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High precision terrestrial laser scanning : measuring the individual impact of floods and landslides on meandering bedrock river dynamics (Rangitikei river, New-Zealand)

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Actively incising and meandering bedrock rivers are an ubiquitous feature of mountain belts, but the mechanisms leading to their formation and evolution are still poorly understood. Part of the problem lies in our limited ability to quantify in situ the mechanisms governing the dynamics of straight bedrock rivers (tool-cover effects, stochastic sediment supply and discharge effects, roughness effects,...). But the rapid and spatially variable rates of bank erosion in meanders also lead to potentially more complex hillslope-channel interactions than in straight river. Terrestrial laser scanner has the potential to shed new light on these interactions and to capture over large surfaces the impact of individual flood and landsliding events. Given the small changes of surface position that must be detected for even the largest rates of bedrock erosion ($\sim$ 5-10 mm/yr) and the 3D geometrical complexity of bedrock meanders, specific survey approaches and post-processing algorithms must be developed. To this end, we started to perform repeated Terrestrial Laser Scanner (TLS) surveys of actively incising meanders in the Rangitikei river (New-Zealand) in 2009.

The Rangitikei river is incising weakly consolidated mudstone at an average rate of 5 mm/yr since 15 kyr and has developed a very sinuous meandering pattern with several cut-off bedrock meanders. Lateral undercutting of 100 m high cliffs generates failures of up to hundred of meters. Alluvial material consists of coarse resistant material (D50 $\sim$20 cm) sourced from upstream, and large boulders locally derived from rockfalls. Exposed bedrock is rare on the bed but shows that abrasion, weathering by wetting-drying cycles and plucking are important incision mechanisms.

Six TLS surveys were performed at bi-monthly to yearly intervals with a Leica Scanstation 2 in 5 reaches of variable planform curvature. Survey length varies from 300 m to 1200 m and point spacing from $\sim$ 5 mm to 5 cm. Point clouds were co-registered between surveys with a combination of rock-anchored targets and cloud matching leading to an uncertainty down to 3 mm in the best cases. In many cases, rock anchored targets offered a better registration than cloud matching owing to significant surface roughness. Bathymetric measurements completed the surveys under water, and bedload impact logger were installed to document threshold of sediment transport. Raw point clouds were automatically processed to classify vegetation, intact bedrock surfaces, landslide deposits and gravels with the CANUPO free software (Brodu and Lague, in press). We developed a new algorithm to compute 3D surface change directly on raw point clouds without a mandatory meshing or gridding phase. It combines large scale calculations for normal estimation and orientation, with small scale surface change measurement. An explicit treatment of surface roughness and registration quality allows to define a local uncertainty at each calculation point.

We present the methodology used to implement high precision surveys, the software tools developed to generate 3D patterns of bedrock erosion and alluvial cover changes, and show the results of the first 6 surveys during which river response to cliff failures and floods of different magnitude can be precisely quantified in 3D.