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Gabriella Lükő

Lagrangian Analysis of River Flow from UAV Videos to Characterize Mixing



Budapest University of Technology and Economics
Department of Hydraulics and Water Resources Engineering

Introduction



- Use of **UAVs** has become common
- In river engineering: **discharge measurements**
- Eulerian characterization of **mixing** is more typical
- The aim of this study:
 - Collecting UAV videos
 - Improving an image-processing algorithm
 - Characterize mixing and chaos

Field measurements



Applied UAV:

- Type: DJI Phantom 3 Standard
- 2.7K camera + gimbal

Location:

- River Danube at 1670 rkm
- Discharge: 1080 m³/s (low water)



Figure 1.
DJI P3S UAV

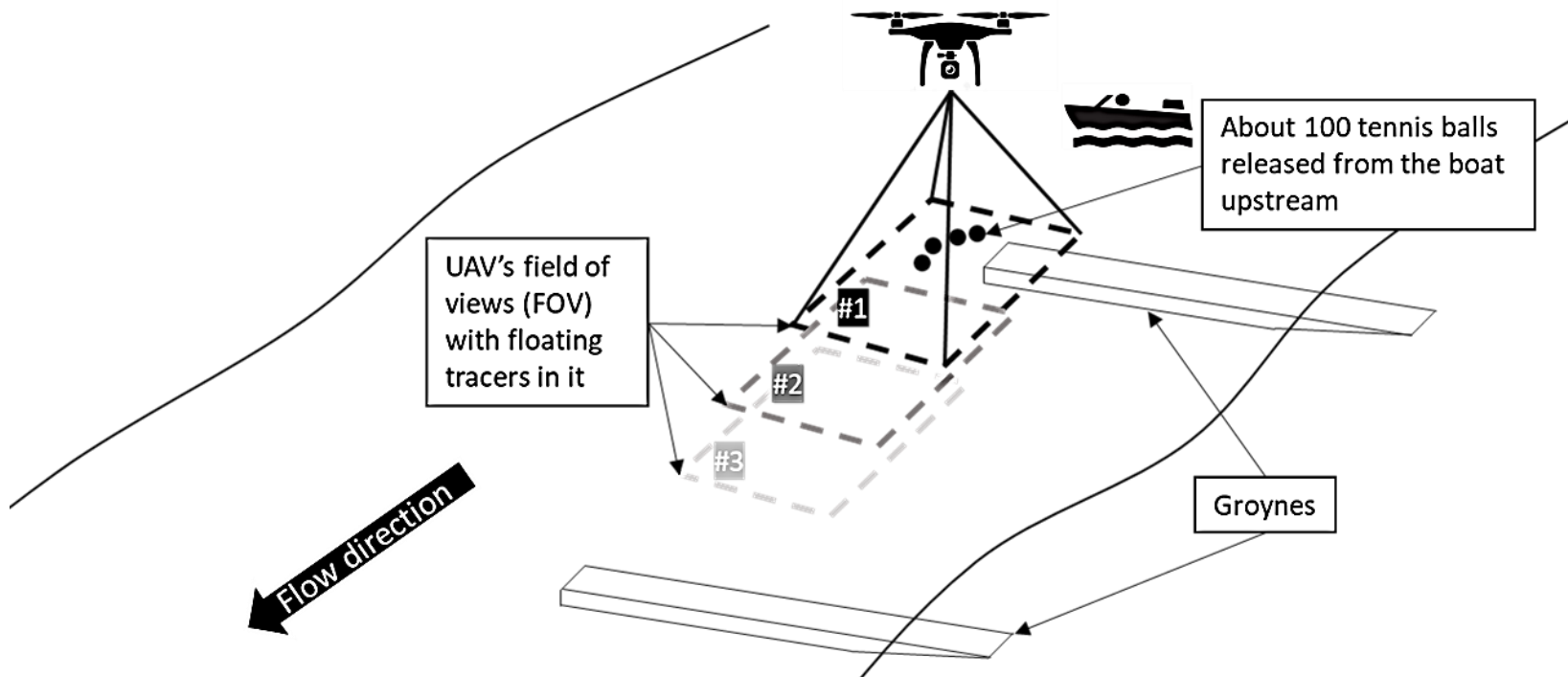


Figure 2. Study site

Particle Tracking Velocimetry (PTV)

