

**PTV APPLICATION TO THE STUDY OF INTERNAL WAVES GENERATED BY
PENETRATIVE CONVECTION**

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ABSTRACT

A laboratory experiment was performed to simulate *penetrative convection* in a stratified lake. Penetrative convection concerns the advance of a turbulent fluid into a fluid layer of stable stratification. This phenomenon is commonly observed in lakes when, owing to surface nocturnal cooling or to superficial wave breaking the initially stable environment near to the free surface is affected by convection with the advancing instable layer showing several domes which penetrate small distances into the stable layer. Water quality in lakes is highly dependent on entrainment of nutrients and pollutants from the deeper hypolimnion (Denman, 1995). Entrainment in a stratified lake may be dominated by thermal convection, organized coherent structures ("large eddies"), or internal waves. The excitation of gravity waves in a stratified lake is important for several reasons. Waves can propagate downward through the stratified metalimnion of the lake producing entrainment in the upper layer (figure 1 and 2), interact with other long wave excited by wind, with patches of turbulence (Weinstock, 1984), can be reflected and create an oscillating boundary layer at the bottom of the lake with the consequent raising of settled matter (Stevens, 1994). A number of laboratory and theoretical models have been developed for internal wave propagation in stratified fluids. However the complex role of internal waves in lake dynamic is still not well understood from a fundamental point of view. It was the aim of this paper to study internal waves generated by thermal impact on the interface during penetrative convection. Particle Tracking Velocimetry (PTV) was employed to reconstruct the field of motion. Specifically this technique allows the lagrangian tracking of tracer particles placed in the fluid. The simulation features, with a growing thickness of mixed layer (ML) depth and a continuous decrease of heat flux at the surface, make not possible to consider the analyzed system in a steady state. However, the time scale of the studied convective phenomena is definitively smaller than the time for significant changes in ML mean temperature and depth. The vertical structure of potential temperature during the deepening of the mixed layer was analyzed and related to the vertical and horizontal velocity as obtained by PTV techniques. The results confirmed the effectiveness of the employed tracking technique to study the internal wave field. Spectral analysis of temperature and velocity signals highlighted the presence of several frequency where energy is concentrated, with the most important one corresponding to the initial strongest temperature jump. An interesting result was the enhanced increase of temperature caused by internal wave in the metalimnion. As the deeper colder fluid is raised up by internal wave oscillation it becomes surrounded by lighter fluid. Without losing its identity the colder fluid is able to increase its temperature by thermal diffusion acquiring the heat of the hotter fluid. The result is a heat transfer rate much higher than the one due to simple molecular diffusion because of the enhanced temperature difference of the two fluid masses. The same happens to any other substance whose concentration presents a vertical gradient.

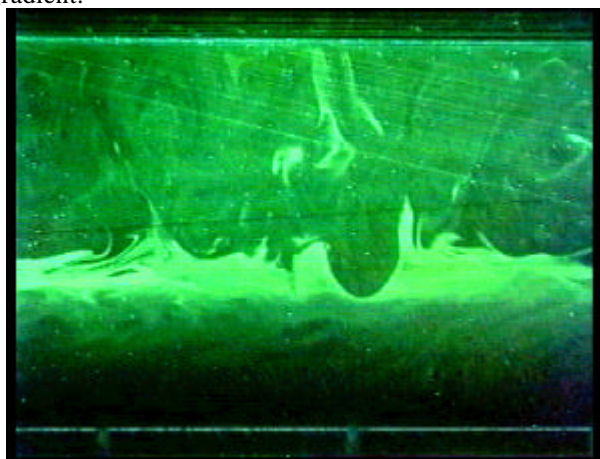


Figure 1. LIF visualization of the impact of a convective eddy on the interface

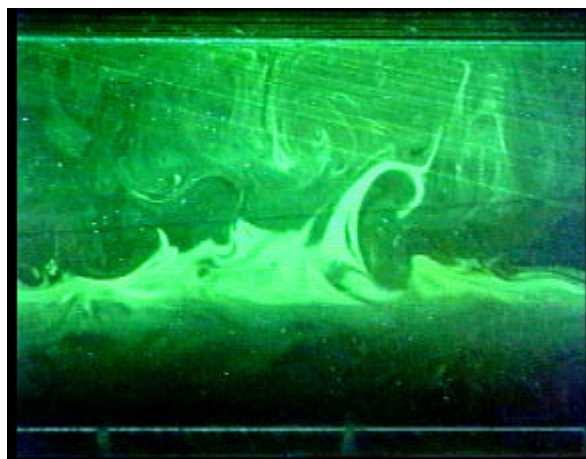


Figure 2. LIF visualization of the rise of heavier fluid inside the mixed layer