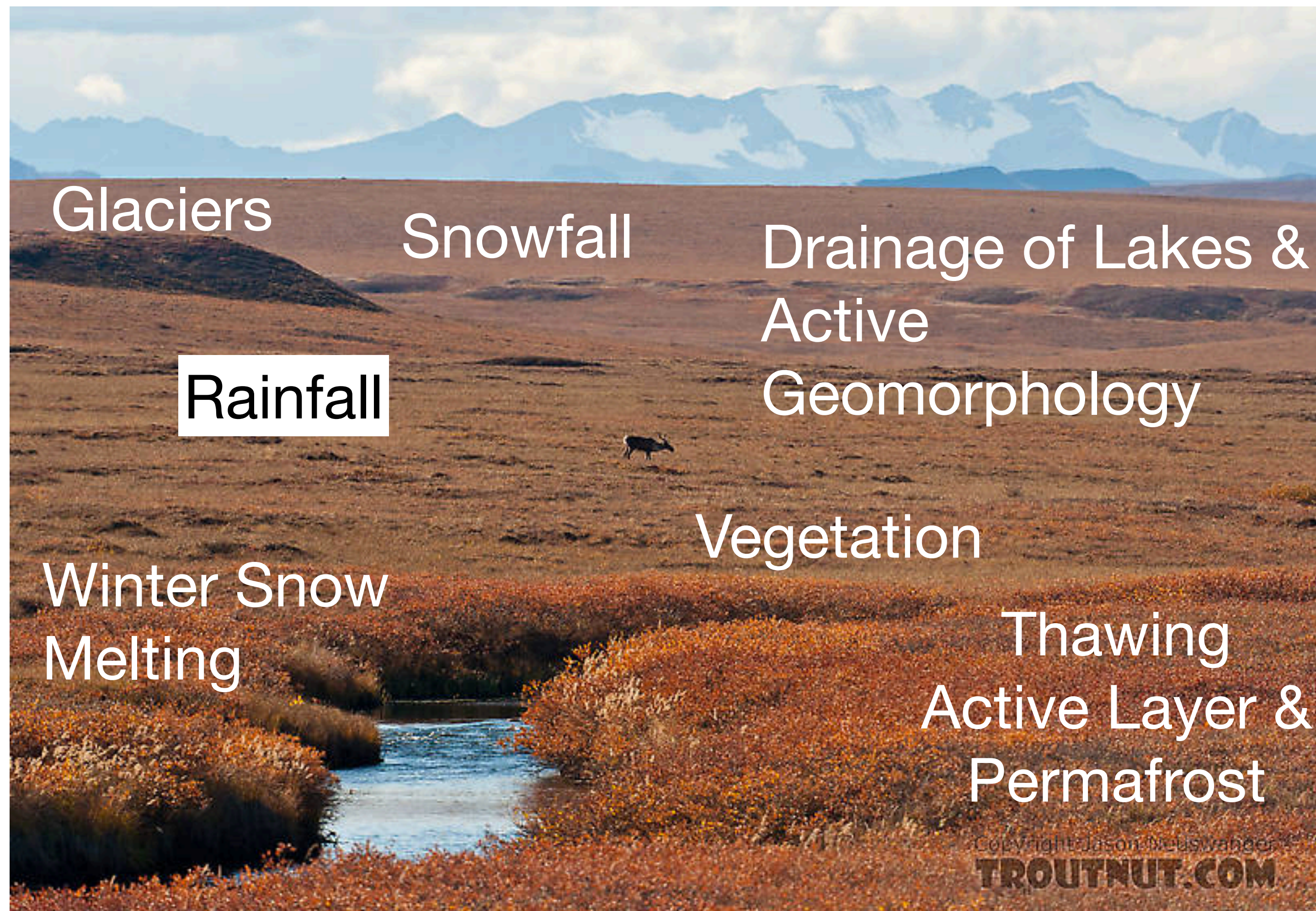


Characterizing long and short term drivers of periglacial catchment hydrology.

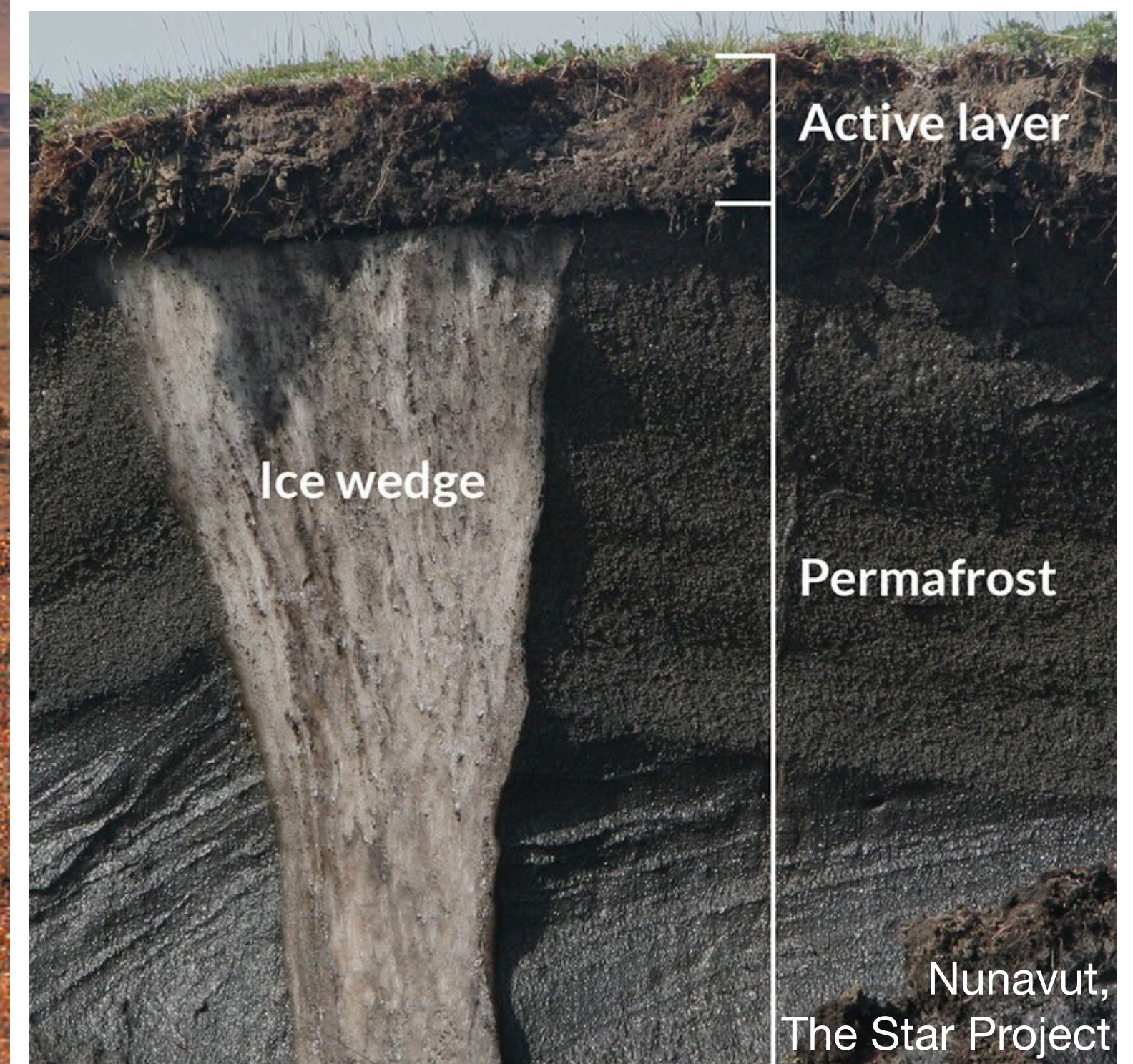


Periglacial systems have multiple sources impacting river runoff.

Goal: isolate a single source [rainfall] and identify what governs its coupling to runoff



Kuparuk River,
The North Slope of
Alaska, USA

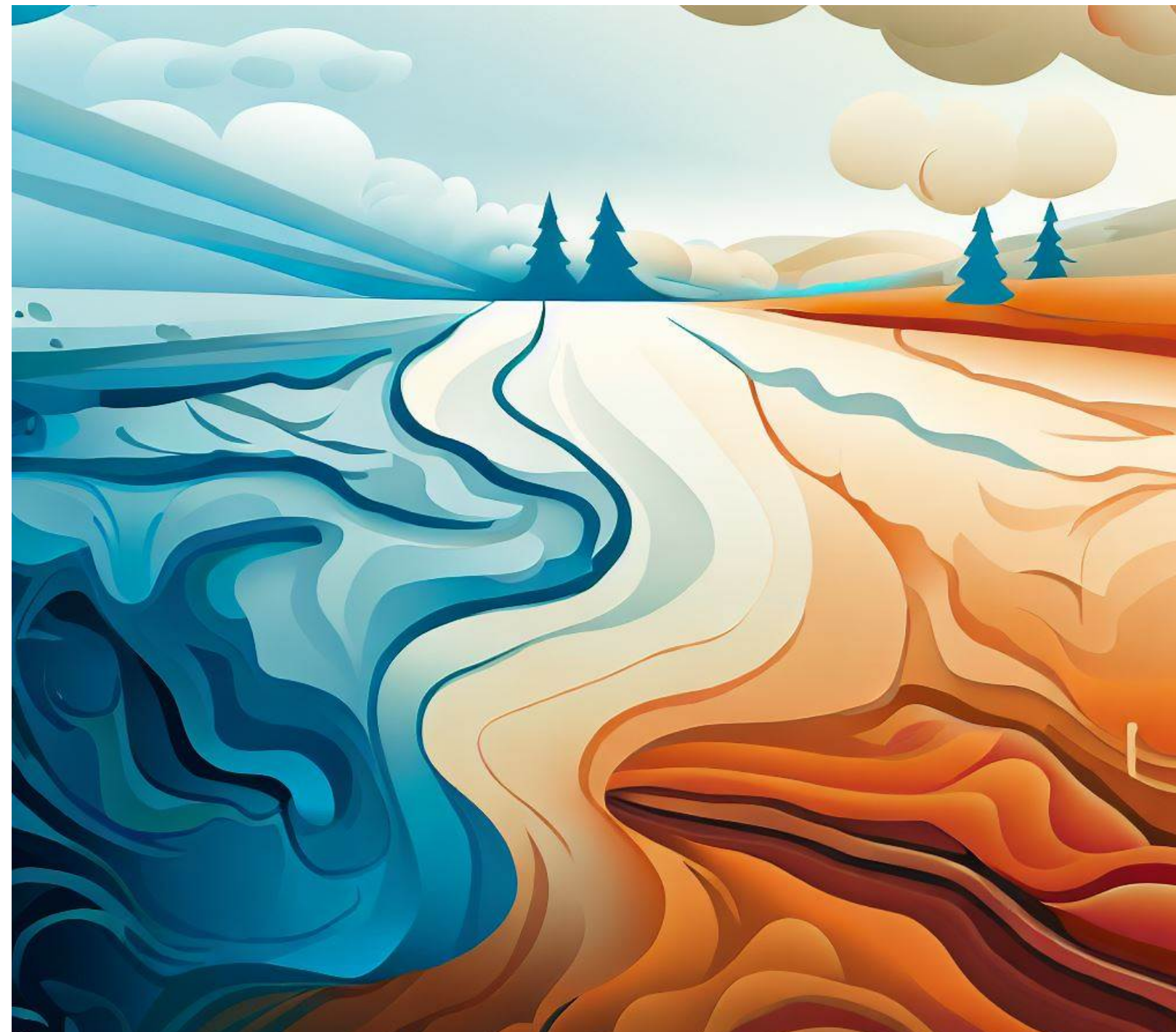


How does the runoff response to rainfall change year-year and month-month?

