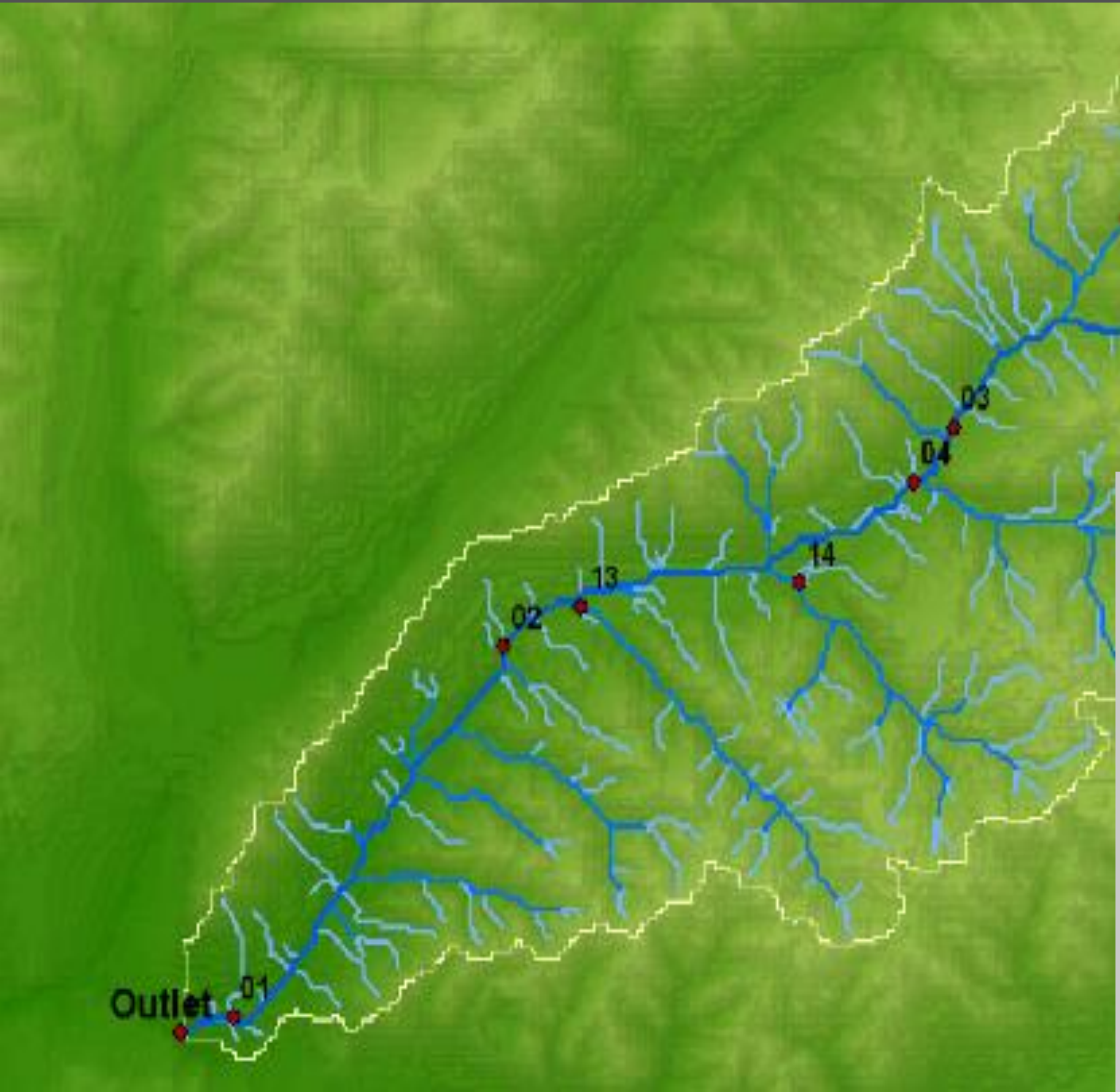
Scaling of Peak Flows in a River Network

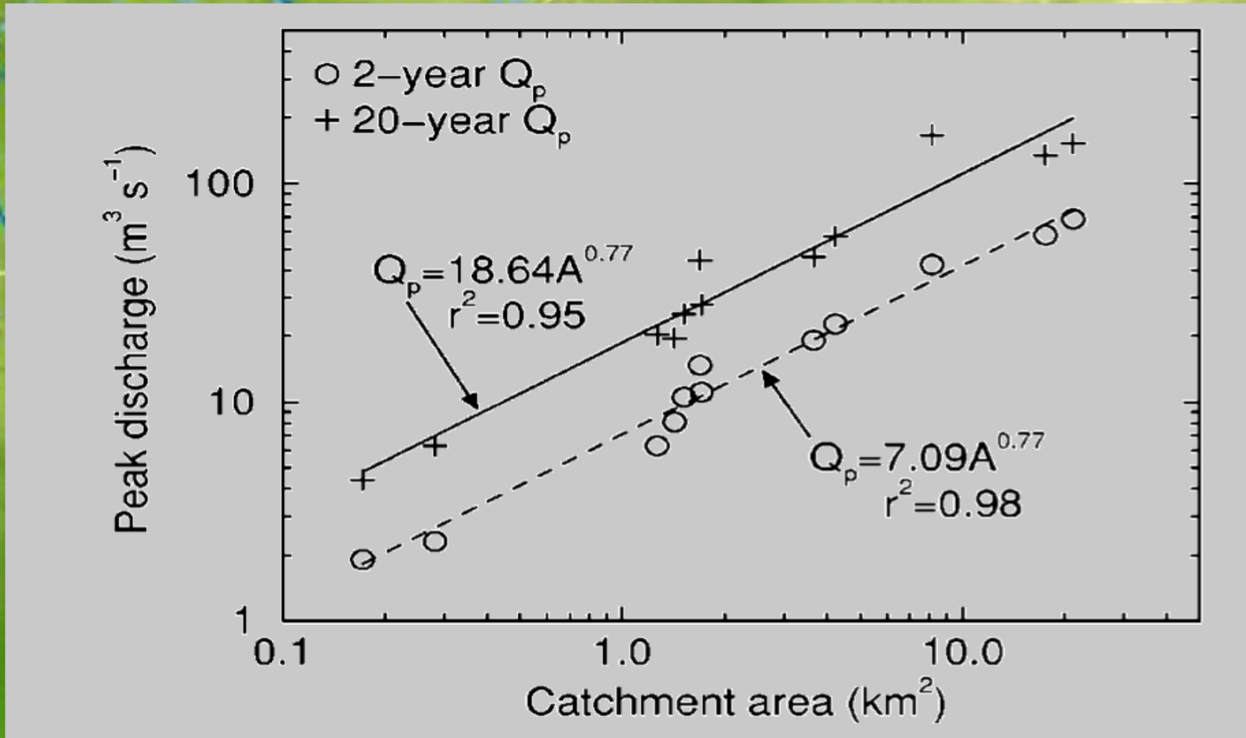
Witold F. Krajewski
with contributions from Vijay Gupta, Ricardo Mantilla, Tibebu Ayalew, Gabriel Perez, Gabriele Villarini

Prediction for Ungauged Basins

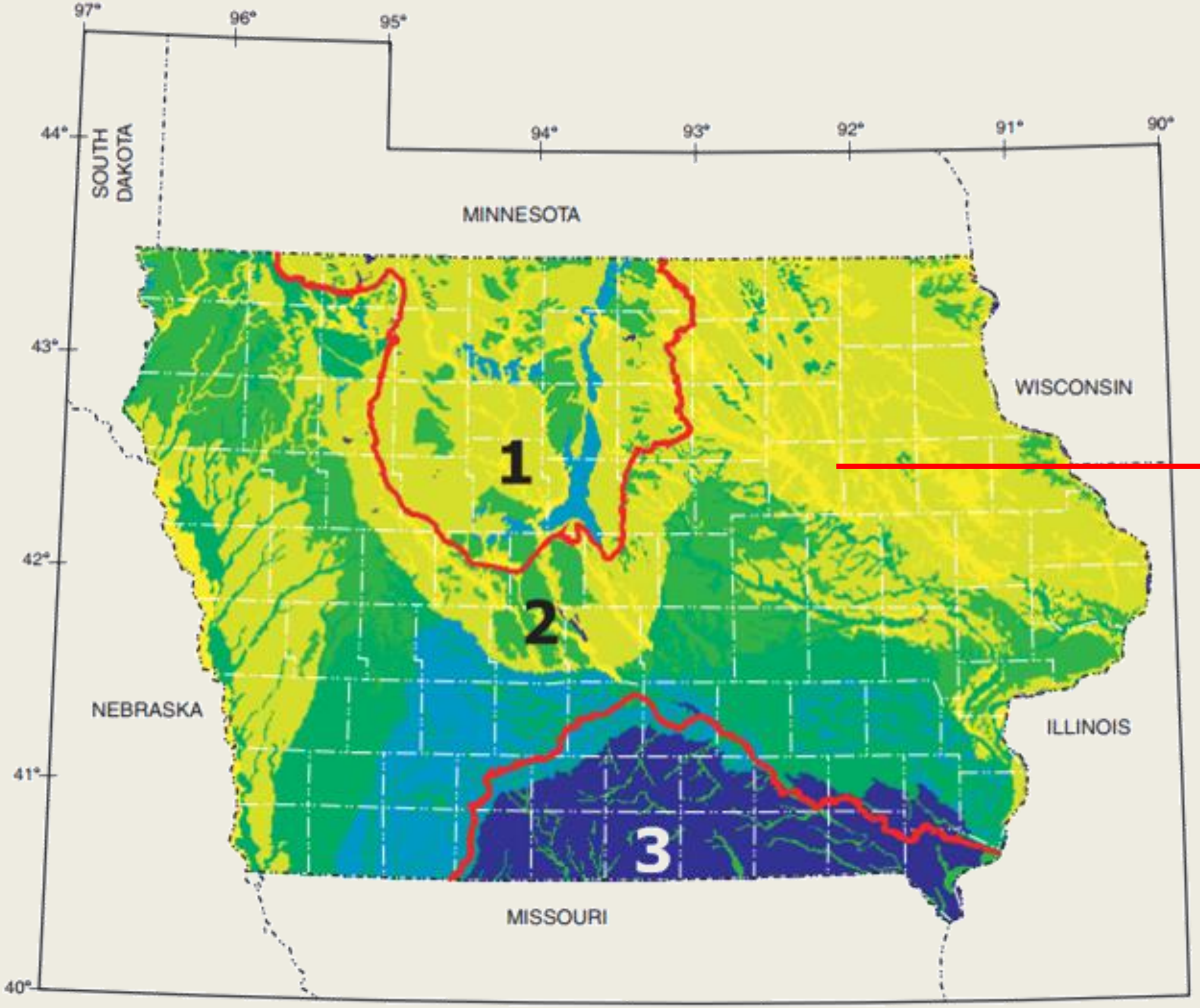
Combining statistical and physical aspects of flood frequency estimation

