Xeos Ares Whitepaper: Turbidity and Chl-a Sensors

This document highlights some laboratory and field measurements made with the Ares family of water quality sensors, demonstrating their excellent performance for science and monitoring of natural water.

Ares Turbidity Moored Field Test

The Bay of Fundy, Canada, is filled and emptied of 100 billion tons of water twice each day. A portion of that water is forced through the Minas Channel in the Minas Basin, producing the world's highest tides. All of that energy keeps a lot of sediment suspended in the water, making it an interesting place to test the Xeos Ares turbidity sensor.

Masts were placed on the tidal flats at two locations along the north side of the Minas Basin: Economy and Portapique, Nova Scotia. The water levels in these areas vary by roughly 10 meters through the course of a tidal cycle. One mast is shown in the figure below. Data were collected in the summer of 2022 over the course of four weeks in July and August. Sensors were mounted at five heights from the bottom and connected to a data logger and battery pack. The sensors were oriented facing down to avoid sediment building up on the sensor faces. At three matching mast-heights, industry standard turbidity sensors were added for comparison purposes. The data logger cycled power to the Ares turbidity sensors, collecting data for 1-minute at 20-minute intervals and recorded the ASCII output from the Ares.



Figure 1: A satellite view of the Portapique estuary (left, image from Google Maps) and mast with sensors at Economy (right).

In post-processing, data for each 1-minute of sampling was averaged to compare to the industry standard sensor. In-air measurements were removed from both data sets. Data for the full deployment is shown below demonstrating the wide variation in turbidities and the excellent agreement between sensors. Upward spikes in readings from the industry standard sensor on days 17 and 23 don't follow the typical tide cycle pattern and may be due to debris in the sensor's field of view. The lower plot below zooms into a portion of the same dataset showing the complex changes in turbidities through the tide cycle.

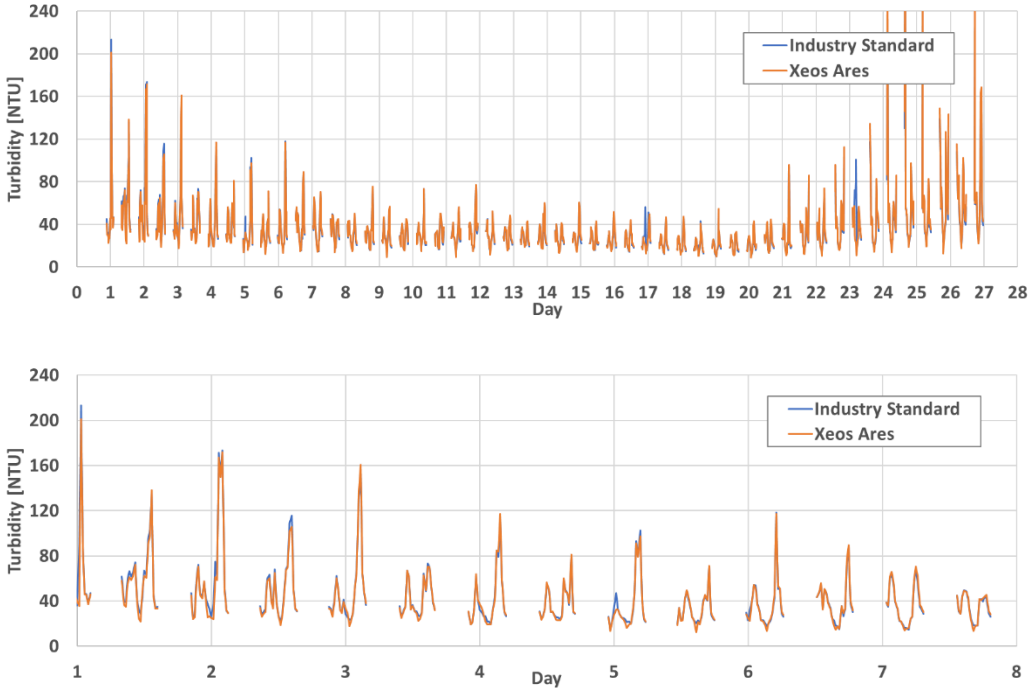


Figure 2: Comparing to an industry standard sensor over 27-days moored in a sediment-rich tidal zone (top) and detail showing the excellent agreement through the complex tide cycle.

The plot below correlates the data for the entire moored period. The agreement is very good. As mentioned earlier, there are a few points where the industry standard sensor was reading higher than expected, but that is likely due to debris in its field of view. The R^2 value is for the entire dataset, but the plot only shows NTU up to 200, as the data above that value are very sparse.