Years

<—>

Months



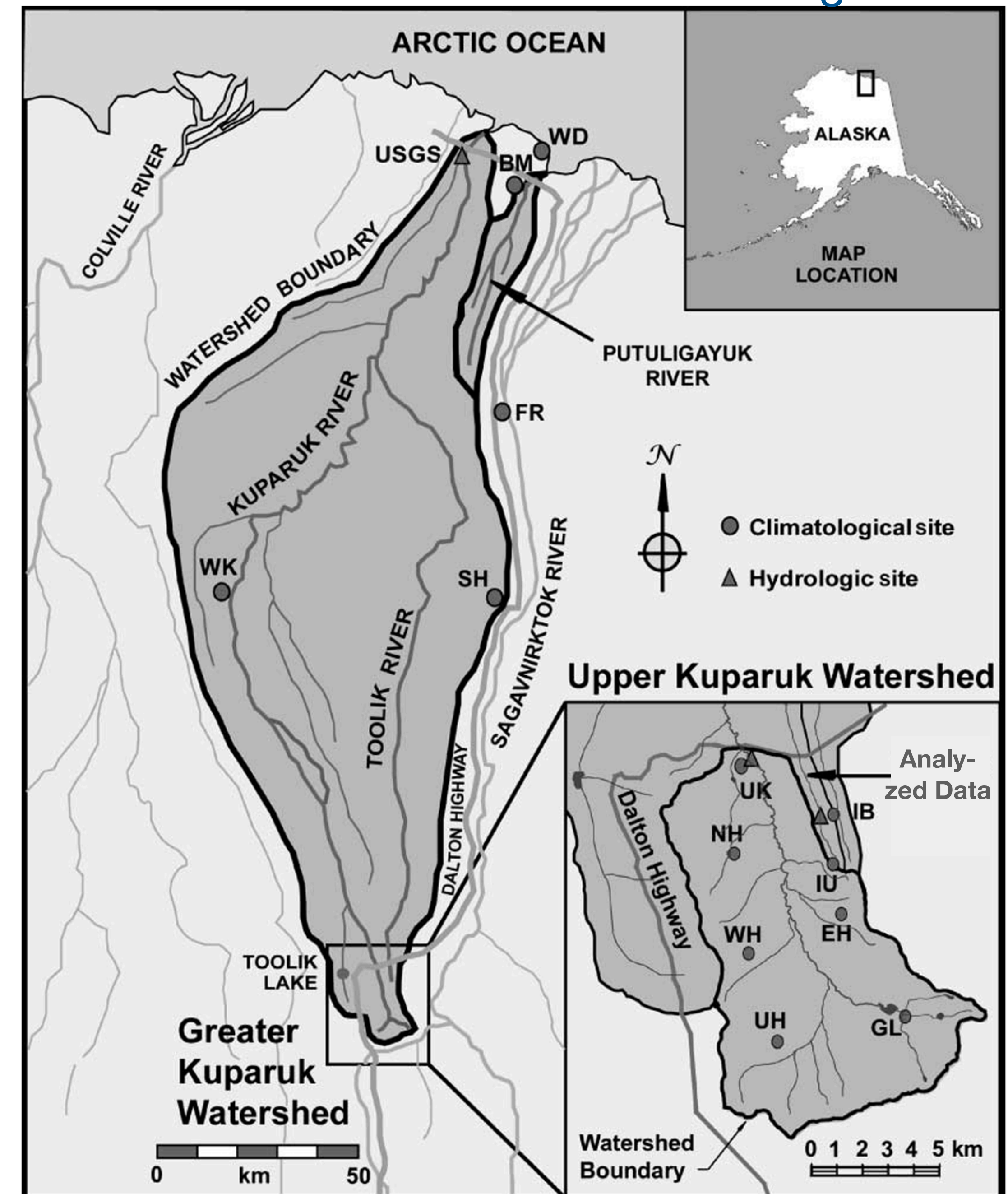
Upper Kuparuk River

Continuous permafrost
Catchment Area: 142 km²



Upper Kuparuk River,
The North Slope of Alaska, USA

TROUTNUT.COM



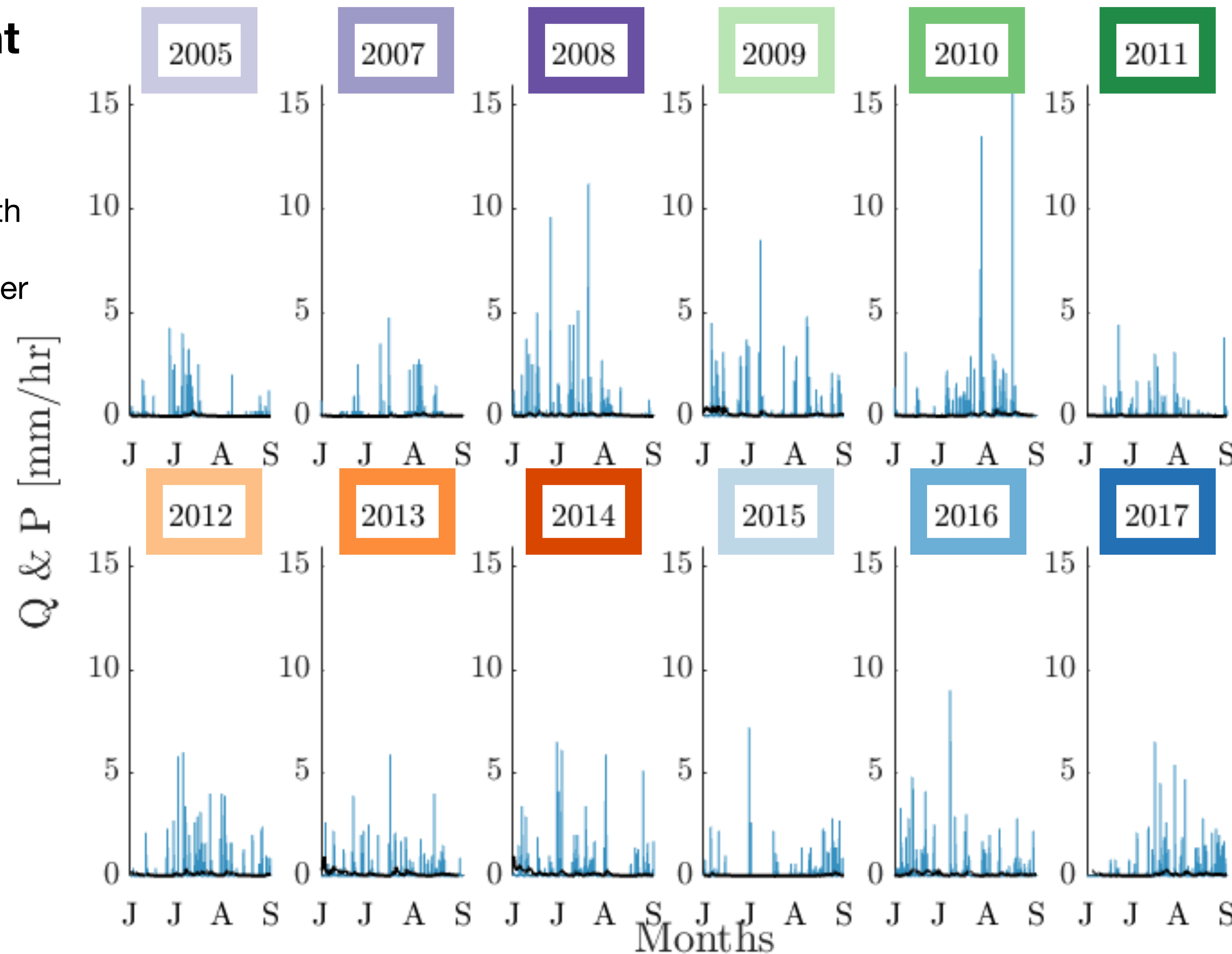
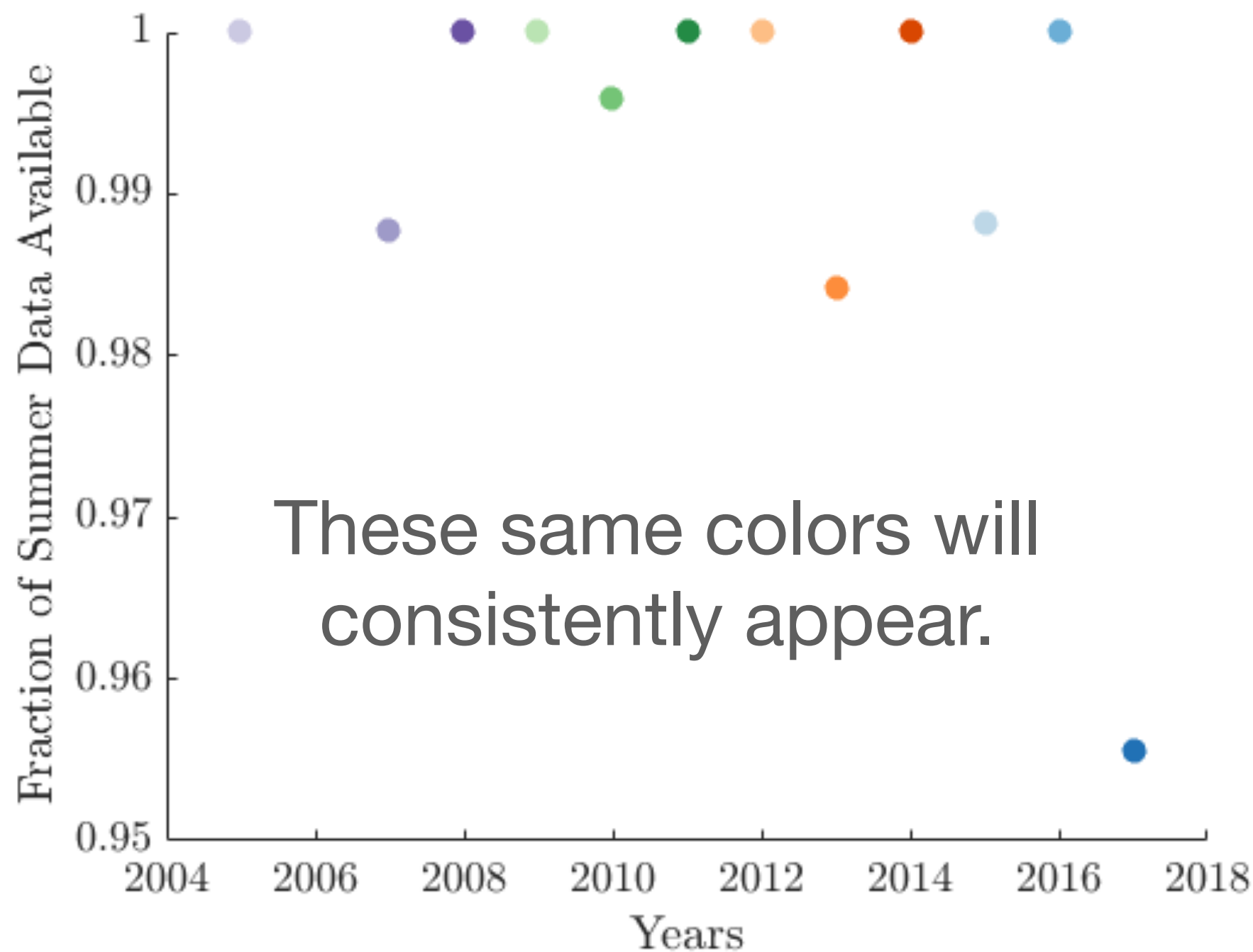
Challenge:

Data availability is inconsistent so we need statistical models to do proper comparisons

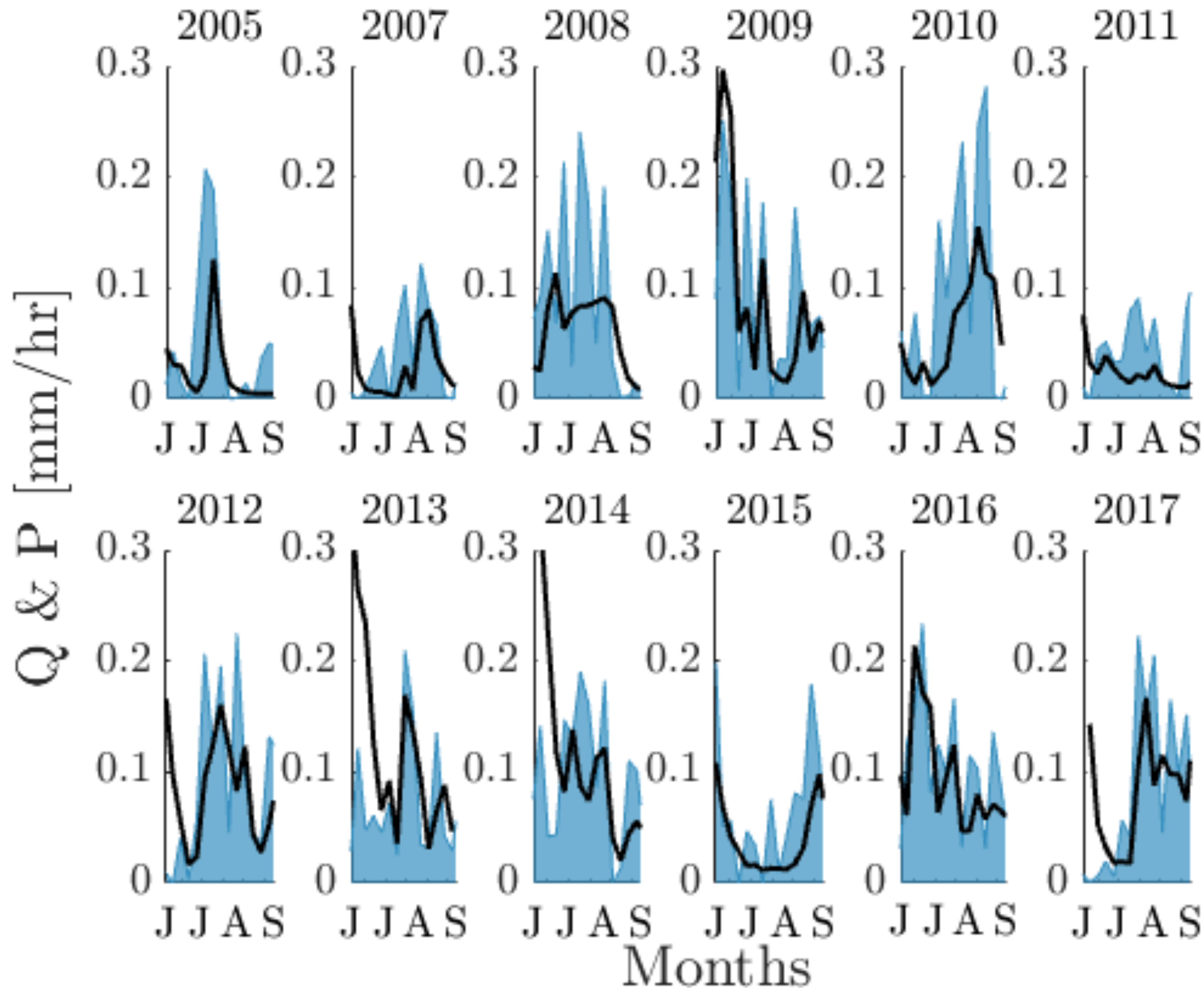
Not many years available (ignore years with summer data < 0.75)

Collection before June and after September are difficult

Isolate rainfall such that $T \geq 4^{\circ}\text{C}$



Weekly Averages of
Precipitation and
Discharge data show
the coupling
between
precipitation and
discharge