Annual flood peaks exhibit scaling



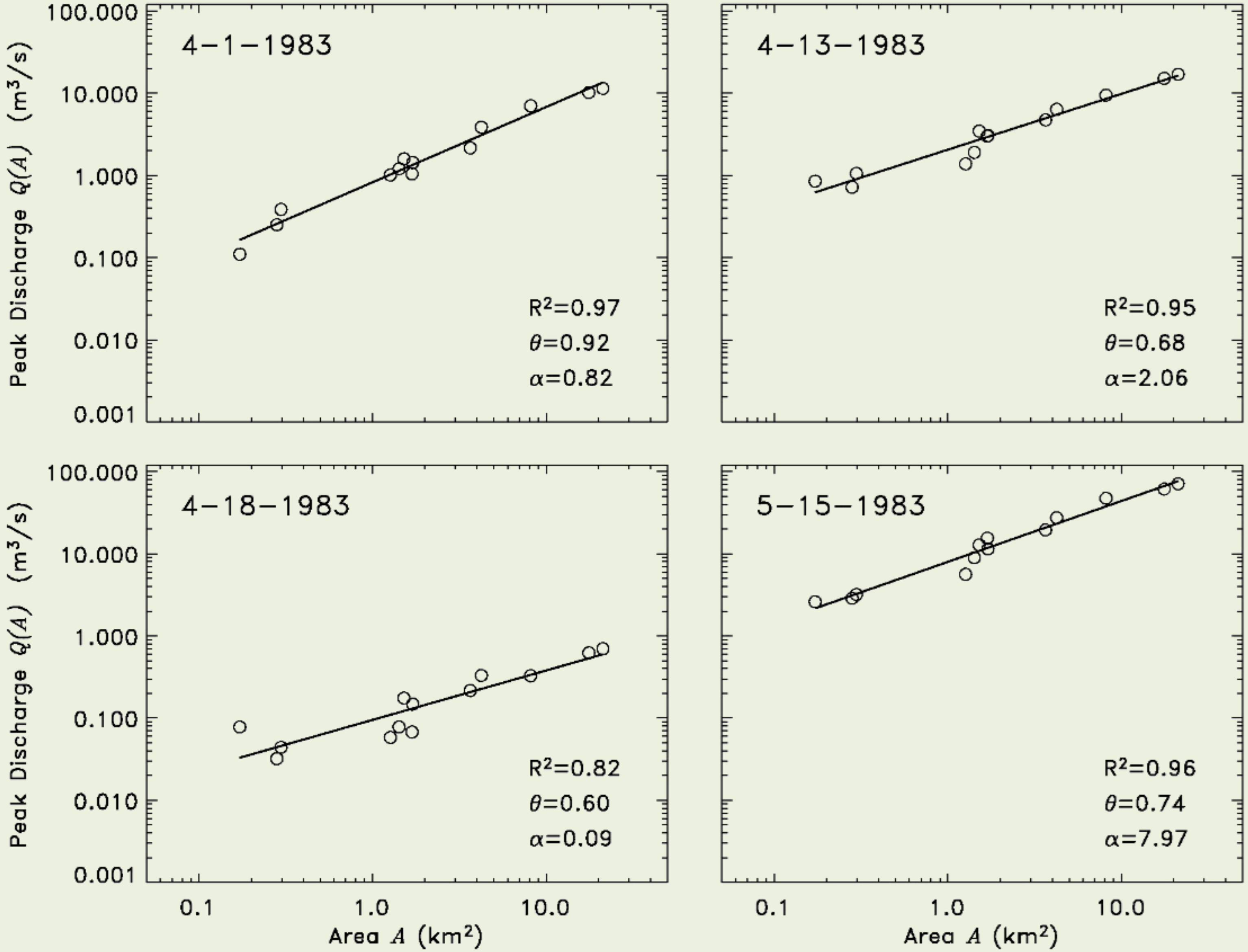


Regional (USGS) flood frequency equations for Iowa:
Do the parameters have any physical basis?

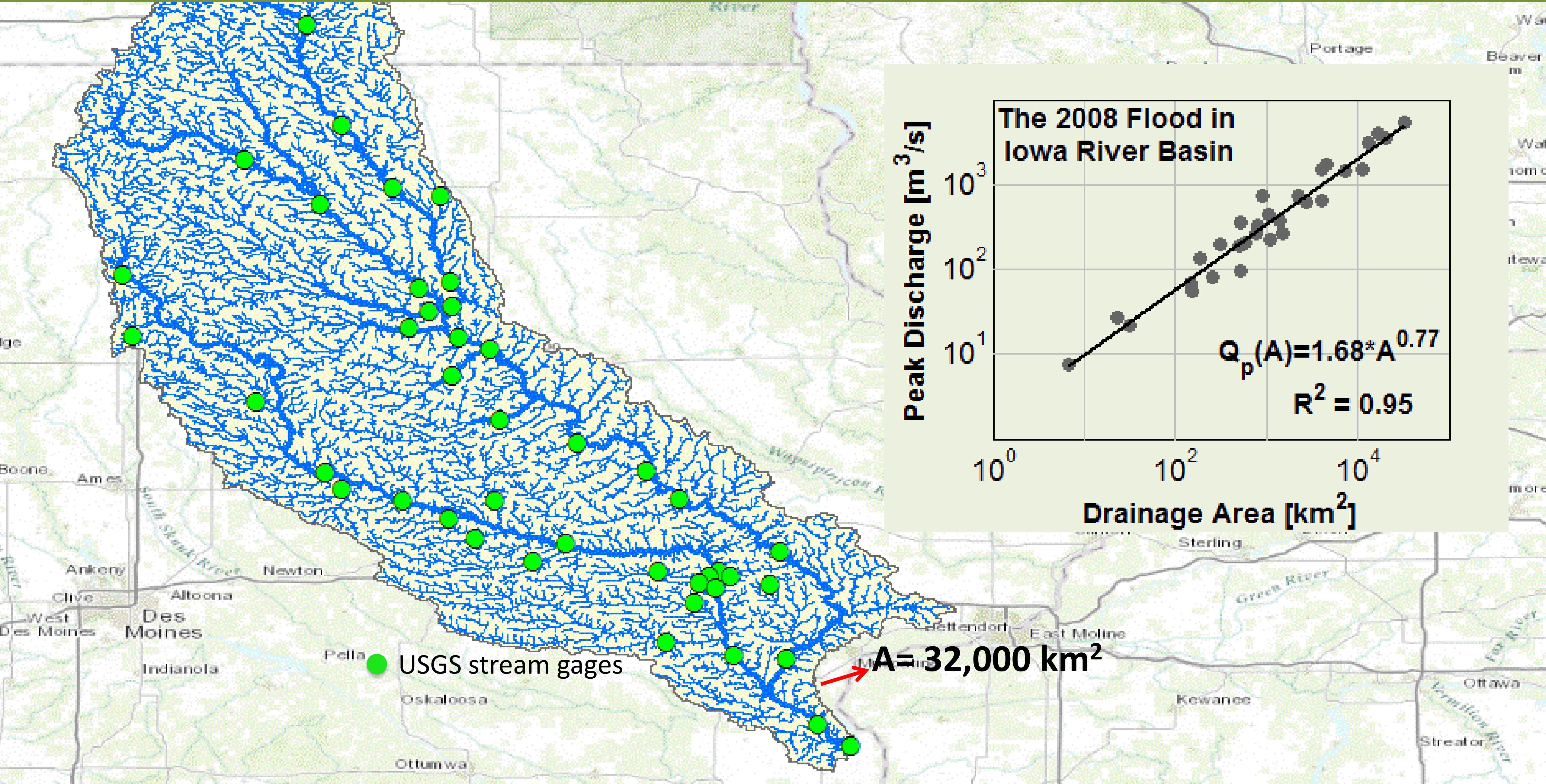


$$
\left\{
\begin{aligned}
Q_2 &= 3.083\,A^{0.54}\\
Q_5 &= 8.242\,A^{0.49}\\
Q_{10} &= 13.24\,A^{0.47}\\
Q_{25} &= 20.84\,A^{0.44}\\
Q_{50} &= 27.16\,A^{0.43}\\
Q_{100} &= 34.34\,A^{0.42}\\
Q_{200} &= 42.45\,A^{0.40}\\
Q_{500} &= 54.56\,A^{0.39}
\end{aligned}
\right.
$$

