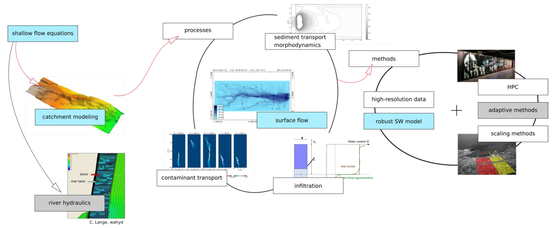
Mesh design for multiscale hydrological simulations: Wavelet-based approach improves model accuracy

I. Özgen-Xian[1], S. Molins[1], G. Kesserwani[2], D. Caviedes-Voullième[3], C. I. Steefel[1]

(1) Lawrence Berkeley National Laboratory, Berkeley, CA, United States, (2) University of Sheffield, Sheffield, UK (3) Brandenburgische Technische Universität Cottbus, Cottbus, Germany

INTRODUCTION

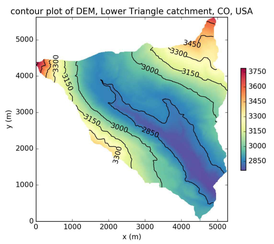
The high computational cost of process-based distributed hydrological simulations at the catchment scale can be approached by *adaptive mesh refinement* (AMR).



The aim is to approximate the high-resolution uniform mesh using a simplified mesh with fewer elements. This contribution presents a fixed AMR approach that is based on wavelet analysis (Kesserwani *et al.*, 2019) that produces a multiresolution triangular mesh from quad-based DEM input data.

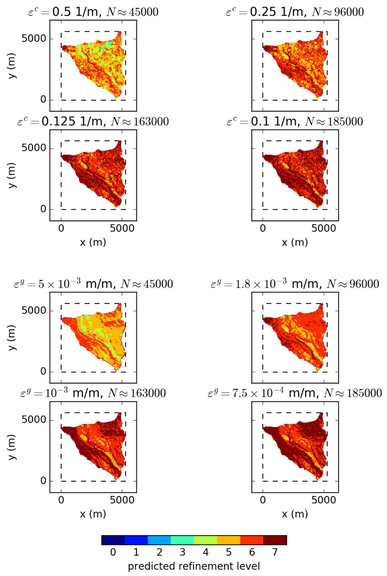
LOWER TRIANGLE, COLORADO

Lower Triangle is a subcatchment of the East River Watershed in Colorado, USA. The catchment is mountainous, and features steep slopes and high elevations. The elevation data is available as a quad-based DEM with 10 m resolution.

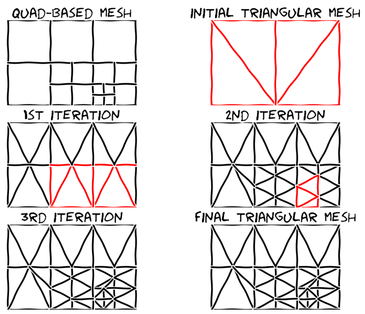


MESHING WORKFLOW

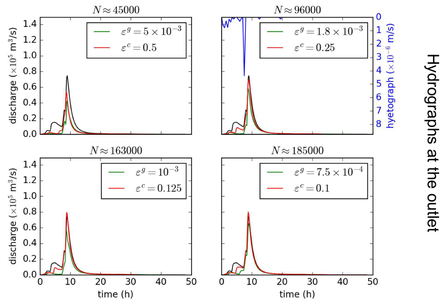
Step 1: Multiresolution analysis of DEM data



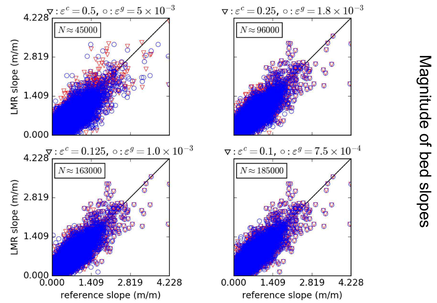
Step 2:Triangular mesh generation



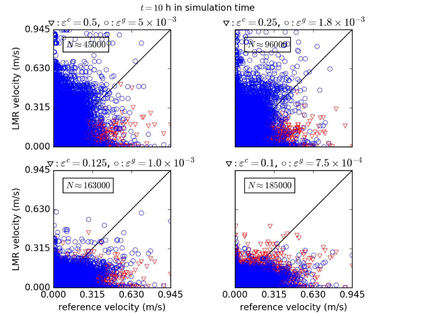
RESULTS



Hydrographs at the outlet



Magnitude of bed slopes



Flow velocities

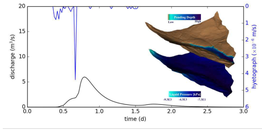
SUMMARY

1. The wavelet-based AMR is a robust method that requires only one user-specified parameter.
2. Either slope or curvature can be used to predict local refinement. For the presented case, a curvature-based refinement has been found to be more advantageous.
3. While the integral discharge at the outlet is accurately predicted by the AMR approach, ponding water depths and flow velocities inside the catchment deviate from high-resolution reference simulation results.
4. Using the proposed AMR approach reduced the computational cost by a factor of 2 up to 3, depending on the number of elements in the reduced mesh.

FORTHCOMING ATTRACTIONS

- An article that provides more details is currently under review.
- We plan to incorporate the presented AMR approach into the mesh generator TINerator: https://raw.githack.com/lanl/LaGriT/tinerator/html/index.html
- Applications to integrated hydrological simulations are in progress.

IDEAS Watersheds tinerator



REFERENCES

Caviedes-Voullième, D., García-Navarro, P., Murillo, J., Influence of mesh structure on 2D full shallow water equations and SCS curve number simulation of rainfall/runoff events. *Journal of Hydrology*, 448-449:39-59, 2012.

Dwivedi, D., Steefel, C. I., Arora, B., Newcomer, M., Moulton, J. D., Dafflon, B., Faybishenko, B., Fox, P., Nico, P., Spycher, N., Caroll, R., Williams, K. H., Geochemical exports to river from the intrameander hyporheic zone under transient hydrologic conditions: East River Mountainous Watershed, Colorado. *Water Resources Research*, 54:8456-8477.

Kesserwani, G., Shaw, J., Sharifian, M. K., Bau, D., Keylock, C. J., Bates, P. D., Ryan, J. K., (Multi)wavelets increase both accuracy and efficiency of standard Godunov-type hydrodynamic models. *Advances in Water Resources*, 129:31—5, 2019.

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