
Light averages	1–200	1	lgtavers
Dark samples	1–65535	1	drksmpls
Light samples	1–65535	10	lgtsmpls
Dark duration (sec)	1–65535	10	drkdurat
Light duration (sec)	1–65535	120	lgtdurat
External device	none, wiper	none	exdevtyp
Ext. dev. pre-run time (sec)	1–120	0	exdevper
Ext. dev. during collection	on, off	off	exdevrun
Ext. dev. minimum interval	1–1440	60	exdval

Periodic Mode of Operation: When power is supplied to the sensor, the sensor goes to a low-power standby mode. Any activity on the input line puts the sensor to the "SUNA>" command interface within three seconds. The sensor returns to low-power standby after a user-selected period of time with no communication.

Continuous Mode of Operation: Data is collected continuously and autonomously when power is supplied to the sensor. Data collection stops when the user removes power or enters a "\$" character.

Fixed-time Mode of Operation: data collection occurs for the time set up by the user. When that time is completed, the sensor enters a low-power standby.

Polled Mode of Operation: the sensor is in low power standby mode until there is activity on the input line. The sensor initializes in 3–4 seconds, then displays a "CMD?" prompt to show that it is ready to receive commands from the controller. The "timeout" value controls the length of time the sensor is in standby mode before it returns to low power standby mode.

For best accuracy, regular dark measurements are necessary to compensate for the change in temperature. Select a dark-to-light data collection rate based on either the number of samples or the duration.

Note:

The lamp turn-off temperature is 35 °C. The lamp should not operate at temperatures above 35 °C.

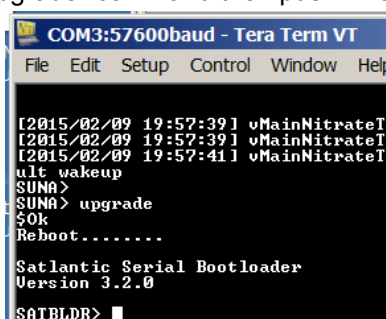
When the lamp reaches the turn-off temperature, the sensor overrides the user-configured mode of operation. The sensor does 5 cycles of 5-light to 5-dark sample collection, then does 1-light to 10-dark cycles until the lamp temperature is below the turn-off temperature.

Contact the manufacturer for information to safely change the turn-off temperature.

4.3.3 Update firmware

At regular intervals, make sure that the current firmware is installed. Go to the seabird-coastal.com web site to get the current firmware for the sensor.

