Synoptic Evaluation of Scale-Dependent Metrics for Hydrographic Line Feature Geometry

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Outline

- Objective: Insure generalization of linear hydrographic features through multiple scales maintains geometric characteristics that reflect geomorphology of the landscape
  - Use of multi-scale data is not limited to cartographic display. Important for analysis and modeling
- Methods
  - Synoptic evaluation of metrics for all features and geomorphological conditions
  - Evaluation of displacement metrics and geographic conditions
- Preliminary Results
- Summary

Methods: Synoptic evaluation of all-feature metrics and geomorphologic conditions

- Workflow on National Hydrography Dataset (NHD) Subbasins
  - Build density partitions (breaks <1.0, 1.0 to < 2.5, $\geq$ 2.5 km/km^2) and assign partition to stream features
  - Simplify subbasin stream features using Bend-Simplify algorithm (Wang and Muller 1998) with 7 tolerances (15, 25, 50, 100, 200, 300, 500 m).
  - For each density partition, compute average metrics of stream features and average geomorphology characteristics.
  - Evaluate relations between metrics and geomorphology characteristics (XY plots, regression analysis, visual review of spatial data patterns).
  - Evaluate metrics before and after simplification

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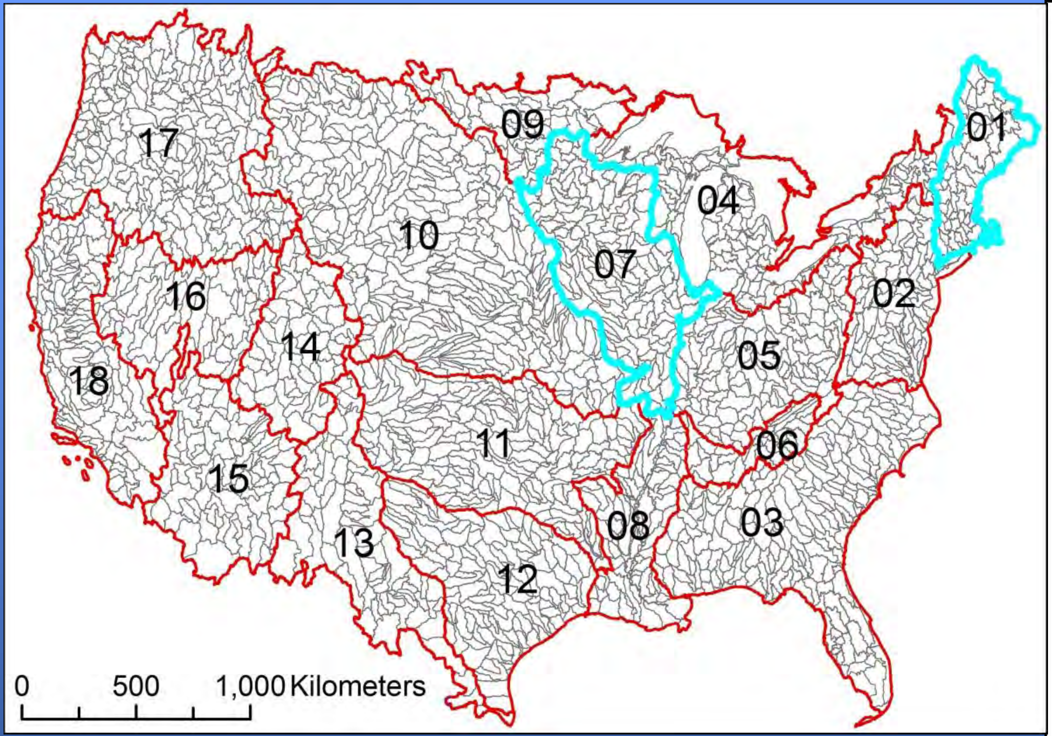
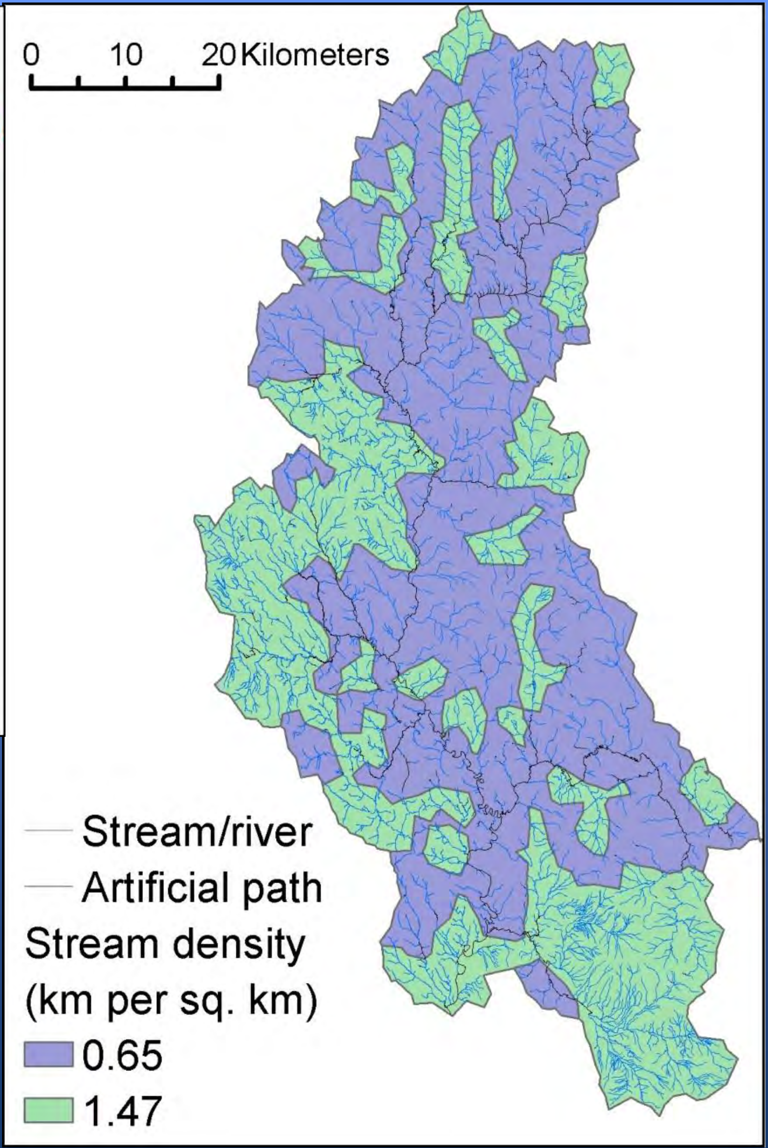
Density Partitions





Stream network density partitions using density breaks at <1.0, 1.0 to < 2.5, $\geq$ 2.5 km/km^2 are built for each subbasin in NHD regions 1and 7.

Example: Upper Connecticut River subbasin (01080101)

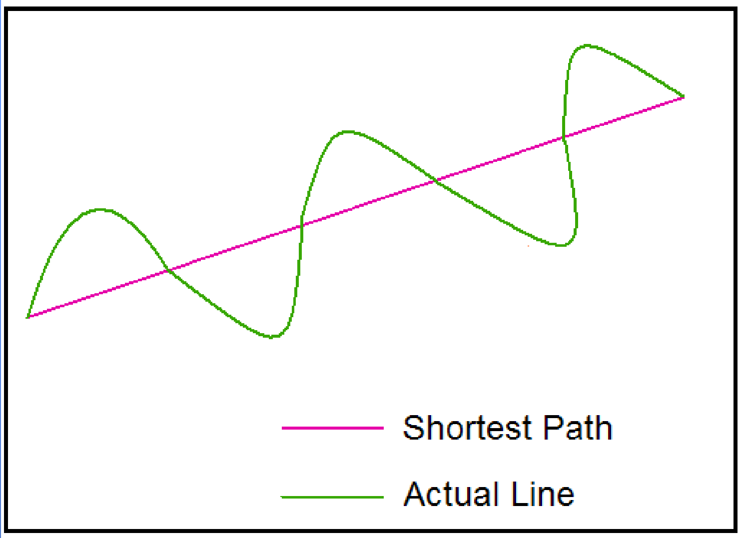
NHD Stream Feature Metrics for each Density Class

- Average sinuosity. Sinuosity is the total length of all segments in a linear feature divided by the distance between the feature endpoints. Average sinuosity: average of all features in a density class.
- Mean of average segment length per feature. Average segment length is the total length of a feature divided by the number of line segments in the feature. The mean value is the mean of all average segment lengths in a density class.
- Average error variance. The sum of the perpendicular distances of each non-endpoint vertex in the feature to the anchor line of the feature divided by the number of non-endpoint vertices, where the anchor line is the line between the two end points (Buttenfield 1986, Shariari et al. 2002). Averaged for all features a the density class.
- Average absolute angularity. The sum of absolute value of direction changes from one segment to the next in a feature divided by the number of direction changes (Buttenfield 1991, Bernhardt 1992, Tsoulos and Skopeliti 2000). Averaged for all features in a density class.

