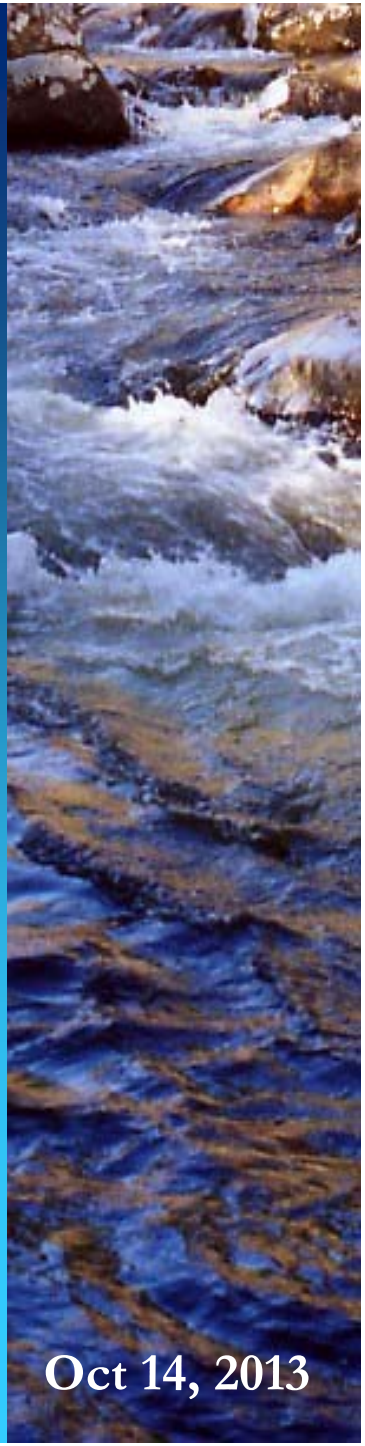
Land Cover Effects on Watershed Hydrologic Memory

Jason P. Julian
Robert H. Gardner



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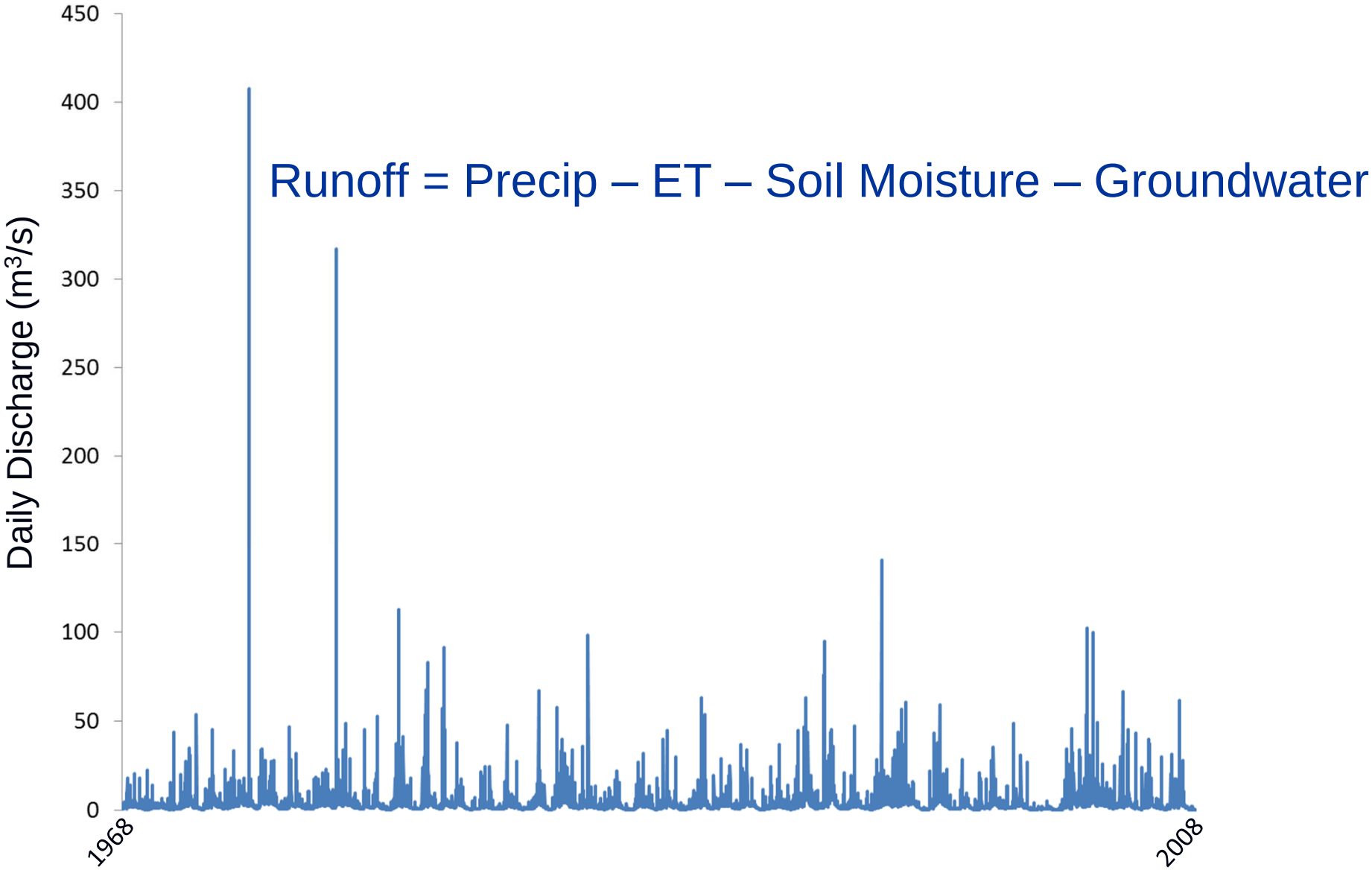
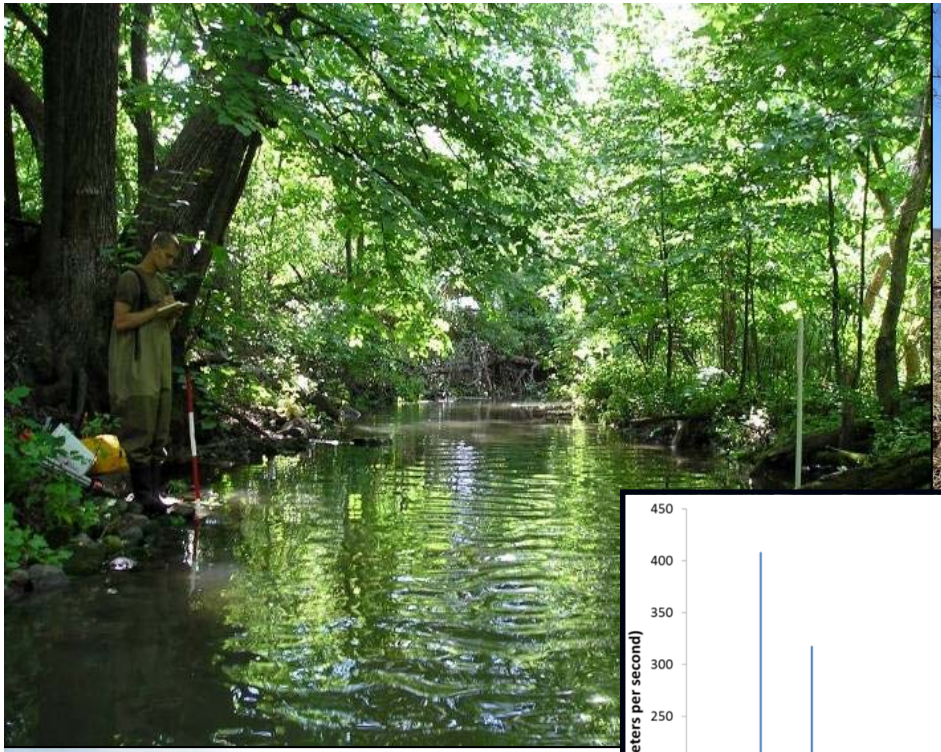
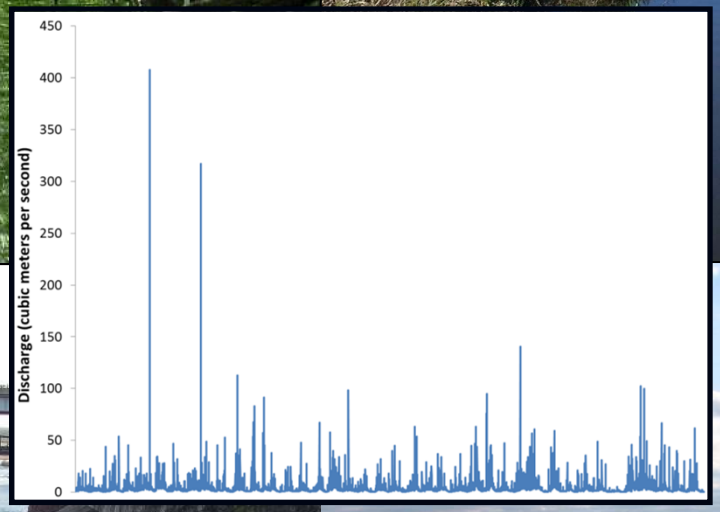
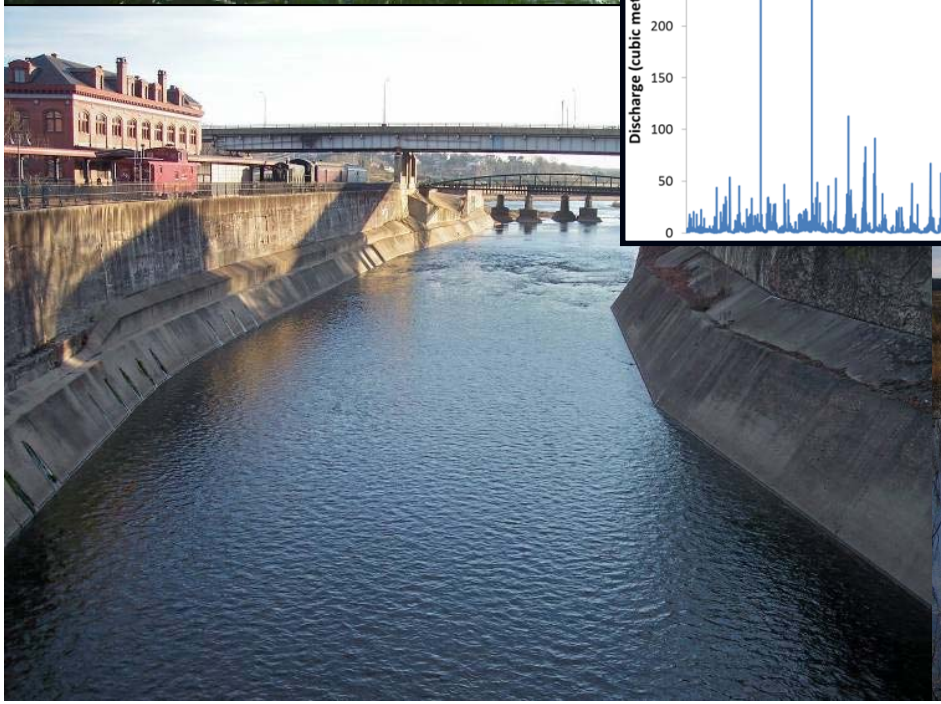
Oct 14, 2013

