3. Absolute Salinity S_A

Perhaps the most apparent change in using TEOS-10 compared with using the International Equation of State of seawater (EOS-80) is the adoption of Absolute Salinity $S_{\rm A}$ instead of Practical Salinity $S_{\rm P}$ (PSS-78) as the salinity argument for evaluating the thermodynamic properties of seawater. Importantly, Practical Salinity is retained as the salinity variable that is stored in national databases. This is done to maintain continuity in the archived salinity variable, and also because Practical Salinity is virtually the measured variable (whereas Absolute Salinity is a calculated variable).

The "raw" physical oceanographic data, as collected from ships and from autonomous platforms (e. g. Argo), and as stored in national oceanographic data bases, are

- Practical Salinity ($S_{\rm P}$, unitless, PSS-78) and
- *in situ* temperature (t, °C, ITS-90) as functions of
- sea pressure (p, dbar), at a series of
- longitudes and latitudes.

Under TEOS-10 all the thermodynamic properties are functions of Absolute Salinity $S_{\rm A}$ (rather than of Practical Salinity), hence the first step in processing oceanographic data is to calculate Absolute Salinity, and this is accomplished by the GSW function **gsw_SA_from_SP**. Hence the function **gsw_SA_from_SP** is perhaps the most fundamental of the GSW functions as it is the gateway leading from oceanographic measurements to all the thermodynamic properties of seawater under TEOS-10. A call to this function can be avoided only if one is willing to ignore the influence of the spatial variations in the composition of seawater on seawater properties (such as density and specific volume). If this is indeed the intention, then the remaining GSW functions must be called with the salinity argument being Reference Salinity $S_{\rm R}$, and most definitely, not with Practical Salinity $S_{\rm P}$. Reference Salinity $S_{\rm R}$ can be obtained from the function **gsw_SR_from_SP**.

The **gsw_SA_from_SP**(SP,p,long,lat) function first interpolates the global Absolute Salinity Anomaly Ratio (R^{δ}) data set using the internal GSW library function **gsw_SAAR** to the (p,long,lat) location. **gsw_SA_from_SP** then uses this interpolated value of R^{δ} to calculate Absolute Salinity $S_{\rm A}$ according to (see Eqn. (A.5.10) of appendix A.5 of the TEOS-10 Manual, IOC *et al.* (2010) and McDougall *et al.* (2012))

$$S_{\rm A} \;=\; \frac{35.165\,04\ {\rm g\,kg^{-1}}}{35}\ S_{\rm P}\left(1 + R^{\delta}\right). \qquad \textit{Non-Baltic} \qquad (1)$$

In this expression $\left(35.165\,04\ {\rm g\,kg^{-1}}/35\right) S_{\rm P}$ is the Reference Salinity $S_{\rm R}$, which is the best estimate of Absolute Salinity of a Standard Seawater sample.

Eqn. (1) is the value of Absolute Salinity returned by **gsw_SA_from_SP** unless the function detects that the location is in the Baltic Sea (where incidentally the internal GSW library function **gsw_SAAR** returns a value of R^{δ} of zero). If the observation is from the Baltic Sea, the Absolute Salinity Anomaly $\delta S_{\rm A}$ is calculated according to $S_{\rm A} - S_{\rm R} = \ 0.087\,{\rm g\,kg^{-1}} \times \left(1 - S_{\rm P}/35\right)$ (from Eqn. (A.5.16) of IOC *et al.* (2010), following Feistel *et al.* (2010)), so that Absolute Salinity $S_{\rm A}$ is given by

$$S_{\rm A} \;=\; \frac{\left(35.165\,04 \ - \ 0.087\right)\,{\rm g\,kg^{-1}}}{35}\,S_{\rm P} \ + \ 0.087\ {\rm g\,kg^{-1}}. \qquad \textit{Baltic Sea} \qquad (2)$$

In summary, the **gsw_SA_from_SP** function returns either Eqn. (1) or Eqn. (2) depending on whether the longitude and latitude of the sample put the observation outside or inside the Baltic Sea. Since Practical Salinity should always be positive but there are sometimes a few negative values from a CTD, any negative input values of $S_{\rm P}$ to this function **gsw_SA_from_SP** are set to zero.

If the latitude and longitude are such as to place the observation well away from the ocean, a flag 'in_ocean' is set to zero as a warning, otherwise it is 1. This flag is only set when the observation is well and truly on dry land; often the warning flag is not set until one is several hundred kilometers inland from the coast. When the function detects that the observation is not from the ocean, R^{δ} is set equal to zero and **gsw_SA_from_SP** returns $S_A = S_R = \left(35.165\,04\ \mathrm{g\,kg^{-1}}/35\right) S_P$ in accordance with Eqn. (1).