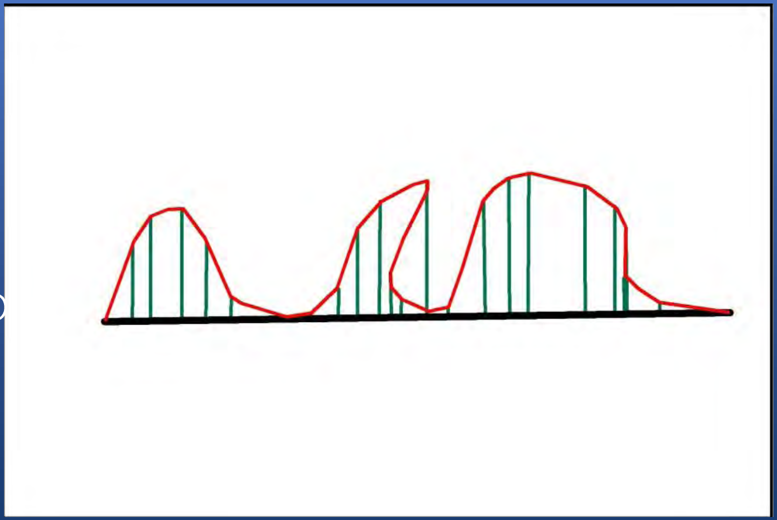
NHD Stream Feature Metrics

Sinuosity: length of a linear feature divided by the distance between its endpoints.

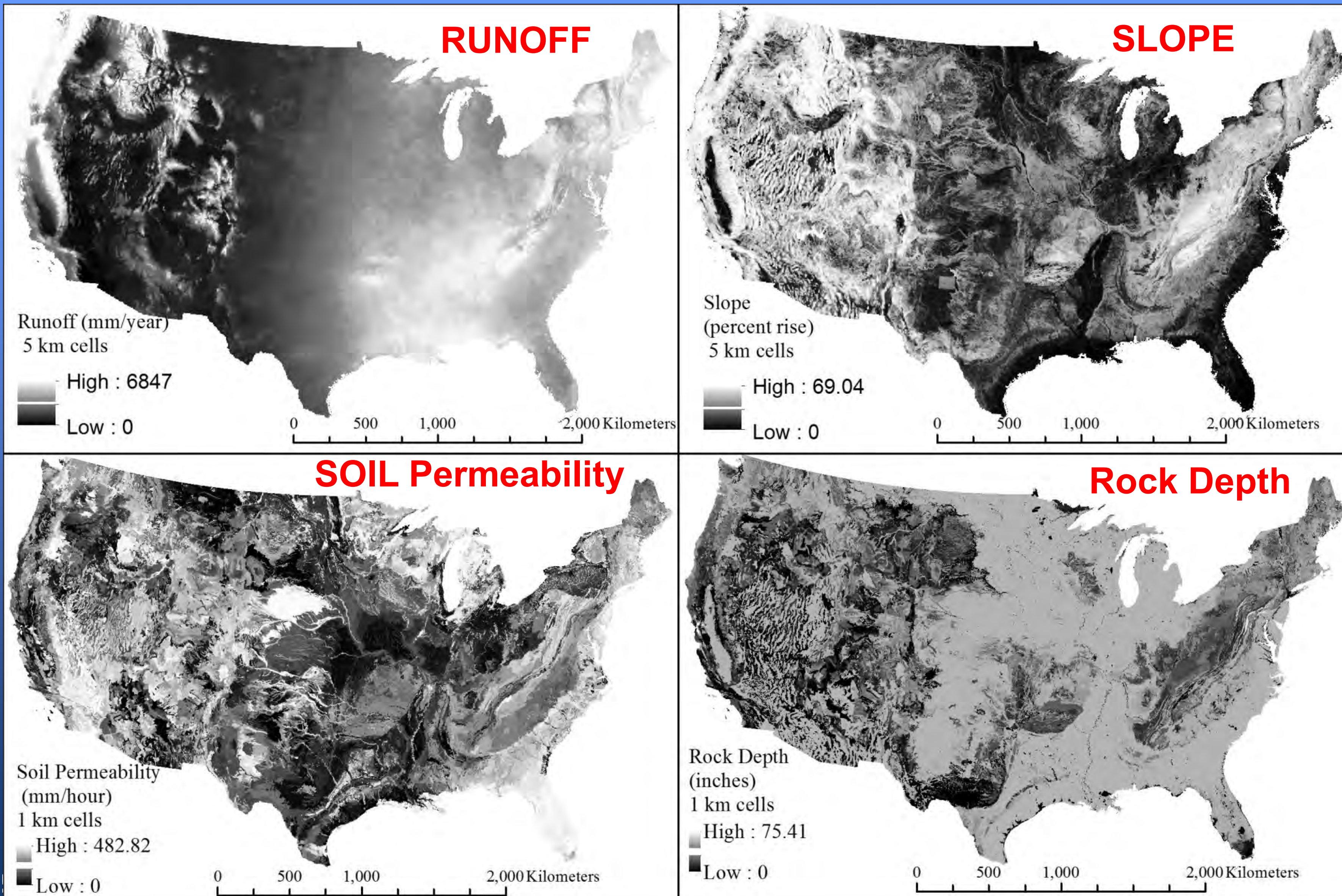
Straight line sinuosity = 1; else sinuosity > 1



Error variance: average of the perpendicular distances of each non-endpoint vertex in a feature to the anchor line of the feature, where the anchor line is the line between the two end points.

