# The wind-mixed layer in the Bay of Calvi

*by*

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Essentially, two models were tested against the observations made at Stareso. The two models were complementary rather than competitive and they appeared to provide valuable insight into the thermocline dynamics although none of them was entirely satisfactory.

The model presented by POLLARD, RHINES & THOMPSON [1973] is essentially a " slab " model. The velocity and density distribution are assumed uniform over the mixed layer. The deepening of the mixed layer with time is studied by means of depth-integrated differential equations relating the mean momentum's evolution with time — and thus the downwards progression of the thermocline — to the competitive effects of Coriolis and wind forces.

The entrainment velocity is determined using the auxiliary hypothesis that the RICHARDSON number is equal to one at the lower boundary of the mixed layer. It is found that after one half inertial period the progression of the thermocline is arrested by rotation at a depth

$$(1) \quad h_{max} \sim \frac{2^{3/4}\, U_*}{\sqrt{N f}}$$

Two objections can be made :

**1.** A slab model can only give first indications and it is of very little use for the interpretation of the general — biological, chemical, physical — dynamics of the mixed layer and the thermocline. The detailed temperature and velocity profiles are of importance.

Observations at Stareso indicate that while the temperature profile is fairly uniform in agreement with the slab model's hypothesis, the velocity varies importantly with depth in the mixed layer. (If a simplification must be made, the assumption of constant vorticity and *not* constant velocity would seem more realistic in view of the observations).

**2.** The closure hypothesis on the RICHARDSON number is rather artificial and the energy or stability arguments given to support it are only partly convincing.

Energy arguments must be used with extreme care in this context [NIHOUL, 1973]. The total energy budget expresses a balance between time variations of the kinetic energy, redistribution of energy by turbulence, production of energy by mechanical forces, inhibition by buoyancy and mechanical dissipation.

One estimates [WOODS 1969, NIHOUL 1973] that as much as 90 % of the energy budget are accounted for by an approximate balance between mechanical energy production and mechanical dissipation. This approximate balance can be used to verify orders of magnitude but to go any further requires difficult evaluations of small differences where terms like turbulent redistribution may play a significant role but are always little known and must be neglected most of the time, for lack of any better estimate.

*Rapp. Comm. int. Mer Médit.*, **23**, 5, pp. 51-52 (1976).

On the other hand, stability arguments applied at a turbulent-laminar interface are also very delicate to exploit. They may point out relevant parameters but they are unlikely to provide very accurate numerical criteria.

The objection however does not invalidate the model proposed by POLLARD *et al.* [1973] although it relies heavily on the Richardson number hypothesis.

Several arguments — and especially those based on energy budgets — suggest that, at the interface between the turbulent mixed-layer and the laminar fluid below, the *flux* RICHARDSON number $R_f$ (rather than the Richardson number $R_i$) reaches a critical value. (0.1, perhaps). Assuming a direct relationship between $R_f$ and $R_i$, several authors have inferred that there corresponds a critical value of $R_i$.

Whether this critical RICHARDSON number is one or not is not quite clear at present but, if such a critical value exists, the essential formula (1) remains qualitatively correct, only the numerical factor is by no means evident.

The model proposed by NIHOUL [1973., 1974*a*] takes into account the variations of velocity and temperature with depth in the mixed layer but it neglects the Coriolis effect. This can only be valid if the depth of the thermocline is sufficiently smaller than some Coriolis length scale ($\sim U_* f^{-1}$) and thus the model is appropriate for the first stage of the entrainment process. The entrainment velocity is found to be constant. The model does not foresee the later slackening of the thermocline's progression and cannot predict the terminal depth.

Observations made at Stareso reveal fairly long periods of steady wind. After a comparatively short initial time ($\sim$ 6 hours), the thermocline has descended to its maximum depth and appears to remain steady as long as the wind keeps blowing without significant changes of speed or direction.

A steady state model is presented. The model is depth dependent and non linear (the eddy diffusivities are functions of the shear). The predicted profiles of temperature and velocity in the mixed layer are shown in good agreement with the observations [NIHOUL, 1974 *b*].

## References


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