1. At regular intervals, make sure that the current firmware is installed. Go to the seabird-coastal.com web site to get the current firmware for the sensor. Save the firmware to the PC.
The firmware is an ".sfw" file.
2. Make sure that the sensor is connected to the PC and a power supply.
3. Start a terminal program such as Putty, HyperTerminal®, or Tera Term.
The steps below use Tera Term as an example.
4. Adjust the baud rate to 57600.
5. Turn the power supply on.
6. Type the "\$" command to see the "SUNA>" prompt.
7. Type the "upgrade" command then push **Enter** to see the "SATBLDR>" prompt.



```

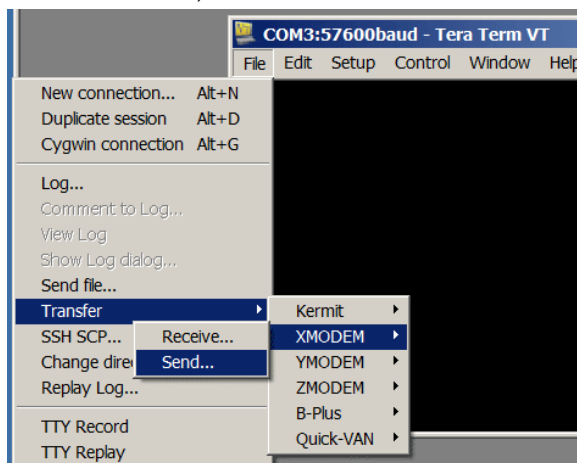
COM3:57600baud - Tera Term VT
File Edit Setup Control Window Help

[2015/02/09 19:57:39] vMainNitrateTe
[2015/02/09 19:57:39] vMainNitrateTe
[2015/02/09 19:57:41] vMainNitrateTe
ult wakeup
SUNA>
SUNA> upgrade
$Ok
Reboot.....

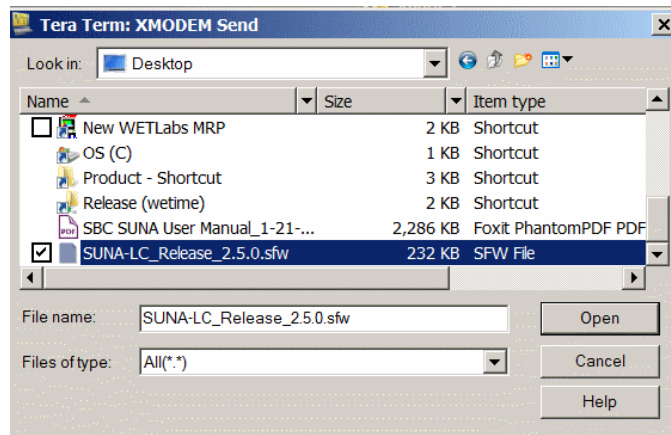
Satlantic Serial Bootloader
Version 3.2.0
SATBLDR>

```

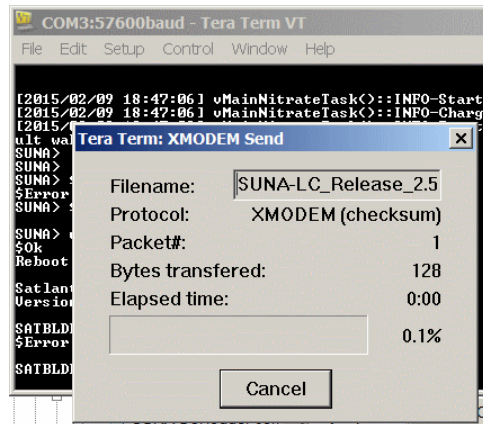
8. Type "w" then push **Enter**.
9. Go to the **File** menu, then select *Transfer > XMODEM Send....*



10. Select the downloaded firmware in the new window and push **Open**.
The firmware is sent to the sensor.

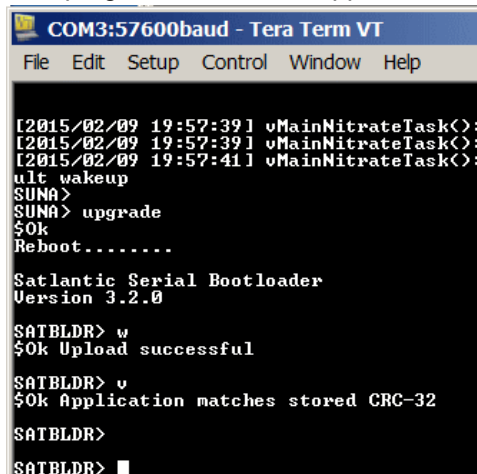


11. Let the terminal program send the firmware to the sensor. This process takes a minute or two.



When it is complete, the terminal program shows "\$Ok Upload successful."

12. Type "v" then push **Enter** to make sure that the firmware is valid. The terminal program shows "\$Ok Application matches stored CRC-32."