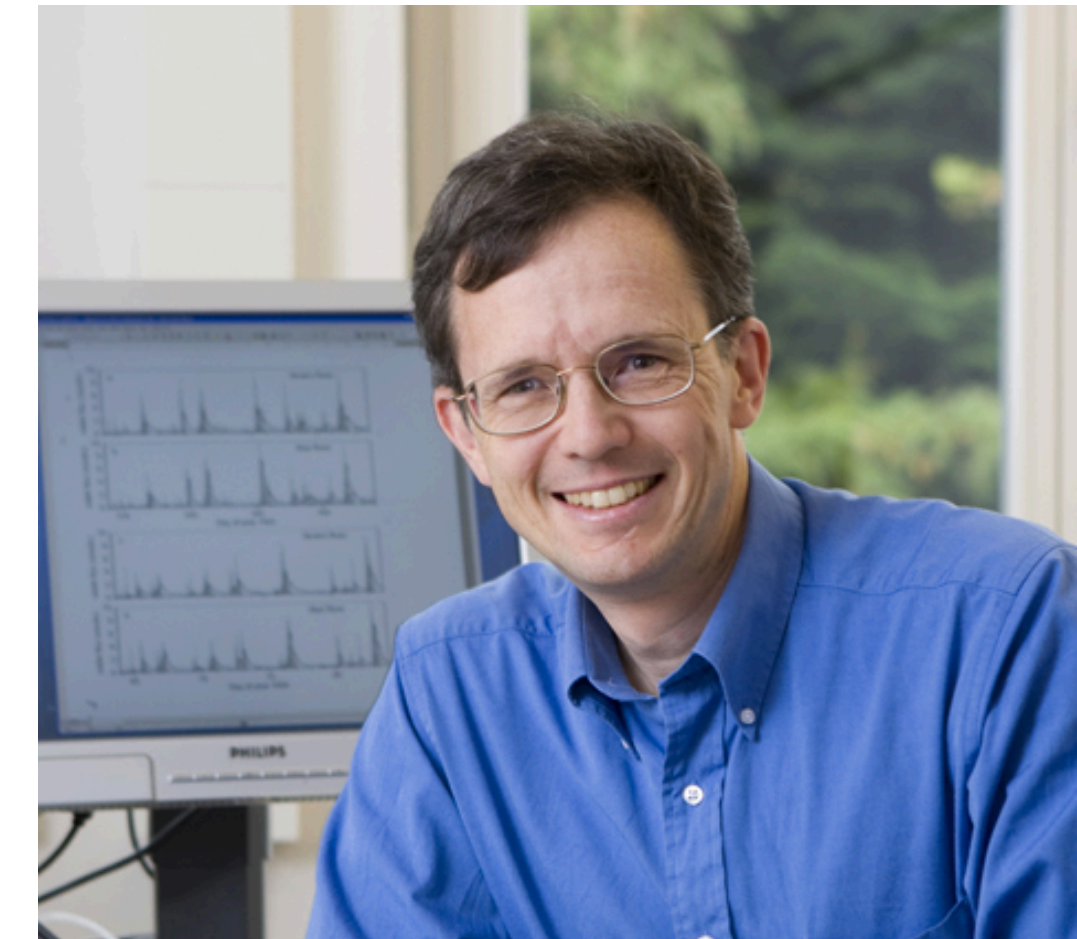
Methodology: Introducing Ensemble Runoff Response Analysis (**ERRA**)



Article

Impulse response functions for nonlinear, nonstationary, and heterogeneous systems, estimated by deconvolution and de-mixing of noisy time series

James W. Kirchner ^{1,2,3,*}



$$y_j = \sum_{k=0}^m \beta_k x_{j,k} + \alpha + \varepsilon_j$$

y_j Runoff for a given j th non-zero rainfall hour

$x_{j,k}$ Rainfall at k lagged hour, for j th non-zero rainfall hour

β_k Predicted correlation (Least-squares), or impulse response function

α Predicted base runoff (Least-squares)

ε_j Residual runoff between predicted and real runoff —> minimized

Methodology: Introducing Ensemble Runoff Response Analysis (ERRA)

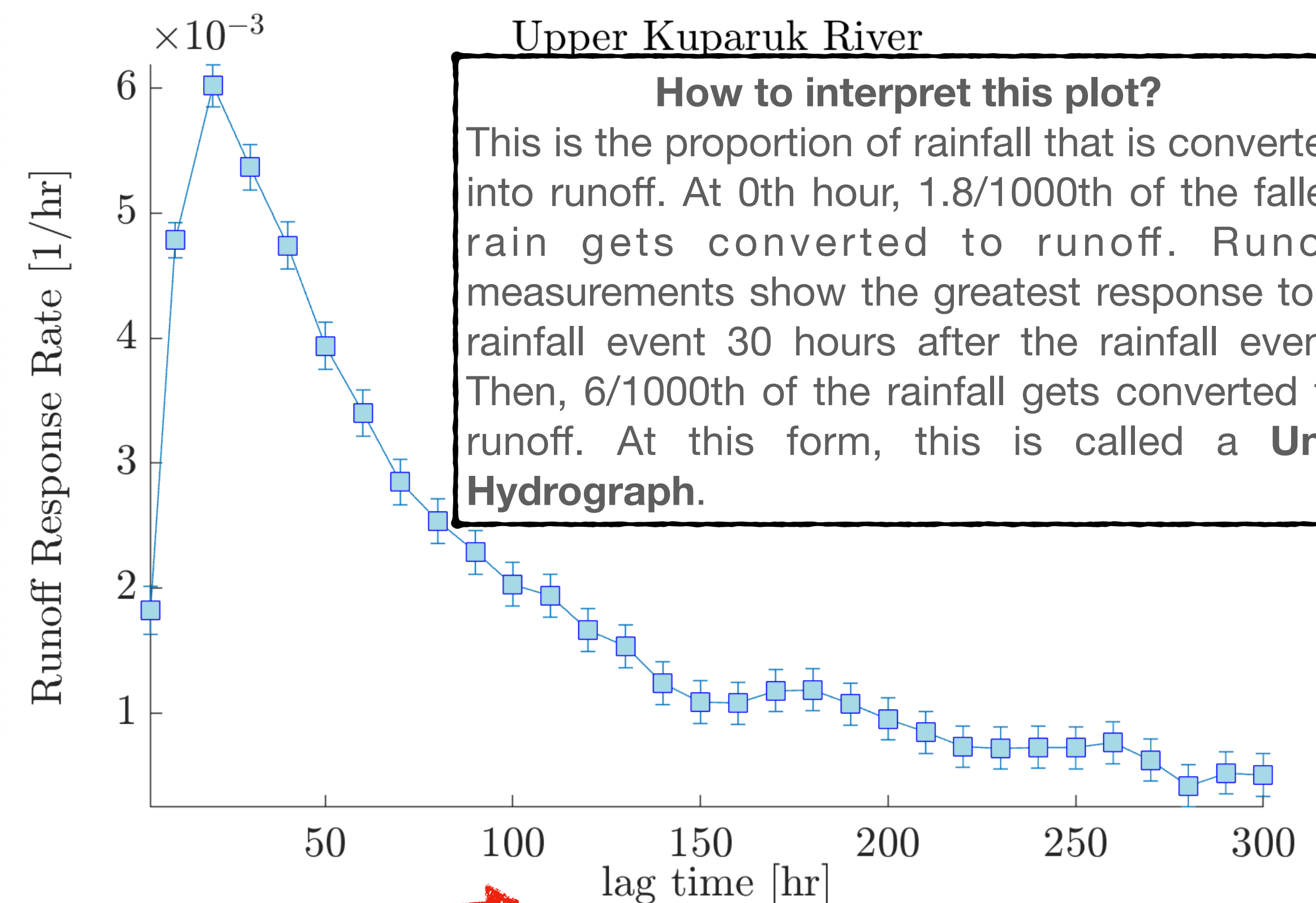


Article

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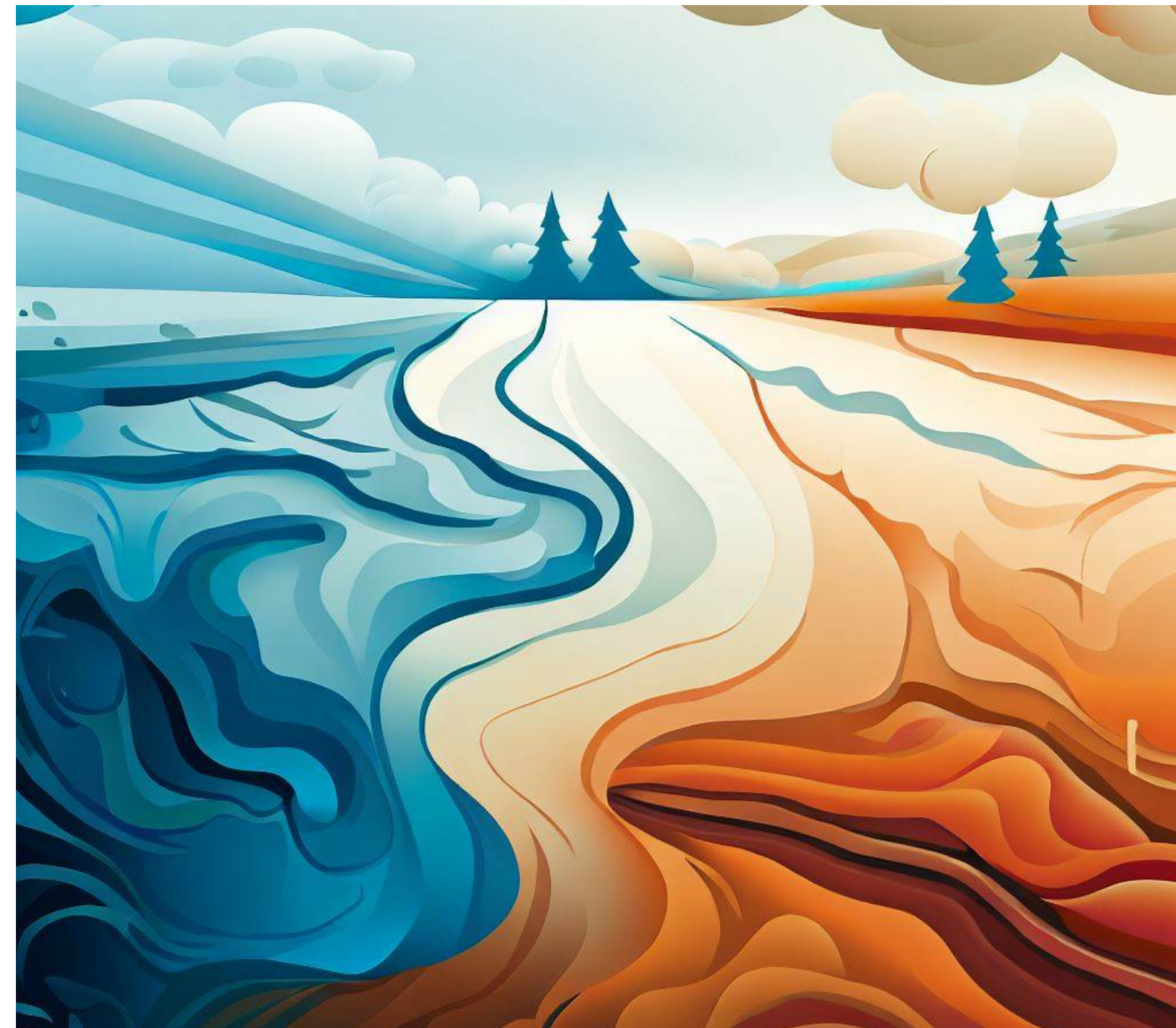
How does the runoff response to rainfall change year-year and month-month?

