

Lagrangian Analysis of River Flow from UAV Videos to Characterize Mixing

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INTRODUCTION

Unmanned Aerial Vehicles (UAVs) are increasingly used in the field of engineering surveys. In river engineering, or in general, water resources engineering UAV based measurements have a huge potential. Indirect video based velocity measurement methods, e.g. Large-Scale Particle Image Velocimetry (LSPIV) (Muste et al., 2008) and Space-Time Image Velocimetry (STIV) (Fujita et al., 2006), became a real alternative for direct flow measurements. These methods deal with the Eulerian analysis of the flow, i.e. the flow is described at fixed points. However, the airborne video recordings inherently allow us to observe the surface processes based on a Lagrangian view, i.e. to describe the flow field with moving particles in the water. In this study the Particle Tracking Velocimetry (PTV) method was applied to assess the spatially complex nature of the flow field in a large river. To the authors' knowledge no such analysis has been performed yet to describe the flow field and mixing processes in large rivers.

FIELD MEASUREMENTS

In the present research an UAV is used to capture the tracers floating on the water surface at a groyne field in the Danube River in Hungary. Hundreds of yellow tennis balls are used as tracers, which are suitable for the image processing method and detailed information can be acquired about the surface flow. Complementary moving boat Acoustic Doppler Current Profiler (ADCP) measurements were also performed to capture the three-dimensional flow velocity field. The post-processed ADCP measurements provided Eulerian spatio-temporally averaged flow field, which could be directly compared with the Lagrangian approach.

PTV ALGORITHM

A MATLAB-based multi-object tracking algorithm was chosen and improved (Student Dave, 2013) to analyze UAV videos. The algorithm is based on two main pillars. First, the particles on each frame of the video are detected. Second, every single detection is matched together along the image sequence using the Kalman-filter. The algorithm successfully reconstructs the trajectories of the tracers.

EULERIAN VERSUS LAGRANGIAN FLOW ASSESSMENT

In **Figure 1** the trajectories reconstructed from PTV analysis (left panel) and the steady-state streamlines fitted on the ADCP based flow velocity distribution at the free surface (right panel) are shown. In the figure, the rectangle shows the UAV's field of view (FOV) located downstream from the tip of the groyne. The differences between the two images clearly underline the additional information on the complex flow patterns contained by the PTV based analysis.

The transversal relocation of the tracers indicates the mixing effect of the vortices generated by the shear layer at the groynes. Performing statistical analysis on the instantaneous velocity fields, a quantitative assessment on mixing parameters can be performed, which cannot be directly derived from ADCP based flow fields.

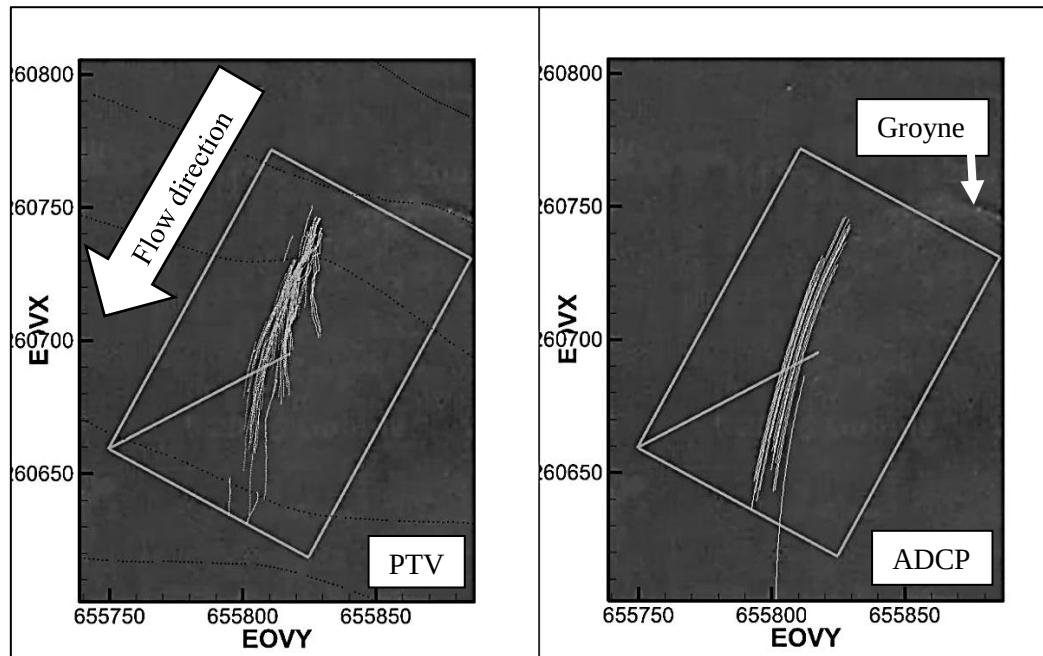


Figure 1. Comparison of the resulted trajectories from the PTV and the ADCP.

CHAOTIC CHARACTERISATION

A possible way to quantitatively describe the spatially and temporally complex nature of the flow at such locations using the PTV results is to reveal the chaotic nature of the flow. The traditional way to characterize this chaotic feature is the determination of the standard Lyapunov exponent of chaotic advection (Tél and Gruiz, 2006). Accordingly, if the initial distance is small between two particles, the growth of the distance in time is proportional to an exponential factor. Zsugyel et al. (2012) used 3-5 particles to analyze this phenomenon, whereas in this study the traveling of hundreds of particles could be analyzed, providing more detailed information on the chaotic nature of the flow. Further attempts will be made to characterize chaotic motion using the river-scale PTV results.

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