Supplemental materials for the discussion paper

How concave are river channels?

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1. Overview

This document contains supplementary materials for the manuscript *How concave are river channels?*, with additional details about the set-up of the numerical modelling runs as well as tests of the sensitivity of the methods to user-defined parameters from some real landscapes.

2. Example parameter files

We have provided example parameter files for running the numerical models and all of the analyses performed in the manuscript, which can be found in directory `Example_parameter_files`. The structure of the directory is as follows:

```
|--Analysis_files
  |--Model_landscapes
     |--movern_0p5
        |--n_is_one
        |--n_is_one_and_half
        |--n_is_two
        |--n_is_two_thirds
     |--movern_0p35
        |--n_is_one
        |--n_is_one_and_half
        |--n_is_two
        |--n_is_two_thirds
     |--movern_0p65
        |--n_is_one
        |--n_is_one_and_half
        |--n_is_two
        |--n_is_two_thirds
  |--Real_landscapes
     |--Loess_Plateau
     |--Waldport_Oregon
     |--Gulf_of_Evia
|--MuddPILE_model
  |--movern_0p5
  |--movern_0p35
  |--movern_0p65
|--Sensitivity_analyses
  |--La_Gomera_sigma
  |--Loess_channel_extraction
```

The directory `Model_landscapes` contains the parameter files used to analyse the model runs. The files for each value of m/n are in a separate subdirectory, also containing subdirectories for each value of n analysed. The directory `Real_landscapes` contains the parameter files used to run the analysis on the example real landscapes, where each landscape is contained its own subdirectory. Each file can be used to run the analysis to estimate the best fit θ value from both the slope-area and χ methods. In addition to the parameter files for running the chi analysis, we also have included georeferencing information for the analysis sites in the form of `hdr` files which contain the coordinate system and extent of each DEM analysed. Users can download SRTM 30m data from https://www.opentopography.org, project it into UTM coordinates and clip to the extents of the data we used with information in the `hdr` files. We have done this using GDAL. You can find instructions on the LSDTopoTools documentation website.

The source code for the analyses in this paper are in the github repository https://github.com/LSDtopotools/LSDTopoTools_ChiMudd2014. You will find links to instructions for installing and running the software there, or you can see the documentation for "Channel steepness analysis with LSDTopoTools" at the main LSDTopoTools documentation website.

We also provide each of the driver files needed to produce the model runs using the MuddPILE software, which is available from https://github.com/LSDtopotools/MuddPILE. The driver files for running the models are contained in the directory `MuddPILE_model`, where each of the sub-directories represents a run with a different *m/n* value. Each file within the sub-directory has the parameters for varying *n* for that value of *m/n*.

Finally we have also provided the parameter files that were used to run the sensitivity analyses on both the σ parameter used in the χ methods and the threshold drainage area for channel extraction. These files can be found in the directory `Sensitivity_analyses`. In order to reproduce the sensitivity analyses the user simply has to run the code using each of the parameter files provided in each sub-directory.

3. Model runs

As described in the main text, we run a series of transient models in order to test the different methods of extracting the concavity index in landscapes where we impose proscribed values of the fluvial incision parameters *m* and *n*. We run a series of models where *m/n* = 0.5, *m/n* = 0.35, and *m/n* = 0.65, and where *n* = 1 (Runs 1 - 3), *n* = 2 (Runs 4 - 6), *n* = 1.5 (Runs 7 - 9), and *n* = 0.66 (Runs 10 - 12). In order to create transient landscapes against which we test our methods, we vary uplift rates over a series of cycles in each run. Each run has a baseline uplift rate (see Table S1), which is increased by a factor of four over 10,000 - 15,000 year cycles. Table S1 reports details of the parameter set-up for each run.

In the main text we show the ability of the method to extract the best fit θ ratio from the model runs for varying values of *n*, where *m/n* = 0.5. Here we also report the best-fit θ values predicted for each value of *n* where *m/n* = 0.35 (Figure S1), and *m/n* = 0.65 (Figure S2).

