Clustering Fine-Scale River Network Topologies for Use in Earth System Models

Laura Torres-Rojas, Noemi Vergopolan,
Daniel Guyumus, Nathaniel Chaney

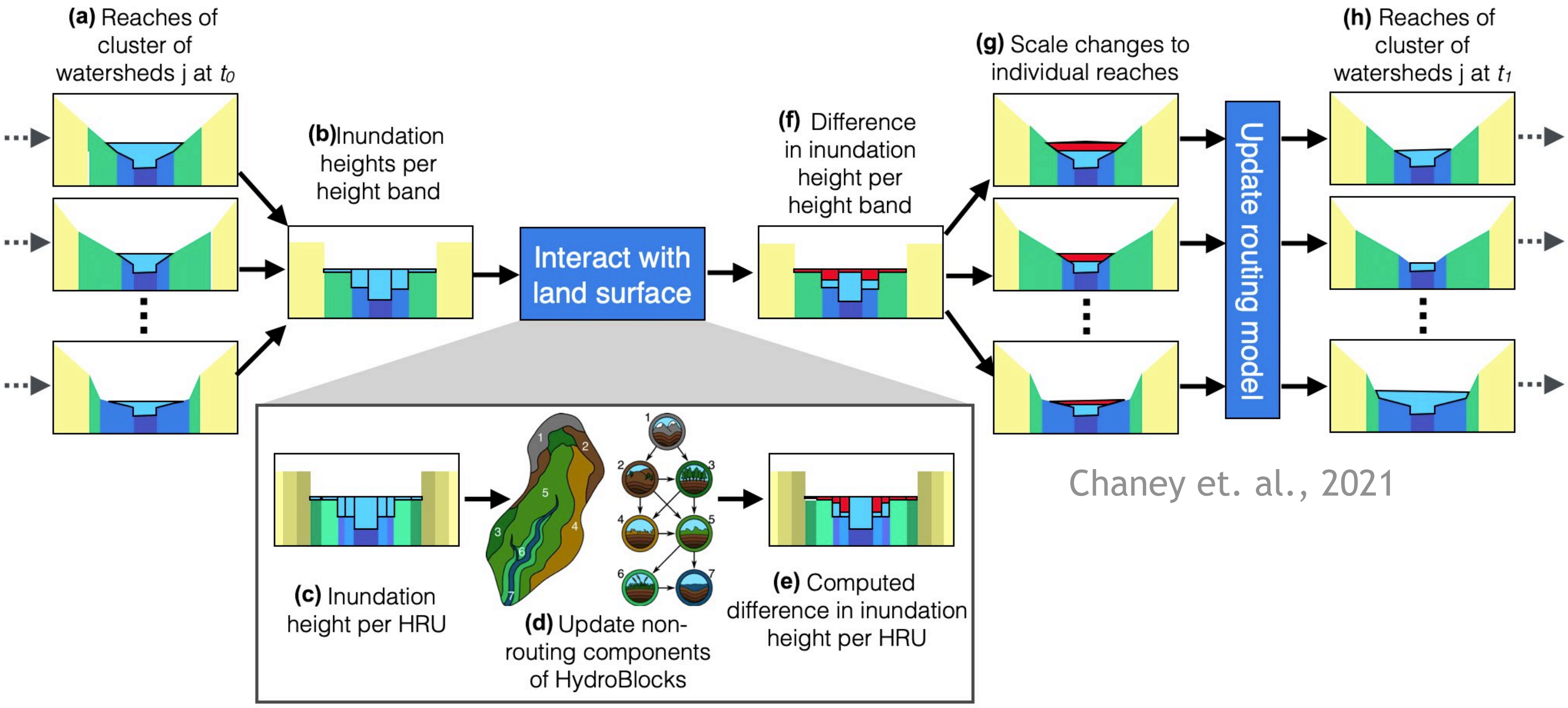
Duke University

Princeton University

Motivation

- Fully distributed vs. Semi-distributed modeling approaches.

- **HydroBlocks** Land Surface Model
- **Limitation routing:** Manageable for ~5,000 channels.

