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Absolute Salinity and TEOS-10: Sea-Bird's Implementation

In December 2009, Sea-Bird implemented the Absolute Salinity calculation as an option in SeaCalc II, a seawater calculator module in SBE Data Processing that computes a number of derived variables from **one user-input data scan**. This implementation, available in SBE Data Processing version7.20a through 7.22.5a, was intended to enable scientists to become familiar with Absolute Salinity and the new equation of state, TEOS-10.

In **September 2013**, Sea-Bird released **SBE Data Processing version 7.23.1**. In this software version:

- **SeaCalc II was replaced by SeaCalc III**, to update the calculations to correspond to the most up-to-date algorithms for Absolute Salinity, and
- **A new module, Derive TEOS-10**, was introduced. Derive TEOS-10 allows you to calculate most relevant TEOS-10 variables when **processing data sets**.

The calculations in SeaCalc III and Derive TEOS-10 are based on algorithms from the TEOS-10 website: www.TEOS-10.org. The SBE Data Processing manual and Help files document the specific equations used from the TEOS-10 website.

Derive TEOS-10 uses temperature, conductivity **or** salinity (practical, EOS-80), pressure, latitude, and longitude to compute the following thermodynamic parameters using TEOS-10 equations:

- Absolute Salinity
- Absolute Salinity Anomaly
- adiabatic lapse rate
- Conservative Temperature
- Conservative Temperature Freezing
- density
- dynamic enthalpy
- enthalpy
- entropy
- gravity
- internal energy
- isentropic compressibility
- latent head of evaporation
- latent heat of melting
- potential temperature
- Preformed Salinity
- Reference Salinity
- saline contraction coefficient
- sound speed
- specific volume
- specific volume anomaly
- temperature freezing
- thermal expansion coefficient

Sea-Bird recommends that you run Derive TEOS-10 after all other processing (filtering, aligning, cell thermal mass corrections, deriving of EOS-80 Practical Salinity parameters, etc.) is complete. The TEOS-10 data can then be averaged in Bin Average (if desired) and plotted in Sea Plot.

Background Information

In June 2009, a new Thermodynamic Equation of State of Seawater, referred to as TEOS-10, was adopted by the Scientific Committee on Oceanic Research (SCOR) and the International Association of Physical Sciences of the Ocean (IAPSO) Working Group 127 (WG127) (McDougall et al., 2009A). The new equation incorporates a more accurate representation of salinity known as Absolute Salinity. The main justification for preferring Absolute Salinity over Practical Salinity is that seawater's thermodynamic properties are directly influenced by the total mass of dissolved constituents (Absolute Salinity). However, the mass of dissolved constituents are regionally variable and are not always accurately represented when using conductivity measurements of seawater, the key parameter in the calculation of Practical Salinity.

An algorithm is available that allows an estimate of Absolute Salinity to be expressed in terms of Practical Salinity (McDougall et al., 2009B). This paper provides an excellent discussion of Absolute Salinity, TEOS-10, and both theoretical and practical considerations of these quantities. However, mature development of the algorithm requires ongoing comparisons of the density calculated from Practical Salinity to the true density measured in the laboratory across the world's oceans. Therefore, accurate calculations of Absolute Salinity are currently limited by the number of real observations, making the valuation of the composition of regional oceanic waters an evolving process.

The WG127 concluded "there are three very good reasons for continuing to store Practical Salinity rather than Absolute Salinity in [such] data repositories." (excerpt from McDougall et al., 2009A, from Page 7).

- *"First, Practical Salinity is an (almost) directly measured quantity whereas Absolute Salinity (the mass fraction of sea salt in seawater) is generally a derived quantity. That is, we calculate Practical Salinity from measurements of conductivity, temperature, and pressure, whereas to date we derive Absolute Salinity from a combination of these measurements plus other measurements and correlations that are not yet well established. Calculated Practical Salinity is preferred over the actually measured in-situ conductivity value because of its conservative nature with respect to changes of temperature or pressure."*
- *"Second, it is imperative that confusion is not created in national data bases where a change in the reporting of salinity may be mishandled at some stage and later be misinterpreted as a real increase in the ocean's salinity. This second point argues strongly for no change in present practice in the storage of Practical Salinity Sp in national data bases of oceanographic data."*
- *"Thirdly, the algorithm for determining the "best" estimate of Absolute Salinity is immature and will undoubtedly change in the future so we cannot recommend storing Absolute Salinity in national data bases. Storage of a more robust intermediate value, the Reference Salinity would also introduce the possibility of misuse of salinity data without providing any real advantage over storing Practical Salinity so we also avoid this possibility."*

"Data stored in national and international data bases should, as a matter of principle, be measured values rather than derived quantities. In this way we [WG127] continue to recommend the storage of measured (in situ) temperature rather than the derived quantity, potential temperature. Similarly, we strongly recommend that Practical Salinity Sp continue to be the salinity variable that is stored in such data bases since Sp is closely related to the measured values of conductivity. This recommendation has the very important advantage that there is no change to the present practice and so there is less chance of transitional errors occurring in national and international data bases because of the adoption of Absolute Salinity in oceanography." (excerpt from McDougall et al., 2009A, Pages 10-11)

References

- www.TEOS-10.org (scripts found here are the basis of algorithms implemented in SBE Data Processing version 7.23.1)
- (McDougall et al., 2009A) McDougall, T.J., Feistel, R., Millero, F.J., Jackett, D.R., Wright, D.G., King, B.A., Marion, G.M., Chen, C-T.A., and Spitzer, P. 2009. *Calculation of the Thermophysical Properties of Seawater*, Global Ship-based Repeat Hydrography Manual, IOCCP Report No. 14, ICPO Publication Series no. 134. http://www.marine.csiro.au/~jackett/TEOS-10/Thermophysical_Manual_09Jan09.pdf
- (McDougall et al., 2009B) McDougall, R., Jackett, D.R., and Millero, F.J. 2009. *An algorithm for estimating Absolute Salinity in the global ocean*, Ocean Science Discussions, http://www.ocean-sci-discuss.net/6/215/2009/osd-6-215-2009.pdf
- http://www.marine.csiro.au/~jackett/TEOS-10/

Application Note Revision History

Date	Description
July 2009	Initial release.
December 2010	SBE Data Processing version 7.20a (just released) implemented Absolute Salinity calculator as an option in SeaCalc II.
October 2012	• Add note that scientists have updated Absolute Salinity algorithms since Sea-Bird's implementation in SeaCalc II in December 2009 (SBE Data Processing 7.20a), but we have not yet updated our SeaCalc II software. • Add note that in 2013 Sea-Bird plans to implement most relevant variables from TEOS-10 in SBE Data Processing's Data Conversion and Derive modules for processing data files.
September 2013	• Add information on SBE Data Processing version 7.23.1, with new modules Derive TEOS-10 and SeaCalc III (replaces SeaCalc II) implementing TEOS-10 algorithms.