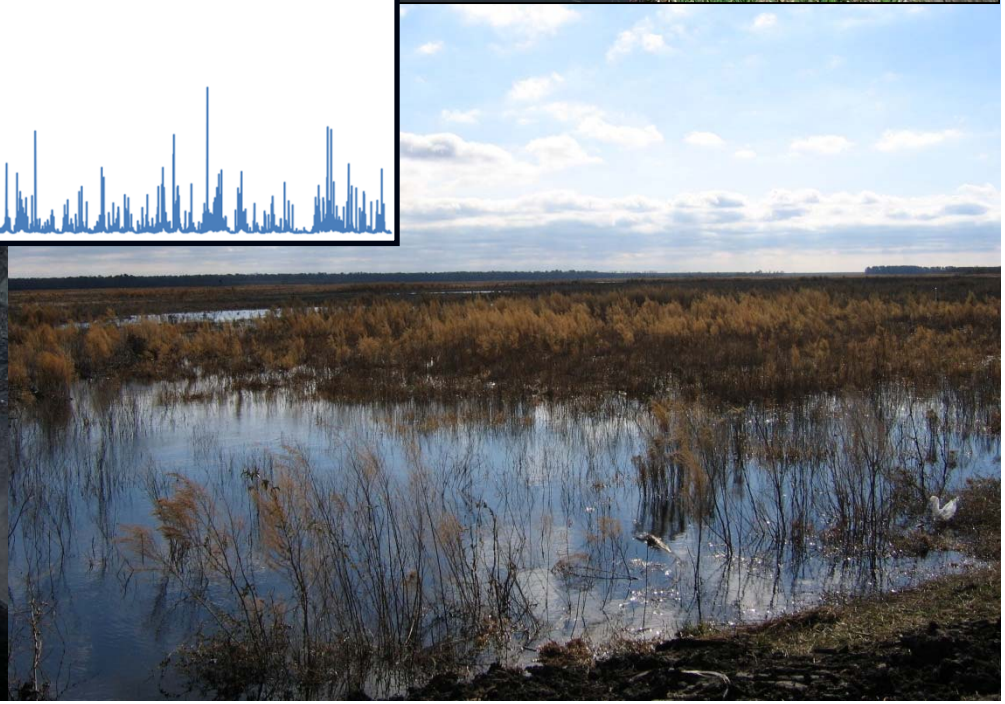
Watershed Hydrologic Memory






Discharge (cubic meters per second)
450
400
350
300
250
200
150
100
50
0





Runoff affected by …

Morphometric variables

Area (A)

Stream order (O_{HS})

Drainage density (D_d)

Mean channel slope (S_c)

Basin shape (R_f)

Geologic variables

Silt-clay percentage ($SC\%$)

Soil depth to bedrock (Z_{br})

Hydrologic variables

Reservoir storage percentage ($RS\%$)

Precipitation effectiveness ratio (R_{pe})

Land-cover variables

Percent water-wetland ($\%WW$)