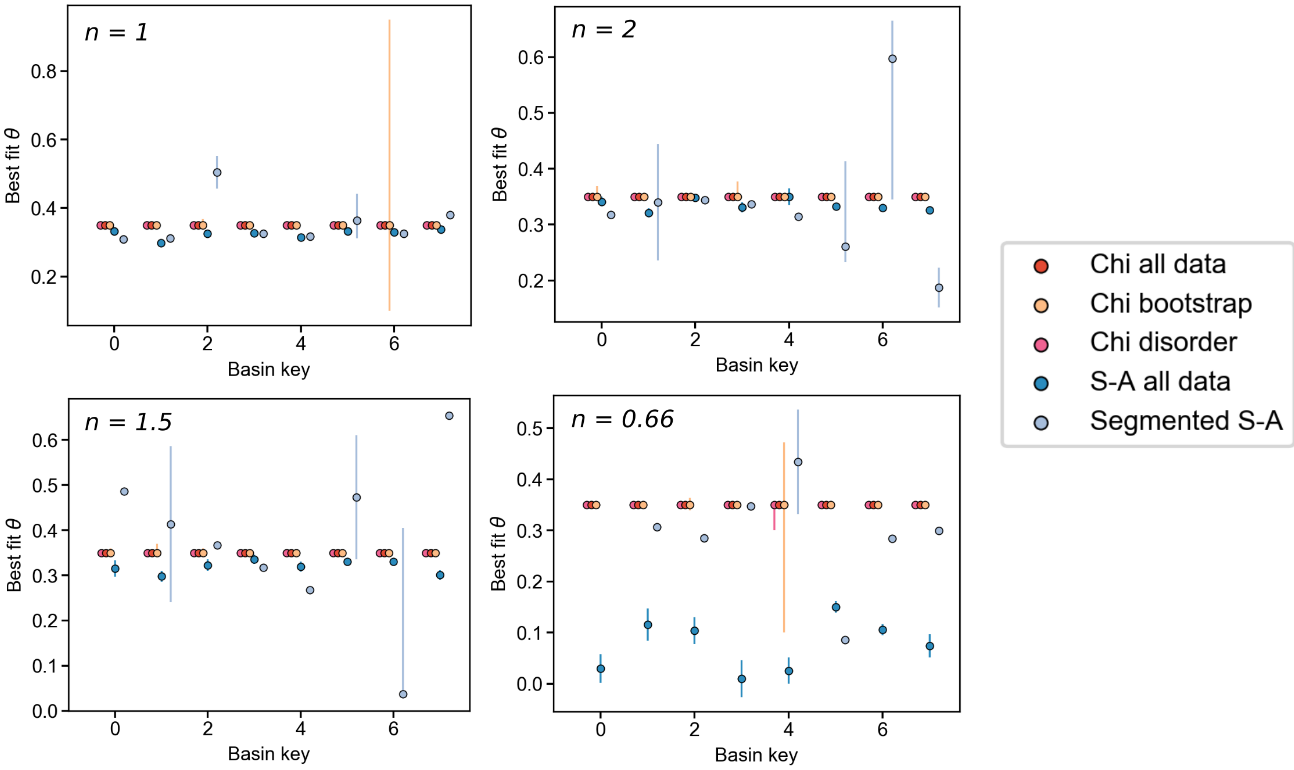

Figure S1. Results of each method for model runs where *m/n* = 0.35 for varying values of *n*. The integral profile methods are shown in reds and the slope-area methods are shown in blues.