Years



Months

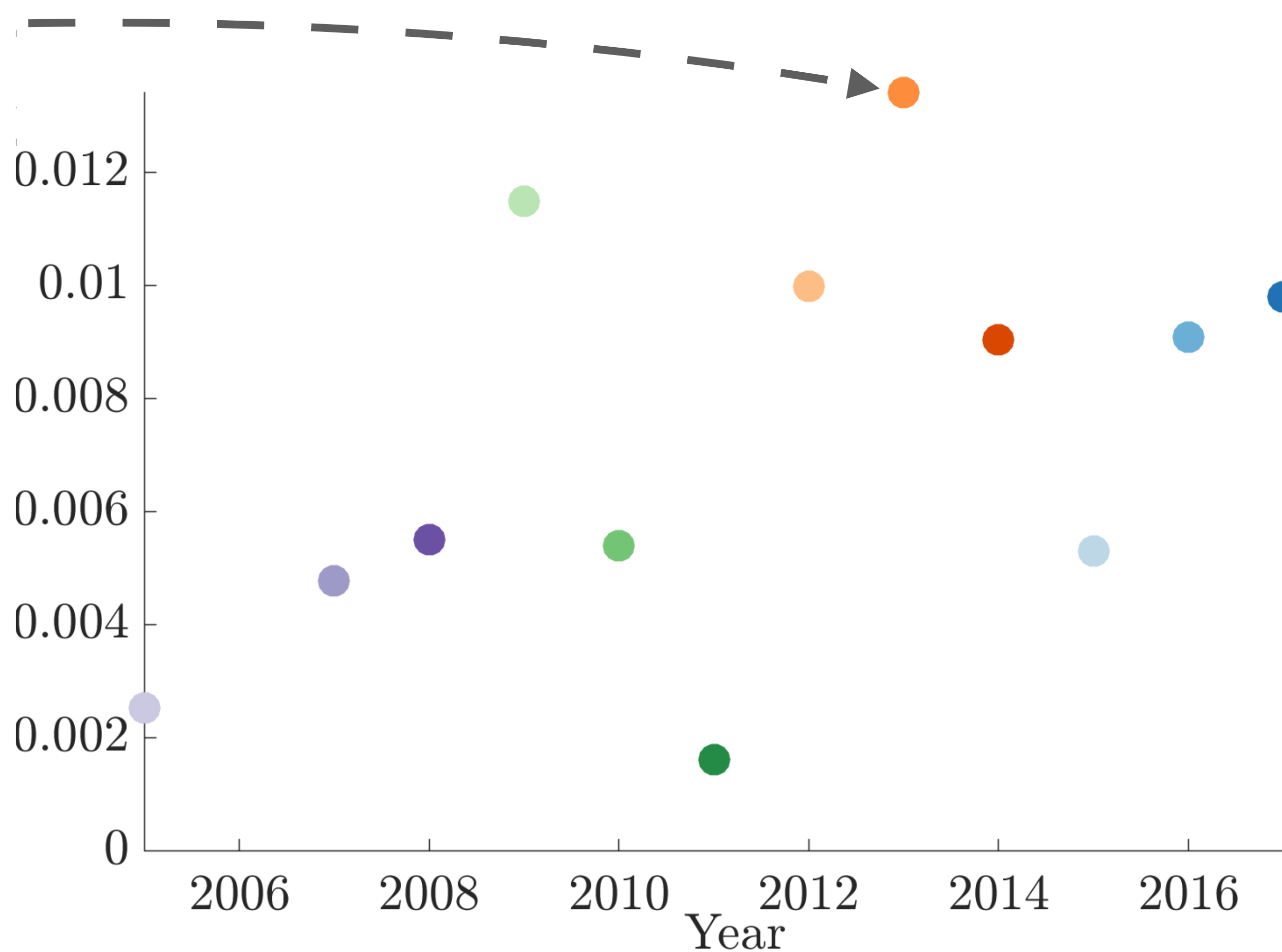
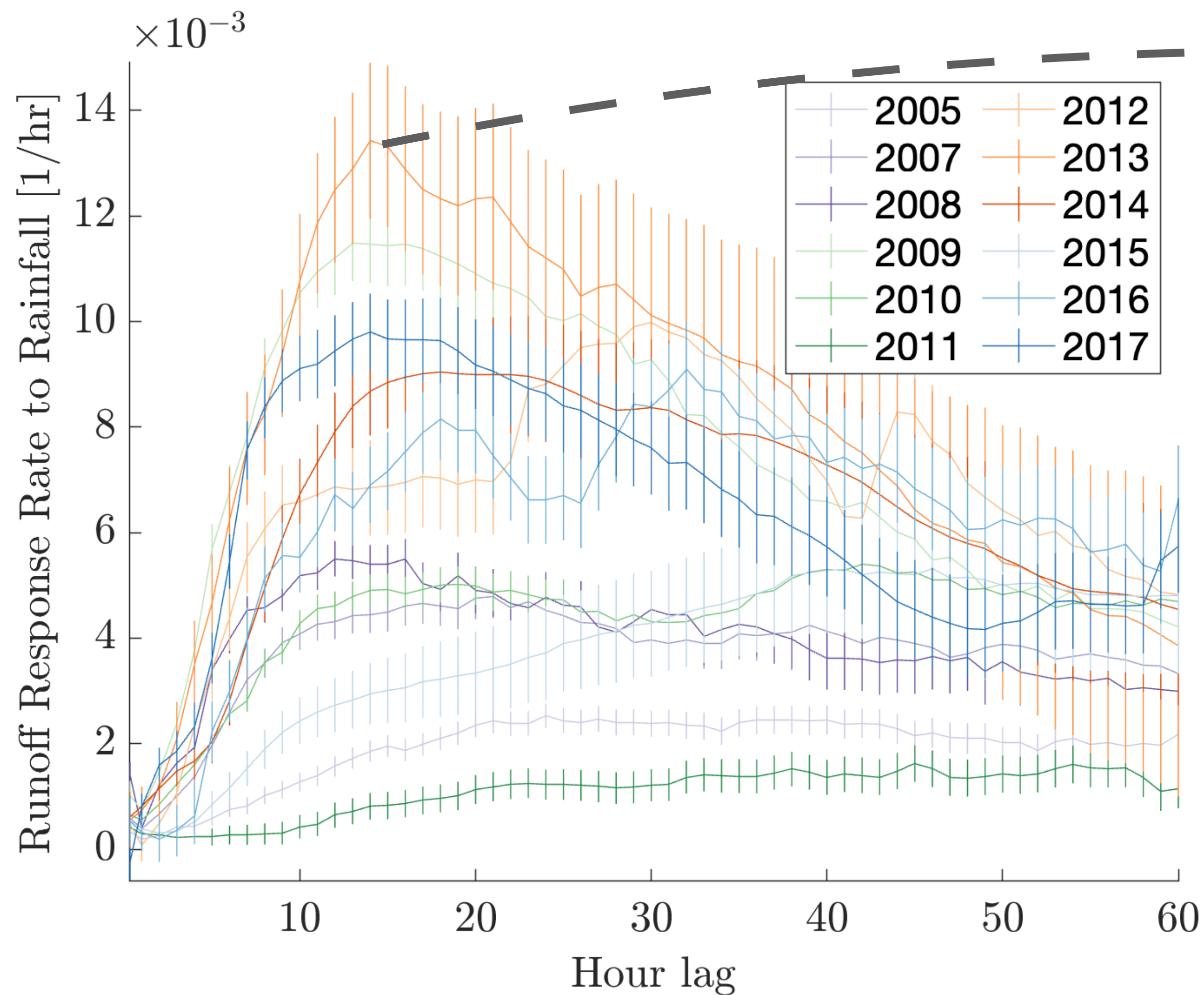
Runoff response to rainfall shows a **positive** correlation with the **summer precipitation** and **negative** correlation with **average winter and spring temperatures**.



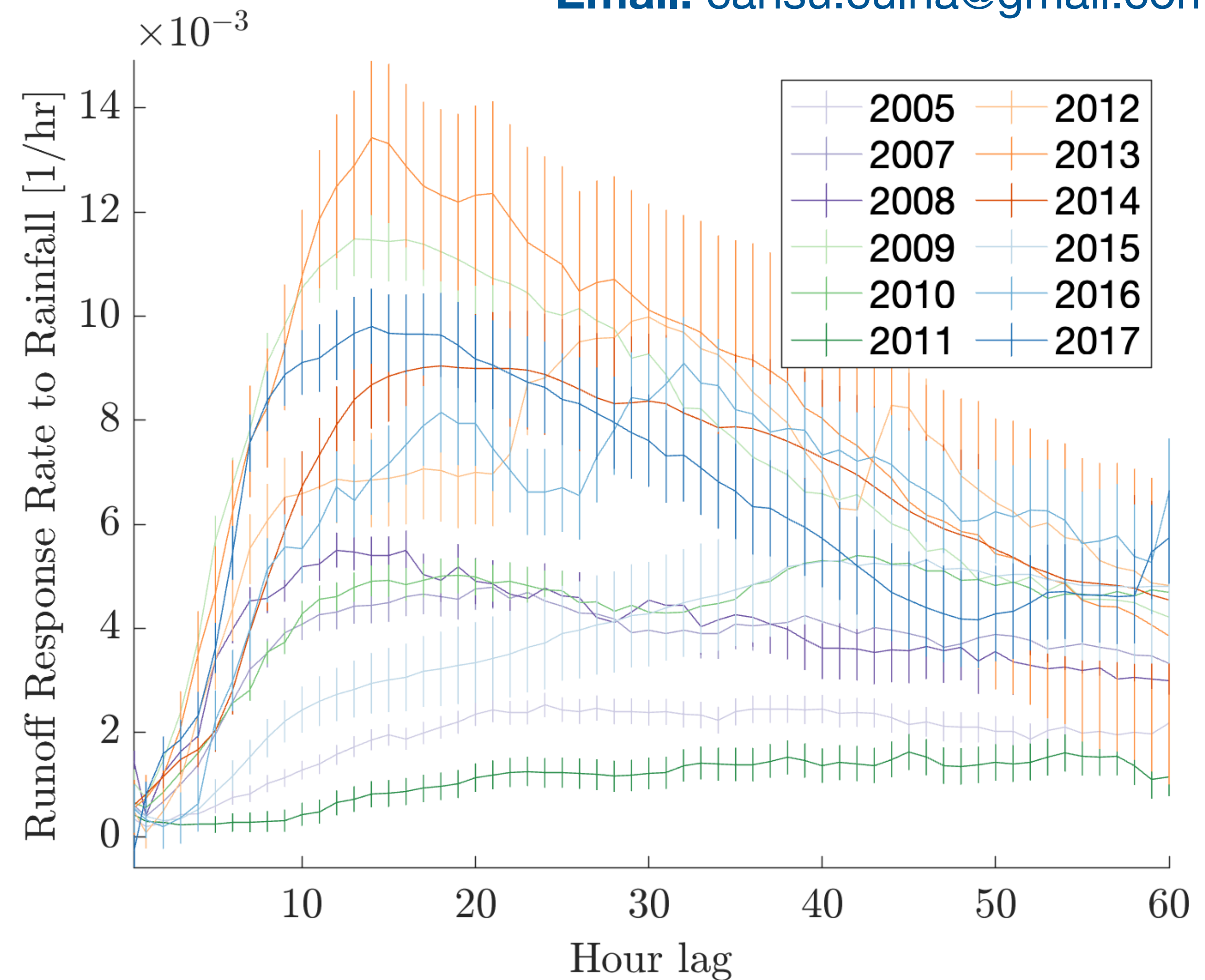
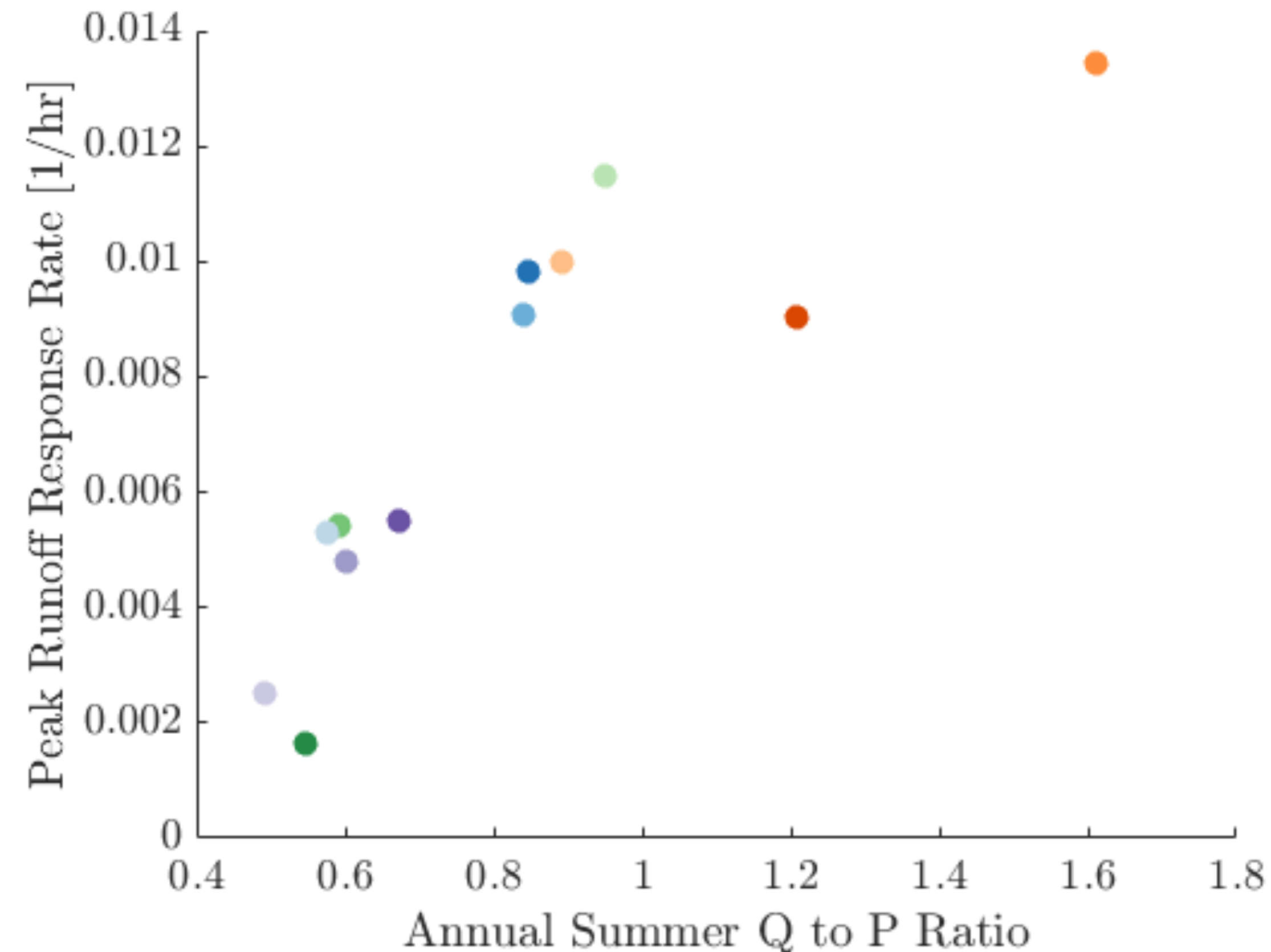
Runoff response to rainfall decreases over the **summer months**.

