



Supplement of

Impact of noise on landscapes and metrics generated with stream power models

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1 Summary

This Supplementary Information document contains 13 figures, extending the results presented in the main manuscript. Figure 1 shows the distributions of noisy functions added to topography in scenarios A–D. Figures 2 and 3 show examples of ‘square’, ‘escarpment’ and ‘domal’ landscapes and planform geometries generated using the same procedures and parametrisations as those presented in the main manuscript but with no inserted noise. Figure 4 shows impact of assumed value of concavity index on uplift rates estimated from χ -analysis. Figure 5 demonstrates how changing the amplitude of noise in the starting condition affects the recovery of θ and U from slope-area analysis, and affects $z(\chi)$ profiles. Figure 6 shows maps of drainage location probabilities for 100 simulations of red, white, and blue noise added to scenarios A–C, demonstrating convergence for 100 models. Figures 7 and 8 show assessment of steady state for landscapes generated with quenched and spatio-temporal noise. Figures 9 and 10 show results analogous to those shown in Figures 17 and 18 of the main manuscript for models with zero mean noise in the range -0.5 to 0.5 . The hashed polygons in panels h of those main manuscript figures show the extent of $z(\chi)$ profiles in these supplementary figures. Figures 11–13 show impact of inserting un-eroded white, red and blue noise on calculated metrics for select landscapes. All of these results are discussed in the main manuscript.

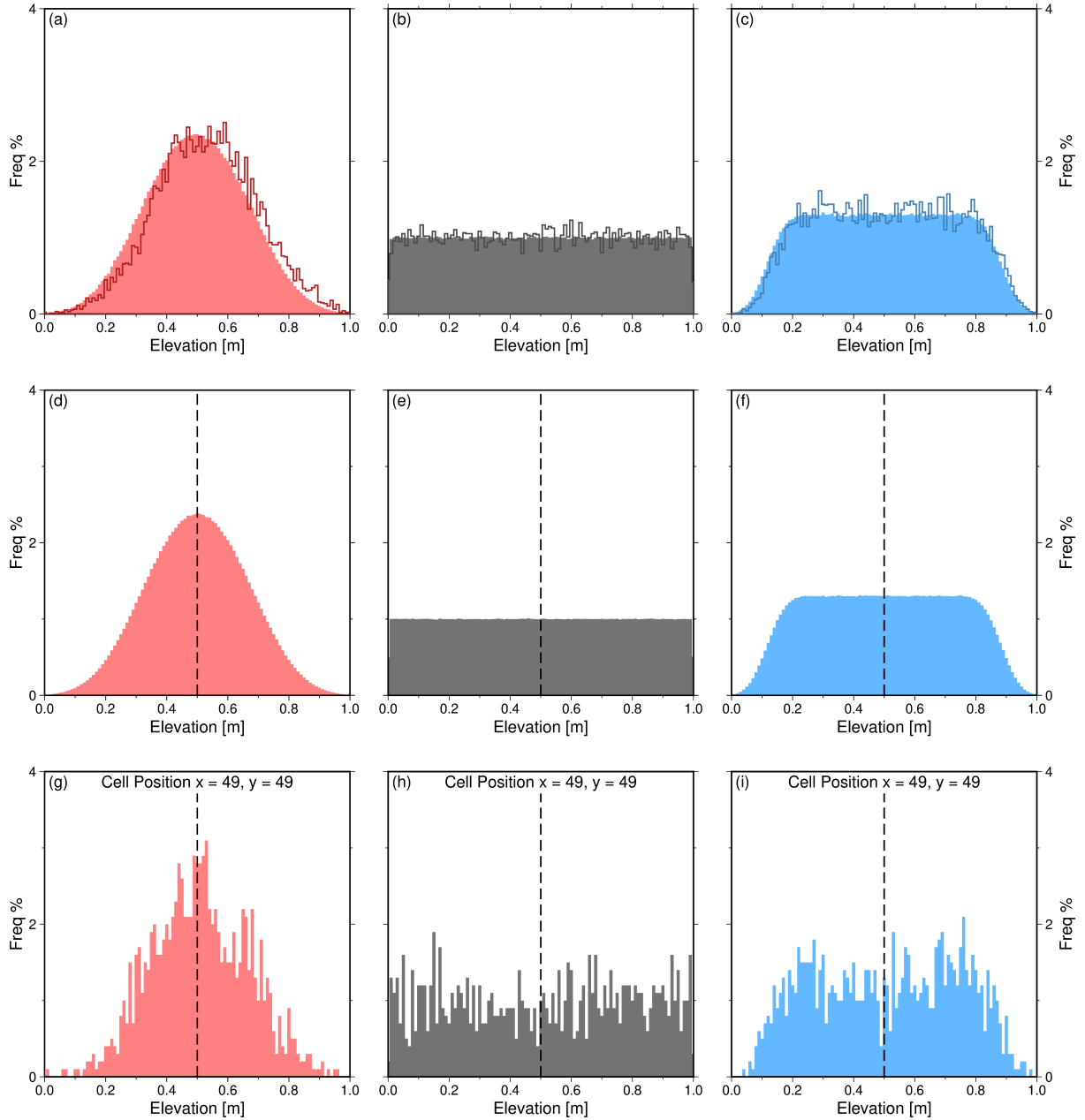


Figure 1. Verifying the distributions of noisy functions added to landscapes (a–c) Filled histograms = distributions of elevations for 100 different noisy functions of red, white, and blue noise respectively. Solid lines = distributions of a elevations for a single simulation. These noisy functions are used as initial conditions in scenarios A–D, as quenched noise in scenario B, and as final noise in scenario D, where they are scaled by $\alpha = 2, 20$, and 200 . (d–f) Distributions of red, white, and blue spatio-temporal noise used for a single simulation within scenario C, for all grid cells. (g–i) As above, for a single grid cell within the same simulation.

