Extraction of multi-thread channel networks using a reduced-complexity flow model

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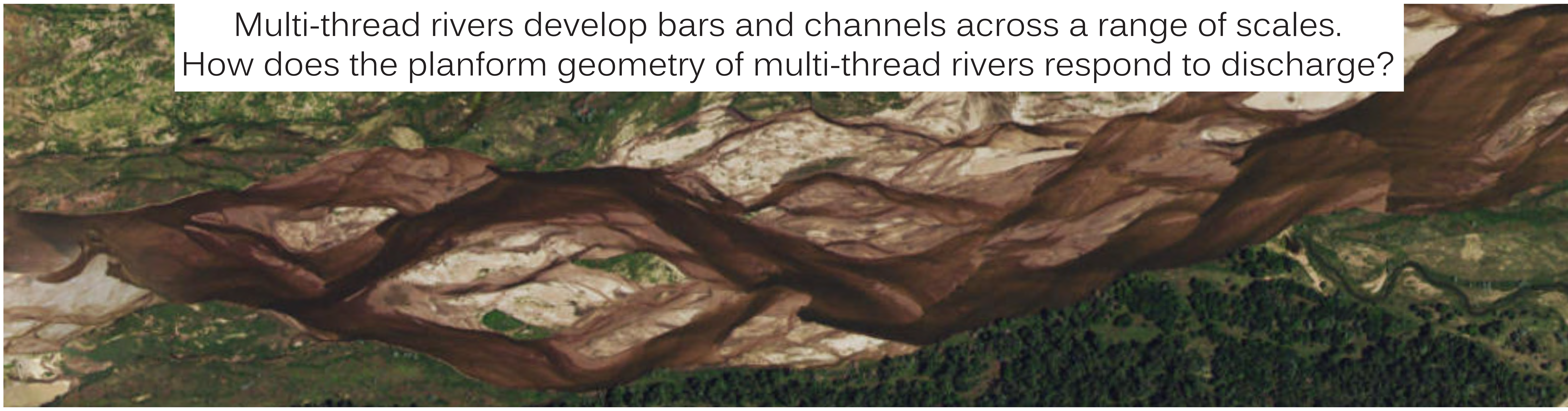
Multi-thread rivers develop bars and channels across a range of scales.
How does the planform geometry of multi-thread rivers respond to discharge?