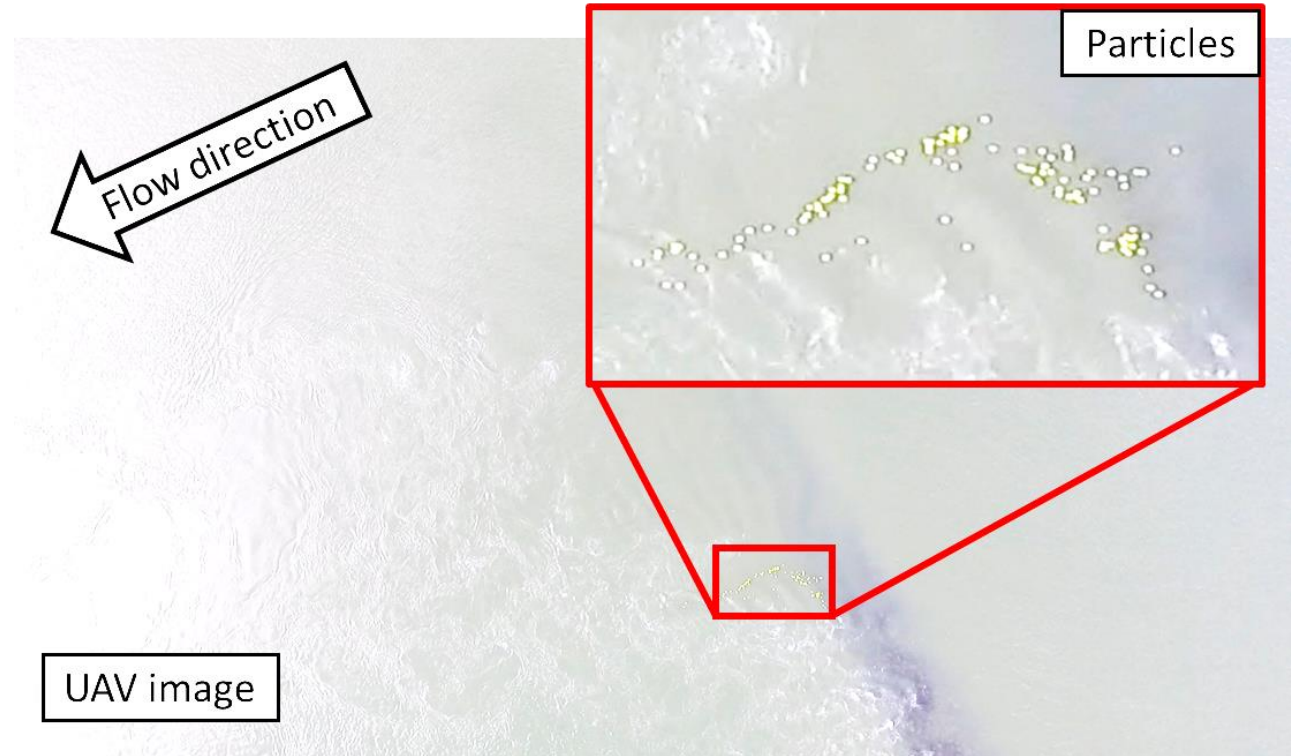
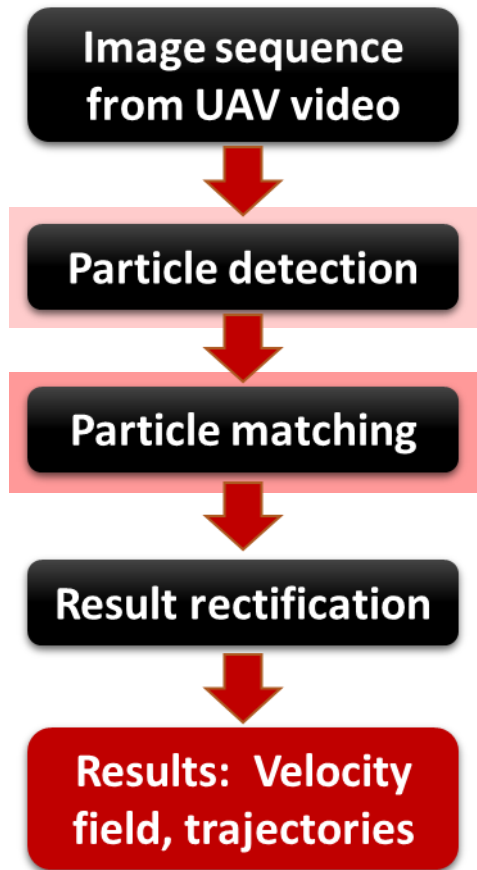


