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Evidence and possible causes of velocity pulsing in a turbidity current in Lake Geneva

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Background

When negatively-buoyant, turbid, riverine inflows reach lakes or reservoirs, they plunge and form a turbidity current (Fig. 1). According to Kostaschuk et al. (2018): „Turbidity currents that are driven by prolonged river flow and constant supplies of suspended sediment are referred to as continuous turbidity currents and can flow for weeks to months. Continuous turbidity currents are characterized by regular fluctuations in velocity or *pulsing* even though the river inflow does not fluctuate." Such pulsing is likely to enhance mixing between the influent and ambient water, thereby increasing the dilution of the turbidity current and consequently decreasing its density excess, which influences the pathway and final destination of all constituents (sediment, oxygen, nutrients, contaminants) it may carry. Furthermore, pulsing is likely to produce spatial variations in bed erosion and deposition. So far, its driving mechanism in lakes is unknown.

→ Existing hypothesis by Kostaschuk et al. (2018) and Best et al. (2005): pulsing may result from Rayleigh-Taylor instabilities generated by *shifting surface lobes* along the plunge line where the river enters the receiving water body.

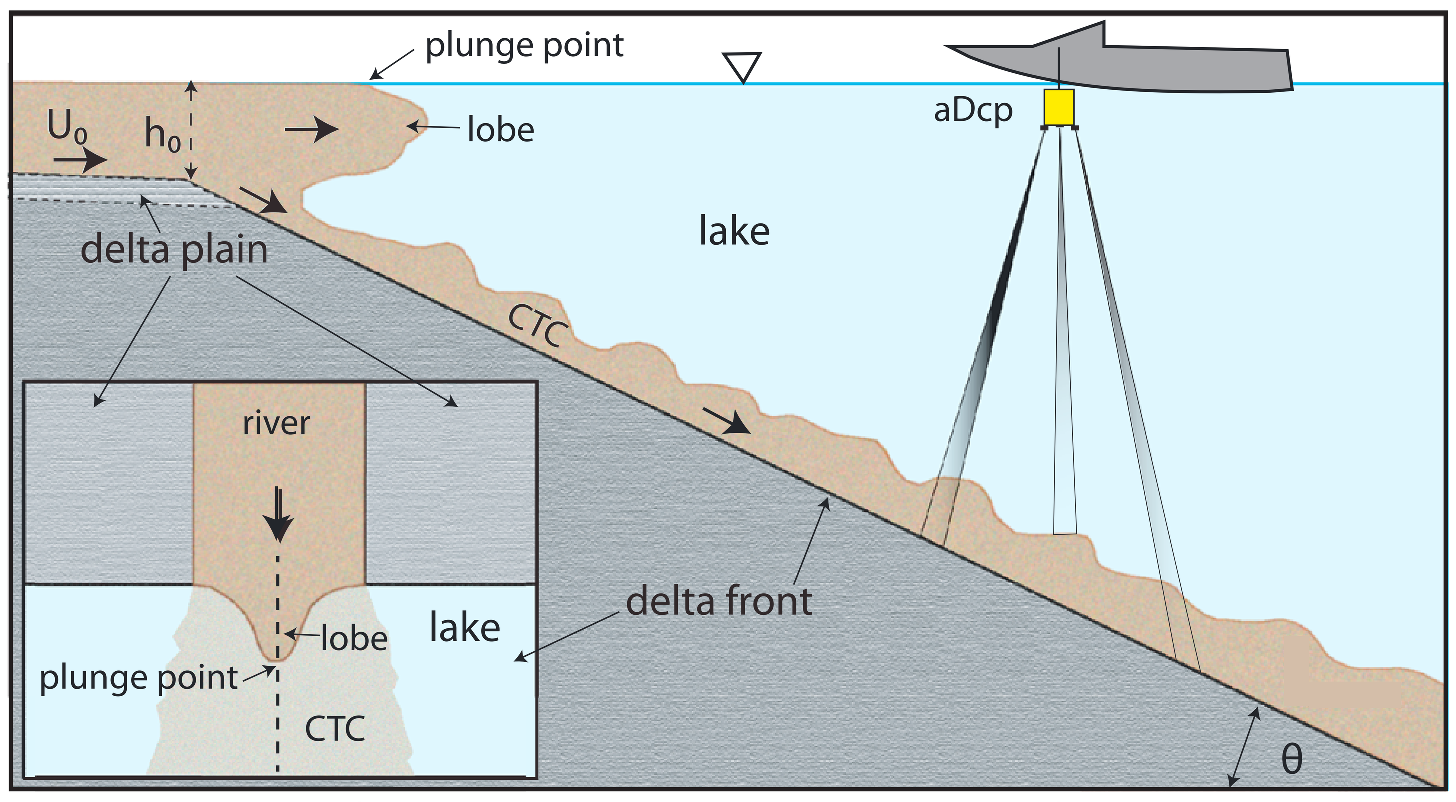

Figure 1: plunging inflow and subsequent turbidity current with ADCP set-up, adapted from Kostachuck et al. (2018)

Science question

Can the combination of sub-surface velocity measurements and high-resolution surface pattern imagery confirm/contradict the link between surface plume dynamics and velocity pulsing?