13. Type "a" then push **Enter**. The SATBLDR starts the new firmware in the sensor.

```

COM3:57600baud - Tera Term VT
File Edit Setup Control Window Help
[2015/02/09 19:57:41] vMainNitrateTask<>::INF
ult wakeup
SUNA>
SUNA> upgrade
$Ok
Reboot.....
Satlantic Serial Bootloader
Version 3.2.0
SATBLDR> u
$Ok Upload successful
SATBLDR> v
$Ok Application matches stored CRC-32
SATBLDR>
SATBLDR> a
$Ok Run Application on startup
SATBLDR> [2015/02/09 20:01:10] setup_system<>
Setup done.
SUNA>

```

14. Turn the power to the sensor off, then back on.
The new firmware operates in the sensor.
15. Go to the **File** menu, then select *Disconnect*

4.4 Theory of operation

4.4.1 Background

The SUNA is a chemical-free nitrate sensor for fresh, brackish, and salt water. The sensor is based on the In-Situ Ultraviolet Spectroscopy (ISUS) that was developed at MBARI (cf. Kenneth S. Johnson, Luke J. Coletti, Deep-Sea Research I, 49, 2002, 1291–1305).

The sensor lights the water sample with its deuterium UV light source and measures this with its spectrometer. The difference between this measurement and a prior baseline measurement of pure water is the absorption spectrum.

Absorbance characteristics of natural water components are in the calibration file of the sensor. The Beer-Lambert law for multiple absorbers makes the relationship between the total measured absorbance and the concentrations of individual components. Based on this, the sensor gives a best estimate for the nitrate concentration with multi-variable linear regression.

If the "Integration Time Adjustment" configuration parameter is set to "On" or "Persistent," the sensor makes measurements with a spectrometer integration time that is 20 times as long as the normal integration time. This increases the signal-to-noise ratio in faint light conditions and lets the sensor operate in optically dense conditions. When the optical density decreases, the sensor goes back to the normal spectrometer integration time.

4.4.2 Description of nutrient units

Nutrient units express the amount of something, usually moles or mass, relative to the volume it is in. Many researchers and scientists use micromoles per liter (μM), a unit that is independent of mass and useful for stoichiometric calculations.

Most fresh water monitoring programs and many researchers use units of milligrams per liter. This unit is almost always expressed as milligrams of relevant atoms per liter—for example, milligrams of nitrogen (N) per liter, rather than milligrams of nitrate per liter. Although nitrate NO_3 is the most prevalent form of nitrogen, this unit is frequently used as a means of easily keeping track of total nitrogen loading. Because milligrams per liter is a mass-based unit and the mass of N and NO_3 are different, this difference is very important to prevent mistakes. Milligrams per liter is also typically referred to as parts per million (ppm), the mass of N relative to the mass of water.

The SUNA V2 sensor measures dissolved nitrate and displays units in micromolar (μM) or milligrams of nitrogen per liter (mg/N/L). The SUNA V2 does not display milligrams of nitrate per liter (mg/L or mgNO_3/L).

4.4.3 Nitrate concentration

Nitrate processing uses the 217–240 nm wavelength range, which contains approximately 35 spectrometer channels. The precision of the nitrate concentration is related to the number of absorbers into which the measured absorbance is decomposed. High absorbance conditions introduce inaccuracies into the nitrate concentrations. Channels with an absorbance of more than 1.3 are not included in the processing. If less than approximately 10 channels remain, the sensor cannot give a nitrate concentration. The user can increase the absorbance cutoff and get decreased-accuracy nitrate concentration at higher absorbances.

4.4.4 Description of adaptive sampling

The SUNA V2 has a 256-channel spectrometer that integrates for a specific length of time, usually 300–500 ms, to maximize the signal while it collects data. When the sensor does a measurement, the spectrograph collects UV light for the length of the integration period. In optically dense waters, with high turbidity or CDOM, very little UV light is transmitted through the water, so the spectrometer "sees" a much lower signal. The SUNA V2 automatically increases the integration period to compensate for the low light, so the sensor collects a strong signal in extreme environmental conditions.

4.4.5 Sensor calibration from manufacturer

Sensors come from the manufacturer with a default class-based calibration. Sensors can have an optional sensor-specific calibration for either fresh water or seawater. The user can configure a seawater calibration to be deployed in either fresh water or seawater.