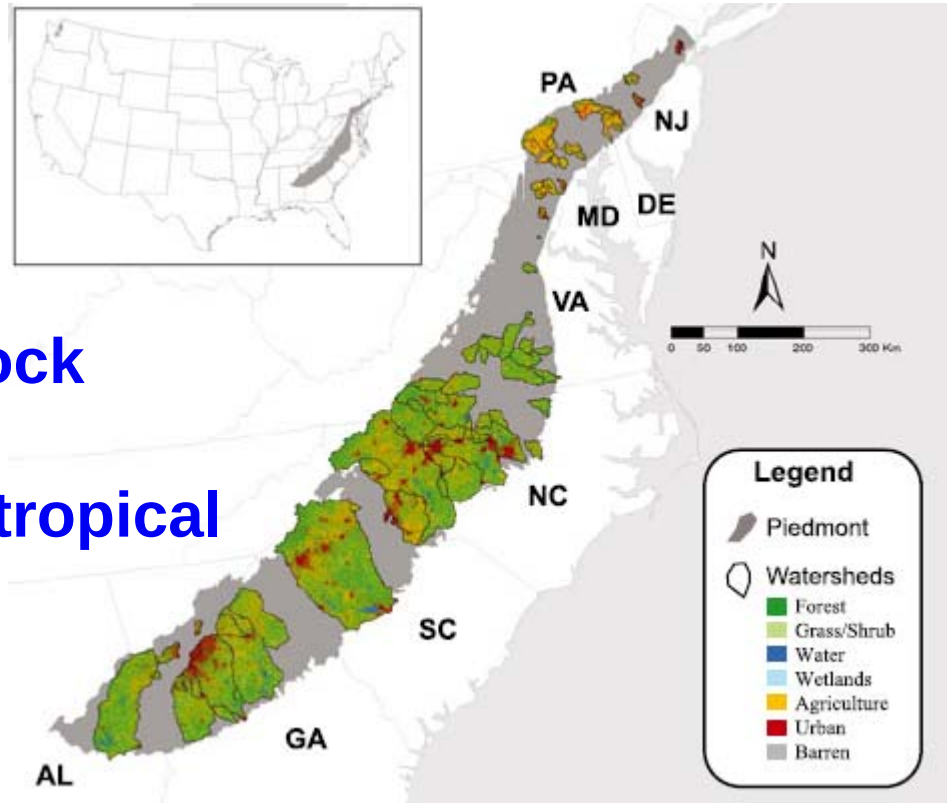
Percent urban ($\%UR$)

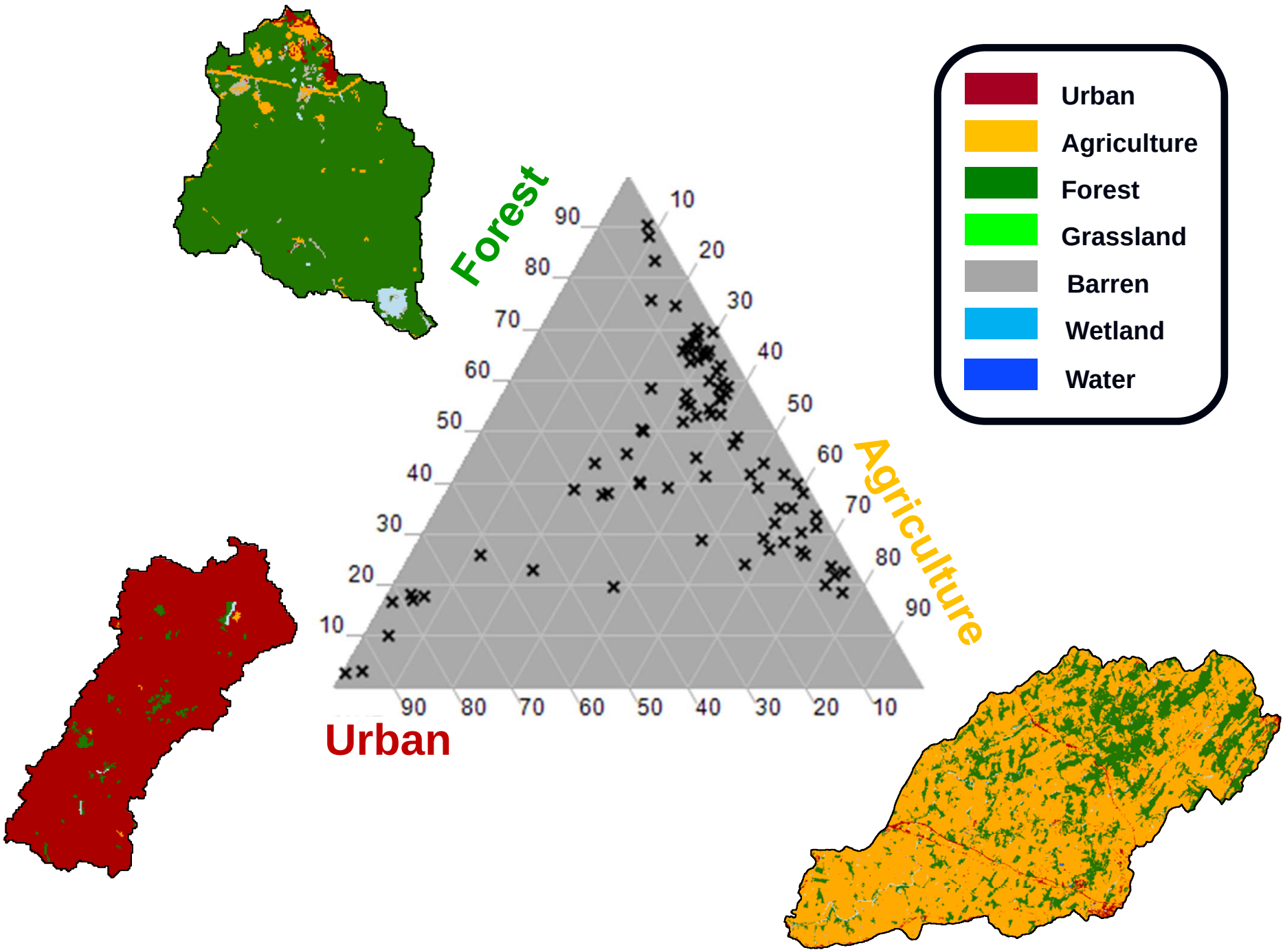
Percent forest ($\%FO$)

Percent agriculture ($\%AG$)

Eastern Piedmont – 87 watersheds

- Similar morphometry
  - Pear- or oval-shaped
  - Dendritic drainage
- Moderate relief
  - neither topographic or subsurface controls dominate
- Similar geology
  - Thick clay-rich soils
  - Deeply weathered bedrock
- Similar climate
  - Mid-latitude, humid subtropical
  - No dry season
- Many flow gages with long continuous daily records




Urban
Agriculture
Forest
Grassland
Barren
Wetland
Water
Forest
Agriculture
Urban
10
20
30
40
50
60
70
80
90

Runoff affected by …

Morphometric variables

Area (A)

Stream order (O_{HS})

Drainage density (D_d)

Mean channel slope (S_c)

Basin form ratio (R_f)

Geologic variables

Silt-clay percentage ($SC\%$)

Depth to bedrock (Z_{br})

Hydrologic variables

Reservoir storage percentage ($RS\%$)

Precipitation effectiveness ratio (R_{pe})

Land-cover variables

Percent water-wetland ($\%WW$)

Percent urban ($\%UR$)

Percent forest ($\%FO$)

