12. Recommended nomenclature, symbols and units in oceanography

This section 12 is from appendix L of the TEOS-10 Manual, IOC *et al.* (2010).

L.1 Recommended nomenclature

The strict SI units of Absolute Salinity, temperature and pressure are kg kg^{-1}, Absolute Temperature in K and Absolute Pressure P in Pa. These are the units predominantly adopted in the SIA computer software for the input and output variables. If oceanographers were to adopt this practice of using strictly SI quantities it would simplify many thermodynamic expressions at the cost of using unfamiliar units.

The GSW Oceanographic Toolbox (appendix N) adopts as far as possible the currently used oceanographic units, so that the input variables for all the computer algorithms are Absolute Salinity in S_A in g kg^{-1}, temperature in °C and pressure as sea pressure in dbar. The outputs of the functions are also generally consistent with this choice of units, but some variables are more naturally expressed in SI units.

It seems impractical to recommend that the field of oceanography fully adopt strict basic SI units. It is however very valuable to have the field adopt uniform symbols and units, and in the interests of achieving this uniformity we recommend the following symbols and units. These are the symbols and units we have adopted in the GSW Oceanographic Toolbox.

Table L.1. Recommended Symbols and Units in Oceanography

Quantity	Symbol	Units	Comments
Chlorinity	Cl	g kg^{-1}	*Chlorinity* is defined as the following mass fraction; it is 0.328 523 4 times the ratio of the mass of pure silver required to precipitate all dissolved chloride, bromide and iodide in seawater to the mass of seawater.
Standard Ocean Reference Salinity	S_{SO}	g kg^{-1}	35.165 04 g kg^{-1} being exactly $35\,u_{PS}$, corresponding to the standard ocean Practical Salinity of 35.
freezing temperatures	t^f, Θ^f	°C	*in situ* and conservative values, each as a function of S_A and p.
Absolute Pressure	P	Pa	When Absolute Pressure is used it should always be in Pa, not in Mpa nor in dbar.
sea pressure. Sea pressure is the pressure argument to all the GSW Toolbox functions.	p	dbar	Equal to $P-P_0$ and usually expressed in dbar not Pa.

gauge pressure. Gauge pressure (also called applied pressure) is sometimes reported from ship-born instruments.	p^{gauge}	dbar	Equal to the Absolute Pressure P minus the local atmospheric pressure at the time of the instrument calibration, and expressed in dbar not Pa. Sea pressure p is preferred over gauge pressure p^{gauge}, as p is the argument to the seawater Gibbs function.
reference pressure	p_{r}	dbar	The value of the sea pressure p to which potential temperature and/or potential density are referenced.
one standard atmosphere	P_0	Pa	exactly 101 325 Pa (= 10.1325 dbar)
isopycnal slope ratio	r	1	$r = \dfrac{\alpha^{\Theta}(p)/\beta^{\Theta}(p)}{\alpha^{\Theta}(p_{\text{r}})/\beta^{\Theta}(p_{\text{r}})}$
Stability Ratio	R_{ρ}	1	$R_{\rho} = \alpha^{\Theta}\Theta_z / \beta^{\Theta}(S_{\text{A}})_z \approx \alpha^{\theta}\theta_z / \beta^{\theta}(S_{\text{A}})_z$.
isopycnal temperature gradient ratio	G^{Θ}	1	$G^{\Theta} = r[R_{\rho}-1]/[R_{\rho}-r]$; $\nabla_{\sigma}\Theta = G^{\Theta}\nabla_n\Theta$
Practical Salinity	S_{P}	1	Defined in the range $2 < S_{\text{P}} < 42$ by PSS-78 based on measured conductivity ratios.
Reference Salinity	S_{R}	g kg^{-1}	Reference-Composition Salinity (or Reference Salinity for short) is the Absolute Salinity of seawater samples that have Reference Composition. At $S_{\text{P}} = 35$, S_{R} is exactly $u_{\text{PS}}S_{\text{P}}$. while in the range $2 < S_{\text{P}} < 42$ $S_{\text{R}} \approx u_{\text{PS}}S_{\text{P}}$.
Absolute Salinity (This is the salinity argument of all the GSW Toolbox functions.)	$S_{\text{A}} = S_{\text{A}}^{\text{dens}}$	g kg^{-1}	$S_{\text{A}} = S_{\text{R}} + \delta S_{\text{A}} \approx u_{\text{PS}}S_{\text{P}} + \delta S_{\text{A}}$ Absolute Salinity is the sum of S_{R} on the Millero *et al.* (2008a) Reference-Salinity Scale and the Absolute Salinity Anomaly. The full symbol for S_{A} is $S_{\text{A}}^{\text{dens}}$ as it is the type of absolute salinity which delivers the best estimate of density when used as the salinity argument of the TEOS-10 Gibbs function. Another name for $S_{\text{A}} = S_{\text{A}}^{\text{dens}}$ is "Density Salinity".
Absolute Salinity Anomaly	δS_{A}	g kg^{-1}	$\delta S_{\text{A}} = S_{\text{A}} - S_{\text{R}}$, the difference between Absolute Salinity, $S_{\text{A}} = S_{\text{A}}^{\text{dens}}$, and Reference-Composition Salinity. In terms of the full nomenclature of Pawlowicz *et al.* (2010), Wright *et al.* (2010b) and appendix A.4 herein, the Absolute Salinity Anomaly δS_{A} is $\delta S_{\text{R}}^{\text{dens}}$.
"Preformed Absolute Salinity", often shortened to "Preformed Salinity"	S_*	g kg^{-1}	Preformed Absolute Salinity S_* is a salinity variable that is designed to be as conservative as possible, by removing the estimated biogeochemical influences on the seawater composition from other forms of salinity (see Pawlowicz *et al.* (2010), Wright *et al.* (2010b)).
"Solution Absolute Salinity", often shortened to "Solution Salinity"	$S_{\text{A}}^{\text{soln}}$	g kg^{-1}	The mass fraction of non-H_2O constituents in seawater after it has been brought to chemical equilibrium at $t = 25°C$ and $p = 0$ dbar (see Pawlowicz *et al.* (2010), Wright *et al.* (2010b)).
"Added-Mass Salinity"	$S_{\text{A}}^{\text{add}}$	g kg^{-1}	$S_{\text{A}}^{\text{add}} - S_{\text{R}}$ is the estimated mass fraction of non-H_2O constituents needed as ingredients to be added to Standard Seawater which when mixed and brought to chemical equilibrium at $t = 25°C$ and $p = 0$ dbar results in the observed seawater composition.

