THE EFFICACY OF USING A MORPHOLOGICAL ACCELERATION FACTOR TO SIMULATE LARGE-SCALE AND LONG-TERM FLUVIAL MORPHODYNAMICS

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① BACKGROUND & TEST SIMULATIONS

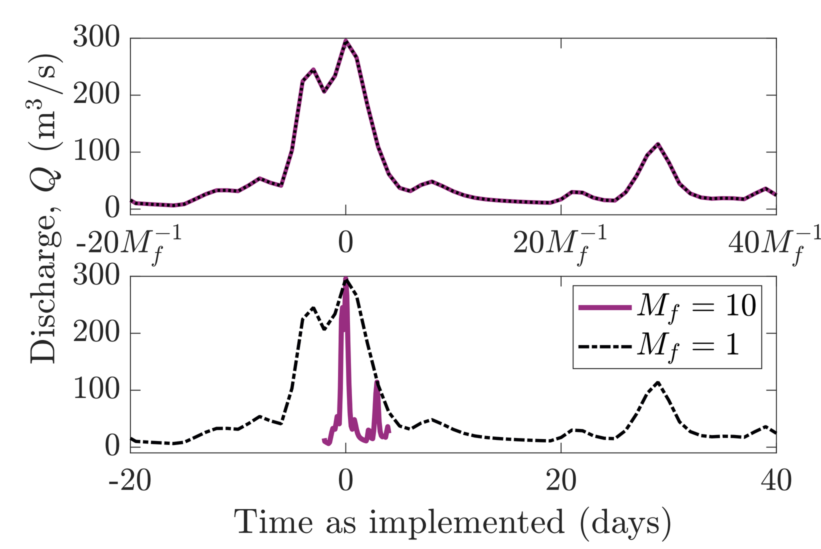
- Large-scale and long-term fluvial morphodynamics are driven by processes which occur at much smaller spatial and temporal scales
  E.g., an advective basin-scale sediment wave propagating through the Nooksack River (Fig. 1) over a multi-decadal time period (Anderson and Konrad 2019)
- These long-term patterns of erosion and deposition can affect flood hazard in populated lowland regions (see Shelby Ahrendt's poster)
- Resolving the relevant range of scales in simulations requires large domains with fine spatial and temporal steps, which is computationally expensive

- **Can we use a morphological acceleration factor (morfac, M_f) to reduce simulation time?**
- The use of morfac assumes linearity between hydrodynamics and resultant morphodynamics

$$\frac{\partial \eta}{\partial (t/M_f)} = -\frac{M_f}{1-\lambda}\nabla \vec{q_b}$$

- Morfac is commonly used in coastal/estuarine simulations with values $O(10^2)$ or greater
- In fluvial simulations the use of morfac is generally confined to steady (or quasi-steady) flow
- **How does using morfac to scale an unsteady hydrograph affect morphodynamics?**

- Implementing morfac here requires adjusting the inflow time-series by a factor of M_f, effectively compressing the upstream boundary hydrograph (Fig. 2)
- Using Delft3D test M_f (5, 7.5, 10, 15, 20, 50), using no acceleration ($M_f = 1$) as a standard



