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Climatic and Geomorphic Influences on the Spatial Scaling of Floods

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Motivation

1. Flood risk analyses that account for:
    - Climate Changes
    - River Channel-Floodplain Geomorphology
2. Prediction in gaged & un-gaged basins
3. Watershed perspective for planning & policy
4. Hydrologic resilience of river basins

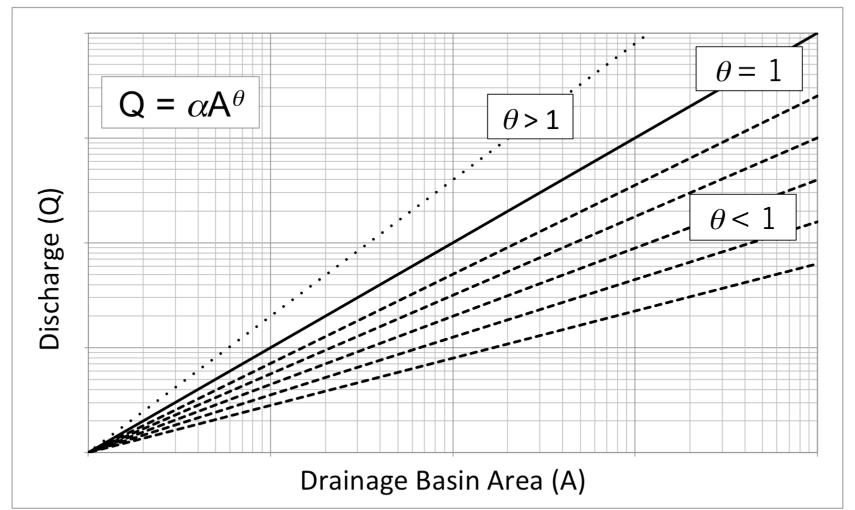
Hydrologic Resilience

- *Ability of a river network to accommodate hydro-climatic shifts without significant changes to channel-floodplain morphology or functioning*

Study Approach

- Discharge-Basin Area relationships widely used in regional flood frequency regression models
- Examine relationships not just for prediction, but *understanding* of physical mechanisms controlling flood magnitude

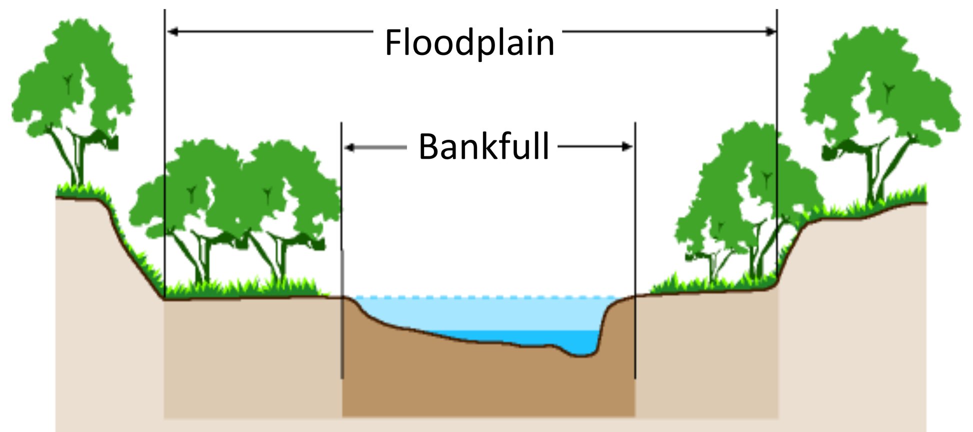
Spatial Scaling of Floods



For scaling of ***floods:*** Q can be peak discharge of *event* or *flood frequency* quantile estimate. Most floods have scaling exponents (θ) less than 1.