The largest influence of the variable seawater composition occurs in the northern North Pacific where $S_A - S_R = \delta S_A$ is as large as $0.027\ \mathrm{g\ kg^{-1}}$ (see Figure 2 of IOC *et al*. (2010) which is reproduced below), this being the difference between Absolute Salinity and the estimate of Absolute Salinity which can be made on the basis of Practical Salinity alone. This increment of salinity equates to an increment of density of approximately $0.020\ \mathrm{kg\ m^{-3}}$.

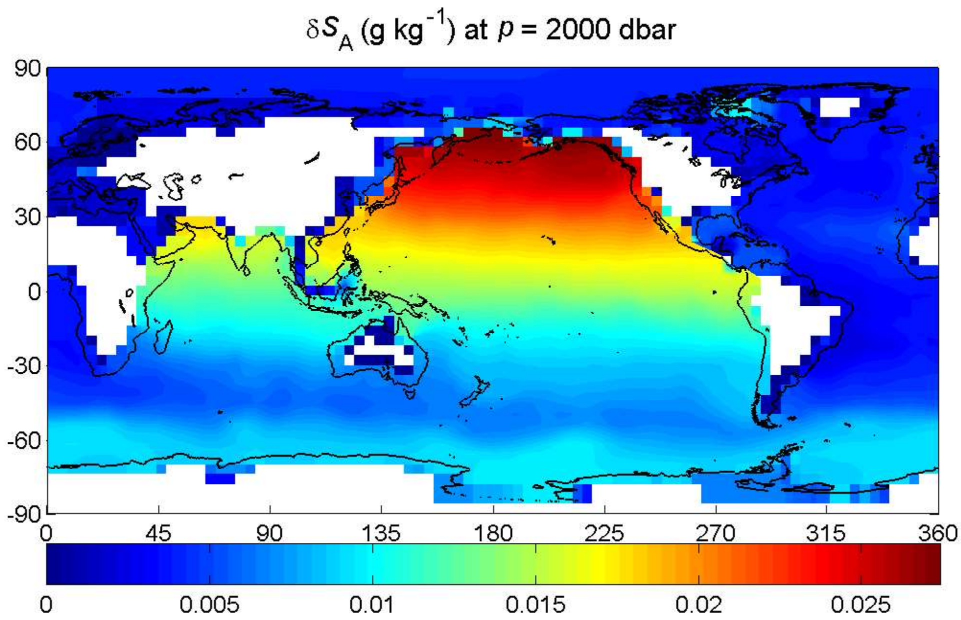

Figure 2 (a). Absolute Salinity Anomaly δS_A at p = 2000 dbar.

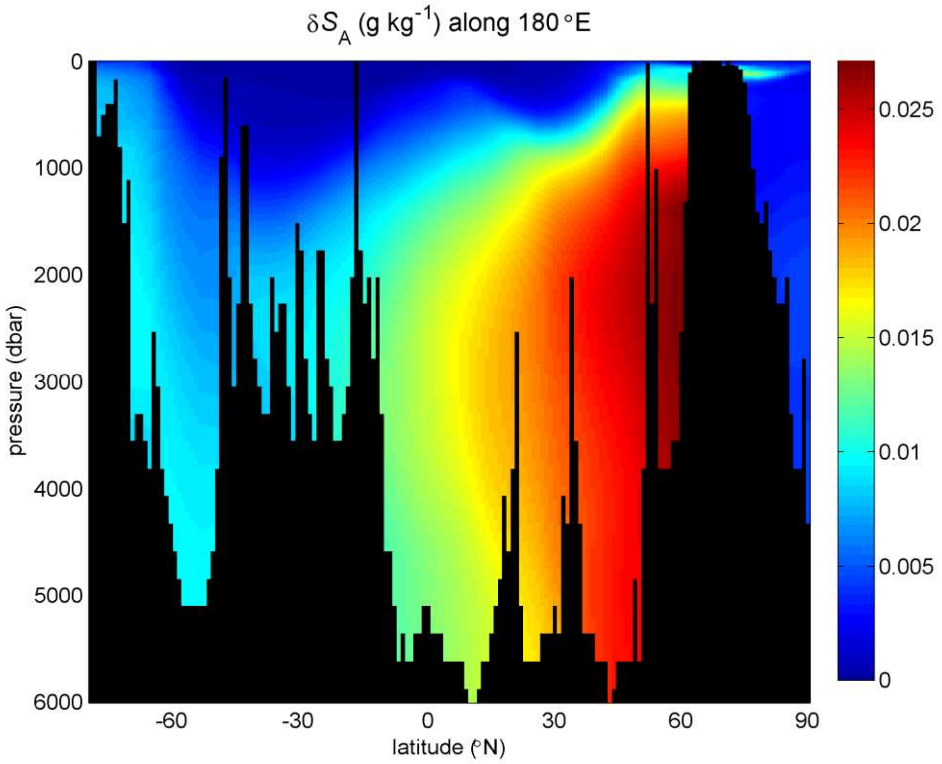

Figure 2 (b). A vertical section of Absolute Salinity Anomaly δS_A along 180°E in the Pacific Ocean.