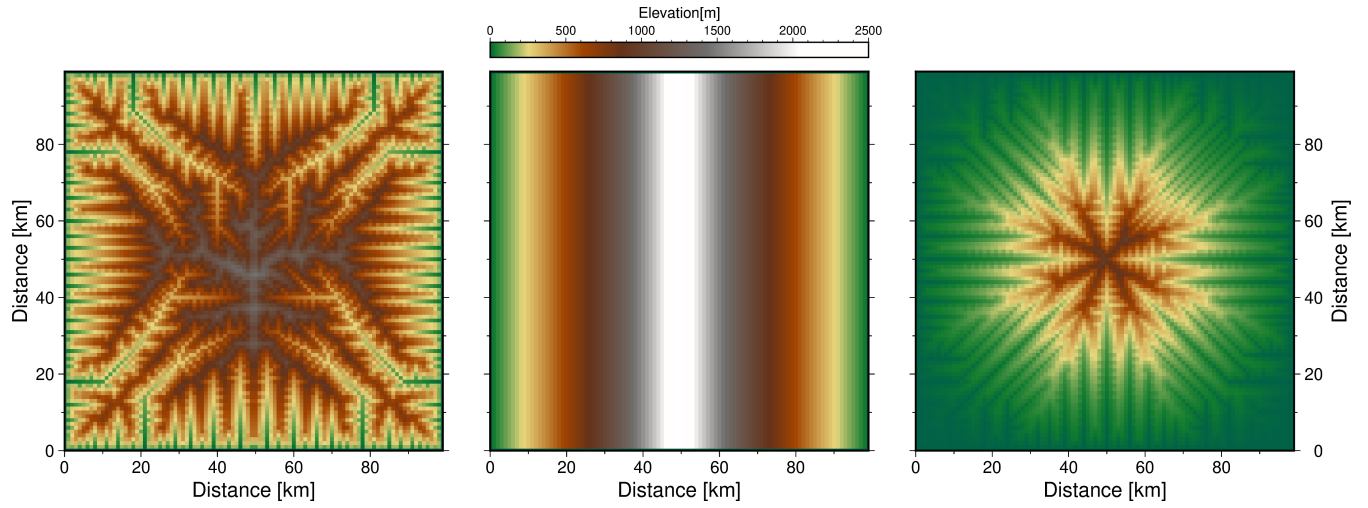


Figure 2. Landscapes without inserted noise. (a) ‘Square’, (b) ‘escarpment’ and (c) ‘domal’ landscapes produced as described in the main manuscript but without added noise.

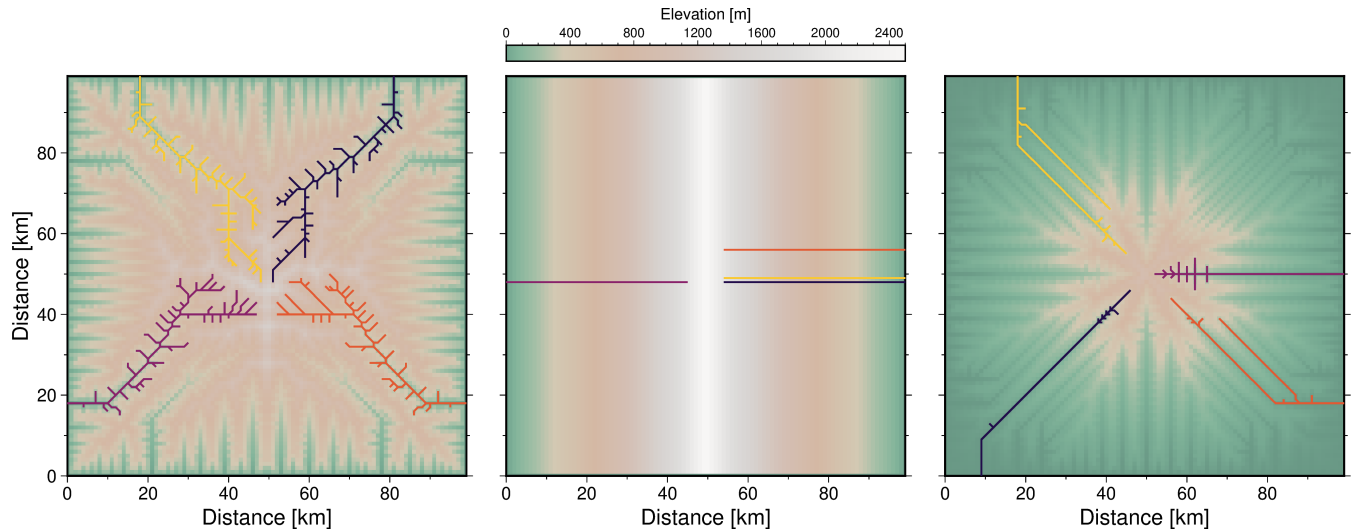


Figure 3. Planforms of drainage networks in landscapes without inserted noise. Coloured lines = four largest drainage networks within the (a) ‘square’, (b) ‘escarpment’ and (c) ‘domal’ landscapes shown in Figure 2 of this document.