- **Why is *θ* less than 1?**
- **What causes variation in *θ*?**

Channel-floodplain morphology



http://ag.arizona.edu/watershedsteward/resources/

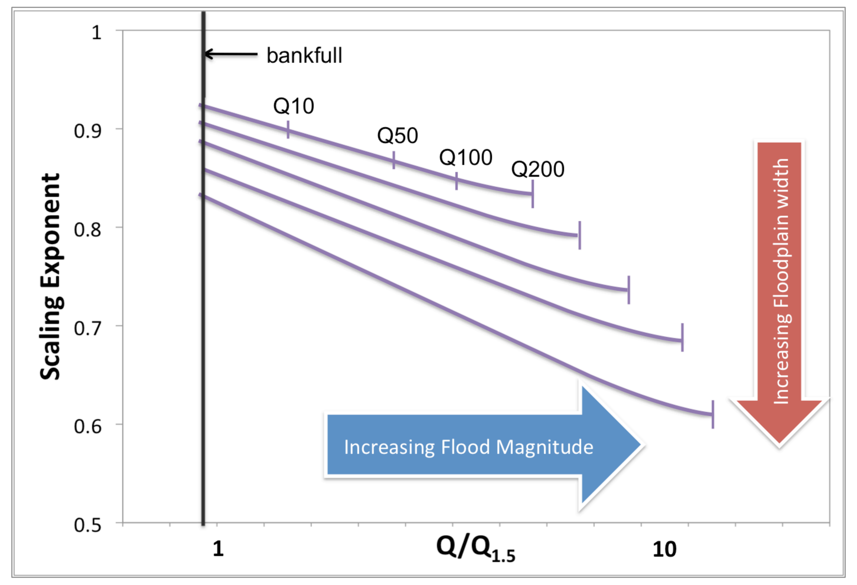
Bankfull flow transports sediment, maintains channel shape and <u>integrates</u> the channel network