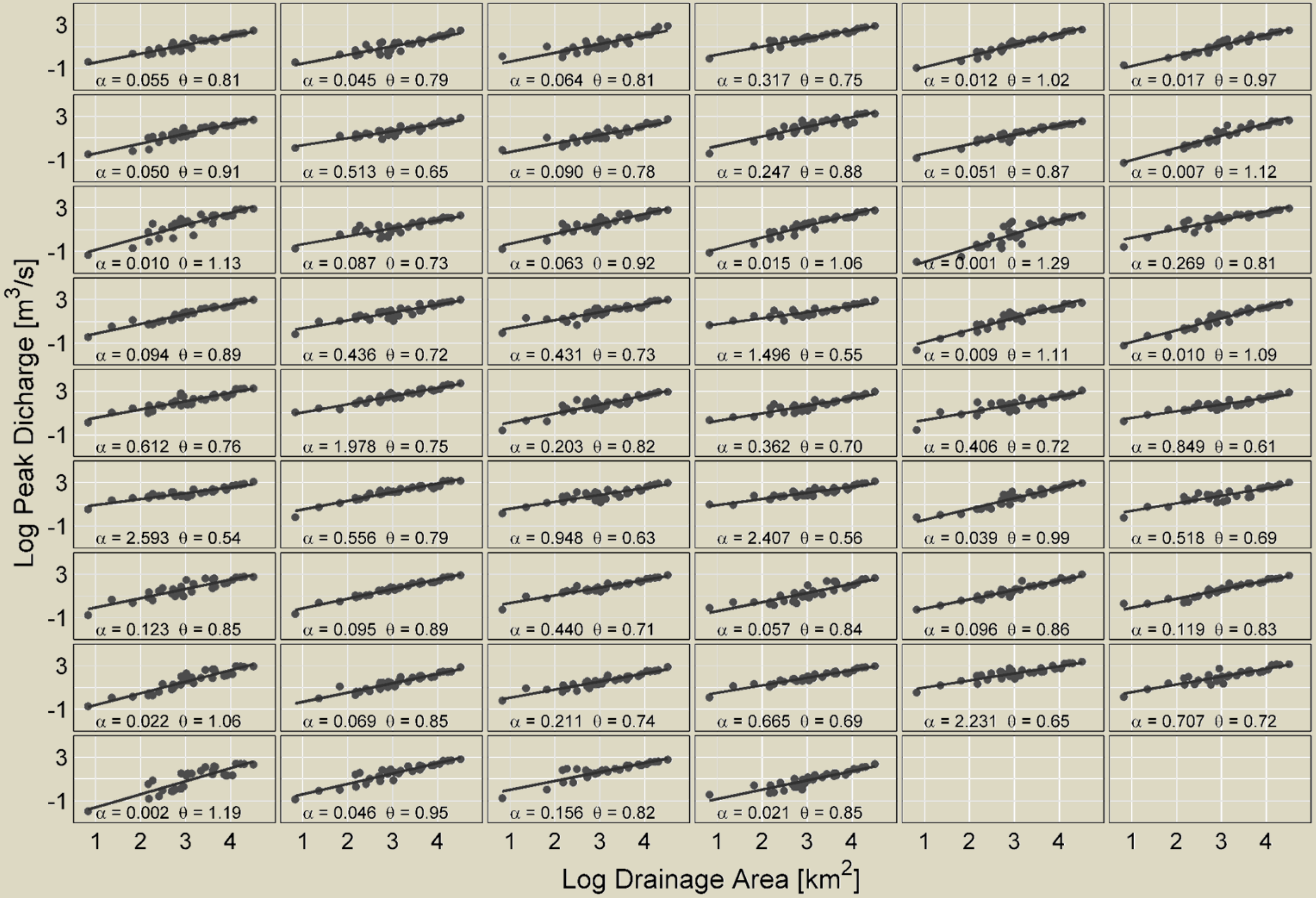
Flood events also exhibit scaling



Strong scaling in peak flows

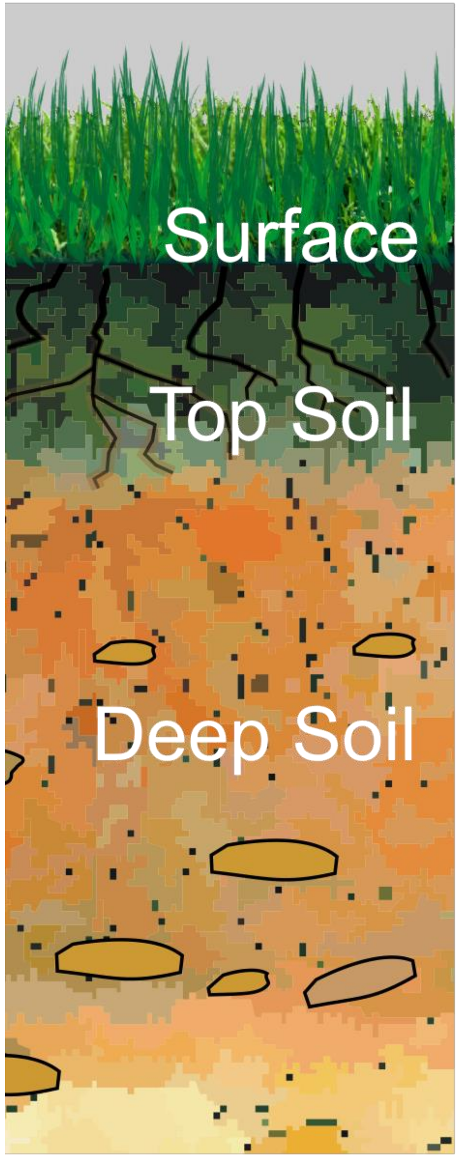


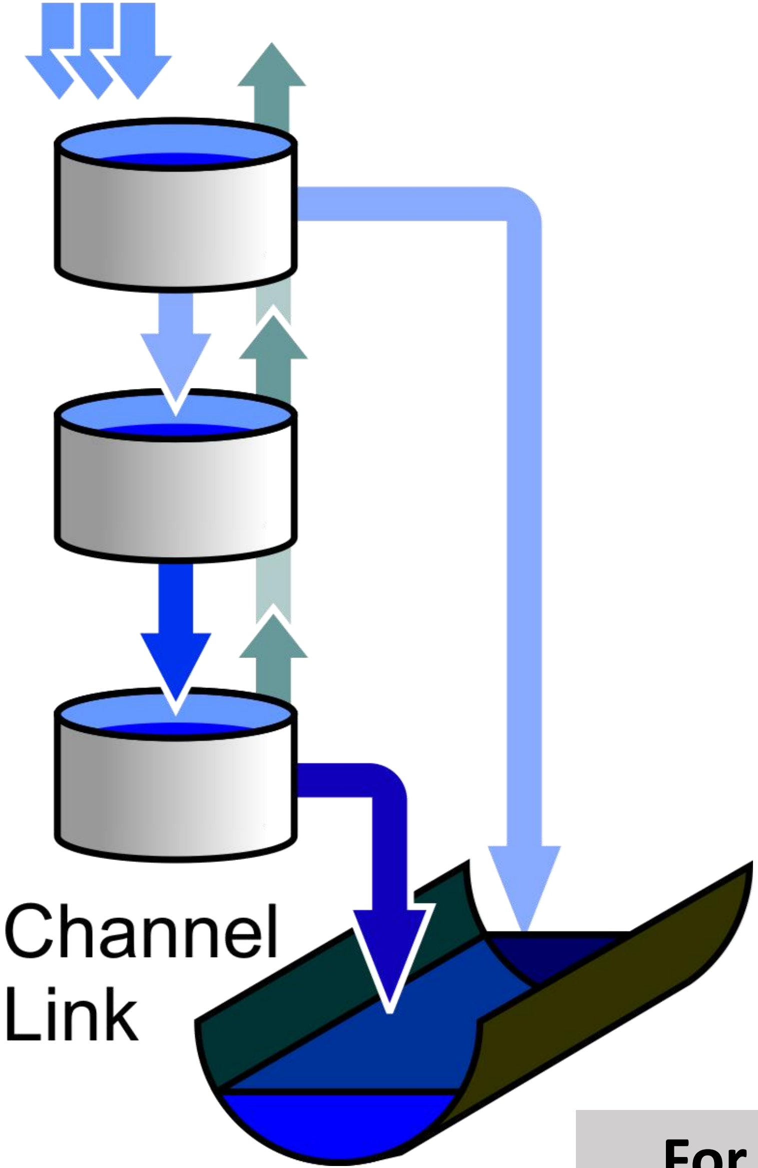
52 events (R^2 ~0.74-0.97) exhibit scaling parameter variability

