This is appendix M of the TEOS-10 Manual (IOC *et al*. (2010)).

Appendix M:
Seawater-Ice-Air (SIA) library of computer software

This software library, the Seawater-Ice-Air library (the SIA library for short), contains the TEOS-10 subroutines for evaluating a wide range of thermodynamic properties of pure water (using IAPWS-95), seawater (using IAPWS-08 for the saline part), ice Ih (using IAPWS-06) and for moist air (using Feistel *et al.* (2010a), IAPWS (2010)). It is divided into six levels (levels 0 through 5) with each successive level building on the functional capabilities introduced at lower levels. Briefly,

- level 0 defines fundamental constants, sets options used throughout the library and provides routines to convert between Practical Salinity and Absolute Salinity
- level 1 defines a complete set of independent and consistent elements that are based on previous work and form the essential building blocks for the rest of the library routines
- level 2 provides access to a set of properties for individual mediums (liquid or vapour water, ice, seawater and dry or humid air) that can be calculated from the level 0 and 1 routines without additional approximations
- level 3 introduces additional functions that require numerical solution of equations. Most importantly, it is at this level that the density of pure fluid water is determined from temperature and pressure information. This permits the definition of Gibbs functions for pure water and seawater that make use of the IAPWS-95 Helmholtz function as a fundamental building block
- level 4 deals with a fairly broad (but not exhaustive) selection of equilibrium properties involving fluid water, seawater, ice and air; and
- level 5 includes a set of routines that build on the SIA routines but violate principals adhered to throughout levels 0 though 4. In particular, non-basic SI units are permitted at this level as discussed below.

As a general rule, the inputs and the outputs of the algorithms in the SIA library are in basic SI units. Hence the salinity is Absolute Salinity S_A in units of $\mathrm{kg\ kg^{-1}}$ (so that for example standard ocean Reference Salinity is input to SIA functions as 0.035 165 04 ($\mathrm{kg\ kg^{-1}}$) rather than 35.165 04 ($\mathrm{g\ kg^{-1}}$), *in situ* temperature is input as Absolute Temperature T in K, and pressure is input as Absolute Pressure P in Pa. Use of these basic SI units simplifies the calculation of theoretical expressions in thermodynamics. The only exceptions to this rule for the units of the inputs and outputs in the SIA library are as follows.

- The function $S_\mathrm{A} = S_\mathrm{A}(S_\mathrm{P}, \phi, \lambda, P)$ that calculates Absolute Salinity (in kg kg^{-1}) when given Practical Salinity S_P (which is unitless and takes numbers like 35 not 0.035) as its salinity input variable, along with location in the form of longitude λ (°E) latitude ϕ (°N) and Absolute Pressure P (Pa). Location is required in this routine to account for the influence of composition anomalies through a lookup table adopted from the GSW Oceanographic Toolbox.

- The inverse function $S_{\mathrm{P}} = S_{\mathrm{P}}\left(S_{\mathrm{A}}, \phi, \lambda, P\right)$. This and the previous routine are found at level 0 since Absolute Salinity is required as an input to many of the higher level library routines.
- General purpose routines that allow for conversions between a broad range of pressure, temperature and salinity units that are in common usage are provided at level 5. The numerical input value and its unit are provided by the user and results are returned in a specified output unit.
- Algorithms are included at level 5 that use non-basic SI units as input and as output. Most noteworthy is the GSW library module that uses the SIA routines to mimic many of the routines in the GSW Oceanographic Toolbox. These routines use IAPWS-09 for pure water in place of IAPWS-95 to provide improved computational efficiency. They have been used to provide independent checks on the corresponding routines in the GSW Oceanographic Toolbox.

Because the IAPWS-95 description of pure water substance (both liquid and vapour) is the world-wide standard for pure water substance, the SIA library is the official description of seawater, although it should be noted that the computer software does not come with any warranty. Rather it is the underlying papers as listed in appendix C that are the officially warranted descriptions.