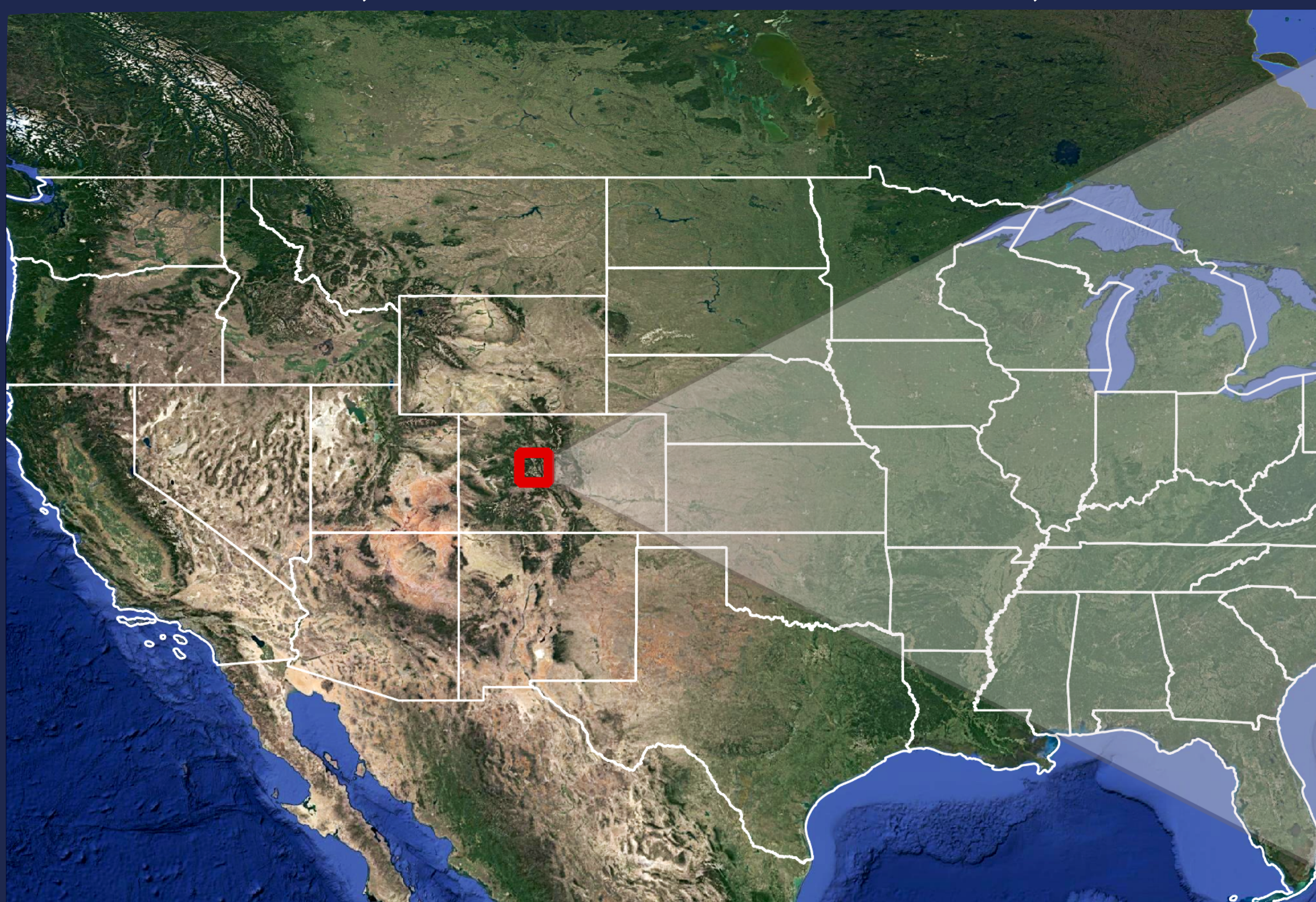


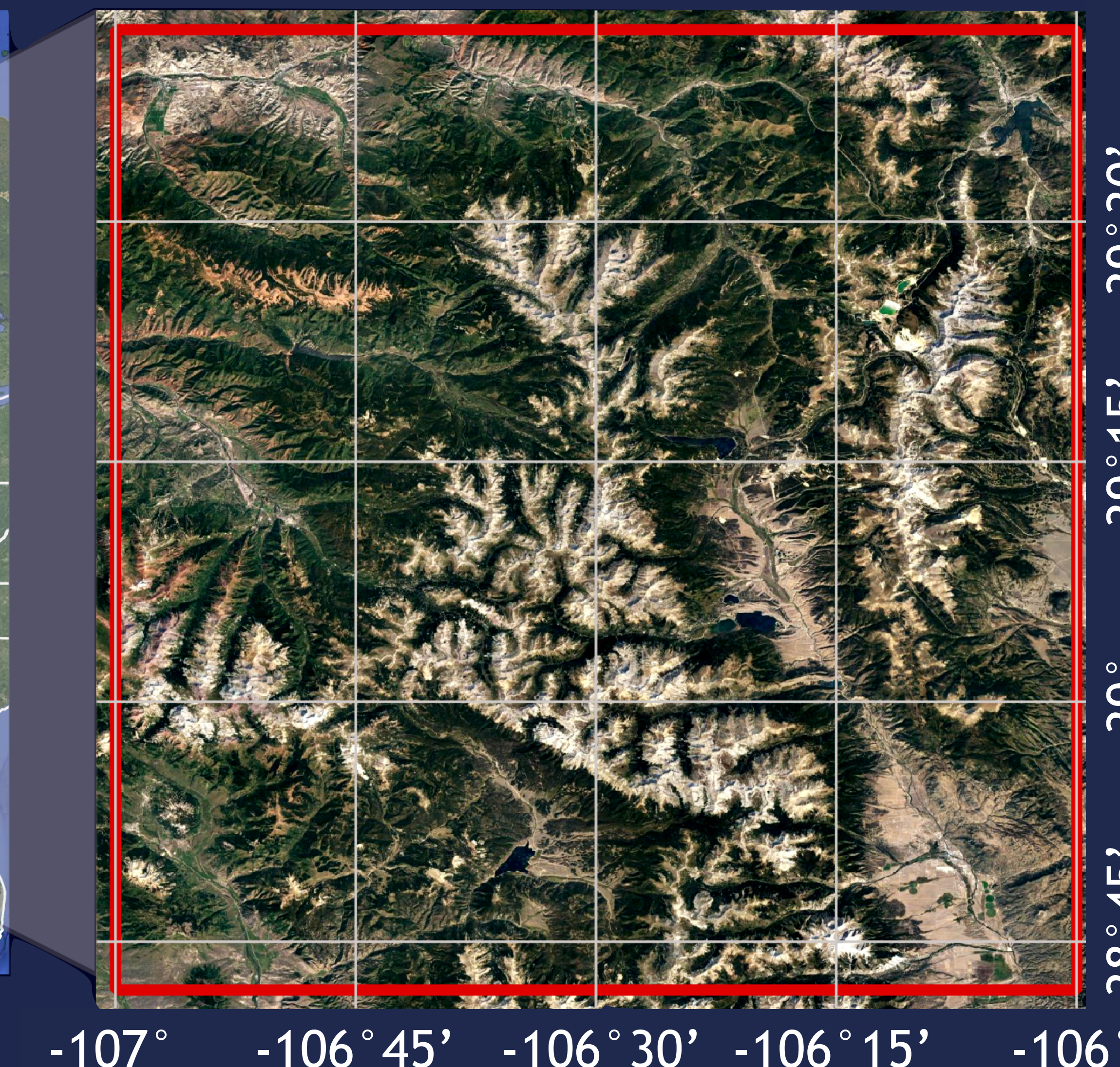
Chaney et. al., 2021

Goal: Simplified structure of river network: Scalability over continental scales.

Study area

1x1 domain, centered in Mt. Elbert, CO





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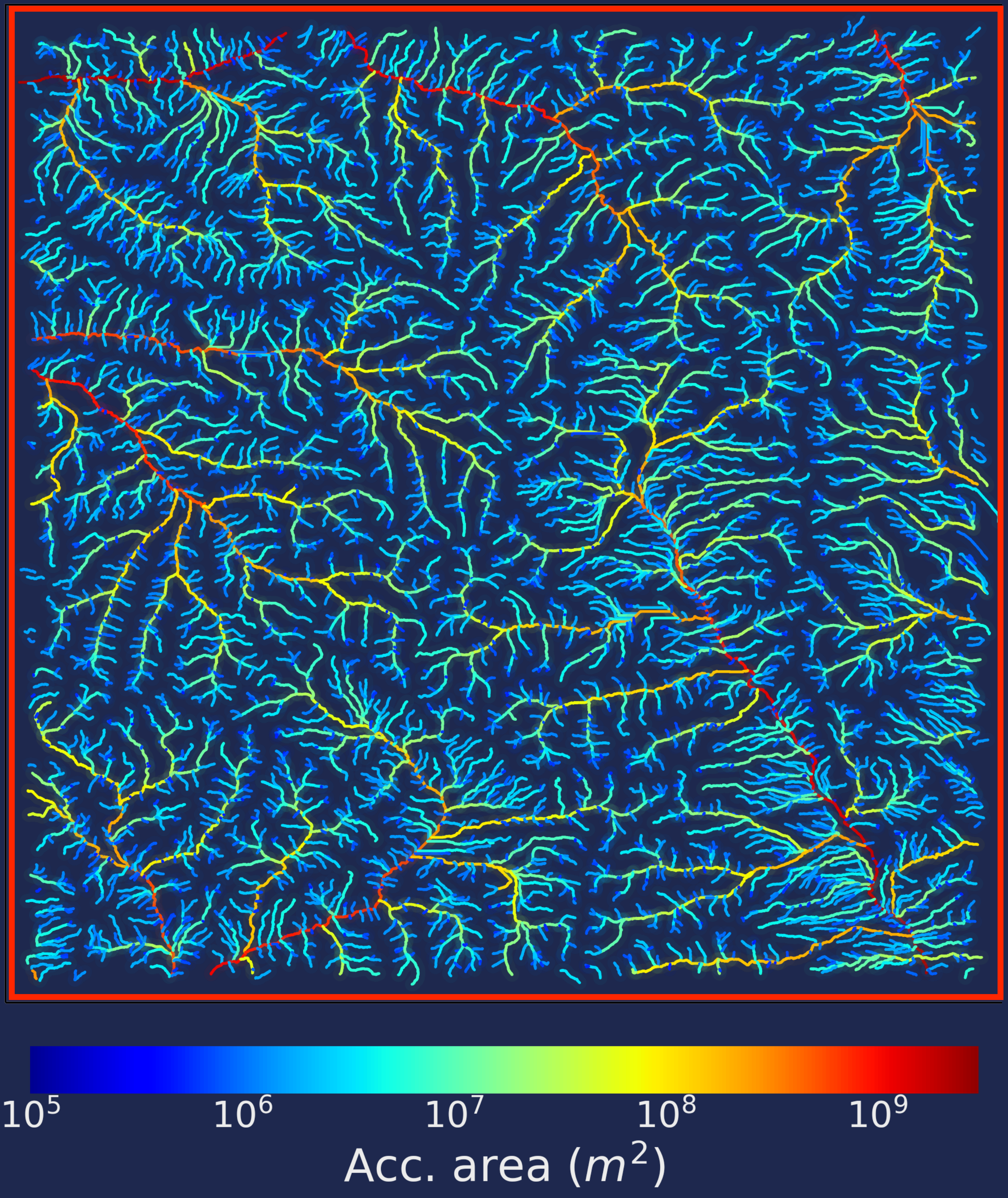