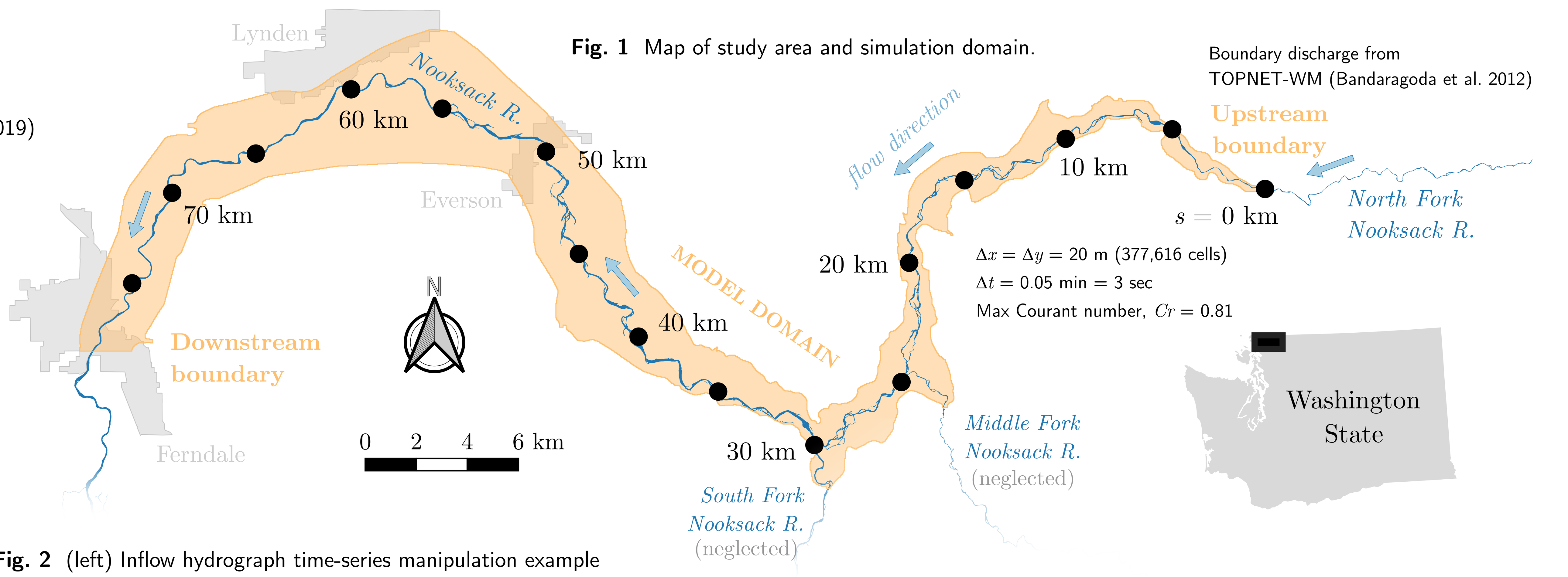


Fig. 1 Map of study area and simulation domain.

Fig. 2 (left) Inflow hydrograph time-series manipulation example for $M_f = 10$. Time values are centered on the peak of the flood.

② FLOOD WAVE PROPAGATION

- Higher M_f values result in more attenuative flood waves (lower celerities and peak flows, Fig. 3a)
- Peak discharge moves downstream as a power-law function of time (Fig. 3b and c)

$$s = \alpha \times t^{\beta}$$

- From fitting (Fig. 3b and c), wave celerity ($c = ds/dt$) is inversely proportional to morfac

$$c \approx 181.3/M_f$$

- Peak discharge reduction (Fig. 3d) is directly proportaional to distance and morfac