The SIA library benefits from the full range of applicability of the IAPWS-95 Helmholtz function for pure water, 0 kg m^{-3} < ρ < 1200 kg m^{-3}, 130 K < T < 1273 K, plus an extension down to 50 K introduced by Feistel et al. (2010a). It does however have two disadvantages as far as the field of oceanography is concerned. First, because IAPWS-95 is valid over very wide ranges of temperature and pressure, it is necessarily an extensive series of polynomials and exponentials which is not as fast computationally as the equation of state EOS-80 with which oceanographers are familiar. Second, the IAPWS-95 thermodynamic potential is a Helmholtz function which expresses thermodynamic properties in terms of density and temperature rather than pressure and temperature as normally used in oceanography. Since IAPWS-95 describes not only liquid water but also water vapour, this Helmholtz form of the thermodynamic potential is natural. Although the library also includes a Gibbs function formulation with temperature and pressure as independent variables, the core routines implement this formulation by first solving $P = \rho^2 f_\rho(T,\rho)$ for ρ and then using IAPWS-95, which is a computationally expensive procedure.

In the GSW Oceanographic Toolbox (appendix N) we present an alternative thermodynamic description of seawater properties based on the IAPWS-09 description of the pure liquid water part as a Gibbs function. The GSW formulation is limited to the Neptunian range (i. e. the oceanographic range) of temperature and pressure and deals only with liquid water, but it is far more computationally efficient since the limited range of validity allows equivalent accuracy with fewer terms and the Gibbs function formulation avoids the need to invert the relation $P = \rho^2 f_\rho(T,\rho)$. This formulation is also implemented at level 5 of the SIA library as a cross-check on the GSW routines and for the convenience of SIA library users working on applications requiring increased computational efficiency. Note however that some of routines in the SIA implementation of the GSW routines are not as fully optimized as the corresponding routines in the GSW Oceanographic Toolbox.

The presence of dissolved salts in seawater reduces the range of applicability of the SIA and GSW seawater routines in comparison with the IAPWS-95 range of applicability for pure fluid water, whether or not the IAPWS-09 Gibbs formulation is used to represent pure water properties. This is because the range of applicability of the saline component of the Gibbs function is limited to $0 \text{ kg kg}^{-1} \le S_A \le 0.12 \text{ kg kg}^{-1}$, $262 \text{ K} \le T \le 353 \text{ K}$, and $100 \text{ Pa} \le P \le 10^8 \text{ Pa}$.

Since this manual focuses on seawater, we refer the reader to Feistel *et al.* (2010b) and Wright *et al.* (2010a) for details on the ice and air components of the SIA library. However, below, we discuss a few features of the library that relate to these additional components. First, we note that the thermodynamic potentials of pure water, ice, the saline part of the seawater Gibbs function and the Gibbs function of moist air have been carefully adjusted to make them fully compatible with each other (Feistel *et al.* (2008a)). Only by so doing can the equilibrium properties of coincident phases be accurately evaluated (for example, the freezing temperature of pure water and of seawater). Many functions involving equilibrium properties of water, vapour, ice, seawater and dry or humid air are implemented in level 4 of the SIA library. To provide an indication of the range of functions available, we have listed the routine names in Table M.1 below. This table comes from Table 3.1 of Wright *et al*. (2010a); we refer the interested reader to Feistel *et al.* (2010b)) and Wright *et al.* (2010a)) for detailed information. Wright *et al.* (2010a) provide a supplementary table that is cross-referenced to their Table 3.1 to give details on the usage of each routine and each table in their supplement references in turn the relevant sections of Feistel *et al*. (2010b) for additional background information.

Due to the fact that each level of the SIA library builds on lower levels and the fact that multiple phases may be involved in the equilibrium calculations, the determination of the ranges of validity of the routines in the SIA library can become rather involved. To deal with this issue, a procedure has been implemented in the library to return an error code for function evaluations that depend on results from any of the basic building block routines from outside of their individual ranges of validity. Numerical check values are provided with each of the routines in the library and auxiliary routines are provided to assist users in the validation of local implementations.

Further details of the SIA software library are provided in the papers Feistel *et al.* (2010b)) and Wright *et al.* (2010a)) and the software is served from the www.TEOS-10.org web site.

Table M.1. The SIA library contents. Module names are in bold and user-accessible routines are in plain type. Each of the Public Routines can be accessed by users. The underlined routines are thermodynamic potential functions including first and second derivatives. The bracketed numbers preceding most module names give the related table numbers in the supplement to Wright et al. (2010a) where detailed information on the use of each function is provided.