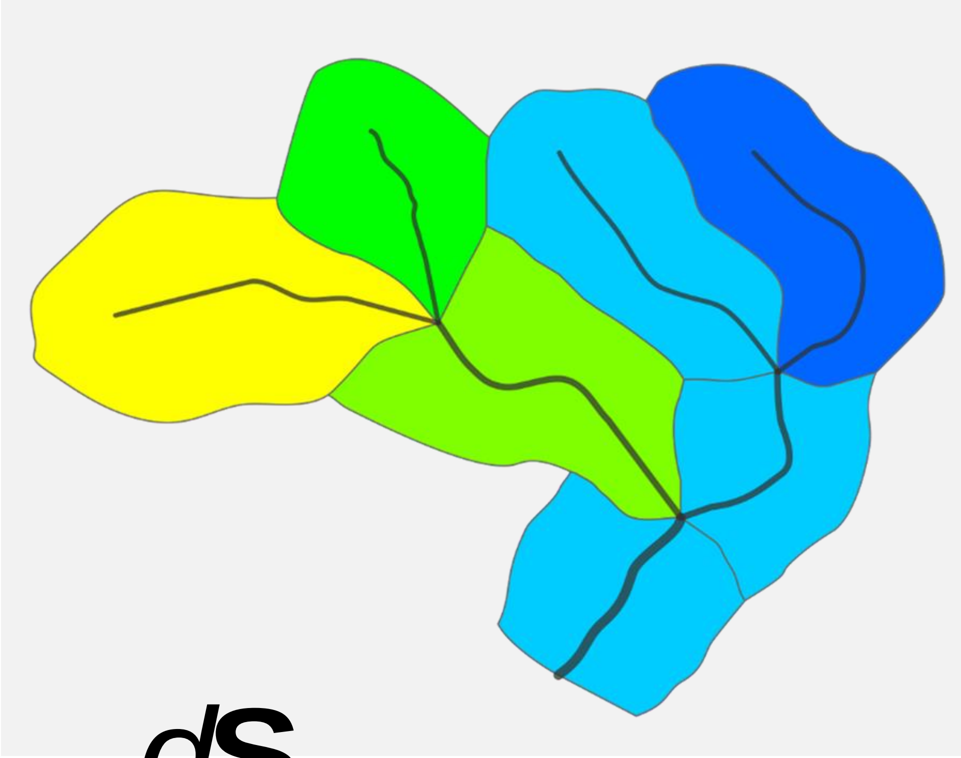


Rainfall-Runoff Model

The Hillslope Link Model







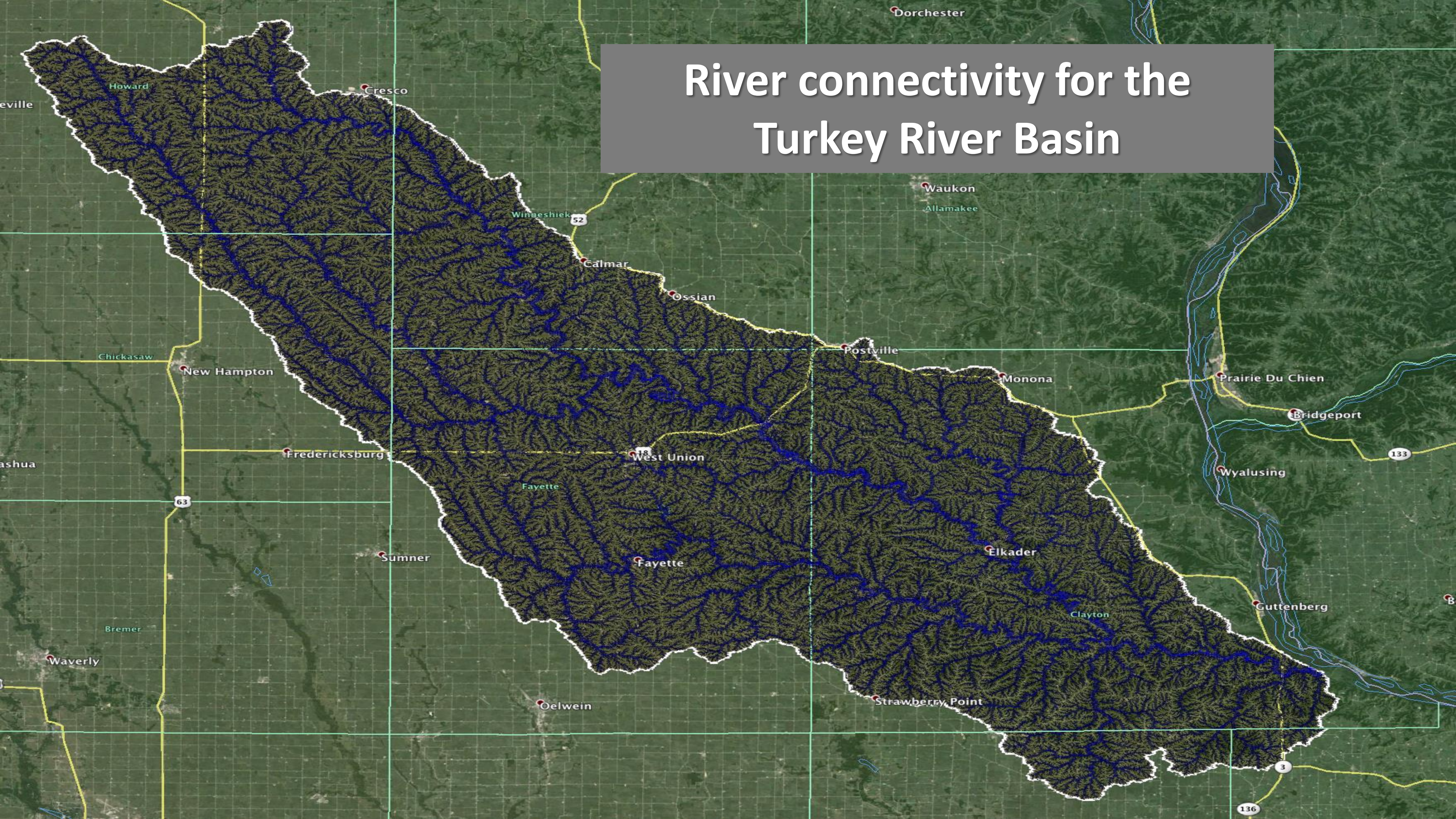
$$\frac{dS}{dt} = f(S, I, P)$$

For Iowa the system of ~2,000,000 equations

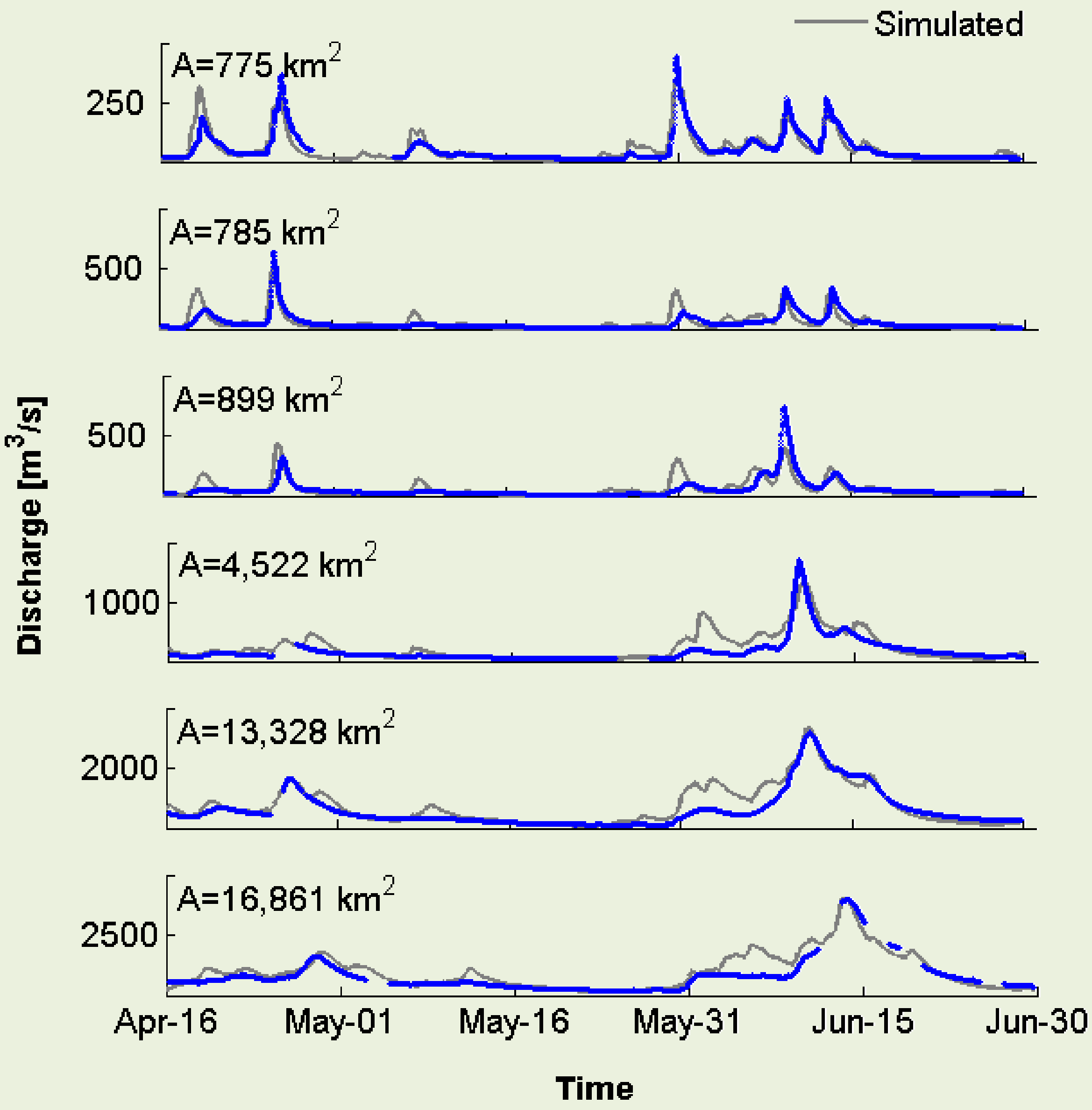
Laser Rd
Jet Rd
Greeley
38
147th St
150th St
C64
155th St
th Ave

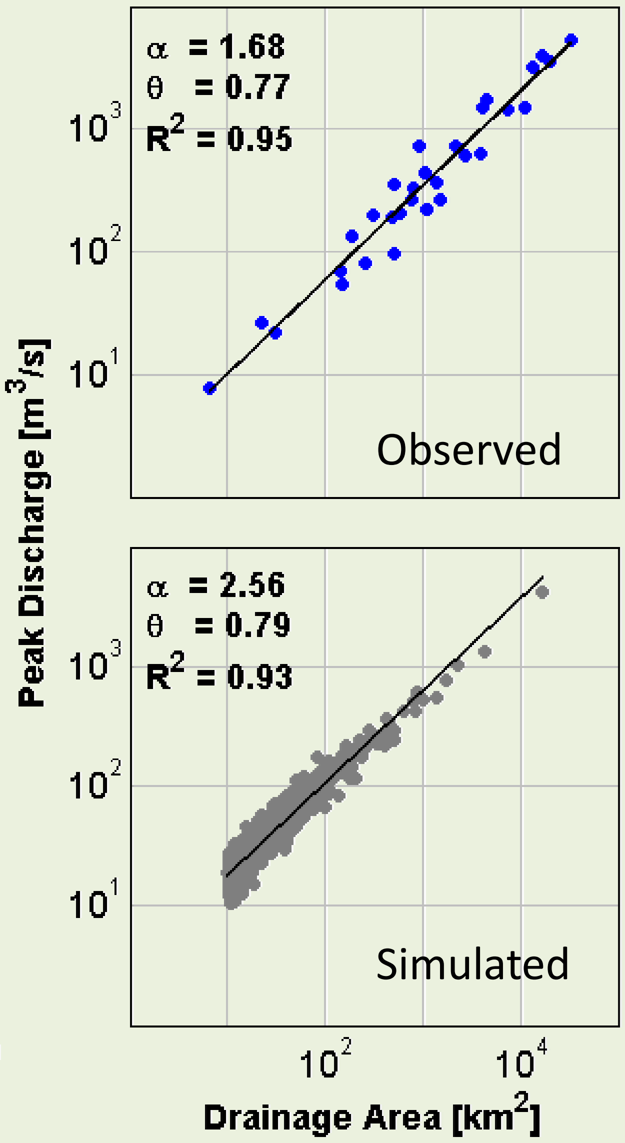

Parameters describing soil conductivity, infiltration capacity, slope, and roughness are assigned to each terrain unit
Greeley
240th Ave
147th St
1000 ft
© 2015 Google
Google earth