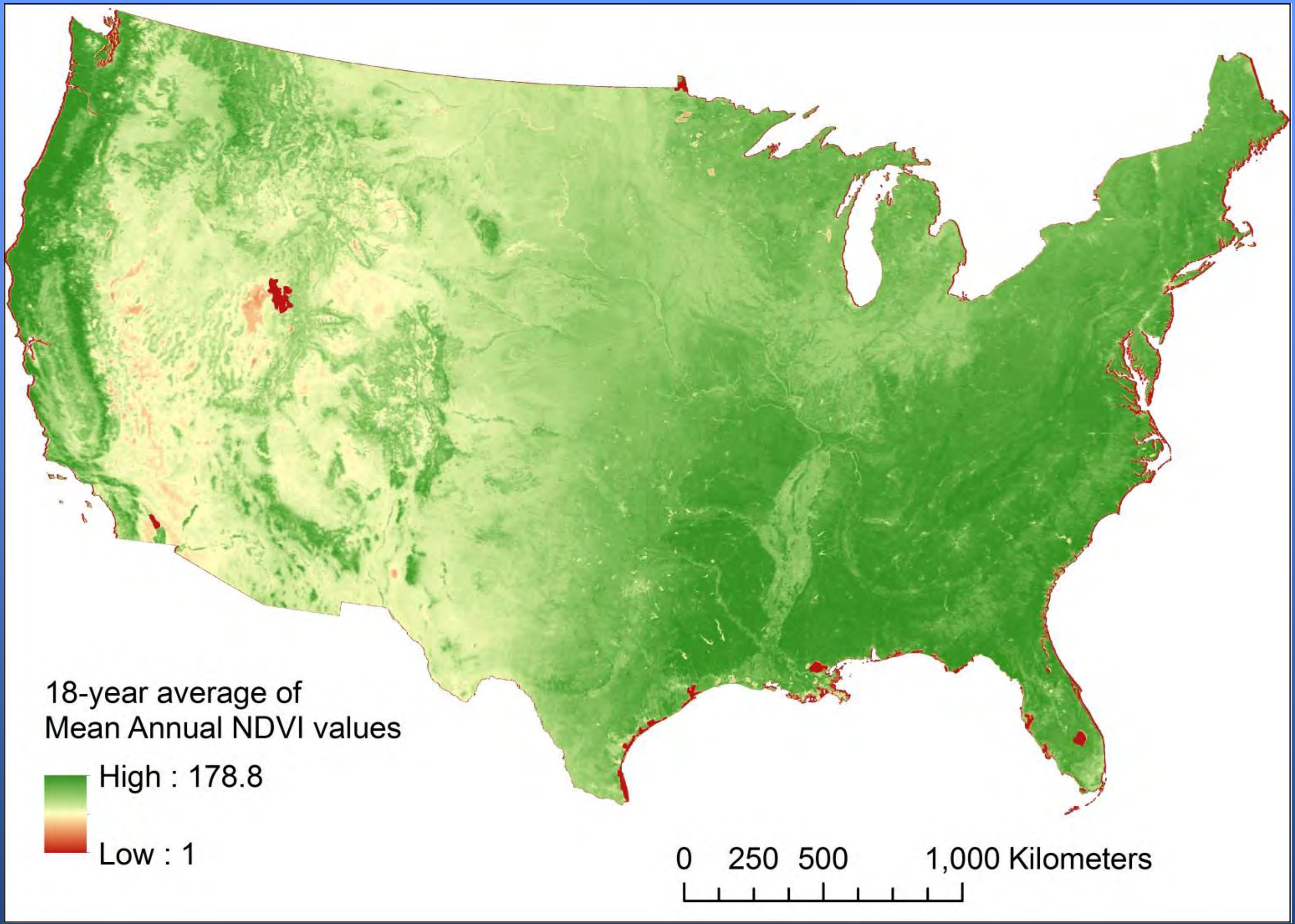


Stream Geomorphology Conditions
(zonal mean for each density partition)



Stream Geomorphology Conditions
(zonal mean for each density partition)

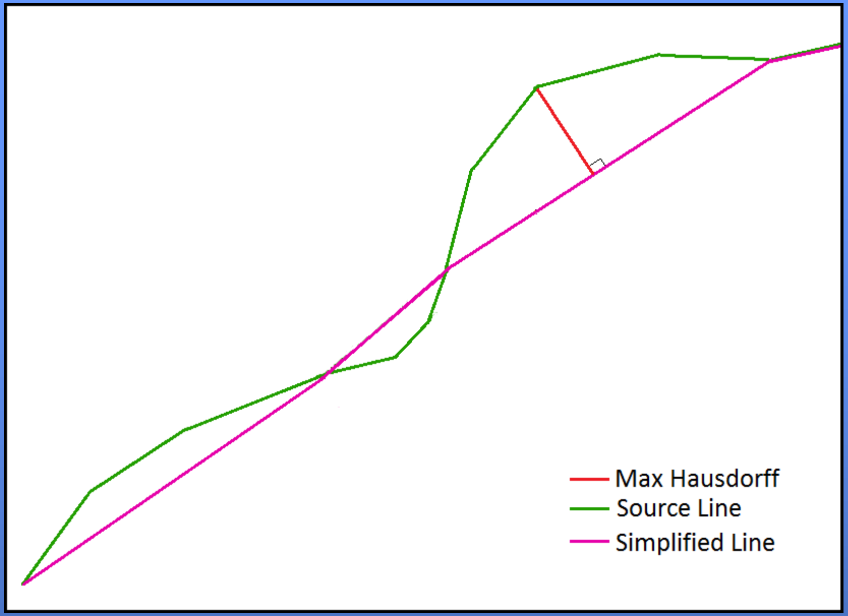
18-year average (1990-2010, skip 1992-1994 because of regional offsets along west and northeast regions) of mean annual Normalized Difference Vegetation Index (NDVI). Data available from National Atlas.



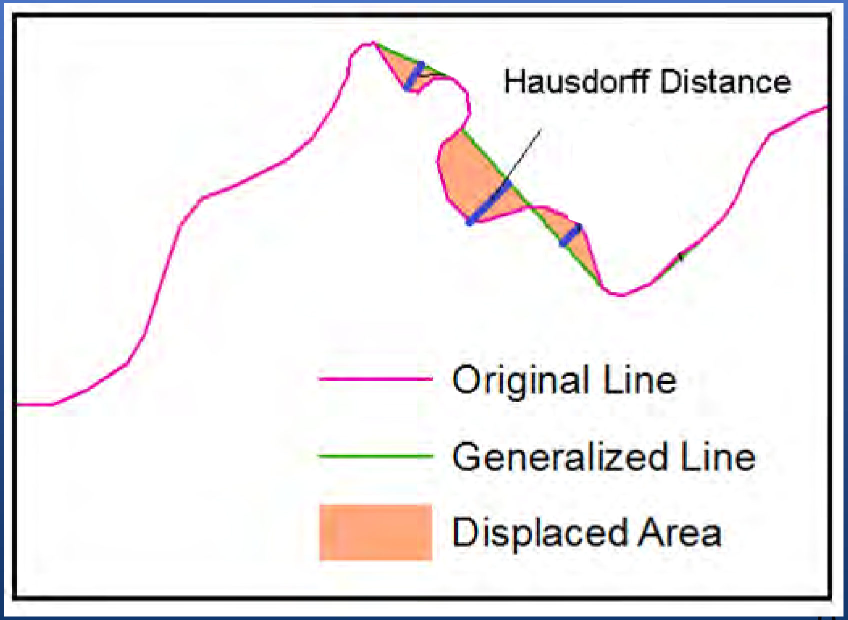
1-km raster 18-year NDVI average. Tested in the weighted flow accumulation model to adjust runoff for the effects of vegetation.

Displacement Metrics for Each Subbasin Density Classes

Maximum Hausdorff distance. The Hausdorff distance between two linear features can be defined as the largest minimum distance between any point on one feature to any point on the other (Hangouët, 1995; Rucklidge, 1996; Nutanong, 2011)



Average areal displacement. The areal displacement for a linear feature is the sum of the area of all displacement polygons created between the original and simplified line feature divided by the length of the original line (White 1985, McMaster 1986).



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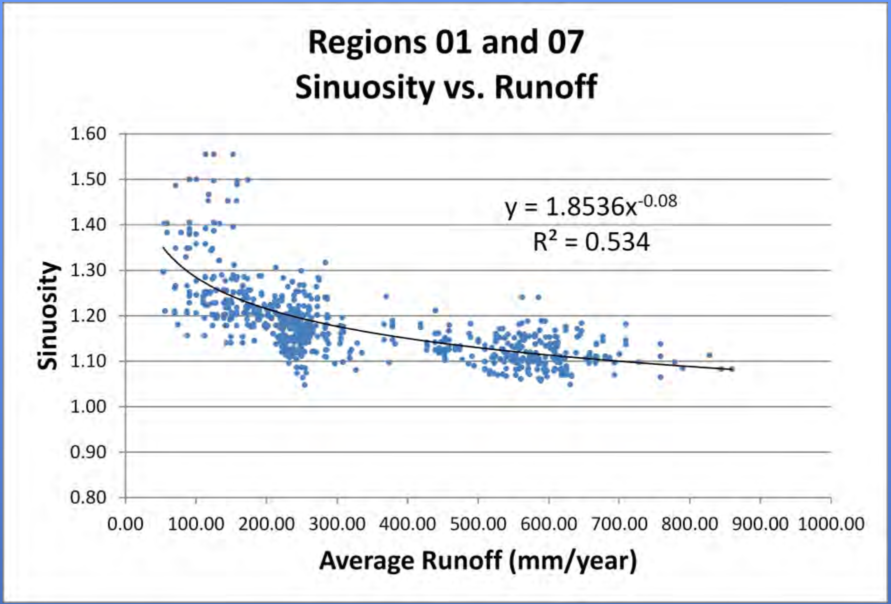
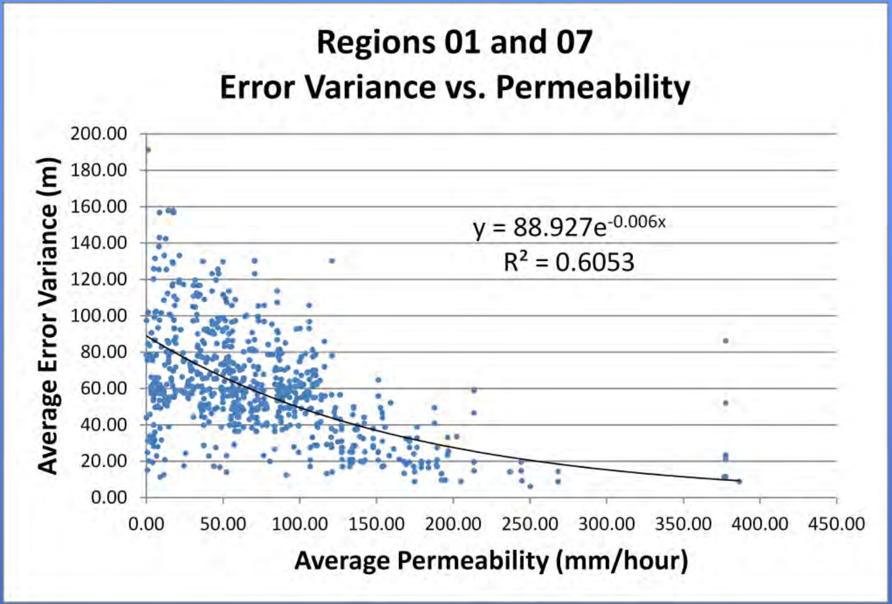
Preliminary Results (Regions 1 and 7)

