THERMODYNAMICS AND EQUATION OF STATE OF SEAWATER

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Trevor J McDougall is a CSIRO Fellow in the Marine and Atmospheric Research division of CSIRO (the Commonwealth Scientific and Industrial Research Organization of Australia). He studied mechanical engineering at the University of Adelaide followed by a Ph.D. at the University of Cambridge, UK.

Dr McDougall’s research is concentrated on fundamental issues in the field of ocean thermodynamics and ocean mixing and particularly how the known conservation equations should be properly averaged and included in ocean models. As other aspects of ocean models have improved over the past twenty years, mixing and its representation has become more important for modelling the ocean’s role in climate change. Trevor’s recent work has been concerned with the accurate description of the “heat content” and other thermodynamic properties of seawater so that the ocean’s role in climate can be more accurately described in coupled climate models.

Abstract

The horizontal variations of density in the ocean are central to estimating the ocean’s circulation and hence the role of the ocean in climate. Oceanographers measure temperature and the conductivity of seawater and use algorithms derived from the equation of state to calculate density and other thermodynamic properties. The existing UNESCO equation of state (EOS-80) has served the community well for thirty years. This equation of state is based on the Practical Salinity Scale of 1980. In 2005 SCOR and IAPSO established Working Group 127 on the “Thermodynamics and Equation of State of Seawater” (henceforth referred to as WG127). This Working Group has devised a new thermodynamic description of seawater, called TEOS-10 (Thermodynamic Equation of Seawater – 2010) which is based on a Gibbs function from which all the thermodynamic properties of seawater can be calculated.

A notable difference from present practice that is being recommended by WG127 is the adoption of Absolute Salinity to be used in journals to describe the salinity of seawater and to be used as the salinity argument to algorithms that give the various thermodynamic properties of seawater. This recommendation deviates from the current practice of working with Practical Salinity and typically treating it as the best estimate of Absolute Salinity. Note however that WG127 strongly recommends that the salinity that is reported to national oceanographic data centers remain Practical Salinity as determined on the Practical Salinity Scale of 1978 (suitably updated to ITS-90 temperatures).

1. The prominent advantages of the new seawater description TEOS-10 are:

   - The availability of internal energy, entropy, enthalpy, potential enthalpy and the chemical potentials of seawater. These quantities were not available from EOS-80 but are central to a proper accounting in the ocean of the heat that is transferred between the ocean, the ice cover and the atmosphere above.
For the first time the influence of the spatially varying composition of seawater can systematically be taken into account through the use of Absolute Salinity. In the open ocean, this has a non-trivial effect on the horizontal density gradient computed from the equation of state (and thereby on the so-called “thermal wind” relation).

This lecture will also describe some mixing and advection processes that arise because of the nonlinear nature of the equation of state of seawater. One of these nonlinearities is called the thermobaric effect which is due to the sound speed being a function of temperature. Because of this thermobaric effect it is quite difficult to describe accurately what we mean by a “surface of constant density” in the ocean. This same nonlinearity in the equation of state can cause numerical instabilities in numerical ocean models.