Runoff response to rainfall
varies dramatically between the
years

We use the Peak Response Rate
[1/hr] to identify year-year
correlations

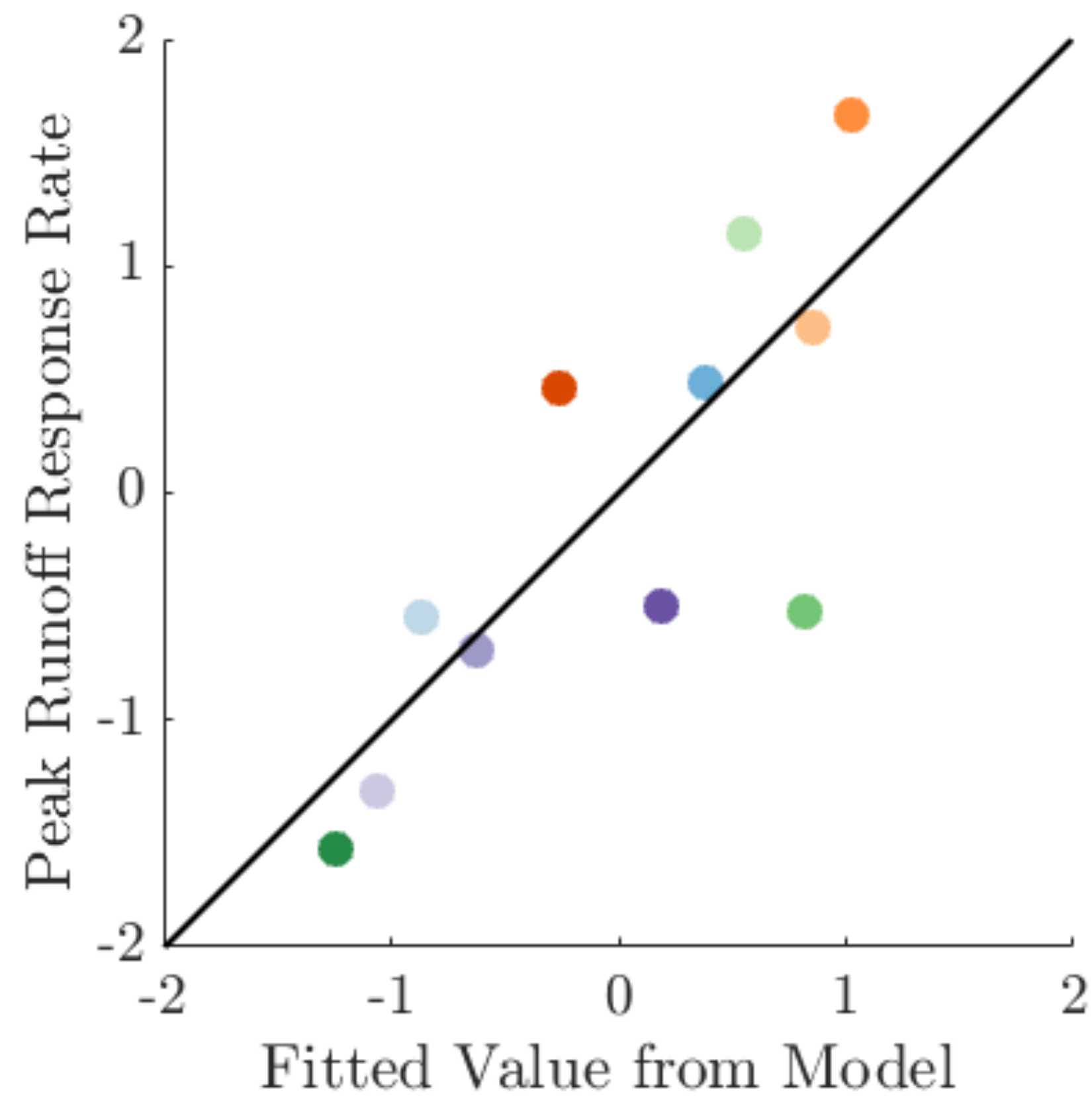


ERRA is able to capture the total runoff to precipitation rate for each year

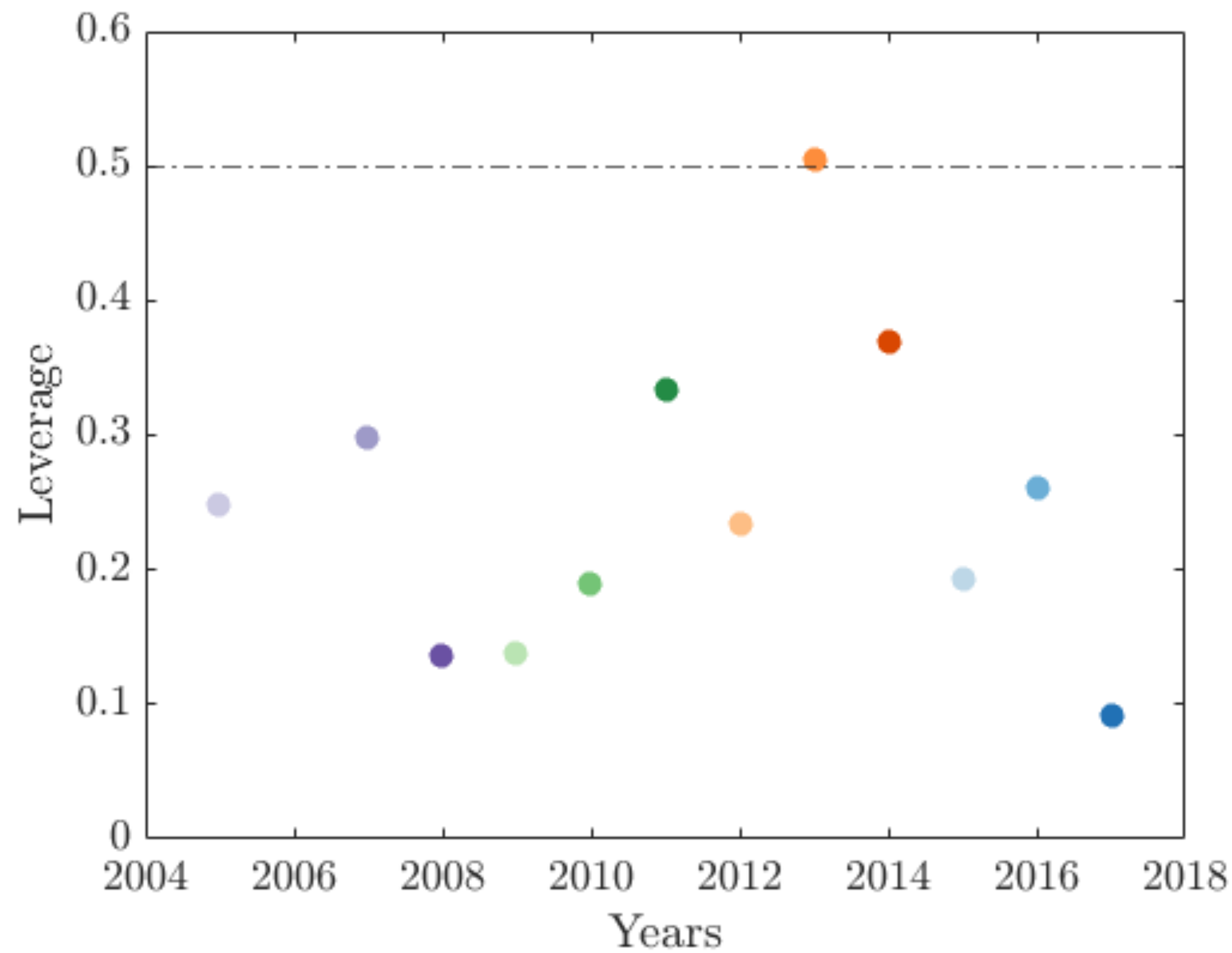


Annual Summer Q to P Ratio is not perfect because it is not able to isolate different sources of discharge like melting glaciers or permafrost thawing

Runoff response to rainfall shows a **positive** correlation with the **summer precipitation** and **negative** correlation with **average winter and spring temperatures**.

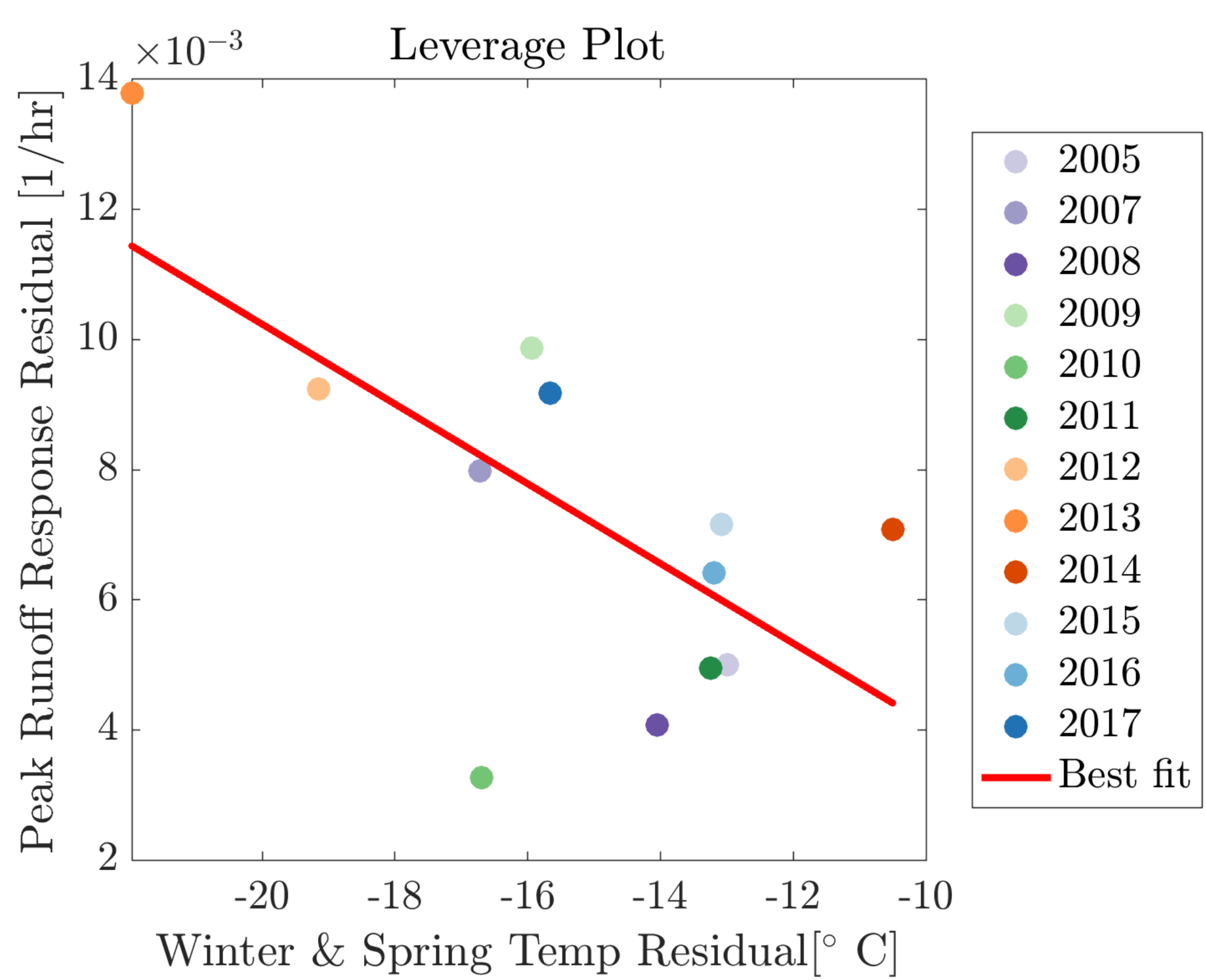
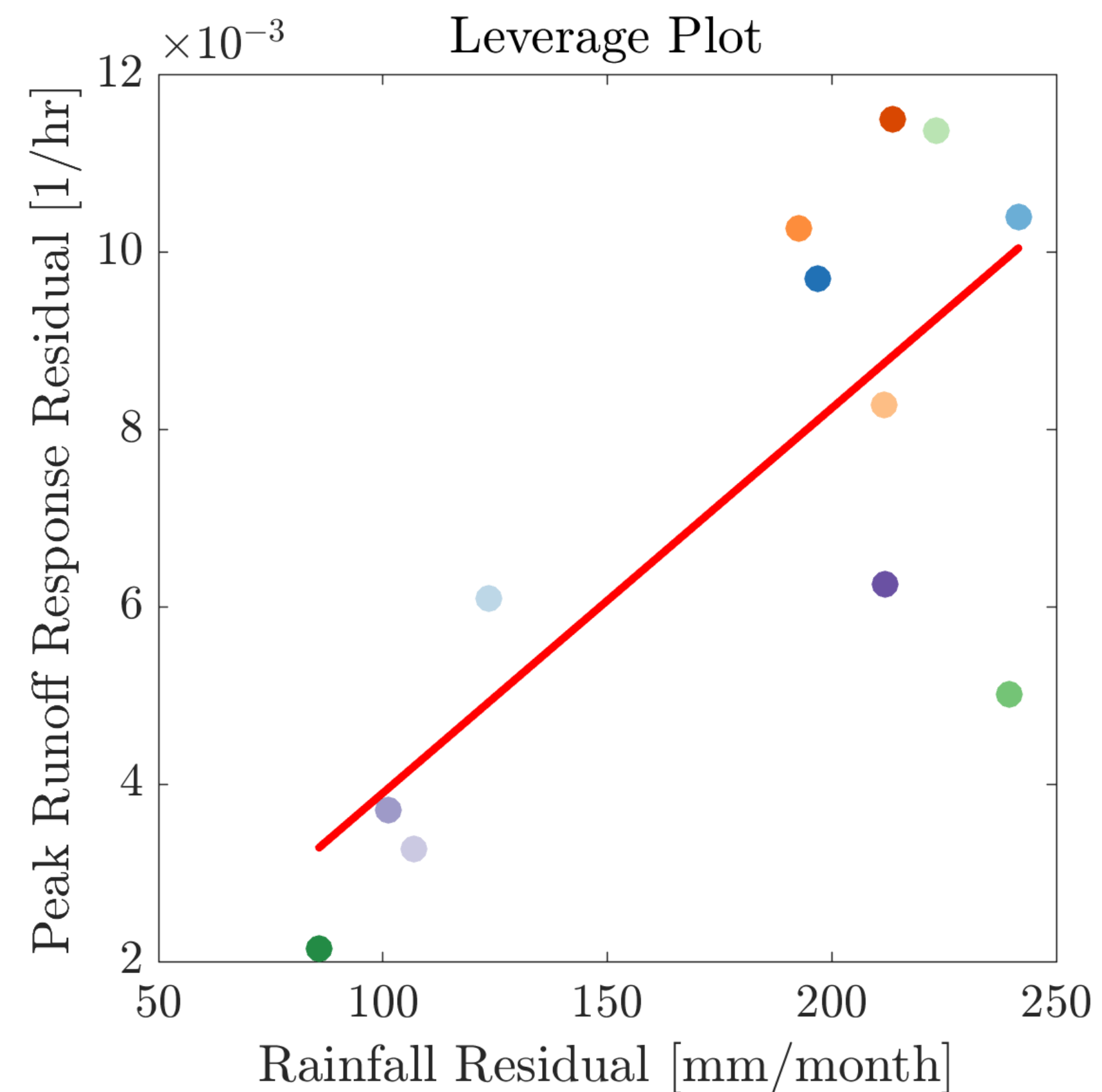


Non-dimensional	Z-score Estimate	tStat	pValue
Summer Precipitation	$(7.0 \pm 2.1) \times 10^{-1}$	3.37	0.008
Avg Winter & Spring Temperatures	$(-5.3 \pm 2.1) \times 10^{-1}$	-2.58	0.029