temperature	t	°C	
Absolute Temperature	T	K	$T/K \equiv T_0/K + t/(°C) = 273.15 + t/(°C)$
temperature derivatives	T	K	When a quantity is differentiated with respect to *in situ* temperature, the symbol T is used in order to distinguish this variable from time.
Celsius zero point	T_0	K	$T_0 \equiv 273.15$ K
potential temperature	θ	°C	Defined implicitly by Eqn. (3.1.3)
Conservative Temperature	Θ	°C	Defined in Eqn. (3.3.1) as exactly potential enthalpy divided by c_p^0.
the "specific heat", for use with Conservative Temperature	c_p^0	J kg^{-1} K^{-1}	$c_p^0 \equiv 3991.867\,957\,119\,63$ J kg^{-1} K^{-1}. This 15-digit number is defined to be the exact value of c_p^0. c_p^0 is the ratio of potential enthalpy h^0 to Θ.
combined standard uncertainty	u_c	Varies	
enthalpy	H	J	
specific enthalpy	h	J kg^{-1}	$h = u + (p+P_0)v$. Here p and P_0 must be in Pa not dbar.
specific potential enthalpy	h^0	J kg^{-1}	specific enthalpy referenced to zero sea pressure, $h^0 = h(S_\text{A}, \theta[S_\text{A}, t, p, p_\text{r}=0], p_\text{r}=0)$
specific isobaric heat capacity	c_p	J kg^{-1} K^{-1}	$c_p = \partial h/\partial T\big|_{S_\text{A}, p}$
internal energy	U	J	
specific internal energy	u	J kg^{-1}	
specific isochoric heat capacity	c_v	J kg^{-1} K^{-1}	$c_v = \partial u/\partial T\big|_{S_\text{A}, v}$
Gibbs function (Gibbs energy)	G	J	
specific Gibbs function (Gibbs energy)	g	J kg^{-1}	
specific Helmholtz energy	f	J kg^{-1}	
unit conversion factor for salinities	u_PS	g kg^{-1}	$u_\text{PS} \equiv (35.16504/35)$ g kg^{-1} $\approx 1.004\,715...$ g kg^{-1} The first part of this expression is exact. This conversion factor is an important and invariant constant of the 2008 Reference-Salinity Scale (Millero *et al.* (2008a)).
entropy	Σ	J K^{-1}	
specific entropy	η	J kg^{-1} K^{-1}	In many other publications the symbol s is used for specific entropy.
density	ρ	kg m^{-3}	
density anomaly	σ^t	kg m^{-3}	$\rho(S_\text{A}, t, 0) - 1000$ kg m^{-3}
potential density anomaly referenced to a sea pressure of 2000 dbar	σ_2	kg m^{-3}	$\rho(S_\text{A}, \theta[S_\text{A}, t, p, p_\text{r}], p_\text{r}) - 1000$ kg m^{-3} where $p_\text{r} = 2000$ dbar
potential density anomaly referenced to a sea pressure of 4000 dbar	σ_4	kg m^{-3}	$\rho(S_\text{A}, \theta[S_\text{A}, t, p, p_\text{r}], p_\text{r}) - 1000$ kg m^{-3} where $p_\text{r} = 4000$ dbar
thermal expansion coefficient with respect to *in situ* temperature	α^t	K^{-1}	$v^{-1}\partial v/\partial T\big|_{S_\text{A}, p} = -\rho^{-1}\partial\rho/\partial T\big|_{S_\text{A}, p}$
thermal expansion coefficient with respect to potential temperature θ	α^θ	K^{-1}	$v^{-1}\partial v/\partial\theta\big|_{S_\text{A}, p} = -\rho^{-1}\partial\rho/\partial\theta\big|_{S_\text{A}, p}$