The calibration file is stored in the sensor and includes the coefficients to calculate nitrate, as well as a reference spectrum. It is necessary for the user to update the reference spectrum as the optical components change over time. The software has a wizard to let the user update the reference spectrum at regular intervals or as necessary. This procedure adjusts the "zero" nitrate value based on a sample of pure water (ultra pure, nano pure, or DI). It is necessary to periodically update the reference spectrum to make sure that the sensor collects accurate data.

For best performance, send the sensor back to the manufacturer annually for maintenance.

4.5 Interferences and mitigation

4.5.1 Uncharacterized species in sample

A number of substances in natural water absorb in the UV spectral range where nitrate absorbs. The spectral signature is usually different from nitrate but certain combinations of water components may cause a bias in the calculated nitrate concentrations.

If the user thinks there are significant concentrations of interfering species, do a random spectral and chemical analysis of the water sample to quantify and correct the optical interference.

4.5.2 Optically dense constituents

The performance of the sensor is compromised in optically dense conditions, which transmit less light than necessary for the regression analysis. As the optical density increases, the quality of the measurement (signal-to-noise) decreases. The accuracy and precision of the nitrate concentration measurements decrease as the quality of the data decreases. High optical densities are frequently caused by CDOM or turbidity in the water sample.

4.5.3 Sample temperature

Seawater has a temperature-dependent absorption rate. Make sure to consider this so that imprecision does not affect the nitrate concentration that is measured. To mitigate this effect, use the sample temperature and salinity values in the nitrate calculation in the host software for post-processing. Note that spectra and related temperature and salinity

data is necessary. The temperature-salinity correction comes from MBARI (cf. Carole M. Sakamoto, Kenneth S. Johnson, and Luke Coletti, *Limnol. Oceanogr.*: Methods 7, 2009.)

4.5.4 Identification of interfering species

The effect of turbidity and CDOM on the measured nitrate concentration was calculated in the laboratory.

Turbidity sample	NTU per mg/L	Absorbance at 225 nm (10 mm) per mg/L	NO ₃ change, μ M, in freshwater per mg/L	NO ₃ change, μ M, in seawater per mg/L
Arizona Road Dust (ARD)	1.25	0.0016	< -0.002 (-2.8 e -5)	0.01 (1.4 e -4)
Kaolin powder	1.5	0.0085	< 0.001 (1.4 e -5)	0.02 (-2.8 e -4)
Titanium dioxide (TiO ₂)	15.0	0.0090	< 0.001 (1.4 e -5)	< 0.001 (1.4 e -5)

CDOM sample	QSD per mg/L particle	Absorbance at 225 nm (10 mm) per mg/L particle	NO ₃ change, μ M, in seawater per mg/L particle	NO ₃ change, μ M, in seawater per mg/L particle
Pony Lake Fulvic Acid reference (1R109F)	N/A	0.017	0.4 (5.6 e -3)	0.6 (8.4 e -3)
Suwannee River Fulvic Acid standard (1S101F)	N/A	0.027	< 0.1 (1.4 e -3)	< 0.1 (1.4 e -3)
Pahokee Peat Humic Acid reference (1R103H-2)	42	0.003	< 0.01 (1.4 e -4)	< 0.1 (1.4 e -3)

An interfering species causes an incorrect nitrate concentration when its spectral characteristics are almost the same as nitrate. The RMSE value is the square root of the mean of the sum of the squared differences between the measured and the fitted absorbance. The RMSE is a measure of the quality of the fit. Independent measurements of turbidity and CDOM, and an analysis of the absorption spectrum help the impact analysis.