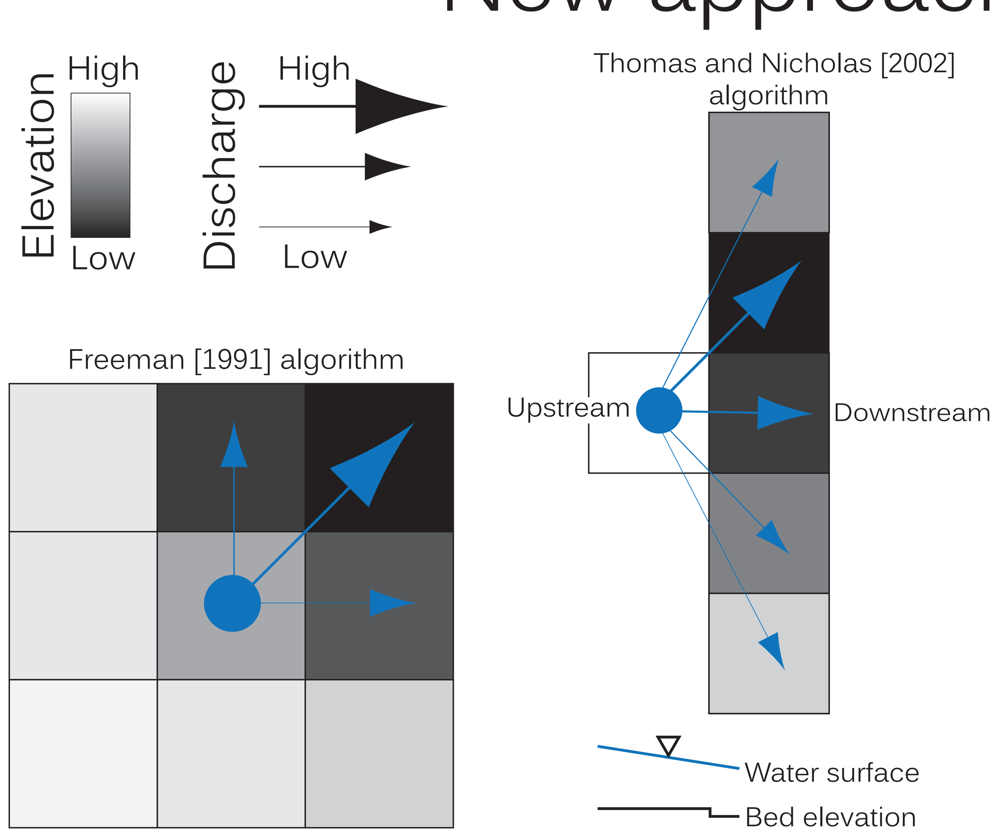
Background

- For experiments, the number of channels in a cross section (i.e., braiding index) peaks at intermediate discharge [1].
- For natural rivers under a single discharge, braid bars are self-affine (bar aspect ratio depends on bar scale) [2].
- The effect of changing discharge on bar size distribution is largely untested.

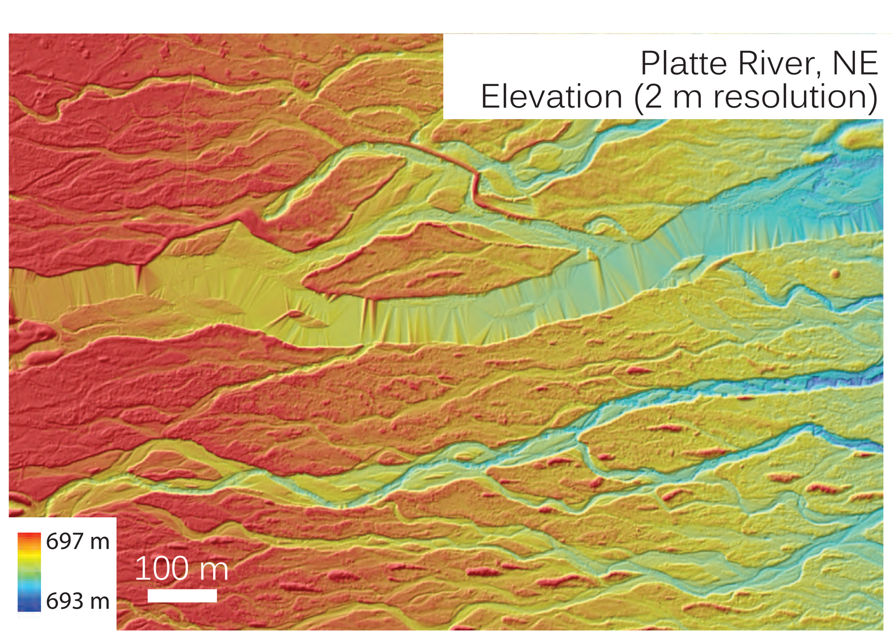
Existing approach to channel mapping: inundation

- Channels and bars have been successfully mapped using inundation for natural and experimental braided rivers [1-4].
- Mapping by inundation has important constraints:
  Nature: channels must be wetted and unobstructed by clouds.
  Experiments: dye highlights flow only until it saturates sediments.