$$\Delta Q \approx 0.02 \times s \times M_f$$

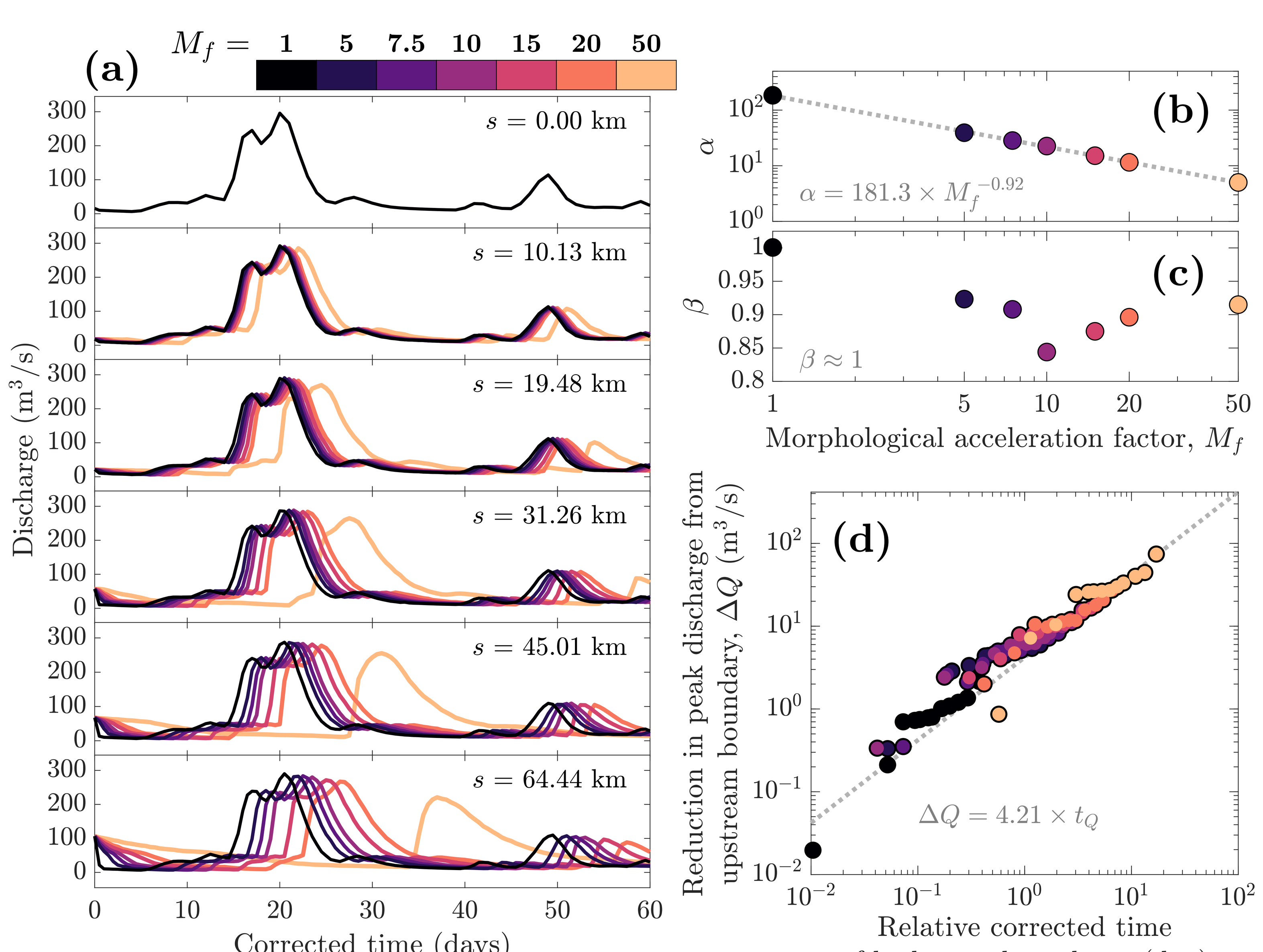


Fig. 3 (a) Discharge time-series at several downstream locations, showing increased flood wave attenuation with increasing morfac, (b and c) fitting parameters for power-law relationship between peak discharge timing and location, and (d) relationship between reduction in peak flow and time.

③ MORPHODYNAMIC RESULTS

- Similar patterns of erosion/deposition, but more muted with higher morfac values (Fig. 4a-c)
- Higher M_f results in higher errors, similar regions of high error (Fig. 4d,e and Fig. 5a)
- Errors higher for regions of high slope (Fig. 5c) and regions of narrow channel width (Fig. 5d)

