CONVECTION DEPTH IN THE OCEAN

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ABSTRACT

The contribution of the convection to the behaviour of the mixed layer in the ocean and the diurnal variation of the convective depth is examined in this paper.

Results shows:

- the importance of the absorption coefficient for the short wave radiation;
- in the ocean the convective layer varies from 2 meters during the night under fair weather conditions, while when the cooling exceeds $B = 300$ watt/m^2, the convection reaches the seasonal thermocline;
- the behaviour of the short therm climatic active layer of the ocean depends on its previous history.

INTRODUCTION

The diurnal evolution of the temperature of the convective surface layer of the ocean is due to the surface diabatic cooling B and to the solar heating ϕ : the latter is released directly in the fluid and therefore the positive buoyancy produced by the solar heating not only balances the negative buoyant water produced on the surface by the heat loss B but also increases the positive buoyancy below the convective layer. This fact makes the climatic active layer of the ocean dependent by its time evolution.

THE THERMAL COMPENSATION LEVEL

The level d at which occurs the balance between B and ϕ as defined by the thermal compensation depth (Kraus and Turner, 1967)

1) $$\phi(0) - \phi(d) = B$$

cannot be assumed as the minimum convective depth D. In fact, if the absorption of the short wave radiation is exponential:

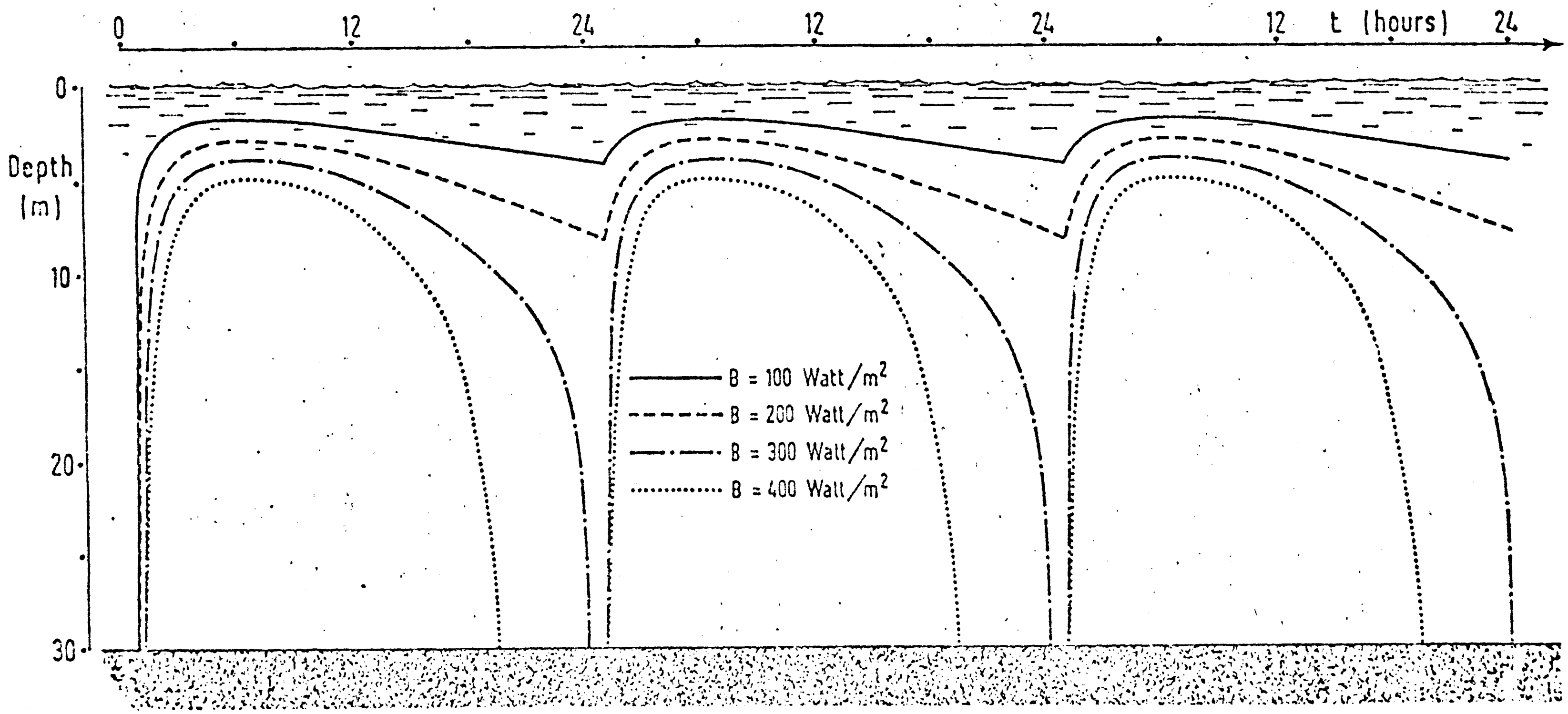

Fig. 1 - The diurnal behaviour of convective layer for different cooling B.

