LISST-AOBS

Super-Turbidity Sensor

User's Manual

Version 1.3

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FOR TECHNICAL ASSISTANCE please contact your local Distributor, or Sequoia if the instrument was purchased directly from Sequoia. Please be sure to include the instrument serial number with any correspondence.

A list of local Sequoia distributors can be found at our website
http://www.sequoiasci.com/about/contact/distributors

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Introduction

LISST-AOBS system parts

The LISST-AOBS is a system with three main parts:

1. LISST-ABS acoustic backscattering sensor
2. Turner Designs Turbidity Plus™ optical backscattering sensor
3. An intelligent Y-cable/adapter that provides SDI-12 interfacing with the two sensors.

The combination of acoustic and optical sensors provides measurements of total sed concentration that are much less affected by particle size than standard turbidity measurements (see *How Super-Turbidity Measurement Works* on page 8)
For complete technical details of the Turbidity Plus™, see the User's Manual at https://www.turnerdesigns.com/turbidity-plus-submersible-sensor.

Data interface and logging options

LISST-AOBS communicates through the SDI-12 protocol version 1.3. Any logger that supports SDI-12 can collect LISST-AOBS data.

Sequoia has teamed with NexSens Technology to integrate the LISST-AOBS with the NexSens X2 logger family. The X2 can automatically detect a LISST-AOBS and deliver its data, with data from other connected sensors, through Wi-Fi, cellular or radio channels. See more in *Operation with the NexSens X2 logger* on page 3.

If operating with a logger other than the X2 family, see *General* SDI-12 Operation on page 5.

Data outputs

LISST-ABS output is expressed in mg/liter, as calibrated with 75-90 µm microspheres. The Turbidity Plus is reported in Volts, not calibrated in terms of concentration. The AOBS output, the absolute concentration in mg/liter, is calculated by the user, as a simple weighted sum of the two other parameters as described in *Processing Logged SDI-12 Data* on page 7.

Wiring

As with any SDI-12 device, only three connections are required: power (nominally 12 V), ground, and SDI-12 data. However, for compatibility with existing LISST-ABS cabling, the LISST-AOBS uses the same 8-pin connector as a standard LISST-ABS. For details, see *Connection Details* on page 11. The user must determine how to connect the LISST-AOBS to the SDI-12 logger. Sequoia Scientific can provide cable pigtails for this purpose.

Operation with the NexSens X2 logger

About the X2 and X2-SDL

The NexSens X2 is a data logger that directly supports the LISST-AOBS, as well as many other SDI-12 sensors. The X2 is sealed in a waterproof (but not submersible) housing. The X2-SDL is functionally identical, but is submersible to a maximum depth of 60 meters.

X2 loggers can communicate their data through a Wi-Fi or cellular connection (depending on hardware configuration), for near-real-time display of data on the WQDataLive website. Raw data can also be offloaded directly to a computer through a USB port.

Sequoia Scientific and NexSens offer complete packages that include an X2 or X2-SDL, and all necessary cabling.

For detailed information, see the X2 Document and Resource Library at https://www.nexsens.com/knowledge-base-v2/data-loggers/x2, and the X2-SDL resources at https://www.nexsens.com/knowledge-base-v2/data-loggers/x2-sdl.

WQDataLIVE

WQData LIVE is a web-based platform for collecting and displaying data from Nexsens loggers. Users of X2 loggers can set up projects on this platform, free of charge. A project can have one or more X2 loggers associated with it, and those loggers can automatically deliver their data to the site through a WiFi or cellular connection (depending on their hardware). The site aggregates the data and offers customizable graphical and tabular displays of data. See https://v2.wqdatalive.com.

CONNECT software

CONNECT is a Windows application for communicating directly to the X2 logger. It is not required for routine logging, but is often helpful for setup. It also allows copying data directly from the memory of the X2. Full information about CONNECT is available at https://www.nexsens.com/knowledge-base-v2/software/connect/user-guide. The software can be can be downloaded from https://www.nexsens.com/support/downloads.

Using CONNECT requires an adapter cable, Nexsens part number UW6-USB-485P, which is supplied with most X2 systems sold by Sequoia. This cable connects to any USB port on your computer or laptop, and to the waterproof connection in the center of the X2 logger's cap.