Figure 3. Raw UAV image

Structure of PTV algorithm



Masking

Gauss filter

Setting color interval

Maximums = detections

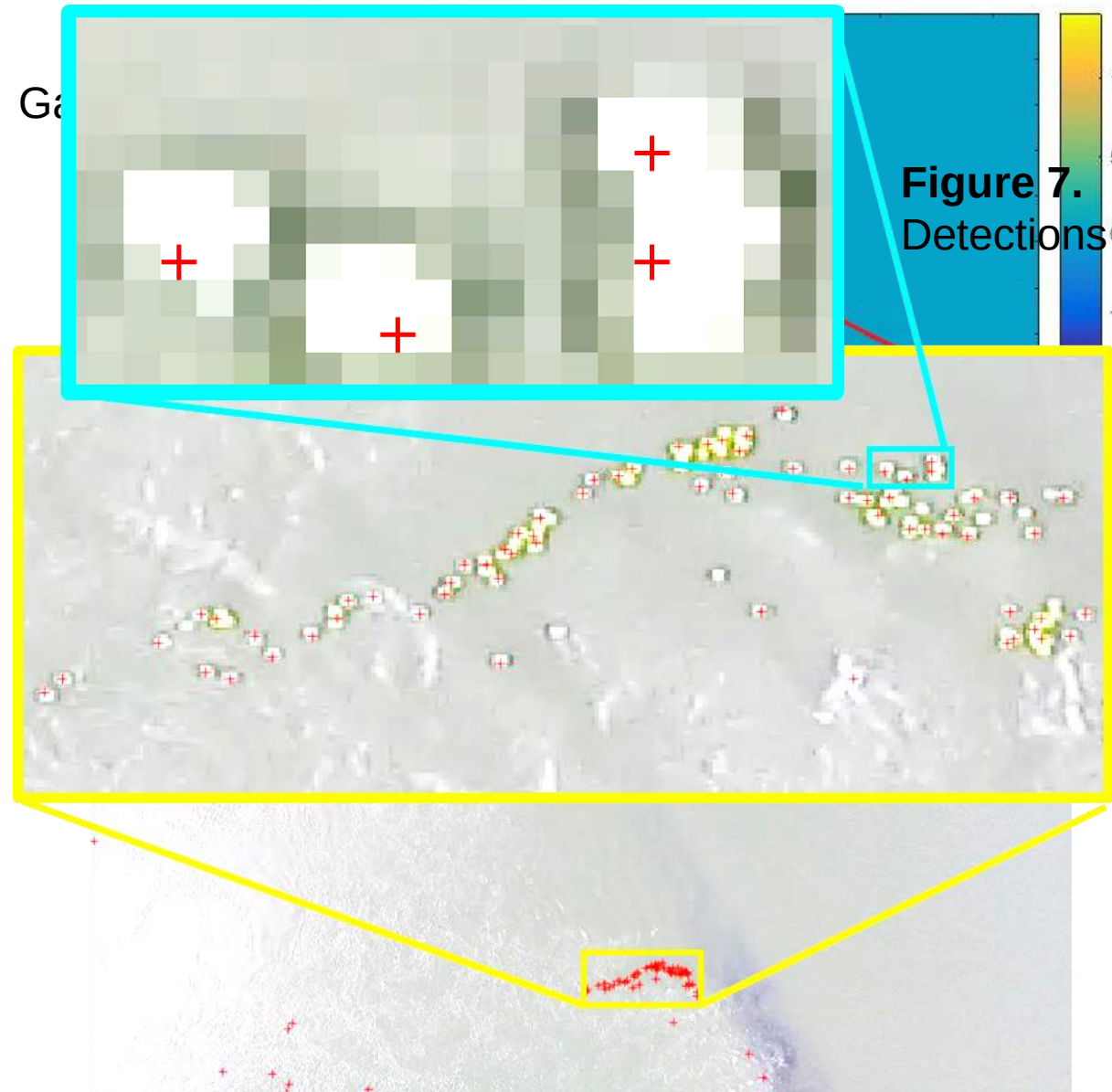
Kalman filter

Chosing the right tracks

Adding new tracks
& deleting bad tracks

Saving good trajectories

Gal



PTV and ADCP results



- Fine-scale
- Unsteady flow structures (eddies)