- expect scaling exponents closer to 1

Floods flow onto floodplain and <u>dissipate</u> flood peaks

- expect lower scaling exponents with larger floods

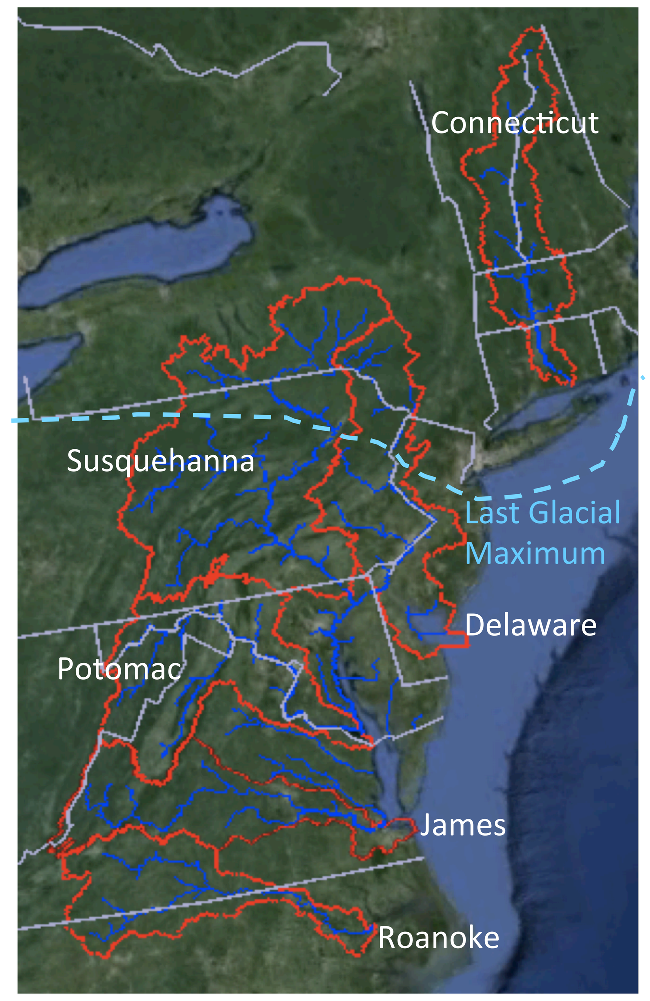
Conceptual Model

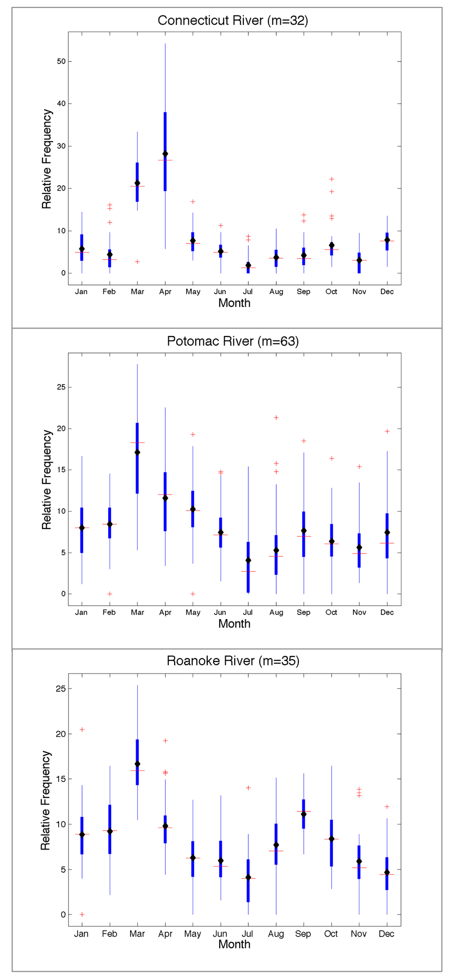


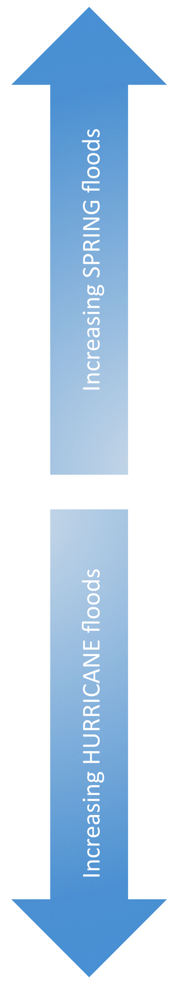
Scaling exponents should **decrease** with:

- **increasing** flood magnitude: greater peak dissipation onto floodplain
- **increasing** floodplain width: greater capacity to dissipate flood peaks

Study Region:
Major Atlantic Slope River Basins







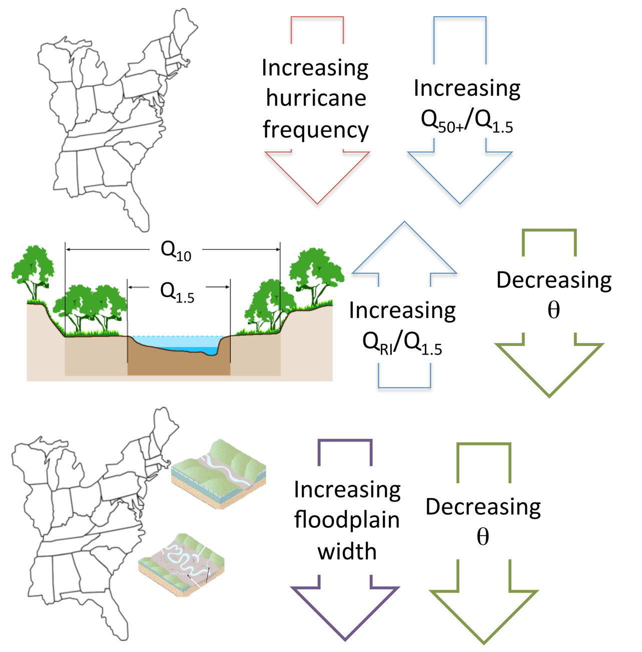
<u>Geology:</u>

- Northern region covered by Laurentide ice sheet at last glacial maximum
- Narrow bedrock valleys in north with no coastal plain
- Well-developed wide coastal floodplains in south

<u>Hydro-climatology:</u>

- Mixture of flood-producing precipitation events:
    - Tropical storms & hurricanes; summer convective storms; winter-spring extra-tropical storms
- Tropical storms dominate flood record in the south, while winter-spring storms dominate in the north