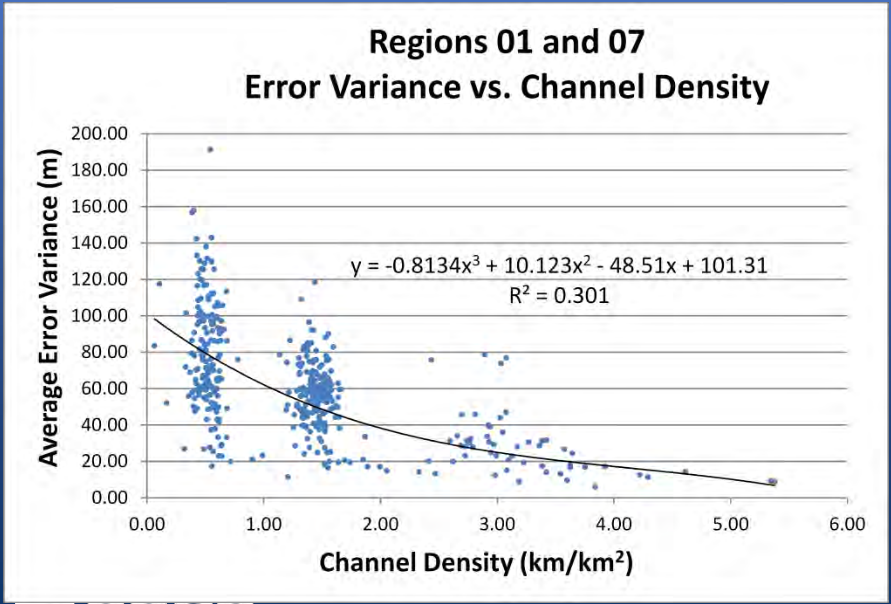
R^2 values (rounded to two decimal places) from regression equations that best predict the average stream morphology characteristic (by density class) from the average 1:24,000-scale stream feature metric

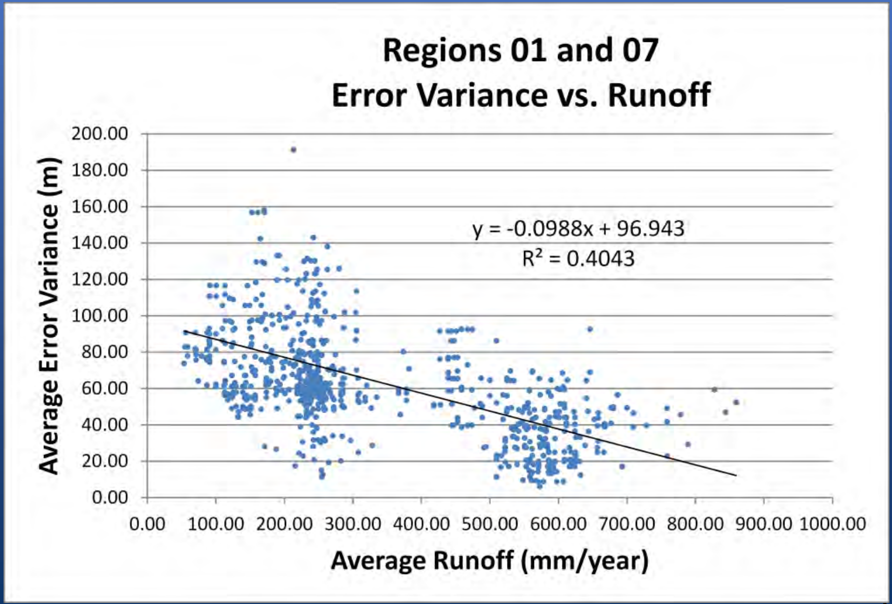
Average Stream Metrics for a Density Class	Sinuosity	Error Variance	Absolute Angularity	Segment Length
Morphology Characteristic				
Slope	0.16	0.07	0.00	0.01
Channel Density	0.03	**0.30**	0.00	0.00
NDVI	0.02	0.04	0.02	0.07
Permeability	0.13	**0.61**	0.02	0.03
Rock Depth	0.15	0.15	0.01	0.00
Runoff	**0.53**	**0.40**	0.00	0.01

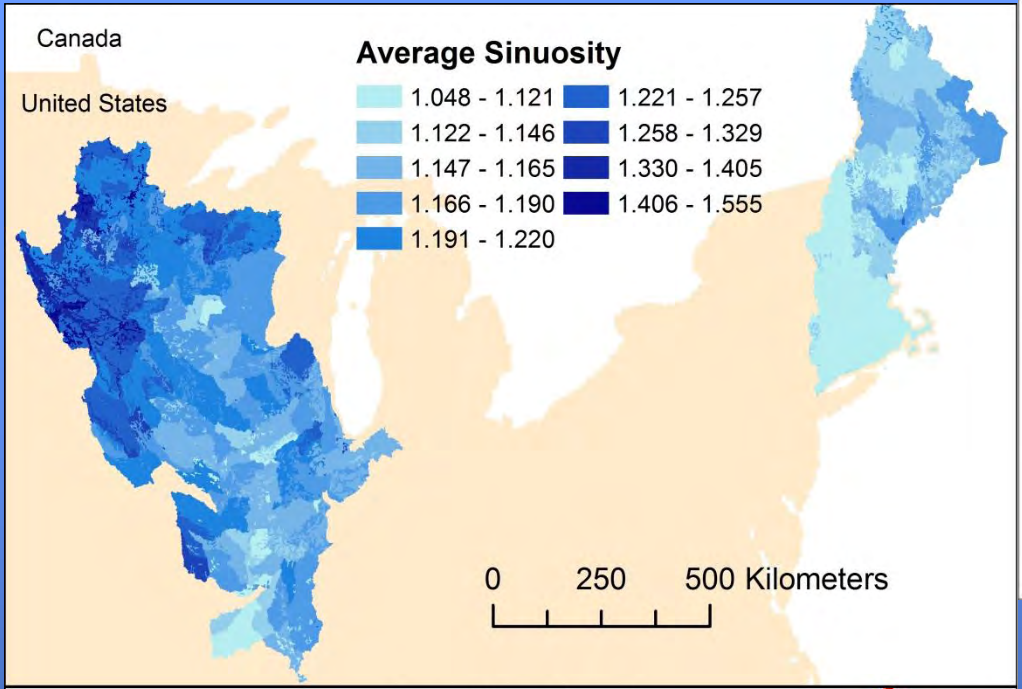
Preliminary Results (Regions 1 and 7)