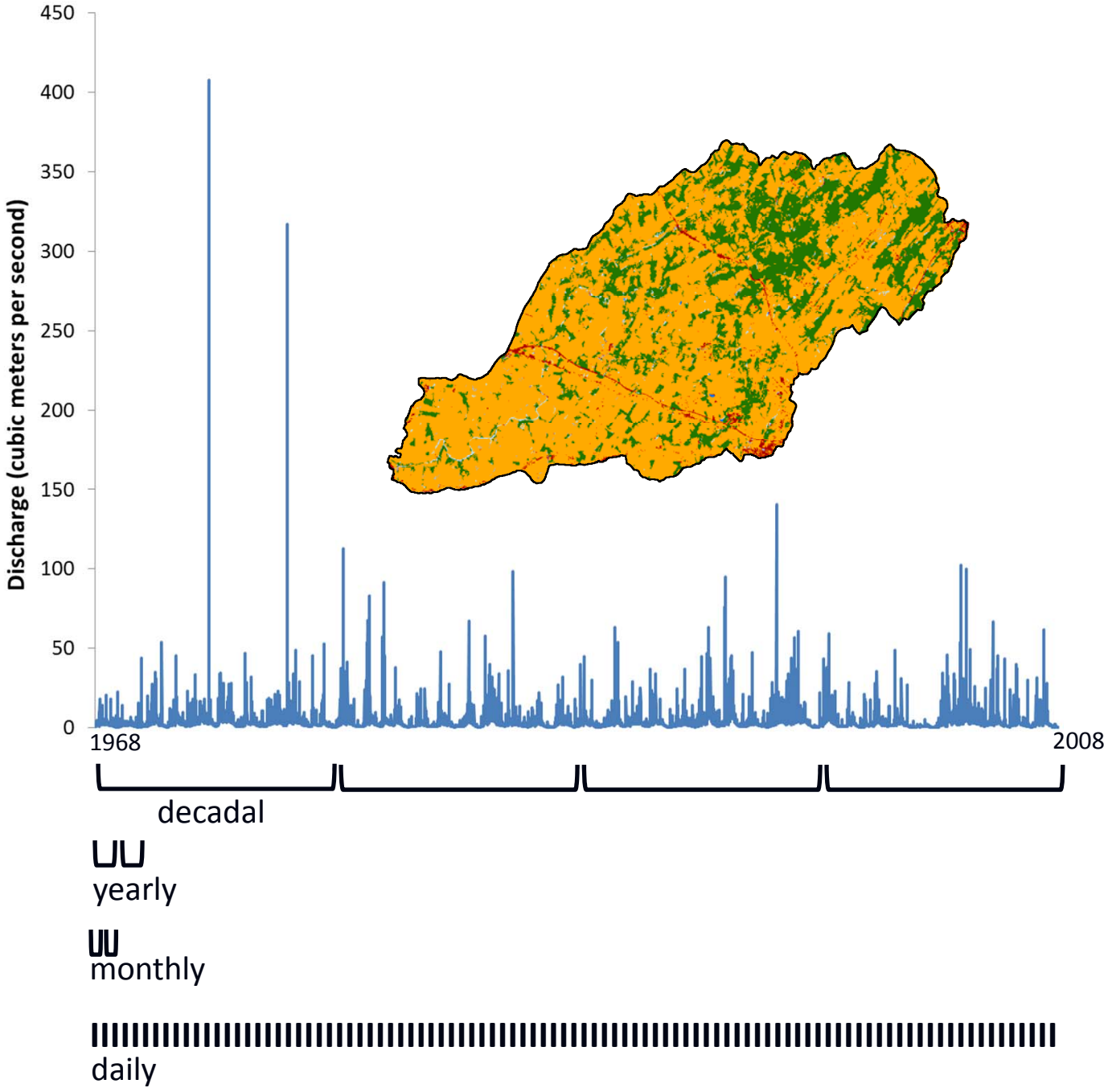
Percent agriculture ($\%AG$)

What about stationarity with respect to climate?

We use the same 40-y (1968-2007) records for all watersheds

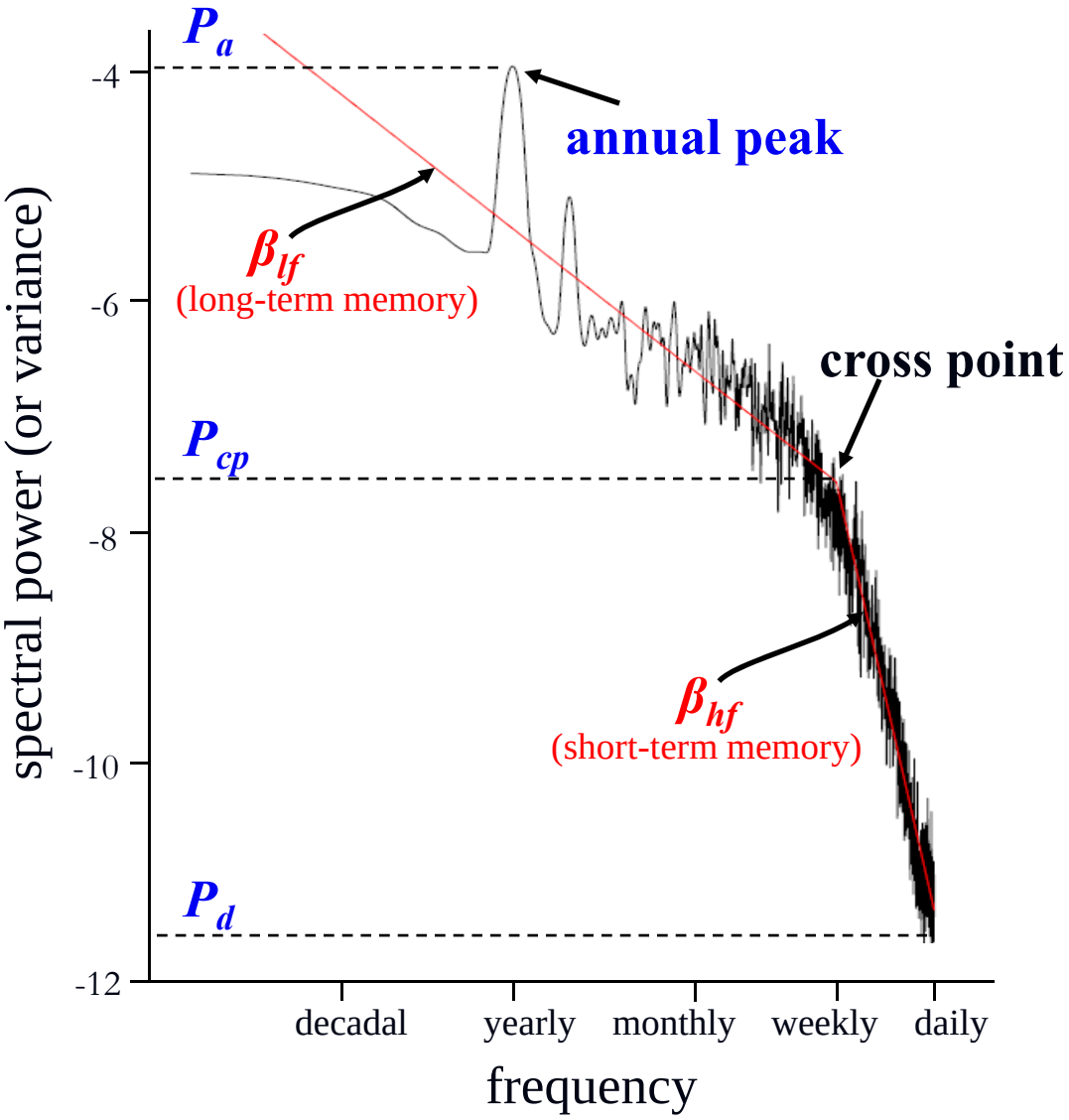
Which period or frequency will you analyze?