Level 0 routines

Constants_0	**Constants_0 (Cont'd)**	**Maths_0**	**(S2) Convert_0**
Public Parameter Values	Parameter Values (cont'd)	Uses	Uses
celsius_temperature_si	mix_air_dmax	constants_0	constants_0
check_limits	mix_air_dmin		
cp_chempot_si	mix_air_tmax	Public Routines	Public Routines
cp_density_si	mix_air_tmin	get_cubicroots	air_massfraction_air_si
cp_pressure_si	molar_mass_air_si	matrix_solve	air_massfraction_vap_si
cp_temperature_si	molar_mass_air_l2000		air_molar_mass_si
dry_air_dmax	molar_mass_h2o_si		air_molfraction_air_si
dry_air_dmin	molar_mass_seasalt_si		air_molfraction_vap_si
dry_air_tmax	pi		asal_from_psal
dry_air_tmin	sal_pmax		psal_from_asal
errorreturn	sal_pmin		
flu_dmax	sal_smax		
flu_dmin	sal_smin		
flu_tmax	sal_tmax		
flu_tmin	sal_tmin		
gas_constant_air_si	sealevel_pressure_si		
gas_constant_air_L2000	so_salinity_si		
gas_constant_molar_si	so_temperature_si		
gas_constant_molar_L2000	so_pressure_si		
gas_constant_h2O_si	tp_density_ice_iapws95_si		
gas_constant_h2O_iapws95	tp_density_liq_iapws95_si		
ice_pmax	tp_density_vap_iapws95_si		
ice_pmin	tp_enthalpy_ice_si		
ice_tmax	tp_enthalpy_vap_si		
ice_tmin	tp_pressure_exp_si		
isextension2010	tp_pressure_iapws95_si		
isok	tp_temperature_si		

Level 1 routines

(S3) Flu_1 (IAPWS95)	**(S4) Ice_1 (IAPWS06)**	**(S5) Sal_1 (IAPWS08)**	**(S6) Air_1**
Uses	Uses	Uses	Uses
constants_0	constants_0	constants_0	constants_0
Public Routines	Public Routines	Public Routines	Public Routines
chk_iapws95_table6	chk_iapws06_table6	sal_g_term_si	air_baw_m3mol
chk_iapws95_table7	ice_g_si		air_caaw_m6mol2
flu_f_si			air_caww_m6mol2
			dry_f_si
			dry_init_clear
			dry_init_Lemmon2000

Level 2 routines

(S7) Flu_2	((S8) Ice_2	(S9) Sal_2	(S10) Air_2
Uses constants_0, flu_1 Public Routines flu_cp_si flu_cv_si flu_enthalpy_si flu_entropy_si flu_expansion_si flu_gibbs_energy_si flu_internal_energy_si flu_kappa_s_si flu_kappa_t_si flu_lapserate_si flu_pressure_si flu_soundspeed_si	Uses constants_0, ice_1 Public Routines ice_chempot_si ice_cp_si ice_density_si ice_enthalpy_si ice_entropy_si ice_expansion_si ice_helmholtz_energy_si ice_internal_energy_si ice_kappa_s_si ice_kappa_t_si ice_lapserate_si ice_p_coefficient_si ice_specific_volume_si	Uses constants_0, sal_1 Public Routines sal_act_coeff_si sal_act_potential_si sal_activity_w_si sal_chem_coeff_si sal_chempot_h2o_si sal_chempot_rel_si sal_dilution_si sal_g_si sal_mixenthalpy_si sal_mixentropy_si sal_mixvolume_si sal_molality_si sal_osm_coeff_si sal_saltenthalpy_si sal_saltentropy_si sal_saltvolume_si	Uses constants_0, flu_1, air_1 Public Routines air_f_si air_f_cp_si air_f_cv_si air_f_enthalpy_si air_f_entropy_si air_f_expansion_si air_f_gibbs_energy_si air_f_internal_energy_si air_f_kappa_s_si air_f_kappa_t_si air_f_lapserate_si air_f_mix_si air_f_pressure_si air_f_soundspeed_si chk_iapws10_table

