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Passive advection and dynamic reorganization of mountainous bedrock rivers: A landscape evolution modeling approach

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Do river basins record reliably pervasive and long time scale tectonic deformation? A positive answer means that river basins advect passively with the crust over which they are imprinted in response to horizontal tectonic deformation. A negative answer means that drainage network reorganization by stream and area capture controls the planview morphology of fluvial landscapes, and erase partly or completely any earlier configuration of river organization.

In order to investigate whether and under what conditions the planview of river basins contains a record of the tectonic horizontal deformation we take as a case study the Southern Alps of New Zealand. Castelltort et al. (this meeting) have presented a detailed analysis of the Southern Alps drainage network, showing significant differences between the east and the west flanks of the mountain range, and an apparent consistant pattern of deformation of the eastern basins. We attempt to explain these observations with a landscape evolution model that couples numerical solutions of erosion and sedimentation for high order rivers with analytical solutions of erosion in low order tributaries and hillslopes. The coupled approach enables determination of the exact location and elevation of the water divide between any adjacent streams, rivers, and basins. As a consequence, reorganization by stream and area capture occurs according to a physical criterion as an end member of continuous migration of water divides.

We impose various horizontal tectonic velocity fields and test the response of the drainage network in a Southern Alps like setting. Our results show striking differences between a scenario where only simple shear is introduced and a scenario where both simple shear and shortening (leading to pure shear) are applied. In the former case all basins deform passively and record the full extent of the imposed tectonic deformation, reorganization is negligible. In the latter case, that shows similarity to the drainage pattern of the Southern Alps, the behavior of river basins differ between the two sides of the orogen. The rivers draining away from the main fault (pro-side) are advected passively and record reliably the imposed tectonic deformation. Simultaneously, the rivers draining to the main fault (retro-side) reorganize continuously by area capture, induced by material advection across fixed geomorphic boundaries: the main water divide and the main fault. A detailed analysis shows how area capture along these two fronts erases the record of simple shear deformation and leads to apparent undeformed basins.