- Large-scale
- Streamlines show permanent flow structures

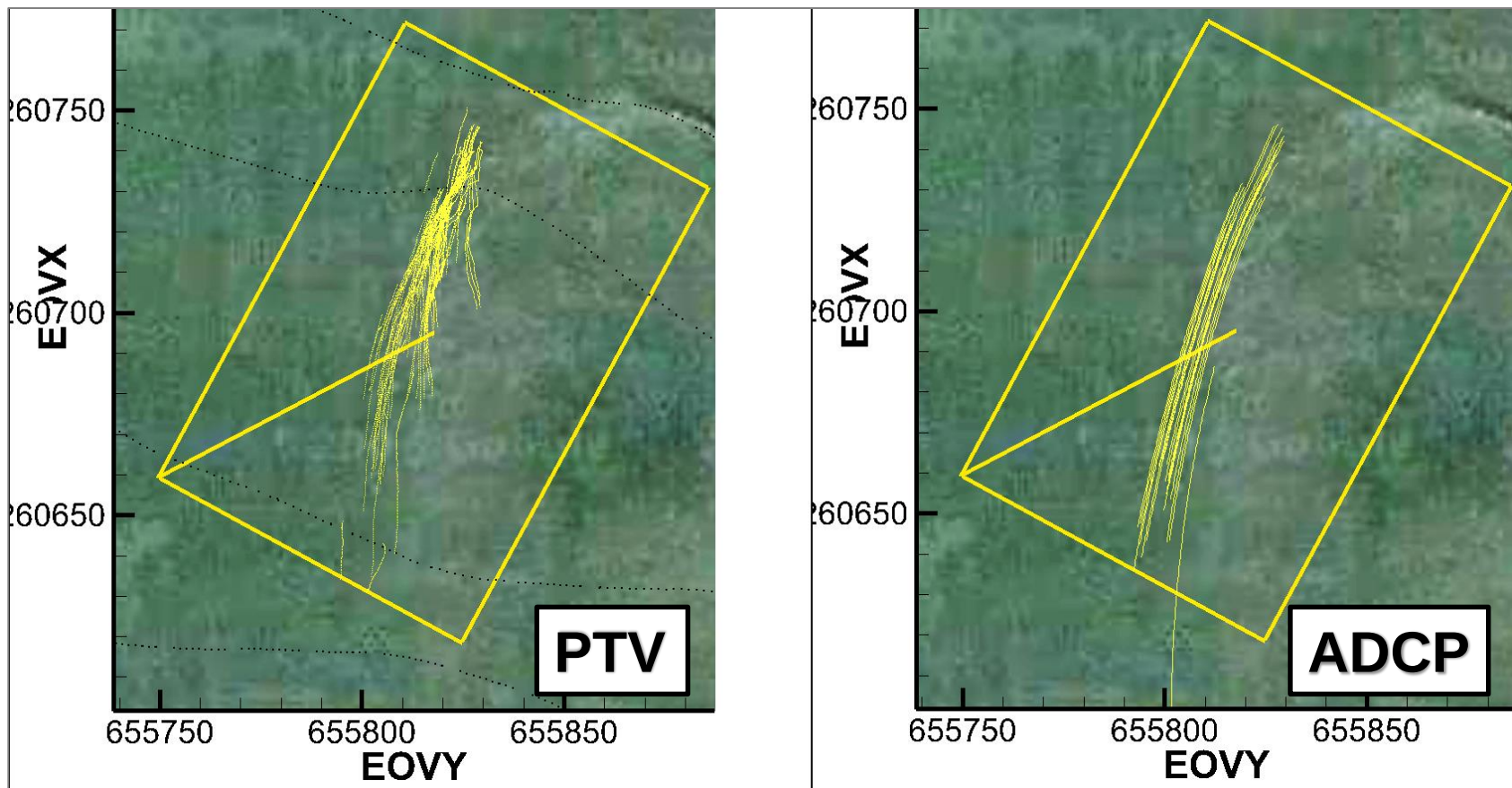


Figure 8. Lagrangian (PTV) versus Eulerian (ADCP) flow assessment

Characterization of mixing



- Probability Density Functions (PDFs)

