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Vertical structure of the upper ocean from profiles fitted to physically-consistent functional forms

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The mixed layer is, as a first proxy, the uppermost part of the ocean where the surface turbulence have mixed all water properties and therefore profiles of all tracers are homogeneous. The lower limit of the mixed layer is the Mixed Layer Depth (MLD) and its determination is of great importance for air-sea interaction and also for the pelagic ecosystem. A variety of algorithms have been developed to determine the MLD from hydrographic data (particularly from temperature T or density σ_θ profiles). We propose a best fit of real profiles to a solution of a simplified conceptual model of the thermocline (similarly for pycnocline). The ideal profile of T as a function of depth z is:

$$T(z) = \begin{cases} a_1 & \text{if} \quad z \leq D, \\ a_3 + b_3(z-D) + a_2 \exp\big(-b_2(z-D) - c_2(z-D)^2\big) & \text{if} \quad z \geq D, \end{cases}$$

being a_1, b_2, c_2, a_3 and b_3 adjustable parameters and $a_2 = a_1 - a_3$ (for continuity). The profile is constant down to the MLD (D in the equation), which is also a parameter of the fitting, and below it the thermocline is modelled by a combination of Gaussian and exponential decay. This family of curves is the solution of a system evolving by diffusion where the boundary and initial conditions are externally controlled and correspond to simplified extreme cases with physical meaning. The Gaussian solution corresponds to an initial condition of a Dirac δ at the boundary (the MLD) $T(z_0, t_0) = \delta(z - z_0)$. The exponential decay corresponds to a case in which the own boundary have been suddenly shifted some depth B ($z \rightarrow z + B$), therefore destroying part of the pre-existing profile. The sum of both curves represents to a high degree of accuracy intermediate solutions, forms of the complementary error function (erfc) resulting from a constant boundary condition $T(z_0, t) = T_0$ or even moving-

boundary schemes $T(\dot{h}(t), t) = T_0$ (being $\dot{h}(t)$ the velocity of the moving boundary). The seasonal thermocline tends asymptotically to a straight line (the permanent thermocline).

The ideal fit for each profile depends on six adjustable parameters and it is accomplished with a differential evolution search algorithm, very effective in escaping of local minima and maxima. The algorithm is applied to a 12 years timeseries of monthly profiles in a fixed station at the southern Bay of Biscay. The results are very robust in accurately representing a wide range of different observed profiles. It is provided a precise determination of the MLD based on the topology of the curve (the way a person by eye would proceed to determine MLD, which is the goal searched in many of the algorithms proposed in literature for MLD determination). It is also provided a precise measure of the gradient of the thermocline and its shape. As the parameters of the fitting are the same for each profile it is possible to look for spatial or temporal coherent variations between profiles.