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Secondary flow structures in large rivers

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Measuring the velocity field in large rivers remains a challenge, even with recent measurement techniques such as Acoustic Doppler Current Profiler (ADCP). Indeed, due to the diverging angle between its ultrasonic beams, an ADCP cannot detect small-scale flow structures. However, when the measurements are limited to a single location for a sufficient period of time, averaging can reveal large, stationary flow structures. Here we present velocity measurements in a straight reach of the Seine river in Paris, France, where the cross-section is close to rectangular. The transverse modulation of the streamwise velocity indicates secondary flow cells, which seem to occupy the entire width of the river. This observation is reminiscent of the longitudinal vortices observed in laboratory experiments (e.g. Blanckaert et al., Advances in Water Resources, 2010, 33, 1062-1074). Although the physical origin of these secondary structures remains unclear, their measured velocity is sufficient to significantly impact the distribution of streamwise momentum. We propose a model for the transverse profile of the depth-averaged velocity based on a crude representation of the longitudinal vortices, with a single free parameter. Preliminary results are in good agreement with field measurements. This model also provides an estimate for the bank shear stress, which controls bank erosion.