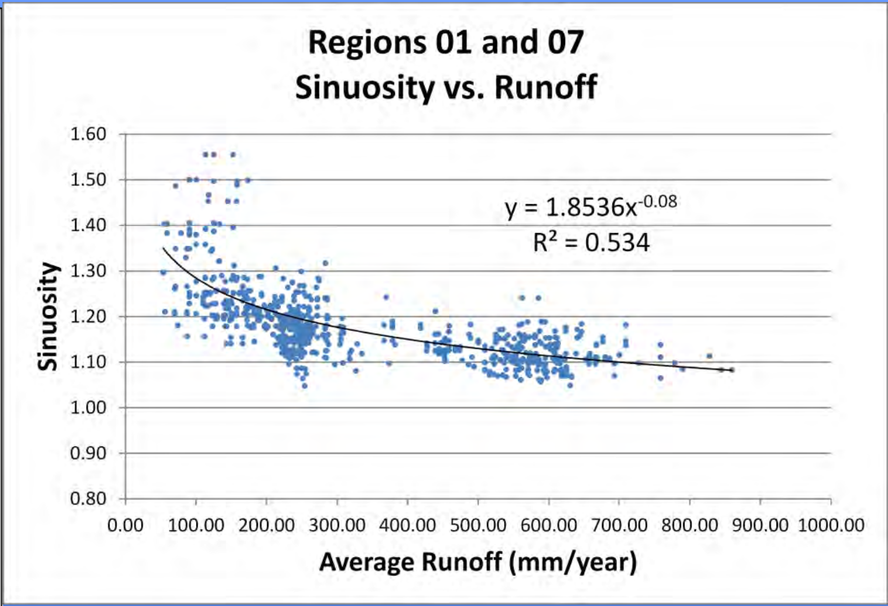


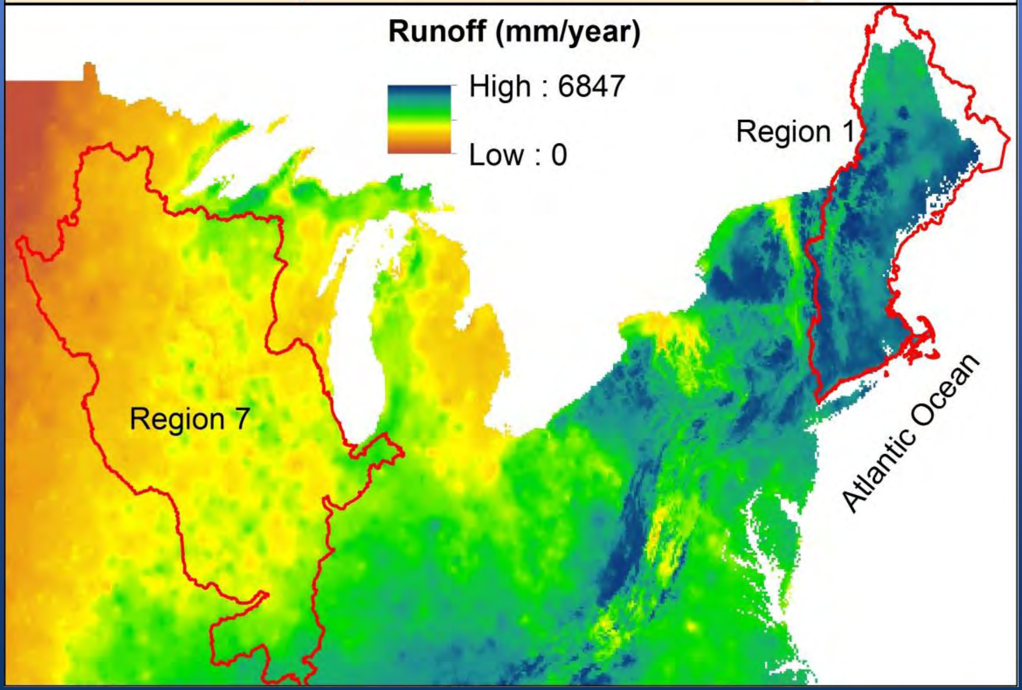










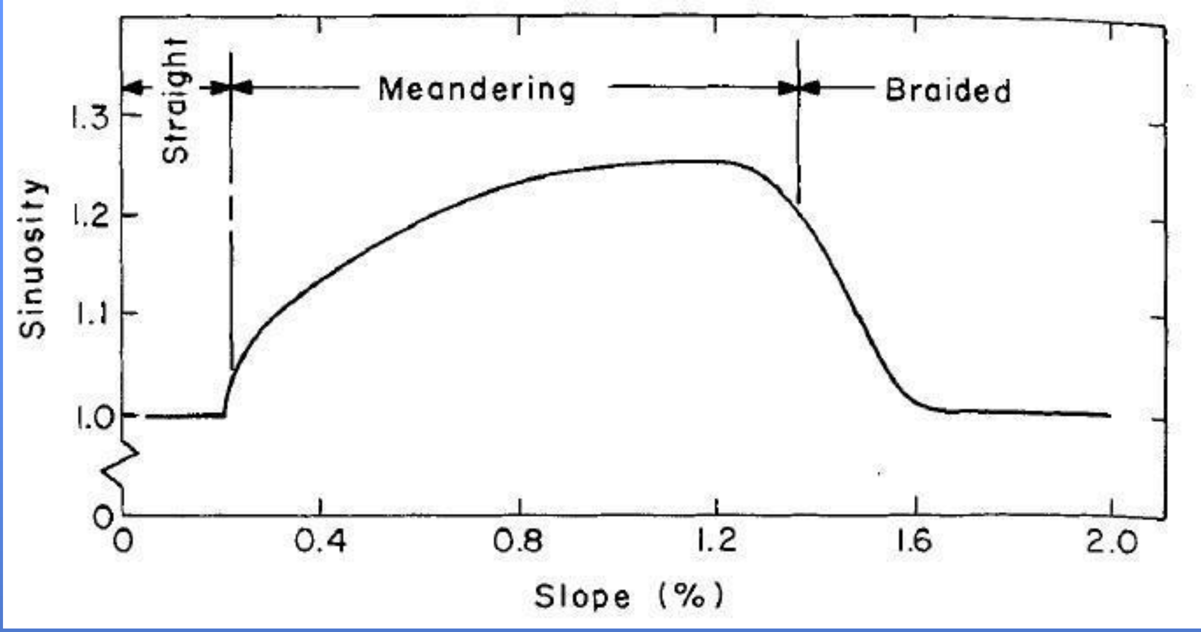


Spatial distribution of sinuosity and runoff.

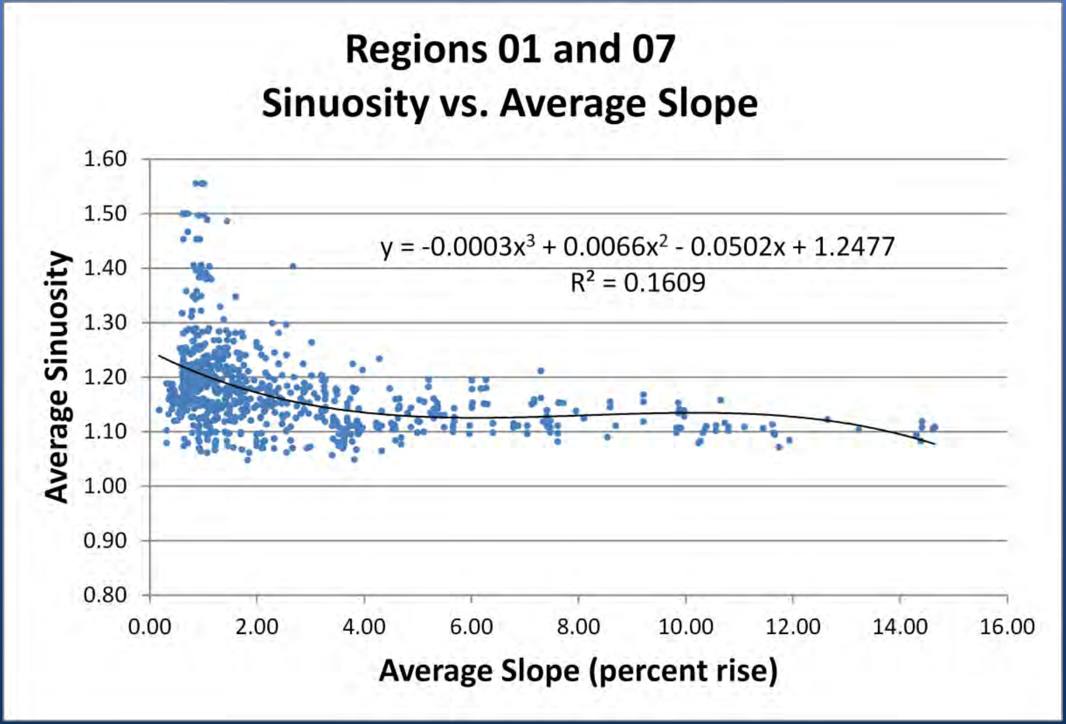
Although relations are weak, it appears the sinuosity and error variance metrics are influenced by geomorphic conditions, particularly runoff and soil permeability.
It is important for modeling that these relations are retained in generalized stream features.