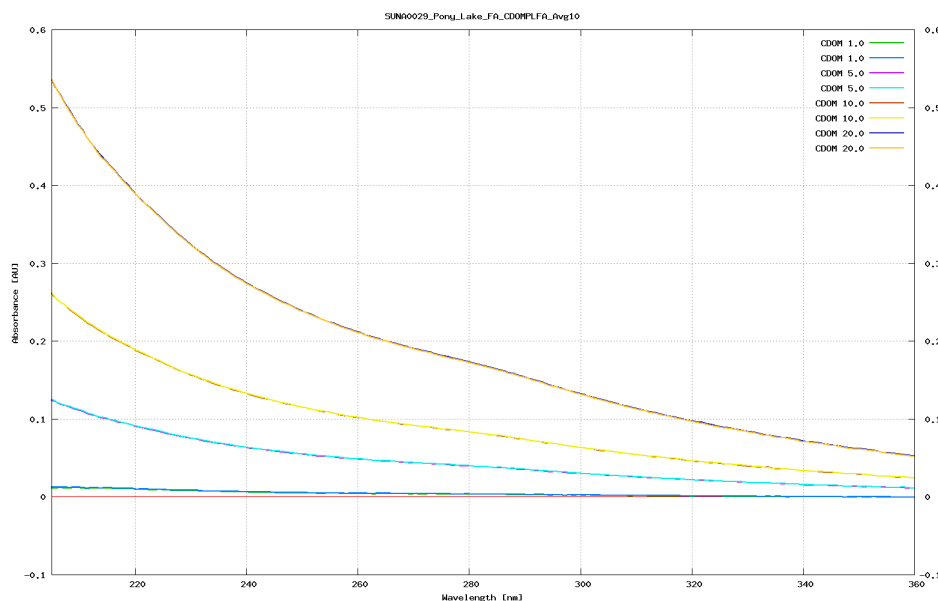
4.5.5 Sensor function

The lamp and other optical components in the sensor change with time. This causes nitrate measurements to change, or "drift." Do regular updates to the reference, or baseline, spectrum to minimize this change.

The output of the lamp is related to its temperature. The manufacturer recommends that the user collect the reference (baseline) spectrum in conditions that are almost the same as a deployment.

4.6 CDOM absorption

Figure 4 Fulvic acid, mg/l. Note that the CDOM spectral shape overlaps with the nitrate processing region.



The model to calculate nitrate fits for 4 parameters: nitrate, bromide, a temperature coefficient and a linear baseline correction that accounts for all additional absorbing species. If the absorption of the sample is high (default cut-off = 1.3 AU), the model can no longer be used effectively to fit parameters or calculate nitrate concentration. The SUNA V2 data output is a root mean square error parameter that indicates the quality of the fit of the models to the absorption curves.

CDOM Absorption Properties

Colored Dissolved Organic Matter (CDOM) is one of the main substance classes that absorbs in the same UV range as nitrate. (Other significant absorbers are seawater, bromide, bisulfite, and suspended particles). CDOM is a mixture of many chemicals, and changes across locations and times, usually depending on its origin. Thus, there is no universal characterization of the UV absorption of CDOM.

CDOM Impact on SUNA Nitrate Concentration

The UV absorption spectra of CDOM changes across the types of CDOM. Some types of CDOM are closer in their absorption to nitrate than others. Types of CDOM that absorb similar to nitrate will cause a larger bias than those that absorb dissimilar. Thus, the concentration of CDOM alone cannot predict the magnitude of the bias.

Quantification and Correction of CDOM Impact

Under ideal conditions, CDOM would be isolated from all other absorbers, and its absorbing properties identified in isolation. A more realistic approach is to independently find the content (nitrate, salinity, CDOM) of a number of water samples (if CDOM is stable over time), and calculate the CDOM-induced bias on the nitrate concentration.

FDOM: Fluorescent Dissolved Organic Matter is a subset of Colored DOM and can be used as a proxy for CDOM (if the composition is stable over time). Most FDOM sensors use a 370 nm excitation source that targets more humic substances, and may not represent absorption in the nitrate range (~220 nm).