Methods

Two field measurement campaigns were undertaken at the negatively-buoyant, turbid Rhône River inflow at Lake Geneva on 26.06.2019 and 11.07.2019. Boat-towed ADCP measurements were performed along a longitudinal-vertical transect coinciding with the river axis in front of the river mouth (Fig. 1 & 2), in an effort to capture velocity pulsing in the Rhône River-fed continuous turbidity current. A mobile, balloon-mounted, high-resolution camera was used (Fig. 2) to capture the surface patterns created by the sediment-rich, inflowing water in the plunging area. Once their presence was confirmed, the frequencies of velocity pulsing and lobe-shifting along the plunge line were compared.

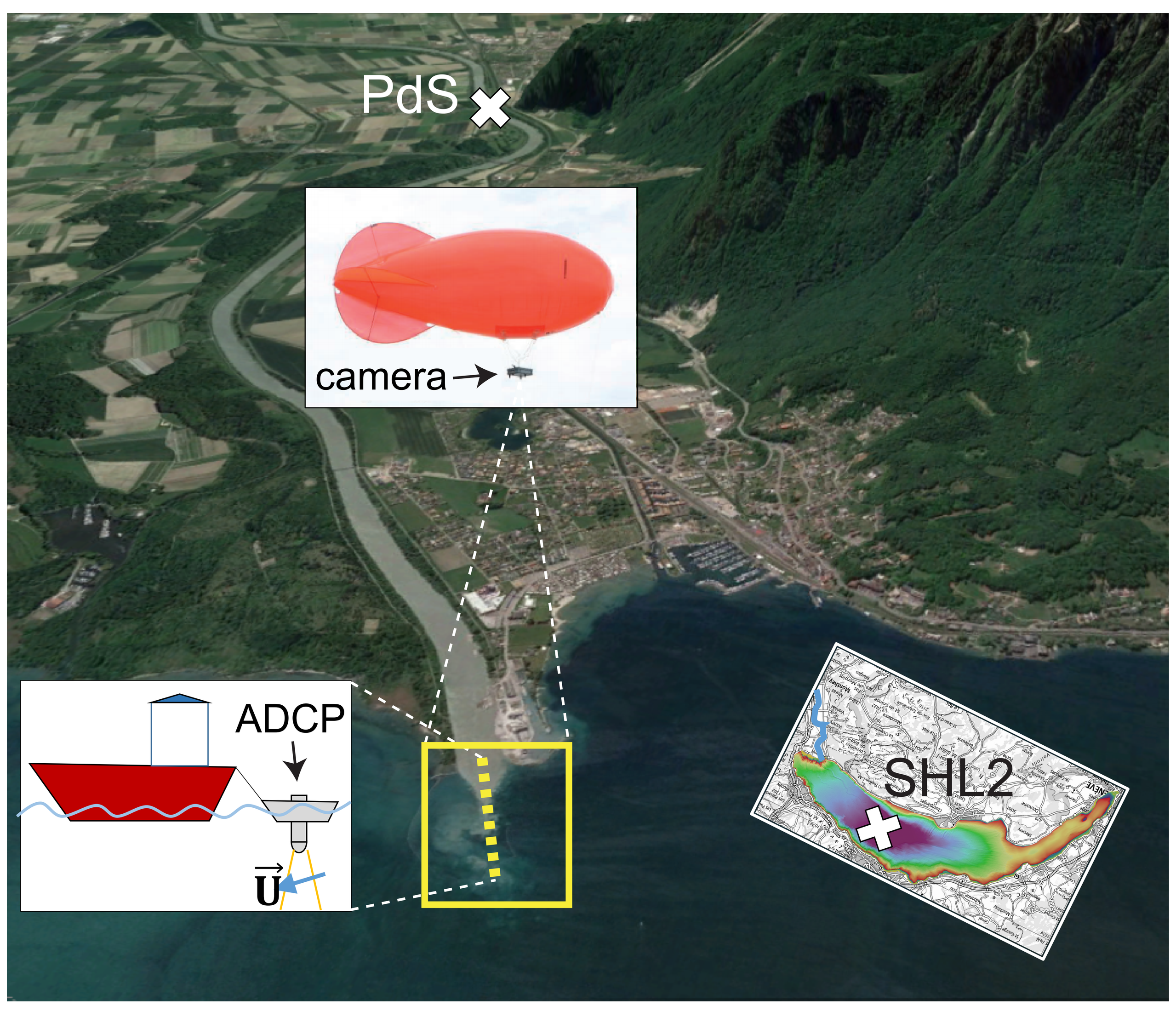

Figure 2: Rhône River inflow into Lake Geneva with boat-towed ADCP and balloon-mounted camera set-ups