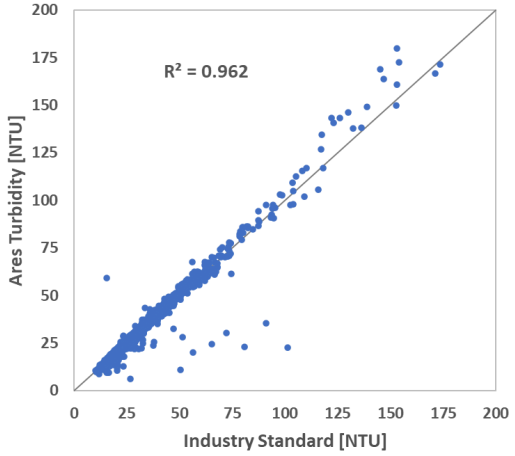


Figure 3: Correlation between NTU readings from the Ares and an industry standard sensor, using one month of field data.

Ares Turbidity Profile Field Test

A CTD profile is presented for Lime Kiln Bay, New Brunswick, a marine aquaculture site.



Figure 4: Satellite view of Lime Kiln Bay, New Brunswick (upper part of image). Image from Google Maps.

Turbidity data from the profile is shown below. The turbidity values here are much lower than the moored dataset. What appears to be noise in the Ares data is real particulate variability in this water. It is easily shown with lab tests that the inherent sensor noise is negligible. This variability may be of interest in some scenarios. Statistical analysis and smoothing can be applied to the dataset post-collection. Or, if a smoother dataset is preferred, the Ares includes a setting to output frames that are an average of ten readings. That reduces the variability at the source, eliminating the need to do the step in post-processing.

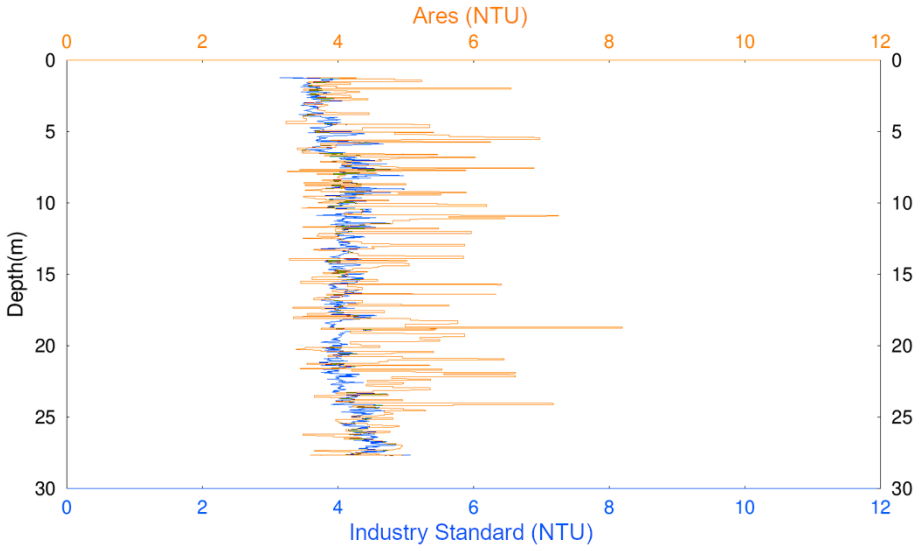


Figure 5: Example profile data for Lime Kiln Bay.

Ares Chlorophyll-a Moored Field Test

The Xeos Ares chlorophyll-a sensor was field tested in Halifax Harbour, Nova Scotia. Sensors were strapped to a mesh panel and lowered into the water alongside a wharf. The sensors were mounted in aquaMeasure modules manufactured by InnovaSea (Bedford, Nova Scotia). Those modules are widely used in the aquaculture industry to collect data over an extended area without the need for cabling. They provided battery power, configurable power cycling, and wireless acoustic data transmission from many sensors to a single receiver. The receiver was connected to the internet for real-time monitoring and plotting of data. For this test, the aquaMeasure was configured to power up the sensors briefly once every five minutes to collect a measurement. The Xeos Ares' low power consumption and fast turn-on time is ideal for this type of application. The sensors were kept in close proximity to allow for better data comparison.



Figure 6: Sensors, housed in acoustic modules, mounted on a mesh pane for system testing and comparison.