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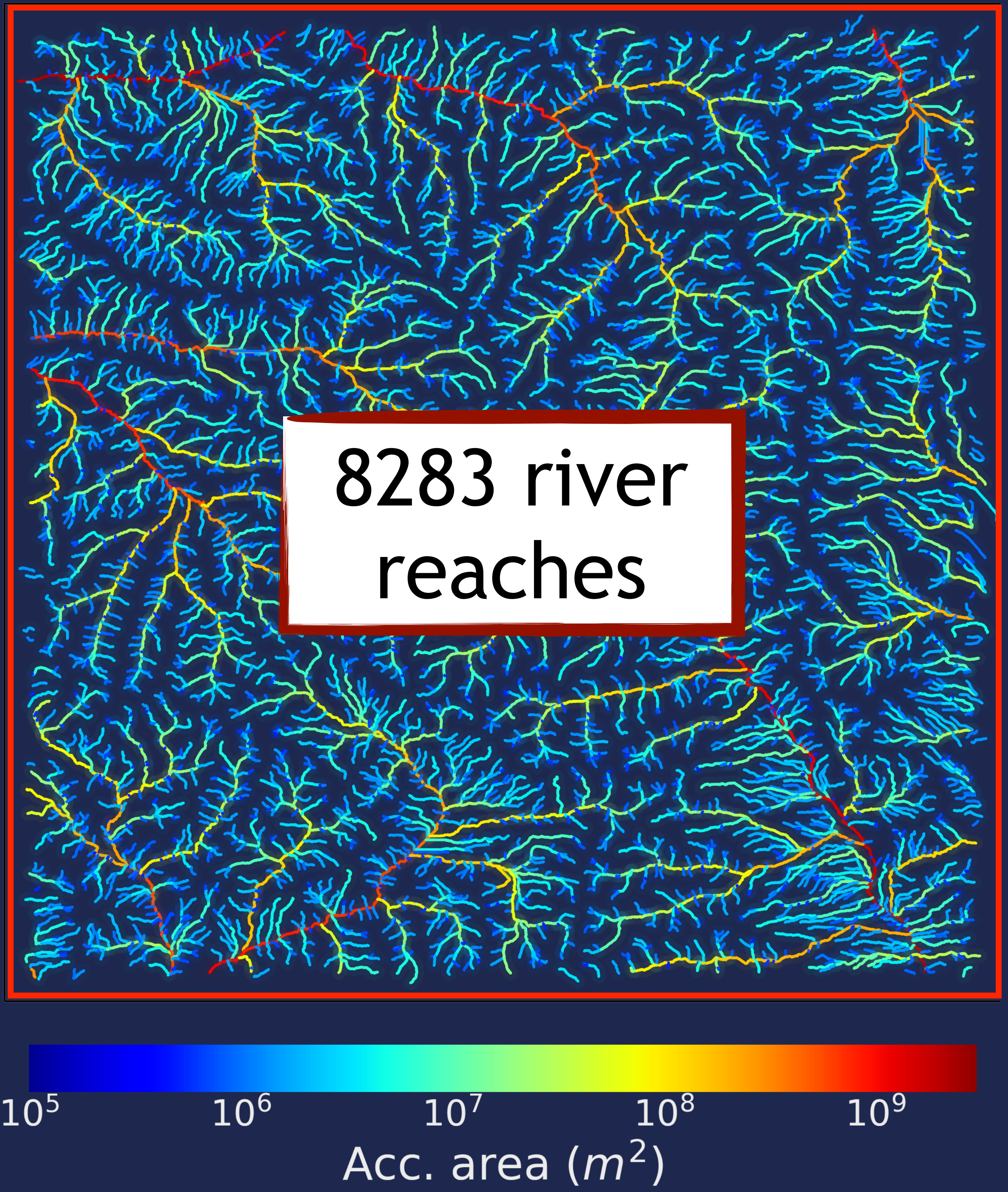

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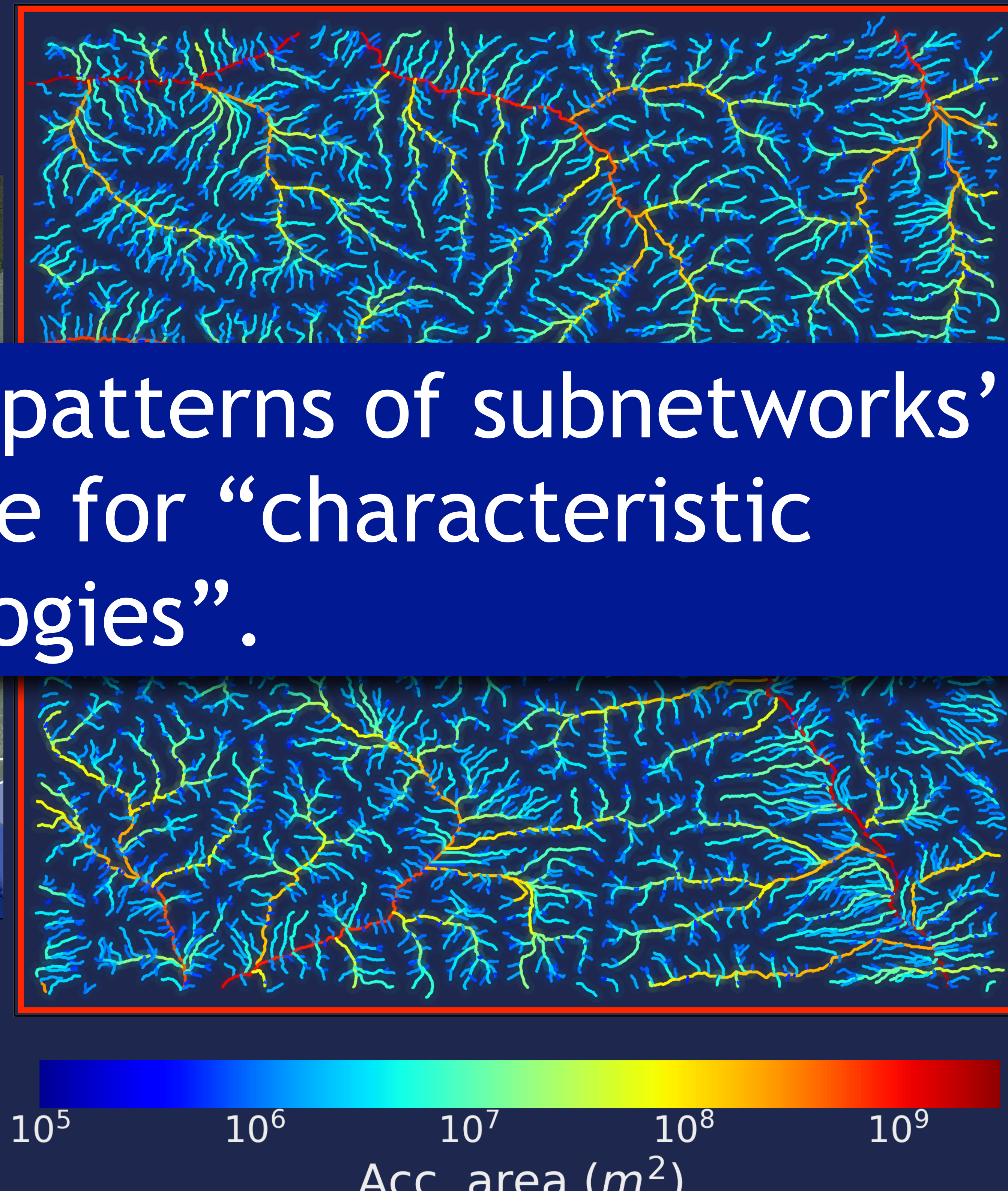
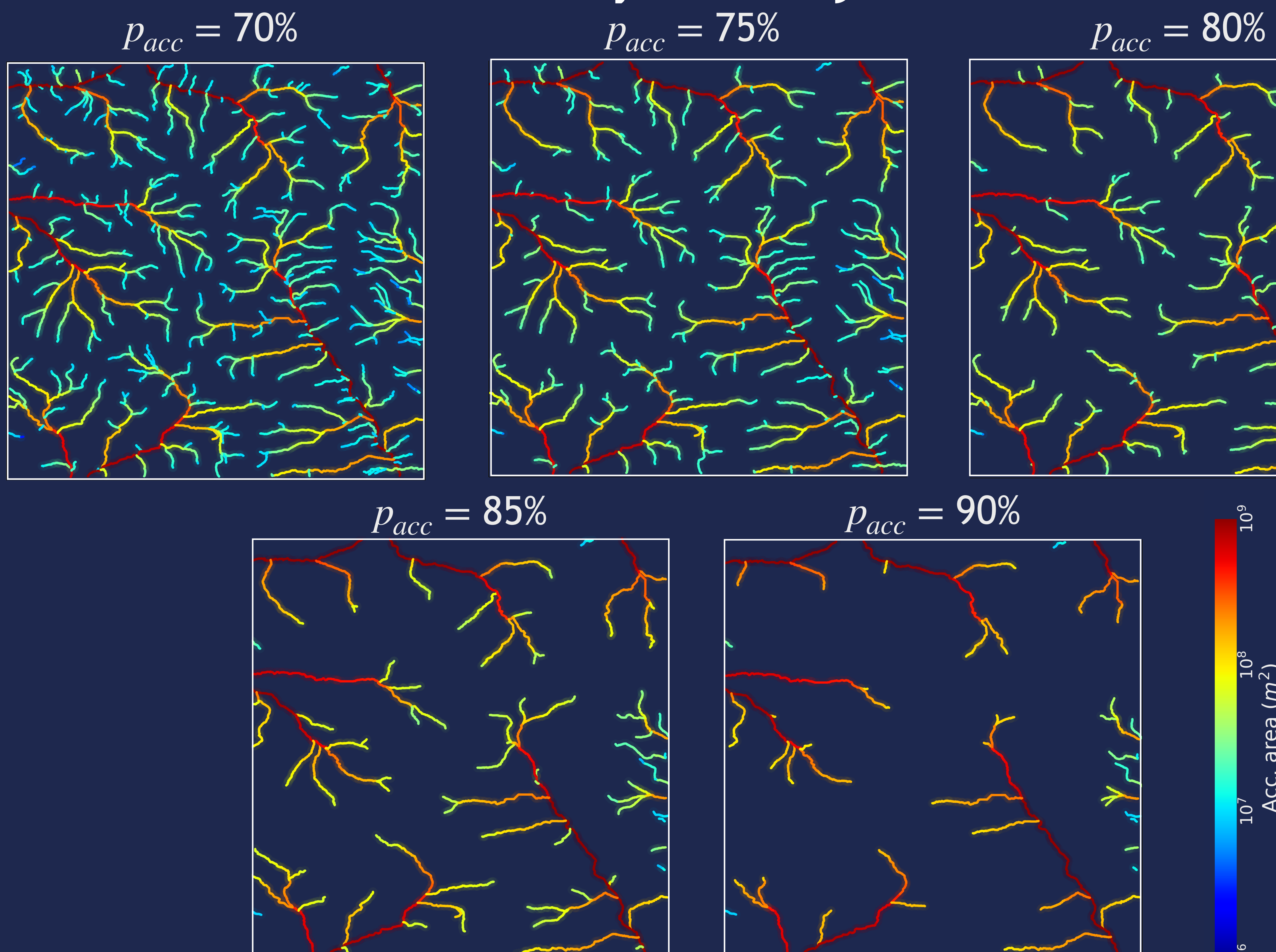