Level 3 routines

(S11) Flu_3a		(S12) Sea_3a	(S13) Air_3a
Uses constants_0, convert_0, maths_0, flu_1 Public Routines get_it_ctrl_density liq_density_si liq_g_si set_it_ctrl_density vap_density_si vap_g_si		Uses constants_0, sal_1, sal_2, flu_3a (convert_0, maths_0, flu_1) Public Routines chk_iapws08_table8a chk_iapws08_table8b chk_iapws08_table8c sea_chempot_h2o_si sea_chempot_rel_si sea_cp_si sea_density_si sea_enthalpy_si sea_entropy_si sea_g_si sea_g_contraction_t_si sea_g_expansion_si sea_gibbs_energy_si sea_internal_energy_si sea_kappa_s_si sea_kappa_t_si sea_lapserate_si sea_osm_coeff_si sea_soundspeed_si sea_temp_maxdensity_si	Uses constants_0, convert_0, maths_0, air_1, air_2 (flu_1) Public Routines air_density_si air_g_si get_it_ctrl_airdensity set_it_ctrl_airdensity

(S14) Flu_3b Uses constants_0, flu_2, flu_3a (convert_0, maths_0, flu_1) Public Routines liq_cp_si liq_cv_si liq_enthalpy_si liq_entropy_si liq_expansion_si liq_gibbs_energy_si liq_internal_energy_si liq_kappa_s_si liq_kappa_t_si liq_lapserate_si liq_soundspeed_si vap_cp_si vap_cv_si vap_enthalpy_si vap_entropy_si vap_expansion_si vap_gibbs_energy_si vap_internal_energy_si vap_kappa_s_si vap_kappa_t_si vap_lapserate_si vap_soundspeed_si		**(S15) Sea_3b** Uses constants_0, sal_2, flu_3a, sea_3a (convert_0, maths_0, flu_1, sal_1) Public Routines sea_h_si sea_h_contraction_h_si sea_h_contraction_t_si sea_h_contraction_theta_si sea_h_expansion_h_si sea_h_expansion_t_si sea_h_expansion_theta_si sea_potdensity_si sea_potenthalpy_si sea_pottemp_si sea_temperature_si set_it_ctrl_pottemp	**(S16) Air_3b** Uses constants_0, convert_0, air_1, air_2, air_3a (maths_0, flu_1) Public Routines air_g_chempot_vap_si air_g_compressibility factor_si air_g_contraction_si air_g_cp_si air_g_cv_si air_g_density_si air_g_enthalpy_si air_g_entropy_si air_g_expansion_si air_g_gibbs_energy_si air_g_internal_energy_si air_g_kappa_s_si air_g_kappa_t_si air_g_lapserate_si air_g_soundspeed_si chk_lemmon_etal_2000

		(S17) Sea_3c Uses constants_0, sea_3a, sea_3b (convert_0, maths_0, flu_1, sal_1, sal_2, flu_3a) Public Routines sea_eta_contraction_h_si sea_eta_contraction_t_si sea_eta_contraction_theta_si sea_eta_density_si sea_eta_entropy_si sea_eta_expansion_h_si sea_eta_expansion_t_si sea_eta_expansion_theta_si sea_eta_potdensity_si sea_eta_pottemp_si sea_eta_temperature_si set_it_ctrl_entropy_si	**(S18) Air_3c** Uses constants_0, convert_0, air_2, air_3a, air_3b (maths_0, air_1, flu_1) Public Routines air_h_si air_potdensity_si air_potenthalpy_si air_pottemp_si air_temperature_si set_it_ctrl_air_pottemp

		(S19) Sea_3d Uses constants_0, sal_2, flu_3a (convert_0, maths_0, flu_1, sal_1) Public Routines sea_sa_si set_it_ctrl_salinity	