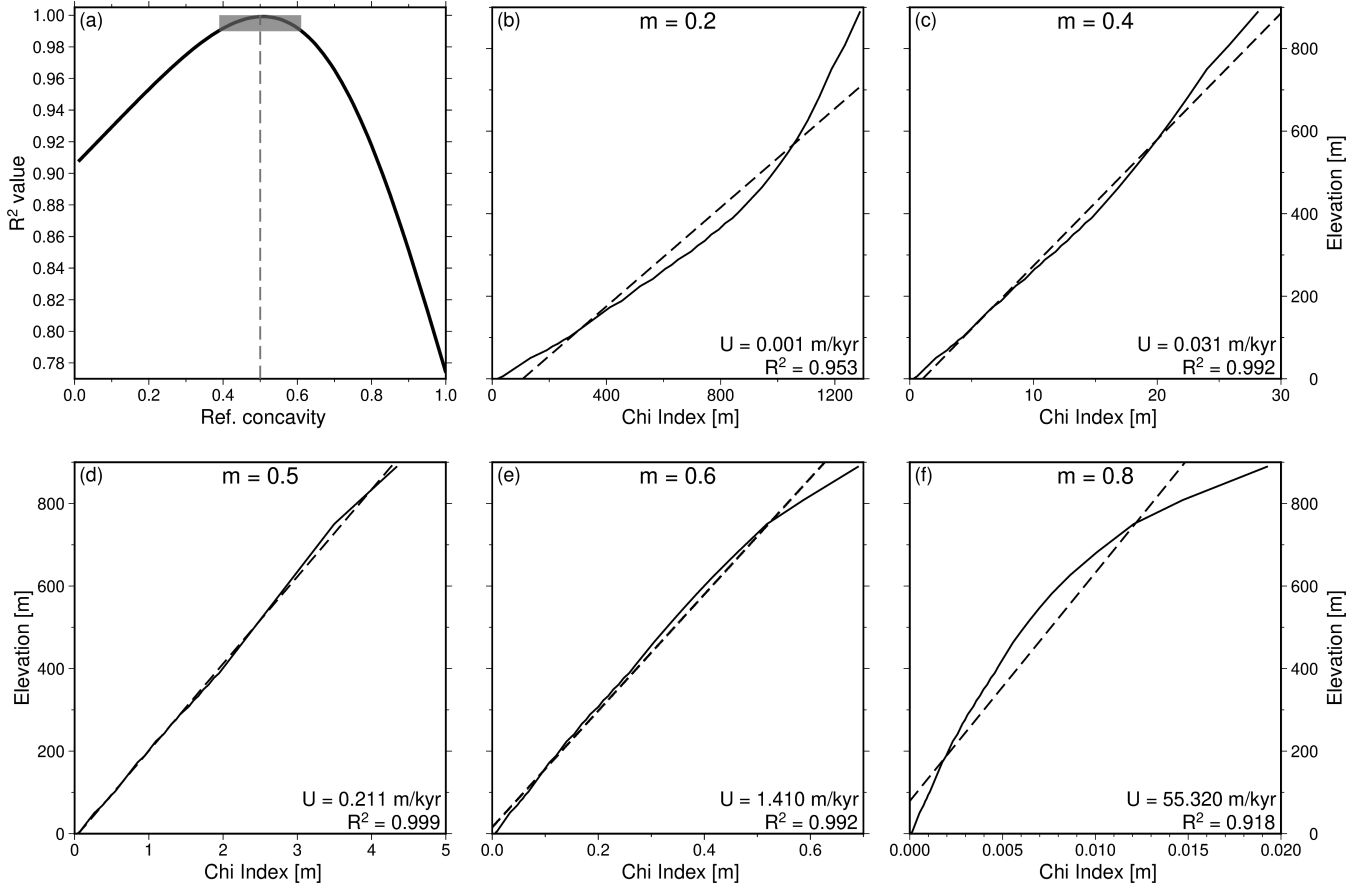


Figure 4. Impact of assumed value of concavity index on recovery of uplift rates from chi-analyses. Chi-analysis of longest river extracted from a steady landscape (at 100 Myr) generated with white noise only in the initial condition (from catchment coloured yellow in Figures 6b and 10d in the main manuscript). (a) Black curve = results from linear regression of chi-elevation data generated with annotated values of concavity index ($\theta = m/n$); dashed line = true value used to generate the synthetic landscape; grey band = values where $R^2 > 0.99$. (b–f) Examples of chi-elevation profiles (solid line) used to generate the solid curve in panel (a) with annotated values of m (note, $n = 1$, hence $\theta = m$). Dashed line = linear regression; note annotated R^2 values and recovered uplift rates (see Equation 19 in the main manuscript).

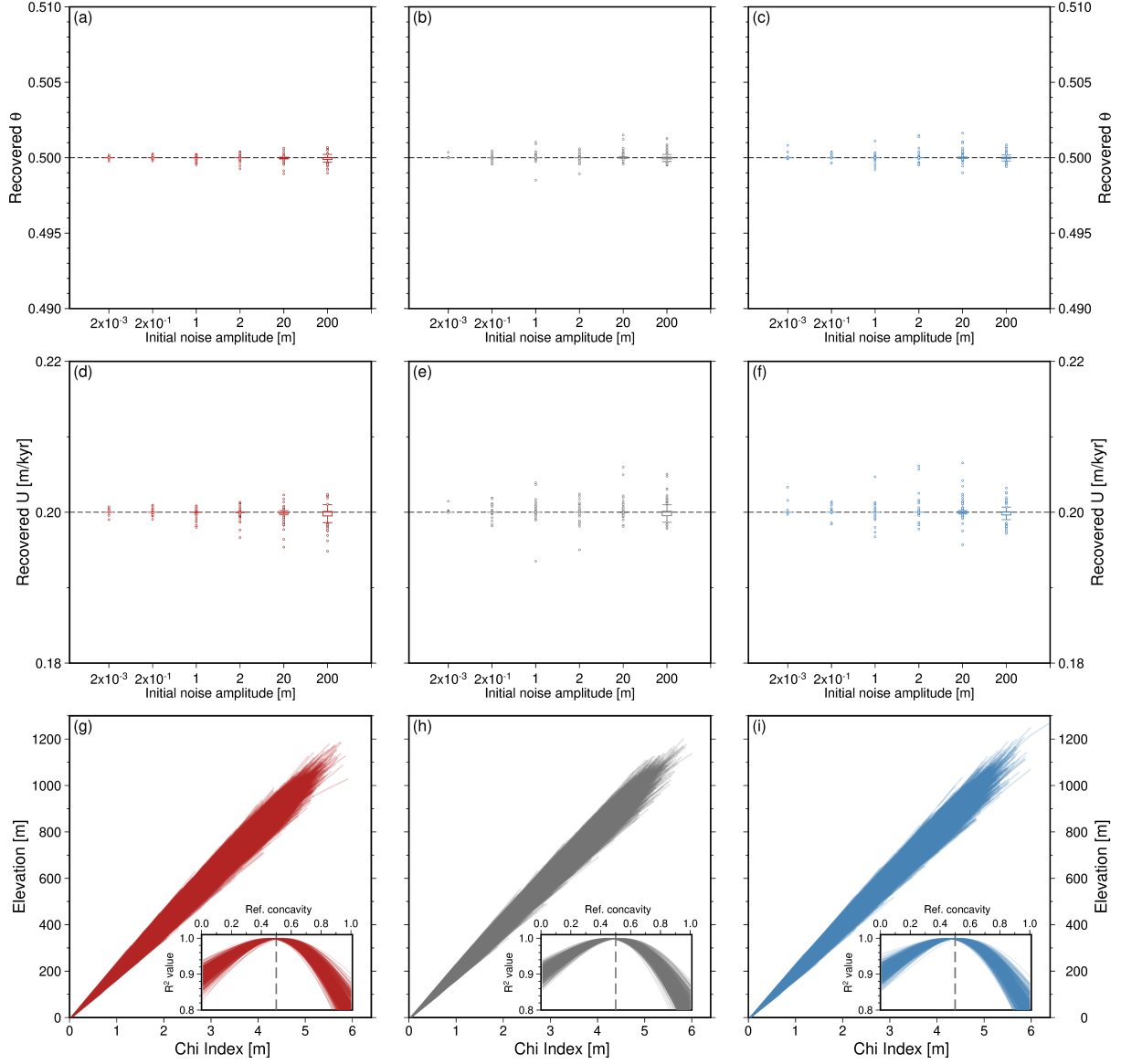


Figure 5. Impact of amplitude of initial red, white or blue noise on geomorphic metrics recovered from steady state ‘square’ landscapes. (a–f) Each box-and-whiskers plot shows results for $M = 100$ landscapes generated with annotated initial noise of indicated colour. Whiskers = $1.5 \times \text{IQR}$, or maxima/minima if higher/lower; dots = fliers. (a–c) Range of θ values recovered from slope-area analysis. Dashed black line shows ‘true’ θ value used to parametrise LEM. (d–f) Range of uplift rates recovered from slope-area analysis. (g–i) χ -elevation profiles and associated reference concavities for all channels in the largest basin in each simulation with the different amplitudes of noise indicated in panels (a–f).

