FAQ to Optimare Precision Salinometer (OPS)

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What is the average sample time/throughput?

Experience shows that a measurement of a sample takes about 6 min. This includes automated rinsing and three repeated measurements. In principal, it would suffice to take one measurement because the data stream can be monitored continuously (ca. 1 Hz data). But tradition in oceanography is to use 3 measurements (whatever the definition of 'one measurement' might be). The through flow speed is constricted by the demand to adjust the sample water's temperature to better than 1 mK, if high accuracy salinities are requested. Only few people realize how small this temperature deviation is. Best accuracy is time consuming. You can chose to be faster (also with the OPS), but you lose accuracy.

How is the instrument standardized? IAPSO standards? Do you make/sell your own standards? Are secondary standards used to monitor drift? How frequently would you recommend standardization of the instrument?

IAPSO standard sea water is the primary standard in oceanography. There is no replacement for this. OSIL (UK) produces this water. The OPS is 'standardized' with OSIL SSW. Usually this is done before and after a measurement session. The user is of course free to choose an appropriate substandard to monitor drift. Often oceanographers use ocean sea water for this purpose. This is not a good idea, as ocean waters are usually not very clean. It is much better to use OSIL Atlantic Sea Water (5 liter bins), which is filtered and UV-treated clean water. If you plan to fill your own substandard bottles, please note that adequate bottle treatment and filling is not trivial.

The instrument does not need a frequent recalibration or standardization if treated with clean water only. The cell dimensions are very stable (no pressure effect, no temperature excursion), and the SBE-Wien Bridge is outstandingly stable, too. The most problematic issue in terms of stability is dirt introduced into the cell by the sample water itself. It depends on the type of water (deep ocean, brackish waters) and the requested accuracy, how often a standardization is necessary. In general, it is more valuable to have fewer very precise reference points than a lot of noisy comparisons.

Is the actual sample temperature monitored within the cell or is the bath temperature monitored?

It is impossible to measure the temperature inside a conductivity cell without disturbing the conductivity measurement. Here, the main bath temperature is measured by the SBE3 and temperature is controlled by very advanced methods. Indeed, temperature control is the most critical single issue in a lab salinometer. Fluctuations in the OPS main bath are below 1 mK. This outstanding value is achieved by using the stirrer as a (variable and fast reacting) heat source. Dissipation of the introduced energy is very homogeneous and thermal mass of the heating element is non-existent. The method is patented.

Is the temperature data collected as part of the software data stream? Is it correct to say that the SBE 3 temperature sensor measures to 0.1mK?

Temperature is included in the data acquisition because this is an essential part of the quality control and proof. The temperature output is documented to 0.1 mK. You may be aware that this is not the specification of absolute accuracy by SBE or Optimare. But short term stability of the sensor is much better than this value: During a year these sensors drift typically by 1 or 2 mK, so that within a measurement session drift is simply irrelevant. The internal evaluation of temperature uses mikroK level. But this is part of the patented bath control only and is not seen by the user.

How frequently does the conductivity cell need replacing/recalibration?

The instrument does not need a frequent recalibration or standardization if filled with clean waters only. The cell dimensions are very stable (no pressure effect, no temperature excursion), and the SBE-Wien Bridge is outstandingly stable, too. The most problematic issue in terms of stability is the dirt introduced into the cell by the sample water itself. It depends on the type of water (deep ocean, brackish waters) and the requested accuracy, how often a standardization is necessary.

Cleaning of the conductivity cell is similar to the familiar procedure of the CTD's sensor. We recommend to store the instrument dry when not in use for several weeks in order to avoid biofouling in the cell. Standardization during the measurement session is usually all that is needed.

We use a SBE 4 on the CTD. Having an instrument that is calibrating the SBE4 CTD sensor that is using an SBE4 sensor seems a bit redundant. Is the modified Optimare cell better than the SBE4 alone?

This might seem so at first sight only. In fact, a comparison with a reference instrument is done mostly with instruments of similar construction. It is common in thermometry to compare two PRTs, and in oceanography we control the SBE3 by a SBE35 standard thermometer. Critical points are that the reference instrument has to be 'closer' to the primary standard, and/or handled more carefully, and/or operated in a superior environment, and/or is more stable &c.. In thermometry this means e.g. that the reference instrument (SPRT or SBE35) is suited to work in the fix point cells while ordinary thermometers (other PRT or SBE3) can't be operated there. In oceanography there have even been times when reference thermometers, namely reversing mercury thermometers, showed less resolution than the UUI (unit under inspection), namely early CTD thermometers. Comparisons have been performed nevertheless, because the stability of the reversing thermometers was known but those of the CTD thermometers had to be still proved, not to mention points of discontinuity in early CTD designs.

The conductivity sensor in the OPS is modified only in shape, but otherwise identical to a SBE4 as supplied by Sea-Bird Electronics. In particular the bridge is not altered in any way. Internal evaluation is a bit more precise (as we do not need to be as fast as the CTD (24Hz) but can measure over ca. a second or so), but this is not important. Important is that the OPS sensor is calibrated directly with our primary standard, IAPSO SSW. This is hardly possible with the CTD sensors. This means that the OPS is closer to the primary standard. Moreover, the SBE4 calibration is done by Sea-Bird using a bath of (almost) constant salinity and varying the bath temperature to arrive at different conductivities. This is not equivalent to a calibration by different salt concentrations, which can be done easily with the OPS (using SSWs with different salinities). Thus, off the standard 35 salinity, the OPS is again much closer to the primary standard.

