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Aanderaa Oxygen Optodes

Best Practices for Maintaining High Data Quality

This document gives recommendations on field adjustments of oxygen optodes.

Done correctly a one or two-point adjustment of an optode will give it almost the same accuracy as when it was factory calibrated. By following these procedures end-users should be able to maintain high accuracy and documented data quality themselves.

Below two different methods are suggested.

Adjustment of saturation calibration in air-bubbled water: The example given is from the Swedish Aquanet project in which about 100 Aquaoptode (model 4531) were used at five field stations for five months in targeted mesocosm studies.

Aanderaa optodes are stable and normally becomes better over time. Do not change foils unless mechanically damaged. During the initial months of storage/use a Foil maturation process occurs resulting in lower readings by several %. The maximum observed maturation induced drift on more than 1000 sensor has been 8 % for sensors with non-factory pre-matured WTW foils (model: 4835, 4531 and 5730 Steinsvik) and 6 % for sensors with factory pre-matured PSt3 foils (model: 4330, 4831, 5331 hadal). During/between field deployments there are possibilities for end users to post-adjust the sensors either by a one-point air-saturation adjustment or by taking reference samples (e.g. water samples and Winkler titration) and/or using a well-calibrated sensor in parallel. If done correctly such an adjustment should result in an absolute accuracy of around 1 % for multipoint calibrated sensors (model: 4330, 4831, 5331 and 5730) and 3 % for two-point calibrated (model: 4835, 4531), see below for more information about factory calibrations. The drift will decrease over time so that during the second year it is not likely to be more than 1-2 %. After this it should be less than 0.5 % per year, unless the foil is mechanically damaged.

Saturation adjustment: After the first year of Aquanet experiments, 16 optodes from one of the sites were immersed into an open tank filled with air-bubbled freshwater and left there to record for several days (Fig. 1). It is important that the aquarium pump takes in air from an open atmosphere outside, not from inside the room/laboratory where O_2 levels will be affected by the on-going activities and/or the ventilation. To verify that optodes are in saturated water you can take them up from the water and hold them just above the surface for a few minutes. There should then be no change in the saturation readings.

Fig. 1: Sixteen (16) optodes immersed into air-bubbled freshwater for post-deployment calibration check.

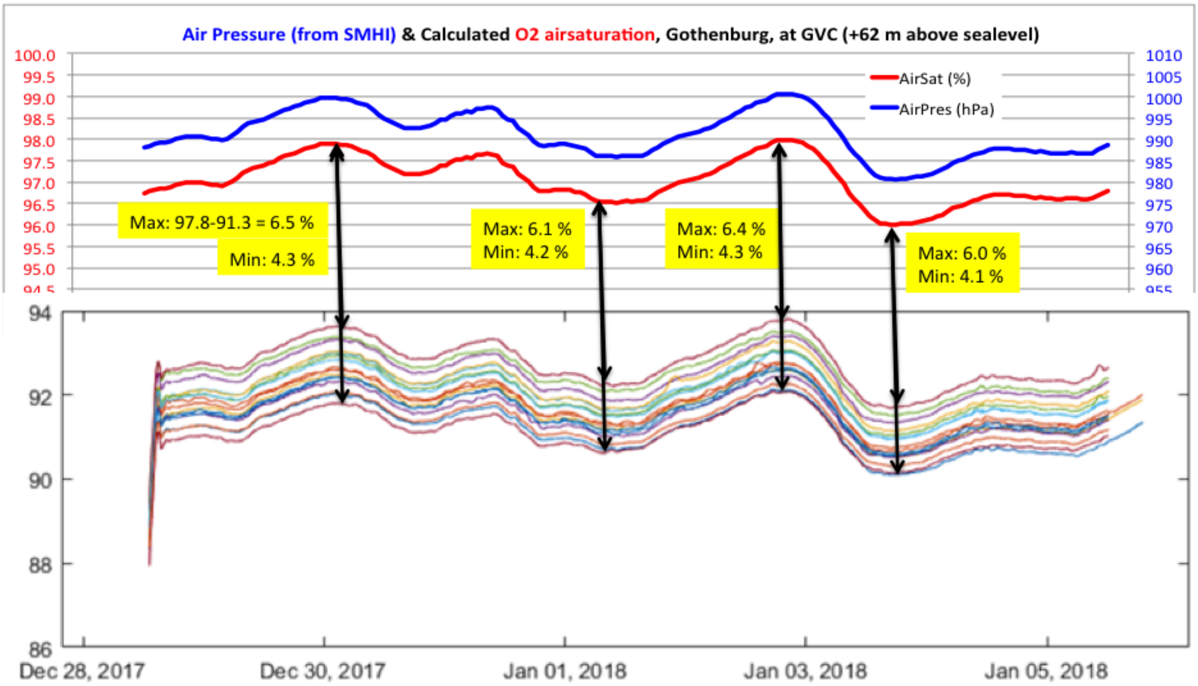

Fig. 2: Saturation readings from 16 optodes in air-bubbled freshwater (lower panel) and variations in local air-pressure (blue curve) and the calculated related air saturation levels compensated for the height above sea level (red curve) during an 8-day period. It should be noted that there is a 0.1-0.5 % difference when air-pressure changes from low-to-high compared to when it changes from high-to-low. The reason for this is an adaptation delay in the water mass in the tank. The smaller and better stirred/bubbled the water volume around the sensors is, the faster the water will reach equilibrium when air-pressure and/or temperature change(s).

The 16 optodes read between 4.1-6.5 % low and should be individually compensated by multiplying the readings by a factor of 1.041 for the sensor that reads the highest and 1.065 for the sensor that reads the lowest.

Adjustment of saturation calibration in air: The method suggested above gives high quality one-point adjustments but can be time consuming. A simpler field method, inspired by in-air calibrations on Argo floats and gliders (Bittig & Körtzinger, 2014; Johnson *et al.*, 2015; Nicholson & Feen, 2017; Bittig *et al.*, 2018) could be used during measurement campaigns but could render lower quality if the optode foil is not wet or the temperature at the foil is different from the one at the temperature sensor.

Simply let the optode(s) log outside in free air for several hours before and after the deployments and note the average air-pressure.

Preferably the recordings should be done during the night when air is normally moister and temperature is lower and more stable.

At sea level at standard air pressure (101.3 kPa = 1 Atm = 14.69 psi) the sensors should show 100 % if wet and 102 % if completely dry and at an air pressure of 100 kPa it should show (1.3/101.3)*100 = 1.3 % lower.

The example below is from a SeaGuard instrument (measuring currents, mooring movements, particles, O_2, temp, salinity and depth) that is in continuous deployment in the Mediterranean Sea (E2-M3A observatory) at 1250 m depth. The instrument was logged in air before and after every deployment (Fig. 3). It was found that the oxygen optode was showing 9 % too low but that it did not drift over the 4-year deployment period that is reported on here. Also, pressure data from the deep water rated pressure sensor indicated that there was no drift since it was tracking with air-pressure in-between deployments.

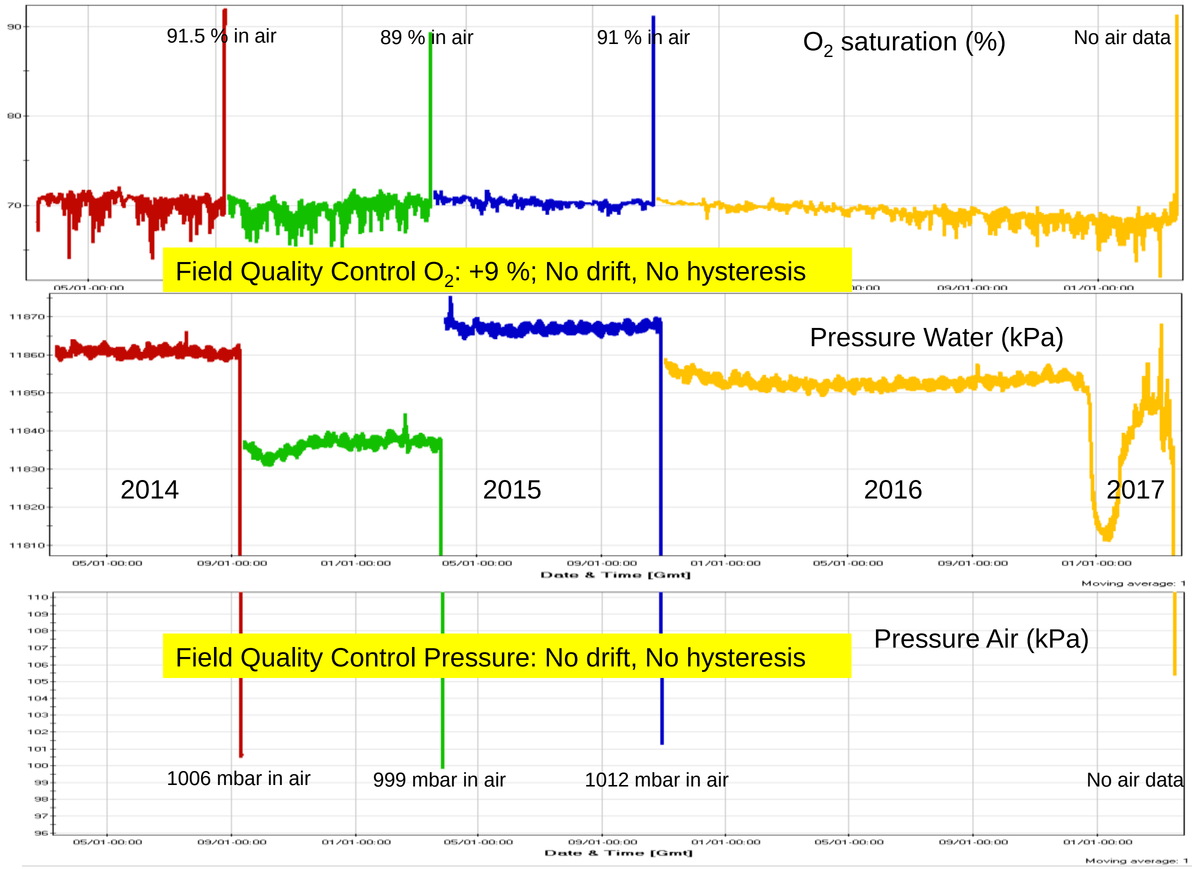

Fig. 3: Simple field quality control letting the instrument log in air. The example shows quality control of the pressure sensor and the oxygen optode mounted on the SeaGuard.

Adjustment of zero (0) readings: To maintain high accuracy when using sensor in low oxygen environments also the zero calibration can be checked but normally its drift is minimal.

The sensor then has to be immersed into an environment with zero oxygen until the readings stabilize at low, close to 0 %. Please observe that plastic sensors and containers will take longer to reach low levels because plastics absorb or dissolve oxygen that can contaminate the surroundings. Methods that can be used include that the sensors could be put into a plastic bag filled with e.g. N_2 gas or immersed into zero oxygen water where oxygen was removed chemically (e.g. sodium sulphite, Na_2SO_3), biologically (put yeast and sugar in body warm water and all O_2 will be consumed). Also boiling or bubbling water with e.g. N_2 gas will create low O_2 water but it is difficult to be sure that its O_2 concentration is absolutely zero.

If a 0 % O_2 check is done this compensation could also be added/subtracted. If the sensor reads e.g. +0.2 µM in N_2gas/anoxic water -0.2 µM should be subtracted from the data. To facilitate calculations we have made an Excel sheet that also gives the text strings to be transferred to the sensor in case a terminal emulator software program is used (see instructions below).