$\phi = \phi(0)\ \exp(-\beta z)\ \sin \omega t$ where $\omega = 2\pi/24$hr, $\delta z = 10$ cm and $\delta t = 60$ sec.

2) $$\phi(z) = \phi(0)\exp(-\beta z),$$

from Eqs. 1) and 2) follows:

3) $$d = \beta^{-1}\log(1 + B/\phi(0)).$$

However, the Eq. 3) defines a statically unstable solution because, if the sea is initially homogeneous down to the seasonal thermocline H deep, the temperature variations are:

$$\partial T/\partial t = 0 \qquad \text{for } 0 \leq z \leq d$$

$$\partial T/\partial t = \beta \frac{\phi(z)}{c_p \rho} > 0 \qquad \text{for } d < z \leq H$$

so that instability occurs as soon as $t > 0$, from below at $z = d$.

THE MINIMUM CONVECTIVE DEPTH

The correct definition of the depth through which acts the convection is defined as follows. If the ocean is initially homogeneous down to the seasonal thermocline H deep:

$T(z,t) = T_0$, $\phi(0) = 0$, $B = 0$ for $t < 0$ and $0 \leq z \leq H$, when $0 \leq t \leq 12$ hr, $B = 0$ and $\phi(z,t) = \phi(0)\exp(-\beta z)\sin\omega t$. Finally, $\phi(z,t) = 0$, $B = 0$ for $t > 12$ hr, where $\omega = 2\pi/24$ hr, $\phi(0) = 900$ watt/m^2 and $\beta^{-1} = 3$ meters (Denman and Miyake, 1973). The corresponding temperature profile is, for $t > 0$:

4) $$\tilde{T}(z,t) = T_0 + \int_0^t \frac{\phi(0,t') - \phi(D(t'),t') - B}{c_p \rho D(t')} dt' \qquad \text{for } 0 \leq z \leq D$$

where D is defined by:

5) $$\lim_{\delta z \to 0} T(D + \delta z, t) = \tilde{T}(z,t) \text{ at all times.}$$

The temperature T and the convective depth D, solutions of Eqs. 4) and 5) depend from the history of the convective layer D and since is not possible to give analitical solutions, the integration is carried out following a numerical technique (Dalu, 1978).

Fig. 1 shows the evolution during 3 days of D for different cooling rate B and the resulting main features are:

- with gentle cooling (B = 100 watt/m^2), D is about 2 meters deep at noon, while for intense cooling (B = 400 watt/m^2) this depth at noon is about 5 meters;

- the evolution is not symmetric around noon because the heat stored during the sunny hours stabilizes the water below the convective layer;
- during the night, for gentle cooling, the convection does not reach the seasonal thermocline, while for intense cooling, this depth is reached.

CONCLUSIONS

The effect of convection is parameterized in the literature by the thermal compensation level d (Kraus and Turner, 1967) which is, however, unrealistic because it results statically unstable. The stability conditions, which defines correctly the depth at which convection acts, gives temperature variation one order of magnitude different.
Moreover, the climatological active layer results less deep of the seasonal thermocline for gentle cooling and only under extreme cooling conditions ($B > 300$ watt/m^2), the climatic active layer is deep as the seasonal thermocline. When the sun inclination above the horizon is taken into account, the convective depth is of the same order but occurs before noon (Dalu and Purini, 1980).

REFERENCES

Dalu G.A., 1978: A parameterization of heat convection for a numerical sea breeze model. Quart. Jour. of Roy. Met. Soc., 104, 797-807.

Dalu G.A. and R. Purini, 1980: A numerical study of marine surface layer in sea breeze regime. Ocean Manag.(In press).

Denman K.L. and Miyake M., 1973: Upper layer modification at Ocean Station Papa: Observation and simulation. Jour. of Phy. Oc., 3, 185-196.

Kraus E.B. and J.S. Turner, 1967: One dimensional model of the seasonal thermocline II. Tellus, 19, 98-105.