All of them

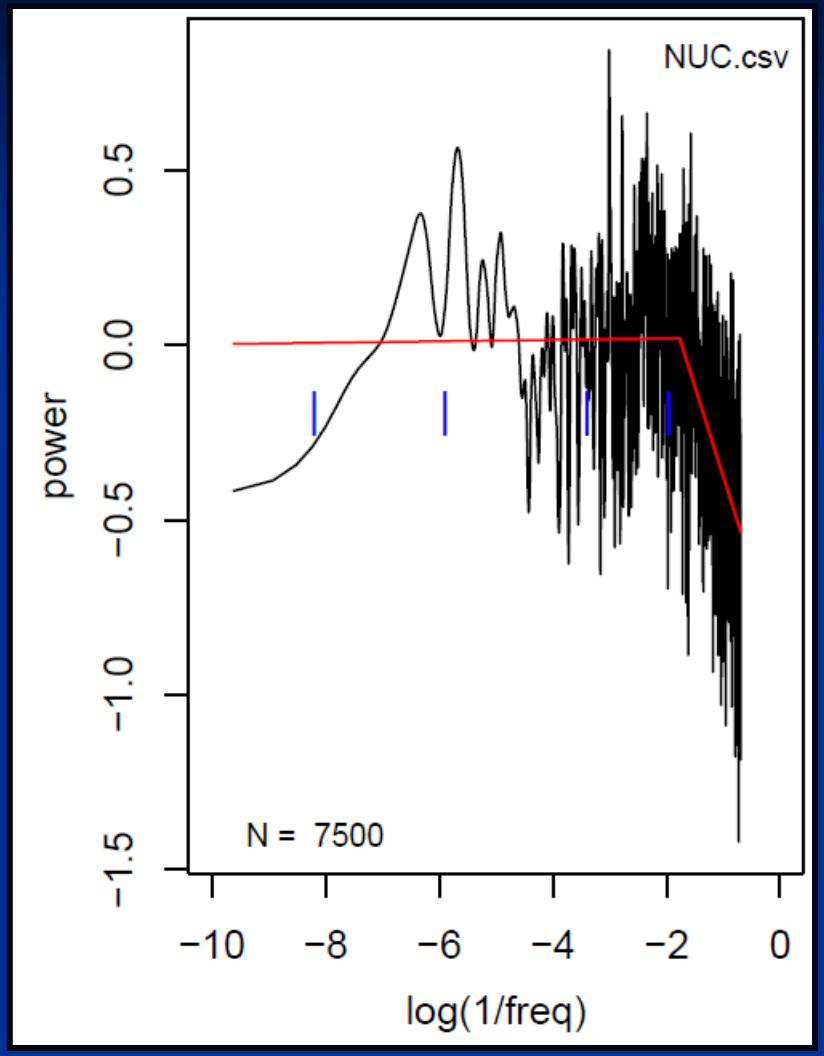

Discharge (cubic meters per second)
450
400
350
300
250
200
150
100
50
0
1968
2008
decadal
yearly
monthly
daily

Power Spectral Analysis

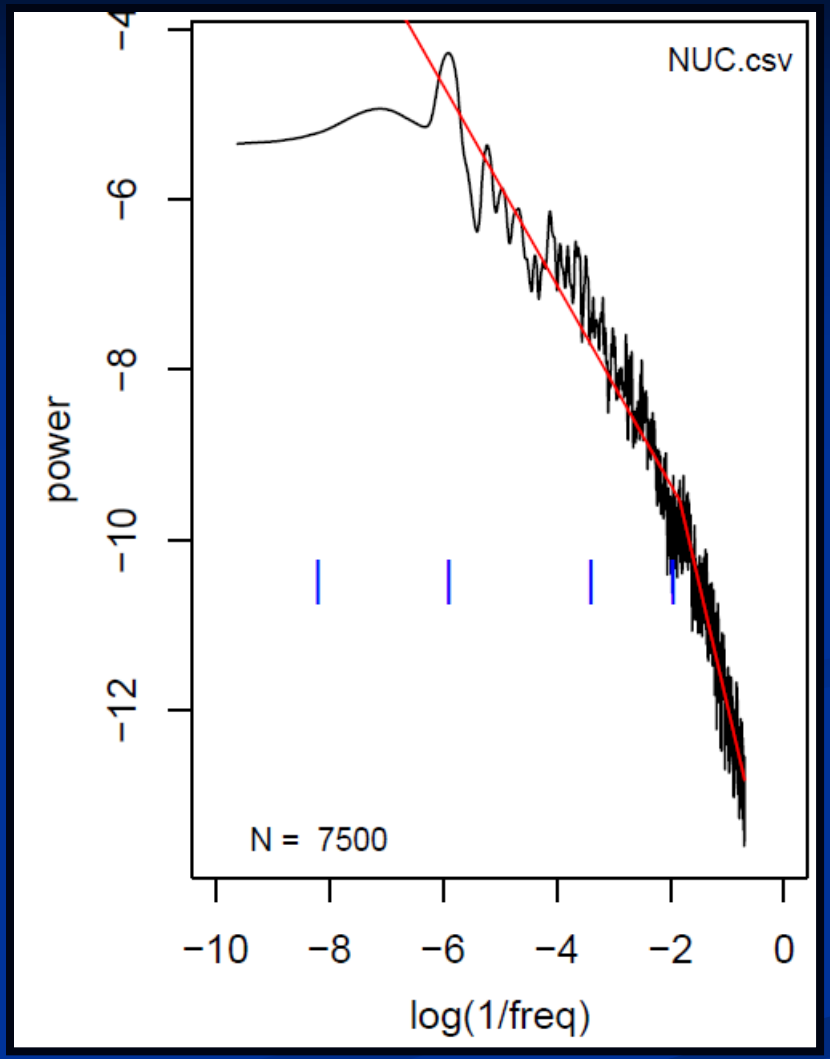
(think temporal correlation using a moving window)



Rainfall - (white-noise)



Runoff - (red-noise)



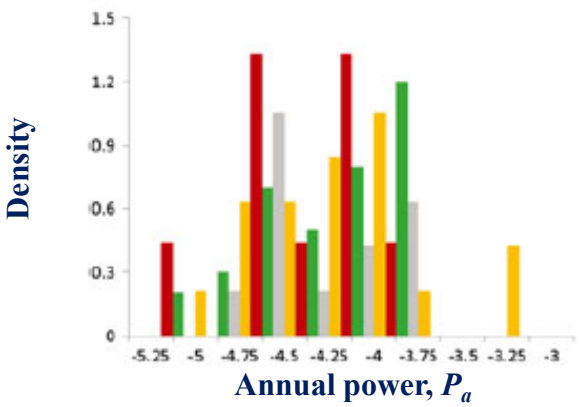
cross-point	f_{cp} = 5.6 ± 0.6	f_{cp} = 6.0 ± 1.3
Short-term memory	$-\beta_{hf}$ = 0.42 ± 0.05	$-\beta_{hf}$ = 1.84 ± 1.15
Long-term memory	$-\beta_{lf}$ = 0.02 ± 0.02	$-\beta_{lf}$ = 0.45 ± 0.16

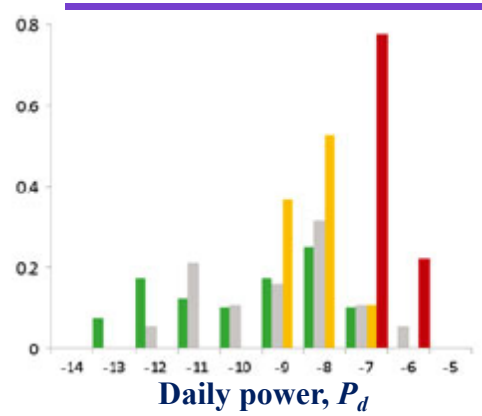
Do landscape attributes dictate a catchment's hydrologic memory?

