Climatic and Geomorphic Influences on the Spatial Scaling of Floods
Carolyn Plank and Karen Prestegaard
Department of Geology, University of Maryland at College Park email: caplank@umd.edu

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

Conceptual Model
Scaling exponents should decrease with:
• increasing flood magnitude: greater peak dissipation on floodplain
• increasing floodplain width: greater capacity to dissipate flood peaks

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

Study Region: Major Atlantic Slope River Basins

Geology:
• 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

Hydro-climatology:
• 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

For scaling of floods: Q can be peak discharge of event or flood frequency quantum estimate. Most floods have scaling exponents (θ) less than 1.
• Why is θ less than 1?
• What causes variation in θ?

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

Bankfull flow transports sediment, maintains channel shape and integrates the channel network
• expect scaling exponents closer to 1
• Floods flow on floodplain and dissipate flood peaks
• expect lower scaling exponents with larger floods

Peak Flood 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 (5%+) trends
  • Min. 10 gages in watershed
  • Watersheds drain to Atlantic

Methods
I. Flood Frequency Analysis
• Fit generalized extreme value distribution to annual maximum series at all gage sites
• Estimated QRI for range of recurrence intervals: 1.5 – 200 year floods

II. Spatial Scaling: QRI = alog(A)
• Linear regression of log(QRI) on log(A) for each QRI
• Determined scaling exponent (θ) and coefficient (a) for each QRI in each river basin

Channel-floodplain morphology

Bankfull flow transports sediment, maintains channel shape and integrates the channel network
• expect scaling exponents closer to 1
• Floods flow on floodplain and dissipate flood peaks
• expect lower scaling exponents with larger floods

Results

I. Flood Frequency Analysis
• Fit generalized extreme value distribution to annual maximum series at all gage sites
• Estimated QRI for range of recurrence intervals: 1.5 – 200 year floods

II. Spatial Scaling: QRI = alog(A)
• Linear regression of log(QRI) on log(A) for each QRI
• Determined scaling exponent (θ) and coefficient (a) for each QRI in each river basin

Implications

• Type of flood risk is tied to river valley morphology:
  • Inundation risk in southern rivers
  • Erosion risk in northern rivers
• Hydrologic Resiliency:
  • 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

Scale exponents:
• 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

Scale exponents:
• 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

High magnitude floods are larger in southern watersheds:
• Hydro-climate of southern watersheds

High magnitude floods are larger in southern watersheds:
• Hydro-climate of southern watersheds