The SBE4 in the OPS also works in a highly superior environment. Temperature is constant and no pressure effects are present. Temperatures in the main water bath are so excellently controlled, and free of fluctuations and inhomogeneities, that the bath is better than existing calibration baths used in thermometry. This is at the expense of an operation far from room temperature (a few K from ambient only), because heat flux into the bath is kept very small. The quality of the thermal management is the key factor in the salinometer measurement of conductivity. It is this aspect which is handled in a much improved way by the OPS. The temperature control is so fast and precise, that operation in adverse conditions (draft, fluctuations) is not compromising the results. This was an important goal, as we want to be able to measure on board.

Why should I use a salinometer at all?

We have to be aware why we use reference salinometers. There are several reasons: We want to check the calibration of the supplier, we want to check whether transportation and handling had an adverse effect on the sensor, we want to check the pressure effect on the measurements, we want to check for temperature effects on the measurements, we want to check the contamination of the CTD-sensor during operation, and perhaps more.

The calibration procedure has already been commented above. The point 'transportation and handling' includes problems with any kind of dirt, exposure to adverse temperatures, and mechanical effects. I guess everybody cleans the sensors before use, so dirt should not be a major problem, but the two other items can hardly be controlled. At present, we account for the pressure effect on the cell by applying the nominal compressibility for the type of glass. This is an approximation and should be checked for the individual cell. The same holds true for the temperature effect. As mentioned previously, 'contamination' is the most dramatic issue for CTD measurements in the ocean. When relating to 'drift', this is certainly the most important source.

Can't we simply perform a salinometer comparison during an expedition?

This is proposed frequently, but not a good idea. The metrological problem is that SSW is our only reference, at sea as in the lab. No CTD-measurement can serve as a reference for a salinometer. Of course, it is the final goal to have a precise and robust salinometer which can be used on board as well as in the lab. And the OPS meets these needs. But a test at sea can only be the final step of a qualification procedure. Unless the salinometer has already proven its characteristics in the lab, and the operator is convinced that the displayed results are always directly related to the content of the conductivity cell, interpretation of results at sea is often misleading. Today's oceanographers forgot, e.g., that gas content of ocean water samples is a problem. This was common knowledge in the 70s (see Graßhoff or Poisson) but somehow escaped from the agenda later. Formation of micro bubbles always occurs in the samples as these are warmed up from usually 4°C to room temperature and pressure is released from 200-400 bar to zero. Because of the superior control and precision of the OPS, recognition of the bubble's effect cannot be avoided. Almost always this is interpreted as 'salinometer drift' or 'instability' while it only shows the precision of the instrument. Ocean samples must be treated before their salinities can be measured – this holds true for measurements by all salinometers, by the way. Moreover we have a multitude of problems at sea that all have to be tightly controlled. Bottle and caps are a problem, as bottles are rarely clean. Note that new bottles are not clean. Used bottles are not clean unless they have been cleaned properly in the lab and stored closed with a dry gas or air filling. Sometimes favoured storage with ocean water filling is always adverse. Stratification in bottles may occur, including stratification in SSW bottles. Stratification does develop rapidly in Niskin bottles, so it matters how fast samples are extracted and from which position (= height) in the Niskin bottle they are taken. Particles in ocean water are another problem, both bio and dead material. In contrast to raw ocean samples, SSW (and Atlantic Water supplied by OSIL) is filtered and UV-treated.

How can the quality of the salinometer be assessed in the lab?

In my view it is already nice to see that the OPS readings are consistent within 0.0002 (range, not standard deviation!) where previously we had to calculate means from more 'cloudy' distributions. A first test is therefore very simple: Measure a bottle of SSW until it is empty and check for the range of the results. A second step could be to do the same with a number of bottles which contain the same water. Then check whether the results are affected by opening a window when it is cold outside. Also check noise in main temperature and conductivity reading. Both are essential parameters for precision measurements.

Can I justify the cost of the OPS to my administration by other arguments than best accuracy?

A good deal of the additional costs of the OPS is absorbed by items one would have to purchase on top of other instruments: DAQ software is complete and variable, peristaltic pump is built in, monitor is built in, Linux PC is built in (industrial PC), computer interface is built in, and a pre bath is non-existent in other designs. You also have a spare SBE3 at sea.

What do you mean by ‘operator independent results’?

A major benefit is the automatic operation which ensures an absolutely steady work flow. This is important for ultimate accuracy. The operator just changes the bottle – everything else is automated (and perhaps we see an automated sample changer some time, who knows?).

Are there future perspectives to incorporate additional measurements in the OPS

A perspective which is not a distant vision but may see a realisation in perhaps a year or two is the incorporation of a density measurement in the OPS. We have worked on this for quite some time by now and I already have a prototype version of a densitometer in my lab. The thermal quality of the main bath is again crucial here. I think it will be possible to better existing densitometers by at least a factor of 2. The idea is to have a modular approach which allows to retrofit the density module in existing OPSs. For regions far away from Atlantic Waters this is, in my view, an important additional measurement, as the introduction of TEOS10 made (a bit painfully) clear to all of us.