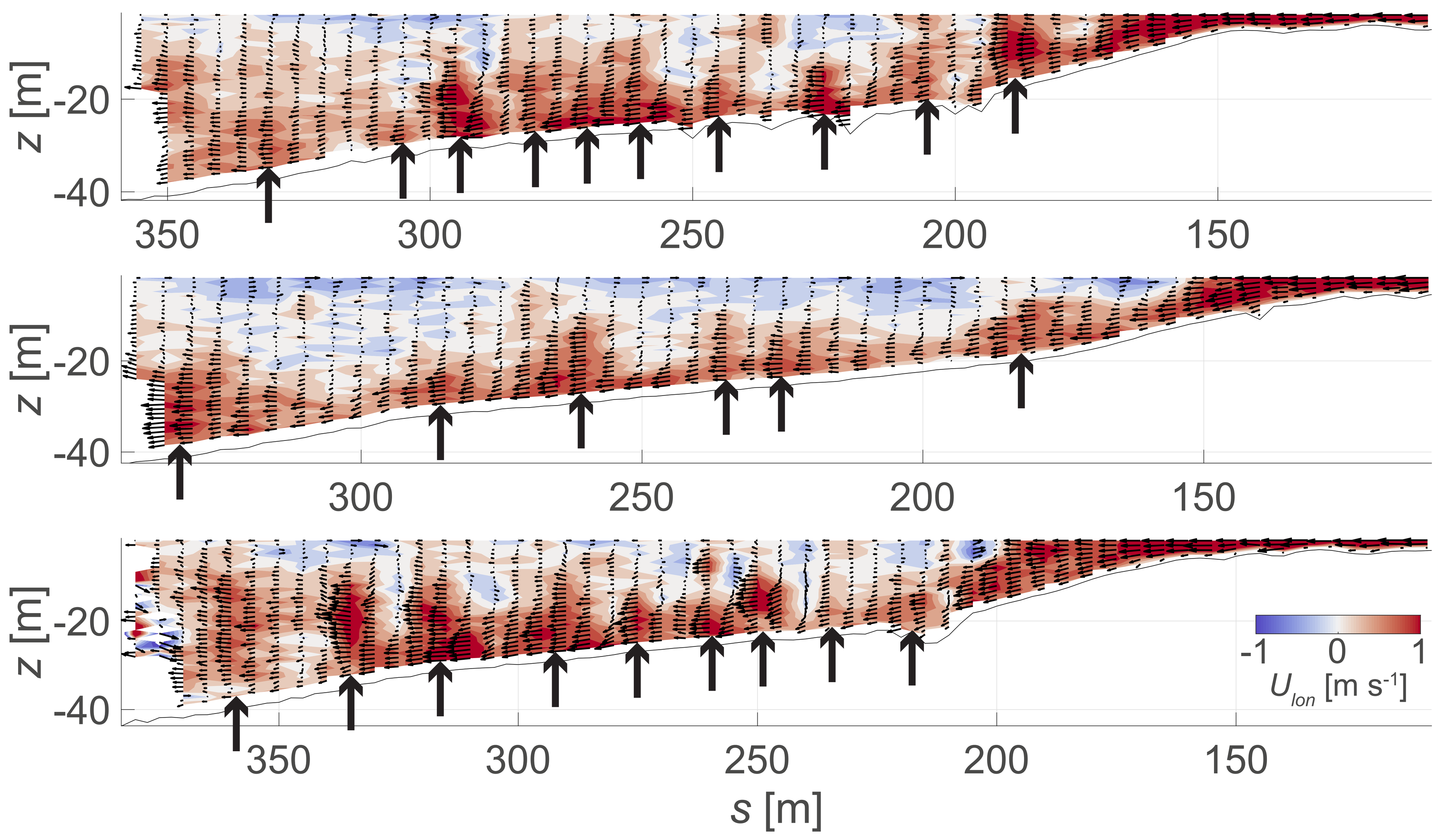

Figure 3: three longitudinal-vertical velocity transects of the plunging Rhône River inflow and subsequent turbidity current exhibiting pulsing