River connectivity for the Turkey River Basin

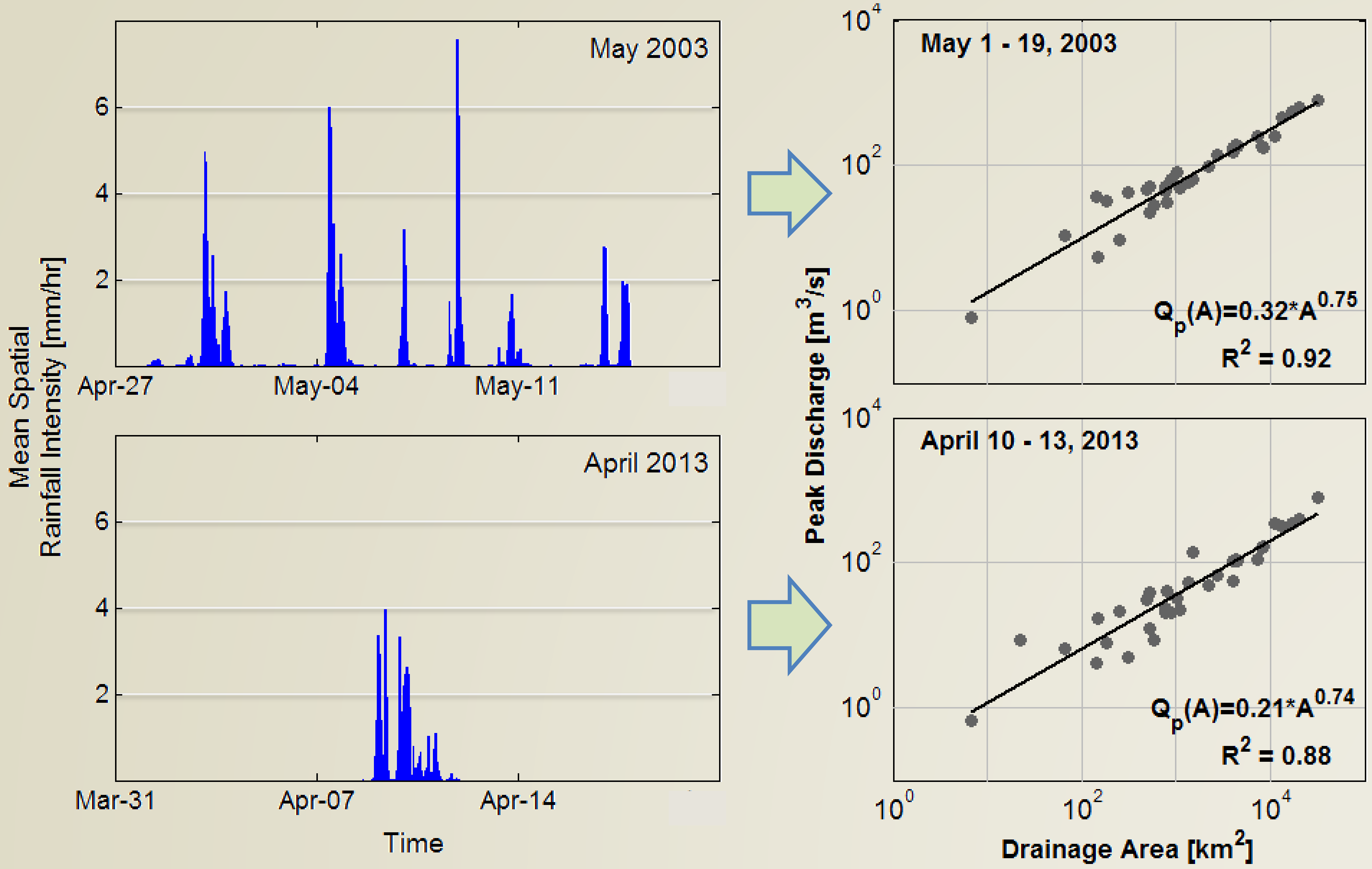


Simulation is essential to diagnose the role of rainfall intermittency

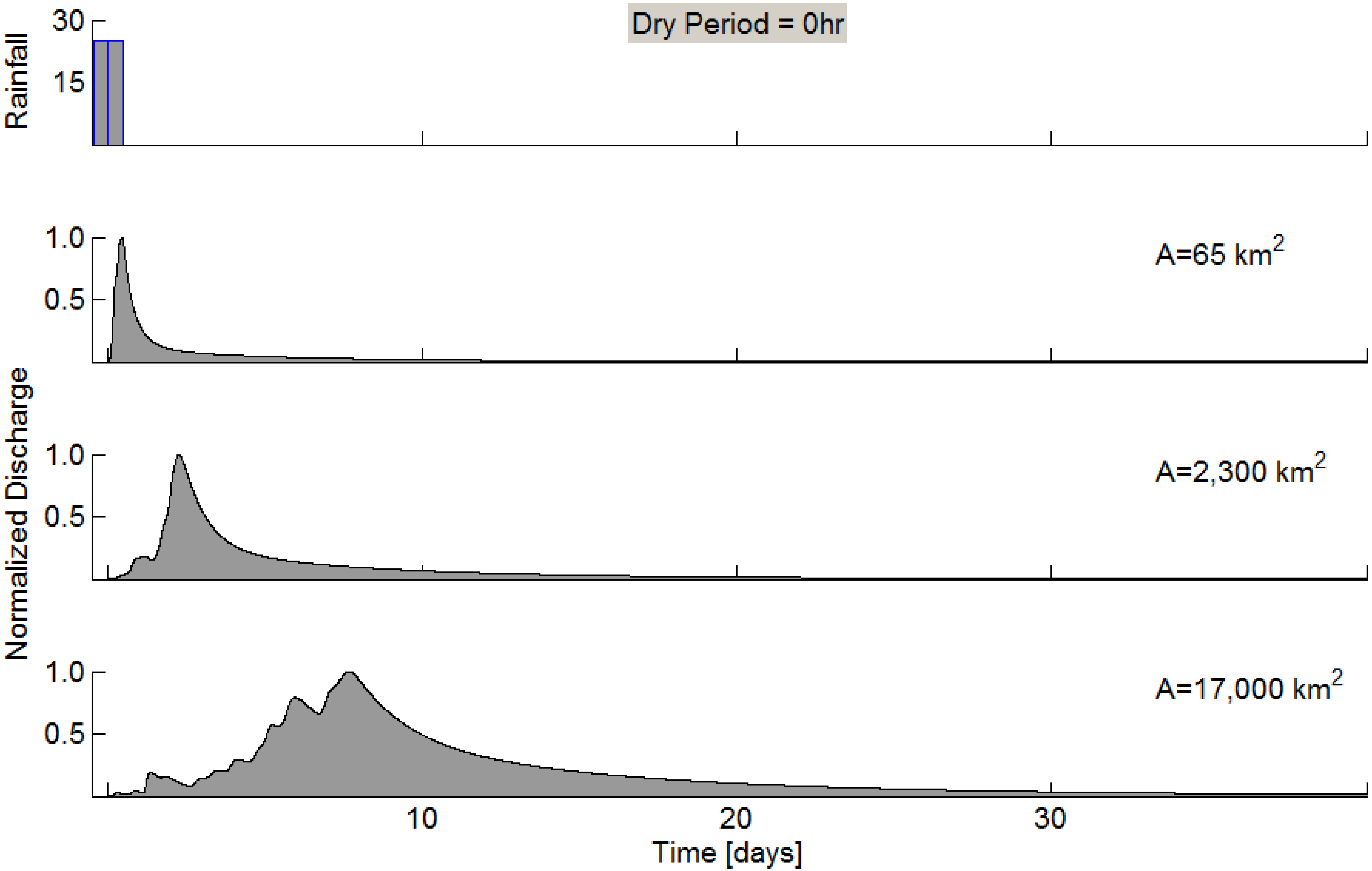




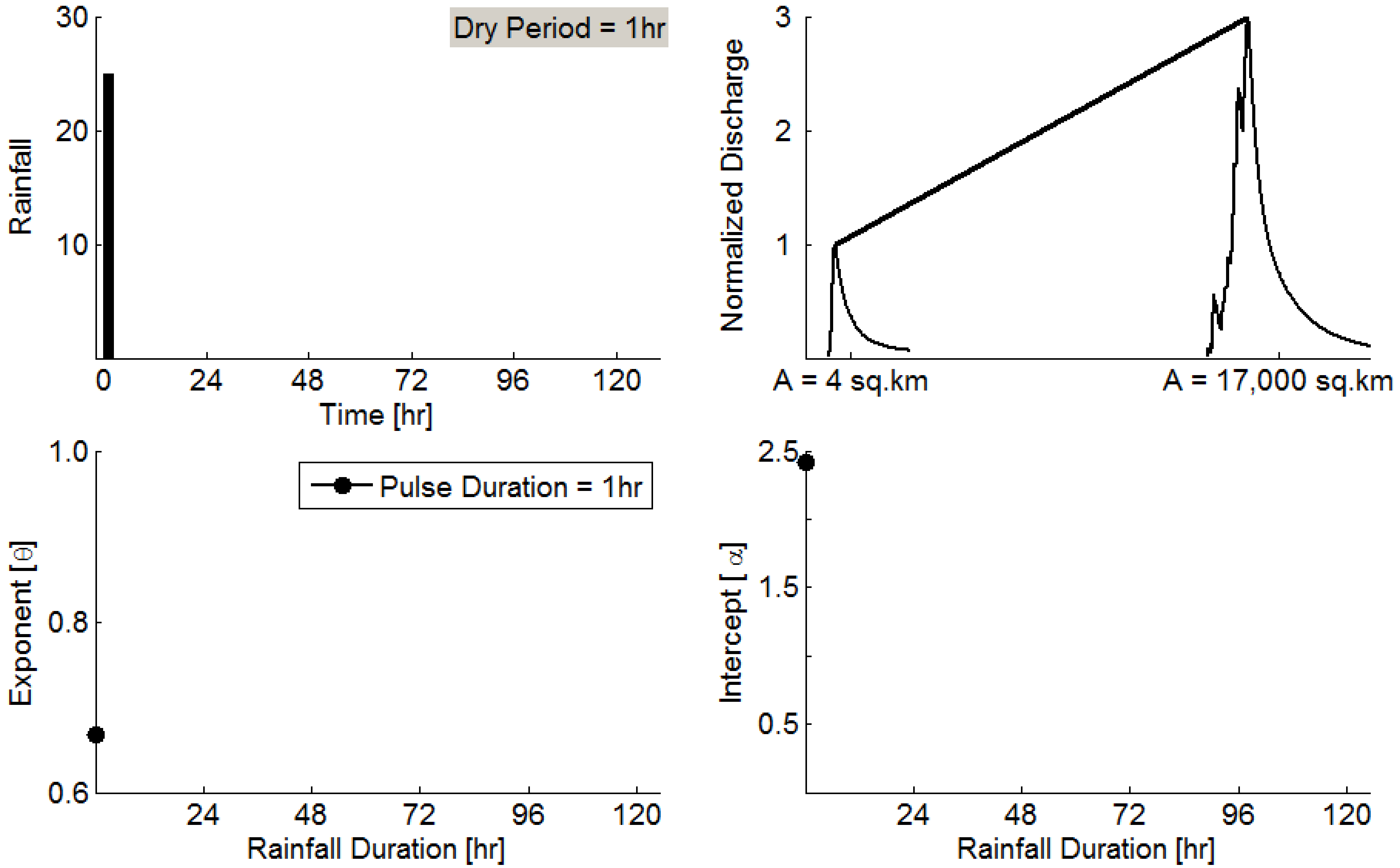
Rainfall intermittency affects peak-discharge scaling structure