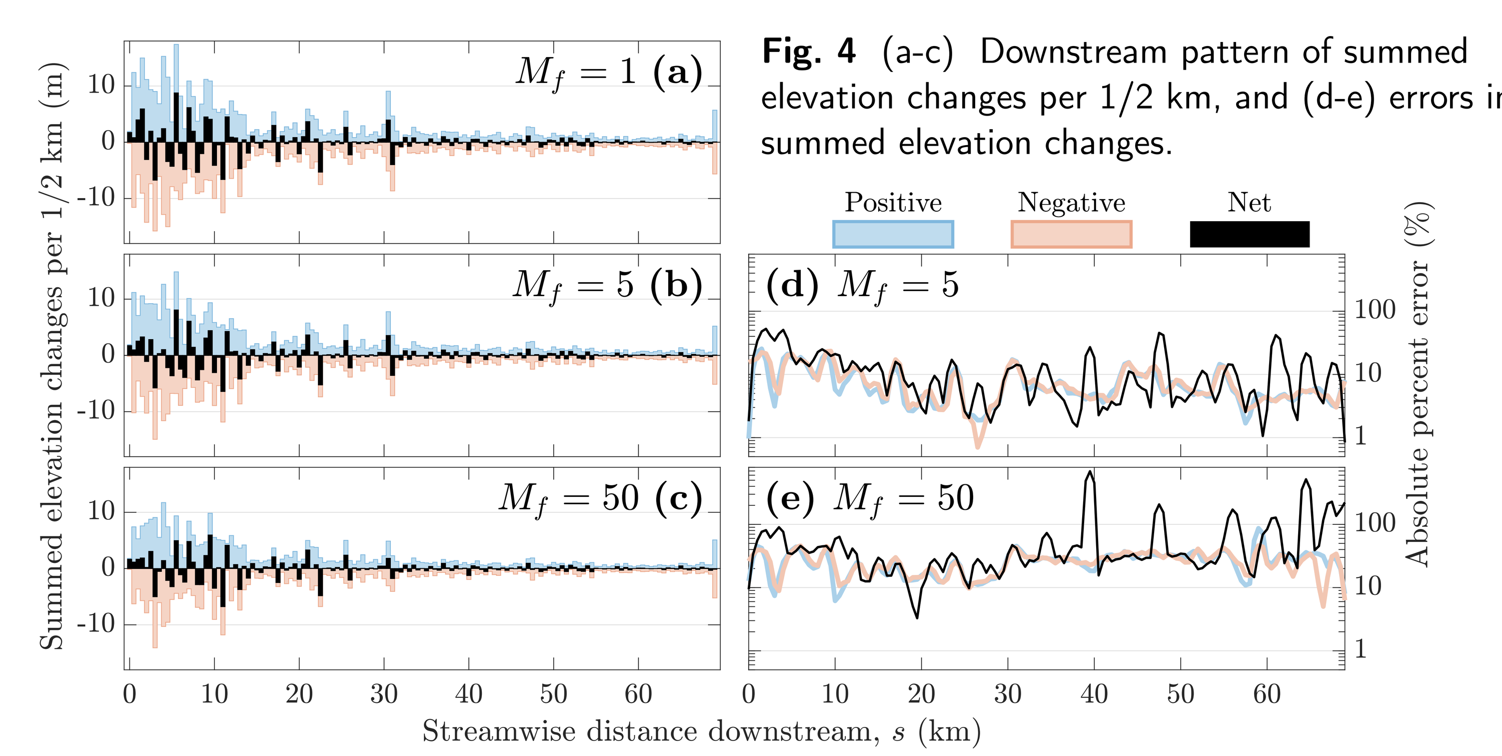


Fig. 4 (a-c) Downstream pattern of summed elevation changes per 1/2 km, and (d-e) errors in summed elevation changes.