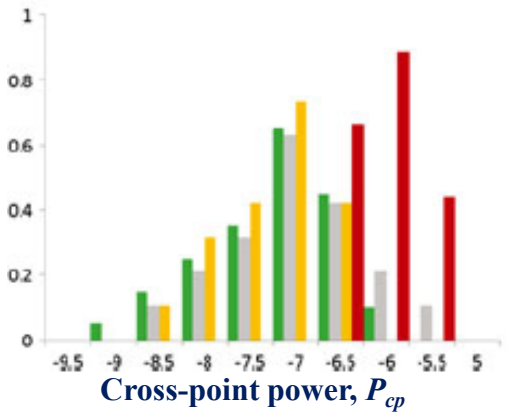
Spectral Variable	Best landscape predictor (r)	Stepwise model r^2 ($\alpha = 0.05$)
Daily power, P_d	*%Wetland* (-0.49)	0.57
Annual power, P_a	*%Wetland* (0.41)	0.21*
Spectral slope, $-\beta_0$	*%Wetland* (0.57)	0.62
Cross point power, P_{cp}	*%Urban* (0.50)	0.39
Cross point frequency, f_{cp}	*Slope* (-0.32)	0.20*
Long-term memory, $-\beta_{lf}$	*%Urban* (-0.47)	0.43
Short-term memory, $-\beta_{hf}$	*%Wetland* (0.55)	0.58