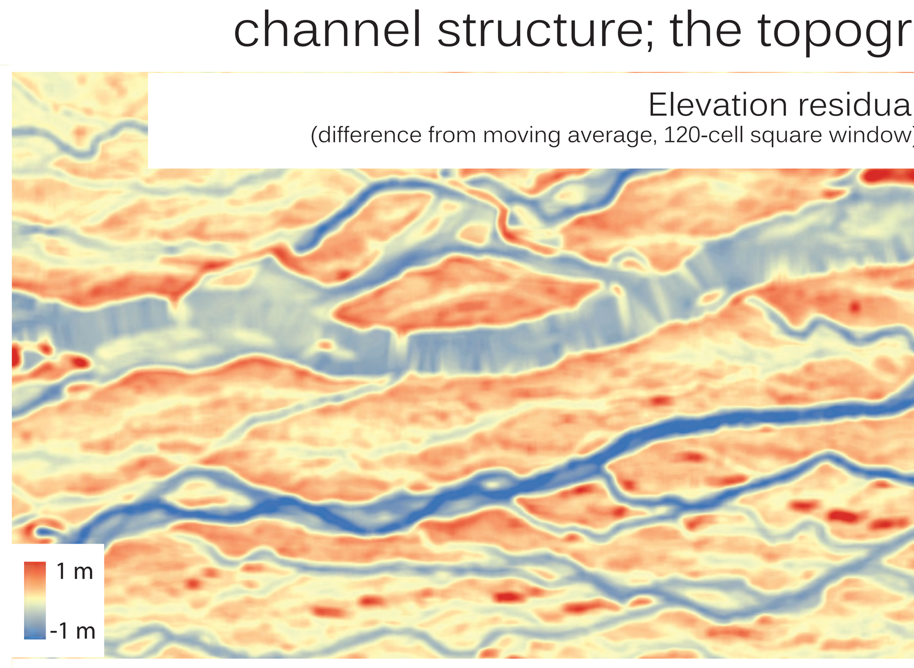
New approach to channel mapping: virtual inundation



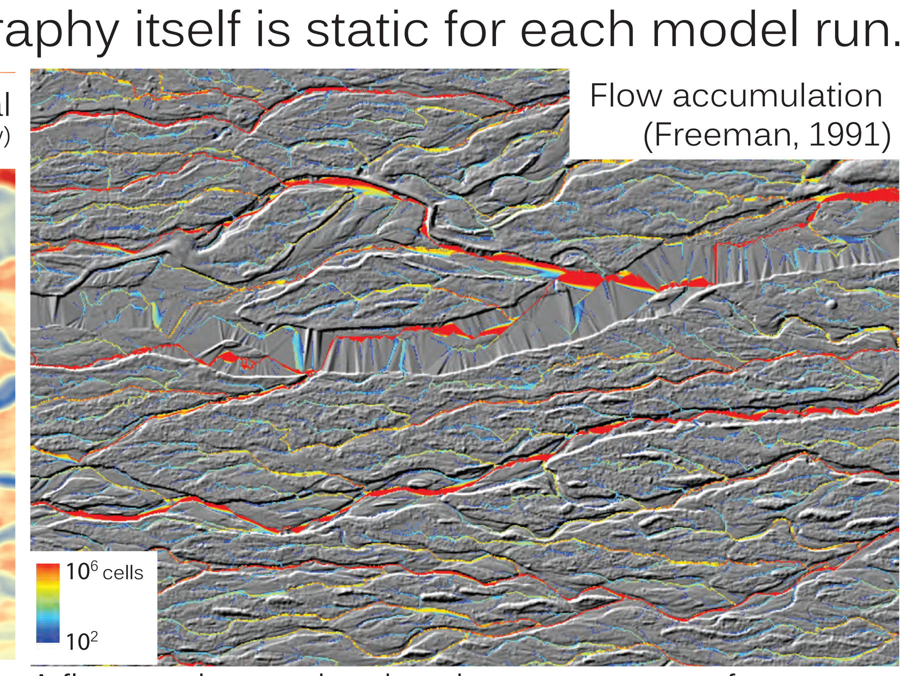
- Single thread channels are commonly extracted from elevation data using local topographic statistics (e.g., curvature) or reduced-complexity flow models.
- In order to capture divergent flow paths in multi-thread channels, flow routing algorithms must allow for flow distribution to multiple downstream cells.
- Two approaches to modeling multiple flow paths include:
  Freeman (1991) algorithm [5]: a unit flow is routed from each cell to all downslope cells.
  Thomas and Nicholas (2002) algorithm [6]: flow is introduced at a predetermined upstream location and routed downvalley, accounting for water surface slope.
- Here flow routing is used as a tool for extracting multi-thread channel structure; the topography itself is static for each model run.