Correcting sensor readings: There are two ways to correct the readings: **A. Externally**: By applying the correction factor(s) as a post-compensation or in real time by the software that logs and presents the incoming data. **B. Internally**: By serially (RS232) connecting the sensors to a PC and change the factor internally. This factor can be changed by using the dedicated Aanderaa software (RT collector) or by sending commands from a terminal emulator software program (e.g. Tera Term, HyperTerminal). Instructions for how to do both are given below in appendix 1 and 2.

Recommendations: It is recommended to do an air saturation quality check of oxygen optodes before and after long deployments.

Please keep records of how sensors mature over time. It will help detect when a sensor starts to behave abnormally.

Sensors should be cleaned before storage and stored with black caps on including some tap water, or with a piece of wet cotton taped against the foil. If sensors are stored dry the foil will dry out which could lead to 1-2 % lower readings. The sensor then needs to be placed in water to hydrate at least 24 h prior to starting filed measurements again. The storage temperature is not important.

Antifouling: Biological fouling is a major impediment for long-term monitoring in shallow water. For antifouling protection of e.g. Aanderaa sensors different solutions have been successfully applied including:

1. Zebratech wipers have been protecting Aanderaa Turbidity, O_2, and pCO_2 sensors/optodes (Fig. 4). With a SeaGuard/SeaGuardII/SmartGuard one of the analog channels can be used to activate a wiper or UV leds. The "warm-up time for the sensor" is used to turn on the wiper/UV for a desired time period. You should set it up with a delay so that it is not wiping/shining sensors when the measurements are done.
2. Copper tape (e.g. 3M 1181) or Copper/Nickel (last much longer) are easy antifouling solution (Fig. 4). When applying the tape please be careful so that there is no contact between the tape and other metal parts. Then the tape will loose its antifouling properties.
3. UV leds in combination with copper tape (Fig. 4) have turned out to be efficient for long (year) deployments on costal observatories. The downside of UV LEDs is that they consume relatively high amounts of power. Please contact Aanderaa to get more detailed recommendations.
4. Electro-chlorination has been successfully applied to Aanderaa and other manufacturers sensors in multiple applications conducted by IFREMER.
5. Ongoing trials: Aanderaa is continuously searching for and testing new combinations of antifouling methods. The focus is on non-toxic methods like fiber/hair cloth and “shark skin” film.

Please contact us to obtain more detailed recommendations and information.

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Figure 4, Left: Wiper protecting of a pCO_2 optode against fouling, wiping is activated by one of the four SeaGuard analog ports. Middle left: multi-parameter instrument with copper tape on some parts after 2 months in an area with high biofouling. The copper tape last for about 1 year and nothing grows on it. Middle right: Close-up of the Turbidity and O_2 optode both measured correctly for 1 and 2 months respectively. Right: Conductivity and O_2 optode on SeaGuard were successfully bio fouling protected by UV-LED's during the active season.

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Aanderaa optode models and their calibrations

Common features: Very well characterized (+150 scientific papers). Extreme stability. High quality temperature sensor. Red reference LED. Stern-Volmer Uchida formulas. Output calibrated values in µM, % saturation and raw data. Dynamic Range: 0-300 % (higher range at request). Calibration range: 0-120 % (higher range at request, special calibrations have been provided for 0-500 %). Response time (63 % in water) standard foil t_{63}<25 s and fast foil t_{63}< 8 s (only for model 4330, 4831 and 5331). Resolution/Precision better than 0.1 µM.

Fig. 4: Aanderaa offers five optode models: ***A****. 5730: 40-point calibrated, WTW foils*, flush mounted, aquaculture cameras, serial output. For OEM sales, restriction apply, please contact us.* ***B****. 4531: 2-point calibrated, WTW foils*, 100 m rated, various connector options, shallow water/aquaculture, serial+analog (V/mA, 2 channels) output.* ***C****. 4835: 2-point calibrated, WTW foils*, 300 m rated, coastal, serial+AiCaP** output.* ***D****. 4330: 40-point calibrated, pre-matured PreSens foils***, 3000/6000/12 000 m rated, high accuracy/deep water, serial+AiCaP*** ***E****. 4831: 40-point calibrated, pre-matured PreSens foils***, 3000/6000/12 000 m rated, high accuracy/deep water/3d party platforms, 8-pin SubCon connector, serial+analog (V/mA) output.*

* WTW FDO 701: WTW is a Xylem company that offers high quality instrumentation for laboratory and wastewater application. Their O_2 optode foils are stable and exceptionally robust against the mechanical wear that often occurs in shallow water application.

** AiCaP: AiCaP: is a modified CAN bus based master-slave communication protocol standard available on most of Aanderaa's smart sensors. AiCaP makes plug-and-play connection, to as many (+40) sensors, possible when connected to an Aanderaa logger or Hub directly and remotely using a single seven wire cable. This is practical in all multi-parameter applications e.g. strings, buoys, ferry boxes, autonomous platforms.

****PreSens PSt3* foils: used on our high accuracy/deep water optodes. These foils are stable and very well characterized for oceanographic use in more than 20 scientific papers (see Bittig et al., 2018 for a recent summary). Used on Aanderaa optodes in thousands of applications since 2002. To minimize initial drift the foils are pre-matured before doing the 40-point calibration, which today is standard for 4330 and 4831. A fast responding version is available (t_{63}< 8 s). The fast foils were upgraded from July 8, 2018 (model 4330 s/n 2994) and April 5, 2018 (model 4831, s/n 737) with foils that has the same low noise level as the standard foils and it is less sensitive to direct incoming sunlight (compared to the previous version fast foils).

It should be emphasized that the foils used on Aanderaa oxygen optodes become more stable over time. The longest operating optodes were delivered in 2002 and most of these still use the original foils. Therefore **foils should <u>not</u> be changed unless they are mechanically damaged. By following the recommendations in this Best Practice document it is possible for end users to keep sensors operational for many years at a high level of accuracy without the necessity for overhaul and calibration by Aanderaa.**

Two-point calibrations: The two-point calibrations (Accuracy ±5% or ±8 µM) are based on a common characterization of a production batch (normally 100) of sensing foils with an additional two-point adjustment for every optode. The two-point calibrated sensors, 4531 and 4835 (see above) are calibrated at 10°C for 100% saturation, and at room temperature (22°C) for the 0% point. For referencing at 100 % saturation three (3) 40-point calibrated optodes (absolute accuracy better than ± 1 %) are used. The calibration of these is back traceable to regular checks in one of our multipoint calibrations tanks, which are regularly verified by water samples analyzed by Winkler titration.

Multipoint calibrations: For application demanding higher accuracy (±1.0 % or ±2 µM) an individual multipoint calibration was optional for the 5730, 4330, 4831 and 5331 optodes from 2012. Since January 1, 2018 it is automatically included without extra cost for all deep-water 4330, 4831 and 5331 models that use PreSens foils. The foil pre-maturation process is standard before calibration. This process removes the initial drift in new foils and brings them to a state where the drift is typically 0.025% per 100,000 measurements.

Fig 5 Left: One of three multipoint calibration systems in operation at Aanderaa. Middle: Detail of multiple sensors inside the temperature regulated bath. Right: Regular control of the 3 reference optodes is done with Winkler titration using an automatic titration system from SI Analytics (a Xylem company).

After pre-maturation the optodes are placed in one of the specially designed automatically controlled temperature-regulated baths where the oxygen saturation is changed by diffusing different mixtures of O_2 and N_2 into the water. The gas mixture is controlled by use of high accuracy Mass Flow Controllers. The water is stirred vigorously to provide homogeneity and oxygen concentration is measured by three reference optodes that are fully calibrated (40 points) by water sampling and Winkler titration one time per year. For continuous control water samples are also taken every month and analyzed by Winkler titration.

Aanderaa has participated, with good results, in an international inter-comparison in which the performance of different leading oxygen calibration laboratories (in Australia, France, Germany, USA, Japan and Norway) were evaluated. These laboratories are mainly focusing on high accuracy calibrations of oxygen optodes for Argo floats and gliders. If of interest please contact us for more information about this work.

Based on the calibration data seven coefficients (c0 to c6) in the modified Stern-Volmer formula derived by Uchida et al, 2008 [17] are calculated:

$$[O_2] = \frac{\left(\frac{P_0}{P_c} - 1\right)}{K_{SV}}$$

and:

$$K_{SV} = c_0 + c_1 t + \ c_1 t^2$$

$$P_0 = c_3 + c_4 t$$

$$P_c = c_5 + c_6 P_r$$

where t is temperature (°C) and P_r is the raw phase shift reading (TCPhase)

After the calibration sequence the performance of all sensors are verified in 20 points covering the complete calibration range. For an example see Fig. 6, below.

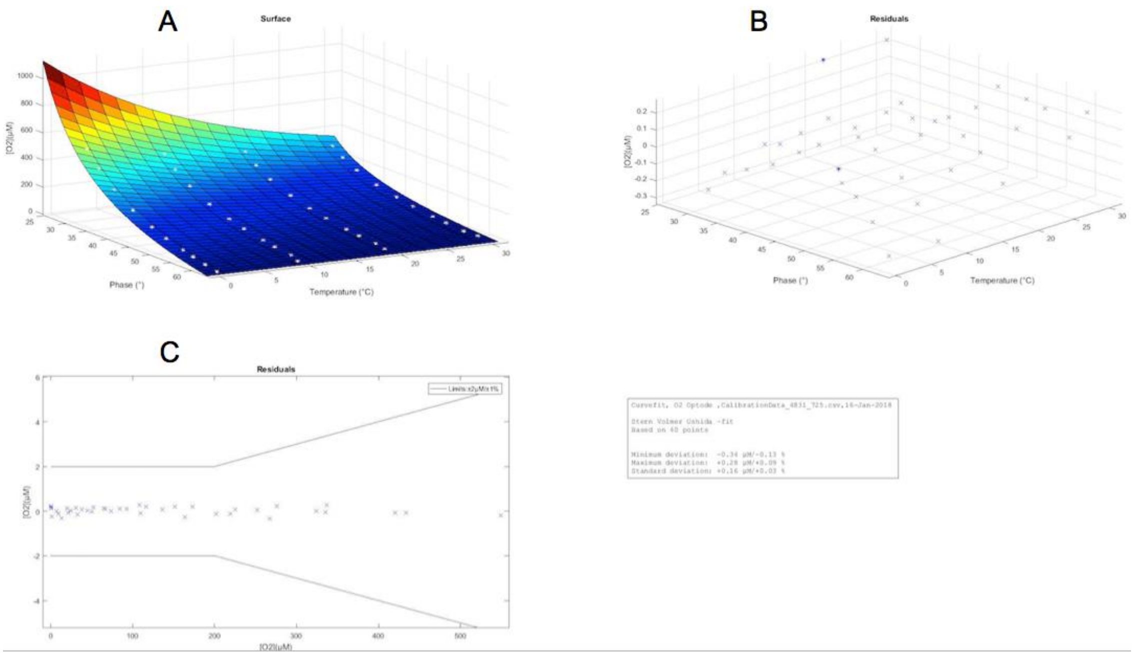

Fig. 6: A: Targeted calibration points for a standard 40-point calibration. Please note that optodes are more sensitive at lower concentrations. B: 3D plot of residuals during the 40-point calibration. C: Residuals at the 20-point check that is done directly after the calibration. A full calibration with check is automatic and takes 48 h.

