Reducing a Stream Network's Horton-Strahler Stream Order Improves the Skill of Flood Inundation Maps from Height Above Nearest Drainage Method

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Abstract

The National Water Model (NWM) currently requires the post-processing of forecast discharges to produce forecast flood inundation maps (FIM) to support the National Weather Service's mission of protecting life and property. Height Above Nearest Drainage (HAND) is a means of detrending digital elevation models (DEM) by normalizing elevations to the nearest, relevant drainage line (creeks, rivers, etc). It's worthy of producing high-resolution FIMs at large spatial scales and frequent time steps using reach-averaged synthetic rating curves. However, HAND based FIMs suffer from a known limitation caused by independent catchments that lack the ability to cross catchment boundaries and ridgelines. To counter this constraint, a version of HAND known as Generalized Mainstems (GMS) is proposed that reduces the Horton-Strahler stream order of the stream network. To demonstrate skill enhancement, we constructed HAND derived at three different stream resolutions including the NWM full resolution (FR), the NWM mainstems (MS) resolution, and the NWM GMS resolution stream networks. The FR stream network contains all NWM forecast locations and the MS resolution stream network contains all river segments at or downstream of NWS river forecast points. GMS contains all segments within the FR stream resolution but instead of deriving HAND by accounting for all river segments at once, it is derived independently at the level path (LP) scale. LPs are unique identifiers propagated upstream from a sub-basin's outlet along the direction of maximum flow distance and repeated recursively until all segments are assigned LP identifiers. These serve as processing units for HAND dataset production and FIMs are made at the LP scale. These FIMs are then mosaiced together, effectively turning the stream network into discrete groups of homogenous unit stream order by removing the influence of neighboring tributaries. Improvement in mapping skill on the order of 2% points of Critical Success Index for MS and 2% points more for GMS is demonstrated by comparing to HEC-RAS FIMs. Additionally, both Probability of Detection and False Alarm Ratio improve which can be partly explained by a positive correlation of stream order with river stage at fixed discharge values within the synthetic rating curves produced by HAND.

Continental Flood Inundation Mapping

Observing FIM skill improve by reducing the stream order for derivation of Height Above Nearest Drainage

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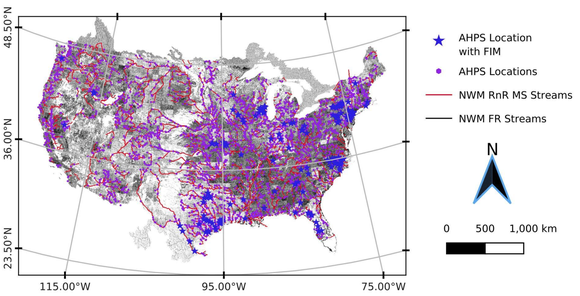
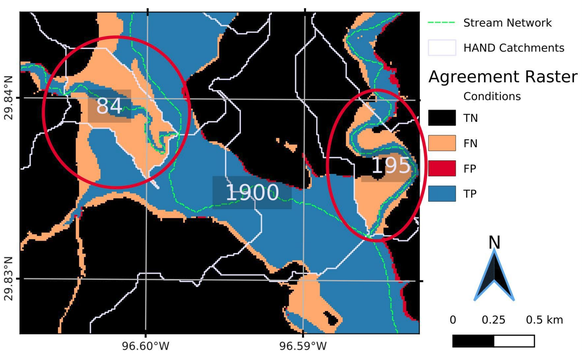
Reducing a Stream Network's Horton-Strahler Stream Order Improves the Skill of Flood Inundation Maps from Height Above Nearest Drainage Method

Introduction

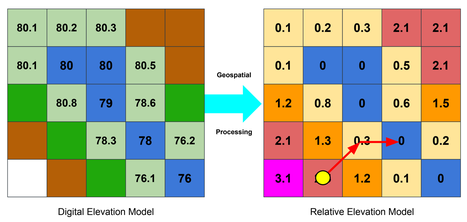
- The NWM produces almost 3 million forecast streamflow values at multiple time horizons every hour.
- Post-processing is required to convert these discharges into stages and inundation extents.
- Height Above Nearest Drainage (HAND) is a terrain index that detrends or normalizes elevation away from mean sea level to the nearest relevant stream elevation.
- Synthetic Rating Curves (SRC) are used to convert stream flows to stages and those are converted to inundation extents using HAND.