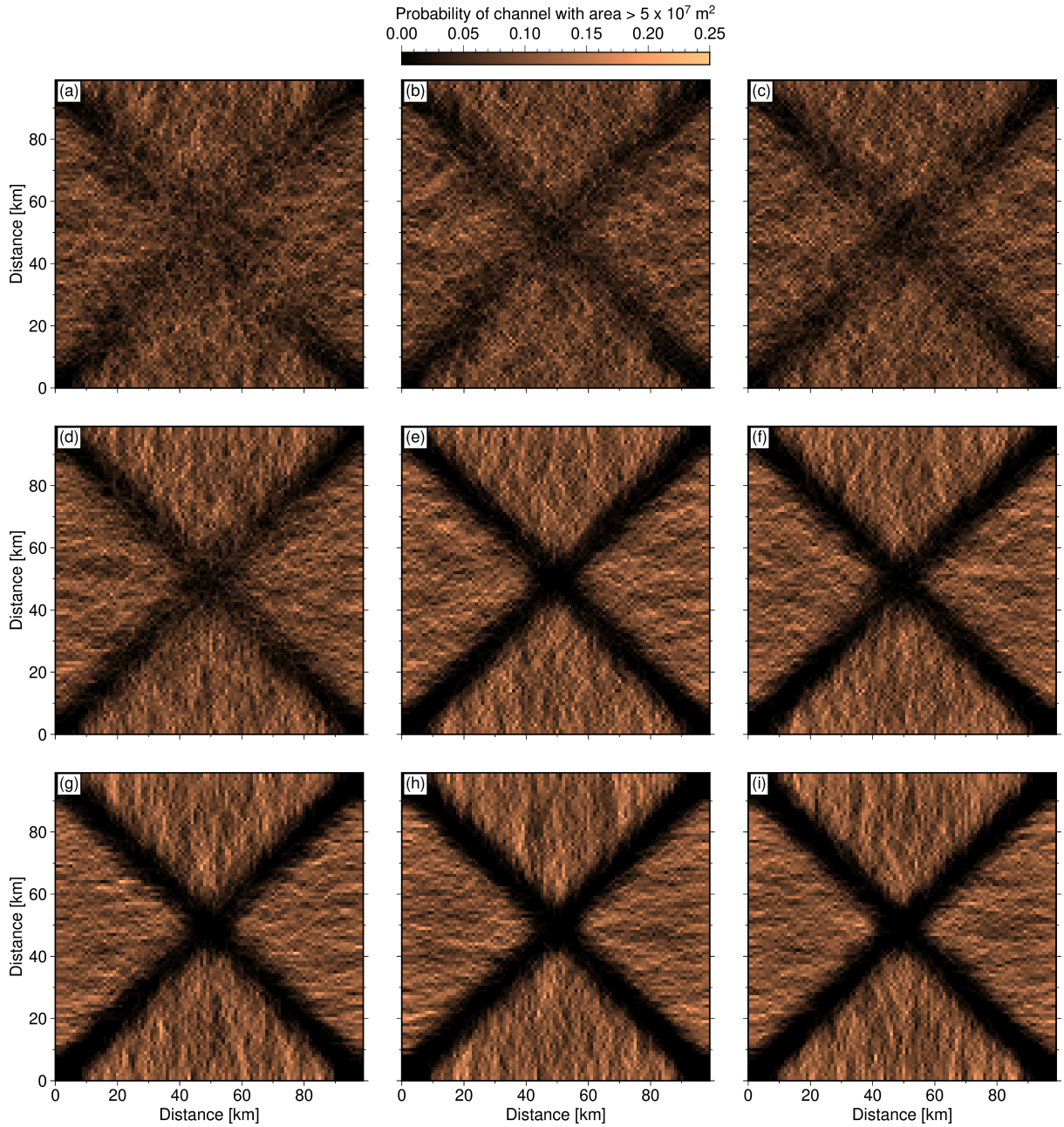


Figure 6. Probability of drainage within landscapes generated by 100 different arrangements of initial, quenched, and spatio-temporal noise. (a–c) Colours indicate probability of a grid cell in 100 ‘square’ landscapes containing a channel with upstream drainage area $> 5 \times 10^7 \text{ m}^2$ generated with initial red (a), white (b), or blue (c) noise. Compare to the equivalent panels in Figure 9a–c of the main manuscript for 1000 simulations, demonstrating convergence from 100 simulations. (d–f) As above, for landscapes containing quenched noise, and (g–i) for landscapes with spatio-temporal noise added. Examples of landscapes with white quenched or spatio-temporal noise added are shown in Figures 17a and 18a.

