LISST-AOBS

Super-Turbidity Sensor

User's Manual

Version 1.1

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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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Contents

Introduction

System parts

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

- LISST-ABS acoustic backscattering sensor
- Turner Designs Turbidity Plus™ optical sensor
- A Y-cable/adapter to provide an SDI-12 interface to the two sensors.

The combination of acoustic and optical sensors provides measurements of total sediment concentration that are much less affected by particle size than standard turbidity measurements (see *How Super-Turbidity Measurement Works* on page 5)

For complete technical details of the Turbidity Plus™, see the User's Manual at https://www.turnerdesigns.com/turbidity-plus-submersible-sensor.

SDI-12 Interface

LISST-AOBS communicates through SDI-12, and is compatible with any logger that supports SDI-12 version 1.3. This document assumes the user is familiar with SDI-12 interfacing. The LISST-ABS natively supports SDI-12 (as described in the LISST-ABS User's Manual), while the SDI-12 interface to the Turbidity Plus is provided by electronics embedded in the Y-cable (described on page 2)

Data outputs

The 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 4.

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 8. The user must determine how to connect the LISST-AOBS to the SDI-12 logger. Sequoia Scientific can provide cable pigtails for this purpose.

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 (but the two addresses must always be different). 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:

- *o*C1! – operate wiper, then start 30-second data average
- *a*C1!—start concurrent 30-second average in LISST-ABS
- [wait 40 seconds from the time of the *o*C1! Command]
- *a*D0!—retrieve the LISST-ABS data
- *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.

- [*o*M1!—operate the wiper (execution takes 10 seconds)]
- *o*C2!—start concurrent 30-second data average of turbidity
- *a*C1!—start concurrent 30-second average in LISST-ABS
- [wait 30 seconds]
- *a*D0!—retrieve the LISST-ABS data
- *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 to 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 follow one of the recommended SDI-12 command sequences, your SDI-12 logger will receive two numeric values for each sample: one from the LISST-ABS and one from the turbidity sensor.

Processing

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

$$C_{AOBS} = C_{ABS} + P*V_{OBS}$$

where

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

P is ordinarily measured by Sequoia Scientific, but can also be measured by customers with proper equipment. 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 particle size. 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, below, shows the contrast between the ABS (shown in blue) and turbidity (shown in 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.

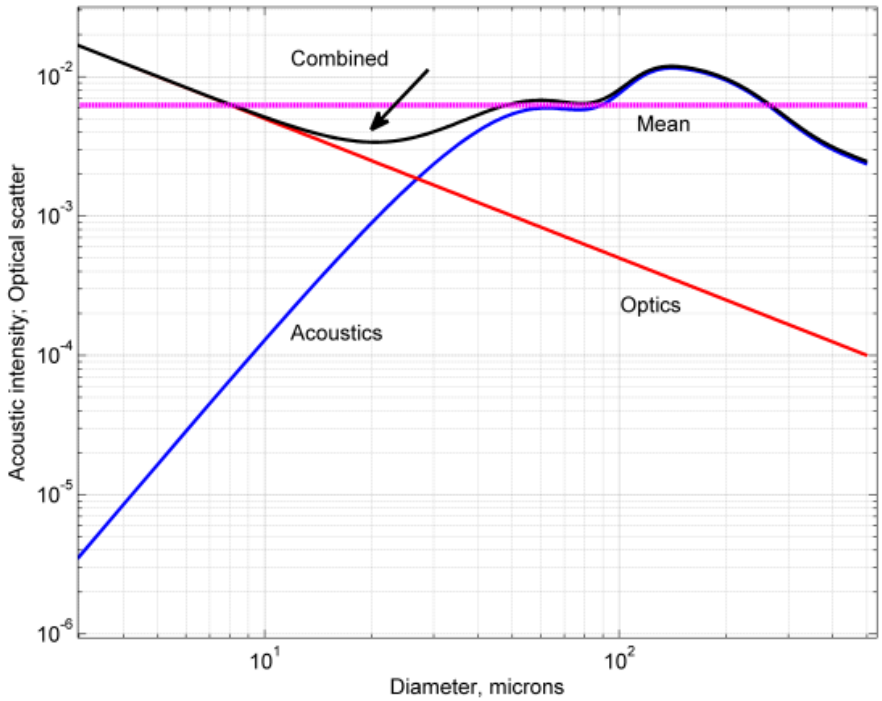


Figure 1—ABS and OBS response versus particle size

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:

$$C_{AOBS} = C_{ABS} + P*V_{OBS}$$

where
C_{ABS} is the concentration reported by the LISST-ABS, in mg/l
V_{OBS} is the voltage from the turbidity sensor
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. 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, below, 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.