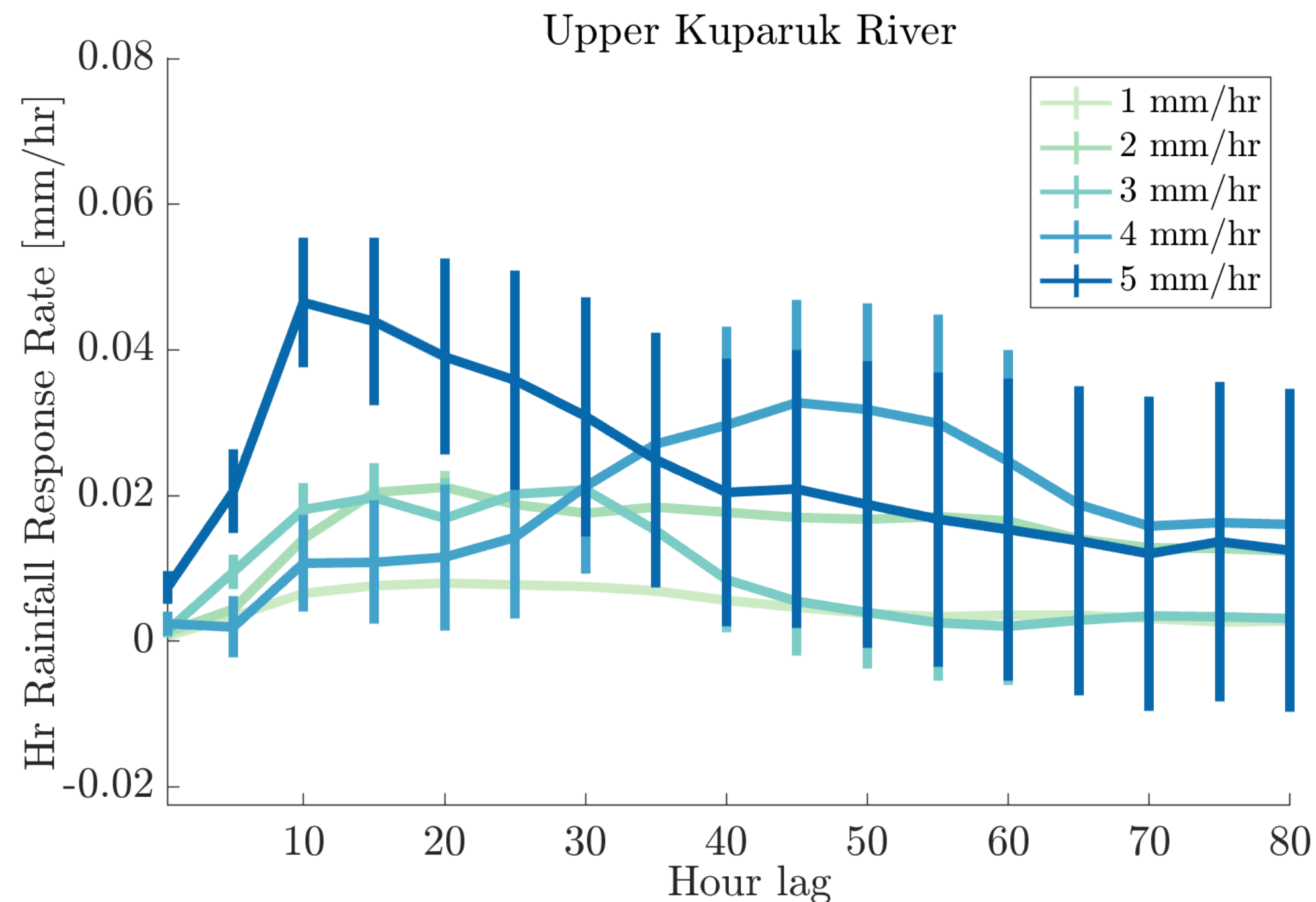


Runoff response to rainfall shows a **positive** correlation with the **summer precipitation** and **negative** correlation with **average winter and spring temperatures**.

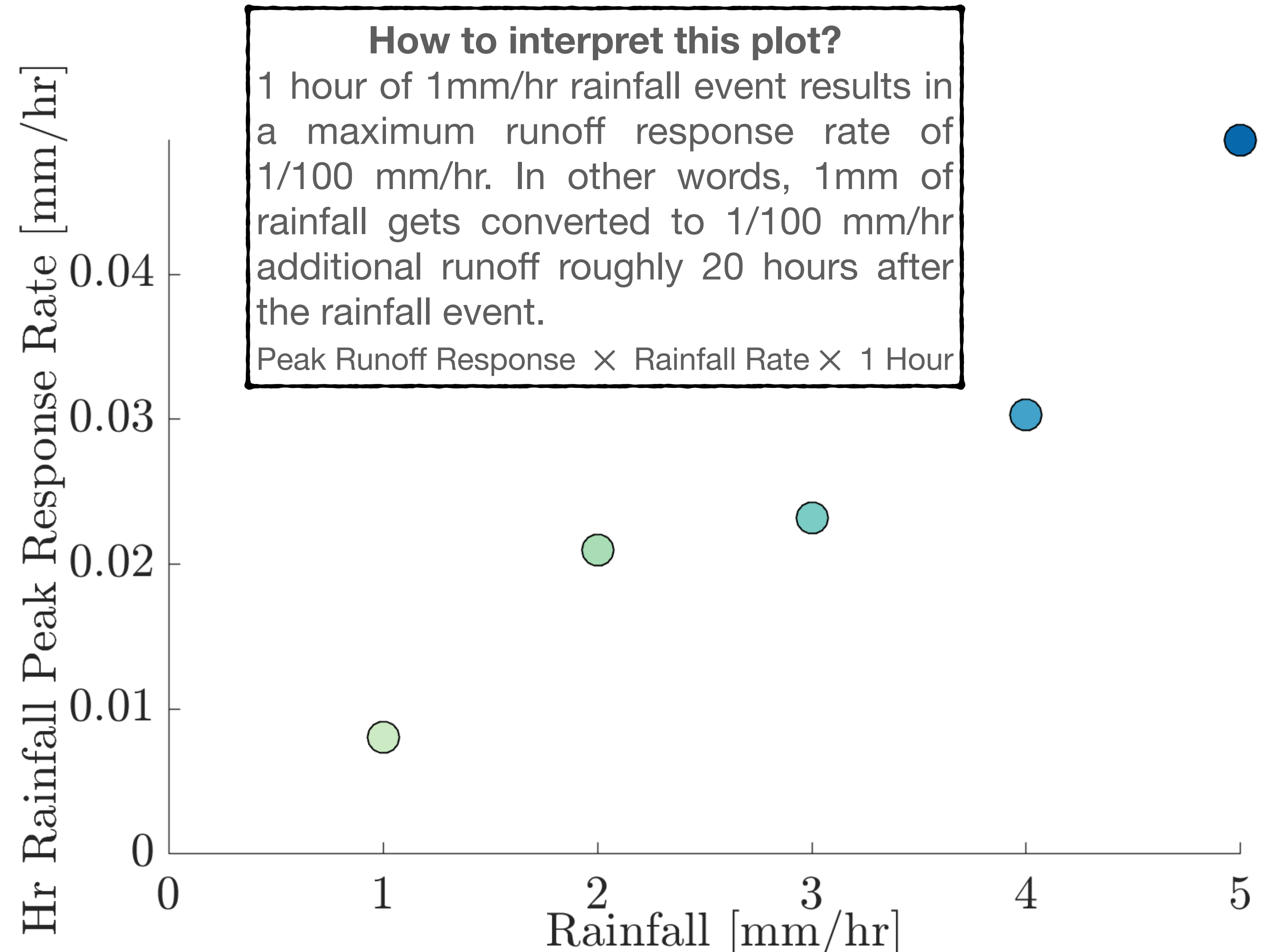
Dimensional	Z-score Estimate	tStat	pValue
Summer Precipitation	$(4.3 \pm 1.3) \times 10^{-5}$	3.37	0.008
Avg Winter & Spring Temperatures	$(-6.1 \pm 2.4) \times 10^{-4}$	-2.58	0.029



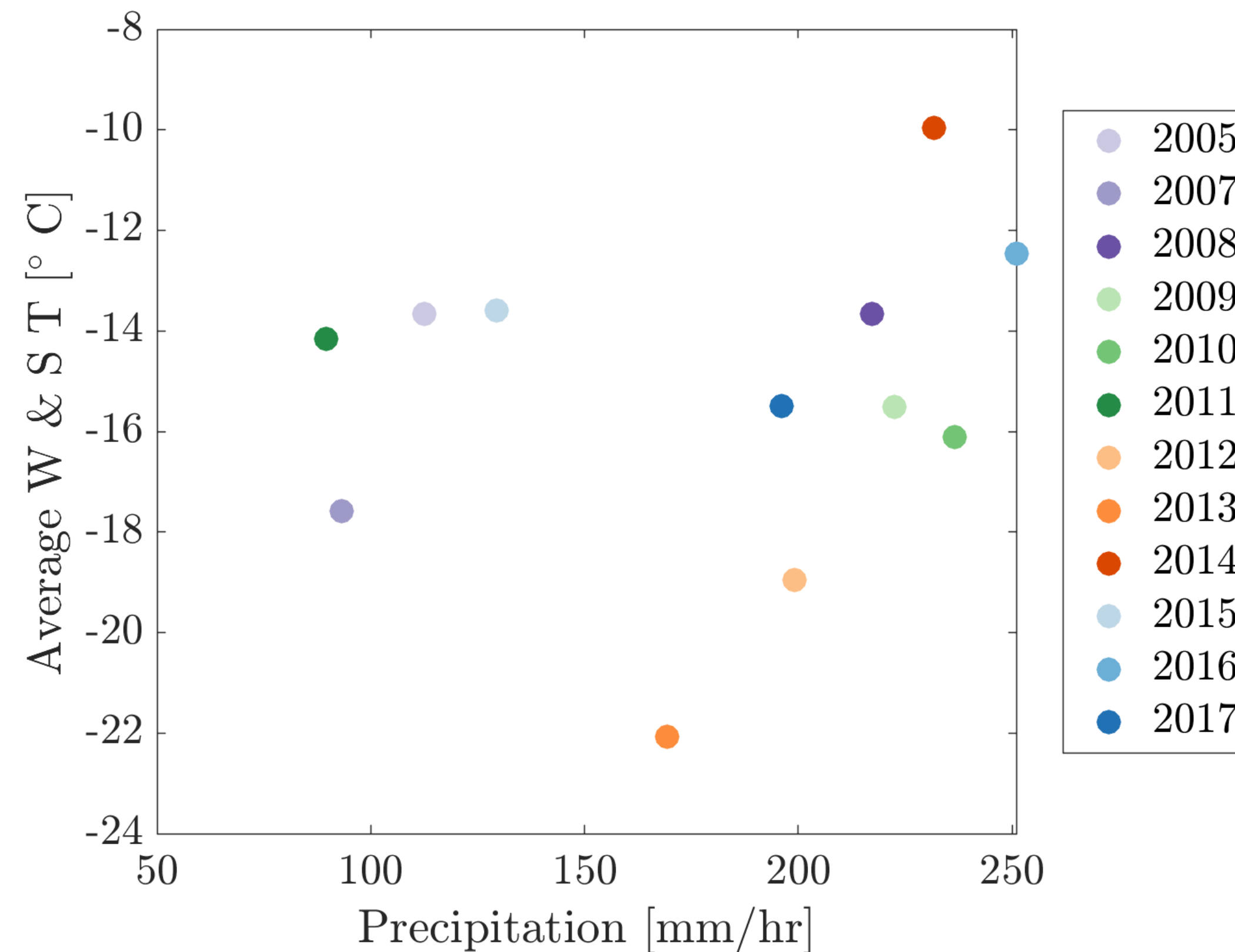
Runoff response is **potentially nonlinear** to the amount of rainfall. This may explain the positive correlation with **summer precipitation**.



These results may reveal active layer response and properties to variable rainfall rates.

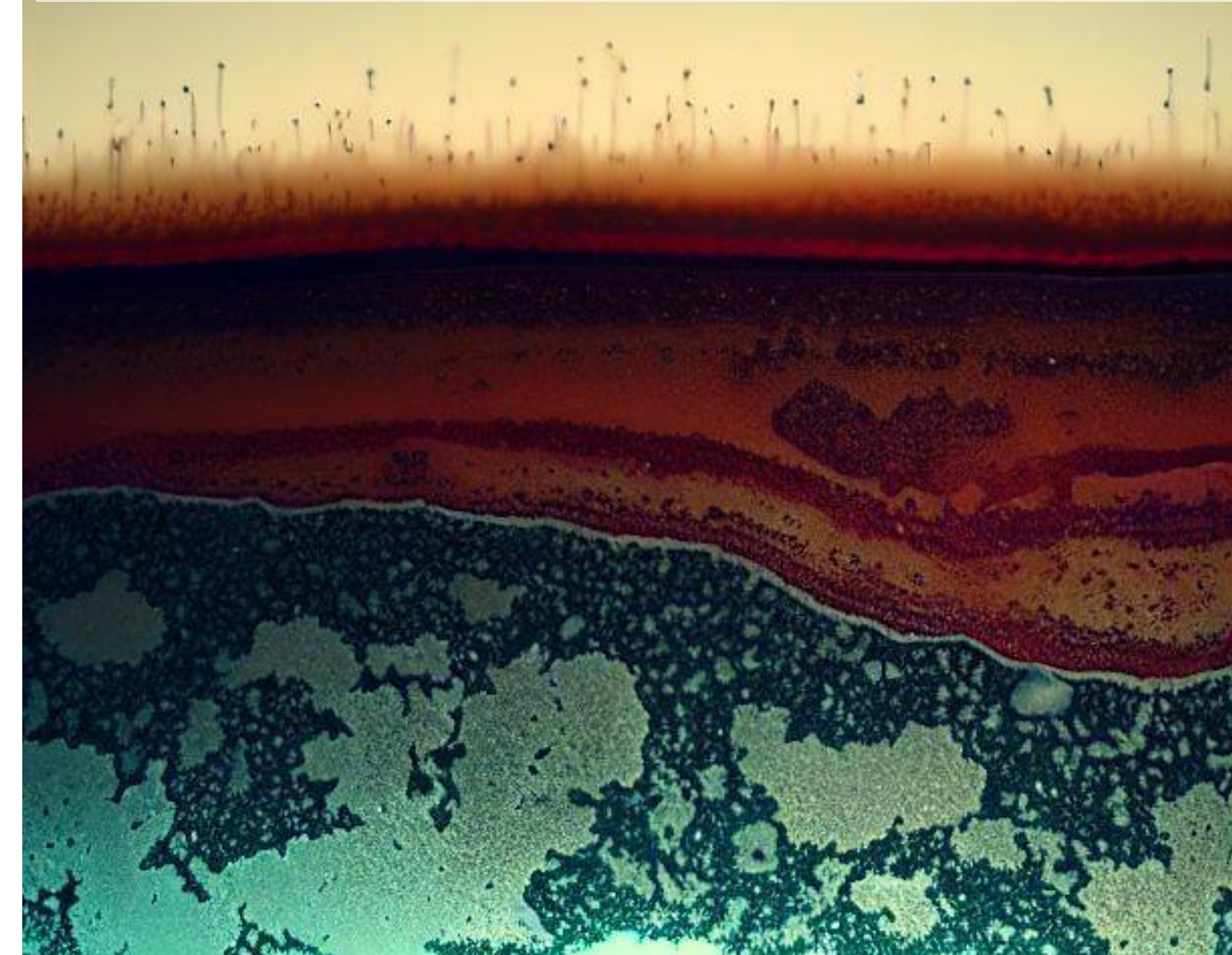


Runoff response to rainfall shows a **negative** correlation with **average winter and spring temperatures**. Because **warmer winters and springs** are associated with more **summer precipitation**?