Our experience from delivering thousands of optodes over more than 15 years is that optical oxygen sensors are non-linear both in response to oxygen and to temperature. In addition their sensing foils, optics and electronics can differ. It is therefore our strong opinion that individual multipoint calibrations are necessary to achieve the highest accuracy through the lifetime of the sensor. In Bittig et al (2018) similar recommendations are also given: *Depending on the kind of optode calibration, handling and usage scenario, accuracy of O_2 measurements can vary considerably (from 1 hPa to more than 20 hPa, see Fig. 11,* in Bittigs paper*, for PSt3 foil optodes). To achieve highest accuracy, each sensor requires an individual multi-point calibration in T-and O_2-space at least once during its lifetime. Foil batch calibrations fail to achieve such high accuracy.*

Be Aware of How Different Manufacturers Give Specifications:

Different manufacturers specify the performance of their sensors differently. It is worth taking this into account when comparing sensor specifications.

When Aanderaa states an absolute accuracy of e.g. (±1 % or ±2 µM), we mean the accuracy of the sensor in the field over the entire range of oxygen concentrations and temperatures. Another manufacturer might mean the laboratory accuracy just after calibration or in some cases how well the sensor returns to the exact same point as it was calibrated in right after it was calibrated. If specified in this way, our accuracy would be approximately ±0.5 %.

When Aanderaa states a 63 % response time of 25 s for the non-transparent foil and 8 s for the faster responding transparent foil, we mean the response time in water at 20°C. Other manufacturers give the response time of their sensors in air. If we were to specify in this way our 63 % response time would be approximately 6 s for the non-transparent foils and 3 s for transparent foils.

Our philosophy is to give specifications, which reflects the field performance of our sensors. We are convinced that this way of specifying is more valuable for the end user.

Scientific papers using Aanderaa optodes

(Only first authors listed, full references in list, updated July 2018.)

Commercially available oxygen optodes for oceanographic application were introduced by Aanderaa in 2002. The proven long-term stability (years) and reliability of these sensors have revolutionized oxygen measurements and several thousand are in use in applications ranging from streams (Birkel 2013) and buried in the river bed (Malcolm 2006,2009,2010, Vieweg 2013) to the deepest trenches (12 000 m) on earth, from aquaculture (Thomas, 2017) to wastewater, from polar ice (Mowlem 2013, Bagshaw 2016) to earthquake areas (Oguri 2016). This document gives examples of published scientific investigations in which Aanderaa optodes have played a central role.
The basic technique and an evaluation of its functioning in aquatic environments were presented in Tengberg (2006), Bittig (2014,2015A,2018). Other studies include use on autonomous floats Joos (2003), Körtzinger (2004,2005,2008), Kihm (2010), Koelling (2017), Johnson (2009,2010,2015), Alkire (2012), Bittig (2015B,2017), Bushinsky (2016), Fiedler (2013), Takeshita (2013), D'Asaro (2013), Nikolov (2015), Plant (2016), Wolf (2018), Sarma (2018) on gliders (Nicholoson 2008,2017, Karstensen 2015, Pizarro 2016, DeYoung 2018, Queste 2018) on Autonomous Underwater Vehicles (Clark 2013), animal-borne (Baileul 2015), autonomous sail buoy (Ghani 2014), long-term monitoring in coastal environments with high bio-fouling (Martini 2007), on crab pots (Shearman 2012), on coastal buoys (Jannasch 2008, Johnson 2010, Bushinsky 2013), on Ferry box systems (Hydes 2008,2009, Hartman 2014), on cabled CTD instruments for profiling down to 6000 m including suggestions for improved calibrations, pressure effect and compensation for slow response (Uchida 2008) and in chemical sensor networks (Johnson et al 2007). In the Hypox project multiple optodes were used on multiple platforms to study Hypoxia (Friedrich 2013). Lo Bue (2011) pointed at potential artifacts in oxygen readings in environments with low currents. It has been found that the lower readings are caused by oxygen consumption occurring when metals are corroding (e.g. one sacrificial Zn anode with a weight of 130 g can consume all oxygen in 700 l of water). In Bittig et al. (2012) a seagoing multipoint Winkler free optode calibration system is described and used. McNeil (2014) suggested calibration methods based on physical properties of the sensing foil. Drazen (2005) presented a novel technique to measure respiration rates of deep sea fish and Sommer (2008) described an automatic system to regulate oxygen levels and to measure sediment-water fluxes during in-situ sediment incubation at vent sites. Wikner (2013) measured respiration rates of oligotrophic waters and pointed out potential artifacts from oxygen dissolved in plastic incubators and Rabouille (2009) benthic O_2 consumption. Also Pakhomova (2007), Almroth (2009,2012), Viktorsson (2013), Cathalot (2012), Caprais (2010), Noffke (2016), Niemisto (2018), Sommer (2009,2016,2017) used the same type of optodes on autonomous landers to perform sediment-water incubations on natural and fish farm affected sediments and with and without the introduction of sediment resuspension. In Wesslander (2011) the dynamics and coupling of carbon dioxide (CO_2) and oxygen weres investigated in coastal Baltic Sea waters and McGillis (2011) described a novel method to assess the productivity of coral reefs using boundary layer and enclosure methods. Champenois (2012) studied variations in community metabolism rates of a Posidonia oceanica seagrass meadow by continuous measurements of oxygen at three different levels during three years. Viktorsson (2012) used yearlong oxygen measurements at several Gulf of Finland locations to calibrate a 3D model for prediction of bottom water oxygen dynamics and the subsequent coupling of low oxygen conditions to release of sediment bound phosphorous. In Atamanchuk (2014,2015A,2015B) and Peeters (2016) pCO_2 optodes were described and used in parallel with O_2 optodes to study biogeochemical processes in fjords, lakes and at Carbon Capture and Storage. Glud (2016) studied nutrient turn-over and mineralization in a Scottish loch and Hamme (2015) O_2 and N_2 dynamics in the Saanich inlet.

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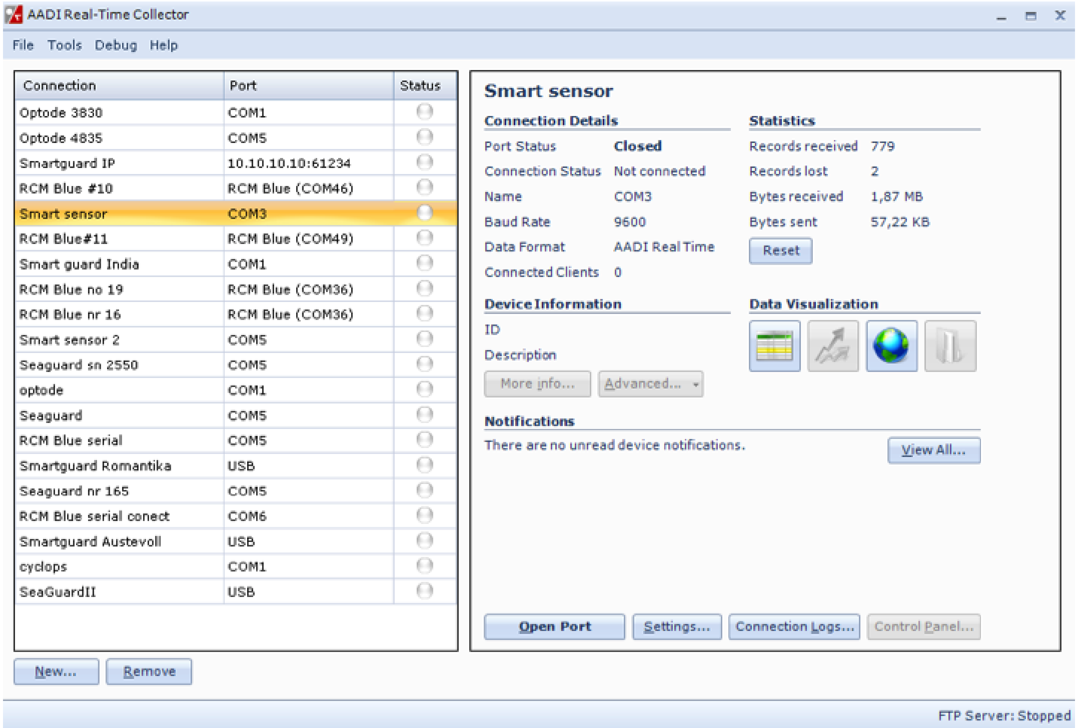
Testimonials of Aanderaa optode stability: Aanderaa oxygen optodes have been used in numerous scientific studies published in peer-reviewed journals (see appendix 1 below for full references). Some of these studies focused on details in the performance of the Aanderaa optodes (see references and citations above):

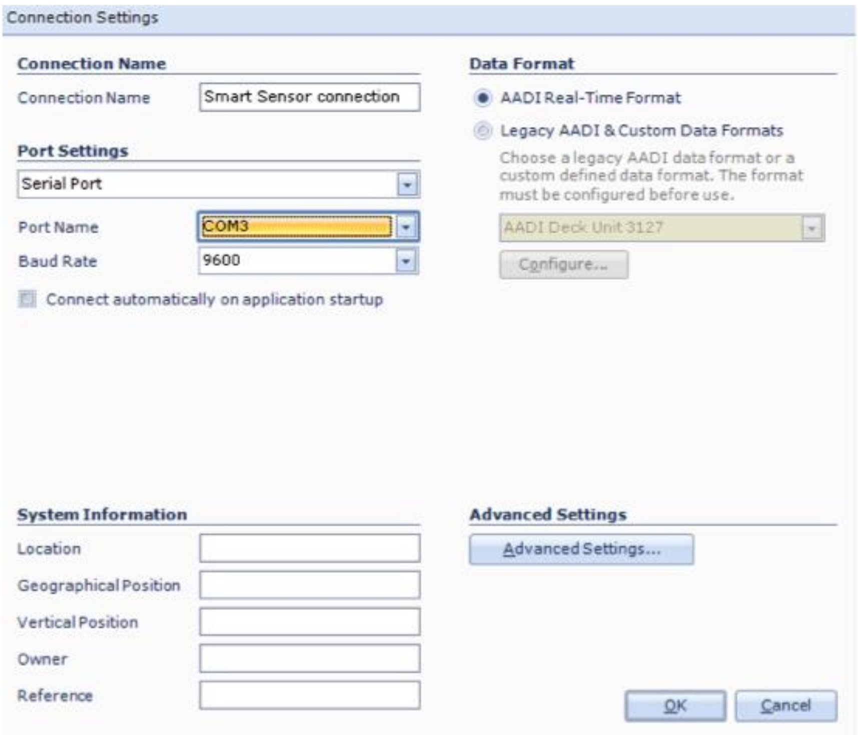
- **Joos et al (2003)**: *"Initial field tests have shown exceptional sensitivity and excellent stability (A. Körtzinger and D.W. R.Wallace, University of Kiel,unpublished data, 2002). The new technology seems well suited to deployment on long-term in-situ moorings, profiling floats, and other autonomous platforms."*
- **Körtzinger et al (2004):** *"The initial results from the first six months of operation are presented. Data are compared with a small hydrographic oxygen survey of the deployment site. They are further examined for measurement quality, including precision, accuracy, and drift aspects. The first 28 profiles obtained are of high quality and show no detectable sensor drift."*
- **Nicholoson et al. (2008):** *"The optode sensor showed no sign of drift when compared to Winkler measurements over the nine months of deployment. Seaglider 021, equipped with the same optode sensor, was stable from its initial February deployment through the end of its second deployment in November, without requiring any recalibration between deployments (data not shown). The optode on glider 020 showed similar stability over its shorter deployment."*
- **Jannasch et al. (2008):** "*Oxygen optode (Aanderaa, 3930). Similar to nitrate, oxygen concentrations within estuaries can vary widely (0 to 400 µM O2). We have found the optode to be resistant to fouling as previously suggested (Tengberg et al. 2006) and to be extremely stable. Sensors were calibrated prior to deployment using the factory-suggested, two-point calibration. There was no noticeable drift in instrument accuracy before and after deployment".*
- **Hydes et al. (2009):** *"The optodes maintained good stability with no evidence of instrumental drift during the course of a year. Over the observed concentration range (230–330 mMm^{-3}) the optode data were approximately 2% low in both years. By fitting the optode data to the Winkler data the median difference between the optode and Winkler measurements is reduced to less than 1 mMm^{-3} (0.3%) in both years."* Comment: Measurements were done every 30 s. Sensors were operated one year at a time, which equals more than 1 Million samples.
- **Johnson et al. (2010)**: *"The oxygen sensor shows no evidence of drift, but it seems to have a small accuracy bias (≤10 µmol/l), as reported for earlier applications of Aanderaa Optode sensors on profiling floats and gliders."* The deployment period was more than 600 days.
- **Champenois and Borges (2012)** *"The comparison of O_2 measured by optodes and by Winkler titration allowed us to determine the accuracy of O_2 measurements by optodes, which was better than ±2.0 mmol kg^{-1}. The accuracy was not significantly different among the three O_2 optodes and remained stable during the study period. The precision of O_2 measurements by the O_2 optodes was better than ±0.1 mmol kg^{-1}, based upon the standard deviation on the mean of 30 measurements during 30 s, which is the standard configuration of measurements used."* Comment: The deployment period was more than 1100 days. Sensors were logged hourly which equals approximately 26,000 samples.
- **Johnson et al. (2015)**: *"Aanderaa optode sensors for dissolved oxygen show remarkable stability when deployed on profiling floats, but these sensors suffer from poor calibration because of an apparent drift during storage (storage drift).* Comment: In this paper results from 47 floats were presented and methods for in air calibration on Argo floats suggested.