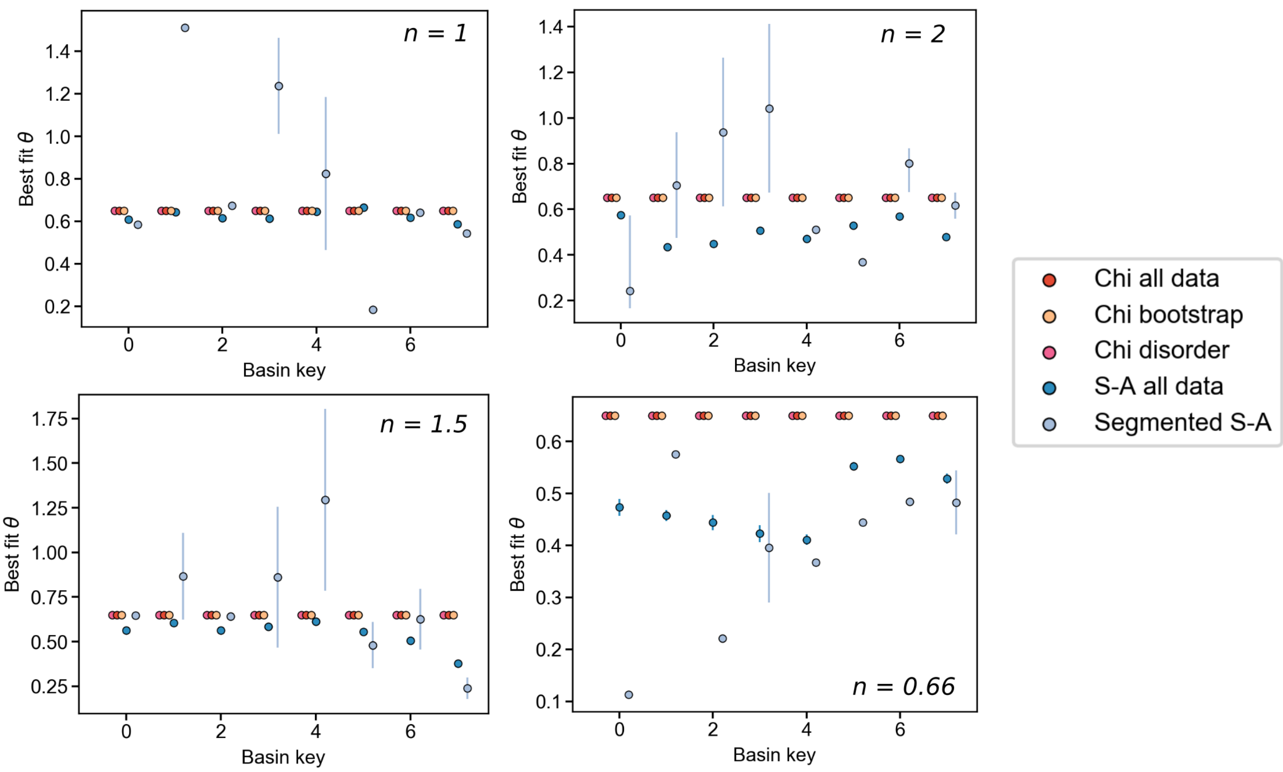

Figure S2. Results of each method for model runs where *m/n* = 0.65 for varying values of *n*. The integral profile methods are shown in reds and the slope-area methods are shown in blues.

Table S1 Parameters used in simulations of transient landscapes. Cycle duration refers to the number of years in each uplift cycle.

Scenario	*m/n*	*m*	*n*	Baseline *U* (mm/yr)	Cycle duration (1000 yr)
1	0.5	0.5	1	0.5	15
2	0.35	0.35	1	0.5	15
3	0.65	0.65	1	0.5	15
4	0.5	1	2	0.5	10
5	0.35	0.7	2	0.5	10
6	0.65	1.3	2	0.5	10
7	0.5	0.75	1.5	0.5	15
8	0.35	0.525	1.5	0.5	15
9	0.65	0.975	1.5	0.5	15
10	0.5	0.33	0.66	0.5	15
11	0.35	0.231	0.66	0.5	15
12	0.65	0.429	0.66	0.5	15

4. Sensitivity to parameters in natural landscapes

We tested the sensitivity of our new methods for determining the concavity index from χ profiles to both the σ and thresholds for channel extraction (see main text).

4.1. Sensitivity to the sigma parameter

The σ (sigma) parameter is a scaling factor in the calculation of the Maximum Likelihood Estimator (MLE) for the integral profile analysis. It is therefore used in both the full and bootstrap integral methods. In order to test the impact of varying σ on the best fit θ values calculated for each basin, we ran the analysis on a series of basins on La Gomera, a volcanic island in the Canary Island Chain, located around 100 km from the west coast of Morocco, where we varied the value of σ from 10 to 300. The MLE values calculated for a basin are dependent on the number of nodes in the tributaries, where the MLE value decreases as the number of nodes increases (see equation (11) in the main text). We therefore increase the value of σ until all the tributaries have a non-zero MLE value, shown in Figure S3 below. For basins with a large number of tributary nodes, such as Basins 2 and 3, a low value of σ can lead to zero MLE values, resulting in the best-fit concavity index being equal to the lowest one tested. As we increase σ the correct concavity index for the basin is identified, which then becomes invariant with increasing σ. We therefore suggest that users select a large value of σ (≥ 1000) when performing χ analysis to constrain the concavity index.