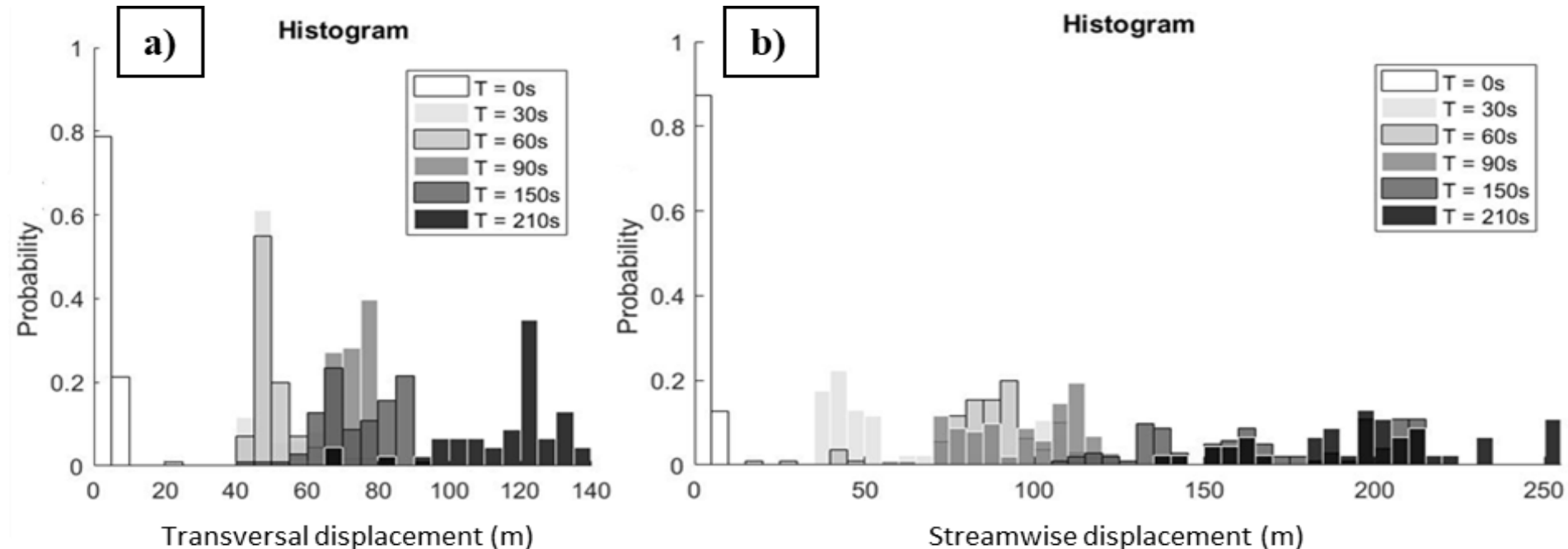


Figure 9. Probability density functions of the transversal (a) and streamwise extension (b) of the particles.

Table 1. The changes of the transversal and streamwise extension of the plume.

Time (T)	0 s	30 s	60 s	90 s	150 s	210 s
Transversal	<10 m	40 m	45 m	50 m	60 m	75 m
Streamwise	<10 m	70 m	75 m	80 m	110 m	>130 m

Characterization of mixing



- Anomalous relative displacement PDFs

The relative displacement $\mathbf{r}(t)$ of a single trajectory is:

$$\mathbf{r}(t) = \mathbf{r}(t_0 + t) - \mathbf{r}(t_0)$$

Anomalous relative displacements:

$$\mathbf{r}'(t) = \mathbf{r}(t) - \mathbf{R}(t)$$

Calculated both:

