Convection of salt fingers in the \textit{C-SALT} region*

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Abstract — We study possible mechanisms of mixing in the northwest part of the Tropical Atlantic (\textit{C-SALT}) and show that homogeneous layers in the staircase structure can be observed across the entire frontal zone of the North Equatorial Countercurrent. In the central region of the frontal zone, one may observe horizontal motions of the upper parts of quasihomogeneous layers with respect to their lower parts and an essential role in the exchange processes is played by turbulence. The peripheral regions of the frontal zone are characterized by the presence of horizontal advection and isopycnic mixing. Far from the frontal interface, the principal contribution to the exchange processes is made by double diffusion. We demonstrate that, for the analysis of the vertical buoyancy fluxes caused by salt fingers, one can use both the Stern relation and the "law of 4/3".

The aim of the present work is:

— to study the mechanisms of formation of the fine structures of the ocean under different (according to quantitative criteria) background hydrologic conditions and the contribution of the effect of salt fingers to these structures;

— to determine the conditions of applicability of the well-known laboratory formulas for the evaluation of the vertical fluxes of heat, salt, and buoyancy caused by the convection of salt fingers to the analysis of the \textit{in situ} CTD-data;

— to obtain reliable estimates for the coefficients of vertical exchange caused by the convection of salt fingers on the basis of the data of small-scale \textit{in situ} measurements.

For this purpose, we

— investigated the staircase structures existing in the zone of thermohaline front of the North Equatorial Countercurrent (within the framework of \textit{in situ} experiments) and

— deduced reliable quantitative estimates of the vertical fluxes of heat, salt, and buoyancy and the characteristic parameters of the fine structures caused by the convection of salt fingers in the ocean on the basis of the vast body of statistical data.

The urgency of these investigations is explained by the fact that the convection of salt fingers is one of the mechanisms of vertical exchange in the ocean. Participating in the transport of heat, salt, and other dissolved substances (including pollutants), salt fingers play an important role in the formation of the vertical structure of

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hydrophysical, chemical, and biological fields. Quantitative estimates of the actual values of the coefficients of vertical exchange caused by salt fingers are very important for the development of physicomathematical models of the dynamic processes in the ocean. The knowledge of the laws governing the processes of exchange is required for the solution of various important practical problems such as the environment protection, prediction of the biological productivity of waters, analysis of the thermal influence of the ocean on the atmosphere, and forecast of weather and climatic anomalies.

The mechanism of convection of salt fingers is connected with the generation of relatively intense vertical fluxes of heat, salt, and buoyancy. In [1-5], one can find the well-known empirical formulas for these fluxes obtained on the basis of the results of laboratory experiments. In what follows, we recall some of these formulas.

1. The vertical buoyancy flux $\beta F_S$ caused by the convection of salt is proportional to the drop of salinity $\Delta S$ in an interlayer containing salt fingers raised to power $4/3$ (the "law of $4/3$") [2, 3, 5]:

$$\beta F_S = C(gk_T)^{1/3}(\beta \Delta S)^{4/3},$$  

where the empirical numerical factor of proportionality $C$ is a function of the density ratio

$$R = \frac{\alpha T_z}{\beta S_z},$$

$\alpha$ and $\beta$ are, respectively, the coefficient of thermal expansion of water and the coefficient of salinity-induced increase in density, and $T_z$ and $S_z$ are the vertical gradients of temperature and salinity.

2. The total buoyancy flux $F_p$ caused by the vertical transport of heat and salt is proportional to the temperature gradient inside the interlayer:

$$F_p = A\nu\left(1 - \frac{1}{R}\right)\alpha T_z,$$


3. The ratio of the vertical fluxes of heat and salt

$$\gamma = \frac{\alpha F_T}{\beta F_S}$$

is a decreasing function of $R$ taking values within the interval $0 < \gamma < 1$. {Accord-