thermal expansion coefficient with respect to Conservative Temperature Θ	α^{Θ}	K^{-1}	$v^{-1}\partial v / \partial\Theta\big|_{S_A,p} = -\rho^{-1}\partial\rho / \partial\Theta\big|_{S_A,p}$
saline contraction coefficient at constant *in situ* temperature	β^{t}	kg g^{-1}	$-v^{-1}\partial v / \partial S_A\big|_{T,p} = \rho^{-1}\partial\rho / \partial S_A\big|_{T,p}$ Note that the units for β^{t} are consistent with S_A being in g kg^{-1}.
saline contraction coefficient at constant potential temperature	β^{θ}	kg g^{-1}	$-v^{-1}\partial v / \partial S_A\big|_{\theta,p} = \rho^{-1}\partial\rho / \partial S_A\big|_{\theta,p}$ Note that the units for β^{θ} are consistent with S_A being in g kg^{-1}.
saline contraction coefficient at constant Conservative Temperature	β^{Θ}	kg g^{-1}	$-v^{-1}\partial v / \partial S_A\big|_{\Theta,p} = +\rho^{-1}\partial\rho / \partial S_A\big|_{\Theta,p}$ Note that the units for β^{Θ} are consistent with S_A being in g kg^{-1}.
isothermal compressibility	κ^{t}	Pa^{-1}	
isentropic and isohaline compressibility	κ	Pa^{-1}	
chemical potential of water in seawater	μ^{W}	J g^{-1}	
chemical potential of sea salt in seawater	μ^{S}	J g^{-1}	
relative chemical potential of (sea salt and water in) seawater	μ	J g^{-1}	$\left(\partial g/\partial S_A\right)_{t,p} = \mu^{S} - \mu^{W}$
dissipation rate of kinetic energy per unit mass	ε	$\text{J kg}^{-1}\text{ s}^{-1}$ $= \text{m}^2\text{ s}^{-3}$	
adiabatic lapse rate	Γ	K Pa^{-1}	$\Gamma = \dfrac{f t}{f P}\bigg|_{S_A,\theta} = \dfrac{f t}{f P}\bigg|_{S_A,\Theta} = \dfrac{f t}{f P}\bigg|_{S_A,\eta} = \dfrac{f v}{f\eta}\bigg|_{S_A,p} = \dfrac{(T_0+\theta)}{c_p^0}\dfrac{f v}{f\Theta}\bigg|_{S_A,p}$
sound speed	c	m s^{-1}	
specific volume	v	$\text{m}^3\text{ kg}^{-1}$	$v = \rho^{-1}$
specific volume anomaly	δ	$\text{m}^3\text{ kg}^{-1}$	
thermobaric coefficient based on θ	T_b^{θ}	$\text{K}^{-1}\text{Pa}^{-1}$	$T_b^{\theta} = \beta^{\theta}\,\partial\left(\alpha^{\theta}/\beta^{\theta}\right)/\partial P\big|_{S_A,\theta}$
thermobaric coefficient based on Θ	T_b^{Θ}	$\text{K}^{-1}\text{Pa}^{-1}$	$T_b^{\Theta} = \beta^{\Theta}\,\partial\left(\alpha^{\Theta}/\beta^{\Theta}\right)/\partial P\big|_{S_A,\Theta}$
cabbeling coefficient based on θ	C_b^{θ}	K^{-2}	$C_b^{\theta} = \partial\alpha^{\theta}/\partial\theta\big|_{S_A,p} + 2\dfrac{\alpha^{\theta}}{\beta^{\theta}}\partial\alpha^{\theta}/\partial S_A\big|_{\theta,p} - \left(\dfrac{\alpha^{\theta}}{\beta^{\theta}}\right)^2\partial\beta^{\theta}/\partial S_A\big|_{\theta,p}$
cabbeling coefficient based on Θ	C_b^{Θ}	K^{-2}	$C_b^{\Theta} = \partial\alpha^{\Theta}/\partial\Theta\big|_{S_A,p} + 2\dfrac{\alpha^{\Theta}}{\beta^{\Theta}}\partial\alpha^{\Theta}/\partial S_A\big|_{\Theta,p} - \left(\dfrac{\alpha^{\Theta}}{\beta^{\Theta}}\right)^2\partial\beta^{\Theta}/\partial S_A\big|_{\Theta,p}$
buoyancy frequency	N	s^{-1}	$N^2 = g\left(\alpha^{\Theta}\Theta_z - \beta^{\Theta}S_{A_z}\right) = g\left(\alpha^{\theta}\theta_z - \beta^{\theta}S_{A_z}\right)$
neutral helicity	H^{n}	m^{-3}	defined by Eqns. (3.13.1) and (3.13.2)
Neutral Density	γ^{n}	kg m^{-3}	a density variable whose iso-surfaces are designed to be approximately neutral, i. e. $\alpha^{\Theta}\nabla_{\gamma}\Theta \approx \beta^{\Theta}\nabla_{\gamma}S_A.$
Neutral-Surface-Potential-Vorticity	$NSPV$	s^{-3}	$NSPV = -g\rho^{-1}f\gamma_z^{n}$ where f is the Coriolis parameter.
dynamic height anomaly	Ψ	$\text{m}^2\text{ s}^{-2}$	$\text{Pa m}^3\text{ kg}^{-1} = \text{m}^2\text{ s}^{-2}$
Montgomery geostrophic streamfunction	Ψ^{M}	$\text{m}^2\text{ s}^{-2}$	$\text{Pa m}^3\text{ kg}^{-1} = \text{m}^2\text{ s}^{-2}$

