

Response to RC2 (22 Sep 2017)

Minor comments

'I think it would be good in the paper to briefly mention other measurements in addition to density that might be recommended to be made on standard seawater, especially measurements that might help interpret changes in density. The authors point out that silicate is in this category. Since the variations in density they are considering are of similar magnitude to variations due to isotopic composition, it seems like that would be another – especially since I believe isotopic composition measurements on water are now fairly routine due to their importance in geoscience.'

This is a similar comment like in the first comment (RC1). We expanded that conclusion and refer to the answer given there.

Since theoretical boundary conditions at 'zero density', i.e. $\lim_{S \rightarrow 0} \Delta\rho(S)$, are not fulfilled by the mathematical formulation of the density–salinity relation (DSR), is there a risk for inconsistencies?

The following change was made to the paragraph at the end of Sect. 4.2:

[..] Since the mathematical formulation of the density-salinity relation is empirical and does not contain any theoretical boundary conditions for infinite dilution, as e.g. implemented in TEOS-10, the question arises whether the relation correctly predicts the density for very low salinities. Additionally, no uncertainty verification in the extrapolation region is possible using the fitting data set. Therefore, additional substitution density measurements were conducted: The density of diluted standard seawater with salinity 2 measured at some temperatures and the density of some samples of the seawater used for determination of the density–salinity relation at 1 °C were measured. The seawater with salinity 2 was prepared like the seawater with salinities from 5 to 30. Unfortunately, the precision in the salinity-2-calibration was lower, so that the uncertainty in salinity is 0.0028 corresponding to an uncertainty in density of 2.2 g m⁻³. The density results were corrected to the uniform isotopic water and the chemical salt compositions as well as air saturation as described in Sect. 3. The density deviations of the corrected results from the predicted values of the density–salinity relation are shown in Fig. 7. In both cases, the deviations are well within the uncertainty in the density–salinity relation. Note that for the measurements on seawater with salinity 2, even if the uncertainty in salinity is treated as an offset to all deviations, the deviation is within its uncertainty. No inconsistencies are caused by the non-compliance with theoretical boundary conditions for very low salinities and atmospheric pressure.

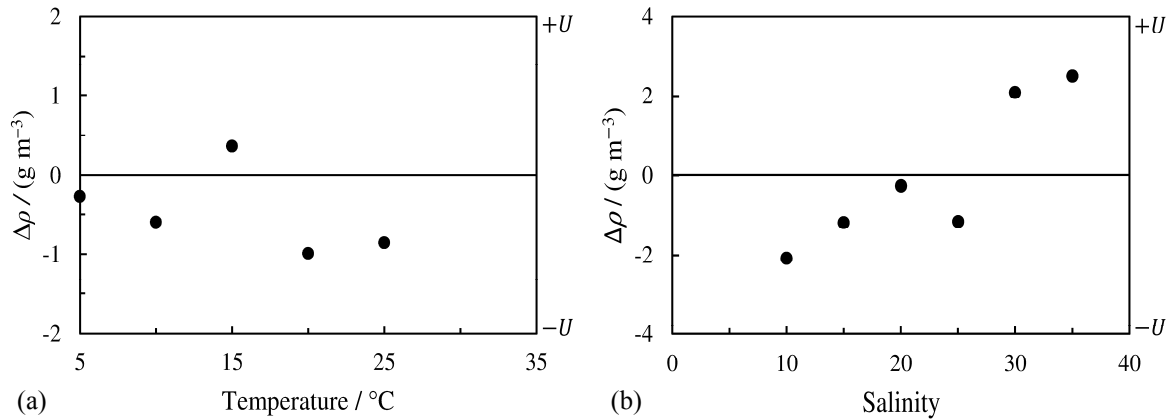


Figure 7. Deviation of measured from predicted seawater densities $\Delta\rho$. (a) In the interpolation range at salinity 2 and (b) in the extrapolation region at 1 °C at atmospheric pressure, respectively. U – Uncertainty in the density–salinity relation.

The following paragraph was added at the end of Sect. 4.3:

[..] As pointed out above, the mathematical formulation of the density–salinity relation is empirical and does not contain any theoretical boundary conditions for infinite dilution. This is also an issue for the density at high pressures, as here the measurement uncertainty in density is higher, thereby causing more variability in the shape of the relation for very low salinities. Therefore, additional measurements were conducted on diluted standard seawater with salinity 2 for some temperatures. The samples used were obtained from the same seawater as described above in Sect. 4.2; the corrections were similar. The density deviations of the corrected results from predicted values of the density–salinity relation are shown in Fig. 10. The deviations are well within the uncertainty in the relation. No inconsistencies are caused by the non-compliance with theoretical boundary conditions for very low salinities and high pressures.

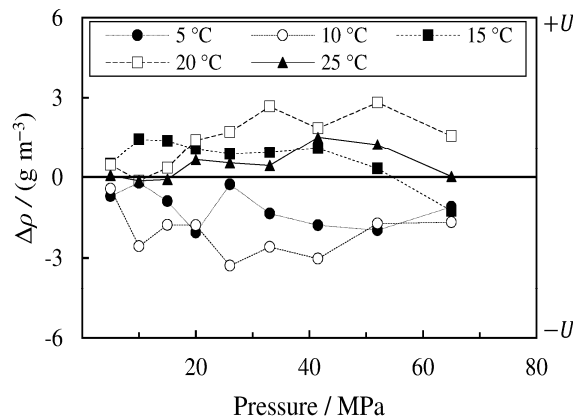


Figure 10. Deviation of measured from predicted seawater densities $\Delta\rho$ in the interpolation range at salinity 2. U – Uncertainty in the density–salinity relation.