Some Aspects of Neutral Surfaces

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The development of the concept of a "neutral surface"[1].

A water parcel that moves adiabatically retains its original potential density, despite changes in its in-situ temperature and in-situ density due to the pressure changes. Thus, for an appropriately defined reference pressure, a potential density surface is a surface of movement for a resident water parcel; if the water is stable, any displacement of the parcel from this surface will be counteracted by the buoyancy forces. However, the definition of the appropriate isopycnal surfaces, on which to follow the spreading of water masses in the ocean interior is far from straightforward. The variation of the in-situ density in the ocean is dominated by pressure effects, and due to the non-linear nature of the equation of state of sea-water, it is not satisfactory to define density surfaces relative to any single pressure level.

The idea of a "perfect" neutral surface.

The concept of hydrostatic stability in the vertical direction can be extended to the three-dimensional movement of a water parcel, and in particular to the surface of neutral buoyancy delineated by the locus of all possible neutral paths of the parcel in question.

Approximating a "perfect" neutral surface: Underlying Problems.

Moving a parcel along a neutral surface implies the knowledge of the local water properties and in particular the variations of θ and S with pressure. However, the oceanographic reality provides data at discrete depths of a network of stations, sometimes widely spaced. Thus some approximate approach is needed. Implicit in the preceding discussion are the problems of where to start a neutral surface and how to extend it. Any observational level (p_A, S_A, T_A) of an arbitrary 'reference station' A, can be used as a 'reference level' to start a neutral surface. However, if our objective is to follow the spreading of a particular water mass, then we should start it from a level, at which the presence of this water mass is established. The major problem in extending the neutral surface is what reference pressure to use in calculating the densities to be compared; in particular, the in-situ density cannot be used due to the effect of the pressure. Thus, the selection of an 'appropriate' reference pressure is crucial and reflects an ambiguity inherent in any method of approximating an 'ideal' neutral surface. Another problem in extending the surface is whether to use throughout the originally selected 'reference parcel', (S_A, T_A) or to redefine the latter from station to station. Related to the last problem is the configuration of the station-network available. Some possibilities to overcome these problems exist. These and their respective utility was considered and the results obtained were sometimes widely different. This is probably due to the "reference parcel" being redefined between widely spaced stations, with contrasting thermohaline properties.

Effects of the compressibility dependence on the thermo-haline properties of a water parcel.

To clarify the above statement a 'path-dependency' test was conducted, i.e. a neutral surface was traced in a network of closely-spaced stations arranged in a closed loop, so that the neutral surface in question was started and in the absence of 'path-dependency' was expected to return to the same level at the original station. The results indicate that redefining a 'reference parcel' from station to station in extending a neutral surface does not, in general, return the surface in question to its original level. This path-dependency is presumably an expression of the inherent ambiguity concerning the depth (pressure) at which a neutral surface occurs, and it is ultimately a manifestation of the dependence of the (adiabatic) compressibility of sea-water on temperature and salinity. However, this problem can be circumvented by the method proposed.

Method proposed.

A set of water parcels with observed temperatures and salinities can be used to start a set of neutral surfaces. The levels at which the adiabatic density gradients for each of these water parcels intersect the in situ density profile at each station in a data set determine the levels of each of the neutral surfaces at that station. The neutral surfaces thereby defined were found to exhibit no path-dependency and their analysis has provided meaningful results[2].

Applications.

Data from the Mediterranean Sea are used to obtain a number of neutral surfaces, which portray vividly the spreading patterns of the Levantine Intermediate water and also of the Deep water in the Eastern Mediterranean.

References.

[1] THEODOROU A., (1983). "The impact of Norwegian Sea overflows on the water masses and deep circulation of the north-east Atlantic". Ph.D.thesis, University of East Anglia, Norwich, England. 301 p.
[2] HARVEY J.G., THEODOROU A., (1986) "The Circulation of the Norwegian Overflow Water in the Eastern North Atlantic", Oceanologica Acta, Vol. 9, No. 4, 393-402.