Idea: Cluster repeating patterns of subnetworks' topologies and solve for "characteristic topologies".

Stage 1: Select reaches to solve explicitly



Stage 2: Clustering topologies

2.1. 35 descriptors of subnetwork topologies

Number of reaches ($n_{reaches}$)	Average bankfull width (μ_{BF})	Average sub-basin elevation (μ_{DEM})	Nullity, unweighted (N_{uw})	Spectral gap, w=slope ($G_{w=S}$)
Total length (ΣL)	Average drainage density (μ_{D_d})	Average sub-basin topological index (μ_{TI})	Nullity, w=1/length ($N_{w=\frac{1}{L}}$)	Wiener number, unweighted (W_{uw})
Total acc. area (ΣAcc)	Max. Drainage density (Max_{D_d})	Average sub-basin aspect (μ_{Asp})	Nullity, w=width ($N_{w=W}$)	Wiener number, w=1/ length ($W_{w=\frac{1}{L}}$)
Average length (μ_L)	Average Shreve order (μ_{ShrOrd})	Average shortest path length, w=width ($\mu_{SPL_{w=W}}$)	Nullity, w=slope ($N_{w=S}$)	Wiener number, w=width ($W_{w=W}$)
Average acc. area (μ_{Acc})	Max. Shreve order (Max_{ShrOrd})	Average shortest path length, w=slope ($\mu_{SPL_{w=S}}$)	Spectral gap, unweighted (G_{uw})	Wiener number, w=slope ($W_{w=S}$)
Average width (μ_W)	Average sinuosity (μ_s)	Average in-degree, w=width ($\mu_{D_{w=W}}$)	Spectral gap, w=1/ length ($G_{w=\frac{1}{L}}$)	Global efficiency ($G.eff$)
Average reach slope (μ_S)	Max. Sinuosity (Max_s)	Average in-degree, w=slope ($\mu_{D_{w=S}}$)	Spectral gap, w=width ($G_{w=W}$)	Global reaching centrality (GRC)

Channel features	Sub-basin aggregated properties	Spectral properties	Classical river network morphology	Graph-theory

Stage 2: Clustering topologies

2.1. 35 descriptors of subnetwork topologies

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Reduce dimensionality before performing clustering

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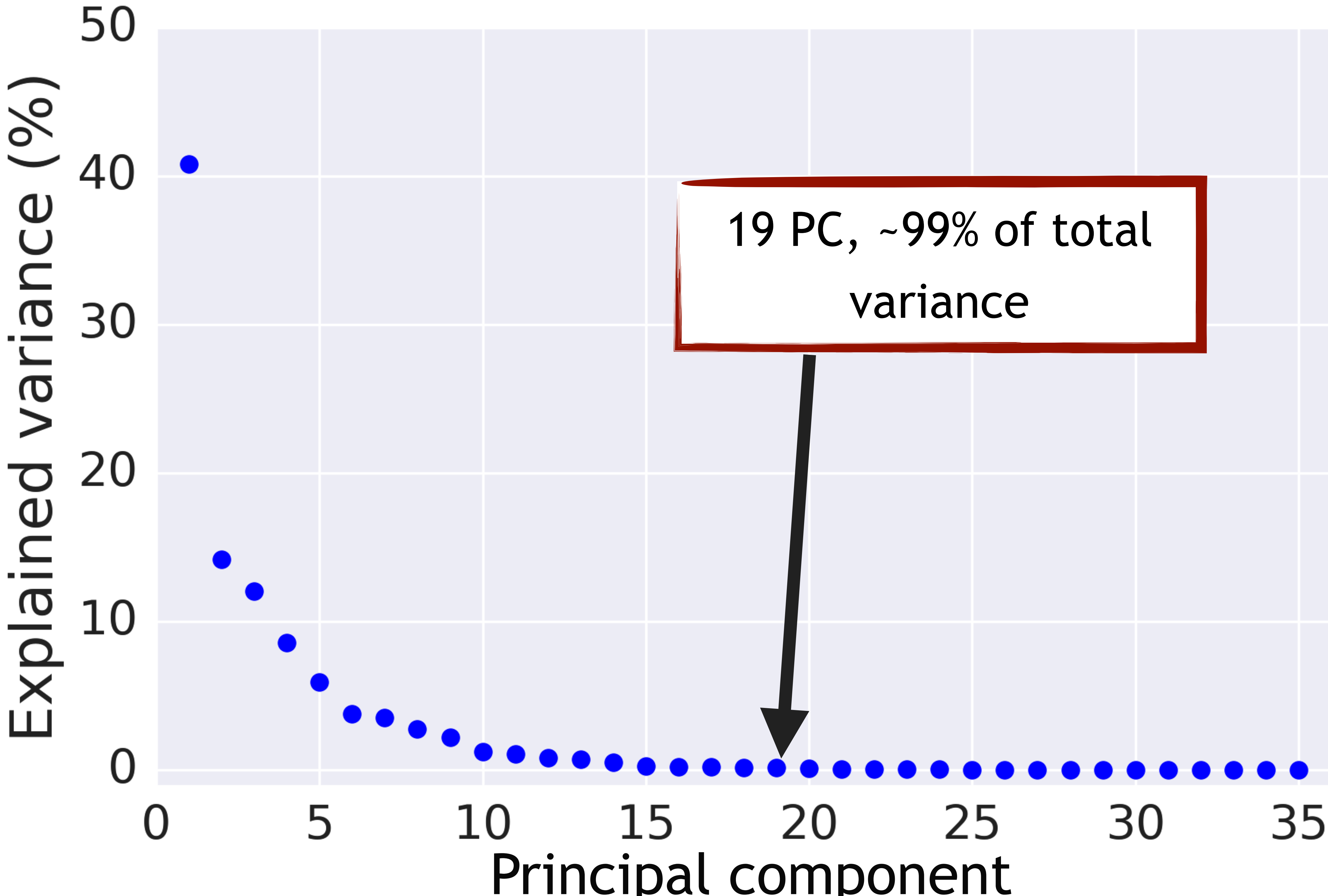
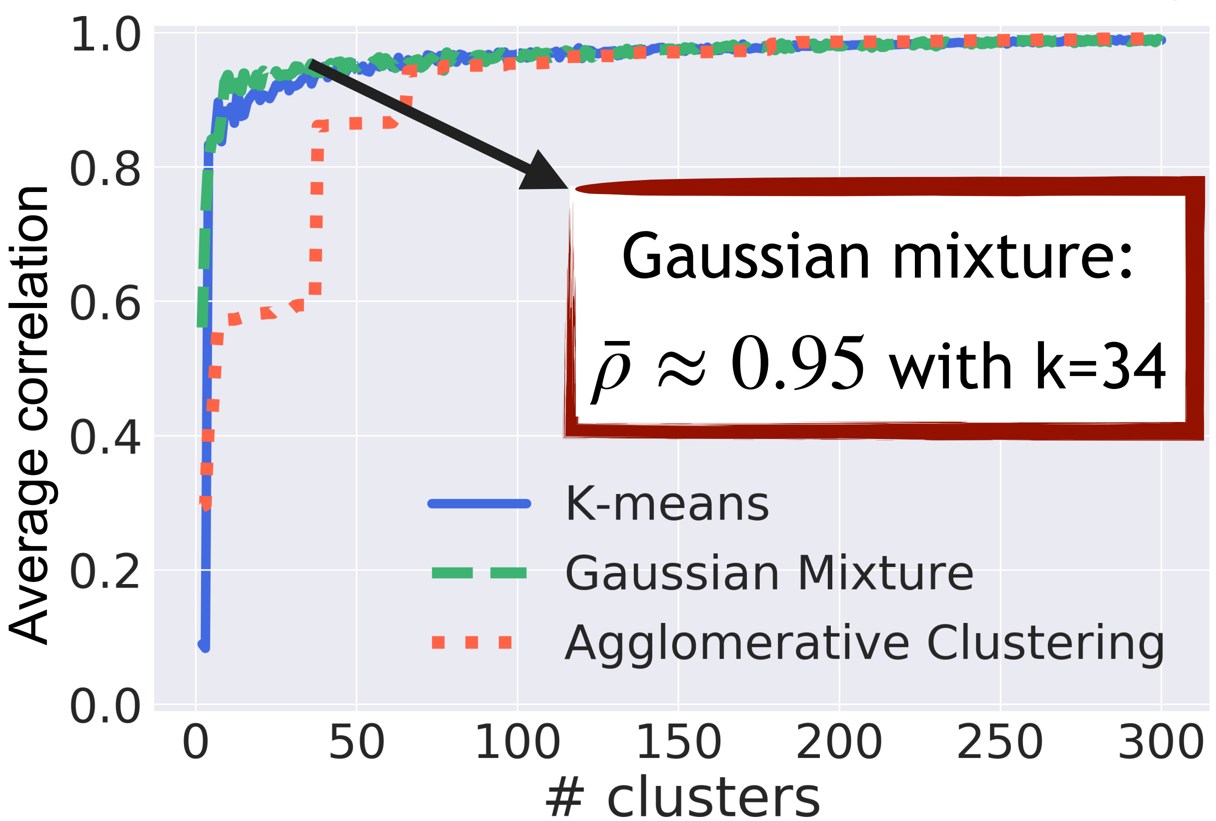
Stage 2: Clustering topologies

