Shallow lake hydrodynamics: an exposure to extreme space and time variations

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Shallow lakes have long received enhanced attention all over the world. Their unique value and multi-purpose utility have been more and more recognised, which have led then unfortunately to misusing a number of them, thus worsening their ecological state even to an alarming extent at places. Furthermore, the recent changes in the global climate or, at least the fact that extremes seem to grow, modified also the boundary conditions for these vulnerable water bodies. The hydrodynamics in shallow water bodies, especially in enclosed or semi-enclosed ones the wind plays an important role. The wind momentum transferred into the water at the lake surface results in waves, turbulence, drift currents, Langmuir circulations, as well as large scale circulations and seiche. This momentum flux drives then indirectly the exchange processes at the lake bottom, the mixing in the water body, and influences also the interaction between the littoral and the pelagic zones.

The largest scale wind-induced hydrodynamic processes are the oscillatory (seiche) and circulatory currents. Oscillations in themselves usually would not result in significant net exchange, but when accompanied by wind-induced circulations their combined influence is significantly enhanced. While seiche can be generated either by the wind or horizontal atmospheric pressure gradient, circulations are induced primarily by the surface wind shear stress field and shaped by a number of factors. Circulations, though always three-dimensional in the most general sense, very often show organised horizontal pattern consisting of large-scale gyres, generated and maintained by various rotation sources [1]. Such sources can be originated e.g. from bottom slopes relative to the depth, irregular wind field [2], irregular lake surface exposure to the wind due to lakeshore land use or to emergent littoral vegetation.

In the presentation fictitious basins as well as case studies lakes from Central-Europe (Neusiedler See, Balaton) will be considered as typical shallow water bodies. Both idealised and measured steady-state as well as unsteady lake flow patterns will be shown and evaluated then reproduced by numerical flow modelling [3]. 3D and 2D flow features as well as their impact on hydrodynamics driven mixing processes will be also tackled, including their characteristic space and time scales. Both conventional mixing approaches and chaotic advection aspects will be analysed [4], the latter as a novel way for the interpretation of processes and patterns often found in nature.

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[2] J. Józsa, E. Napoli, B. Milici, *Bound-Layer Meteorology*, **2007**, *123*, 159-175.

[3] T. Krámer, J. Józsa, *Computers & Fluid*s, **2007**, *36*, 562-577.

[4] G. Károlyi, M. Pattantyús-Ábrahám, T. Krámer, J. Józsa, T. Tél, Proc. *Institution of Civil Engineers-Engineering and Computational Mechanics*, **2010**, *163*, 251-259.