How and why is stream sinuosity related to geomorphic conditions?

(right) Schumm (1973) suggests channel stability, shape, and sinuosity are influenced by sediment load, and critical thresholds in sediment load and slope alter a channel's pattern, which cause variations in channel sinuosity over the course of the river channel.



(above) Two critical thresholds of valley slope control where channel patterns change from straight to sinuous and from sinuous to a braided pattern (Schumm 1973).



(left) Region 1 and 7 sinuosity values show a very weak relation with slope. Additional data needed.

How and why is stream sinuosity related to geomorphic conditions?

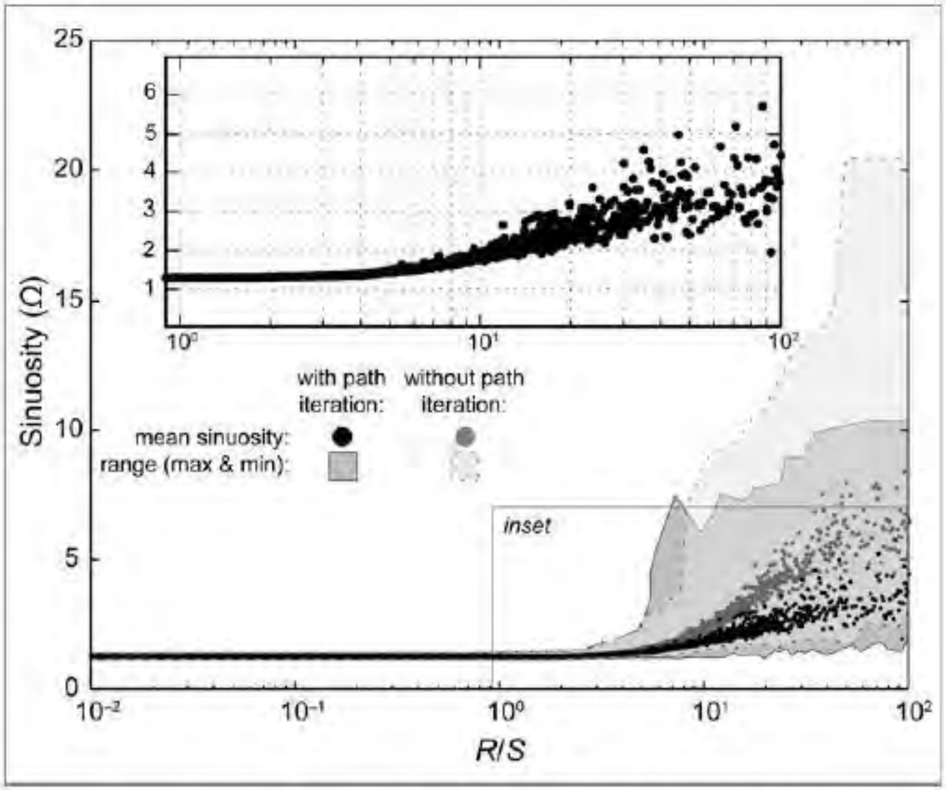
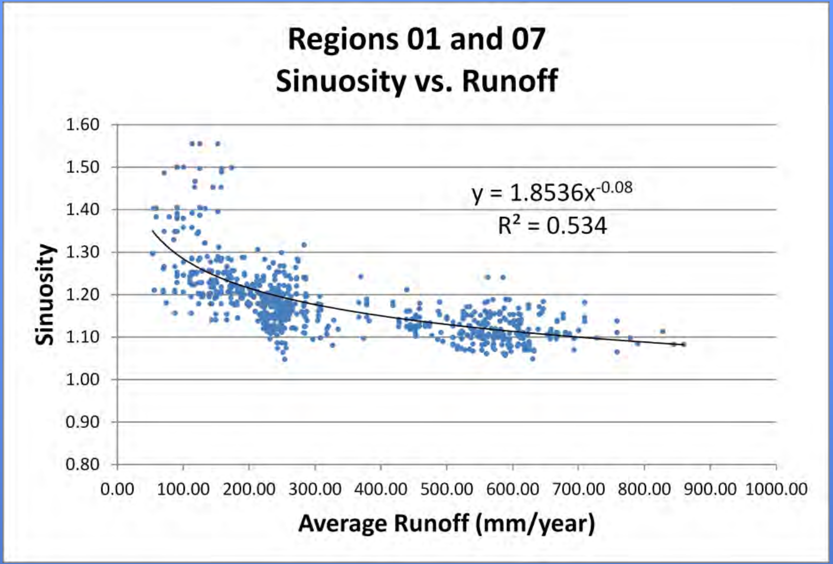


Fig. 2. Semilog plot showing ensemble results of modeled sinuosity (Ω) versus relative resistance (*R/S*). Shaded regions illustrate the range (maxima to minima) of sinuosities produced by the model with (dark region) and without (light region) the iteration rule to shorten supersinuous paths. Black dots and gray dots show the mean sinuosities for both cases, respectively. *Inset* shows in greater detail mean sinuosities generated with the iteration rule. Additional statistical properties of the model are provided in Fig. S3.



(left) Working with a mathematical flow model, Lazarus and Constantine (2013) suggest sinuosity is directly related to flow resistance relative to mean landscape slope.

By considering relative flow resistance inversely related to surface runoff, this theory may explain the inverse relation between sinuosity and runoff in Regions 1 and 7.