Absorption: The data output of the SUNA V2 is the absorption at 350 nm and 254 nm (A350 and A254). These wavelengths are outside the nitrate absorption range and can be used to make an estimate of the impact of CDOM. If absorption is high (>1.3 AU), the SUNA will not be able to collect adequate light to make a measurement.

RMSE: The root mean square error parameter from the SUNA V2 can be used to make an estimate of how well the nitrate spectral fit is. This should usually be less than $1E-3$. If it is higher there is spectral shape (likely due to CDOM) that adversely impacts the nitrate estimate.

Pathlength: SUNA V2 comes in both a 10 mm and a 5 mm pathlength version. Because absorbance is directly proportional to pathlength, a halved pathlength provides a tolerance of approximately twice the background absorption.

4.7 Optional equipment

4.7.1 Wiper

The wiper cleans the optical window of biological growth and particulates so that the quality of the data collected stays constant. The wiper works in all modes of operation of the sensor. The wiper operates one time before each time that data is collected.

The wiper operates at 90 degrees. Make sure the wiper can operate without any blockage. Each cycle of the wiper across the optical window takes approximately 15 seconds. There is a minimum required delay of 30 seconds between wiper cycles.

Figure 5 SUNA with wiper



The wiper drive shaft has a mechanism that lets the wiper be moved manually without damage. Make sure that the wiper is not bent or pushed off of its axis of rotation.

4.7.2 Anti-fouling guard

Use the anti-fouling guard for moored deployments that do not use a pump. The guard is attached to the sensor by a plastic clamp. The foul guard is made of perforated copper that goes around the sample volume to prevent biofouling and lets the sample volume flush. Operate the sensor horizontally and point the sample volume area downward so that air bubbles and sediment do not collect.

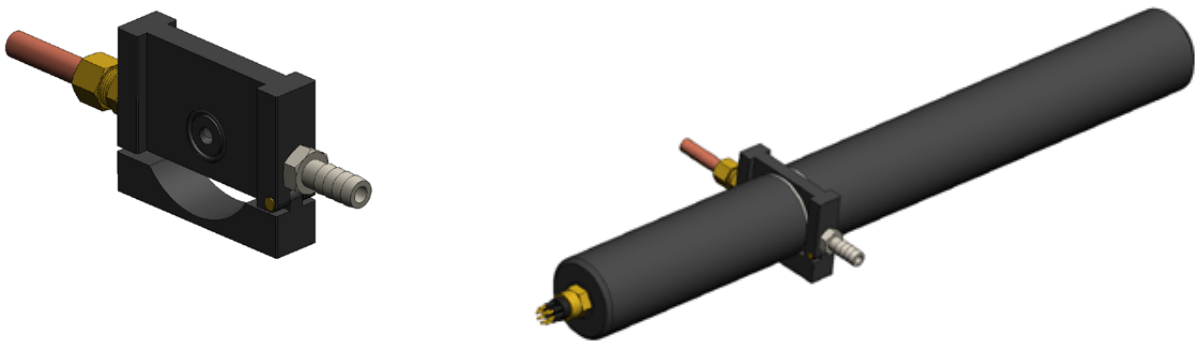
Figure 6 Copper anti-fouling guard



4.7.3 Flow cell

Use the flow cell for moored deployments that require a pump. Attach the flow cell to the sensor with the manufacturer-supplied plastic clamp. The flow cell seals against the pressure housing of the sensor so that the water from the pump flows across the optical path of the sensor. The flow cell has a copper tube on the inlet port and a plastic barbed fitting on the outlet port that connects to the pump with flexible tubing. Spare parts for the flow cell include elbow fittings so that the user can adjust the position of the sensor for deployment.