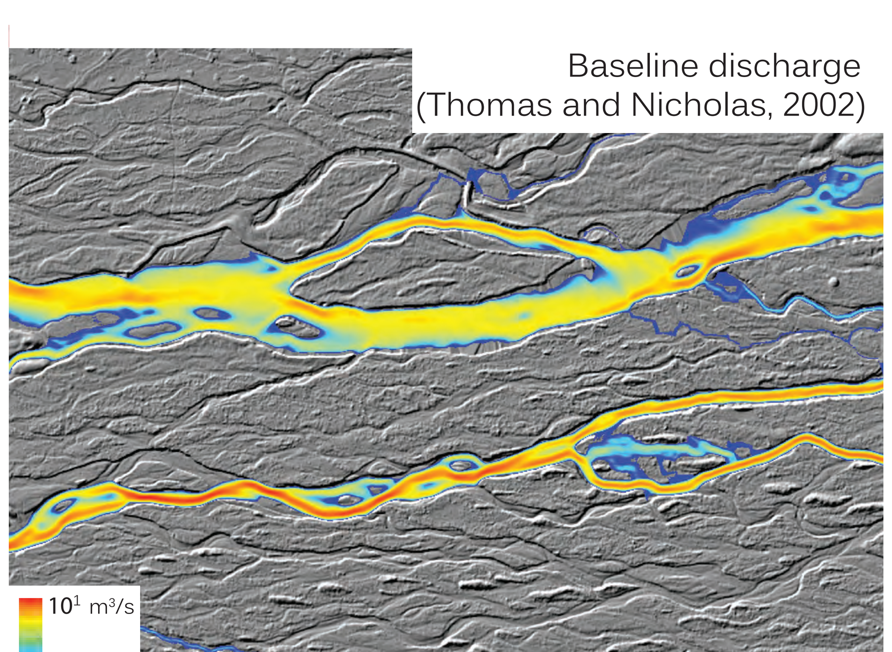
A LiDAR-based digital elevation model. Artifacts occur at wetted areas in the widest channel.



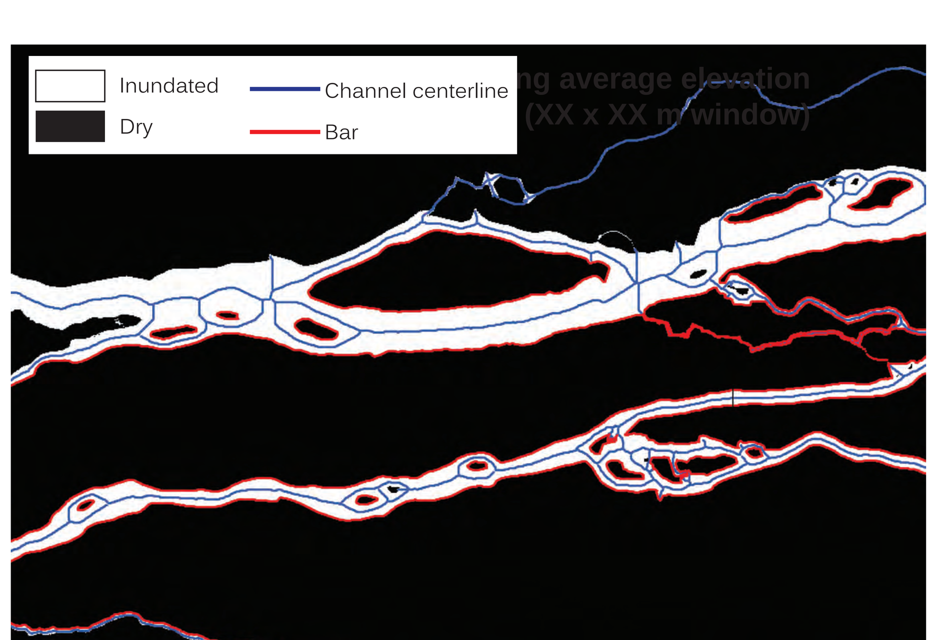
Bars and channels are partially separated, as for other local topographic statistics (e.g., slope, curvature).