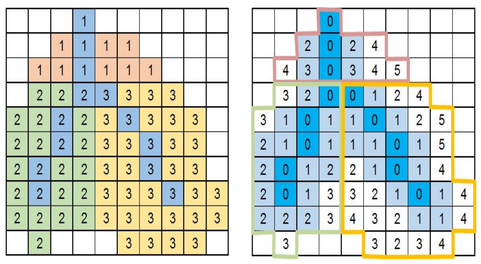


NWM Stream Networks, Full Resolution (FR) and Mainstems (MS), as well as the Advanced Hydrologic Prediction System (AHPS) locations and those with FIMs.



False Negatives (FN) associated with HAND inundation at junctions of high flow rivers and lower flow tributaries. This is caused by independent catchments which lack hydrodynamic connectivity. Above map compares to HEC-RAS 1D models for 100 year events as furnished by FEMA Region 6.

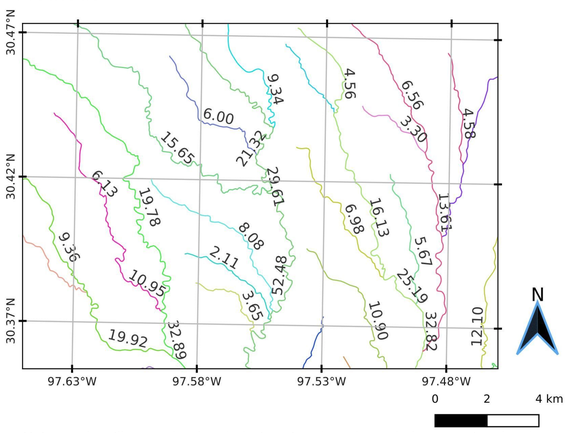




$$Q[y] = \frac{1}{n}\frac{V[y]^{5/3}S^{1/2}}{LB[y]^{2/3}}$$

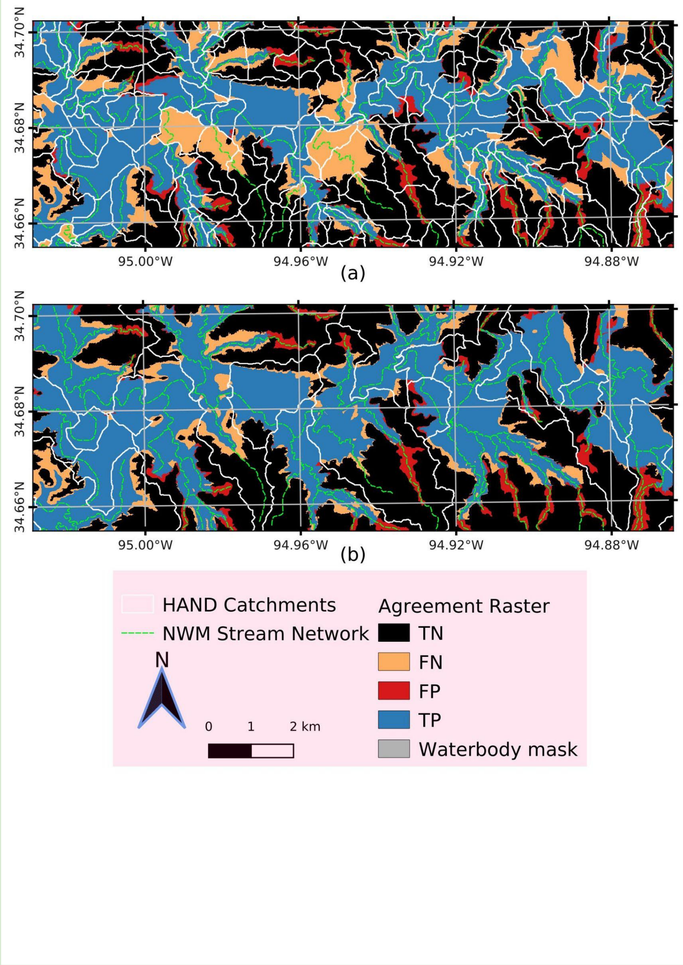
Detrending digital elevation models (DEM) by normalizing elevation to the nearest, relevant drainage line elevation. The resulting catchments and HAND values are used to derive synthetic rating curves using reach-averaged parameters.

