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Hydrodynamic aspects of large river confluence with different water densities

Tatyana Lyubimova[1], Anatoliy Lepikhin[2], Yanina Parshakova[1], Stuart Lane[3], Carlo Gualtieri[4], and Bernard Roux[5]

[1]Institute of Continuous Media Mechanics UB RAS, Computational Fluid Dynamics Laboratory, Perm, Russian Federation (lubimova@psu.ru)

[2]Mining Institute UB RAS, Land Hydrology Laboratory, Perm, Russian Federation

[3]University of Lausanne, Institute of Earth Surface Dynamics, Lausanne, Switzerland

[4]University of Napoli Federico II, Department of Civil, Architectural and Environmental Engineering, Napoli, Italy

[5]Aix-Marseille Université and Ecole Centrale Marseille, Marseille, France

River confluences are characterized by complex 3D changes in flow hydrodynamics and bed morphology and provide important ecological functions. The current literature on river confluences suggests that their hydrodynamics and morphodynamics are controlled by three aspects: (1) the geometry (planform and junction angle) of the confluence, (2) the momentum flux ratio of the tributaries and (3) the level of concordance between channel beds at the confluence entrance. However, the difference in water densities between the tributaries, and the associated stratification, potentially may impact on hydrodynamics and mixing as well, but such aspects has received less attention by far, and has not yet been subject to systematic investigation.

The objective of this study is to investigate hydrodynamics and mixing within the confluence zone of the Kama and Vishera rivers (Russia). During the warm period, the water densities in these rivers are similar due to the peculiarities of their hydrological basins. Hence density effects are negligible. However, in winter, the mineralization level of waters in the Vishera river significantly exceeds that in the Kama river. Even due to a significant decrease in the discharge of these rivers, the densimetric Froude number Fr is of the order of unity. This condition provided the motivation for investigating the effects of density differences on hydrodynamic and mixing at such river confluence.

The study of these effects was carried out on the basis of full-scale field measurements and numerical experiments in a full 3D formulation (i.e. with no hydrostatic approximation). Both the field measurements and the numerical results suggest that hydrodynamics processes at the confluence in the absence and in the presence of density stratification are fundamentally different.. At large densimetric Froude numbers (at small density differences) the waters of the Vishera and Kama rivers flow, practically without mixing, for several kilometers in the form of two parallel streams and at Fr of the order of unity, the more mineralized (more dense) waters of the Vishera river flow under the less dense waters of the Kama river leading to much more rapid mixing.

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