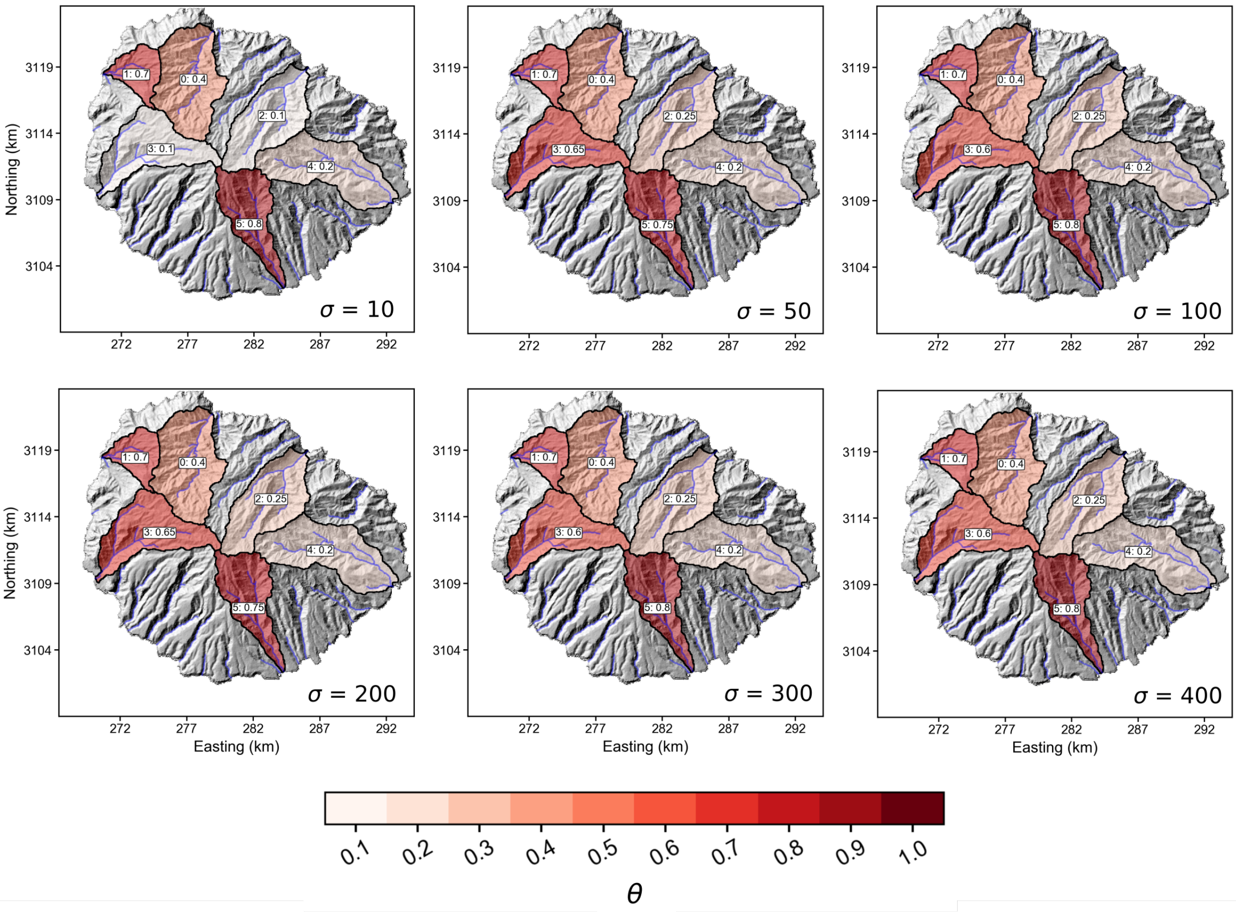

Figure S3. Sensitivity of the bootstrap method of calculating the concavity index to the σ parameter, where σ varies from 10 to 300. Analysis is run on basins from La Gomera, Canary Islands, UTM Zone 28N. The MLE method becomes insensitive to σ as σ increases. For this site, the θ value becomes invariant for every basin at a $\sigma \geq 200$. Basins 3 and 5 are the last basins to become invariant. For every other basin, θ is constant at $\sigma \geq 10$.

4.2. Sensitivity to the threshold drainage area

We also tested the sensitivity of the methods to the threshold drainage area for channel extraction. Figure 4 shows the best-fit θ values for basins in the Loess Plateau, China (see main text), where we vary the threshold drainage area from 900,000 m^2 to 9,000,000 m^2. We find that both the slope-area methods and the χ methods are relatively insensitive to the threshold area for channel extraction, both in terms of the distribution of best fit θ values (Figure S4, first column), and the spatial variation in concavity indices in different basins (Figure S4, second column).