Figure 7 SUNA flow cell



Section 5 Troubleshooting

5.1 SUNA general troubleshooting

⚠ WARNING	
Nitrate sensors use an ultraviolet (UV) light. Do not look directly at a UV light when it is on. It can damage the eyes. Keep products that have UV light away from children, pets, and other living organisms. Wear polycarbonate UV-resistant safety glasses to protect the eyes when a UV light is on.	
Possible problem	Possible solution
Sensor does not appear to be on	Check that the cable is connected and the power source is on.
	Turn the sensor off for at least 60 seconds. Turn the power on again. If the sensor still does not appear to be on, use a different cable.
	Check that the voltage supplied to the sensor is between 8–15 VDC with at least 1 amp of current. Check the cable voltage: put the leads of a DMM in DC voltage mode at contacts 1 (+) and 2 (-) of the cable to see if there is voltage. If not, use a different cable.
	Check the mode of operation. The sensor may be in an unknown mode. Start a terminal program, supply power to the sensor, and type "\$" then "Enter" three or more times. A prompt from the sensor shows.
	Check the cable for continuity. Refer to the sensor specifications for connector functions.
	Check the power consumption. Use a power supply with an accurate digital current indicator. <ul style="list-style-type: none">current > 500 mA at 12V: sensor is in data collection mode. Put a piece of white paper into the optical area and make sure that there is a blue spot. If there is not, the sensor may be in an unknown mode or there is a system failure.current > 5 mA: sensor is in "standby" mode and gives a result over the RS232 input.current > 100 µA: sensor is not in operation. Contact Customer Support.

5.2 SUNA operation troubleshooting

Possible problem	Possible solution
Self-test fails for internal humidity	Monitor the sensor and do a sensor self-test at regular intervals. Make sure that the sensor is not attached to any frame so tightly that the pressure housing is out-of-round.
Self-test fails for low spectrum average or high dark counts	Clean the optical windows with a low-lint swab or tissue and isopropyl alcohol. The average value in DI water is within specifications shown below. <ul style="list-style-type: none">Dark spectrum: 500–1000 counts, with a standard deviation of no more than 12 counts.Maximum light spectrum: no more than 55000, with no more than 60-count standard deviation.Average light spectrum: approximately 10000–15000 counts, with ranges to at least 20000 counts. An average value of <10000 may mean that the optical windows are dirty or stained, or that the lamp is degraded.
Baseline "drift"	Check if the lamp is degraded. Apply drift corrections if the rate is approximately 0.004 mgN/L per hour of lamp "on" time.
Wiper does not operate correctly	<ul style="list-style-type: none">Make sure that there is a check in the box for "Integrated Wiper Enabled" in the <i>General</i> tab of the <i>Settings</i> tab of the software.Check the alignment of the wiper brushes and make sure that the wiper is not bentIf the wiper is from another manufacturer, check that the battery contacts are functional.Contact Customer Support for further help.

5.3 SUNA communication troubleshooting

Possible problem	Possible solution
Collected data is different from transmitted data	<ul style="list-style-type: none"> Check the clock settings in the sensor. Make sure that there is no extra averaging or data collection in the setup. Check the data output settings.
Problems with sensor-to-software communication	<ul style="list-style-type: none"> Make sure that the sensor-PC cable is connected correctly. Make sure the current software and firmware are installed.
Self-test fails to complete	Make sure that the sensor has an external power source; external power is necessary to turn on the lamp.