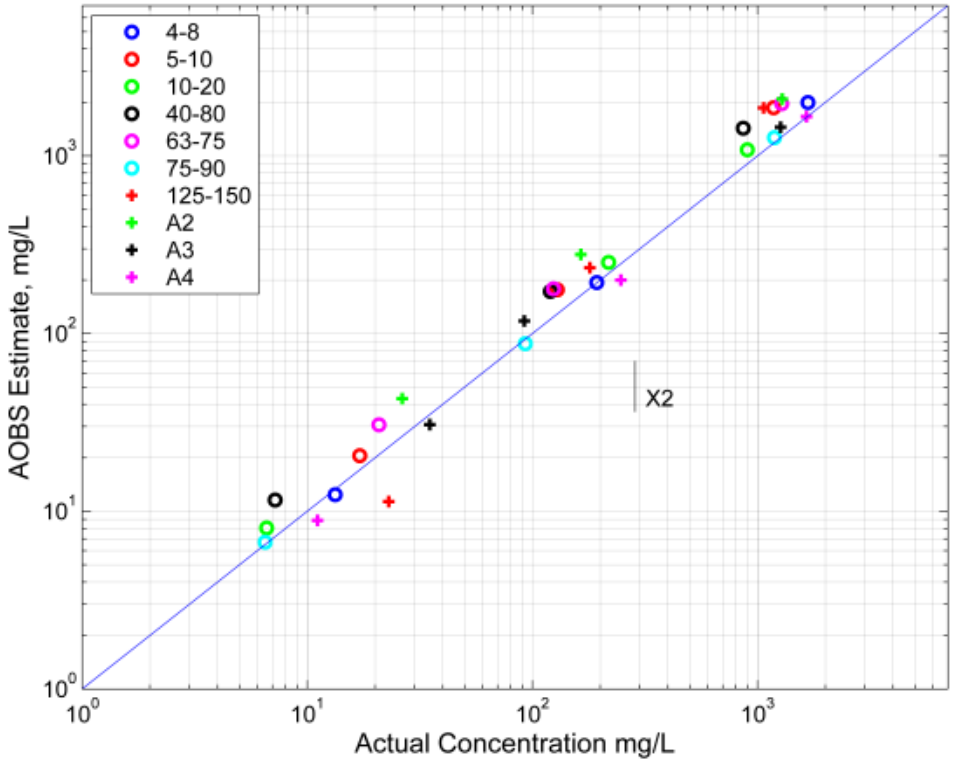


Figure 2—Response of combined AOBS sensor for various particle sizes

Connection Details

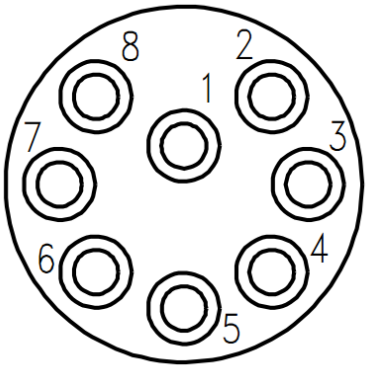
Pin functions

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.

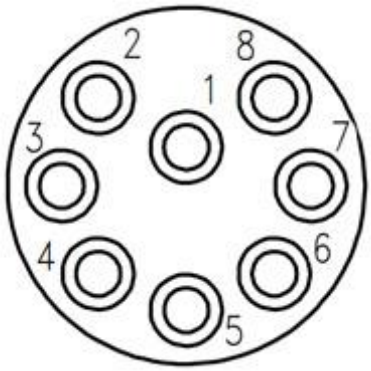
1. Common
2. Supply voltage, 10 to 18 V
3. Common
4. No connection
5. No connection
6. SDI-12 input/output
7. No connection
8. Common

The Common pins are interchangeable and connected to each other inside the adapter.

Male connector numbering



Mating connector numbering

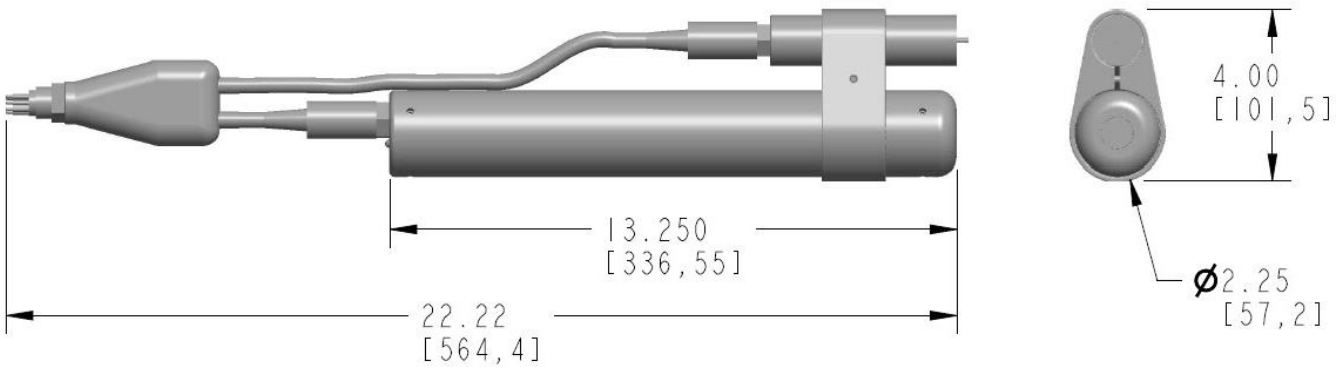


Cables

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]

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Revision history

Version 1.1 Improved figure 1. March, 2020
Version 1.0 First released version, March 2020