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Interactive comment on "Constraining the Stream Power Law: a novel approach combining a Landscape Evolution Model and an inversion method" *by* T. Croissant and J. Braun

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General comments

This study describes a method to invert landscapes for values of erosional parameters in the detachment-limited erosion model and/or for uplift rate. The authors solve the Stream Power formulation (i.e. $\partial h/\partial t = U - KA^mS^n$) using the FastScape landscape evolution model (Braun & Willet, 2012). In their scheme, the minimum misfit between real or synthetic landscapes at steady-state (i.e. $\partial h/\partial t = 0$) and theoretical landscapes is sought. Misfit is calculated using cells that contain rivers. They used

Sambridge's (1999a, b) neighbourhood algorithm to minimise misfit by varying (and covarying) K, m, n and U. They ran two suites of tests. First, a synthetic landscape (for which K, m, n, and U are known) was inverted. Their results show that if K and U are known then m and n can be reliably retrieved (their Figures 2a, b, c). n and m trade-off positively, which reinforces previously published results (e.g. Stock & Montgomery, 1999). If K, m and n are free parameters then the erosional parameter values are more poorly constrained and K trades off strongly against m and n (their Figures 3a, b). Although the absolute values of m and n are poorly constrained, their relative values are well resolved. K cannot be constrained using this approach and must be determined independently. If U is also a free parameter then the authors show that the absolute values of m and n can not be determined, but their relationship is well constrained. The values of U and K, and their relationship are not constrained. In a second suite of tests, the topography of the Whataroa catchment, New Zealand, was inverted. The authors state that this catchment is at steady-state. First, by assuming that U is known, they invert for K, m and n within bounded ranges. Their Figure 6 shows that n and m, K and n, and K and m trade-off. The absolute values of the erosional parameters is poorly constrained, but the relationship between these parameters is reasonably well resolved. They also invert for an uplift rate coefficient, α, which determines the amount uplift between the drainage divide and the Alpine fault in their theoretical landscapes. They tentatively argue that uplift rate increases away from the Alpine fault.

This study builds upon work that used optimisation schemes to invert longitudinal river profiles for uplift rate histories and constrain erosional constants (e.g. Roberts & White, 2010; Roberts et al. 2012). Croissant and Braun have shown that for well-defined problems the relative and absolute values of erosional parameter values (n and m) can be determined by inverting a landscape. By taking an integrative approach they avoid many of the problems that accompany slope-area analysis (i.e. differentiation of noisy data, binning, and resultant unstable solutions). The value of the erosional constant

K must be determined independently. These results confirm the findings of previously published work.

Specific comments

I have three comments regarding the approach and results of this study. First, it is encouraging to see that when K and U are known, the values of n and m can be reliably retrieved for a synthetic landscape. However, when K is also free predicted n and m are incorrect. Why are the best-fitting values of n and m smaller than they should be? As well as showing misfit scatter plots and PDFs, you should show comparisons between observed and theoretical river profiles. These additional plots help the reader to see how well you are fitting data. Apart from Figure 2e & 2f, the authors do not show calculated landscapes. Show observed vs. theoretical river profiles, and difference maps (i.e. reference topo - best fitting model topo) for each test. By plotting misfit as a function of n and m along minimum misfit valleys the reader could evaluate if the values of n and m are well constrained. Secondly, what do the results of inversions where synthetic reference topography was generated with $n \neq 1$ look like? Can you reliably retrieve $n \neq 1$? Thirdly, you should include results from inverting real and/or synthetic transient landscapes in this manuscript. Can you more reliably retrieve erosional parameter values in transient landscapes?

Technical corrections

- Pg. 899, line 25–pg. 900, line 2. I think that the phrasing here is a bit odd. Presumably you didn't run models with $K < 10^{-6}$ because of the computational burden of running with small time steps? If so, I would state that.

- Pg. 906, lines 19–27. What Roberts & White (2010) and Roberts et al. (2012) did is not accurately reported. In their studies erosional constants are not 'fixed at arbitrary values'. Rather erosion rate was calibrated against independent constraint. The values of m and n are constrained by the minimum residual misfit between theoretical and observed river profiles (e.g. Figure 11, Roberts et al., 2012), which is a similar approach to what was described in this manuscript. K is constrained using independent constraints (i.e. local incision estimate, known uplift histories). In their studies, calculated uplift was not assumed to be related to dynamic support. The shapes of river profiles do not directly tell us about the mechanism of uplift, but provide useful clues about the temporal and spatial evolution of uplift.
- Spelling and grammatical mistakes (e.g. pg. 892, lines 2 (tectonic), 20 (provide); pg. 893, line 17 (commonly); pg. 894, lines 2 (define SPM), 3 (increase); pg. 901, lines 3 (New Zealand), 10 (dryer); pg. 903, lines 10 (et), 13 (constrained); pg. 904, line 28 (constrain); pg. 907, line 2 (containing).
- Figure 2d, e, f. Add extra elevation label to colour bar for scale.
- Figure 5. More detail would help the reader to locate themselves. Show drainage divide and location of Alpine fault. Show the location of pixels (rivers) used to calculate misfit. Linking this figure to plots of observed and theoretical river profiles would help the reader to evaluate the goodness of fit.

Interactive comment on Earth Surf. Dynam. Discuss., 1, 891, 2013.