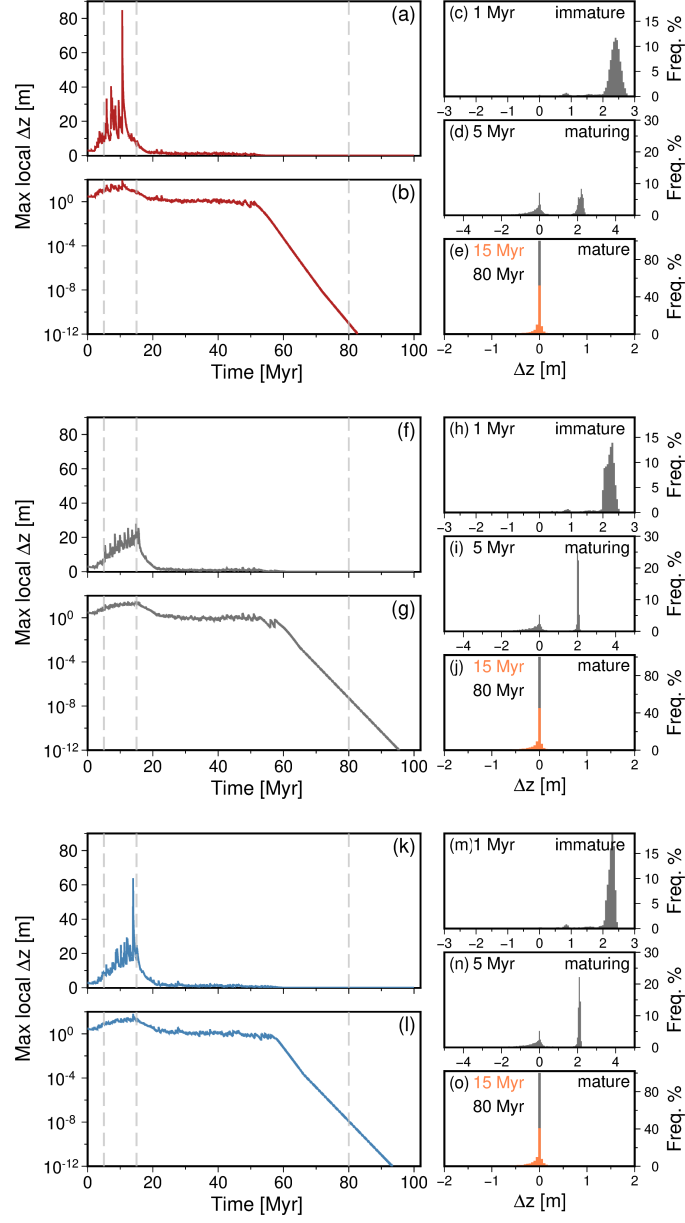


Figure 7. Identifying steady state landscapes with quenched noise. In each of these examples the same arrangement of red (a–e), white (f–j) or blue (k–o) noise is inserted at each time step into ‘square’ landscapes. See scenario B in Figure 3 of the main manuscript. (a) Evolution of maximum change in local elevation (Δz_{α}) between consecutive time steps ($\Delta t = 0.01$ Ma; see Equation 9 in main manuscript). Grey dashed vertical lines correspond to histograms shown in panels (c)–(e). (c) Histogram of elevation change, Δz , for all grid cells between 0.99 and 1 Myr. (d) & (e) As per (c), from 4.99 → 5 Myr, 14.99 → 15 Myr and 79.99 → 80 Myr, respectively. (f–j) As above for white noise. (k–o) As above for blue noise.

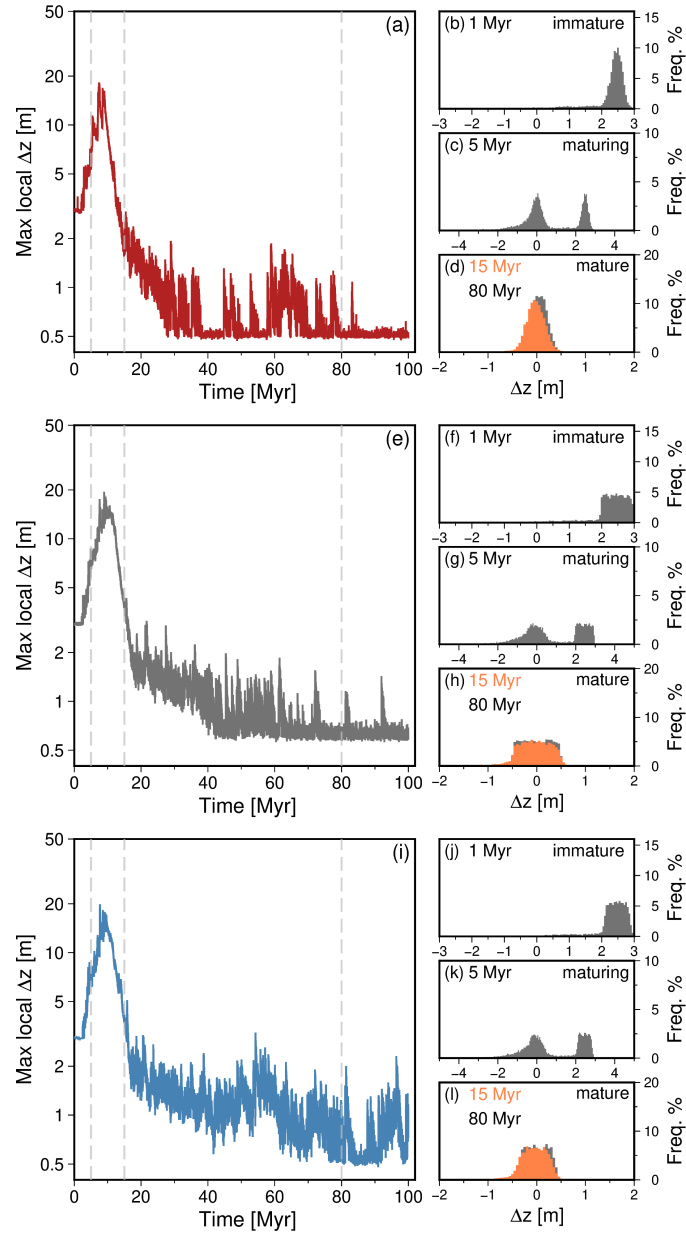


Figure 8. Identifying steady state landscapes with spatio-temporal noise (scenario C). In each of these examples the same distribution but different arrangements of red (a–d), white (e–h) or blue (i–l) noise is inserted at each time step into ‘square’ landscapes. See Figure 7 for extended description.