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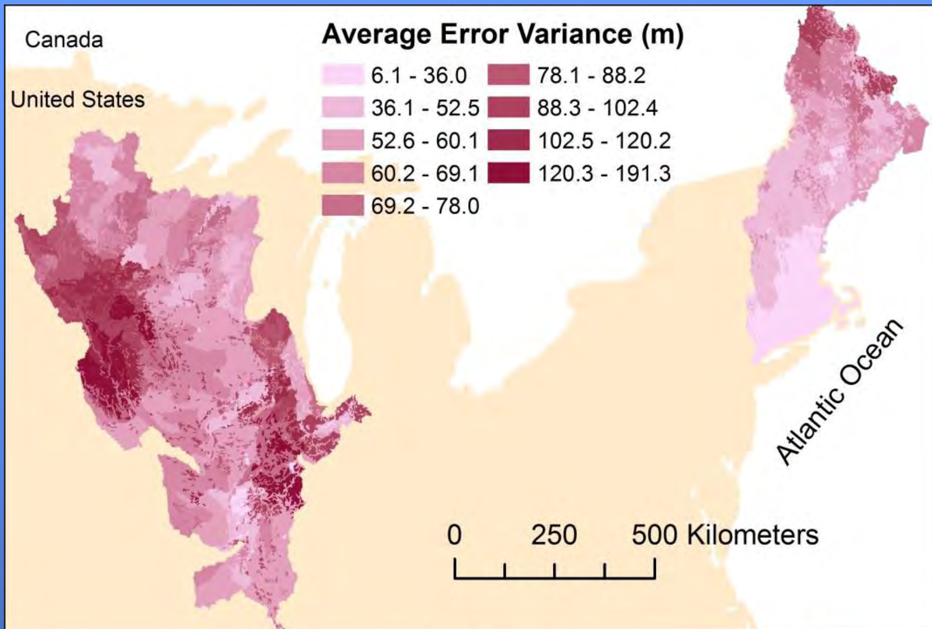
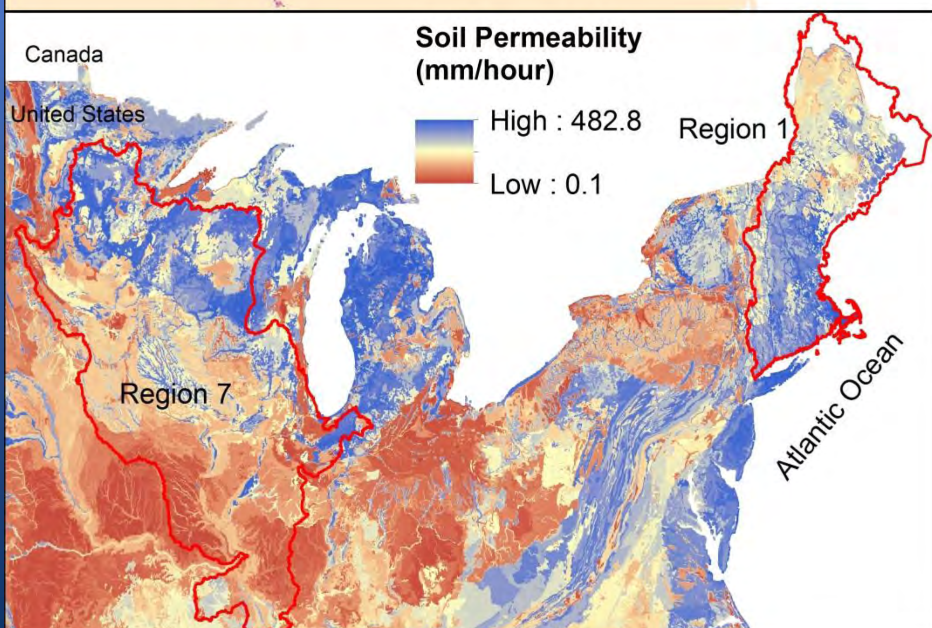
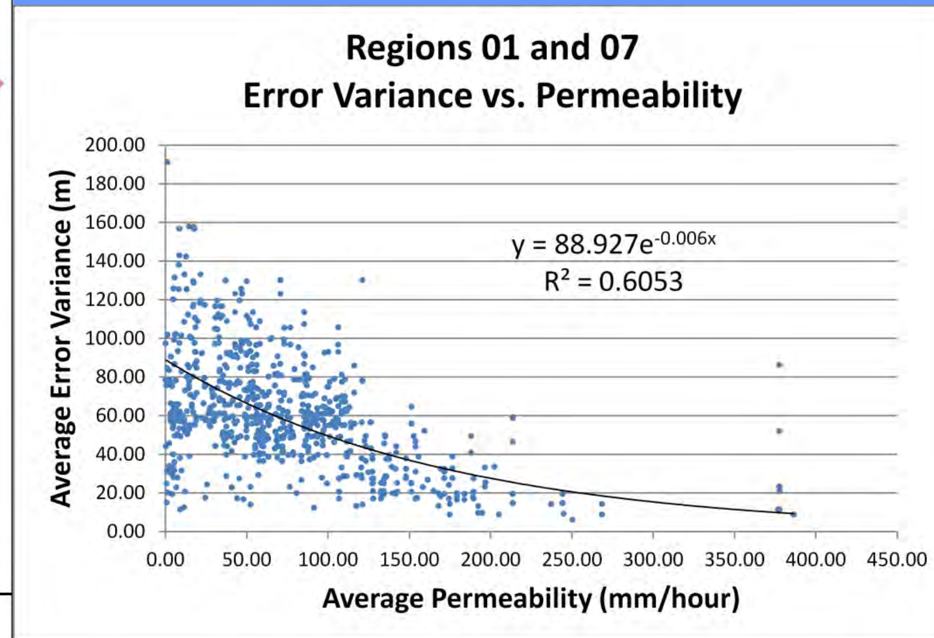
Spatial distribution of error variance and permeability