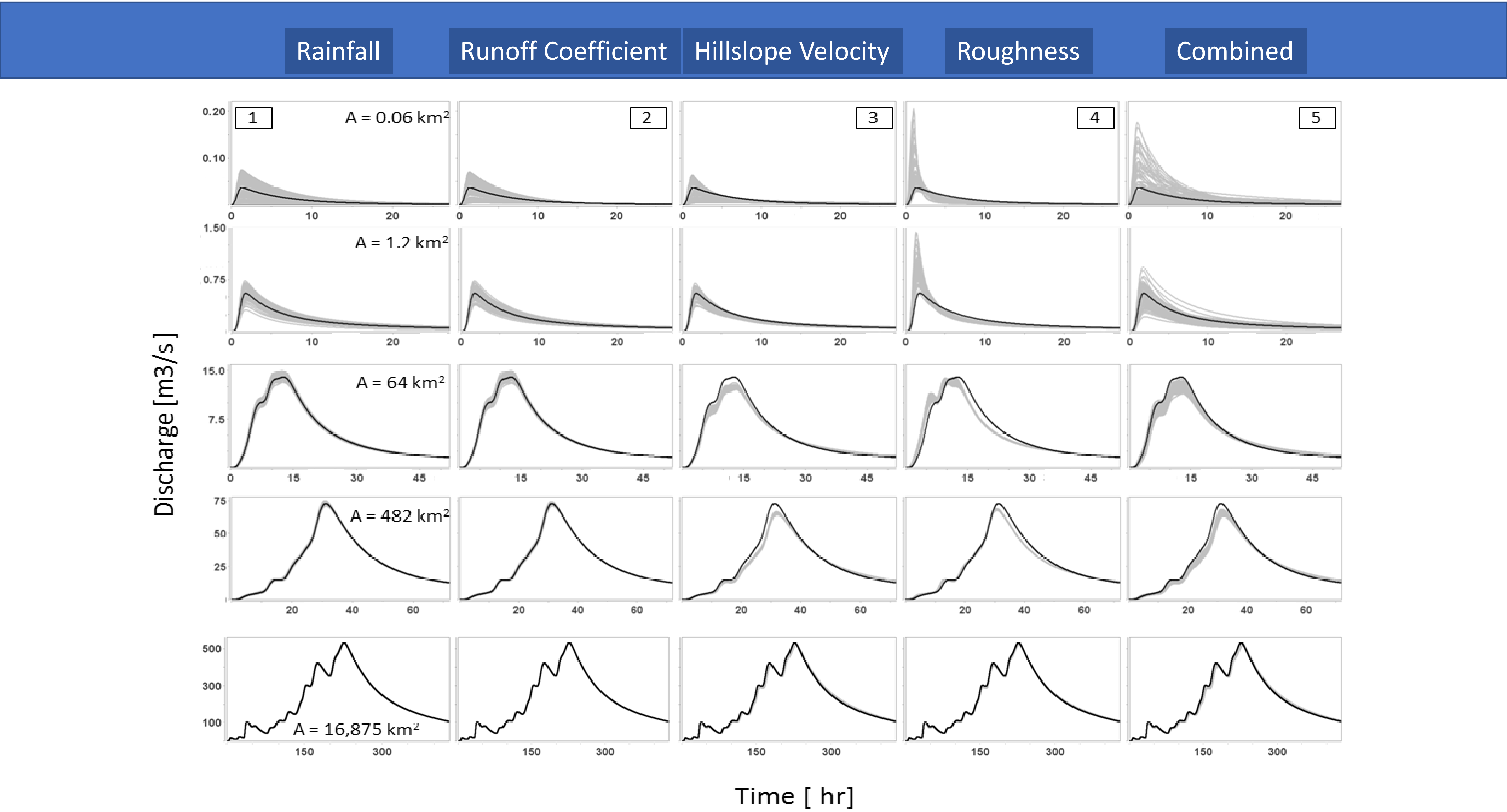


Rainfall temporal intermittency significantly affects peak-discharge scaling structure



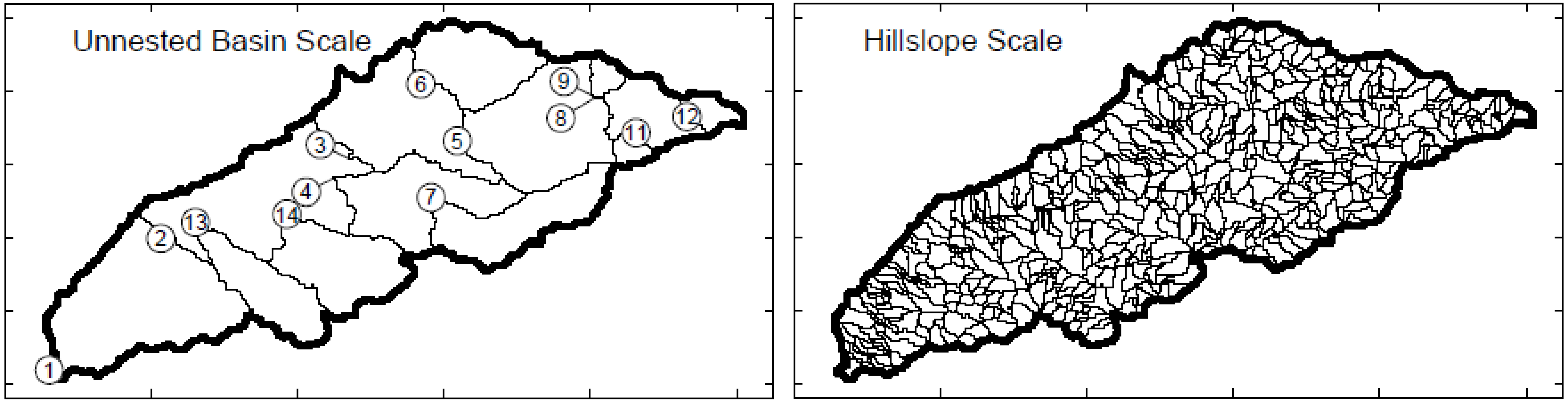
Rainfall temporal intermittency significantly affects peak-discharge scaling structure