Data was collected in the fall of 2023 over five weeks from late October through November. The first week of data was the most interesting and is presented below, though the tracking of the sensors was excellent over the full five weeks. While both sensors were on a five-minute schedule, their samples were at different time slots to avoid conflicts when acoustically transmitting data.

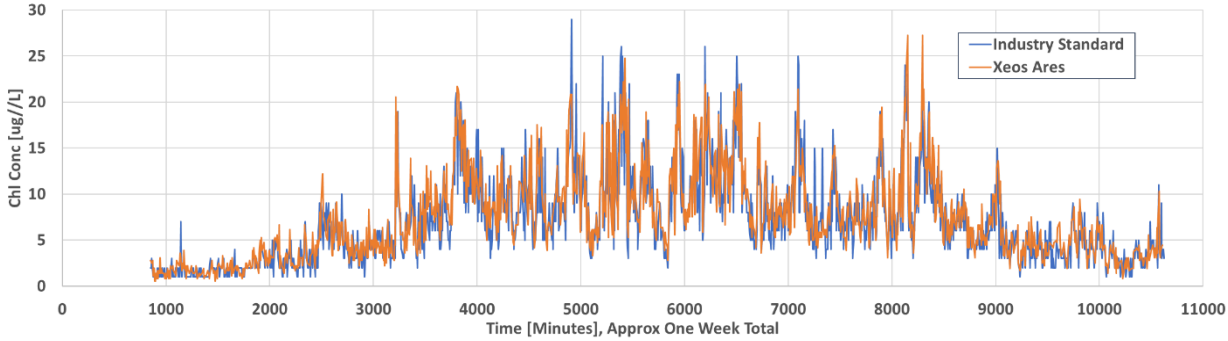


Figure 7: One week of moored chlorophyll-a concentrations, collected at 5-minute intervals, showing the excellent tracking between the Xeos Ares and an industry standard sensor.

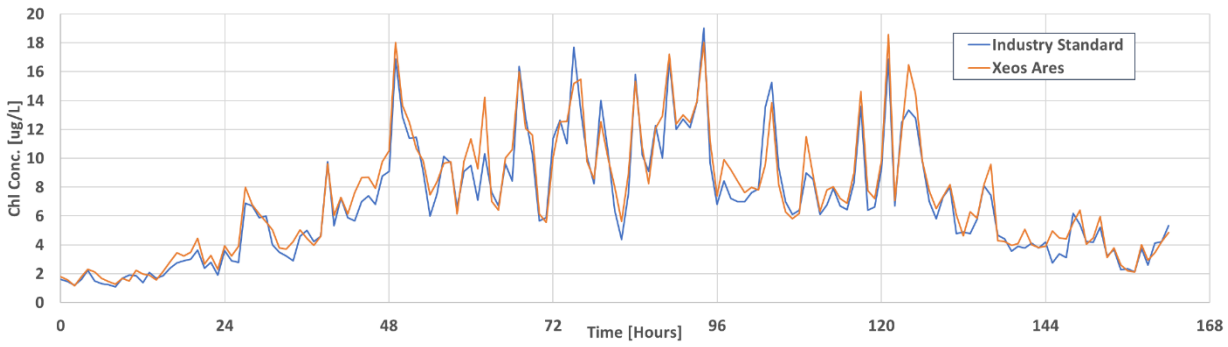


Figure 8: The same data as the previous plot, showing hourly averages.

Correlation of the data between the Xeos Ares and the industry standard is shown below, based on the hourly averages of the first week. Some variability is expected due to the small spatial separation and the different sampling time slots. Nonetheless the correlation is very good.

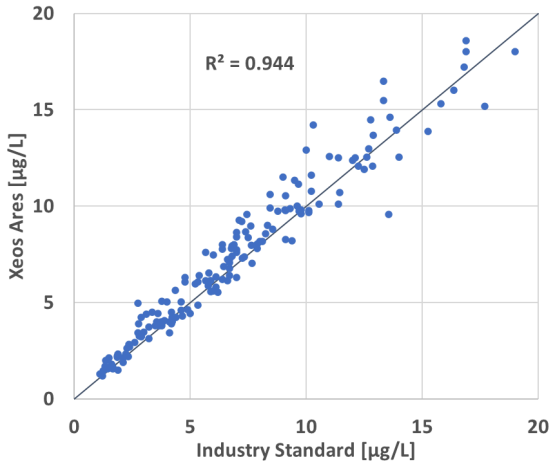


Figure 9: Correlation between µg/L readings from the Ares and an industry standard sensor, using one week of field data.