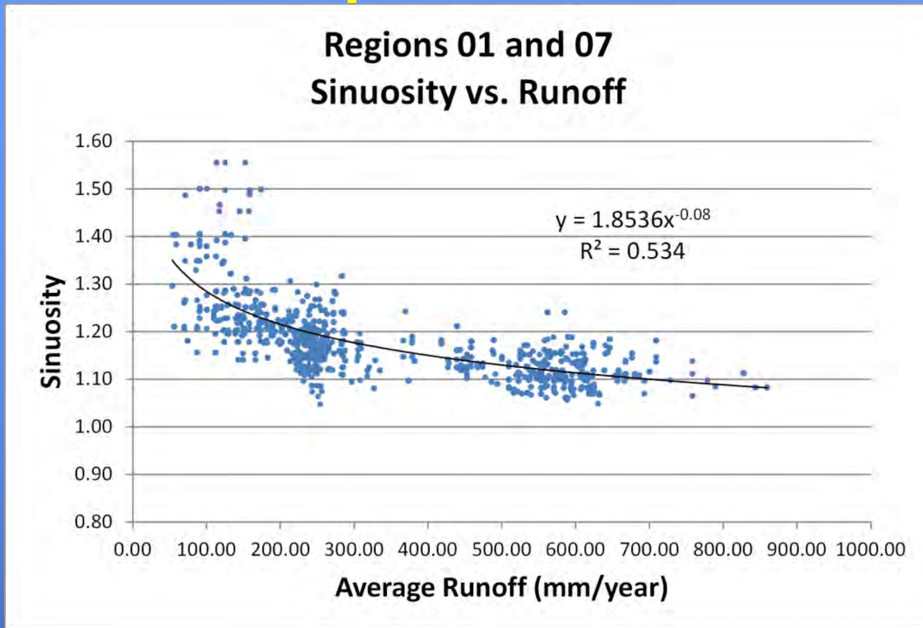


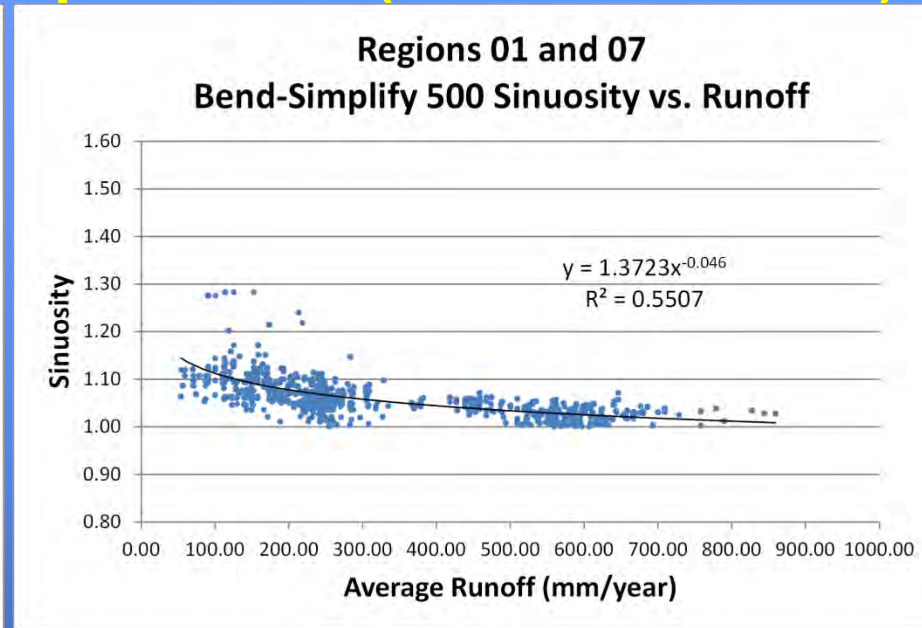


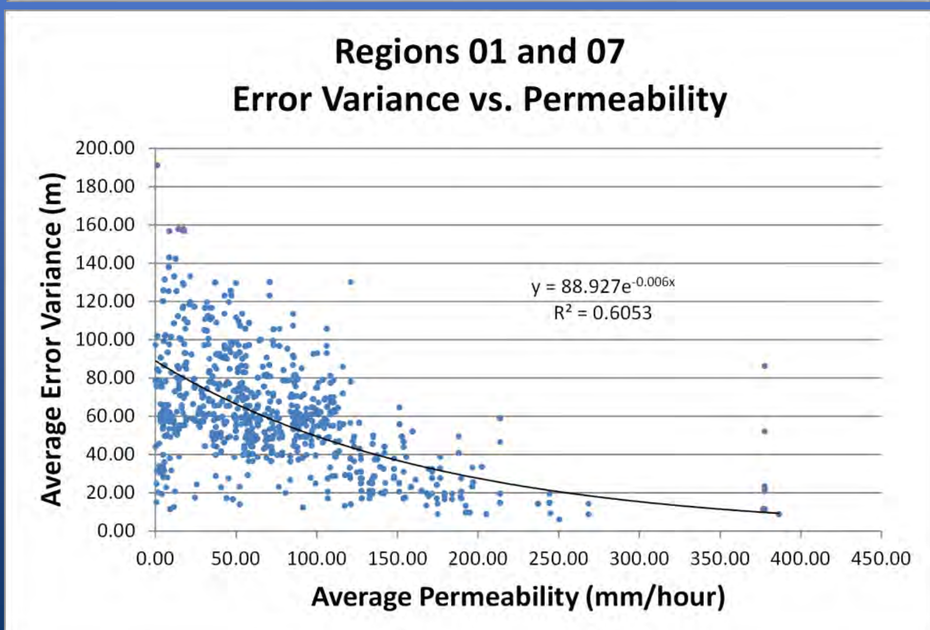


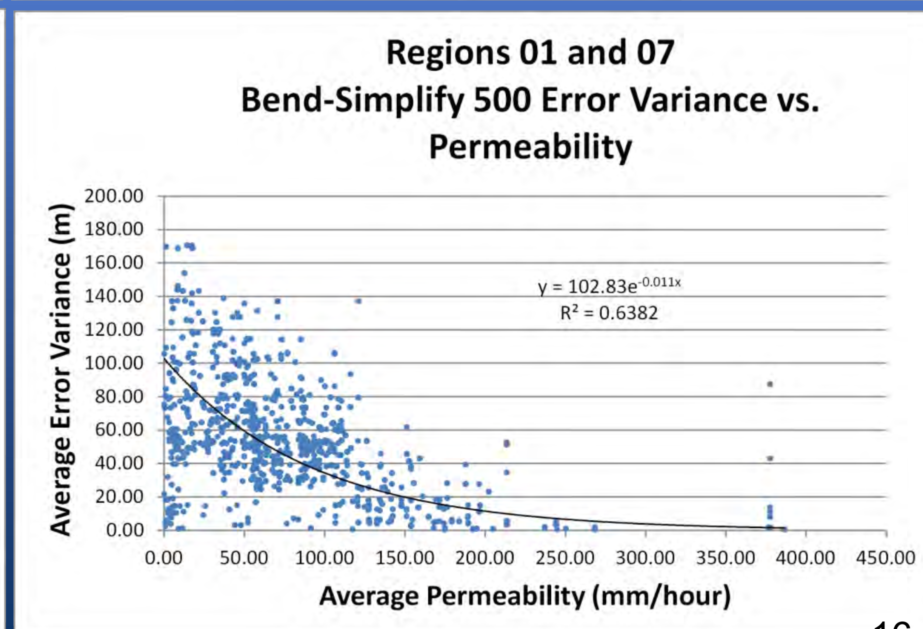
Regions 1 and 7 contain only about 1/4th of the range of permeability values in the conterminous United States.

Examples of effects of simplification (500 m tolerance)

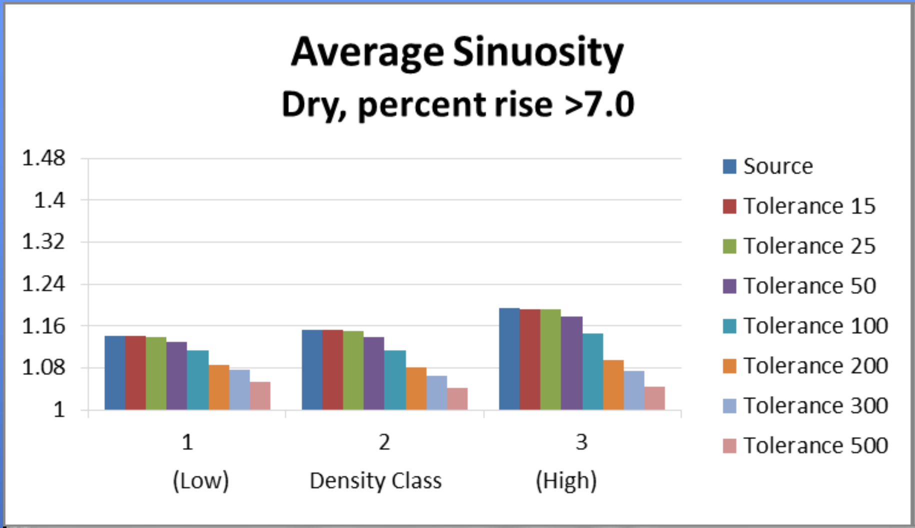


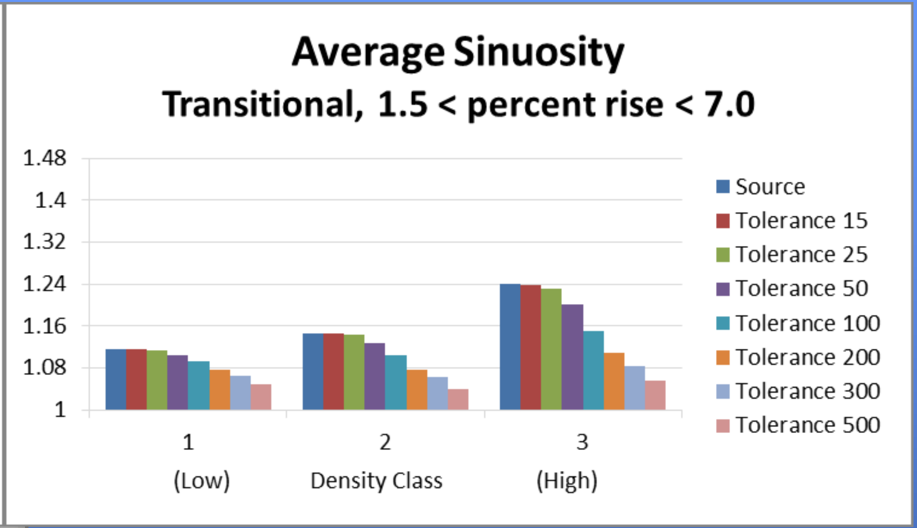


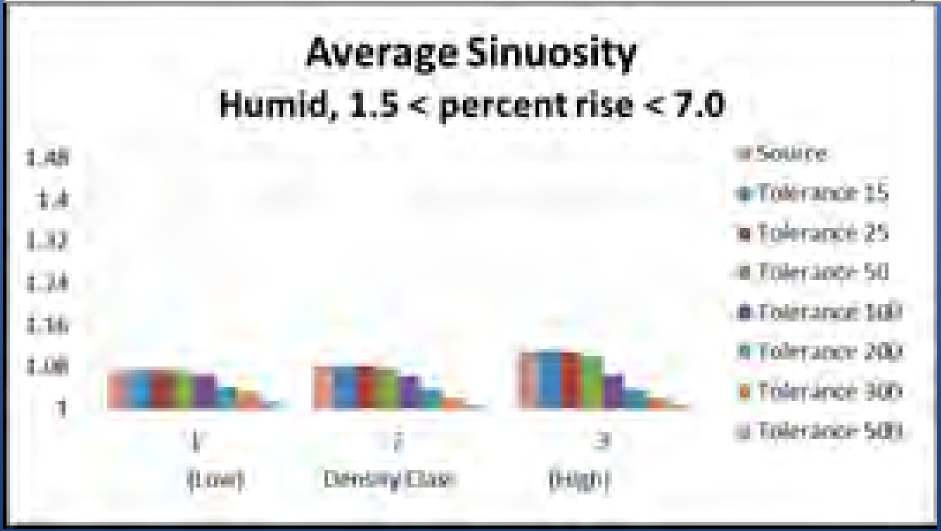




Example of local change in sinuosity from subbasins in different conditions







Simplification reduces sinuosity, and a greater impact appears for features in higher density partitions.

Summary

- Preliminary examination of relations between geometric characteristics of stream features in the high-resolution NHD and landscape stream geomorphic conditions.
- Evaluated features in regions 1 and 7 (northeast and north central plains of the United States).
- Results suggest inverse relations exists between stream feature sinuosity and landscape runoff, and between stream feature error variance and runoff. Additional analysis is needed to validate and extend these relations for the full range of conditions in the United States.
- Goal: classify cartographic stream features by geomorphology and identify appropriate simplification relations for each class.

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Thank you!