In order to gauge the importance of the spatial variation of seawater composition, the northward gradient of density at constant pressure is reproduced below from Fig. A.5.1 of IOC *et al*. (2010) for the data in a world ocean hydrographic atlas deeper than 1000m. The vertical axis in this figure is the magnitude of the difference between the northward density gradient at constant pressure when the TEOS-10 algorithm for density is called with S_{A} (as it should be) compared with calling the same TEOS-10 density algorithm with S_{R} as the salinity argument. Figure A.5.1 shows that the "thermal wind" is misestimated by more than 2% for 58% of the data in the world ocean below a depth of 1000m if the effects of the variable seawater composition are ignored. When this same comparison is done for only the North Pacific, it is found that 60% of the data deeper than 1000m has "thermal wind" misestimated by more than 10% if S_{R} is used in place of S_{A}.

The first version of **gsw_SA_from_SP** was made available in January 2009 (then called gsw_ASal). The second version (version 2.0) was released in October 2010 and superseded version 1. The third version (version 3.0) was released in May 2011 and supersedes version 2.0. This is unchanged in version 3.05 which was released in March 2015.

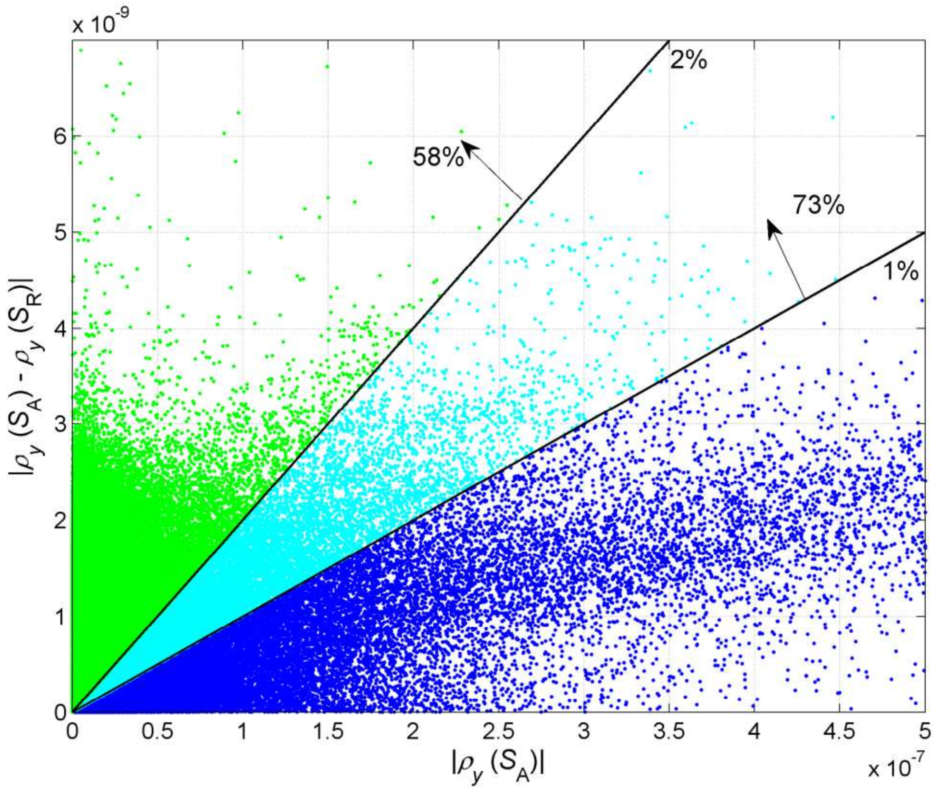

Figure A.5.1. The northward density gradient at constant pressure (the horizontal axis) for data in the global ocean atlas of Gouretski and Koltermann (2004) for $p > 1000$ dbar. The vertical axis is the magnitude of the difference between evaluating the density gradient using S_{A} versus S_{R} as the salinity argument in the TEOS-10 expression for density.

As discussed in Pawlowicz (2010), Wright *et al*. (2011) and IOC *et al*. (2010), there are actually several contenders for the title of the "absolute salinity" of seawater, namely "Solution Salinity", "Added-Mass Salinity", and "Density Salinity". The paper of Wright *et al*. (2011) presents a clear and readable account of this difficult subject, however the nuances surrounding these different definitions of absolute salinity need not concern most physical oceanographers. Under TEOS-10 the words Absolute Salinity and symbol S_{A} are reserved for "Density Salinity" such as can be deduced using laboratory measurements with a vibrating beam densimeter.