$\mathbf{r}'_1$ – streamwise

$\mathbf{r}'_2$ – transversal direction

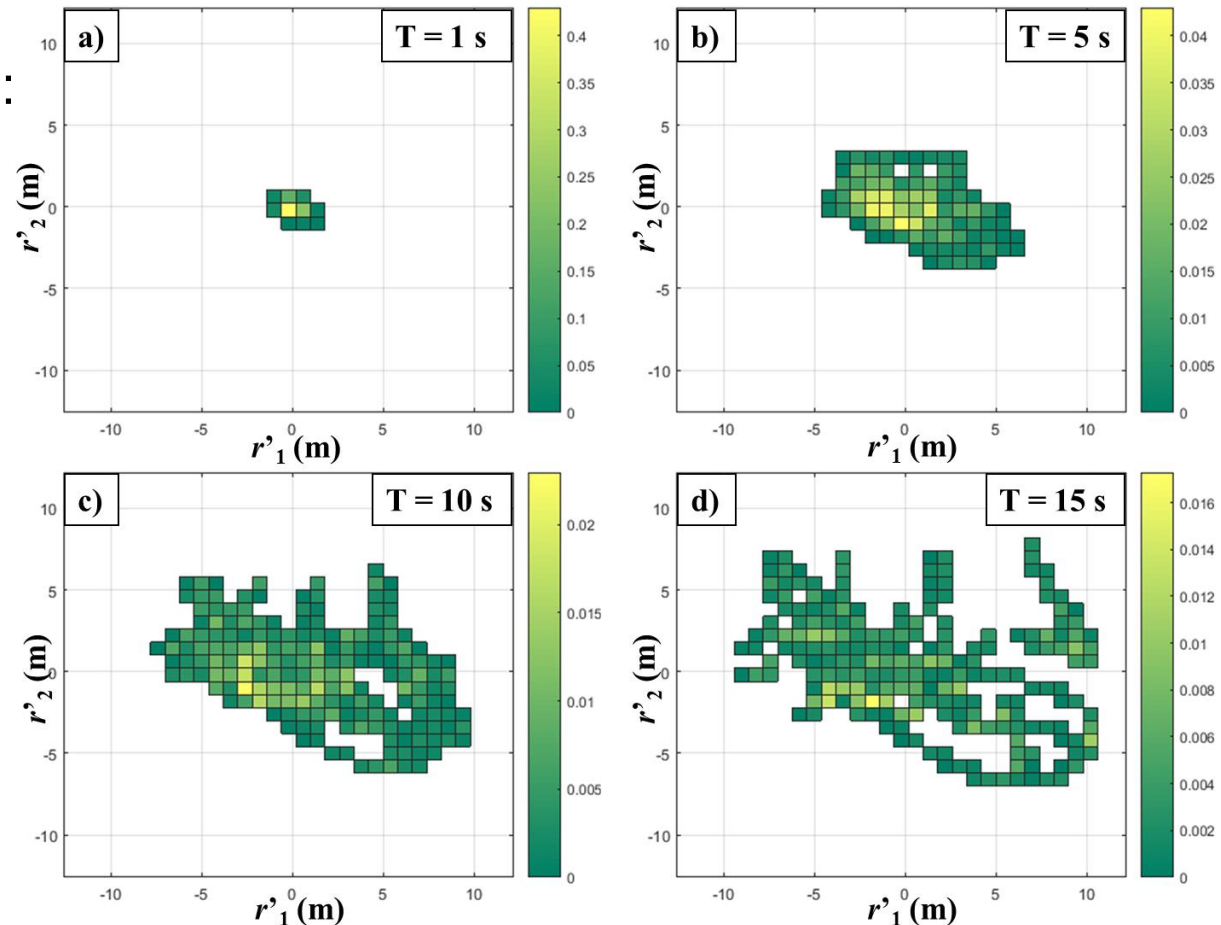


Figure 10. Anomalous relative displacement PDFs at $T = 1$ (a), 5 (b), 10 (c) and 15 (d) s.

Characterization of Chaos



The Lyapunov exponent (λ) is described as:

$$\Delta r = \Delta r_0 \cdot e^{\lambda t}$$

Local prediction time (τ):