Appendix 1: Enter a foil adjustment into the sensor using Real-Time Collector

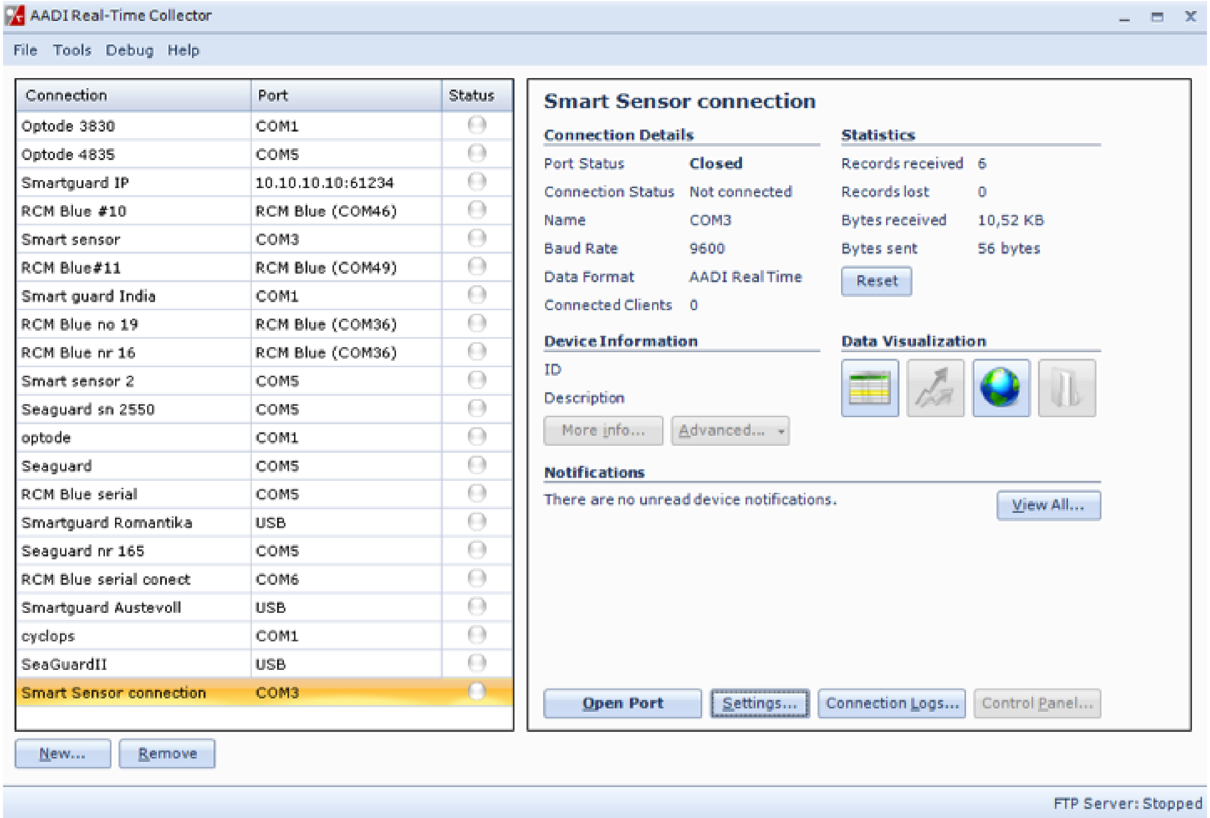
Serially connect sensor to computer and power (one USB connector on the 3855 cable is to give power, 5-14 V, to the sensor) and start Real-Time Collector. Please observe that the quality of USB to Serial convertors is variable. Some work well and some are unreliable/do not work at all. From investigations we have found that KEYSPAN convertors work reliably on different computers with different operating systems.



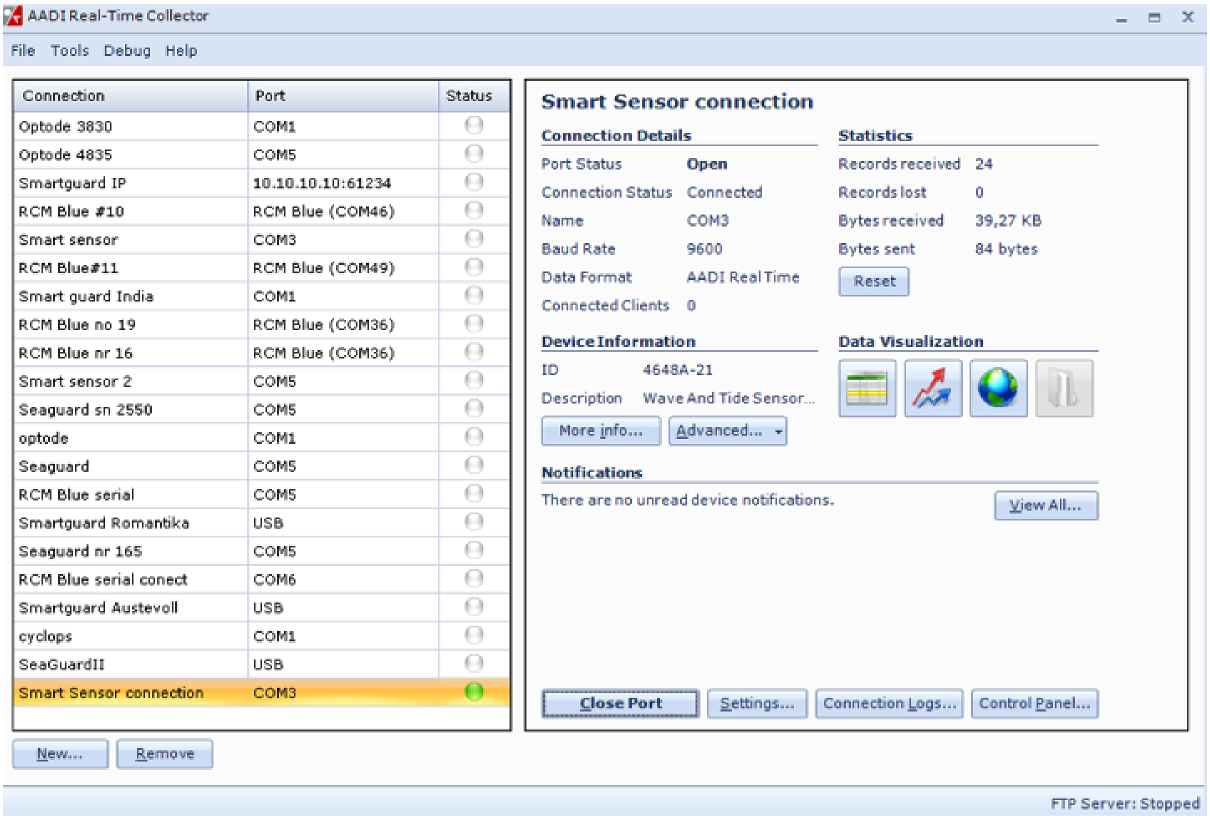
If you have no Aanderaa Smart Sensor connection established since before: press "New" in the lower left corner.



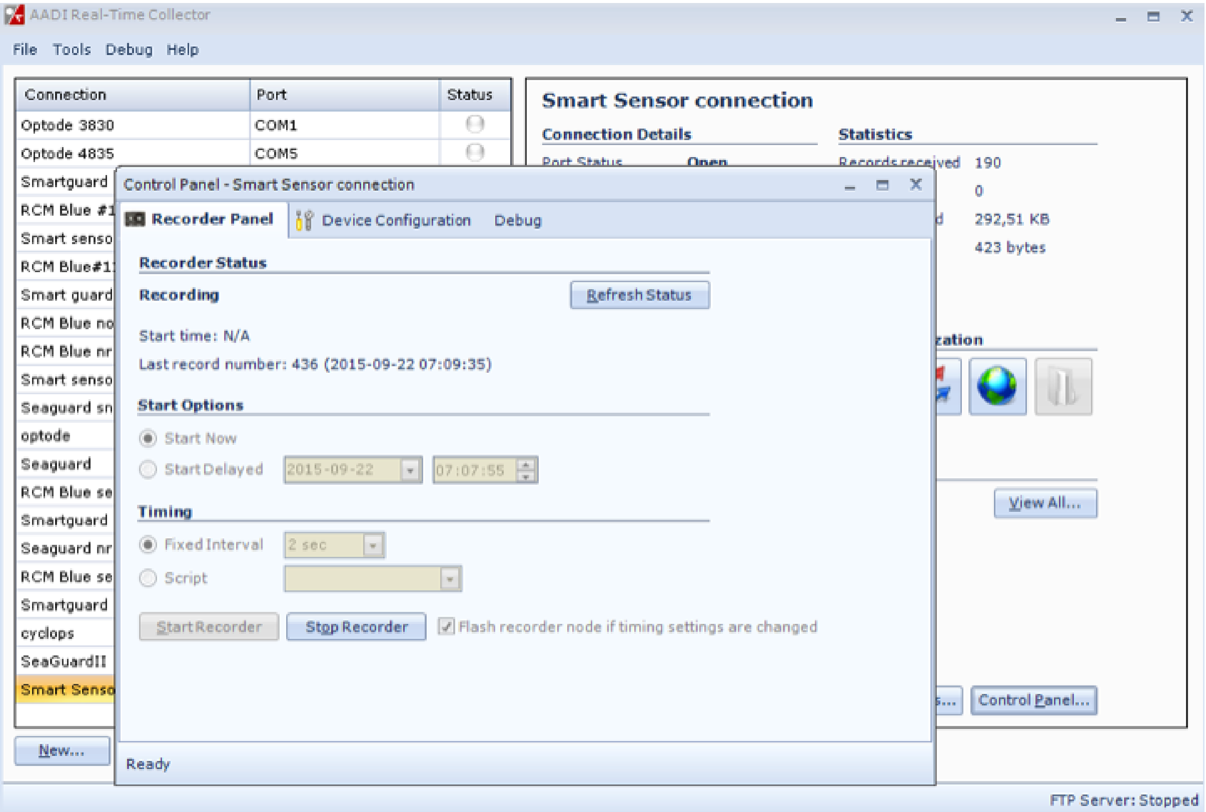
On "Port Settings" select "Serial Port" from drop down menu. Select the correct baud rate (default is 9600 when sensor is delivered) and the correct COM port (see Port mapping in Windows). Name the connection and use AADI Real-Time Format. Then click "OK".