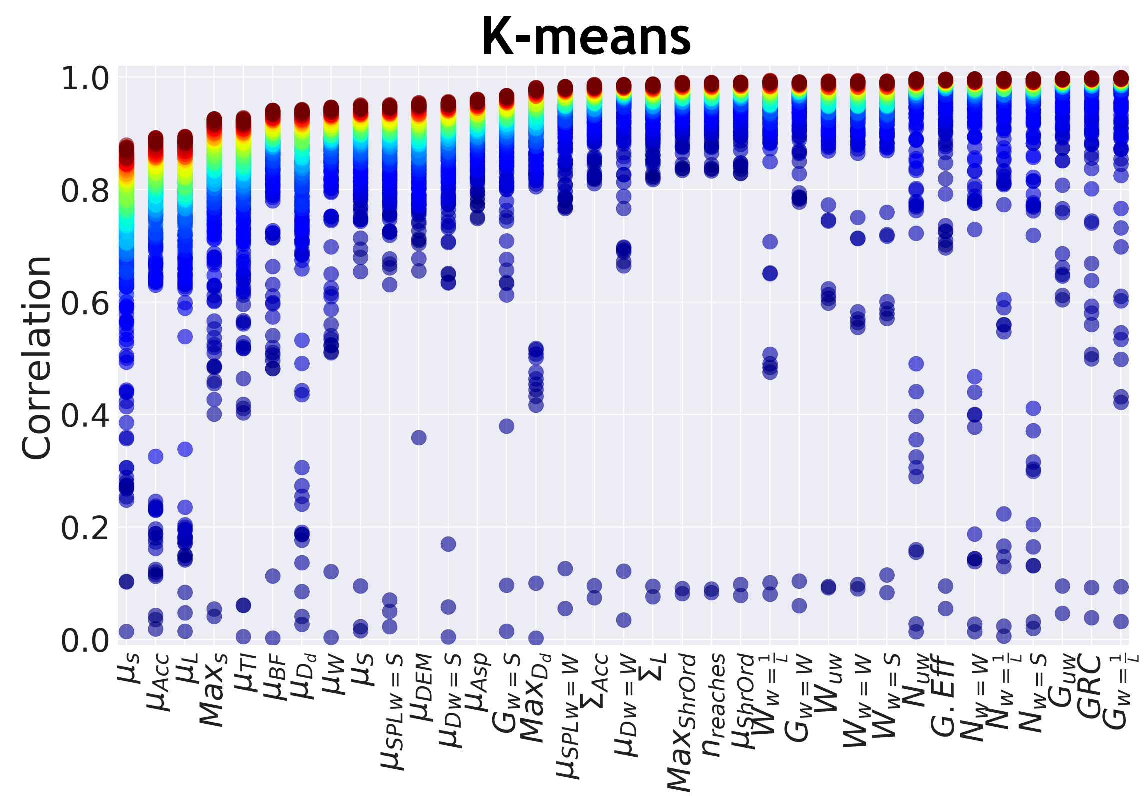
2.2. PCA for 85% threshold (~1,200 subnetworks)