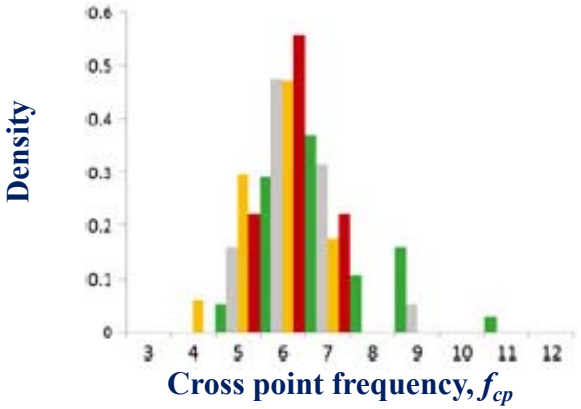
*** Low correlation**

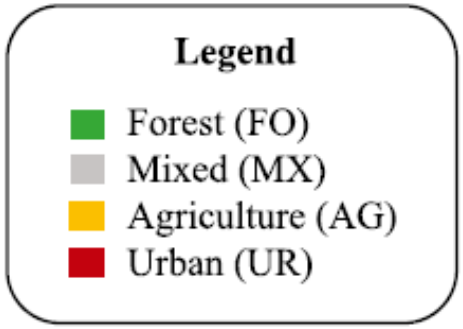
Runoff Variance

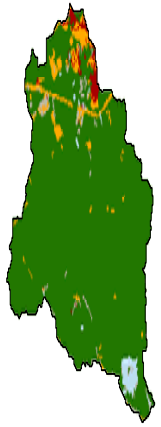




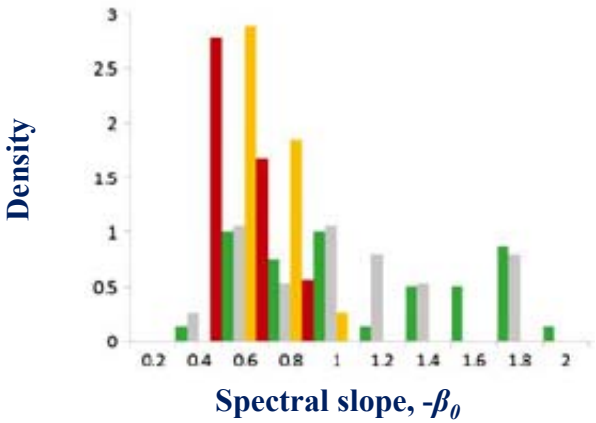


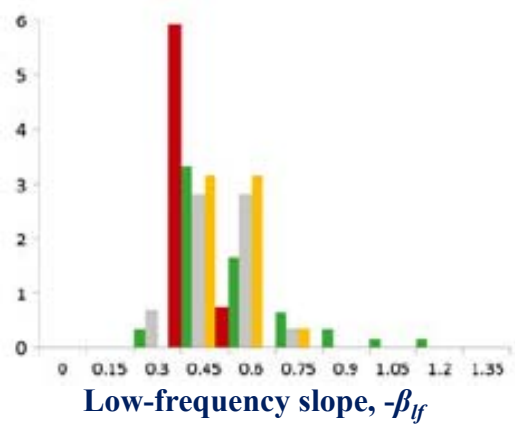


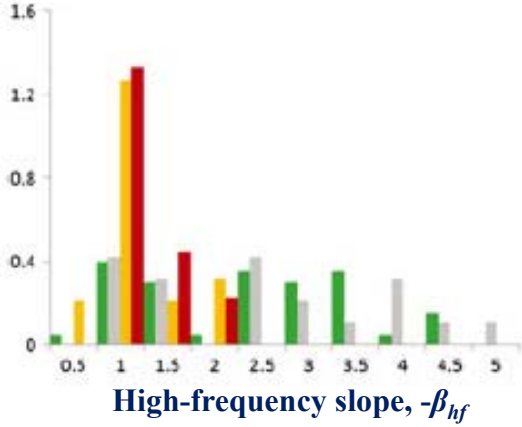




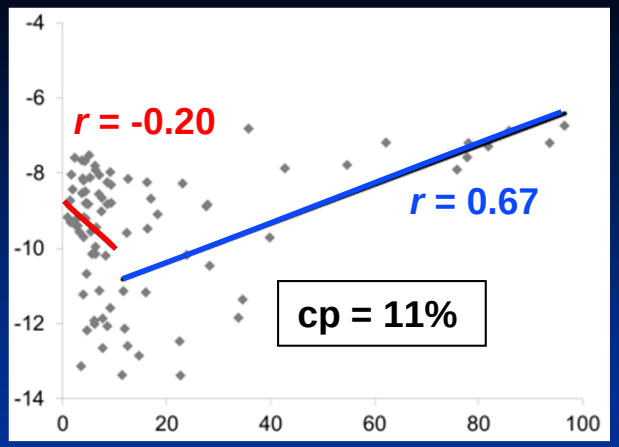
Watershed Memory

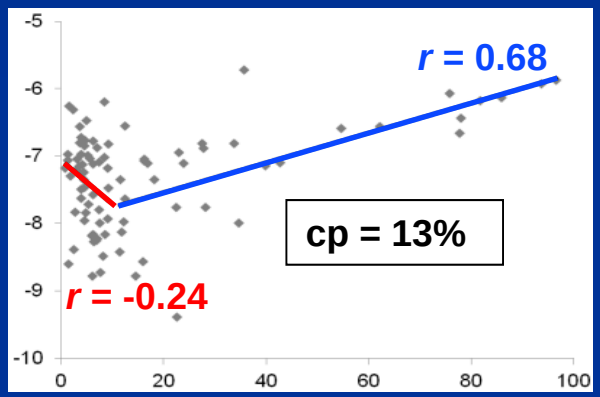


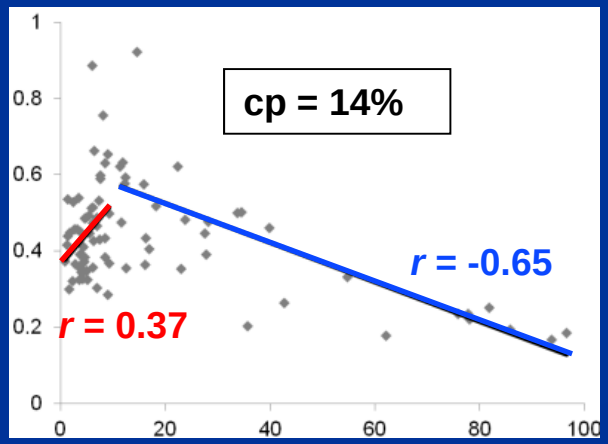




Urban Thresholds



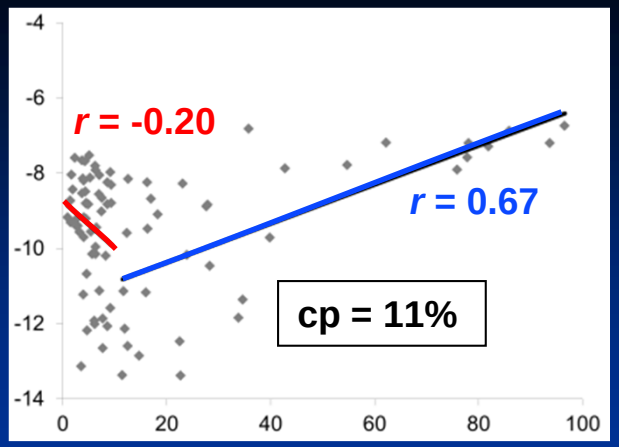


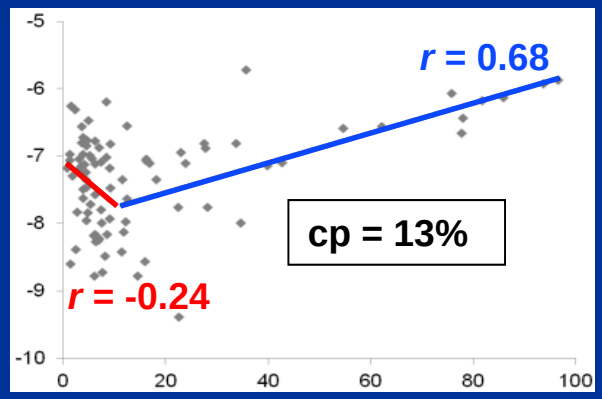


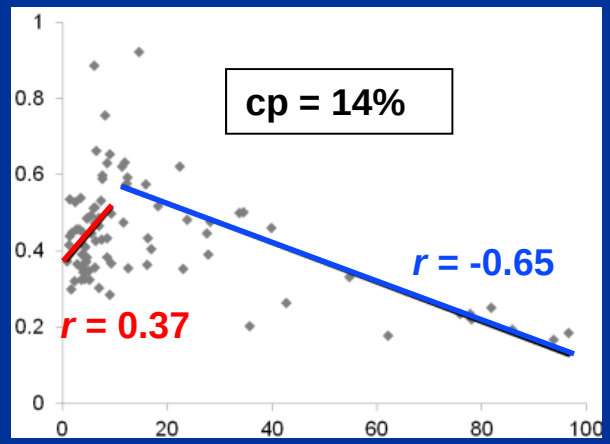
Stream biota studies with 10-15% threshold

- Paul and Meyer, 2001, *Ann Rev Ecology, Evolution, and Systematics*
- Utz et al., 2009, *Ecological Indicators*
- Roy et al., 2003, *Freshwater Biology*

Urban Thresholds





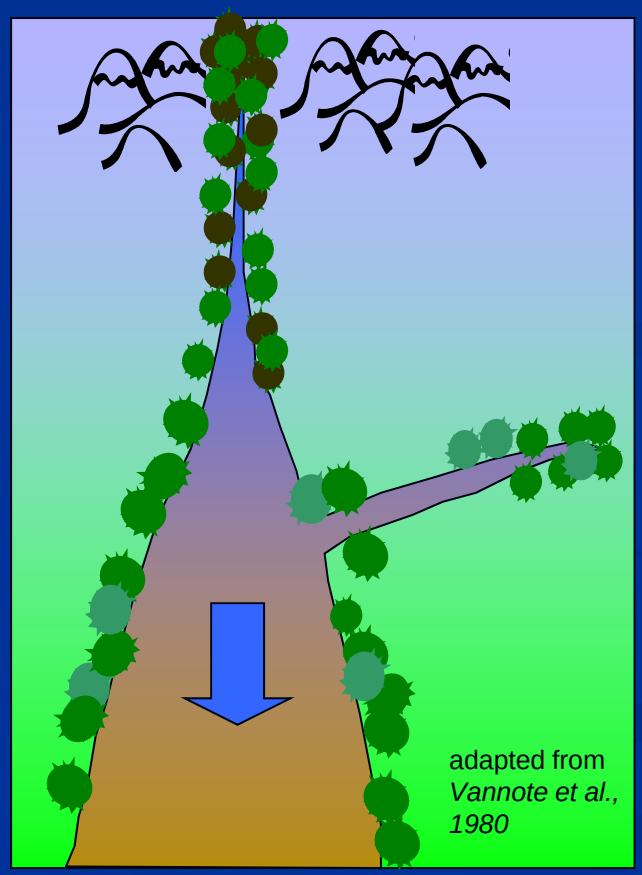


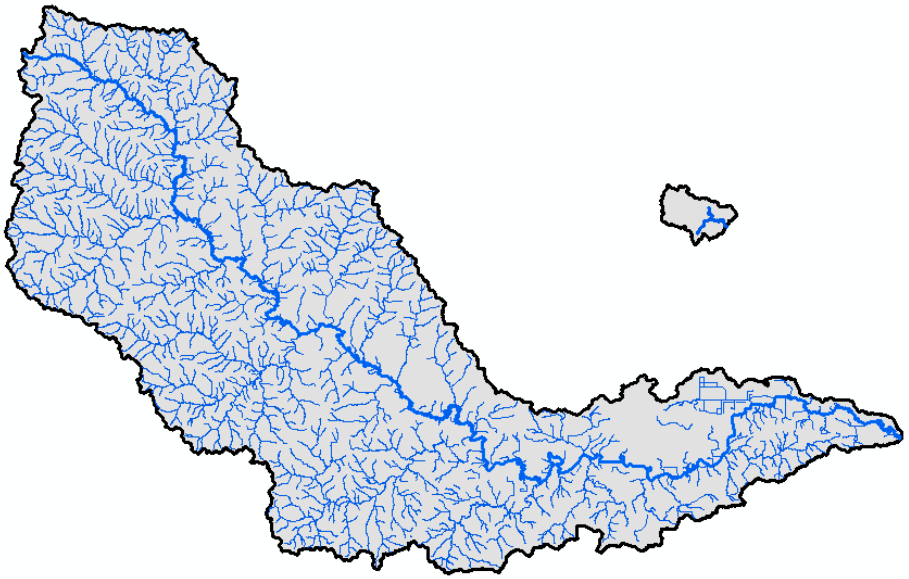
Affects hydrologic drought?