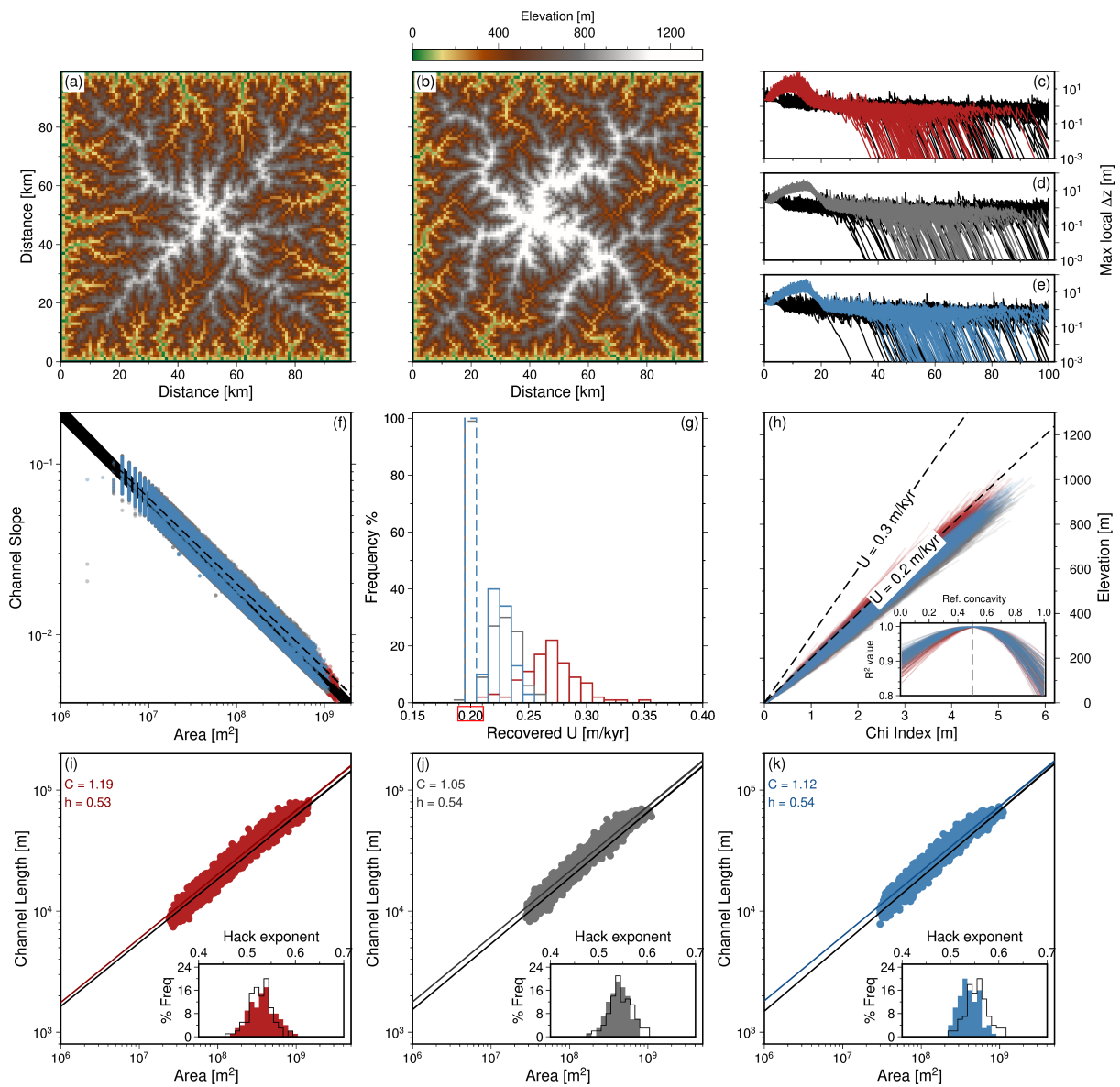


Figure 9. Comparison of geomorphic metrics for steady state ‘square’ landscapes evolving with initial or quenched zero-mean noise. (a) Topography (at 100 Myr) generated with -0.5 to 0.5 m of identical (i.e., quenched) white noise added at every time step. (b) Landscape at 100 Myr generated with identical initial condition to (a) but with no additional noise, i.e., scenario A in Figure 2. (c–e) Changes in maximum local relief in $M = 100$ landscapes generated with only initial noise (black lines), and red, white or blue quenched noise (coloured lines). (f–k) Geomorphic metrics for $M = 100$ for red, white or blue landscapes generated with quenched noise unless otherwise indicated. (f) Slope-area relationship for grid nodes with drainage area exceeding 4 km^2 . Black lines = linear regression. (g) Solid lines = histograms of uplift rate recovered from each of the 100 red, white, and blue quenched noise landscapes from slope-area analysis. Dashed lines = results for landscapes with only initial noise. Red rectangle = ‘true’ uplift rate used to parametrise the LEMs ($U = 0.2 \text{ m/kyr}$). (h) $z(\chi)$ profiles for the main channel and its tributaries of the largest drainage basin in each simulation, produced using $\theta = 0.5$. Inset shows the R^2 value of different reference concavities. (i–k) Upstream drainage area vs. channel length for main trunks of the forty largest drainage networks in the red (i), white (j), and blue (k) quenched noise landscapes. Black line = non-linear least squares best-fit. Filled/black histograms show the range in Hack exponent for each simulations from quenched noise/initial noise landscapes.

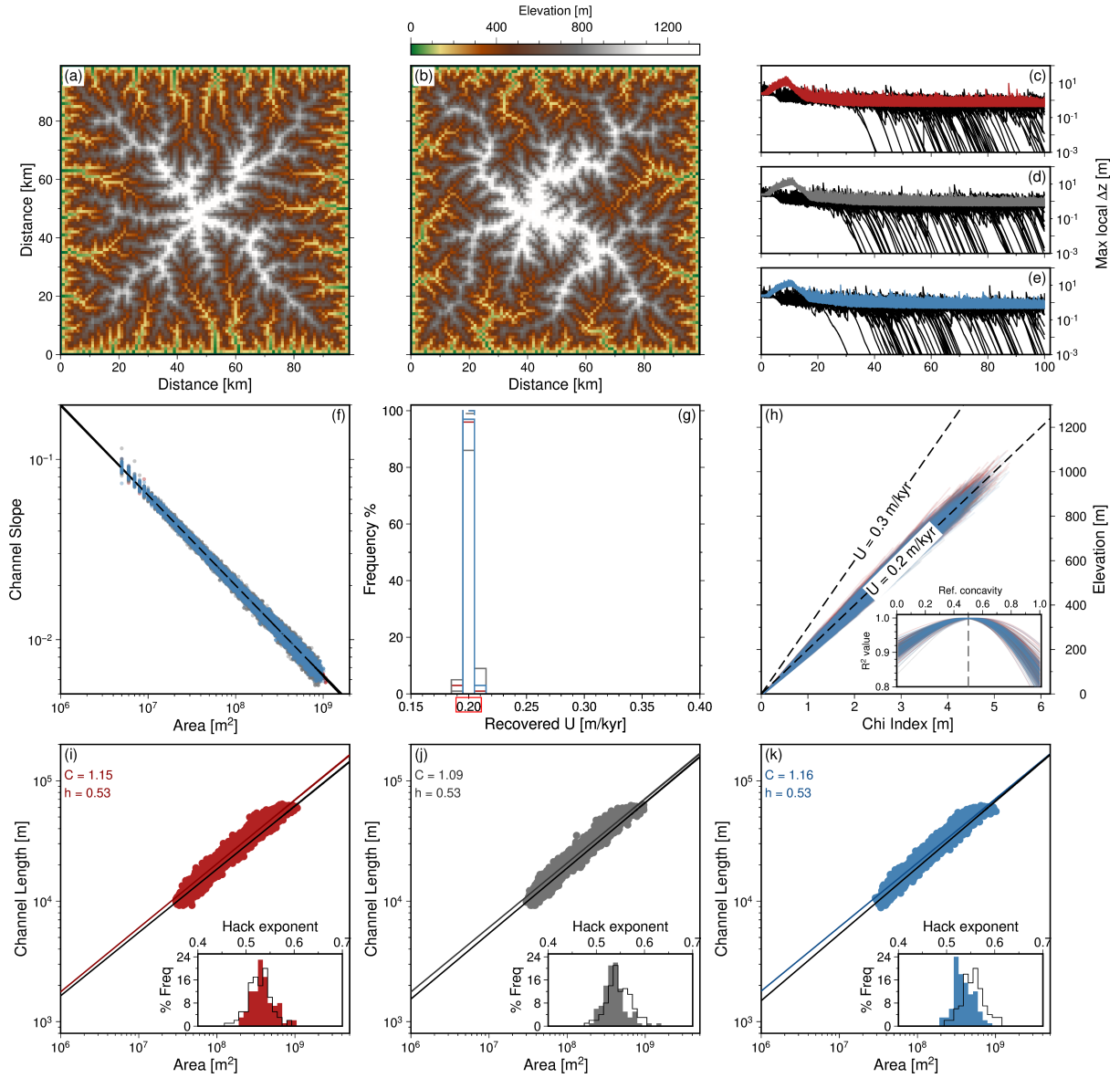


Figure 10. Comparison of geomorphic metrics for ‘steady state’ ‘square’ landscapes evolving with initial or spatio-temporal zero-mean noise. (a) Example of a ‘steady state’ landscape (at 100 Myr) generated with different (spatio-temporal) arrangements of white noise of amplitudes -0.5 to 0.5 m added at each time step. (b) ‘Steady state’ landscape (at 100 Myr) generated with identical initial condition to (a). (c–k) Same annotation as for Figure 9 for models with spatio-temporal red, white or blue noise, or noise added only to the initial condition.