$$\tau = \frac{1}{\lambda}$$

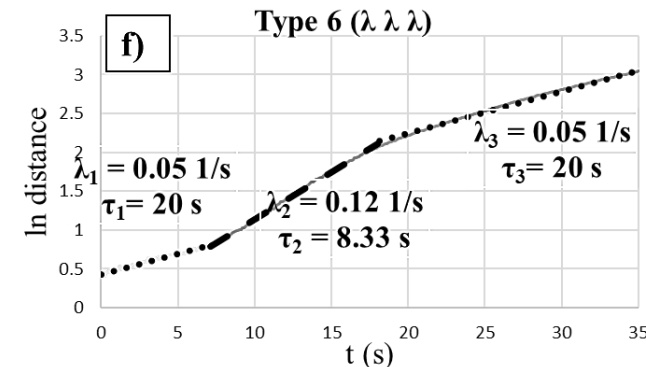
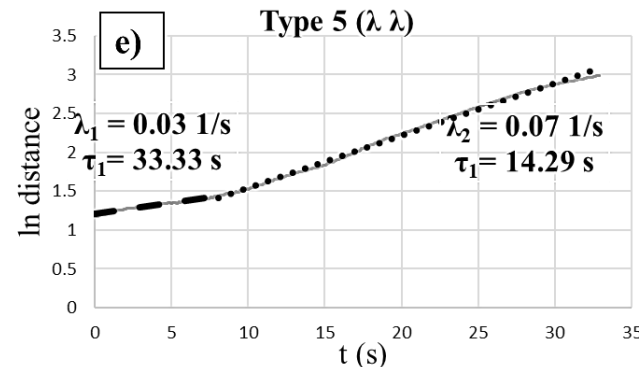
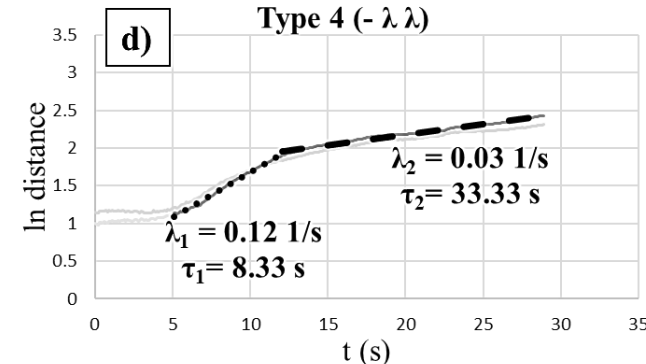
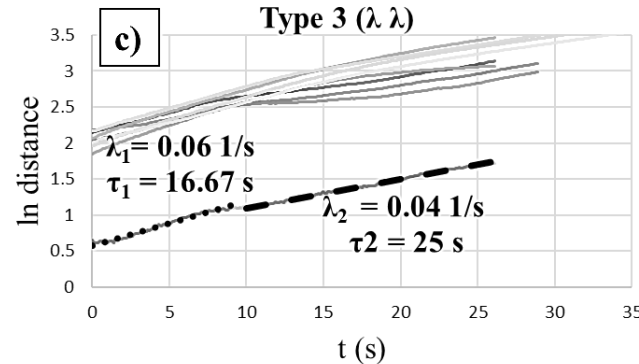
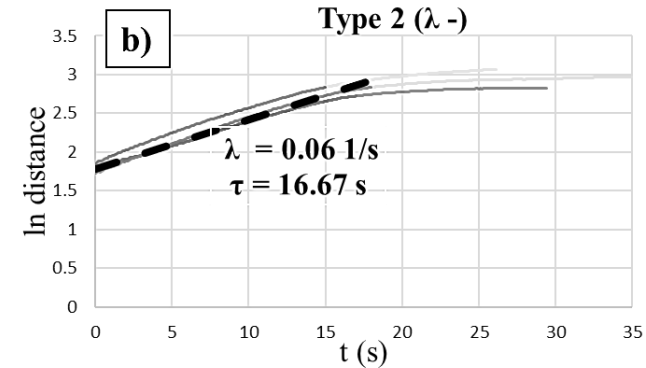
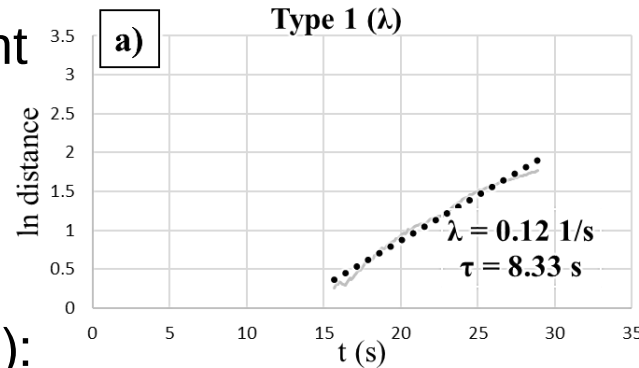