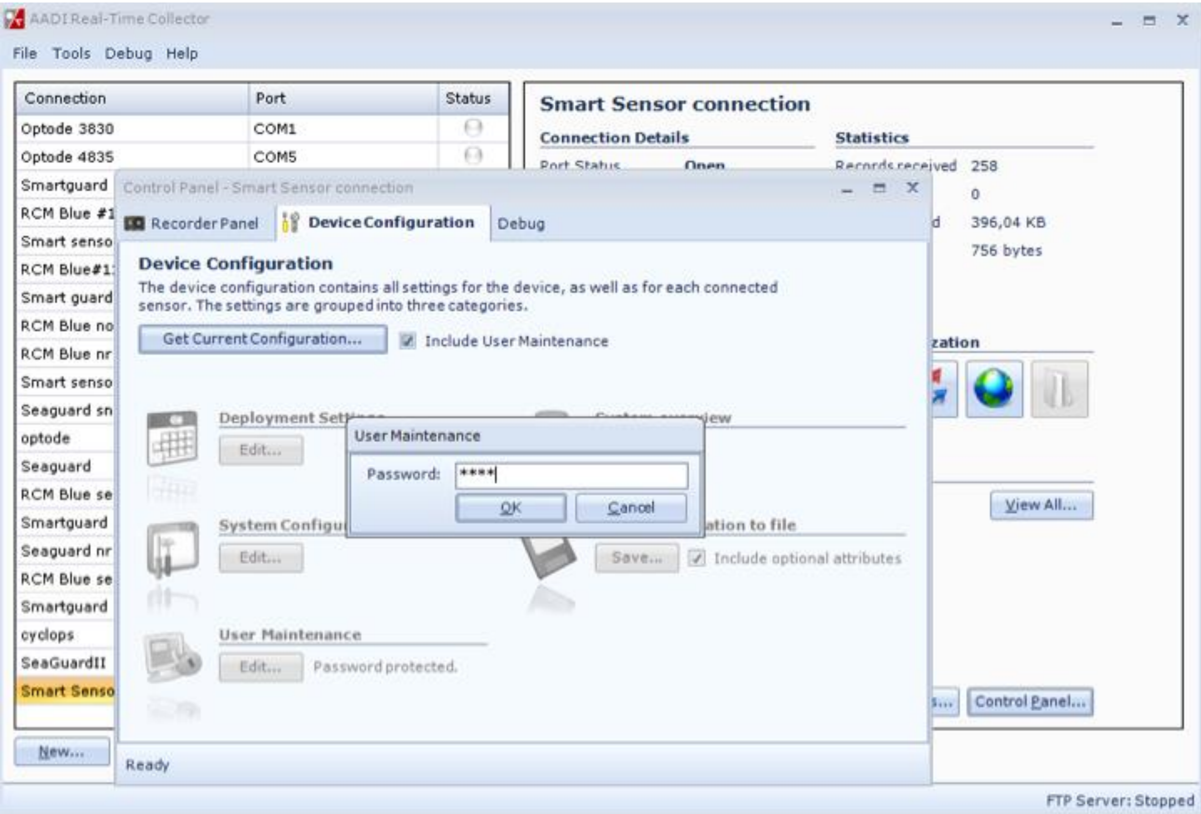
Connect any Aanderaa Smart Sensor (Pres/Wave/Tide/Temp, Doppler Current/Temp, Doppler Current Profiling/ Temp, O2/Temp, pCO2/Temp, Cond/Sal/Temp, Temp, Motus) to COM port and Power and press "Open Port"



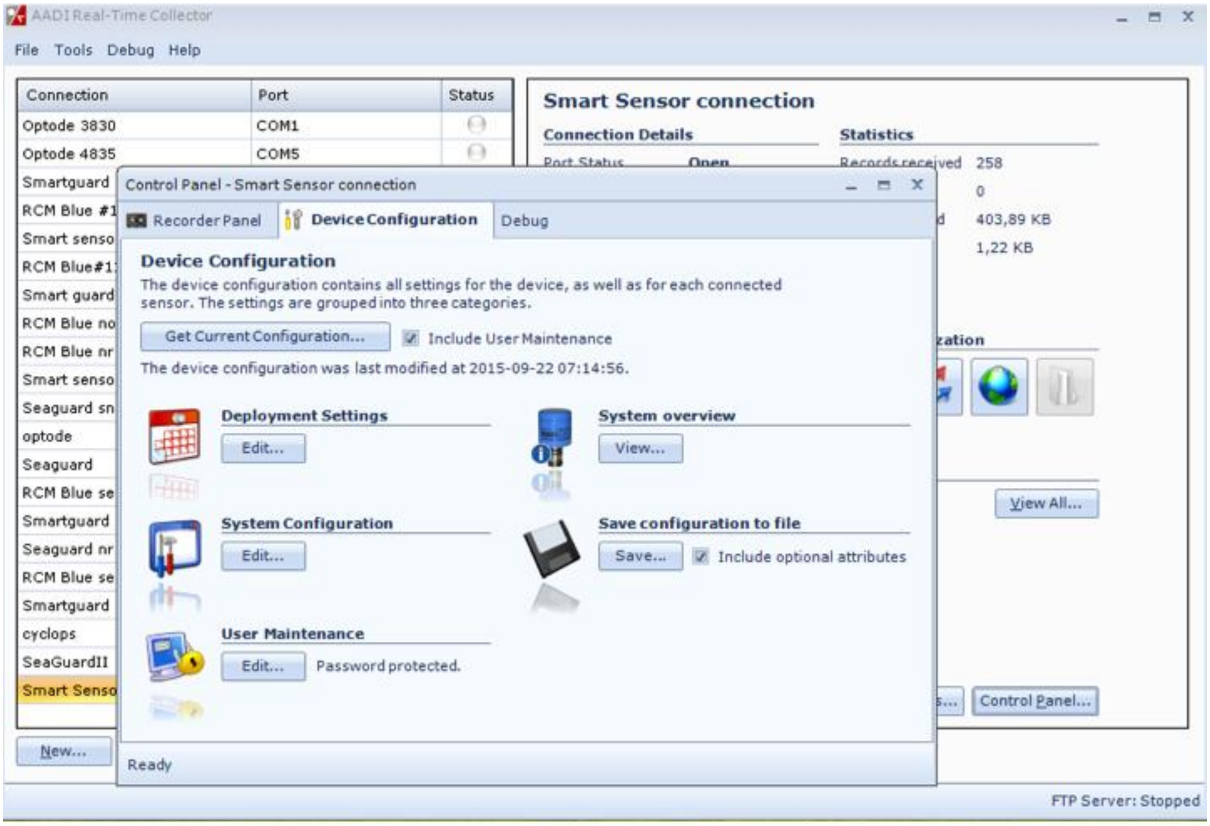
Established connection gives green light and shows which sensor is connected (many sensors and instruments can be connected simultaneously, see list for some examples, we have connected, collected data and presented results in real-time from +70 sensors). Click "Control Panel" to enter the settings.



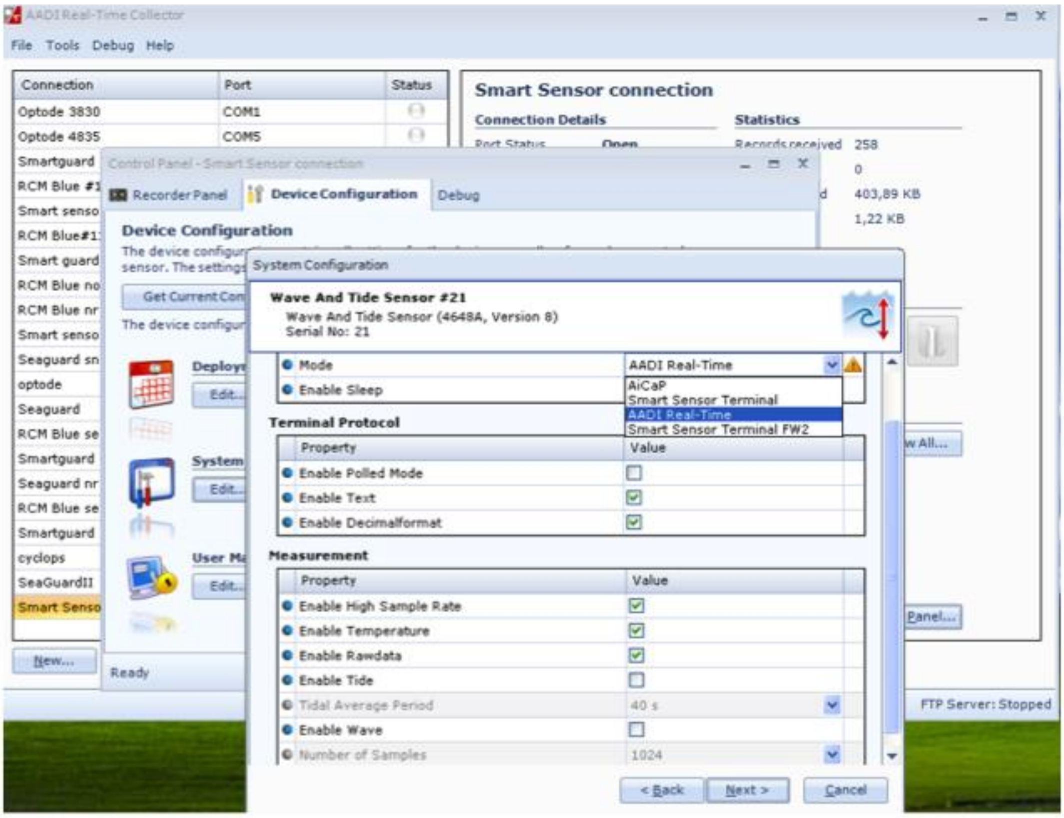
If sensor is running click "Stop Recorder" and then "Device Configuration" in selection at top of opened window.



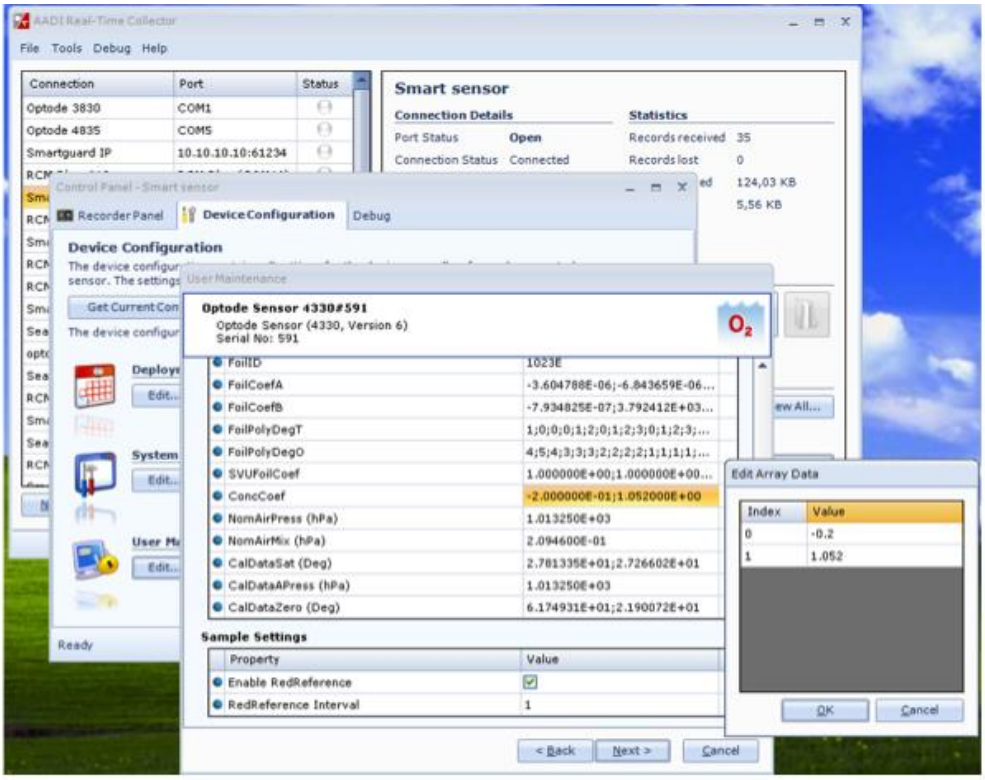
If access to all settings is of interest tick "User Maintenance" click "Get Current Configuration" and fill out Password which is 1000 for all sensors. Then click "Ok".