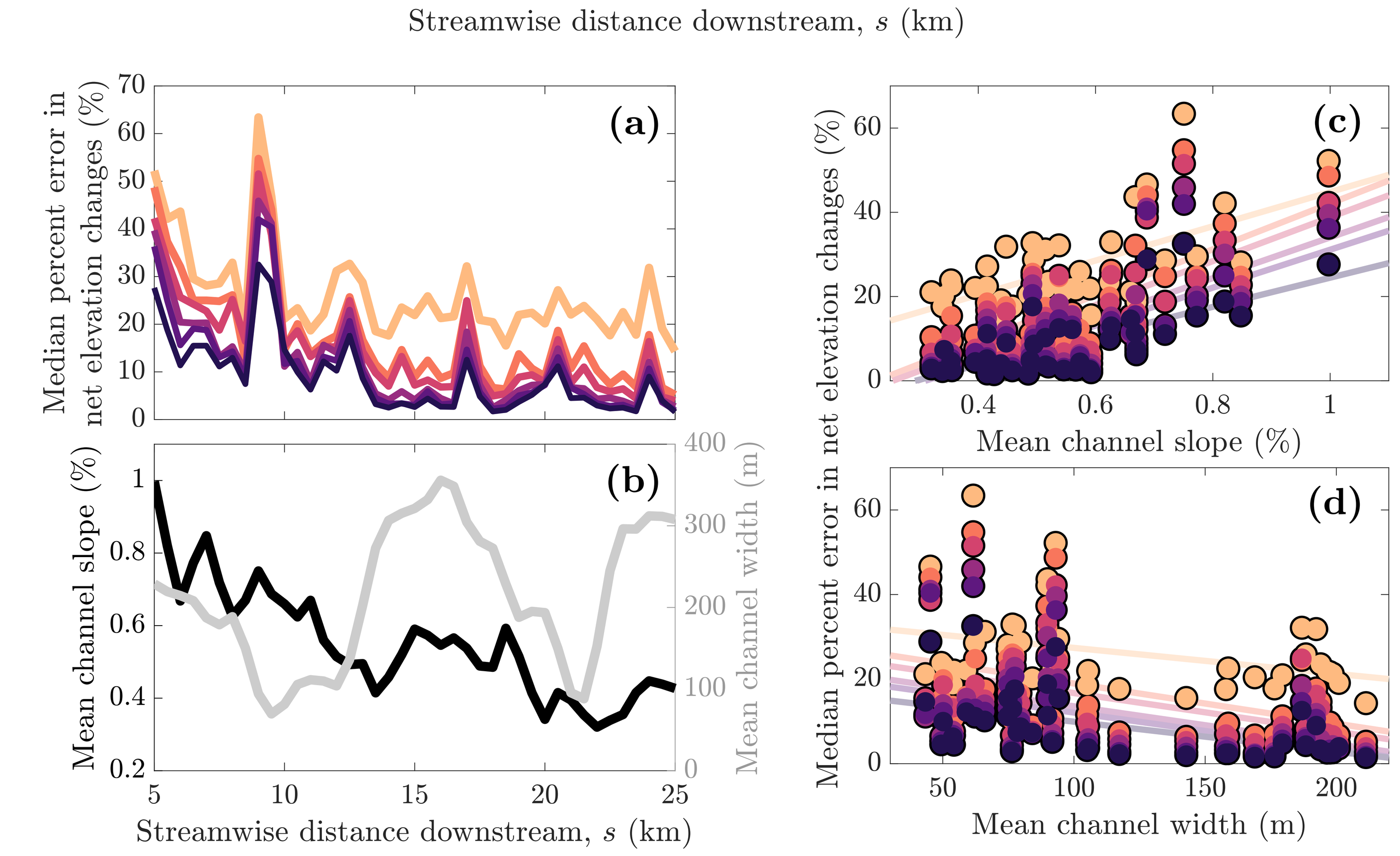


Fig. 5 (a) Downstream variation in median percent error of elevation change, (b) downstream mean channel slope and width, (c) trends between error and slope, and (d) trends between error and width.

④ SUMMARY & CONCLUSIONS

- Hydrograph time-series manipulation creates more attenuative flood waves
- Discharge magnitude reduction increases linearly with morfac
- Lower peak discharge magnitudes result in underprediction of morphodynamic changes
- Shallower slopes, wider channels generally result in lower errors
- Lower morphological acceleration factors result in overall lower errors (Fig. 6)
- Minimum total errors are $O(10^1)$% for a single event
- Using a high morphological acceleration factor in this way may not be a viable option for large-scale and/or long-term morphodynamics in the Nooksack River
- How can we simulation long-term sediment movement to predict change in flood risk in lowlands?
- Alternative approach: cyclic representative hydrograph rather than realistic irregular time-series flow

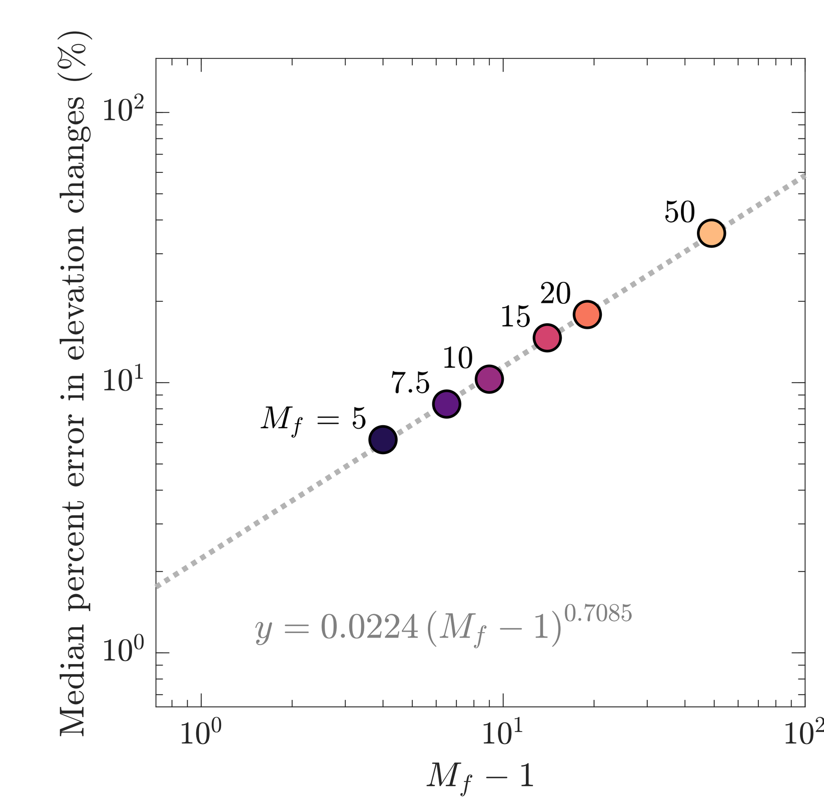


Fig. 6 Absolute median percent error in net elevation changes (from the beginning to end of the simulation, over the entire spatial domain) relative to $M_f = 1$.

⑤ REFERENCES & ACKNOWLEDGMENTS

Anderson, S.W. and C.P. Konrad (2019), Downstream-propagating channel responses to decadal-scale climate variability in a glaciated river basin, *Journal of Geophysical Research: Earth Surface* 124(4): 902-919, doi: 10.1029/2018JF004734.

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