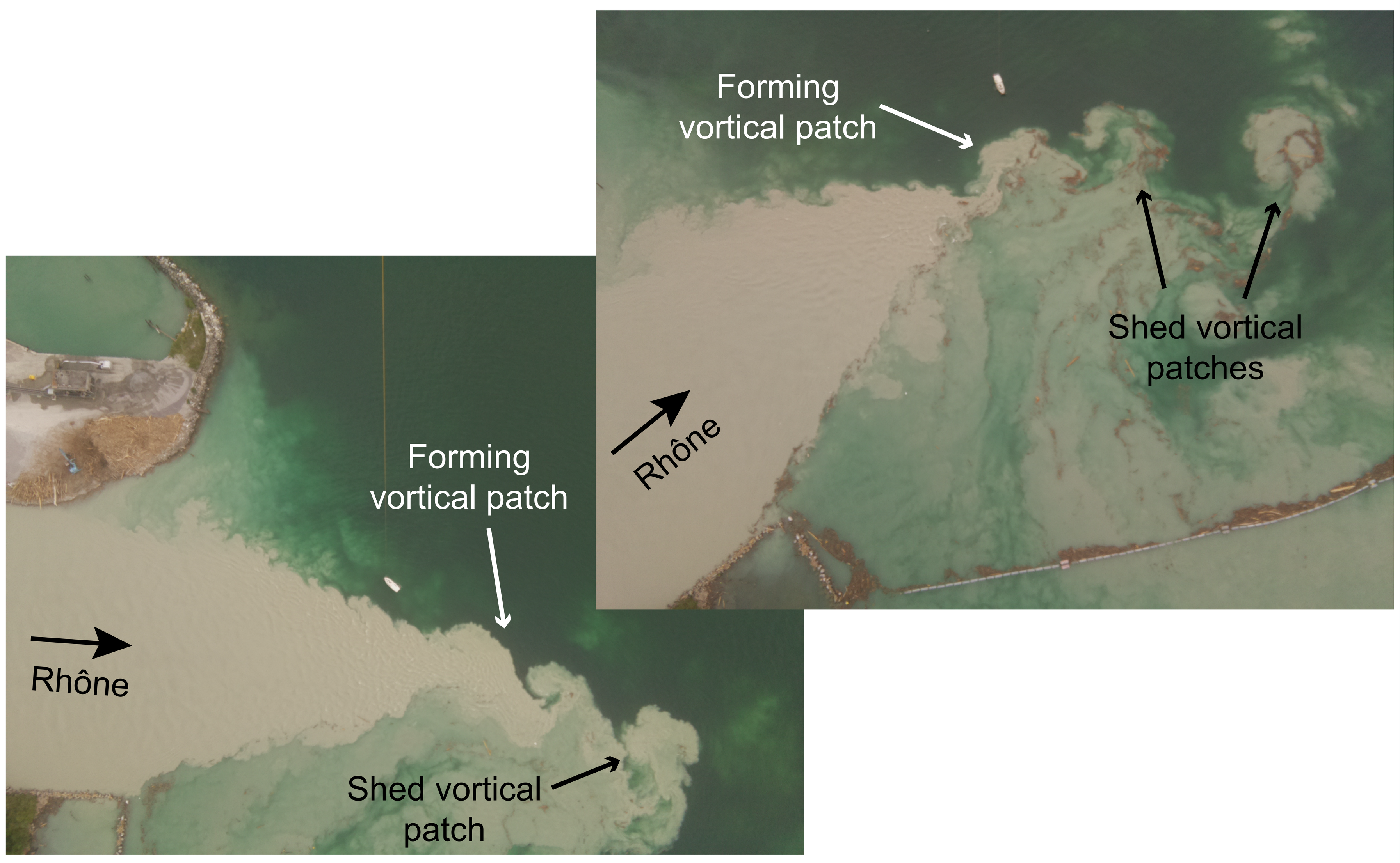

Figure 4: two balloon-mounted camera images of the plunging Rhône River inflow showing the formation and shedding of vortical patches

Velocity pulsing & vortex shedding frequencies [min^{-1}]					
velocity pulsing	0.44	0.68	0.66	0.67	0.47
vortex shedding	0.80	0.45	0.61	0.75	0.82

Table 1: comparison of the measured velocity pulsing and vortex shedding frequencies

Results and discussion

The boat-towed ADCP measurements confirm the presence of pulsing in the velocity profile of the turbidity current (Fig. 3). The balloon-mounted camera images show a largely consistent, triangle-shaped, sediment-rich surface plume surrounded by a myriad of turbulent mixing processes (Fig. 4). Among these mixing processes the shedding of vortical patches downstream of the triangle-shaped plume seems to match the description of „shifting surface lobes along the plunge line" by Kostachuck et al. (2018) the closest. Both the velocity pulsing and vortex shedding measurements present the clearest and highest-resolution ones in a lake to date. The frequencies of the velocity pulsing and vortex shedding are compared in Table 1 and are of the same order of magnitude, which presents a first indication of a possible causal relationship. A detailed, step-by-step comparison of the balloon-mounted camera images and ADCP velocity measurements might lead to more conclusive answers.

References

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