Hypotheses

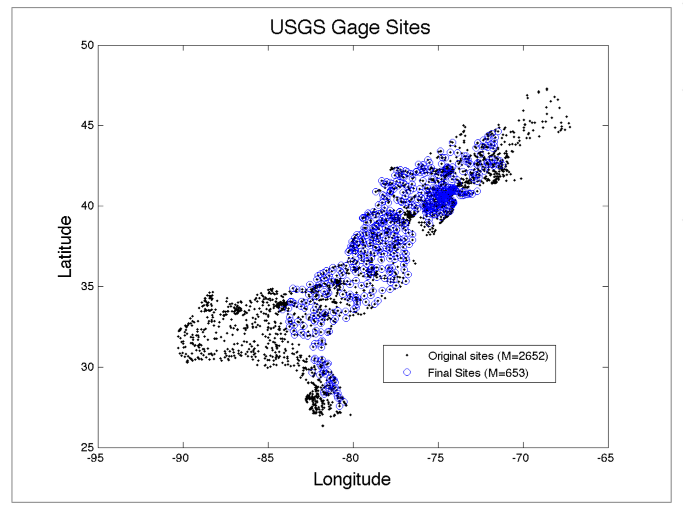


H1: largest dimensionless discharges (for RI>50) are in southeastern rivers

H2: lower scaling exponents for larger floods in all rivers

H3: Rivers with wider floodplains will have the lowest scaling exponents

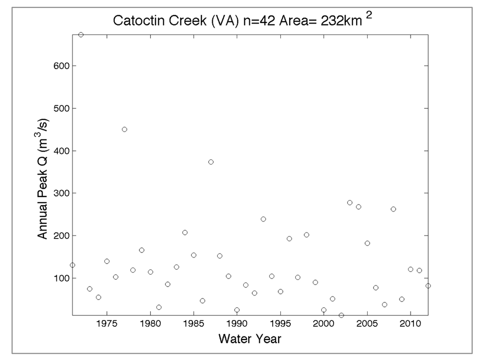
Methods

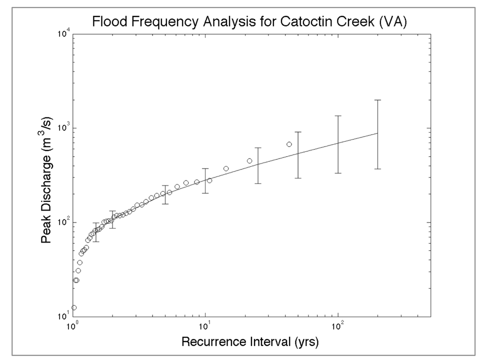


- Peak Flow Data from USGS Stream Gages: Annual Maximum Series
- Initial Criteria: all gages in New England, Mid-Atlantic & South Atlantic Hydrologic Regions
- Final criteria:
    - Min. 25 yrs of peak flow data
    - No major gaps in record
    - Flow not affected by regulation or channelization
    - No significant (α=1%) trends
    - Min. 10 gages in watershed
    - Watersheds drain to Atlantic

I. Flood Frequency Analysis

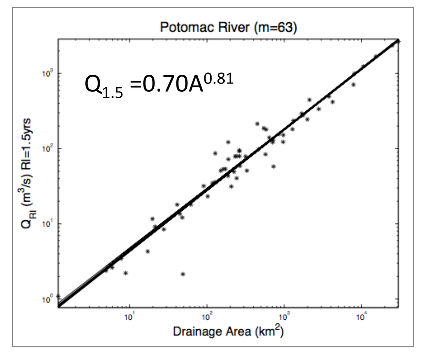
- Fit generalized extreme value distribution to annual maximum series at all gage sites
- Estimated Q_{RI} for range of recurrence intervals: 1.5 – 200 year floods