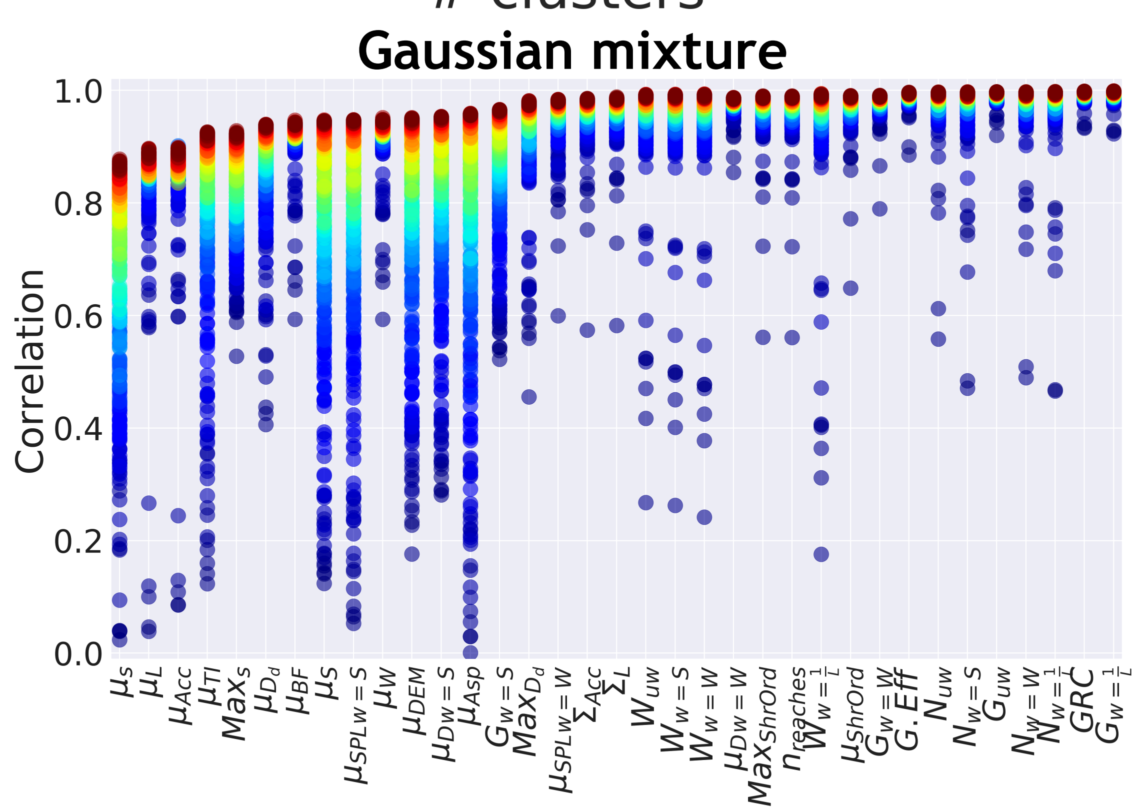


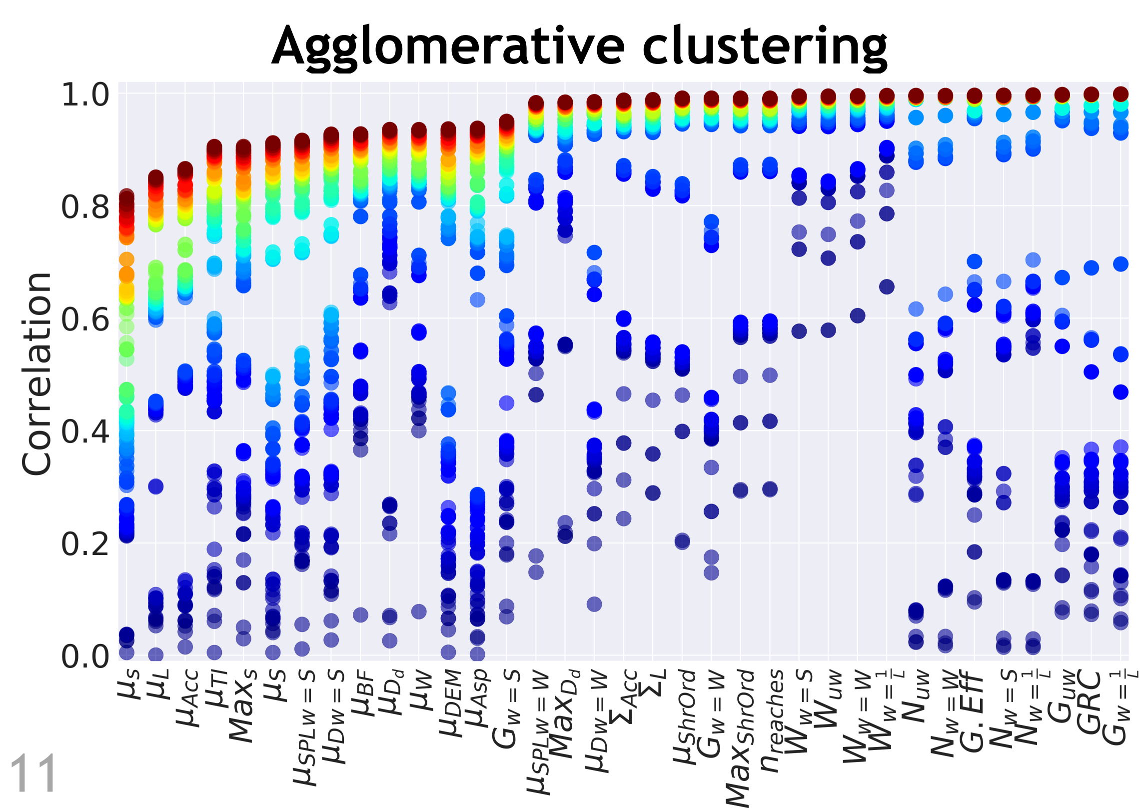
Stage 2: Clustering topologies

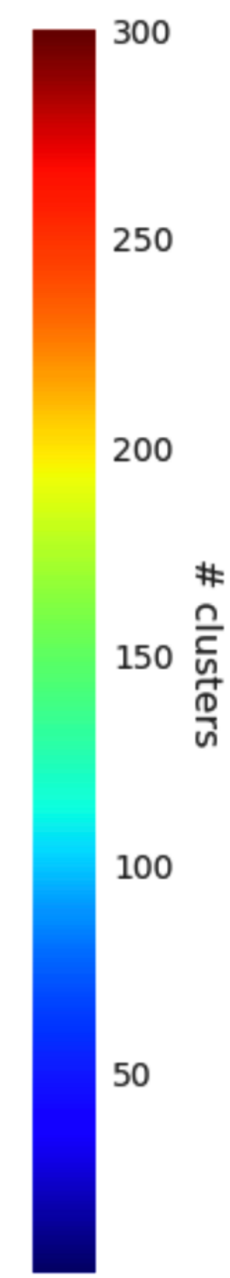
2.3. Selection: clustering algorithm and number of clusters





