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A million miles from rivers: secondary flow in submarine canyon-fan systems.

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In both subaerial and submarine meander bends, fluid flow travels in a helical spiral, as centrifugal and hydrostatic forces balance the turbulent shear stress within the flow. Understanding the sense of the secondary flow circulation is important because the near bed orientation of the fluid flow vector strongly affects sediment transport and hence meander bend morphodynamic evolution, the patterns of surface grain size sorting and therefore the character of the sedimentary deposits produced. To evaluate the conditions favouring the onset of distinctive secondary flow circulations (and in particular, to discriminate cases when the near-bed radial flow is directed towards the inner bank (‘river like’) or outer bank (‘river reversed’), we develop a holistic analytical model incorporating centrifugal and Coriolis forces, the radial pressure gradient and the baroclinicity of the flow. This new model is validated using experimental data and used to highlight the influence on the secondary flow of the principle physical forces acting on the flow.

Previous analytical studies have considered a temporally constant, two-dimensional, rotationally invariant, framework that leads to vanishing radial material flux conditions when applied to flows within bounded channels. However, we show that a three-dimensional flow framework, with non-zero radial material fluxes resultant of flow super-elevation and overspill, is required to capture the rotational structure of flow within submarine meanders. Given this three-dimensional model, we present phase-space diagrams indicating the variation of the generic vertical structure of rotational flow within submarine meanders. Our findings highlight the importance of the radial flux boundary conditions as the primary control of secondary flow dynamics of submarine meanders. Further, the new model presented here suggests that the propensity for the occurrence of “river-reversed” secondary flow in canyon-fan networks is greater than recently advocated.