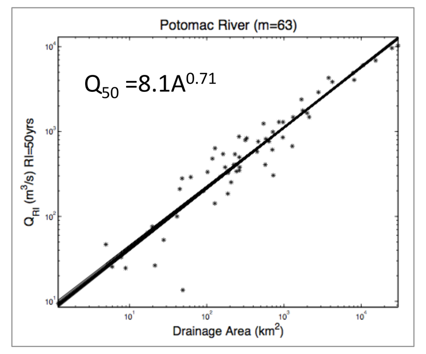


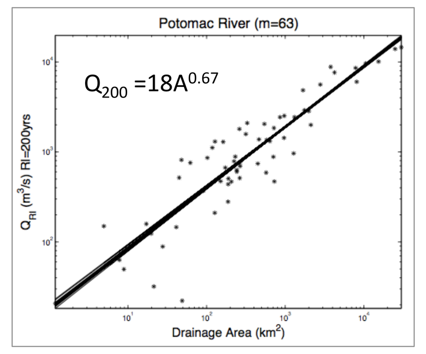


II. Spatial Scaling: $Q_{RI} = \alpha \log(A)^{\theta}$

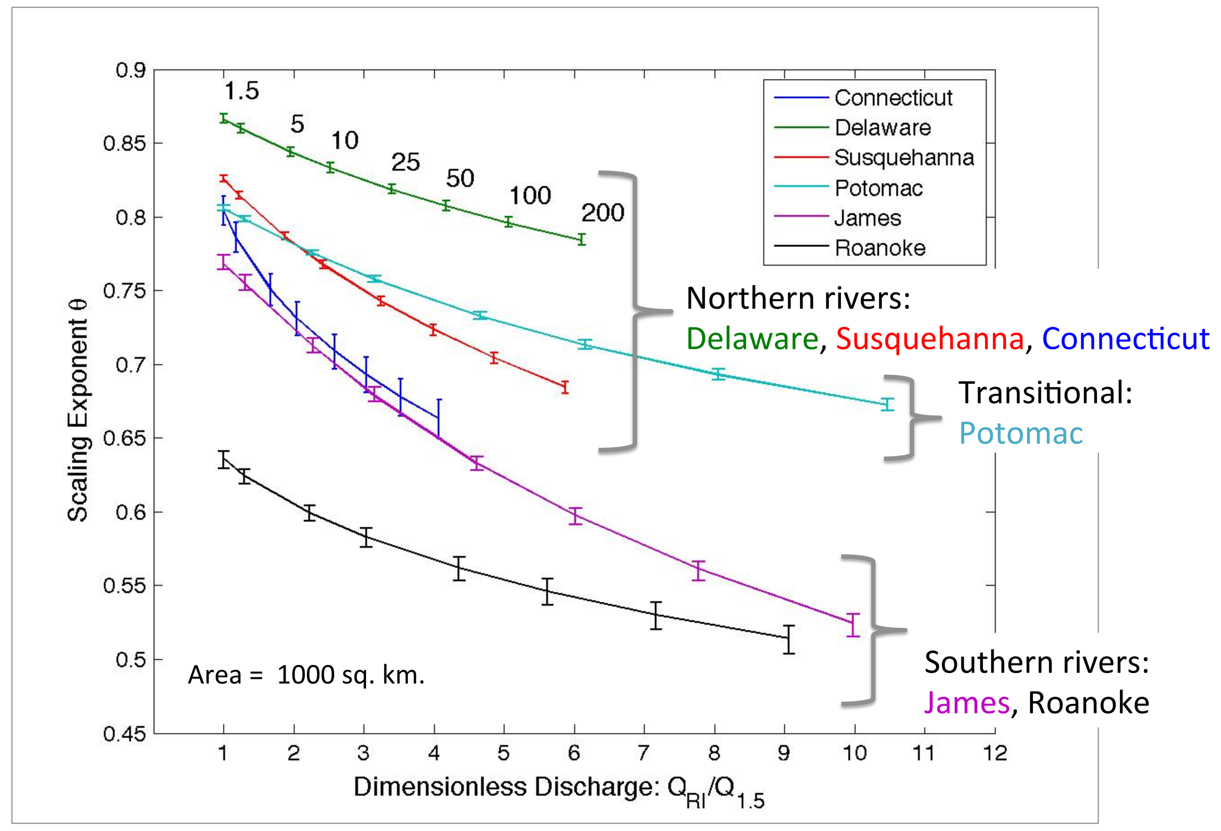
- Linear regression of $\log(Q_{RI})$ on $\log(A)$ for each Q_{RI}
- Determined scaling exponent (θ) and coefficient (α) for each Q_{RI} in each river basin







Results



<u>Scaling exponents:</u>

- **Decrease** as dimensionless discharge increases in all river basins
- Are **higher** in northern river basins:
  Connecticut, Delaware, Susquehanna
- Are **lower** in southern river basins:
  James, Roanoke

Potomac River basin is **transitional**

- Morphology of northern watersheds
- Hydro-climate of southern watersheds

High magnitude floods are larger in southern watersheds:
Potomac, James, Roanoke

Implications

- Type of **flood risk** is tied to river valley morphology:
    - **Inundation** risk in southern rivers
    - **Erosion** risk in northern rivers
- <u>Hydrologic Resiliency</u>:
    - Northern river valleys *less resilient* to increasing frequency of large magnitude floods:
        - Narrow river valleys cannot accommodate large flood flows
    - Southern rivers are *more resilient to climate changes* **IF** floodplain morphology & functions are preserved: BUT urban development affects these functions