SDI-12 Addressing

By default, the LISST-AOBS occupies SDI-12 addresses 0 and 1. If your system includes other devices, you must ensure that they have unique addresses. The LISST-AOBS addresses can be changed, but are limited by the X2 logger detection script to the range 0 to 9, and the address of the LISST-ABS must be lower than that of the Y-cable interface.

Initial setup

Please follow the latest Quick Start Guide from NexSens, available at https://www.nexsens.com/knowledge-base-v2.

If you purchased the complete X2-LISST-AOBS system as a package, the X2 logger will already be set up to with knowledge of the LISST-AOBS that is connected.

If you add sensors or otherwise change the configuration of the system, you must run the X2's process for detecting which sensors are connected. This can be initiated either with the CONNECT software, or through the X2's WiFi web interface. For instructions on running sensor detection from CONNECT, see https://www.nexsens.com/knowledge-base-v2/software/connect/user-guide/run-sensor-detection.

Parameter labels on WQDataLIVE

In a WQData LIVE project, the 3 parameters from the LISST-AOBS are, by default, labeled as follows:

1. Suspended Particle in mg/L—the direct output of the LISST-ABS.
2. Voltage—the direct output of the Turbidity Plus sensor
3. Suspended Particle in mg/L—the AOBS composite concentration, as described on page 7.

For clarity, we recommend that after setting up a project on WQDataLIVE, you change the parameter names from their defaults. To do this:

1. On your WQDataLIVE project's dashboard, pull down the Admin menu and select Settings.
2. On the Settings page, find the Parameter Settings section.
3. Under Parameter Settings, click on the name of the logger location, then on the name of the logger.
4. Now you should see a list of all the parameters measured by the logger, including the LISST-AOBS parameters. You can edit the names as you see fit. We recommend "ABS Concentration", "Turbidity" and "Total Concentration".

General SDI-12 Operation

Overview

The acoustic (LISST-ABS) and optical (Turbidity Plus) sensors in the LISST-AOBS share power and data connections, but are independent with respect to the SDI-12 data interface. They have independent SDI-12 addresses and somewhat different command sets. The commands for the Turbidity measurement are detailed below, while those for the LISST-ABS are described in its separate manual.

Addressing

When shipped from Sequoia Scientific, the LISST-ABS is normally set to address 0 (zero), and the adapter for the Turbidity Plus is set to address 1. You can change the addresses according to your own requirements, using standard SDI-12 methods. In this document, we use *a* to represent the LISST-ABS address, and *o* for the address of the optical sensor.

Sampling and averaging

The ABS and turbidity sensors in the LISST-AOBS can be sampled every 1 to 2 seconds, using the SDI-12 *M* command. However, we recommend collecting 30-second averages in most cases, to reduce the effect of natural variability due to turbulent motion of particles. 30-second averaging is executed with the C1 and C2 commands. Because “C” commands are concurrent, this allows collecting 30-second averages simultaneously from the acoustic and optical sensors.

Recommended command sequences

The following command sequence operates the wiper on the Turbidity Plus wiper before each sample:

1. *o*C1! – operate wiper, then start 30-second data average
2. *a*C1!—start concurrent 30-second average in LISST-ABS
3. *wait 40 seconds from the time of the oC1! Command*
4. *a*D0!—retrieve the LISST-ABS data
5. *o*D0!—retrieve the Turbidity Plus data

You can also operate the wiper with a separate command. This is appropriate if you do not wish to operate the wiper at every sample.

1. [*o*M1!—operate the wiper (execution takes 10 seconds)]
2. *o*C2!—start concurrent 30-second data average of turbidity
3. *a*C1!—start concurrent 30-second average in LISST-ABS
4. *wait 30 seconds*
5. *a*D0!—retrieve the LISST-ABS data
6. *o*D0!—retrieve the Turbidity Plus data

SDI-12 Command Reference

The following commands are understood by the circuit embedded in the Y-cable adapter, to control and sample data from the Turbidity Plus sensor. These are separate, and somewhat different, from the commands for the LISST-ABS sensor (for those, see the LISST-ABS User's Manual).