Level 4 routines

(S20) Liq_Vap_4	(S21) Ice_Vap_4	(S22) Sea_Vap_4	
Uses constants_0, maths_0, flu_1, flu_2, flu_3a (Convert_0) Public Routines chk_iapws95_table8 liq_vap_boilingtemperature_si liq_vap_chempot_si liq_vap_density_liq_si liq_vap_density_vap_si liq_vap_enthalpy_evap_si liq_vap_enthalpy_liq_si liq_vap_enthalpy_vap_si liq_vap_entropy_evap_si liq_vap_entropy_liq_si liq_vap_entropy_vap_si liq_vap_pressure_liq_si liq_vap_pressure_vap_si liq_vap_temperature_si liq_vap_vapourpressure_si liq_vap_volume_evap_si set_liq_vap_eq_at_p set_liq_vap_eq_at_t set_it_ctrl_liq_vap	Uses constants_0, maths_0, flu_1, flu_2, ice_1, ice_2 Public Routines ice_vap_chempot_si ice_vap_density_ice_si ice_vap_density_vap_si ice_vap_enthalpy_ice_si ice_vap_enthalpy_subl_si ice_vap_enthalpy_vap_si ice_vap_entropy_ice_si ice_vap_entropy_subl_si ice_vap_entropy_vap_si ice_vap_pressure_vap_si ice_vap_sublimationpressure_si ice_vap_sublimationtemp_si ice_vap_temperature_si ice_vap_volume_subl_si set_ice_vap_eq_at_p set_ice_vap_eq_at_t set_it_ctrl_ice_vap	Uses constants_0, maths_0, flu_1, sal_1, sal_2, flu_3a, sea_3a, flu_3b (convert_0, flu_2) Public Routines sea_vap_boilingtemperature_si sea_vap_brinefraction_seavap_si sea_vap_brinesalinity_si sea_vap_cp_seavap_si sea_vap_density_sea_si sea_vap_density_seavap_si sea_vap_density_vap_si sea_vap_enthalpy_evap_si sea_vap_enthalpy_sea_si sea_vap_enthalpy_seavap_si sea_vap_enthalpy_vap_si sea_vap_entropy_sea_si sea_vap_entropy_seavap_si sea_vap_entropy_vap_si sea_vap_expansion_seavap_si sea_vap_g_si sea_vap_kappa_t_seavap_si sea_vap_pressure_si sea_vap_salinity_si sea_vap_temperature_si sea_vap_vapourpressure_si sea_vap_volume_evap_si set_it_ctrl_sea_vap set_sea_vap_eq_at_s_p set_sea_vap_eq_at_s_t set_sea_vap_eq_at_t_p	

	(S23) Ice_Liq_4	(S24) Sea_Liq_4	
	Uses constants_0, maths_0, flu_1, ice_1, flu_2, ice_2 Public Routines ice_liq_chempot_si ice_liq_density_ice_si ice_liq_density_liq_si ice_liq_enthalpy_ice_si ice_liq_enthalpy_liq_si ice_liq_enthalpy_melt_si ice_liq_entropy_ice_si ice_liq_entropy_liq_si ice_liq_entropy_melt_si ice_liq_meltingpressure_si ice_liq_meltingtemperature_si ice_liq_pressure_liq_si ice_liq_temperature_si ice_liq_volume_melt_si set_ice_liq_eq_at_p set_ice_liq_eq_at_t set_it_ctrl_ice_liq	Uses constants_0, flu_1, sal_1, flu_2, sal_2, flu_3a (convert_0, maths_0) Public Routines sea_liq_osmoticpressure_si set_sea_liq_eq_at_s_t_p set_it_ctrl_sea_liq	

		(S25) Sea_Ice_4 Uses constants_0, convert_0, maths_0, flu_1, ice_1, sal_1, ice_2, sal_2, flu_3a, sea_3a, flu_3b (flu_2) Public Routines sea_ice_brinefraction_seaice_si sea_ice_brinesalinity_si sea_ice_cp_seaice_si sea_ice_density_ice_si sea_ice_density_sea_si sea_ice_density_seaice_si sea_ice_dtfdp_si sea_ice_dtfds_si sea_ice_enthalpy_ice_si sea_ice_enthalpy_melt_si sea_ice_enthalpy_sea_si sea_ice_enthalpy_seaice_si sea_ice_entropy_ice_si sea_ice_entropy_sea_si sea_ice_entropy_seaice_si sea_ice_expansion_seaice_si sea_ice_freezingtemperature_si sea_ice_g_si sea_ice_kappa_t_seaice_si sea_ice_meltingpressure_si sea_ice_pressure_si sea_ice_salinity_si sea_ice_temperature_si sea_ice_volume_melt_si set_it_ctrl_sea_ice set_sea_ice_eq_at_s_p set_sea_ice_eq_at_s_t set_sea_ice_eq_at_t_p	

