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Autumnal down-slope cascading modulated by day/night variations of solar heating

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Sloping sides of natural basins favour the formation of cross-shore temperature gradients (differential coastal heating/cooling), which cause significant littoral-pelagial water exchange. Autumnal denser water cascading from sloping lake boundary, modulated by day/night variations of solar heating is considered numerically, in order to reveal the development of the cascading process in time, spatial structure of the exchange flows, and diurnal variations of volumetric flow-rate of littoral-pelagial exchange flow, as well as to compare its daily maxima at different depths/cross-sections, with known quasi-steady state predictions under constant buoyancy flux.

The development of the exchange flow passes two phases: (i) appearance and adjustment to day/night buoyancy flux variations; and (ii) the 'quasi-steady' exchange, when variations of the flow rate in every next diurnal circle is more or less like that of the previous day. The duration of the first phase depends on local depth ($\sim$ 1 day for depths of about 10 m, $\sim$ days for depth down to 15-25 m, and $\sim$ 5 days; down to 30 m for the considered initial linear vertical temperature stratification). Maximum horizontal exchange takes place in the cross-section where the thermocline meets the slope, and the cold down-slope currents detach from the bottom. Its location advances off-shore with time, in accordance with the deepening of the upper mixed layer. The existence of a specific coastal circulation cell, with different water dynamics from those above the main part of the slope, is a characteristic feature of horizontal convective exchange.

The mean value of the specific volumetric flow rate of the convective exchange, driven by day/night oscillations in its fully developed 'quasi-steady' phase increases almost linearly with local depth, and is about twice as large as the quasi-steady exchange values, predicted by formula Q=0.0013xd**(1.37) (Q is measured in m**2/s, and local depth above the slope d – in m (Chubarenko, 2010, Oceanology. 50(2): 166–174)), suggesting that the 'thermal siphon', energized by oscillating day/night buoyancy fluxes, flushes coastal regions twice as efficienly as just developed cascading, under (more or less) uniform external conditions in field observations and laboratory experiments, which lie behind the given formula. Flushing time in the considered case has an order of 10–60 hours for the littoral zone of 6–30 m depth.

Application of convective 'phase diagrams' (e.g., Q vs. ΔT) is suggested as a convenient way to describe the day/night convective exchange, allowing for visualization of the flow development process, its coherency and the time lag of the development at different depths.

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