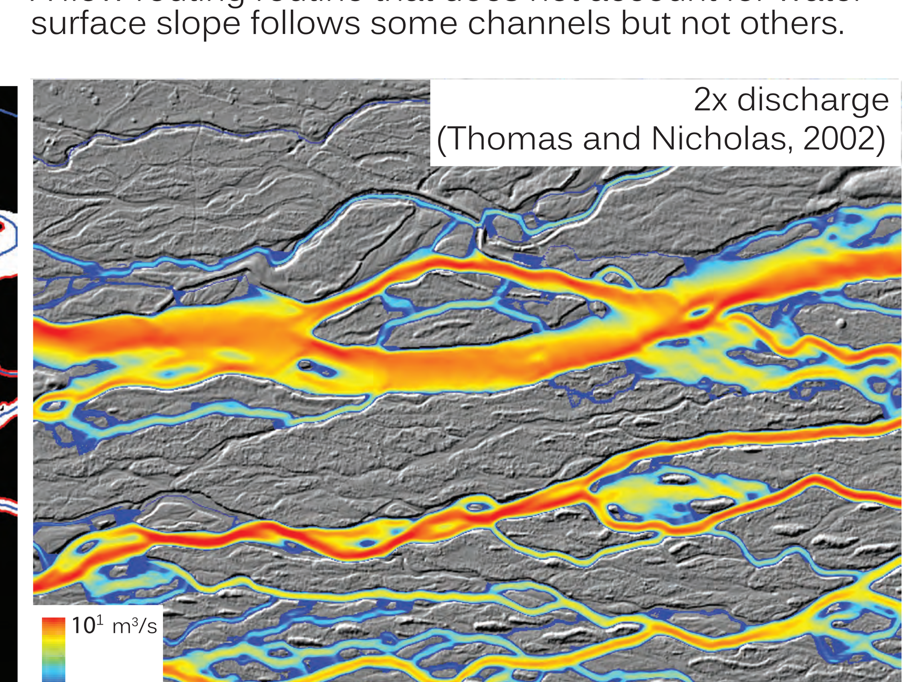
A flow routing routine that does not account for water surface slope follows some channels but not others.



A flow routing routine that accounts for water surface slope produces more realistic inundation patterns [6].