		(S26) Sea_Air_4 Uses constants_0, convert_0, maths_0, flu_1, sal_1, air_1, flu_2, sal_2, air_2, flu_3a, sea_3a, air_3a, air_3b, liq_vap_4, liq_air_4a Public Routines sea_air_chempot_evap_si sea_air_condense_temp_si sea_air_density_air_si sea_air_density_vap_si sea_air_enthalpy_evap_si sea_air_entropy_air_si sea_air_massfraction_air_si sea_air_vapourpressure_si set_it_ctrl_sea_air set_sea_air_eq_at_s_a_p set_sea_air_eq_at_s_t_p	

(S27) Liq_Ice_Air_4 Uses constants_0, convert_0, maths_0, flu_1, ice_1, air_1, flu_2, ice_2, air_2, air_3b, ice_liq_4 (air_3a) Public Routines liq_ice_air_airfraction_si liq_ice_air_density_si liq_ice_air_dryairfraction_si liq_ice_air_enthalpy_si liq_ice_air_entropy_si liq_ice_air_ifl_si liq_ice_air_iml_si liq_ice_air_liquidfraction_si liq_ice_air_pressure_si liq_ice_air_solidfraction_si liq_ice_air_temperature_si liq_ice_air_vapourfraction_si set_liq_ice_air_eq_at_a set_liq_ice_air_eq_at_p set_liq_ice_air_eq_at_t set_liq_ice_air_eq_at _wa_eta_wt set_liq_ice_air_eq_at _wa_wl_wi set_it_ctrl_liq_ice_air		**(S28) Sea_Ice_Vap_4** Uses constants_0, maths_0, flu_1, ice_1, sal_1, sal_2 Public Routines sea_ice_vap_density_vap_si sea_ice_vap_pressure_si sea_ice_vap_salinity_si sea_ice_vap_temperature_si set_it_ctrl_sea_ice_vap set_sea_ice_vap_eq_at_p set_sea_ice_vap_eq_at_s set_sea_ice_vap_eq_at_t	

(S29) Liq_Air_4a Uses constants_0, convert_0, maths_0, flu_1, air_1, flu_2, air_2, flu_3a, air_3a, air_3b, liq_vap_4 Public Routines liq_air_a_from_rh_cct_si liq_air_a_from_rh_wmo_si liq_air_condensationpressure_si liq_air_density_air_si liq_air_density_liq_si liq_air_density_vap_si liq_air_dewpoint_si liq_air_enthalpy_evap_si liq_air_entropy_air_si liq_air_icl_si liq_air_ict_si liq_air_massfraction_air_si liq_air_pressure_si liq_air_rh_cct_from_a_si liq_air_rh_wmo_from_a_si liq_air_temperature_si set_it_ctrl_liq_air set_liq_air_eq_at_a_eta set_liq_air_eq_at_a_p set_liq_air_eq_at_a_t set_liq_air_eq_at_t_p	**(S30) Ice_Air_4a** Uses constants_0, convert_0, maths_0, air_1, ice_1, ice_2, air_2, air_3a, air_3b, ice_vap_4 (flu_1, flu_2) Public Routines ice_air_a_from_rh_cct_si ice_air_a_from_rh_wmo_si ice_air_condensationpressure_si ice_air_density_air_si ice_air_density_ice_si ice_air_density_vap_si ice_air_enthalpy_subl_si ice_air_frostpoint_si ice_air_icl_si ice_air_ict_si ice_air_massfraction_air_si ice_air_pressure_si ice_air_rh_cct_from_a_si ice_air_rh_wmo_from_a_si ice_air_sublimationpressure_si ice_air_temperature_si set_ice_air_eq_at_a_eta set_ice_air_eq_at_a_p set_ice_air_eq_at_a_t set_ice_air_eq_at_t_p set_it_ctrl_ice_air		

(S31) Liq_Air_4b Uses constants_0, flu_3a, air_3a, liq_air_4a (convert_0, maths_0, flu_1, air_1, flu_2, air_2, air_3b, liq_vap_4) Public Routines liq_air_g_si liq_air_g_cp_si liq_air_g_density_si liq_air_g_enthalpy_si liq_air_g_entropy_si liq_air_g_expansion_si liq_air_g_kappa_t_si liq_air_g_lapserate_si liq_air_liquidfraction_si liq_air_vapourfraction_si	**(S32) Ice_Air_4b** Uses constants_0, convert_0, ice_1, air_3a, ice_air_4a (maths_0, flu_1, air_1, flu_2, ice_2, air_2, air_3b, ice_vap_4) Public Routines ice_air_g_si ice_air_g_cp_si ice_air_g_density_si ice_air_g_enthalpy_si ice_air_g_entropy_si ice_air_g_expansion_si ice_air_g_kappa_t_si ice_air_g_lapserate_si ice_air_solidfraction_si ice_air_vapourfraction_si		