Ares Turbidity Lab Characterization

A sensor needs to be reliable, accurate, and precise. The Xeos Ares sensors have undergone rigorous characterization to ensure the data produced is of the highest quality. Some of these results are included here.

Turbidity sensor linearity was determined using a dilution series. The 'calculated' axes are relative to the maximum turbidity point, using a dilution to 70% at each step. The industry standard sensor was found to have a linearity of 99.0%, while the Ares has a linearity of 99.9%. A linear sensor simplifies the calibration process and reduces uncertainty in the turbidity measurement, given the typical linear fit used for calibration.

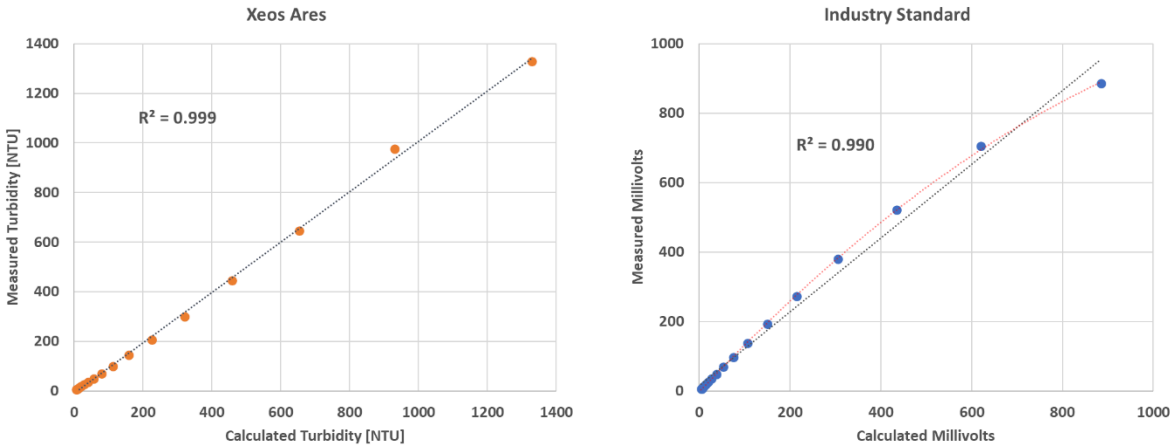


Figure 10: Linearity of the Ares turbidity sensor compared to an industry standard.

A field-deployed sensor must also be able to cope with a wide temperature range. Excitation LEDs, typically used in optical sensors, exhibit a temperature-dependent intensity, and are a significant source of uncertainty. At lower temperatures the output power of an LED increases increasing the measured signal.

In laboratory tests we characterized the Ares turbidity sensor over 0-40 °C. The industry standard sensor varied by +/- 17% over the temperature range. In contrast, the Ares varied by only +/- 4%, or 0.2% per °C.

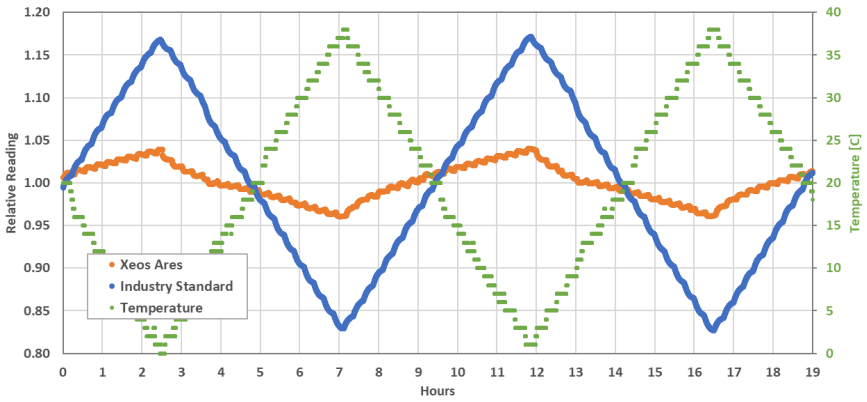


Figure 11: A temperature cycling timeline, showing the increase in signal with decreasing temperature. The Ares displays a much smaller dependency than the industry standard sensor.

Summary

The Xeos Ares family of sensors have been designed to provide high quality data for science and environmental monitoring of natural waters while being low cost and low power. They compare exceptionally well to industry standard sensors, often outperforming them. We look forward to working with you to meet your measurement requirements.