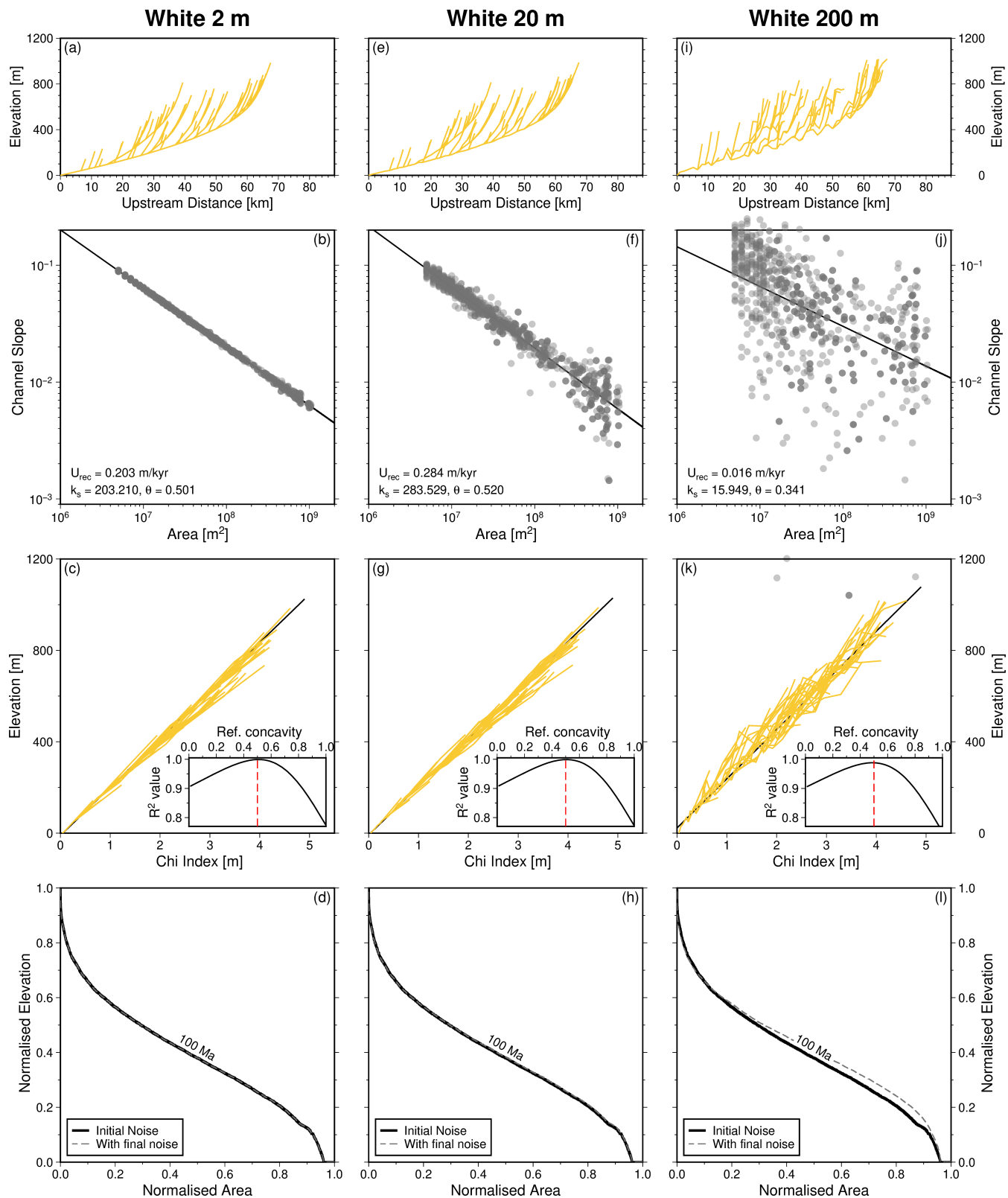


Figure 11. Examples of geometries of river profiles and associated metrics in landscapes with un-eroded white noise. (a–d) Results when up to 2 m of un-eroded noise is added to steady state landscape shown in Figure 6b of the main manuscript (see Figure 19 of main manuscript). (a) Longitudinal profiles of rivers extracted from largest basin. (b) Grey circles = slope-area analysis and associated metrics of the longest river. Note: some measurements extend beyond panel bounds in later examples with higher amplitude noise. Black line = linear regression; associated values of θ , k_s and U_{rec} are annotated. True uplift rate = 0.2 m/kyr, and $\theta = 0.5$. (c) Chi-elevation profiles of rivers shown in panel (a). Black line = linear regression. Inset shows R^2 values for different concavity indices used to linearise river profiles; red dashed line = true value used to produce the landscape. (d) Hypsometry of steady state landscapes with only initial noise (solid) and with additional (un-eroded) noise (dashed). (e–h) and (i–l) Results when up to 20 and 200 m of un-eroded noise are incorporated, respectively.