Longitudinal Spatial Patterns in Spectral Variables

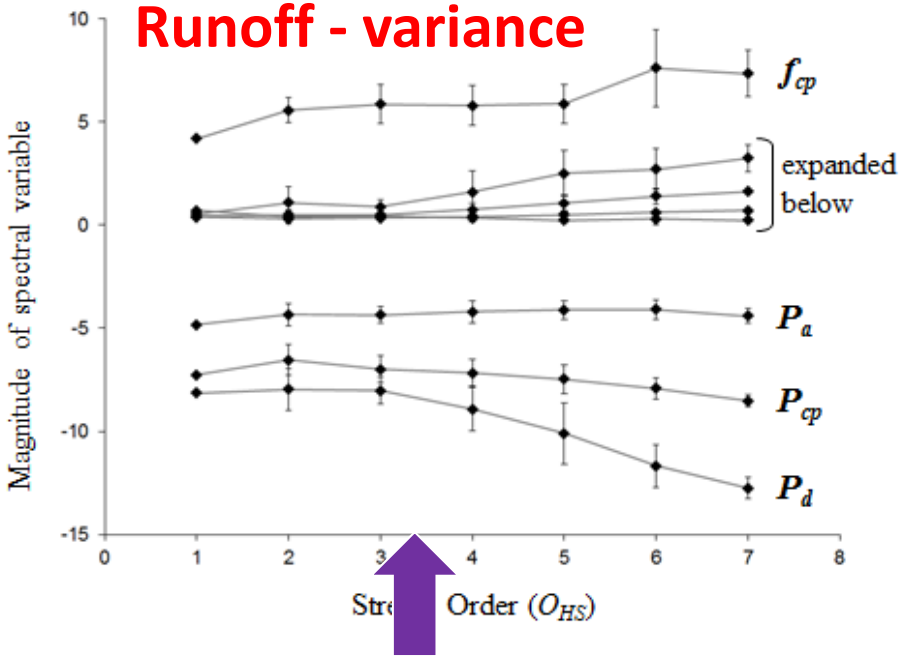
Stream Order

1
2
3
4
5
6
7

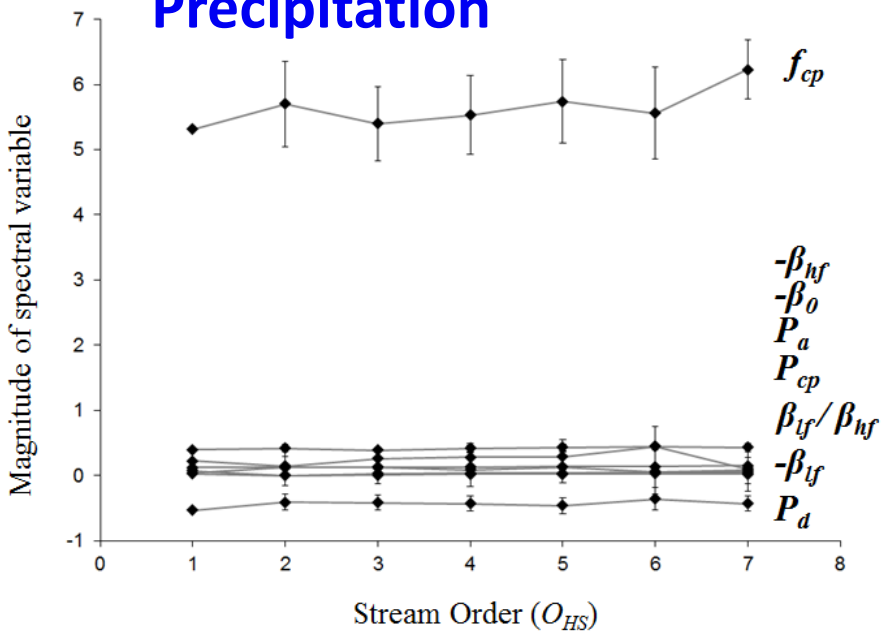




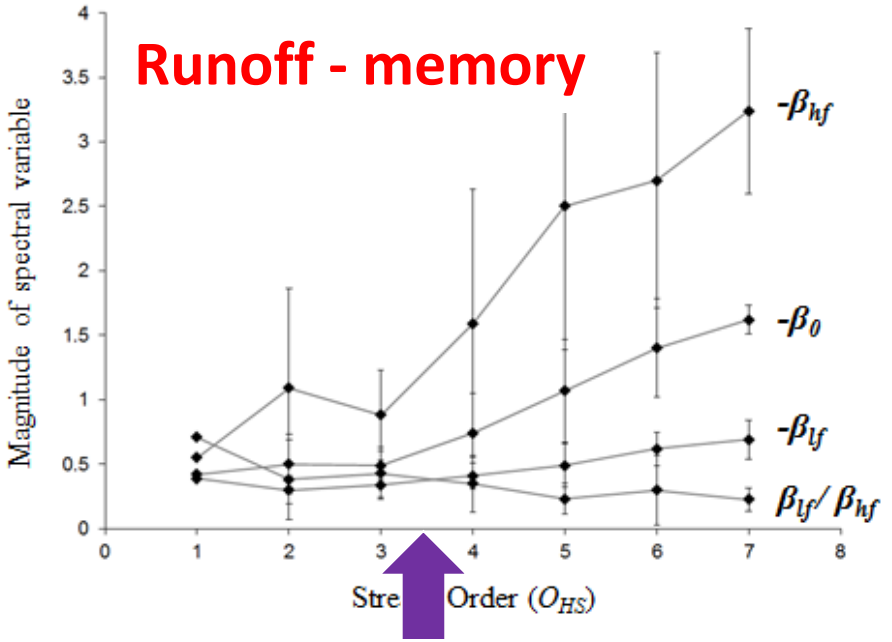
Runoff - variance



Precipitation



Runoff - memory



A matrix for characterizing Hydrologic Signatures?

	Climate-influenced	Landscape-influenced
Low frequency	P_a	$-\beta_{lf}$
High frequency	f_{cp}	$-\beta_{hf}$

Land Cover Effects on Runoff

- Land cover can have considerable and **predictable** effects on runoff patterns (aka watershed memory)
- 10-15% urban threshold above which urban coverage becomes the dominant control on runoff patterns
- Downstream threshold (after 3rd-order) where watershed processes become dominant over precipitation in determining runoff patterns in Eastern Piedmont
- Matrix for hydrologic signatures:

[climate vs. landscape effects] [low vs. high frequency events]

Questions?

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Land cover effects on runoff patterns in eastern Piedmont (USA) watersheds

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[2] *Appalachian Laboratory, University of Maryland Center for Environmental Science, Frostburg, MD 21532, USA*