(S33) Liq_Air_4c Uses constants_0, air_3a, ice_liq_4, liq_air_4a, liq_air_4b (convert_0, maths_0, flu_1, ice_1, air_1, flu_2, ice_2 air_2, flu_3a, air_3b, liq_vap_4) Public Routines liq_air_h_si liq_air_h_cp_si liq_air_h_density_si liq_air_h_kappa_s_si liq_air_h_lapserate_si liq_air_h_temperature_si liq_air_potdensity_si liq_air_potenthalpy_si liq_air_pottemp_si set_it_ctrl_liq_air_pottemp	**(S34) Ice_Air_4c** Uses constants_0, convert_0, ice_liq_4, ice_air_4b (maths_0, flu_1, ice_1, air_1, flu_2, ice_2, air_2, air_3a, air_3b, ice_air_4a, ice_vap_4) Public Routines ice_air_h_si ice_air_h_cp_si ice_air_h_density_si ice_air_h_kappa_s_si ice_air_h_lapserate_si ice_air_h_temperature_si ice_air_potdensity_si ice_air_potenthalpy_si ice_air_pottemp_si set_it_ctrl_ice_air_pottemp		

Level 5 routines

(S35) Flu_IF97_5	(S36) Ice_Flu_5	(S37) Sea_5a	(S38) Air_5
Uses constants_0 Public Routines chk_iapws97_table fit_liq_density_if97_si fit_liq_g_if97_si fit_vap_density_if97_si fit_vap_g_if97_si	Uses constants_0 Public Routines fit_ice_liq_pressure_si fit_ice_liq_temperature_si fit_ice_vap_pressure_si	Uses constants_0, sea_3a, sea_3b, sea_3c (convert_0, maths_0, flu_1, sal_1, sal_2, flu_3a) Public Routines sea_alpha_ct_si sea_alpha_pt0_si sea_alpha_t_si sea_beta_ct_si sea_beta_pt0_si sea_beta_t_si sea_cabb_ct_si sea_cabb_pt0_si sea_ctmp_from_ptmp0_si sea_ptmp0_from_ctmp_si sea_thrmb_ct_si sea_thrmb_pt0_si	Uses constants_0, air_3b, liq_air_4a (convert_0, maths_0, flu_1, flu_2, flu_3a, air_1, air_2, air_3a, liq_vap_4) Public Routines air_lapserate_moist_c100m

(S39) Liq_F03_5	(S40) OS2008_5	(S41) GSW_Library_5	(S42) Convert_5
Uses constants_0 Public Routines chk_iapws09_table6 fit_liq_cp_f03_si fit_liq_density_f03_si fit_liq_expansion_f03_si fit_liq_g_f03_si fit_liq_kappa_t_f03_si fit_liq_soundspeed_f03_si	Uses flu_1, flu_2, flu_3a, ice_1, liq_vap_4, sal_1, sal_2 (constants_0, convert_0, maths_0) Public Routines chk_os2008_table	Uses constants_0, maths_0, liq_f03_5, flu_1, flu_3a, sal_1, sal_2, sea_3a, sea_3b, sea_5a (convert_0) Public Routines gsw_alpha_ct gsw_alpha_pt0 gsw_alpha_t gsw_asal_from_psal gsw_beta_ct gsw_beta_pt0 gsw_beta_t gsw_cabb_ct gsw_cabb_pt0 gsw_cp gsw_ctmp_from_ptmp0 gsw_dens gsw_enthalpy gsw_entropy gsw_g gsw_kappa gsw_kappa_t gsw_pden gsw_psal_from_asal gsw_ptmp gsw_ptmp0_from_ctmp gsw_specvol gsw_svel gsw_thrmb_ct gsw_thrmb_pt0	Uses constants_0, convert_0 Public Routines cnv_pressure cnv_salinity cnv_temperature