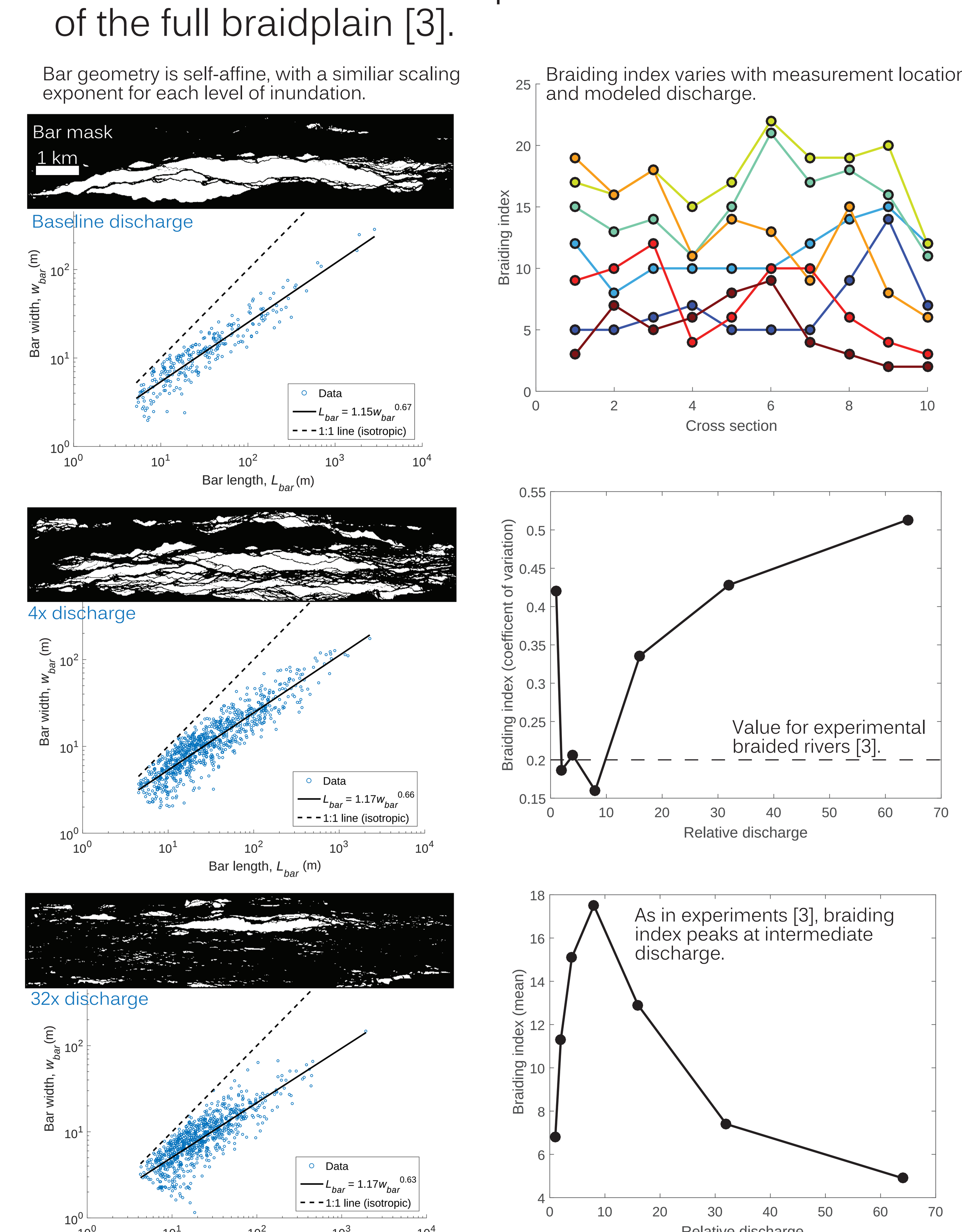
The spatial extent of inundation is used to automatically map bars and channels.



Successively higher modeled discharges cause greater inundation and reveal more bar and channel structure.

Bar and channel statistics

- Bar dimensions and braiding intensity were measured for an incrementally doubled discharge using the Thomas and Nicholas [2002] model.
- Ten cross sections were spaced at half the width of the full braidplain [3].



Key findings

For a test case on the Platte River (NE):

- A simplified flow model isolates multi-thread channels and bars from topography data.
- As a marker of discharge change, braiding index is more responsive than bar anisotropy.
- Measurements of braiding index and bar dimensions are consistent with previous observations, and suggest that modeling can be used to systematically account for morphometric sensitivity to discharge.

References. [1] Egozi, R., Ashmore, P., 2008, Earth Surf. Proc. Land. 33(14), 2121–2138. [2] Sapozhnikov, E., Foufoula-Georgiou, E.,1996, Water Resour. Res. 32(5),1429-1439. [3] Ashworth, P.J., Best, J.L., Jones, M.A., 2007, Sedimentology 54, 497–513. [4] Marra, W.A., Kleinhans, M.G., Addink, E.A., 2014, ESPL 39(6), 766-778. [5] Freeman, T.G., 1991, Computers and Geosciences 17(3), 413-422. [6] Thomas, R., Nicholas, A.P., Geomorphology 43 (2002) 179–195. **Acknowledgments.** This work was supported by the SAFL Industrial Consortium and the Sediment Experimentalists Network. I thank Chris Paola, Efi Foufoula-Georgiou, Alejandro Tejedor, and Jean-Louis Grimaud for helpful discussions, and the Nebraska Department of Natural Resources for topography data.