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# A chaotic advection analysis of environmental flows in shallow inland waters

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In the early nineties Kranenburg (1992) gave examples on the importance of chaotic advection in inland surface water environment, namely wind-induced lake circulations. It was probably one of the first applications of the approach in such shallow conditions, developed decades ago in paint and food industry, where chaotic advection became an important issue to stir in an irreversible way substances being immiscible in the conventional diffusion sense. Liang et al. (2005) have recently made further steps in evaluating and quantifying the above mentioned flows in terms of Poincaré sections, stable and unstable manifolds as well as mean distance between initially neighbouring water particles. However, as is known there are further parameters in chaotic advection analysis that give even more detailed, or at least different, complementary insight into the processes. Of these parameters, the so-called finite time or finite size Lyapunov exponent (FSLE) are expected to facilitate the identification of strong and weak shearing sub-regions thus qualifying local stirring rates (d'Ovidio et al. 2004). These parameter fields can also help in finding barriers across which material transfer is hindered, and avenues along which transport is channelled by the inherently unsteady advective flow field. In our paper we focus on various time-depended velocity fields covering both simple, synthetic 2D tests and more complex, shallow, depth-averaged cases. First an analytical sinusoidal velocity distribution with abrupt, periodical alternation in direction is implemented to understand the main features of the FSLE. A sensitivity analysis is also carried out on the scale of the various numerical parameters. Second, more realistic, numerically modelled, unsteady velocity fields occurring in shallow inland water environment are applied in which the quantified chaotic advection features can facilitate the identification of sub-regions with occasionally drastic spreading dif-

ferences. Such an analysis is expected to contribute to the understanding of complex patterns observed in nature and e.g. to the engineering planning in the aquatic environment.

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