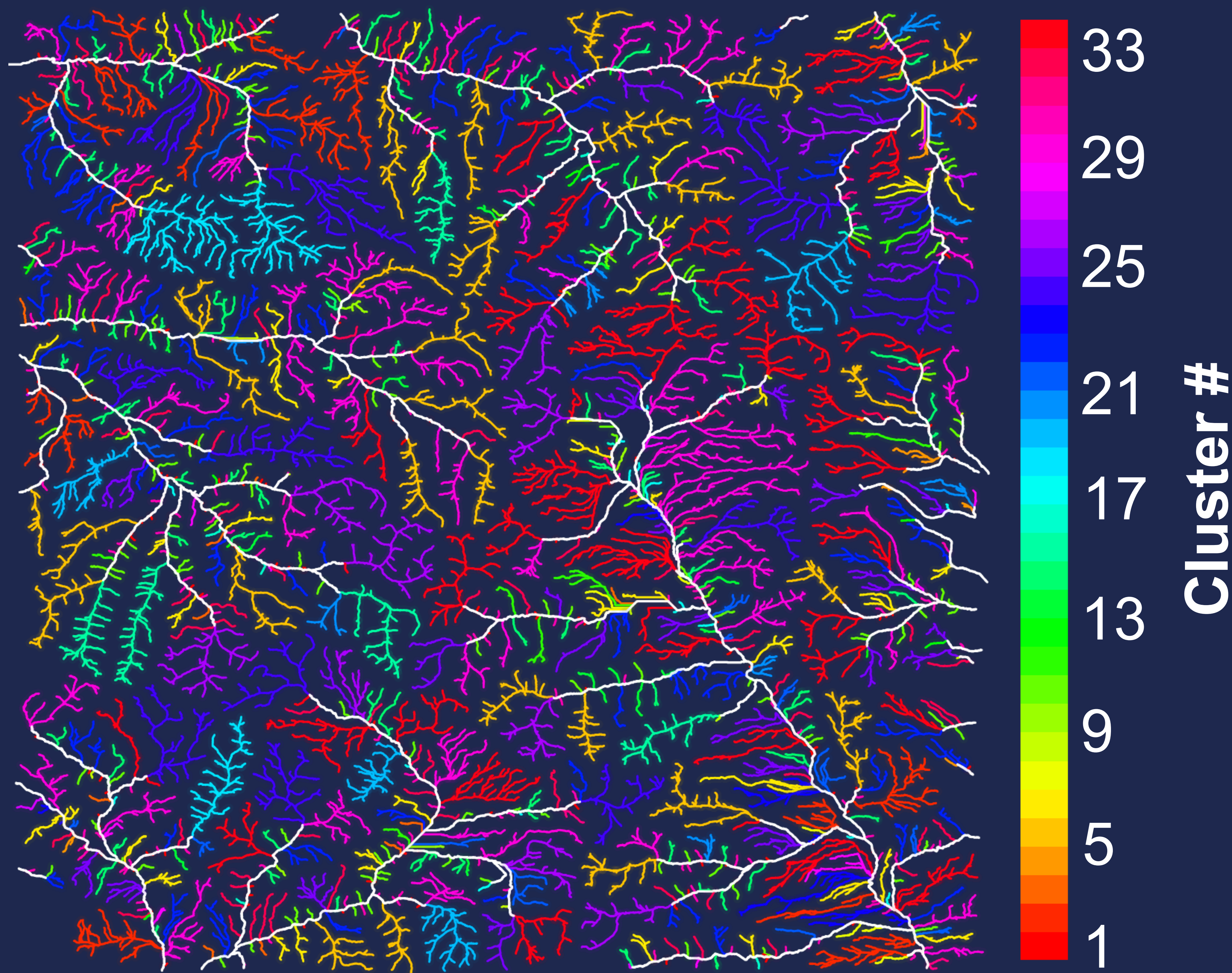






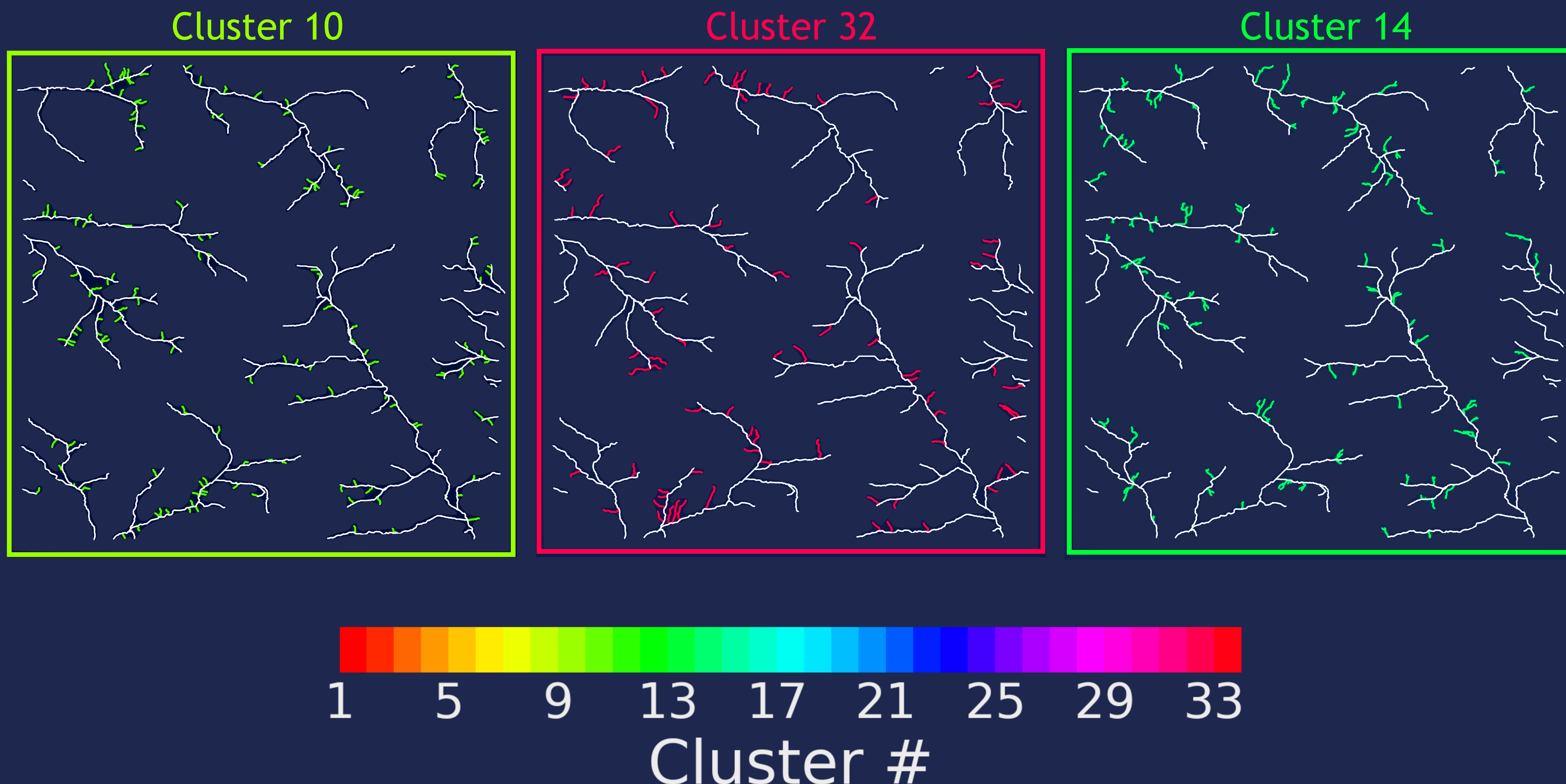
Stage 2: Clustering topologies

2.4. Clustering



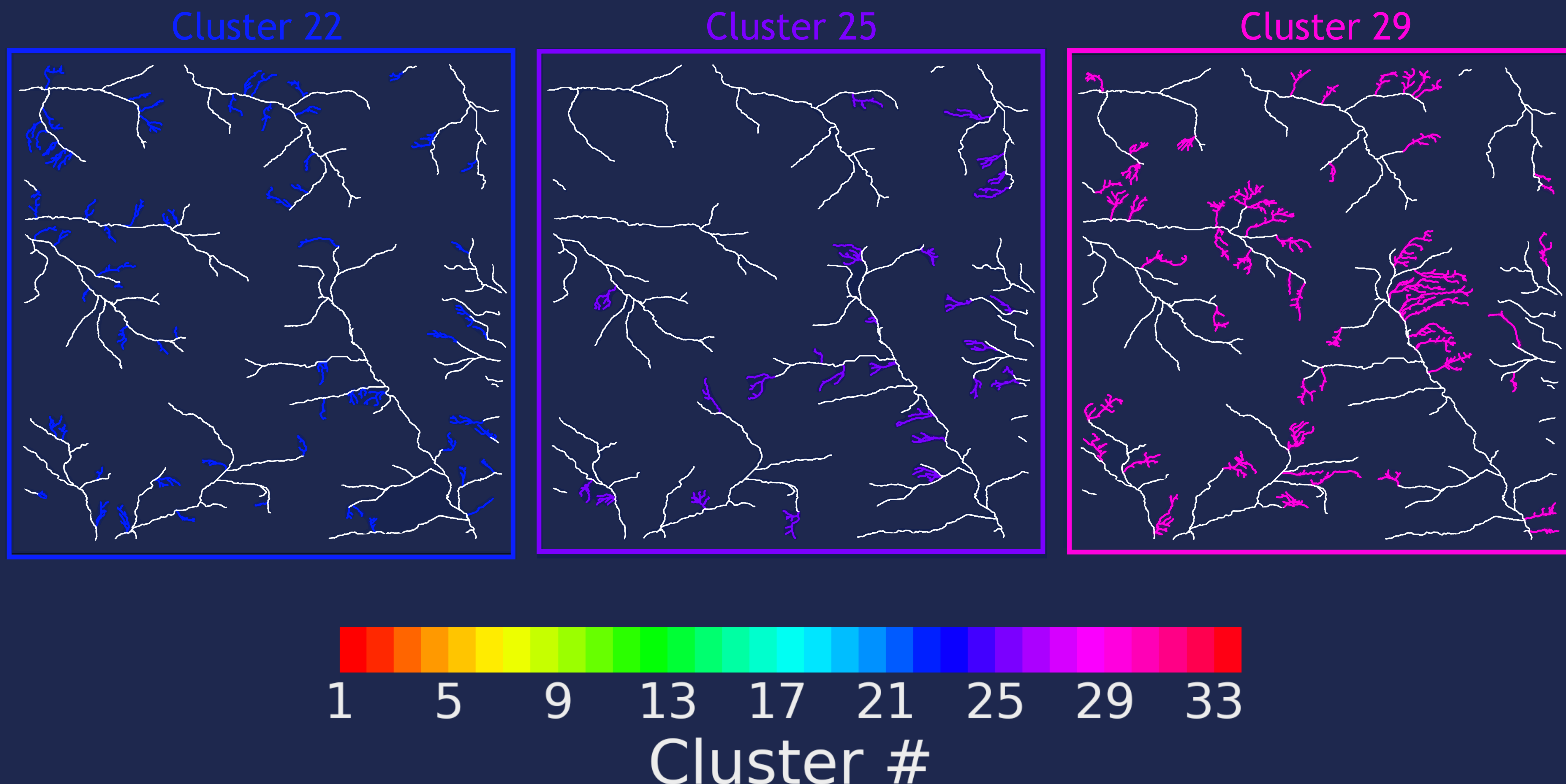
Stage 2: Clustering topologies

2.4. Clustering: First-order streams and simple topologies



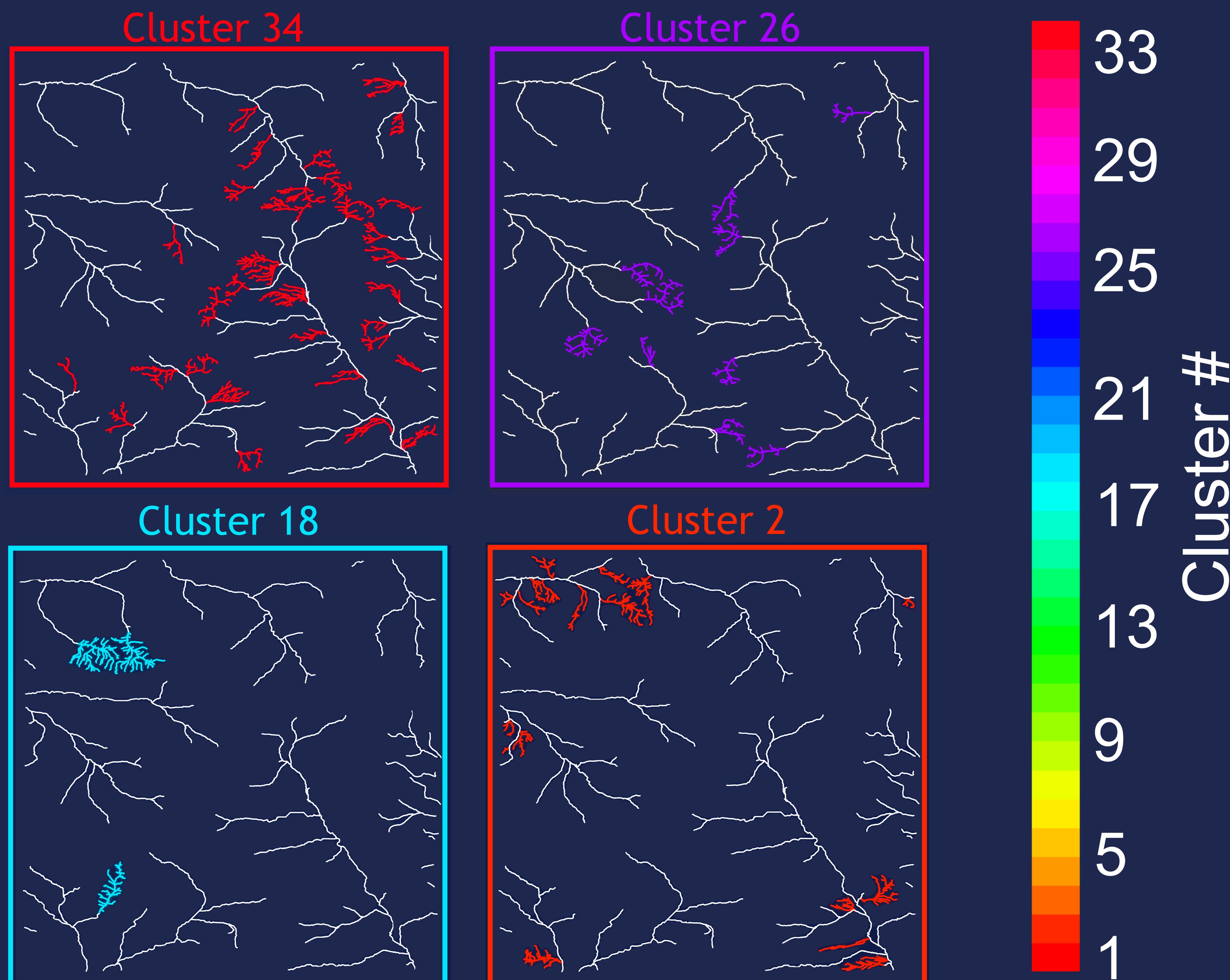
Stage 2: Clustering topologies

2.4. Clustering: Intermediate complexity structures



Stage 2: Clustering topologies

2.4. Clustering: Highly complex structures



Stage 2: Clustering topologies

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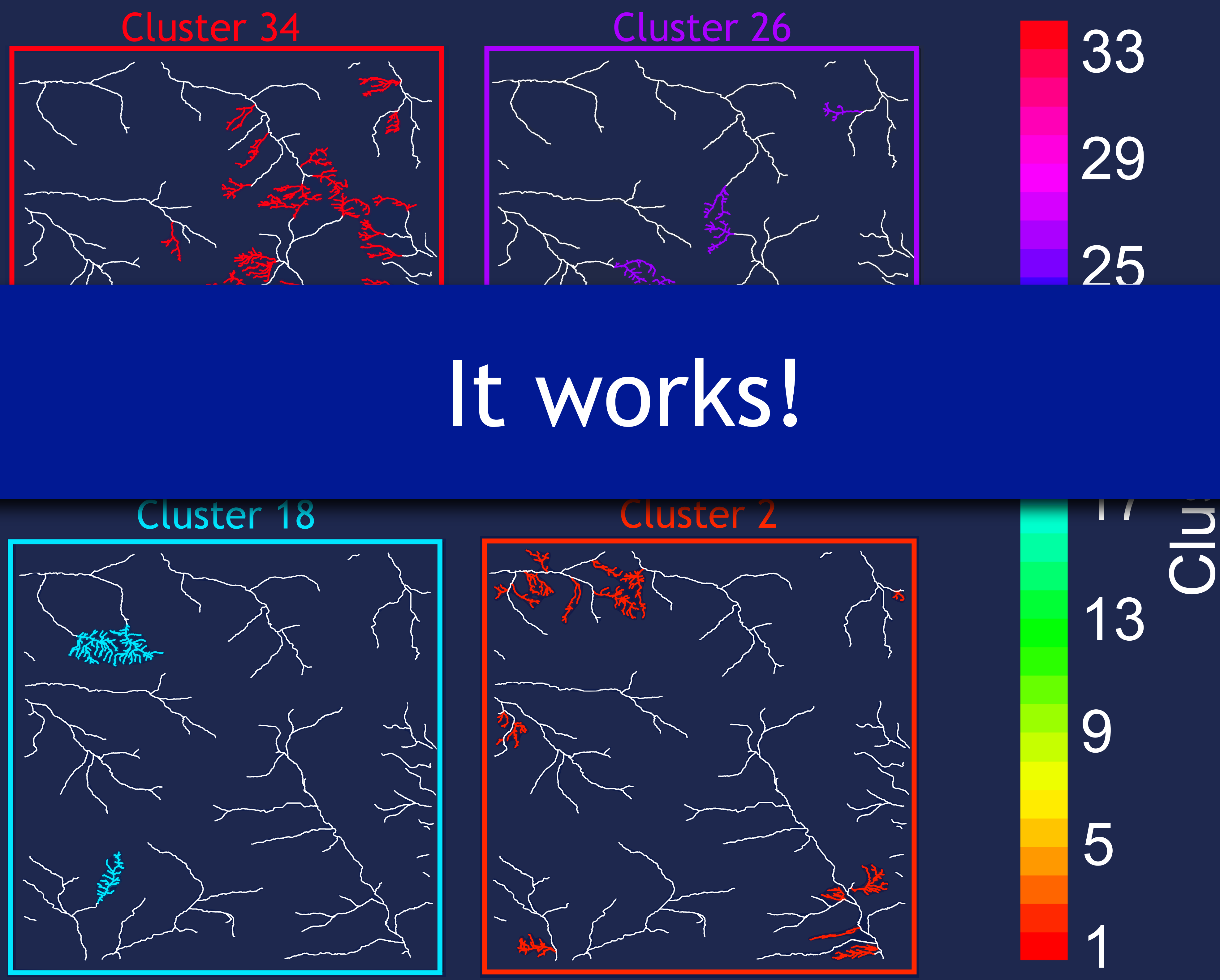

It works!

Final Thoughts and Future Directions

- **Cluster the river channel structure over sets of interconnected reaches (i.e., topologies): Possible!**
- Some questions remain:
  1. Influence of different covariates on the obtained clustering + weights used within the clustering.
  2. Are the selected topological metrics enough to characterize the trees on all scales? (i.e., complex vs. simple networks).
  3. Characteristic topology + 2-way coupling.
- Quantify computational saving derived from applying a topological clustering vs. “fully distributed” routing solution.
- **Preliminary results show that topological clustering is a feasible and promising alternative to implement within ESMs.**

Laura Torres-Rojas
laura.torres@duke.edu

Duke
UNIVERSITY