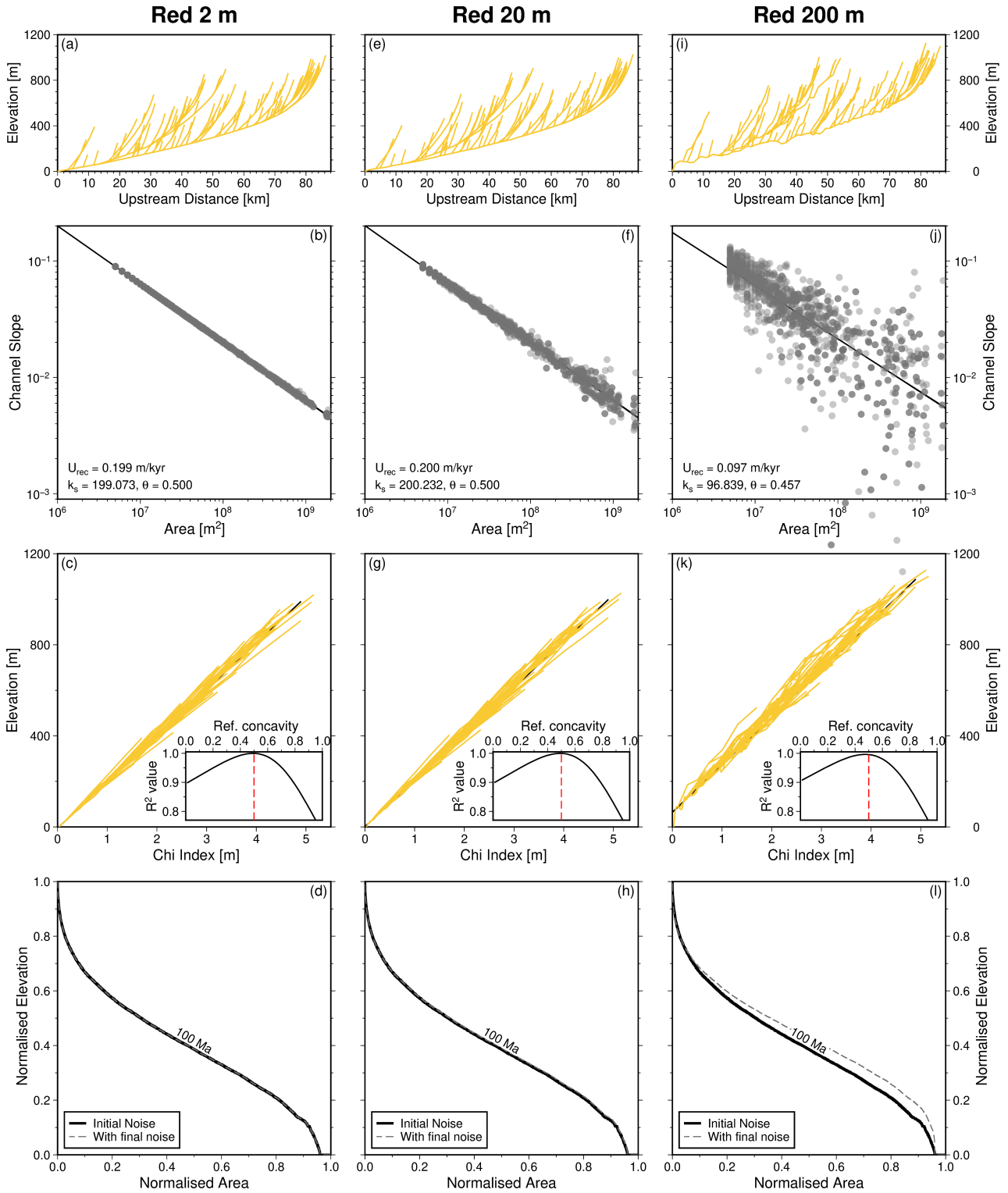


Figure 12. Geometries of river profiles and associated metrics generated with un-eroded red noise. (a–j) See caption to Figure 11 for extended description.

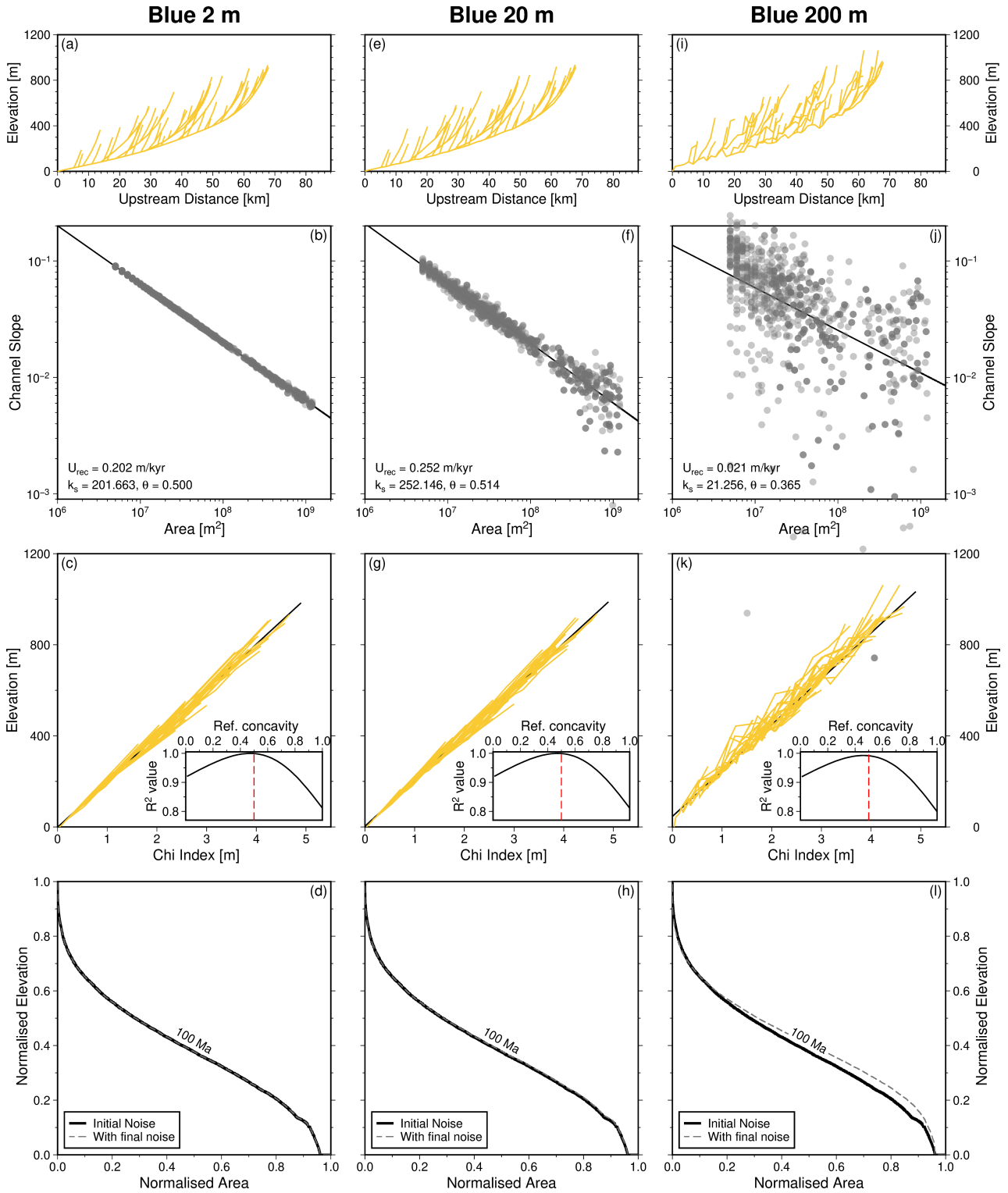


Figure 13. Geometries of river profiles and associated metrics generated with un-eroded blue noise. (a–j) See caption to Figure 11 for extended description.