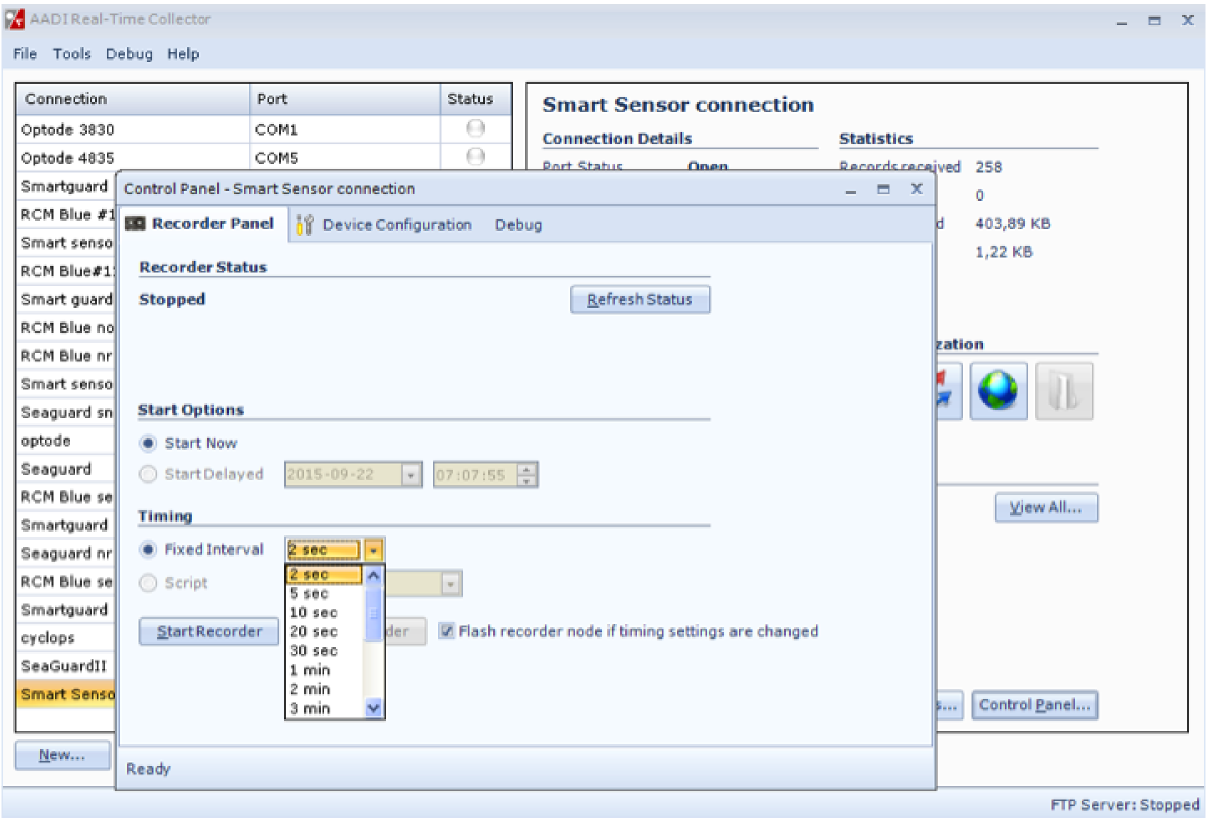
To access most common settings click "System Configuration" (normally enough). For more advanced settings click "User Maintenance" (caution in changing things here).



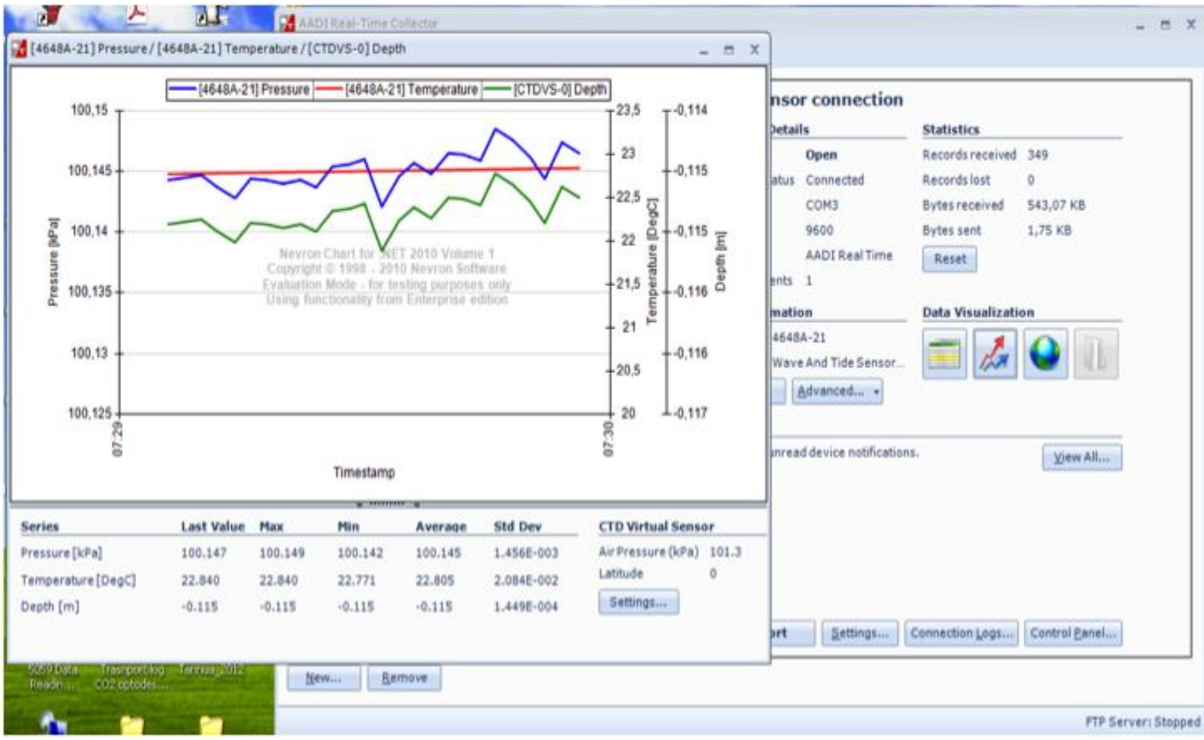
Access to needed deployment settings in "System Configuration" (normally enough). AADI Real-Time (xml) to be used with RT-Collector, Smart Sensor Terminal (ASCII) with standard terminal program. AiCaP is a CAN bus based protocol which is used for plug-and-play connection to Aanderaa instruments (e.g. SeaGuard, SmartGuard)



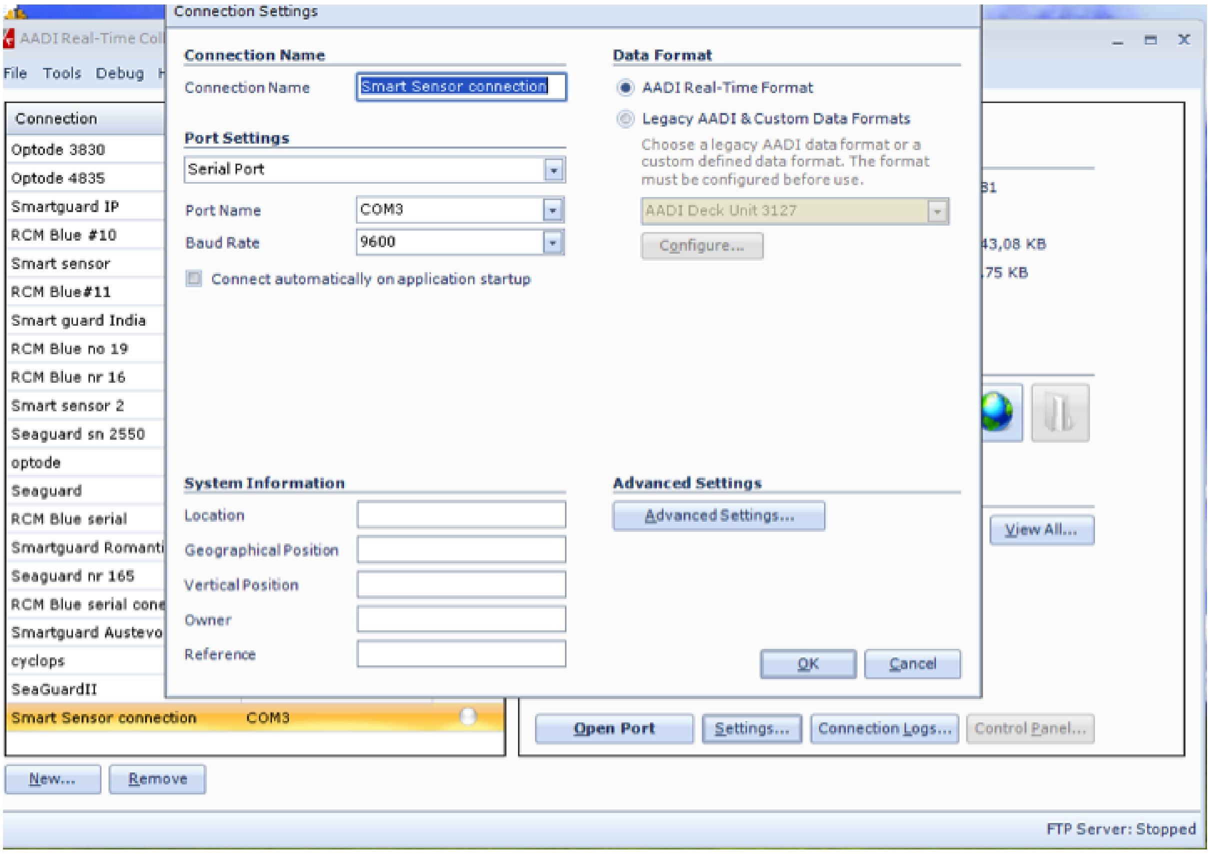
In some cases user maintenance is useful, consult manual before changing settings. The example shows a drift adjustment of a two-point calibrated oxygen optode that read 5.2 % to low at 100 % air saturation (air-bubbled water, 1013 hPa air-pressure) and 0.2 uM to high at 0 oxygen. The ConcCoef is adjusted (double click to edit) so that 0.2 uM is subtracted from incoming values and then they are multiplied with 1.052 (+5.2 %).



