On the chaotic features of mixing at river groynes

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The traditional way to describe mixing processes is the Fickian approach. However, this method provides often poor results applied to complex river flows, e. g. in the vicinity of groynes. These typical river training works narrow the river cross-section, thereby accelerating the flow to maintain sufficient depth for the navigation. In such flow field where inherent unsteadyness is present, the basic mixing process is chaotic advection, which is best handled as Lagrangian transport [1].
In order to detect chaotic features of fluvial mixing processes in such complex geometry flows, after some promising field measurements recorded in the River Danube using GPS-equipped floating buoys we turned to laboratory flow measurements where more particles can be investigated. In a single groyne setup thousands of floating particles were followed using particle tracking velocimetry (PTV) technique. This allowed us to reconstruct the instantaneous flow surface velocity field in every time step. In the reconstructed velocity field numerical particles were deployed and tracked in a Lagrangian way. After the analysis of the trajectories parameters originated from the chaos theory were calculated.
The flushing time – i. e. the elapsed time until a particle reaches a given x-coordinate - distribution (Fig. 1) shows a fractal-like, filamentary structure. Originally neighbour particles may have very different flushing time which indicates the sensitivity of the initial conditions. These are important indicator of the chaotic nature of the mixing. In addition, filaments which mark the largest flushing times correspond to the stable manifold of the flow.
Finite size Lyapunov-exponent field, its dependence on the starting time, the escape rate and the fractal-dimension were also calculated.
Using the mentioned tools of Lagrangian analysis we are able to provide a more detailed picture on mixing processes in the vicinity of groynes and separate sub-regions characterized with different mixing efficiency.

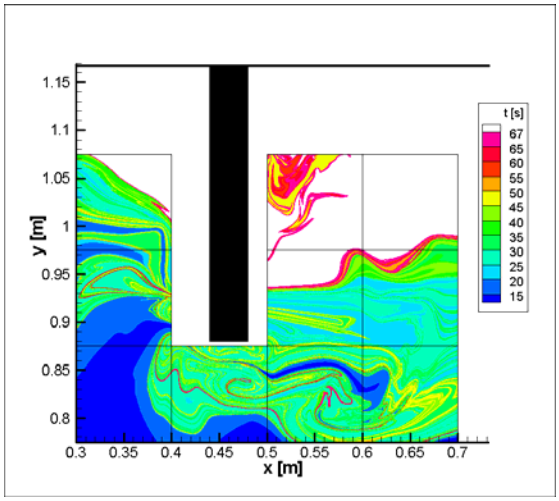

Figure 1: Spatial distribution of the flushing time in the vicinity of the groyne

[1] H. Aref, *Journal of Fluid Mechanics* **1984**, *143*, 1-21.