Methods



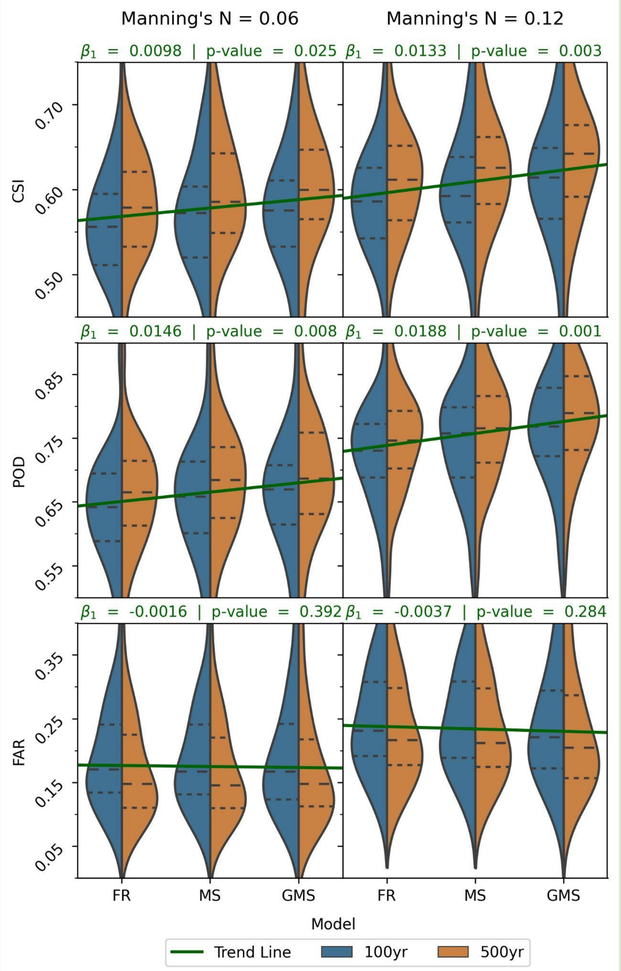
Unique colors illustrate level-path designations based on arbolate sum. Level path identifiers are propagated upstream following the direction of maximum arbolate sum at each junction. The other directions are assigned a new unique levelpath identifier.

Agreement Maps

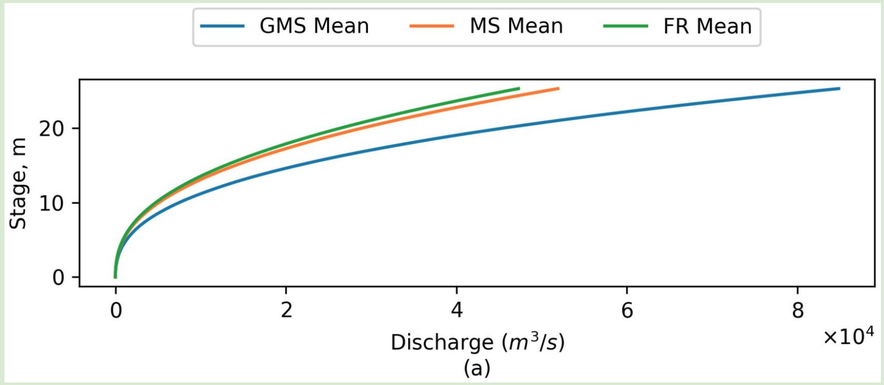


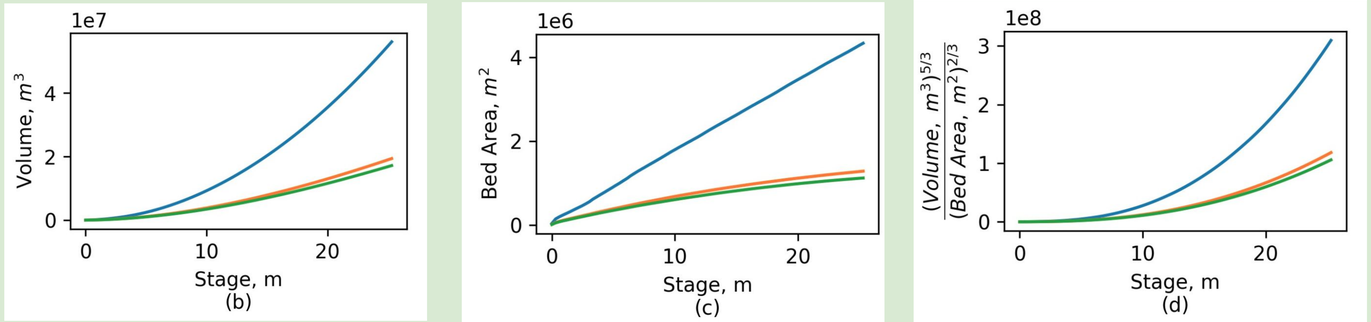
Agreement maps showing distribution of results when compared to validation maps. Results for FR HAND (a) and GMS HAND (b).