Average winter and spring temperature is not correlated with **annual precipitation**.

This result may be indicative of permafrost characteristics. For example, maybe warmer winters and springs have an easier time thawing the active layer. This active layer can then store more water than years with colder winters and springs.



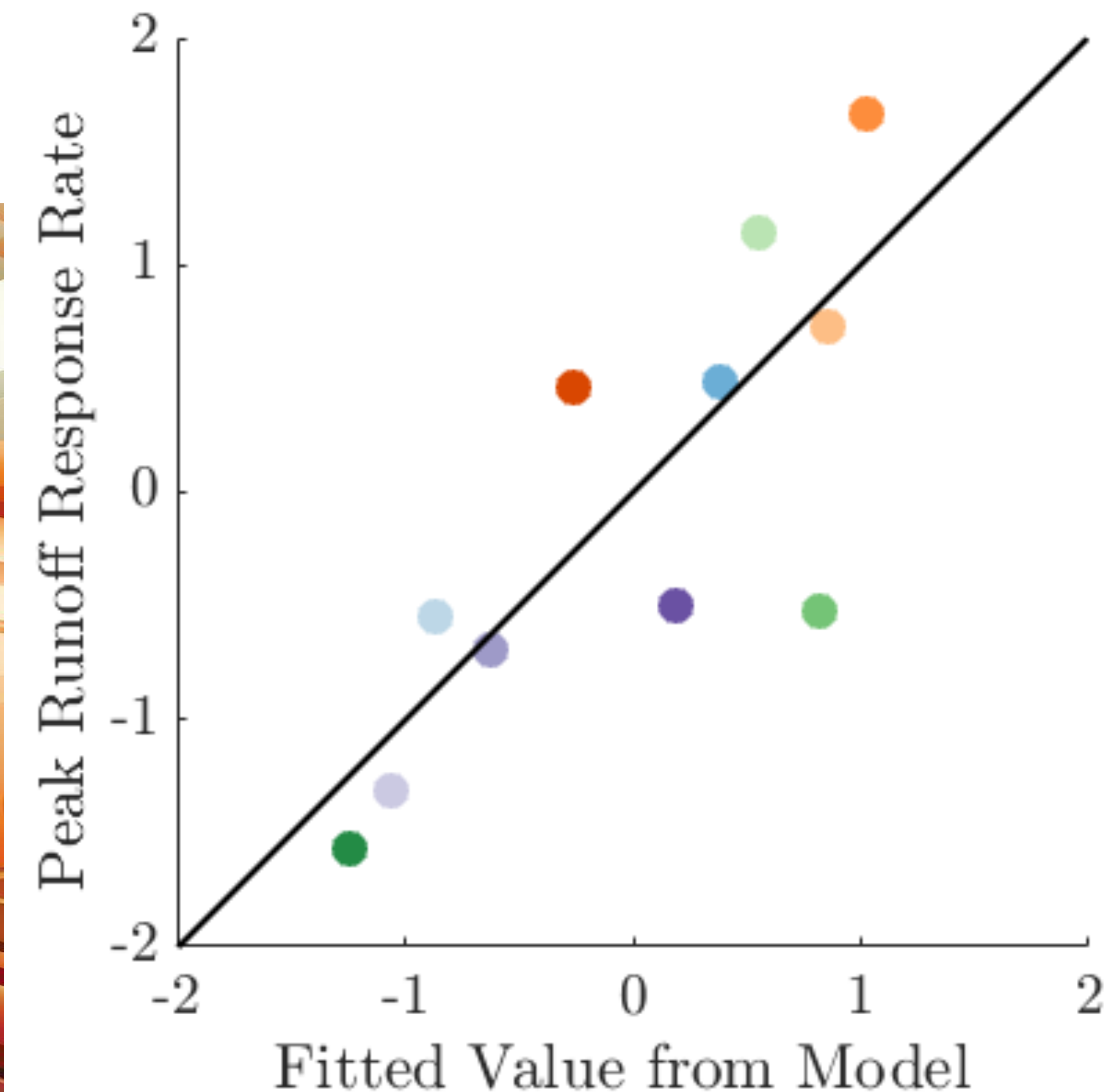
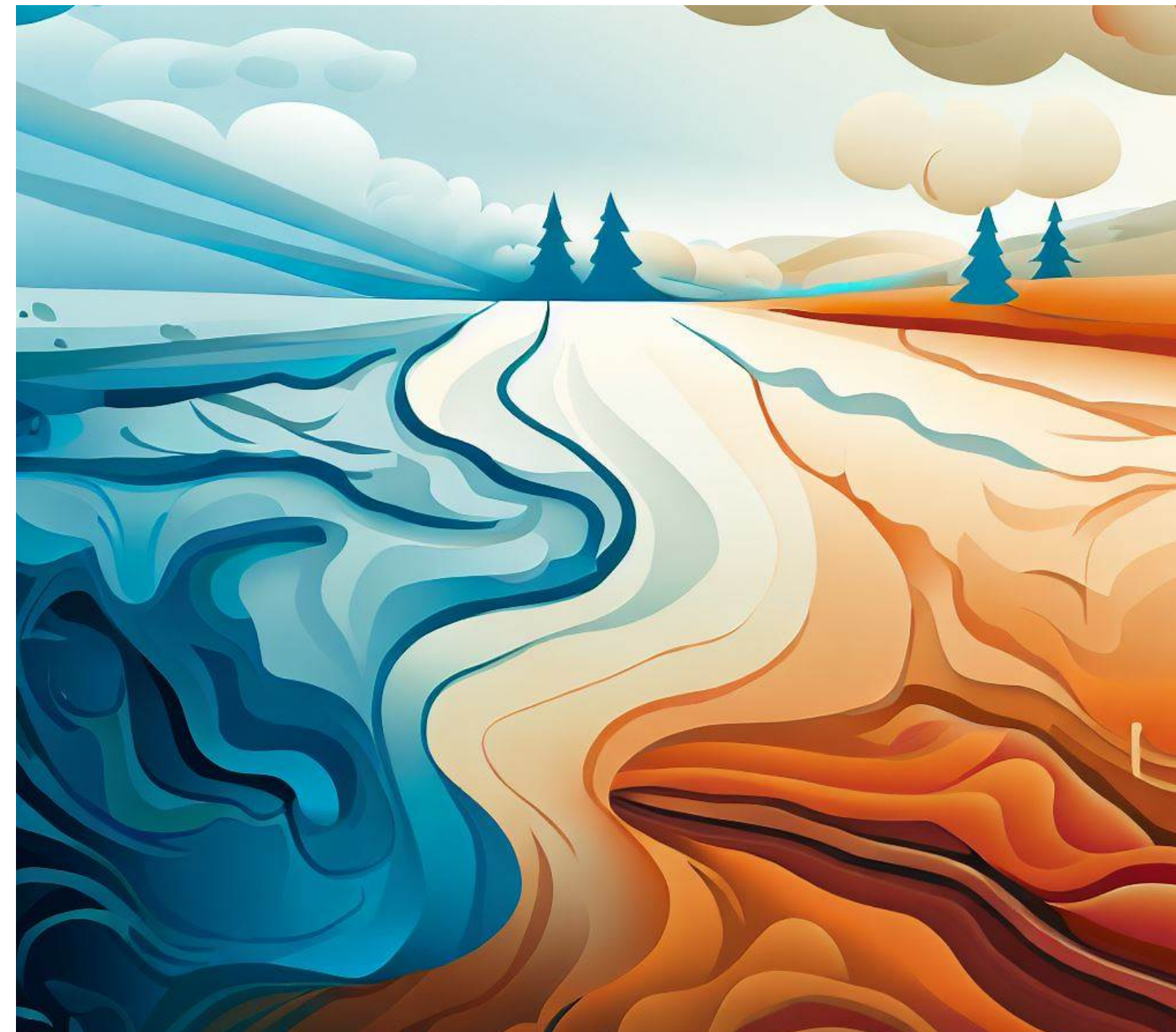
Model Cross Section of the Active Layer and Permafrost; Not to scale

How does the runoff response to rainfall change year-year and month-month?

Years

<—>

Runoff response to rainfall shows a **positive** correlation with the **summer precipitation** and **negative** correlation with **average winter temperatures**.



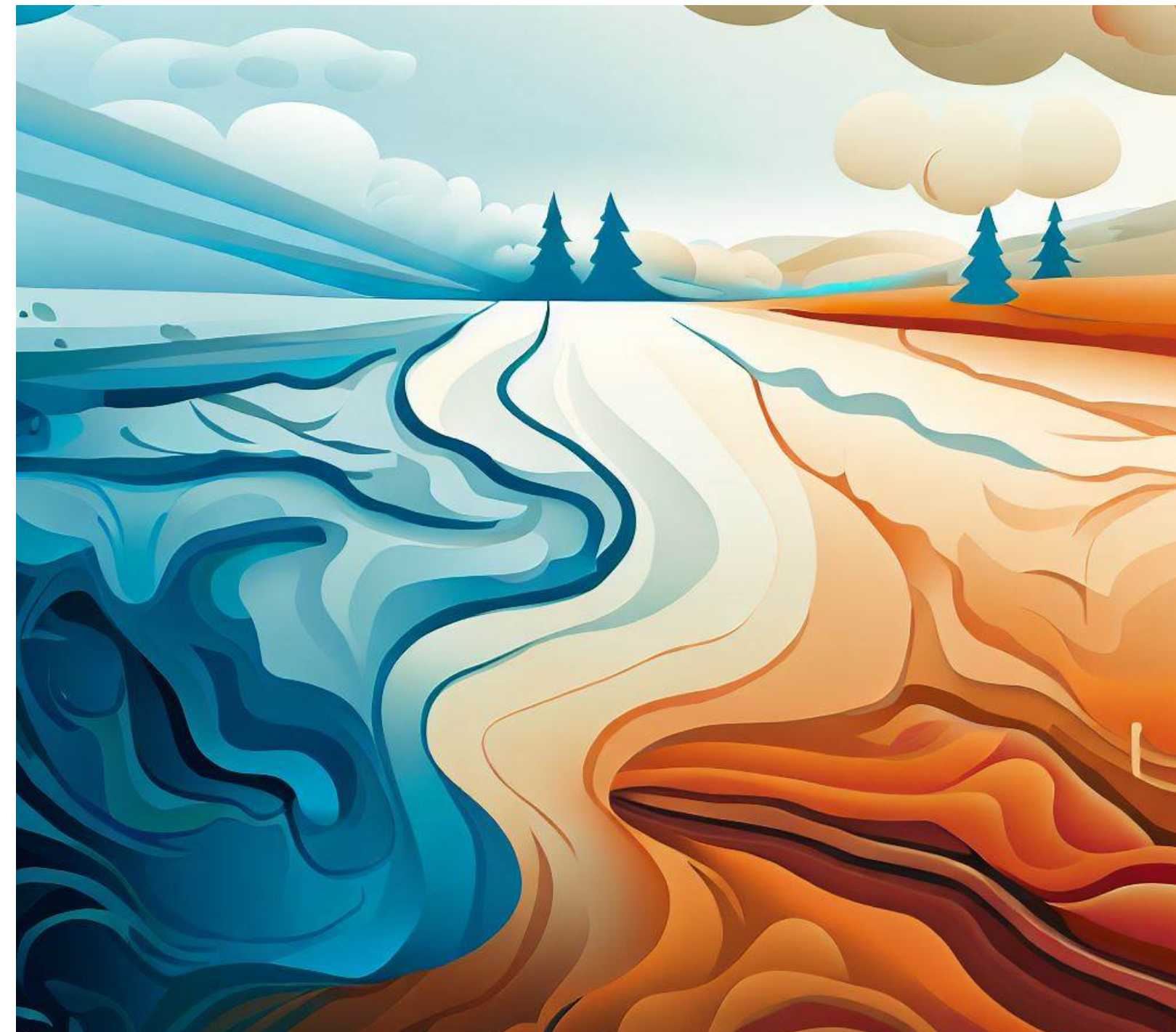
How does the runoff response to rainfall change year-year and month-month?