Command Name	Command Code	Notes
Address Query	?!	Request address (requires that no LISST-ABS be connected to the Y-cable)
Acknowledge Active	*o***!**	Request response from sensor at address *o*
Change Address	*o***A***x***!**	Change address of sensor at address *o* to *x*
Send Identification	*o*I!	Send ID string including SI address, SDI version, Manufacturers ID and sensor model
Start Measurement	*o*M! *o*M1! *o*M2! *o*M9!	Sample the turbidity voltage once Run the wiper for 10 seconds, then check the position of the wiper. If the position is correct, the next D command will return a value < 0.5. Sample the power supply voltage (reported in Volts upon next D command) Sample the temperature of the electronics (reported in C upon next D command)
Start Concurrent Measurement	*o*C1! *o*C2!	Operate the wiper for 10 seconds, then collect a 30-second average of the turbidity voltage. Collect a 30-second average (without operating the wiper).
Send Data	*o*D0!	Requests output data from the preceding M or C command.

Processing Logged SDI-12 Data

Raw data

If you are using a properly configured Nexsens X2 or X2-SDL logger (see p. 3), the logger automatically calculates the optimized total concentration value, in addition to delivering the LISST-ABS and Turbidity values.

If you are using a different logger, and follow one of the recommended SDI-12 command sequences (see p.5) , your SDI-12 logger will receive two numeric values for each sample: one from the LISST-ABS and one from the turbidity sensor.

Processing

When set up and calibrated by Sequoia, the LISST-AOBS Y-cable controller holds calibration coefficients and calculates the combined AOBS concentration estimate.

To calculate the total concentration estimate, C_{AOBS}, use the formula

$$C_{AOBS} = C_{ABS} + P^*(V_{OBS} - V_0)$$

where

C_{ABS} is the concentration reported by the LISST-ABS, in mg/l
V_{OBS} is the voltage from the turbidity sensor
V_0 is the offset voltage of the turbidity sensor in clean water
P is the pairing factor in mg/l/V

P and V_0 are ordinarily measured by Sequoia Scientific, and provided when you purchase an AOBS sensor from Sequoia. The coefficients can also be measured by customers with proper equipment and training. Contact Sequoia for details.

How Super-Turbidity Measurement Works

The LISST-AOBS combines two measurement techniques: acoustic (ultrasonic) and optical, to measure suspended sediment concentration, providing data superior to either technique alone.

Acoustic

The acoustic measurement is provided by the LISST-ABS, which measures backscattering with 8 MHz ultrasonic pulses. The LISST-ABS works best for particles with diameters from 30 to 400 µm. For more details, see the LISST-ABS User's Manual.

Optical

The optical measurement is provided by a Turner Designs Turbidity Plus™ sensor with integrated anti-fouling wiper. The Turbidity Plus's sensitivity to particles, like that of any turbidity sensor, is inversely related to the size of the individual particles. That makes turbidity a poor proxy for total particle mass, because turbidity from small particles can be the same as for a much larger mass of large particles.

Figure 1 shows the contrast between the ABS (blue curve) and turbidity (red) sensor responses versus particle size. For particles larger than about 30 µm, the ABS response is relatively flat, while the response of the turbidity (OBS) sensor is strongest for smaller sizes.