Violin Plots of Metrics



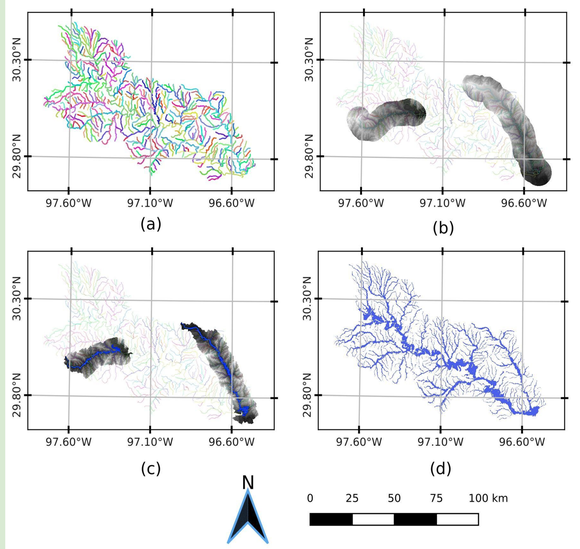
Violin plots comparing FR, MS, GMS versions of HAND with increasing reliance on stream networks of lower stream order. Performance increases for two event magnitudes across two Manning's N values due to improvements in POD and FAR.



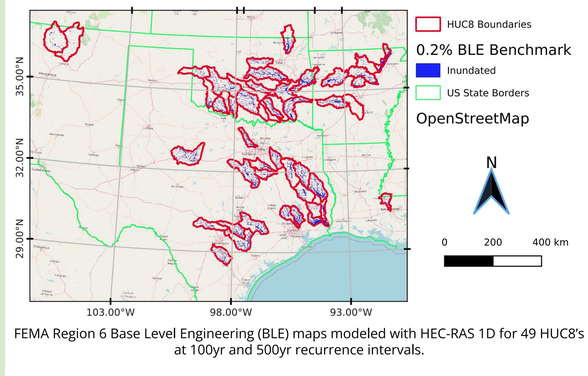


Shows the average rating curve for each model FR, MS, and GMS (a). The more stream order reduction is relied on the more the rating curve gets biased downward. Shows how volume is biased up (b) and how the same effect on bed area is observed (c). Shows the net effect of the changes on volume and bed area which is explained by the larger catchments (d) .

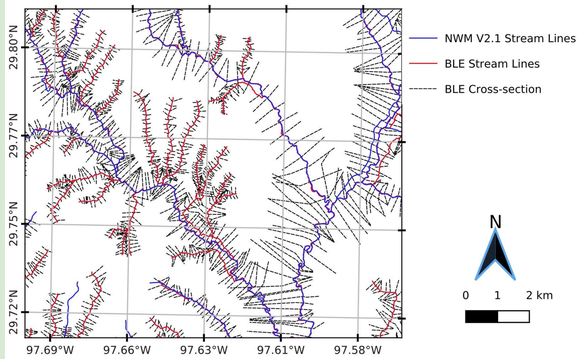
Methods (continued)



Shows levelpaths for an entire HUC8 (a). DEMs are clipped for every levelpath independently but only two are shown (b). Every levelpath is independently used to derive HAND but only two are show for clarity (c). FIMs for each HAND dataset are mosaiced together (d)



FEMA Region 6 Base Level Engineering (BLE) maps modeled with HEC-RAS 1D for 49 HUC8's at 100yr and 500yr recurrence intervals.



BLE cross-sections are intersected with NWM stream lines to derive stream flows used for validation.

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Poster

Repository