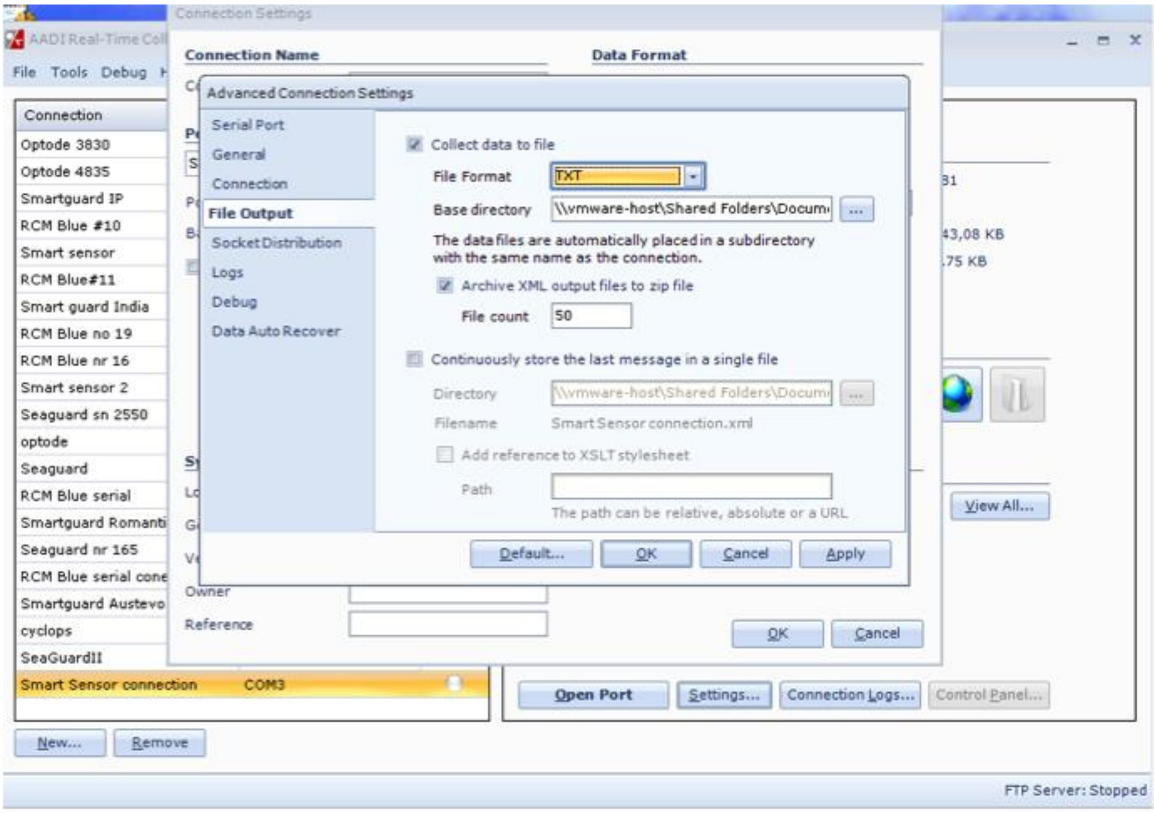
When finished go to "Recorder Panel" and select the "Fixed interval" that you want and then "Start Recorder". Then close menu to go back to main menu.



If sensor is set to "AADI Real-Time" (see above) go to main menu and select most suitable option for "Data Visualization" (Graph or Table). If Graph select what parameters to be presented. Right click on graph to enter into graph settings.



To log data in xml or txt close communication "Close Port" and click on "Settings". Select "Advanced Settings".

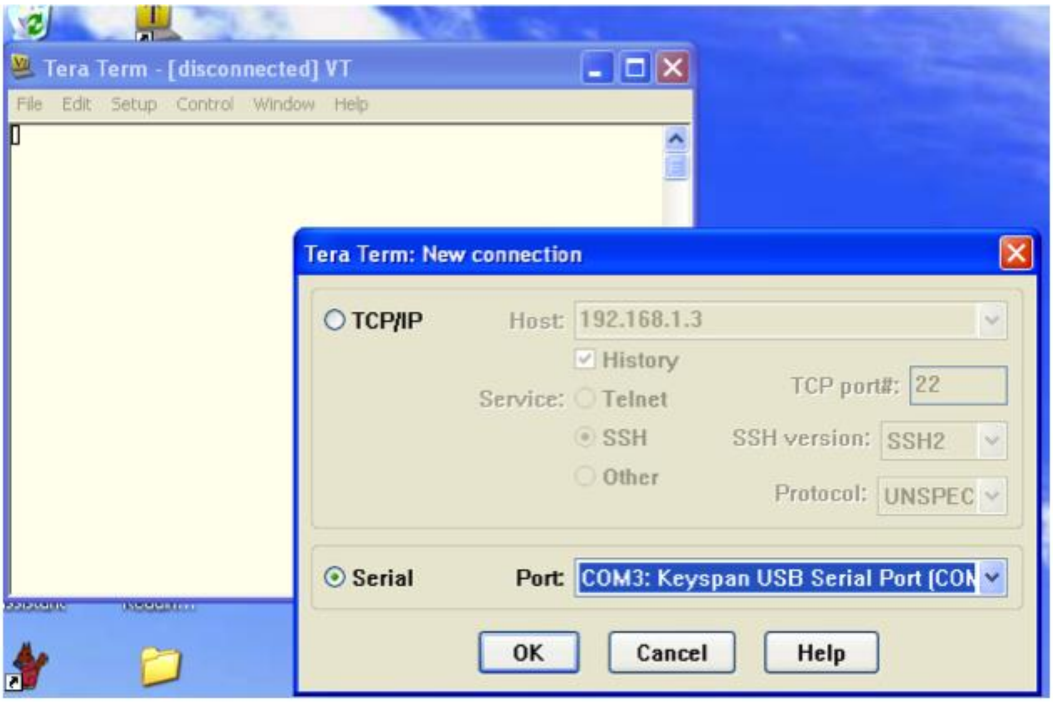


In “Advanced Connection Settings” select “File Output” click ”Collect data to file” and select File Format (xml or txt) and location. The name of the stored file will be the same as the name of the connection. Click “Apply” + “OK”. Then open the port again, incoming data will be stored to the specified file.

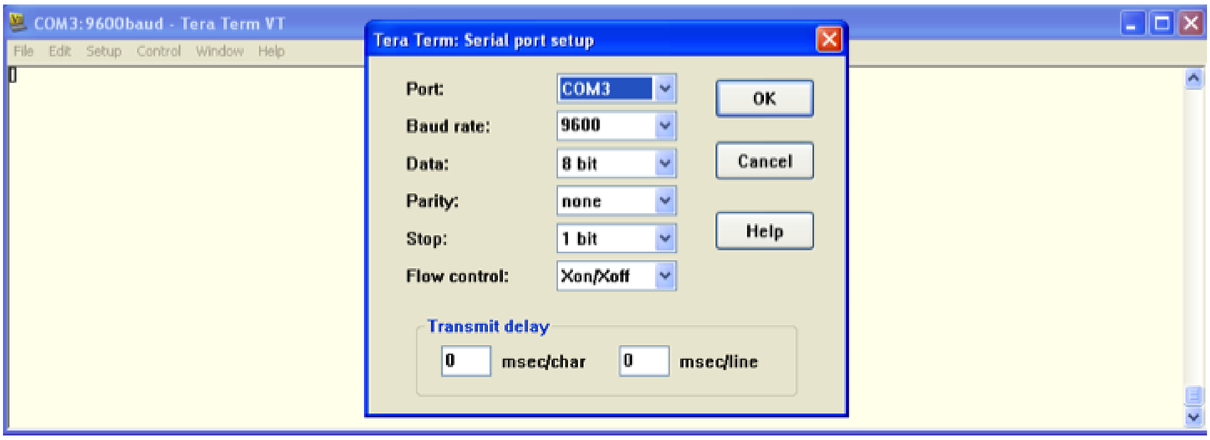
Appendix 2: Enter a foil adjustment into the sensor using terminal software

Different types of freely available software exist to communicate and change settings in sensors that use serial communication. One example is Tera Term. Below you will find step by step how to enter, communicate and change settings of Aanderaa smart sensors using the Tera Term software. For another terminal software the procedures should be similar.

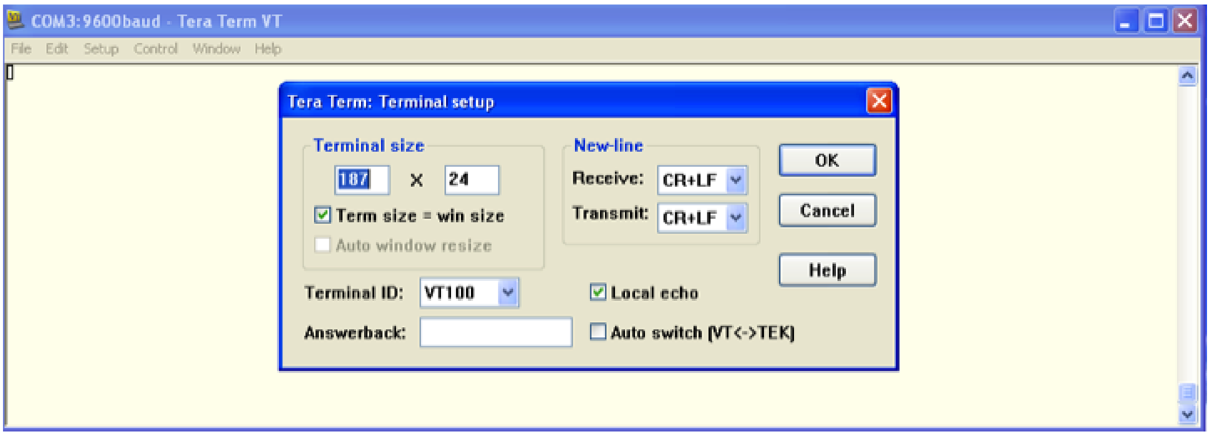
Serially connect sensor to computer and power (one USB on 3855 cable is to power the sensor with 5-14 V) and Start Tera Term. Please observe that the quality of USB to Serial convertors is variable. Some work well and some are unreliable/do not work at all. From investigations we have found that KEYSPAN convertors work reliably on different computers with different operating systems.



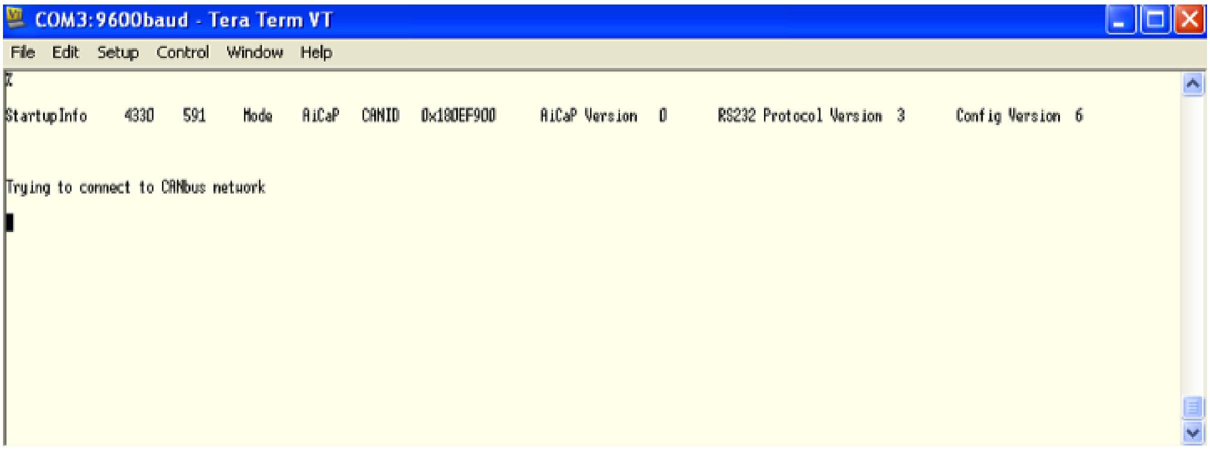
Select "Serial Port" and the correct COM port (see Port mapping in Windows). Then click "OK".