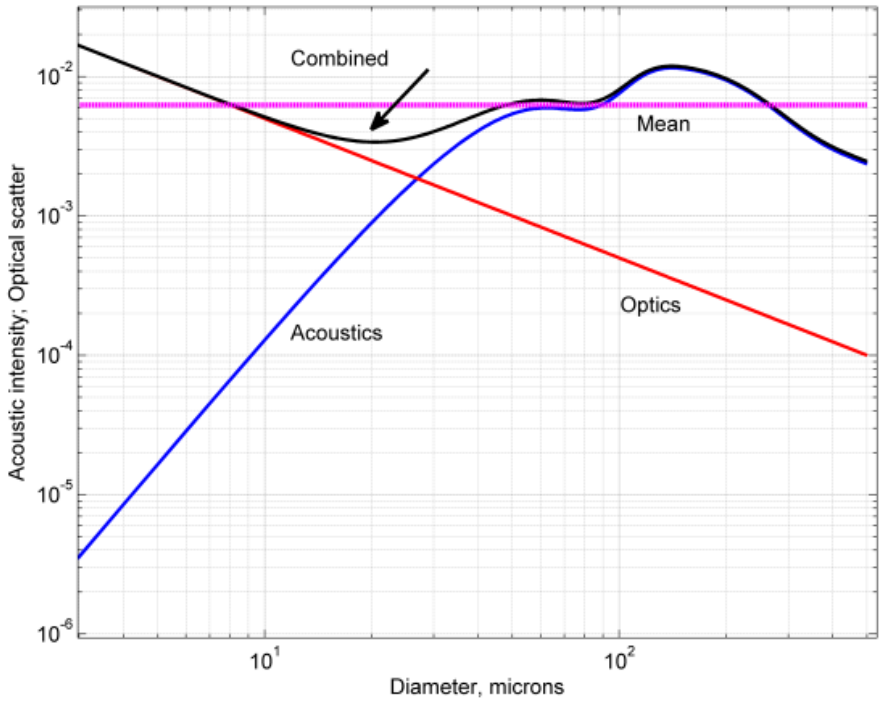


Figure 1—ABS and OBS response versus particle size

Pairing ABS with turbidity

By combining the complementary characteristics of the optical and acoustic measurements, the LISST-AOBS provides better tracking of total sediment concentration than either measurement alone. We can define a combined concentration measurement, C_{AOBS}, as follows:

$$C_{AOBS} = C_{ABS} + P * (V_{OBS} – V_0)$$

where

C_{ABS} is the concentration reported by the LISST-ABS, in mg/l
V_{OBS} is the voltage from the turbidity sensor
V_0 is the voltage from the turbidity sensor in clean water
P is the pairing factor in mg/l/V

Intuitively, we can see from Figure 1 that adding the two sensor responses will produce a curve that is “flatter” than either curve alone, but it is not obvious what value of P is optimum. From a combination of theory and experiment, we find that the optimum pairing factor is

$$P = C_{ABS}/V_{OBS}$$

when measured with particles of 30 µm diameter, and with a high enough concentration to make the clean-water offset V_0 negligible. Put another way, P should have the value that equalizes the acoustic and optical contributions to C_{AOBS} from 30 µm particles.

Measuring Pairing Factor

To determine the pairing factor P in practice, we immerse the AOBS sensors in a suspension of natural particles (Arizona Test Dust) filtered to a range of 20 to 40 µm, that is, centered on the 30 µm optimum size cited above. The outputs of the two sensors provide C_{ABS} and V_{OBS}, and the ratio of those values is the pairing factor P.

Pairing Results

Figure 2 shows the response of a properly paired AOBS sensor to a wide range of particle sizes and concentrations. While obviously imperfect (perfect data would lie on the diagonal blue line), these results are vastly superior to what could be expected from a simple turbidity measurement.