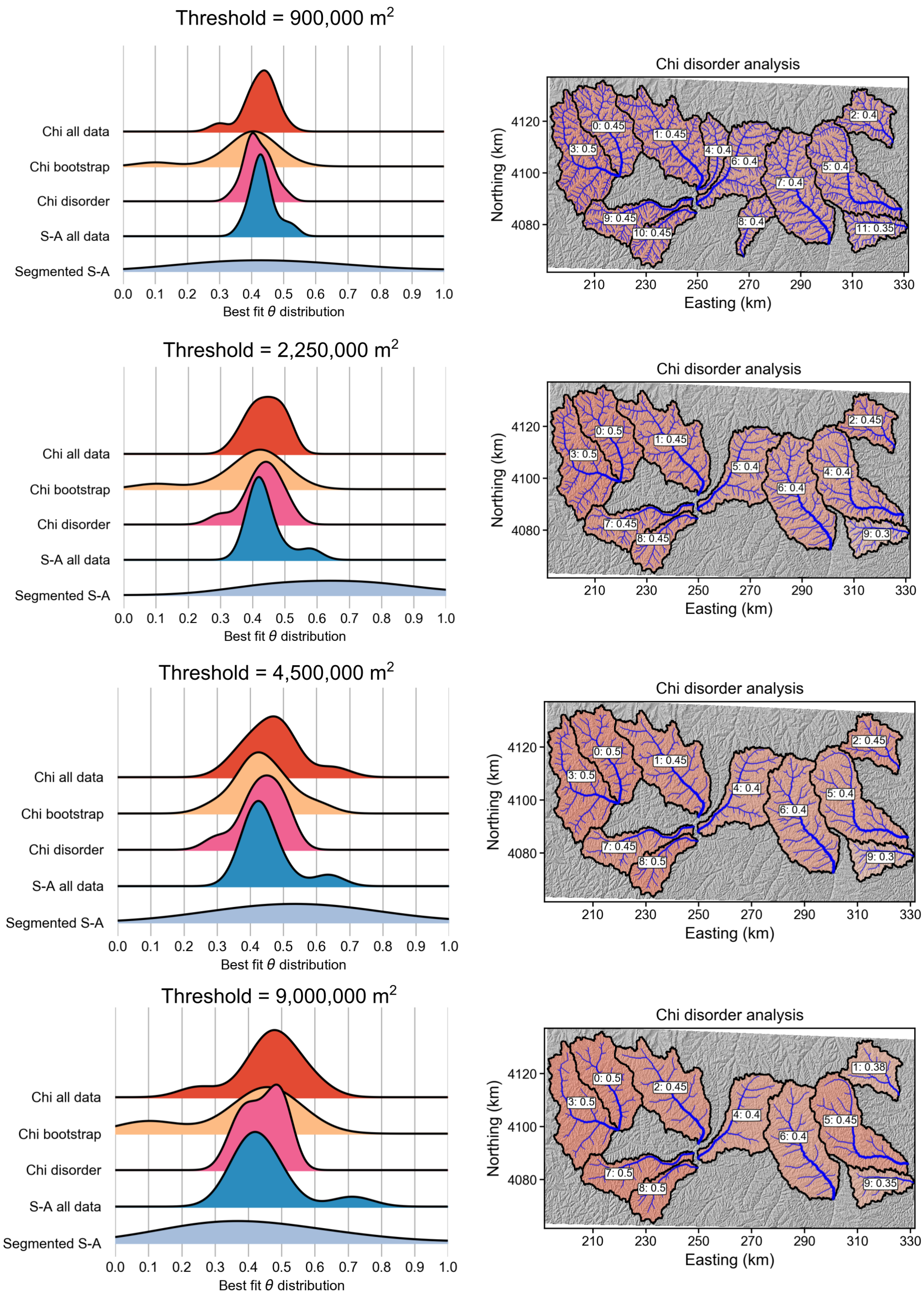

Figure S4. Sensitivity of the methods to the threshold drainage area for channel extraction. The left column shows density plots of the predicted concavity index for all basin across the landscape, and the right column shows the θ value predicted for each basin using the disorder method, draped over a shaded relief map. Basins are coloured by θ where lighter red corresponds to a lower concavity index. Analysis is run on basins from the Loess Plateau, China, UTM Zone 49N.