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Metrics for assessing the performance of morphodynamic models of braided rivers at event and reach scales

Richard Williams (1), Richard Measures (2), Murray Hicks (3), and James Brasington (4)

(1) School of Geographical and Earth Sciences, University of Glasgow, Glasgow, United Kingdom (richard.williams@glasgow.ac.uk), (2) River and Coastal Geomorphology, NIWA, Christchurch, New Zealand (richard.measures@niwa.co.nz), (3) River and Coastal Geomorphology, NIWA, Christchurch, New Zealand (murray.hicks@niwa.co.nz), (4) School of Geography, Queen Mary, University of London, London, United Kingdom (j.brasington@qmul.ac.uk)

Advances in geomatics technologies have transformed the monitoring of reach-scale (10^0-10^1 km) river morphodynamics. Hyperscale Digital Elevation Models (DEMs) can now be acquired at temporal intervals that are commensurate with the frequencies of high-flow events that force morphological change. The low vertical errors associated with such DEMs enable DEMs of Difference (DoDs) to be generated to quantify patterns of erosion and deposition, and derive sediment budgets using the morphological approach. In parallel with reach-scale observational advances, high-resolution, two-dimensional, physics-based numerical morphodynamic models are now computationally feasible for unsteady, reach-scale simulations. In light of this observational and predictive progress, there is a need to identify appropriate metrics that can be extracted from DEMs and DoDs to assess model performance. Nowhere is this more pertinent than in braided river environments, where numerous mobile channels that intertwine around mid-channel bars result in complex patterns of erosion and deposition, thus making model assessment particularly challenging.

This paper identifies and evaluates a range of morphological and morphological-change metrics that can be used to assess predictions of braided river morphodynamics at the timescale of single storm events. A depth-averaged, mixed-grainsize Delft3D morphodynamic model was used to simulate morphological change during four discrete high-flow events, ranging from 91 to 403 m^3s^{-1}, along a 2.5 x 0.7 km reach of the braided, gravel-bed Rees River, New Zealand. Pre- and post-event topographic surveys, using a fusion of Terrestrial Laser Scanning and optical-empirical bathymetric mapping, were used to produce 0.5 m resolution DEMs and DoDs. The pre- and post-event DEMs for a moderate ($227m^3s^{-1}$) high-flow event were used to calibrate the model. DEMs and DoDs from the other three high-flow events were used for model assessment using two approaches. First, “morphological” metrics were applied to compare observed and predicted post-event DEMs. These metrics include measures of confluence and bifurcation node density, bar shape, braiding intensity, and topographic comparisons using a form of the Brier Skill Score and cumulative frequency distributions of rugosity. Second, “morphological change” metrics were used to compare observed and predicted morphological change. These metrics included the extent of the morphologically active area, pairwise comparisons of morphological change (using kappa and fuzzy kappa statistics), and comparisons between vertical morphological change magnitude and elevation distribution. Results indicate that those metrics that assess characteristic features of braiding, rather than making direct comparisons, are most useful for assessing reach-scale braided river morphodynamic models. Together, the metrics indicate that there was a general affinity between observed and predicted braided river morphodynamics, both during small and large magnitude high-flow events. These results thus demonstrate how high-resolution, reach-scale, natural experiment datasets can be used to assess the efficacy of morphological models in predicting realistic patterns of erosion and deposition. This lays the foundation for the development and assessment of decadal scale morphodynamic models and their use in adaptive river basin management.