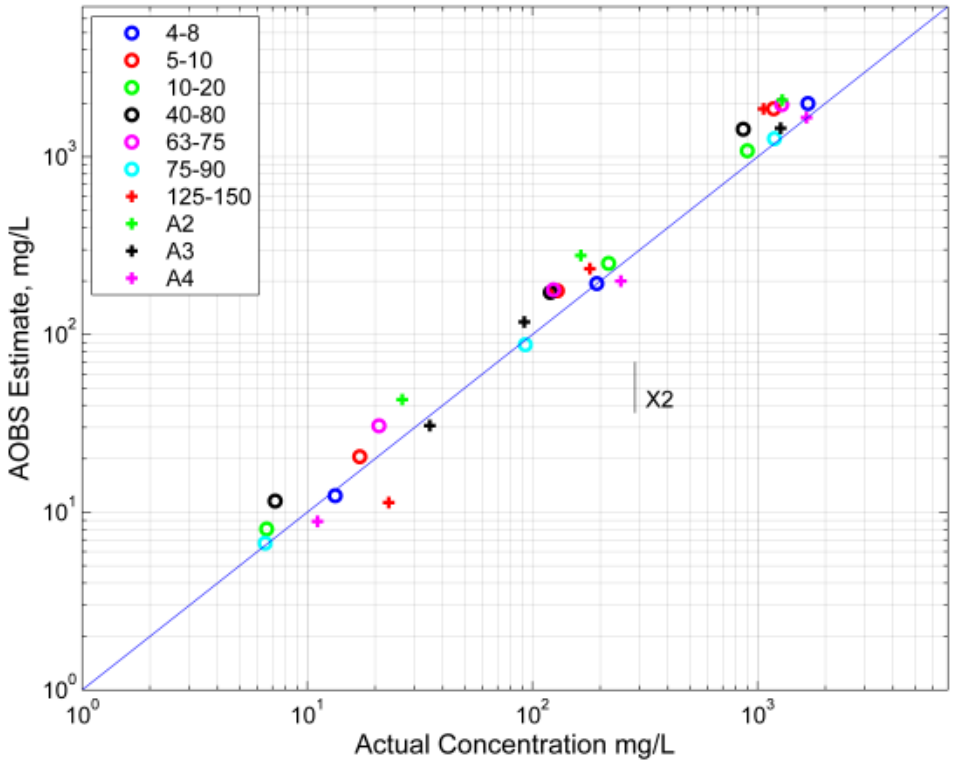


Figure 2—Response of combined AOBS sensor for various particle sizes

Connection Details

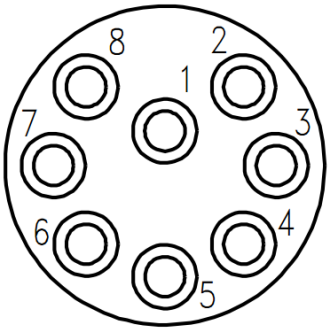
Pin functions

The endcap connector on the LISST-AOBS Y-adapter is an Impulse MCBH8-M-P, wired as shown below. Mating connector is MCIL8-F-S.

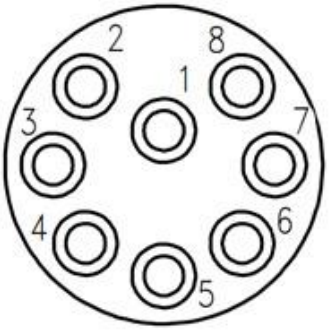
1. Common*
2. Supply voltage, 10 to 18 V
3. Common*
4. No connection
5. No connection
6. SDI-12 input/output
7. No connection
8. Common*

* Connected inside the AOBS.

Male connector numbering



Female mating connector numbering

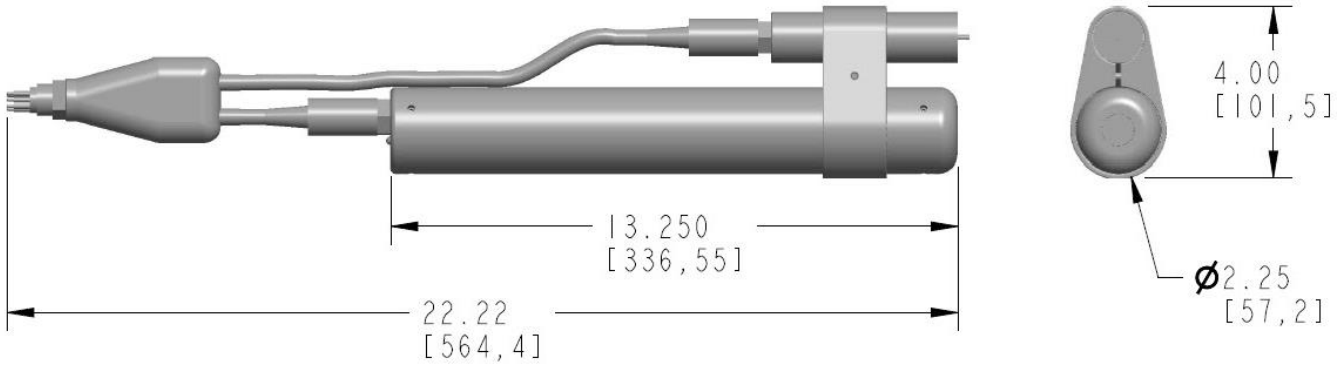


Cables

Green-jacketed cables supplied by Sequoia Scientific for the LISST-ABS are compatible with the LISST-AOBS adapter. See the LISST-ABS manual for details.

Specifications

- Power Consumption (typical, 12 V input):
  - Idle: 80 mA
  - Sampling: 120 mA
  - Sampling and wiper running: 130 mA
- Input voltage: 10 to 15 VDC (maximum limited by Turbidity Plus™)
- Maximum depth: 100 meters (limited by LISST-ABS)
- Settling time from power-on: 3 seconds
- Dimensions: see drawing below
- Concentration measurement range:
  - 1 mg/liter minimum
  - 10 g/liter maximum for particles of any size
  - 30 g/liter maximum for particles 20 µm or smaller
- Weight: 0.9 kg in air; buoyant in water
- Housing materials: Acetal and ABS plastic



Dimensions in inches [mm]

Revision history

Version 1.3	Remove incorrect warranty statement. For warranty information see www.sequoiasci.com/support/warranty
Version 1.2	General revision and formatting, add information about X2 loggers, May 2020
Version 1.1	Improved figure 1. March, 2020
Version 1.0	First released version, March 2020