PISH (Pressure-Integrated Steric Height)	Ψ'	kg s^{-2}	streamfunction for f times the depth-integrated relative mass flux, see Eqns. (3.31.1) – (3.31.5).
Coriolis parameter	f	s^{-1}	$1.458\,42\,x10^{-4}\sin\phi$ s^{-1}, where ϕ is latitude
molar mass of Reference Seawater	M_S	g mol^{-1}	M_S is the mole-weighted average atomic weight of the constituents of Reference Seawater, $M_S = 31.403\,821\,8...$ g mol^{-1}, from Millero *et al.* (2008a).
molality of seasalt in Reference Seawater	m_{SW}	mol kg^{-1}	$m_{SW} = \square_i m_i = \dfrac{1}{M_S}\dfrac{S_A}{(1-S_A)}$. m_i is the molality of constituent i in Reference Seawater.
valence factor of Reference Seawater	Z^2	1	$Z^2 = \square_i X_i Z_i^2 \ ...1.245\,289\,8$ where Z_i is the charge of seawater constituent i which is present at the mole fraction X_i in Reference Seawater (from Millero *et al.* (2008a)).
ionic strength of Reference Seawater	I	mol kg^{-1}	$I \;=\; \tfrac{1}{2}m_{SW}Z^2 \;=\; \tfrac{1}{2}\square_i m_i Z_i^2$ $= 0.622\,644\,9\, m_{SW}$ $\cup \dfrac{0.622\,644\,9}{0.031\,403\,821\,8}\text{mol kg}^{-1}\dfrac{S_A}{(1-S_A)}$. m_i is the molality of constituent i in Reference Seawater.
osmotic coefficient	ϕ	1	$\phi(S_A,T,p) = \dfrac{g(0,t,p) - \mu^W(S_A,t,p)}{m_{SW}R(T_0+t)}$ where the molar gas constant, $R = 8.314\,472$ J mol^{-1} K^{-1}. See also Eqns. (2.14.1) and (3.40.9) for an equivalent definition of ϕ.

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