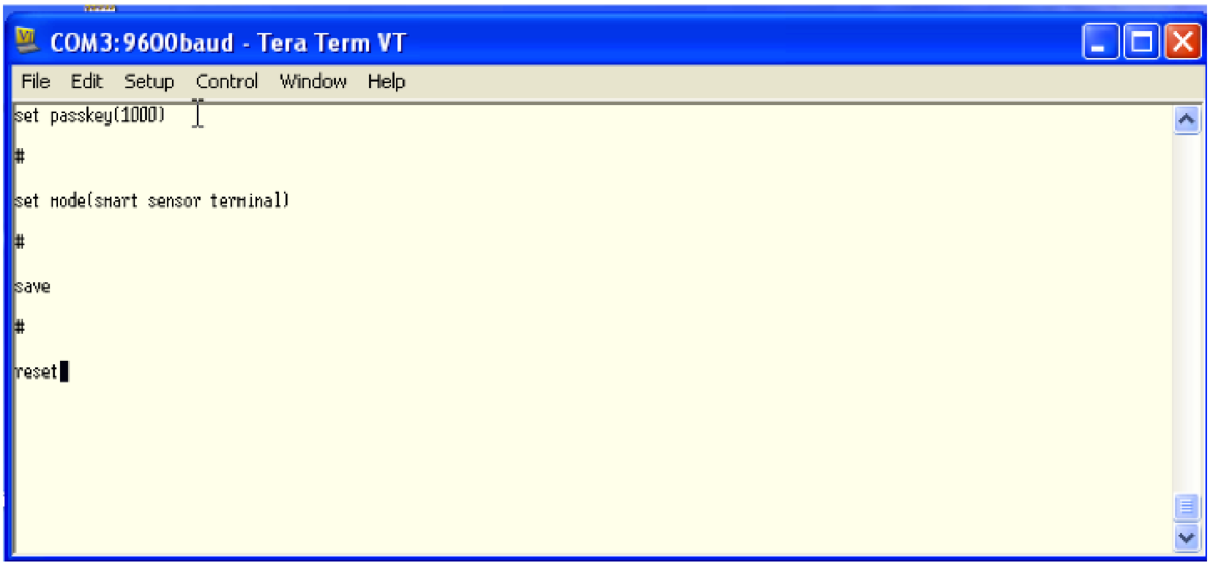
Select “Serial Port” under “Setup” and set up the COM port as shown above. The default setting of the smart sensors when delivered is a Baud rate of 9600. Click “OK”.



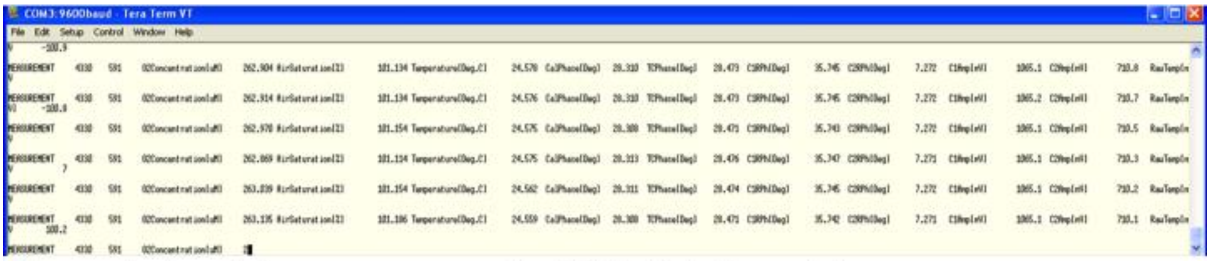
Select “Terminal” under “Setup” and set up with Carriage Return (CR) + Line Feed (LF) and Local echo as shown above. Click “ OK”.



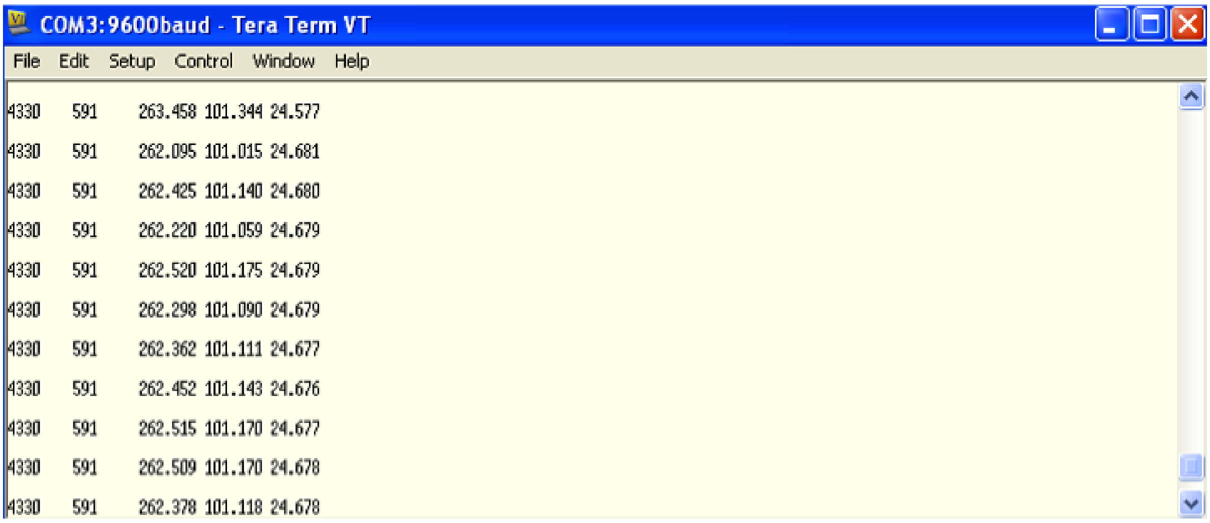
Dis-connect and Re-connect power. The sensor will tell you in which output mode it is set-up (the options are: AiCap, Smart Sensor Terminal, AADI Real-Time, Analog Output). You can type “help” or consult manual to see available commands/settings. You can type “get all” to see all coefficients and settings of the connected sensor. The commands are not case sensitive but you must respect if there is/is not a space in-between characters.



Change the output to serial communication (with text) by typing the following commands: 1. set passkey(1000) + CR (Carriage Return) ➔ wait for return of #; 2. set mode(smart sensor terminal) + CR ➔ wait for return of #; 3. save + CR ➔ wait for return of #; type reset or disconnect and reconnect power. The sensor will start presenting data at the pre-set interval.



The example above is for oxygen measurements with full text including raw data



The example above is for oxygen measurements (Oxygen in µM, Oxygen in % saturation and Temperature), with the text removed and without raw data. To change to this type of text string type the following commands: 1. set passkey(1000) + CR (Carriage Return) ➔ wait for return of #; 2. set enable text(no) + CR ➔ wait for return of #; 3. set enable rawdata(no) + CR ➔ wait for return of #; 4. save + CR ➔ wait for return of #; type reset or disconnect and reconnect power. The sensor will start presenting data at the pre-set interval.

Get actual Air Pressure (hPa)[1] 995

Connect Optode to PC with terminal program[2]

Expected Air Saturation (based on air pressure)

Enter result from Optode[3] Saturation: 95,00% 98,22%

Get current offset and slope coefficients by sending the following commands to the Optode:

Set Passkey(1)
Get ConcCoef

New Coefficients

	$ConcCoef_0$	$ConcCoef_1$	$ConcCoef_0$	$ConcCoef_1$
Enter current coefficient values:	-0,2	1	-0,2	1,0339

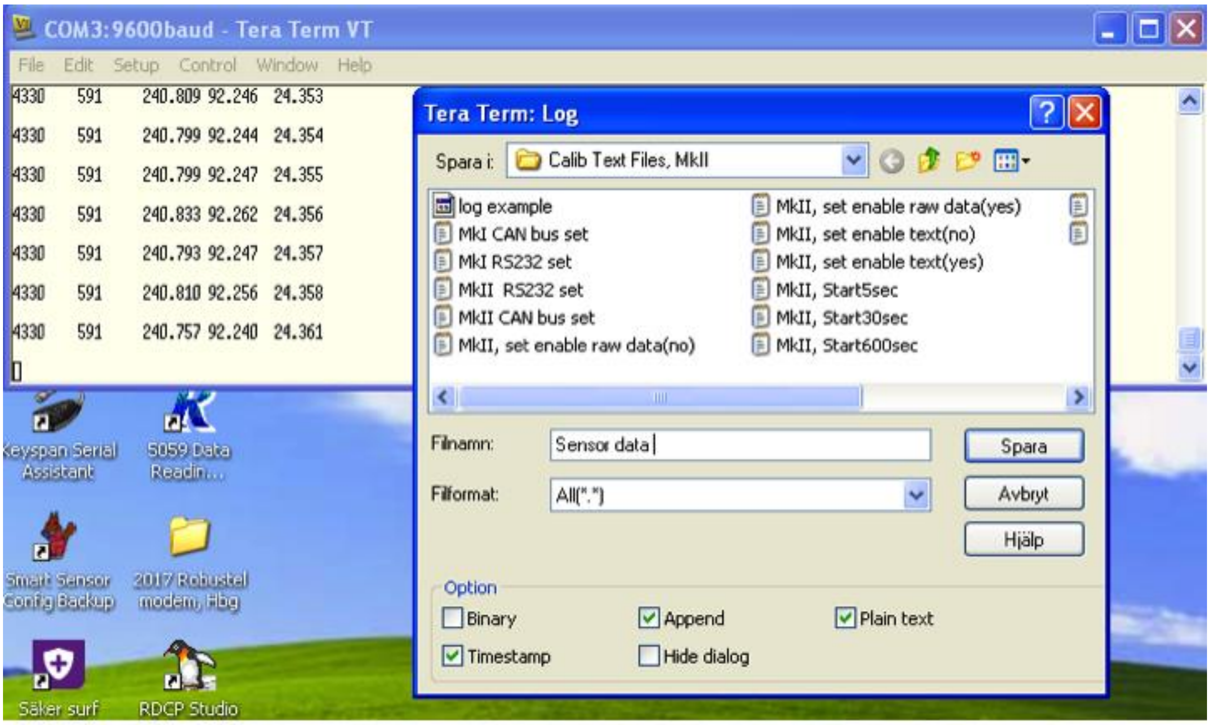
Save updated offset and slope coefficients by sending the following commands to the Optode:

Set Passkey(1000)
Set ConcCoef(-0,2, 1,0339)
Save

Check that the new readings from the Optode correspond to expeced Air Saturation level: 98,22%

Notes
1 Preferably without correction with repect to heigth above sea level
2 For instance Tera Term, Baudrate 9600,1 stop bit, XON/XOFF Handshake, Terminal Setup\New Line\Transmit: CR+LF
3 The optode foil should preferably be soaked for 24 hours prior to the adjustment

The example above shows a drift adjustment calculation using an Excel sheet available from Aanderaa of a two-point calibrated oxygen optode that read 3.4 % to low at 98.2 % air saturation (air-bubbled water, 995 hPa air-pressure) and 0.2 uM to high at 0 oxygen. The ConcCoef is adjusted so that -0.2 uM ($ConcCoef_0$) is subtracted from incoming values and then they are then multiplied with 1.0339 (+3.4 %, $ConcCoef_1$).



All commands and data can be logged. Click on "File" and select "Log". Type a name for the log file and select "Option". If Timestamp is crossed off the time will be taken from the computer.