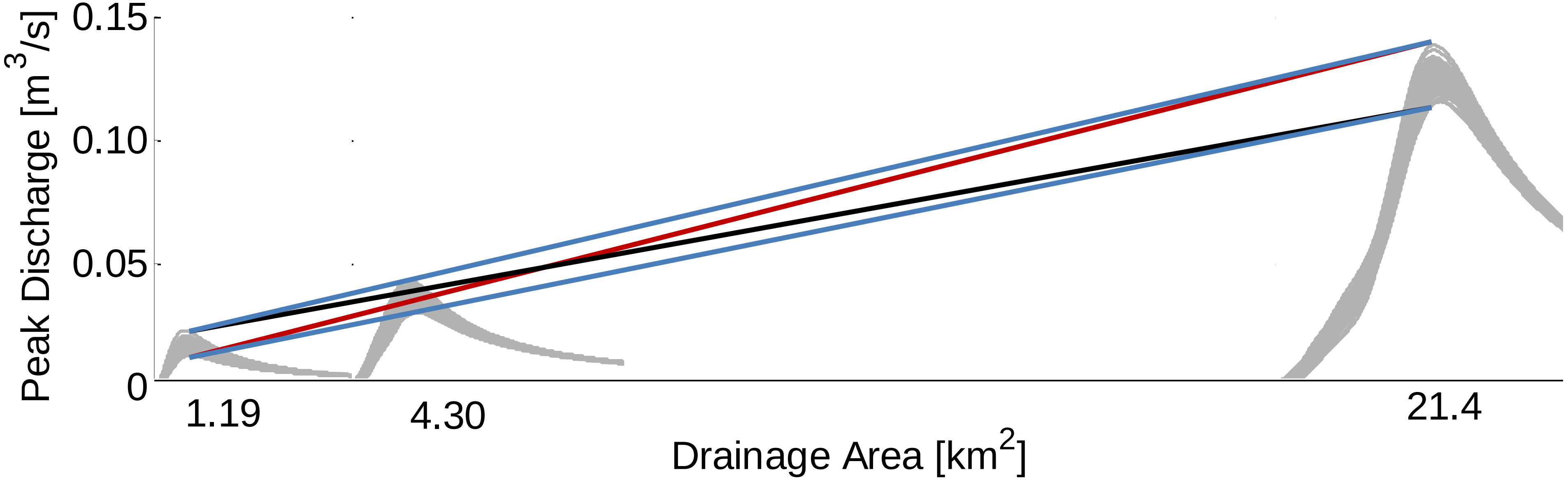


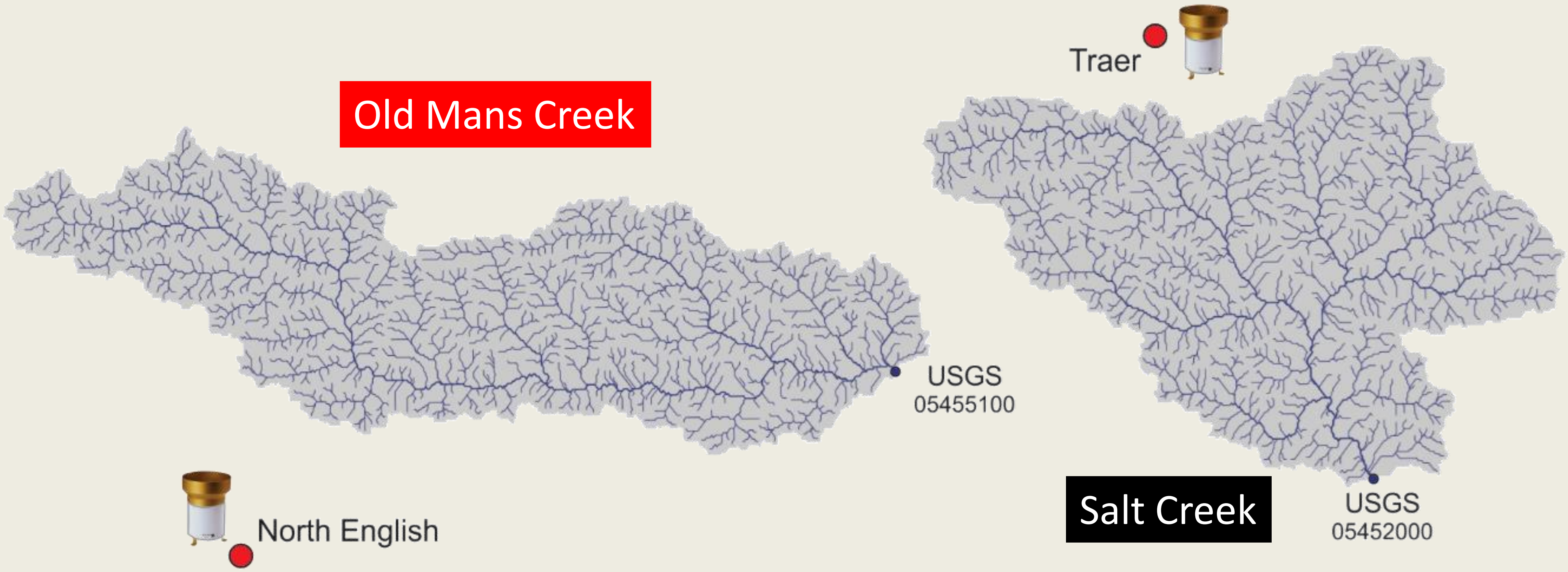


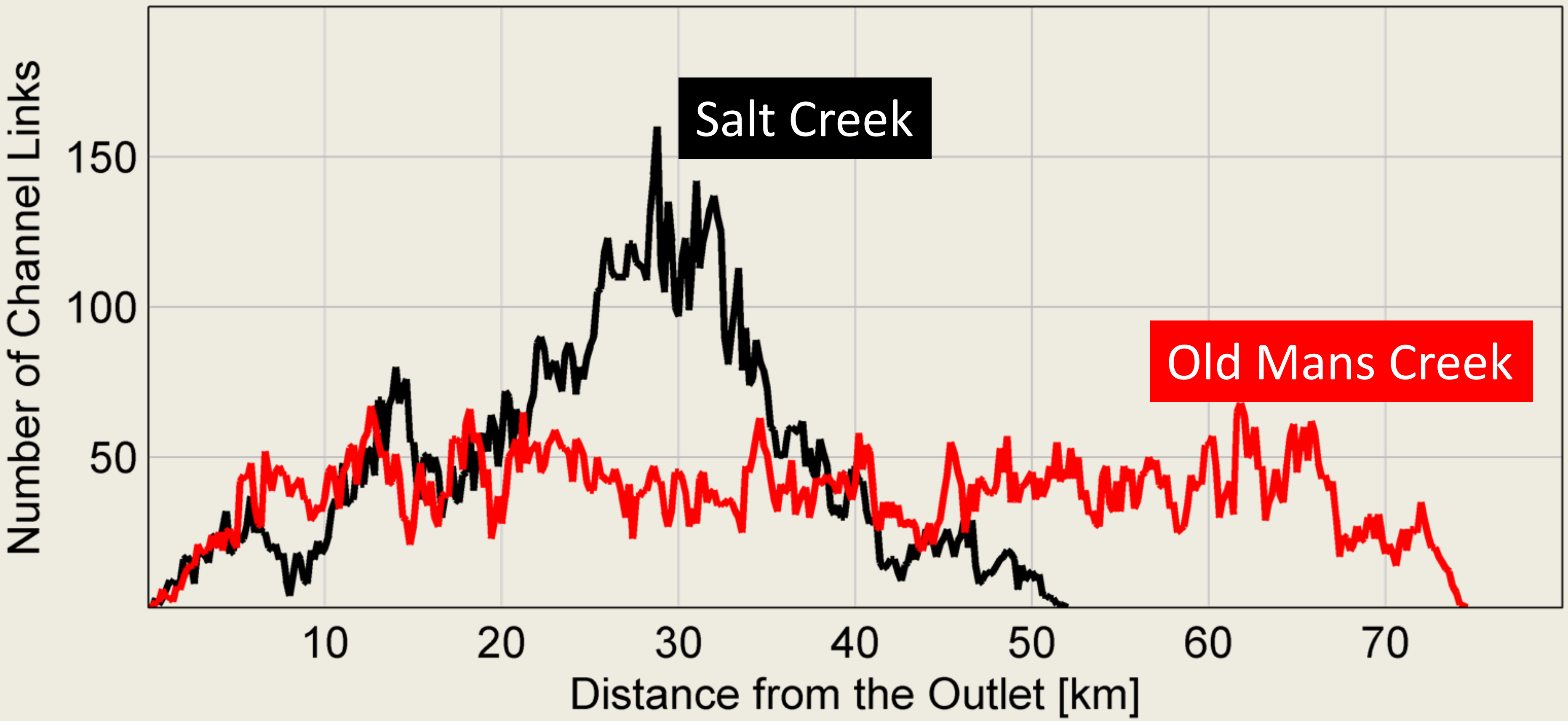
Rainfall
Runoff Coefficient
Hillslope Velocity
Roughness
Combined
1
2
3
4
5
A = 0.06 km²
A = 1.2 km²
A = 64 km²
A = 482 km²
A = 16,875 km²
Discharge [m3/s]
Time [hr]

