Geophysical Research Abstracts,
Vol. 10, EGU2008-A-01263, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-01263
EGU General Assembly 2008

1 Littoral-pelagial water exchange due to differential coastal cooling

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Laboratory and numerical investigations of flows resulting from differential water cooling in shallow coastal regions are presented. 16 sets of laboratory experiments were carried out in a 5-m long laboratory channel with gentle slopes of aspect ratio 0.1-0.02. Water temperature and deformation of tracer tracks were registered, and then velocity profiles and discharges calculated. The three-dimensional non-hydrostatic numerical model MIKE3-FlowModel (DHI Water & Environment) was applied to simulate the processes in an initially linearly stratified fresh-water basin, resembling size and bottom slope of Lake Űberlingen (sidearm of the Lake Constance). Simulations show a distinct day/night rhythm of (always unsteady) a cascading process: an intense vertical mixing in night-time (from 9-11 pm to 10-12 am) is replaced by stronger horizontal exchange in day-time. Maximum horizontal on- and off-shore flow velocities (up to 2-3 $cm\ s^{-1}$) are correspondingly observed in the upper layer and immediately above the thermocline. Within two weeks, the initial linear temperature profile is transformed by the cooling process into a more realistic shape: (i) upper iso-thermal layer, (ii) sharpened thermocline and (iii) the rest of the initial profile in deeper layers. Immediately above the thermocline, a 5-7 m thick layer is formed, which is *heated* due to the mixing; this feature was found to be the common case in field data, corroborating an importance of the cascading process for lake-scale water dynamics. Finally, a

scaling analysis is applied, which suggests that, for cascading flows, two dimensionless combinations are of importance: (i) the aspect ratio and (ii) the ratio of vertical to horizontal flow velocities. The latter indicates a stage of the development of the cascading process: in the beginning of the cooling episode, vertical convection is strong, but horizontal flows are not yet developed; towards the end, vertical convection weakens, but the horizontal pressure gradient supports the horizontal flow for a long time after that. Summarizing laboratory, numerical and published field results, down-slope discharges are analyzed in terms of the developed scaling. It is argued that horizontal exchange is maximal at the end of a slope, with its magnitude proportional to the depth of an upper mixed layer in a deep part of the basin. The work is supported by grant of RFBR 07-05-00850.