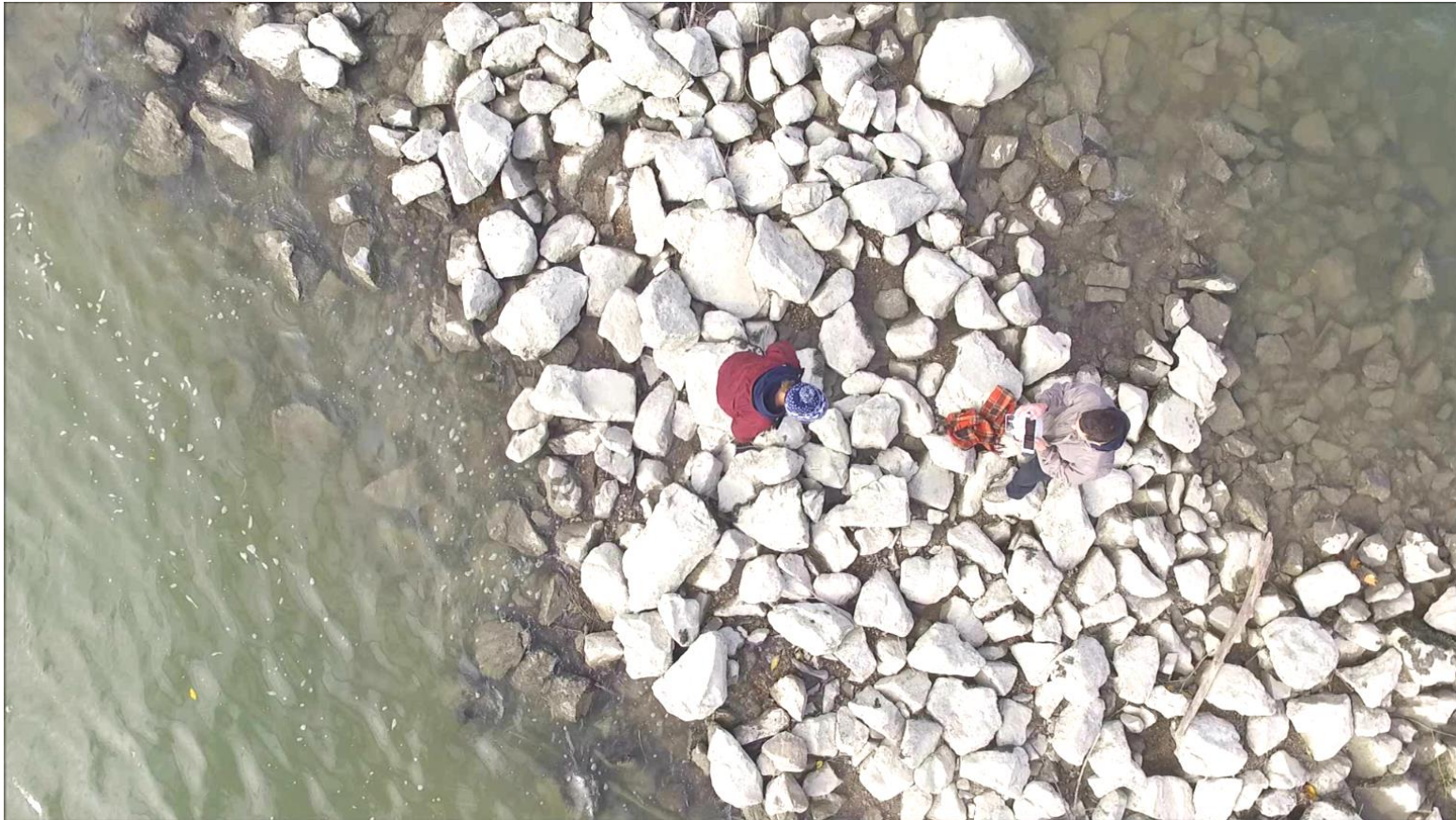
Figure 11. The six types of characterized particle pair separation curves.

Conclusions



- UAV-based PTV measurements have been carried out
- MATLAB algorithm has been improved to enable the quantitative description of mixing processes
- Relative displacements of tracers have been calculated as well as characterizing the chaotic nature of the flow
- Technical implementation of the UAV measurements need to be improved for more detailed analysis in the future

Thank you for your attention!



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