3.3 Conservative Temperature

Conservative Temperature Θ is defined to be proportional to potential enthalpy according to

$$\Theta(S_{\mathrm{A}},t,p) = \tilde{\Theta}(S_{\mathrm{A}},\theta) = h^{0}(S_{\mathrm{A}},t,p)/c_p^0 = \tilde{h}^{0}(S_{\mathrm{A}},\theta)/c_p^0 \qquad (3.3.1)$$

where the value that is chosen for c_p^0 is motivated in terms of potential enthalpy evaluated at an Absolute Salinity of $S_{\mathrm{SO}} = 35u_{\mathrm{PS}} = 35.165\,04\ \mathrm{g\,kg^{-1}}$ and at $\theta = 25\ °\mathrm{C}$ by

$$\frac{\left[h(S_{\mathrm{SO}},\,25°\mathrm{C},\,0) - h(S_{\mathrm{SO}},\,0°\mathrm{C},\,0)\right]}{(25\ \mathrm{K})} \approx 3991.867\,957\,119\,63\ \ \mathrm{J\,kg^{-1}\,K^{-1}}, \qquad (3.3.2)$$

noting that $h(S_{\mathrm{SO}},\,0\ °\mathrm{C},\,0\,\mathrm{dbar})$ is zero according to the way the Gibbs function is defined in (2.6.5). In fact we adopt the exact definition for c_p^0 to be the 15-digit value in (3.3.2), so that

$$c_p^0 \equiv 3991.867\,957\,119\,63\ \ \mathrm{J\,kg^{-1}\,K^{-1}}. \qquad (3.3.3)$$

When IAPWS-95 is used for the pure water part of the Gibbs function, $\Theta(S_{\mathrm{SO}},0\ °\mathrm{C},0)$ and $\Theta(S_{\mathrm{SO}},25\ °\mathrm{C},0)$ differ from 0 °C and 25 °C respectively by the round-off amount of $5\times10^{-12}\ °\mathrm{C}$. When IAPWS-09 (which is based on the paper of Feistel (2003), see appendix G) is used for the pure water part of the Gibbs function, $\Theta(S_{\mathrm{SO}},0\ °\mathrm{C},0)$ differs from 0 °C by $-8.25\times10^{-8}\ °\mathrm{C}$ and $\Theta(S_{\mathrm{SO}},25\ °\mathrm{C},0)$ differs from 25 °C by $9.3\times10^{-6}\ °\mathrm{C}$. Over the temperature range from $0°\mathrm{C}$ to $40°\mathrm{C}$ the difference between Conservative Temperature using IAPWS-95 and IAPWS-09 as the pure water part is no more than $\pm1.5\times10^{-5}\ °\mathrm{C}$, a temperature difference that will be ignored.

The value of c_p^0 in (3.3.3) is very close to the average value of the specific heat capacity c_p at the sea surface of today's global ocean. This value of c_p^0 also causes the average value of $\theta-\Theta$ at the sea surface to be very close to zero. Since c_p^0 is simply a constant of proportionality between potential enthalpy and Conservative Temperature, it is totally arbitrary, and we see no reason why its value would need to change from (3.3.3) even when in future decades an improved Gibbs function of seawater is agreed upon.

Appendix A.18 outlines why Conservative Temperature gets its name; it is approximately two orders of magnitude more conservative compared with either potential temperature or entropy.

The SIA and GSW software libraries both include an algorithm for determining Conservative Temperature Θ from values of Absolute Salinity S_{A} and potential temperature θ referenced to $p = 0\ \mathrm{dbar}$. These libraries also have an algorithm for evaluating potential temperature (referenced to $0\ \mathrm{dbar}$) from S_{A} and Θ. This inverse algorithm, $\hat{\theta}(S_{\mathrm{A}},\Theta)$, has an initial seed based on a rational function approximation and finds potential temperature to machine precision ($\sim10^{-14}\ °\mathrm{C}$) in one and a half iterations of a modified Newton-Raphson technique (McDougall *et al*. (2010b)).

Also, note Figure A.17.1 below (from IOC *et al*. (2010)) showing the difference between potential temperature and Conservative Temperature.

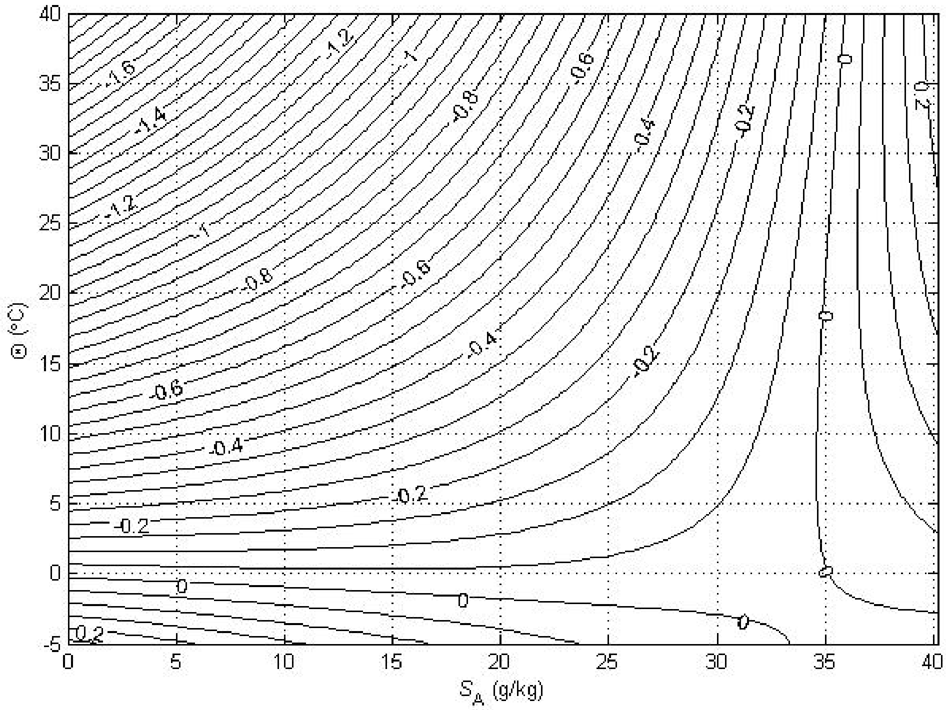

Figure A.17.1. Contours (in °C) of the difference between potential temperature and Conservative Temperature $\theta - \Theta$. This plot illustrates the non-conservative production of potential temperature θ in the ocean.