Towards flood frequency estimation

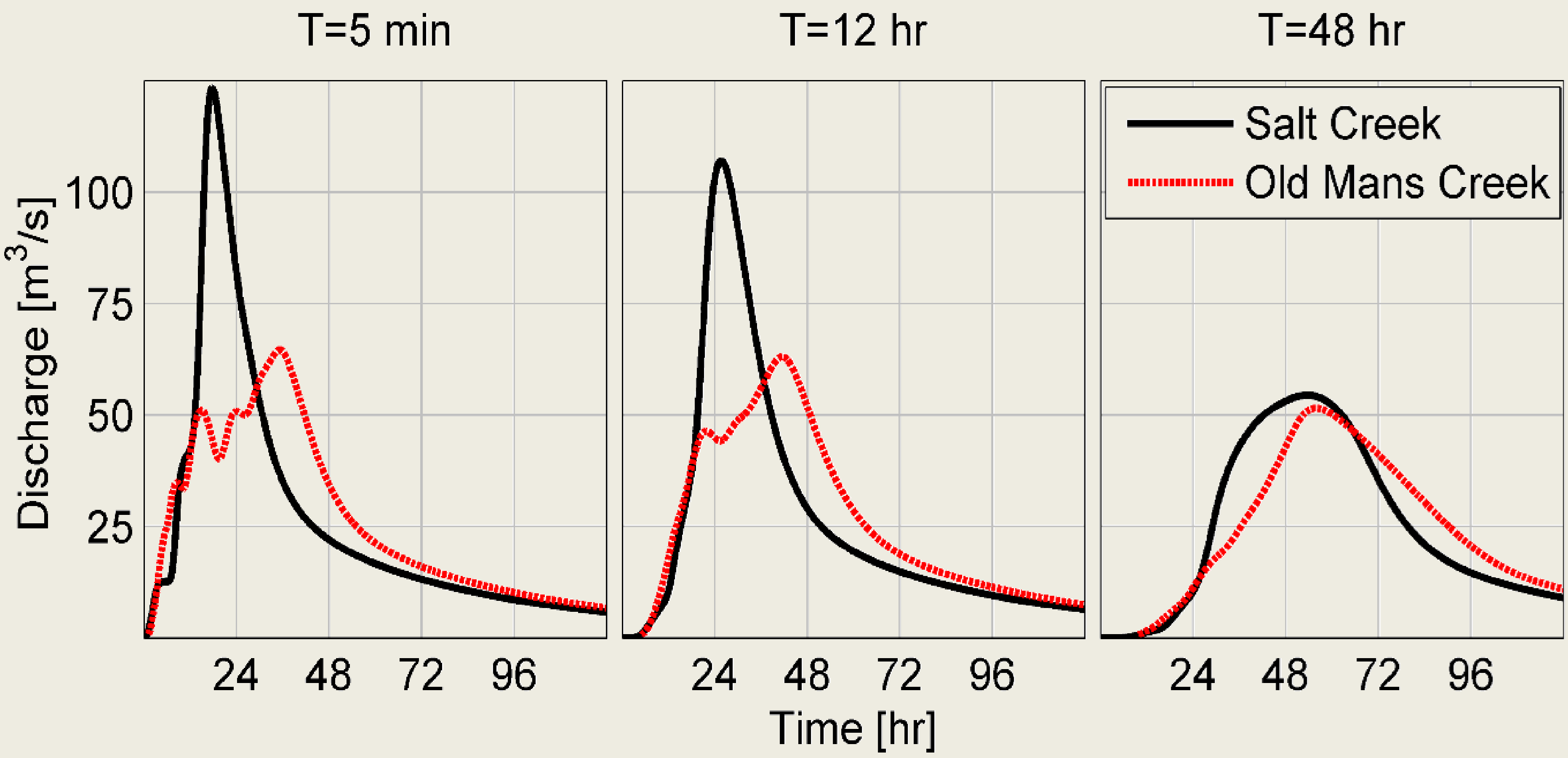




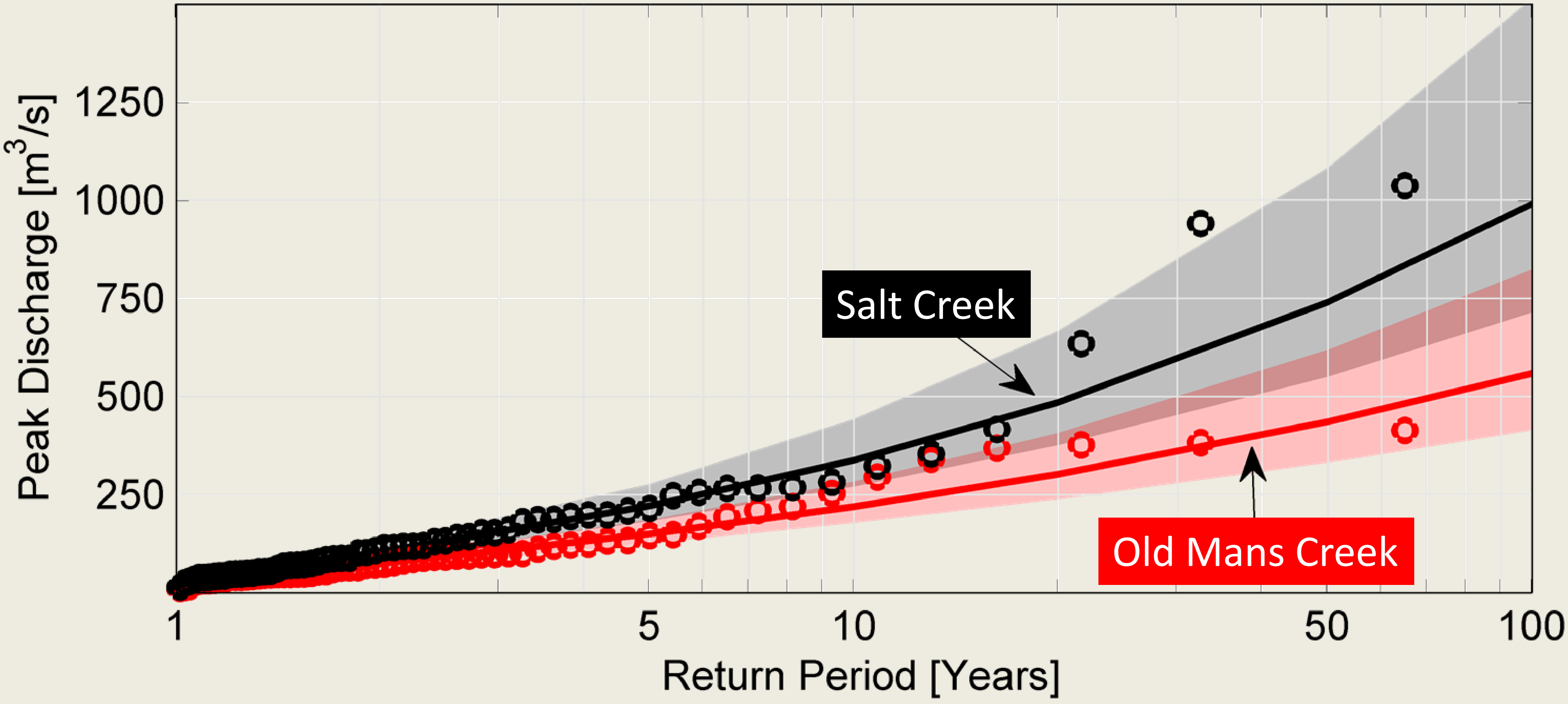

Old Mans Creek
USGS
05455100
North English
Traer
Salt Creek
USGS
05452000


Salt Creek
Old Mans Creek
Number of Channel Links
150
100
50
10
20
30
40
50
60
70
Distance from the Outlet [km]

The longer the storm the more similar the response

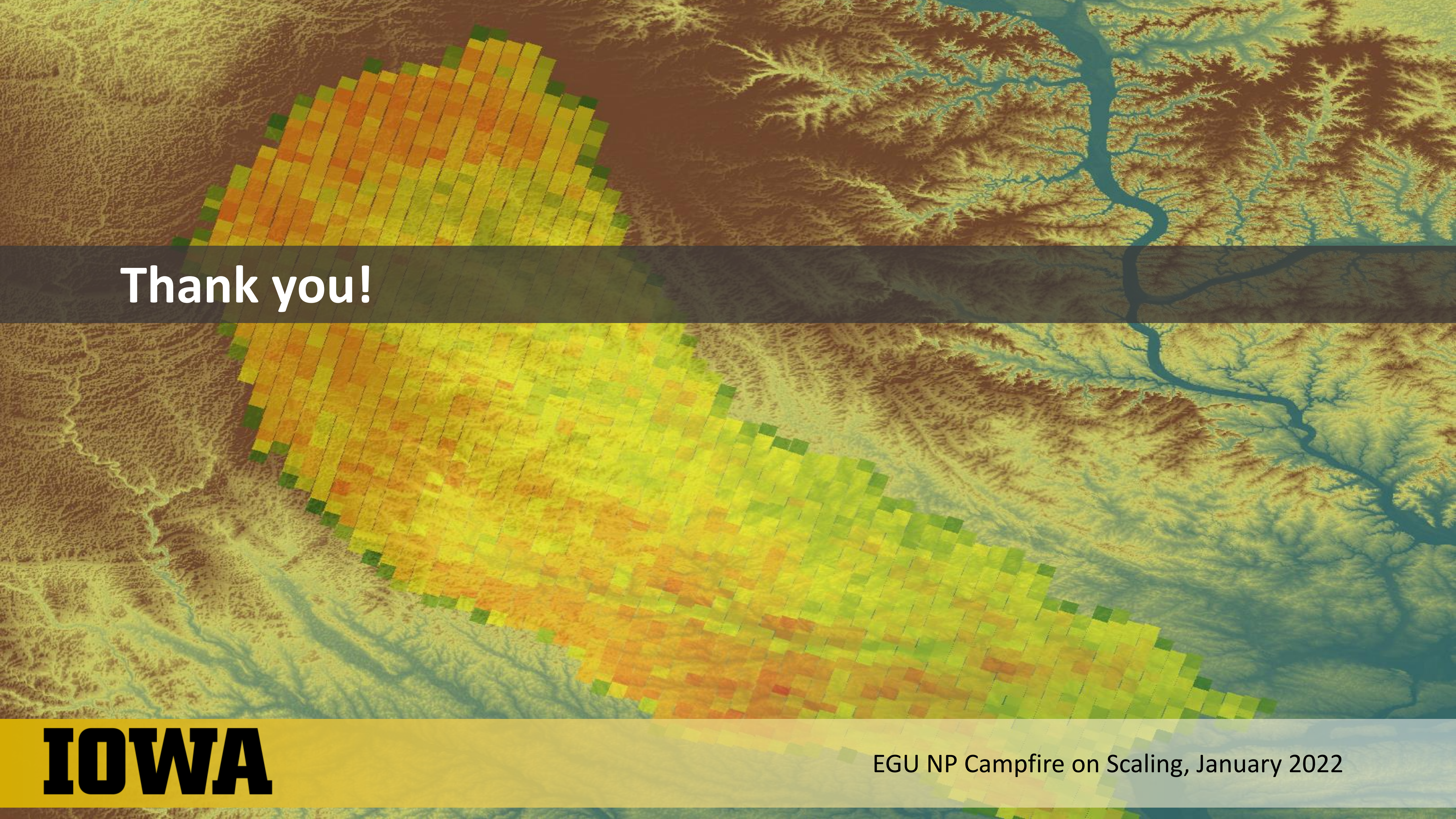


Same size, different shape, different the response



Summary:

- The scaling exponent increases with increasing rainfall duration
- The intercept increases with increasing excess rainfall
- Rainfall intermittency and antecedent moisture systematically affect the peak-discharge scaling structure
- **Rainfall-runoff models are essential but only if they have skill without calibration**



Thank you!