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OSD

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Interactive Comment

Interactive comment on "Metrological traceability of oceanographic salinity measurement results" *by* S. Seitz et al.

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Firstly, we would like to thank referee #1 for carefully reading the paper and revealing some flaws, which enables us to improve its quality.

C368: Concerning the correlation of G_su and G_SSWu. We assumed a stable measurement device, i.e. that the results of several conductance measurements just fluctuate randomly. Under this condition it is reasonable to assume that an determination of the covariance of G_KClm and G_SSWm (and likewise that of G_su and G_SSWu) according to eq. (17) of GUM 2008 would give approximately zero. Therefore we assumed them to be uncorrelated (seen as random variables; see GUM 5.2.1), all the more because the measurements are not done simultaneously. Nevertheless, we admit that eqs. (5) convey the impression that a correlation is not of importance, at all. An individual measurement device might well show instabilities, which affect both variables similarly (e.g. a slow temperature drift). This needs to be considered by introducing correlation terms in the uncertainty calculation. To be more accurate, we will mention that a more detailed uncertainty calculation needs to account for correlation terms in eqs. (5).

C368: Concerning the introduction of standard uncertainty. Indeed, we introduced the standard uncertainty somewhat careless. The probability function corresponding to a measured quantity is indeed not necessarily normally distributed. We will correct this accordingly. However, we would like to note that in practice the widespread understanding of standard uncertainty as a measure for the uncertainty that corresponds to the 68% confidence level of a normal distribution is, to a certain extend, appropriate. Even if the distribution is not normal, the degree of confidence, which is attributed to the standard uncertainty, is of this order for many practical cases. For a triangular distribution it is about 65 %, for a rectangular distribution it is about 58 %.

C368: Concerning the stated uncertainty of a Guildline Autosal salinometer we have cited the uncertainty from the data sheets of the manufacturer, who didn't state the coverage factor. We didn't perform the calculations done in M. Le Menn 2009, but it is rather likely that the Autosal uncertainty is not an expanded one as well.

C368: Concerning sensitivity. The sensitivity coefficients in GUM are a measure for the sensitivity of a measurement function with respect to an input quantity. Sensitivity in VIM corresponds to the sensitivity of the indication system of a measuring device with respect to a change of the measured quantity (see VIM 4.12). In p.1314 we refer to the latter. A "sensitivity" contribution is typically considered, if there is no or just little statistical spread in the indicated values. Then the limited resolution of the display must be considered in the uncertainty calculation. However reading this paragraph again, we have realized that the text suggests that the sensitivity contribution must also be determined by statistical means, which is obviously not true. We will correct this.

OSD

7, C444–C448, 2010

Interactive Comment

C369: Concerning simplification of eqs. 6. Unfortunately the proposed formula is not readable in the published comment . Anyhow, we are aware that eqs.(6) could be significantly simplified using eq. (4). However, to our feeling the correlation between eqs. (6) and eqs. (2) and (4) is more obvious in the present formulation, so we would prefer not to change it.

C369 Concerning CTD calibration procedure described after (p 1315). The described calibrations include an increased effort that is not necessarily justified for measurements in the oceans. However, for measurements in brackish seawater, such as the Baltic sea, it is necessary practice. When calibration is performed just at S=35 a larger conductance range below 28 mS/cm can not be covered just by temperature variation. Moreover, the uncertainty related to the influence of temperature on the transmitter of the conductivity sensor can be quantified only, if calibration is performed at several salinities.

C369 More on the conductivity calibration Yes, CTD calibration must indeed be described more exactly. We will change this accordingly (see below).

C369: Concerning eq. (7) and (8) We agree with the referee, that the eqs. do not reflect the actual calibration procedure. It was our intention to demonstrate the general relation between the uncertainty of the final result (Practical Salinity) and those of the actually measured input quantities (conductances, temperatures, pressures, Practical Salinities of the reference bath(s)). With respect to this rather general intention the eqs. are correct. We also agree that a detailed uncertainty calculation needs to consider the aspects mentioned by the referee. However, such a detailed uncertainty calculation and the corresponding assessment of individual uncertainty contributions and possible correlations between input quantities is beyond the scope of the paper which is focused on traceability. However, we see that the eqs. are misleading. So we will not give expressions for the uncertainty in a revised version, but we will refer to Le Menn 2009. Then the CTD part will read as follows:

Finally, a peculiarity concerning the traceability of conductivity ratio results measured with CTD-probes should be mentioned. Habitually CTDs are inserted into a stirred and temperature stabilized seawater bath for calibration. Conductances are measured at various temperatures and, depending on the intended application, at one or more salinities. The salinities are represented by Practical Salinity measurements using a SSW calibrated salinometer. Calibration is done at atmospheric pressure. Afterwards a sensor-specific calibration curve is numerically fitted to the data in order to correlate the CTD conductance signal to a conductivity, calculated from the Practical Salinity and the temperature by inverting the Practical Salinity relations.

Additionally to the laboratory calibration in situ calibrations during cruises are frequently done. Here simultaneously to the CTD-measurements temperature measurements by a standard thermometer and collection of water samples are carried out in a well mixed layer. The Practical Salinity of the samples is measured by a Salinometer (calibrated with SSW). The conductance signal of the CTD is corrected (if necessary) by comparison to a conductivity obtained by inverting the PSS-78. The input quantities are the Practical Salinity of the sample, the temperature of the calibrated standard thermometer and the data of the pressure sensor. Uncertainties of practical salinity results using CTDs were recently investigated in detail (M. Le Menn 2009) and are not discussed here. But it must be mentioned that due to the above procedure a CTD- measurement of Practical Salinity includes an additional level within the calibration hierarchy (see Fig. 1), which necessarily results in an additional contribution to the total uncertainty. Hence, the uncertainties associated with Practical Salinity results obtained from CTD measurements are inevitably larger than those obtained from Salinometer measurements.

C369 Concerning sec. 4.1. The value of 0.002 is currently most widely accepted. It therefore seems reasonable to us to use this value in the presented estimation. On the other hand the calculation can easily be adapted to another value. We will mention this in the paper.

OSD
7, C444–C448, 2010

Concerning sec. 6. As pointed out in the introduction a single quantity to estimate salinity can be used only if the relative mass fractions of the dissolved components are constant, i.e. only if the amount of water is changing. This is a fundamental prerequisite for using chlorinity, conductivity or any other measured quantity that is sensitive to a change in the amount of water as a measure for salinity. It will also be a fundamental prerequisite for a density based measurement of practical salinity. Hence, within this frame, the question for the effect of composition anomalies is not admissible since they are a priory not covered, neither by PSS-78 nor by a new density based metrological reference. So, assuming constant mass fractions it doesn't matter at all, if one uses a conductivity sensor, a oscillation-type density meter or any other sensor to measure density. As long as the sensor is sensitive to a change in density (which, in this regard, is equivalent to a change in the amount of water) and as long as the measurement results are referred to an SI density standard (which gives the "true" density value). We will try to precise this in the manuscript. On the other hand, as the referee has pointed out, composition anomalies are of interest. Approaches to deal with the issue are outlined in the measurement models (v) and (vi). The effect of composition anomalies on density based salinity measurements need to be investigated, which also includes density and temperature measurements under high pressure. As mentioned, the idea of using density for traceability is promising, but still a lot of work needs to be done before density based salinity measurements can be put into practice.

Interactive comment on Ocean Sci. Discuss., 7, 1303, 2010.