5.4 SUNA warnings and error messages

Possible problem	Possible solution
Data warnings and error messages	<p>Contact Customer Support. If possible, have the information listed below:</p> <ul style="list-style-type: none"> screenshot of the "Application Console" of the software. "messages.log" file—go to the Transfer Files window and select the <i>Log Files</i> tab. Copy the file to the PC for Customer Support.
Negative nitrate concentration	<p>Clean the optical area and check the reference spectrum. Apply a new one if necessary.</p> <ul style="list-style-type: none"> Make sure that the sensor is in water. Check that the "Deploy in Fresh Water" box has the appropriate check in it. Check for salinity compensation.
Analysis of nitrate standard shows sensor is possibly out of specification	<p>Check that the nitrate standard concentrations are accurate. Make sure the dilutions were done correctly and that the standards are used within 1 week (in the lab) or before expiration (unopened standards). Verify that the standards were made in comparable units (mg/L as nitrogen or μMoles).</p> <p>Check the sensor settings. Make sure that the "Deployed in Fresh Water" setting has a check in the box if the sensor operates in fresh water.</p>
Poor correlation with field samples (grab samples)	<p>Check the sensor for fouling or lamp change ("drift"). Clean the optical windows and do a blank check.</p> <ul style="list-style-type: none"> Set the sensor to do a self-test. Check light:dark counts, such as high CDOM or other absorbers and other data about the sensor. Check for matrix interferences that can cause measurement errors. Do measurements for a wider range of constituents and do possible lab matrix spikes to isolate the cause. <p>Check the representativeness of the data collection site. If the data from the sensor does not agree with grab samples but shows good performance, the site may not be representative of conditions, or the water is not well mixed.</p>
Data collection rate is very slow	<p>Check if the internal memory is on. Data collection starts after approximately 5 seconds.</p> <p>Check if the "adaptive integration" is on. Data collection starts after approximately 500 milliseconds ($20 \times$ "integration period").</p>
Nitrate values are not stable	<ul style="list-style-type: none"> Check that the optical area is not blocked with debris. Check that the wiper functions correctly. Clean and dry the optical area.

Possible problem	Possible solution
Nitrate value are frequently "-1" or "NAN"	Check that the lamp intensity is sufficient. Measure the spectrum in DI or tap water. Maximum output is > 10000. For best case, > 30000.
	Check the data: if the maximum is < 1000 and the lamp intensity is sufficient, the water sample is optically dense.
SELFTEST alert for lamp intensity or high humidity	Check the sensor for high internal humidity. Do a "selftest": if humidity is > 50%, the sensor may have a leak. Contact Customer Support. if humidity is > 30%, the sensor is probably ok. Contact Customer Support.

Revised editions of this user manual are on the manufacturer's website.

6.1 Warranty

This sensor is warranted against defects in materials and workmanship for one year from the date of purchase. The warranty is void if the manufacturer finds the sensor was abused or neglected beyond the normal wear and tear of deployment.

6.2 Service and support

The manufacturer recommends that sensors be sent back to the factory annually to be cleaned, calibrated, and for standard maintenance.

Refer to the website for FAQs and technical notes, or contact the manufacturer for support at:

support@sea-birdcoastal.com

Do the steps below to send a sensor back to the manufacturer.

1. Contact the manufacturer for a Return Merchandise Authorization (RMA).
Note: *The manufacturer is not responsible for damage to the sensor during return shipment.*
2. Remove all anti-fouling treatment from the sensor before sending it back to the manufacturer.
Note: *The manufacturer will not accept sensors that have been treated with anti-fouling compounds for service or repair. This includes tri-butyl tin, marine anti-fouling paint, ablative coatings, etc.*
3. Use the sensor's original ruggedized shipping case to send the sensor back to the manufacturer.
4. Write the RMA number on the outside of the shipping case and on the packing list.
5. Use 3rd-day air to ship the sensor back to the manufacturer. Do not use ground shipping.
6. The manufacturer will supply all replacement parts and labor and pay to send the sensor back to the user via 3rd-day air shipping.

6.3 Waste electrical and electronic equipment



Electrical equipment that is marked with this symbol may not be disposed of in European public disposal systems. In conformity with EU Directive 2002/96/EC, European electrical equipment users must return old or end-of-life equipment to the manufacturer for disposal at no charge to the user. To recycle, please contact the manufacturer for instructions on how to return end-of-life equipment, manufacturer-supplied electrical accessories, and auxiliary items for proper disposal.

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