Years

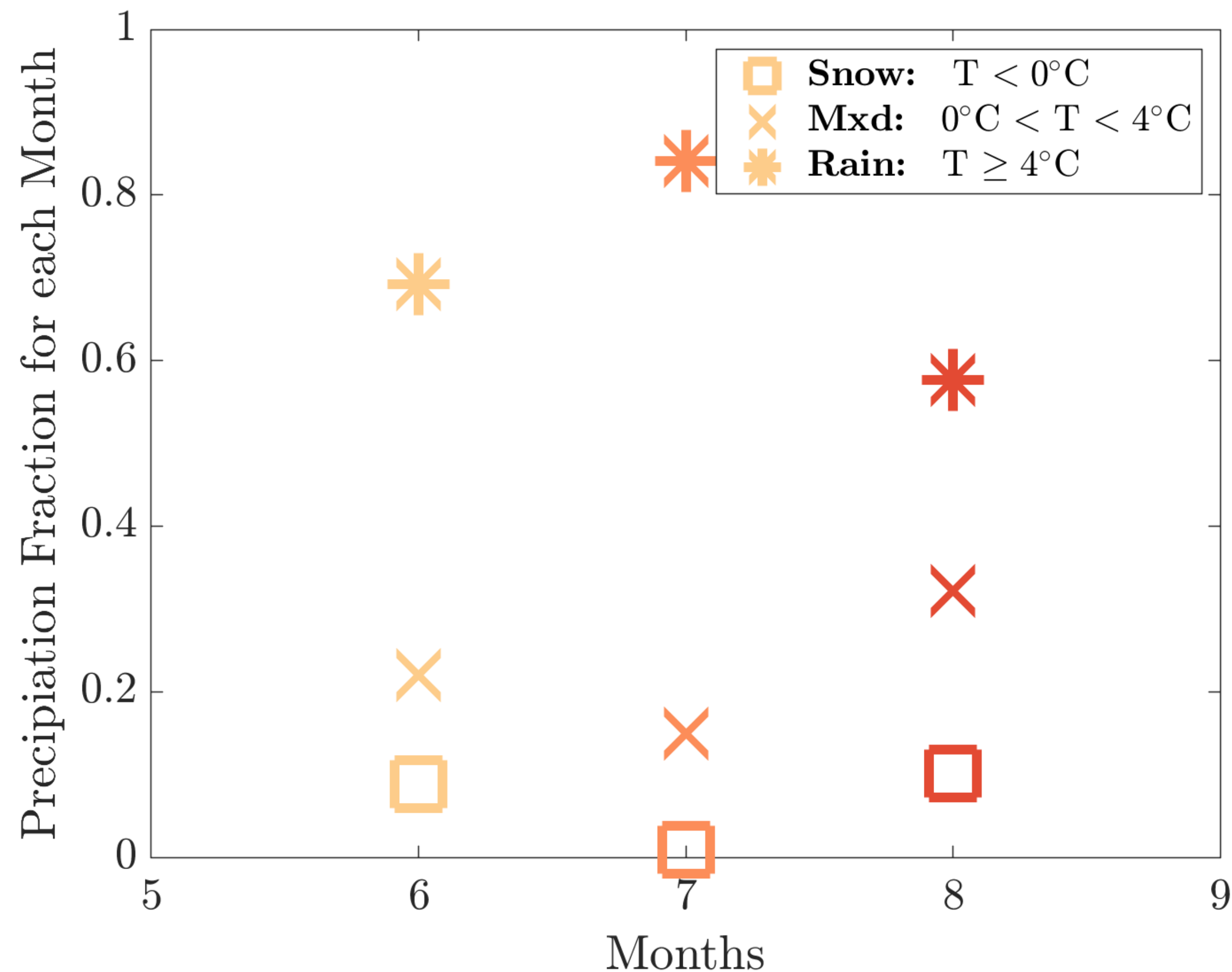


Months

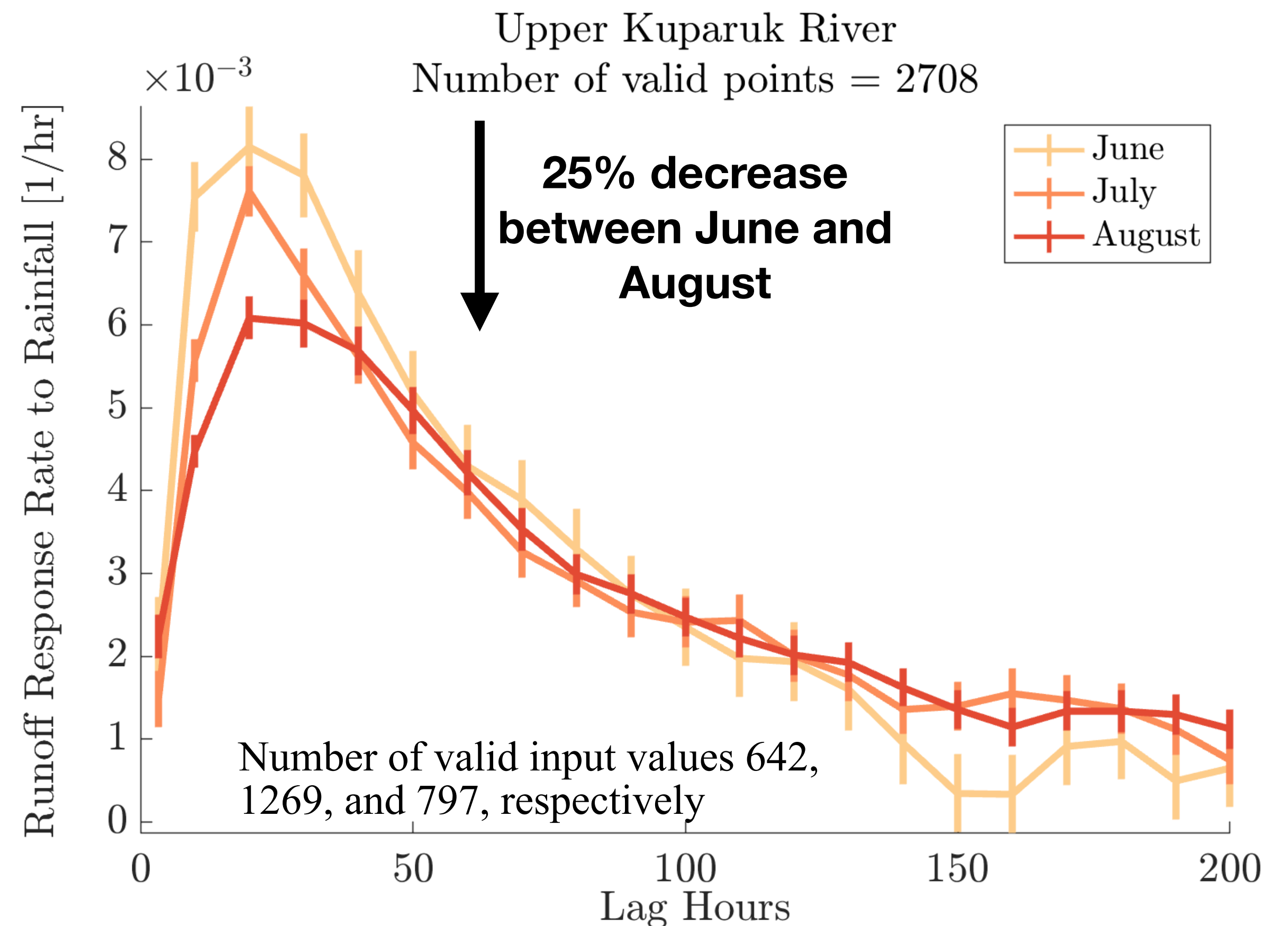
Runoff response to rainfall shows a **positive** correlation with the **summer precipitation** and **negative** correlation with **average winter temperatures**.



Runoff response to rainfall decreases over the **summer months**.

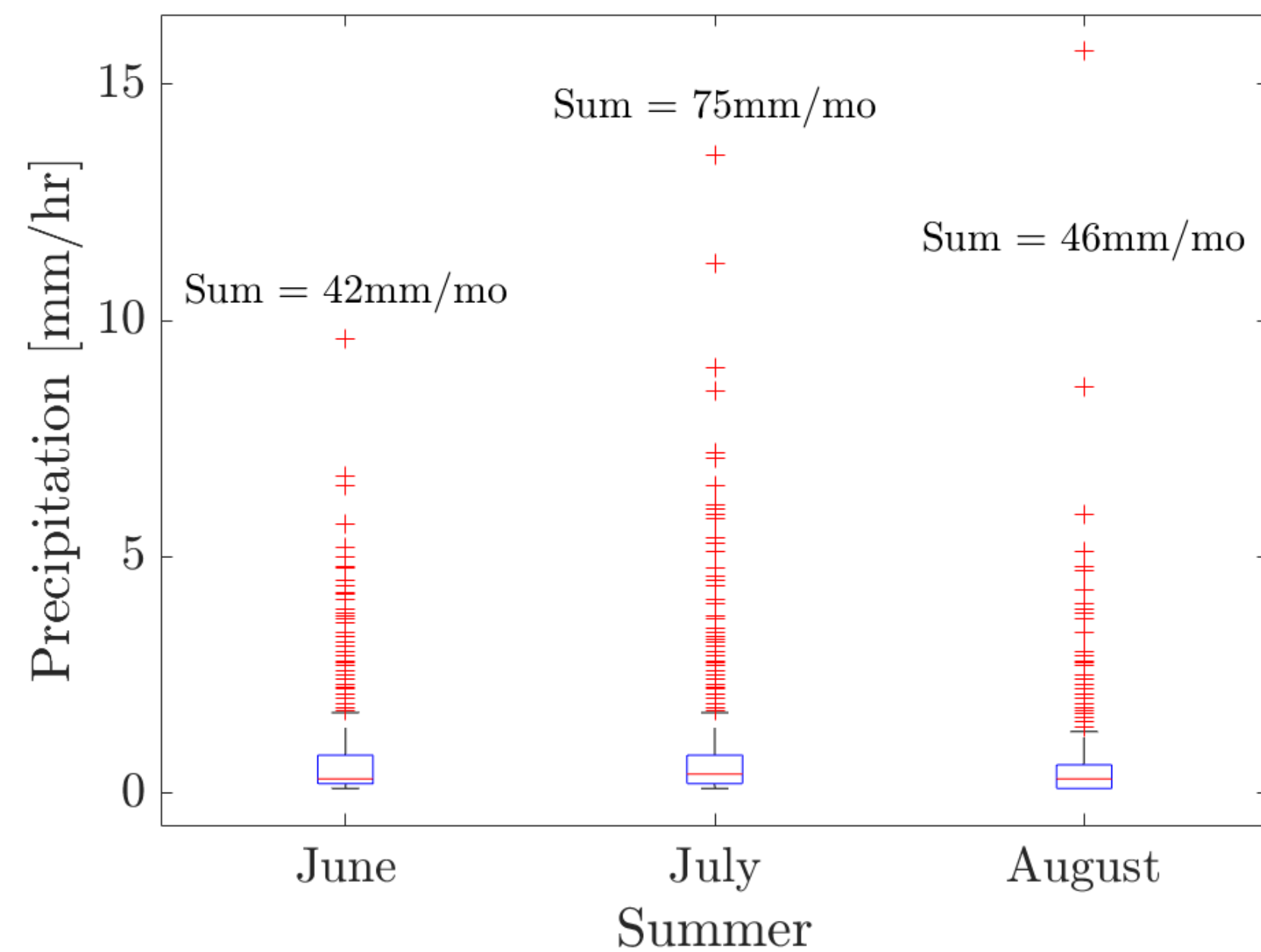
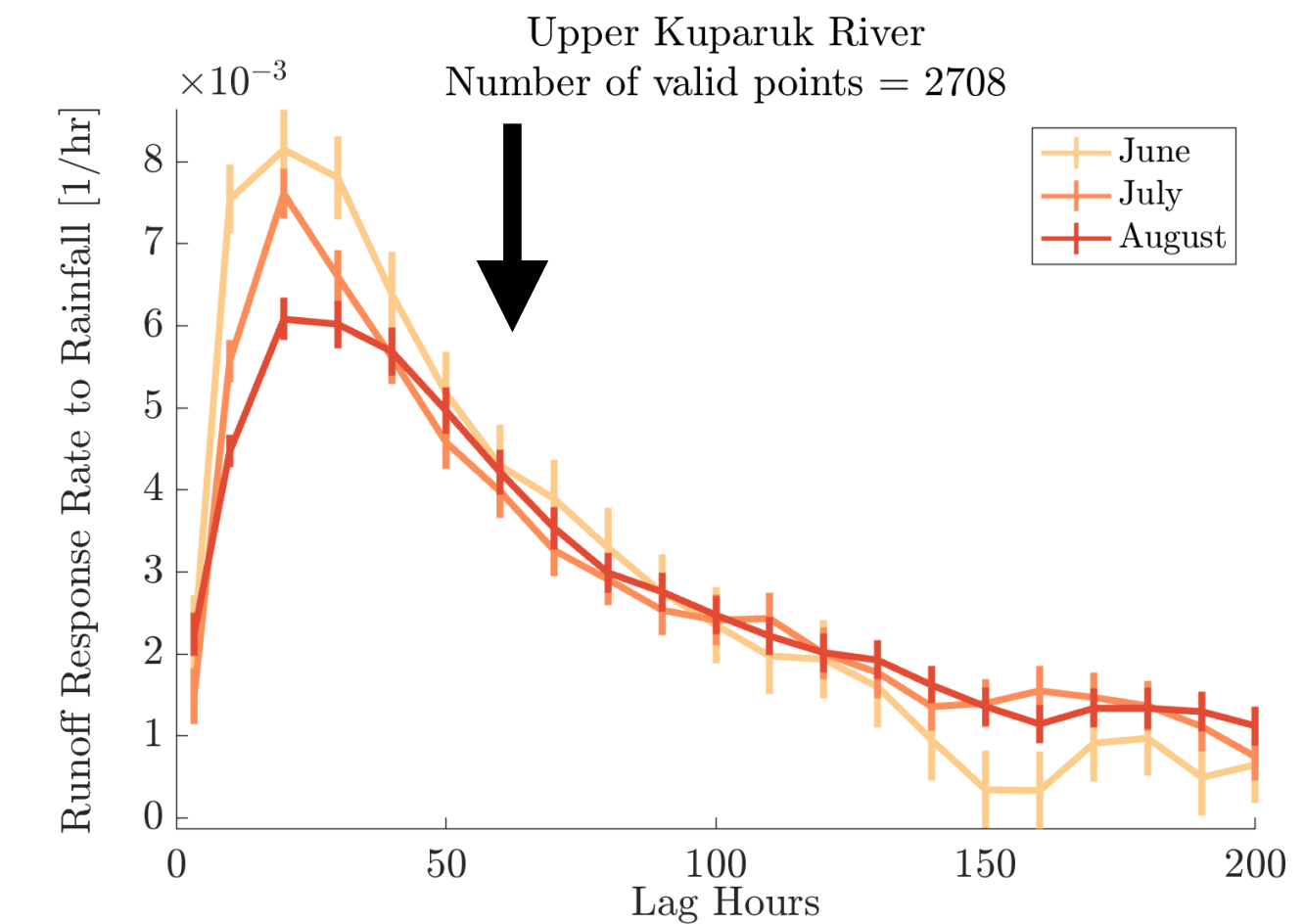


It snows more in June and August than July, so isolate temperatures $\geq 4^{\circ}\text{C}$.

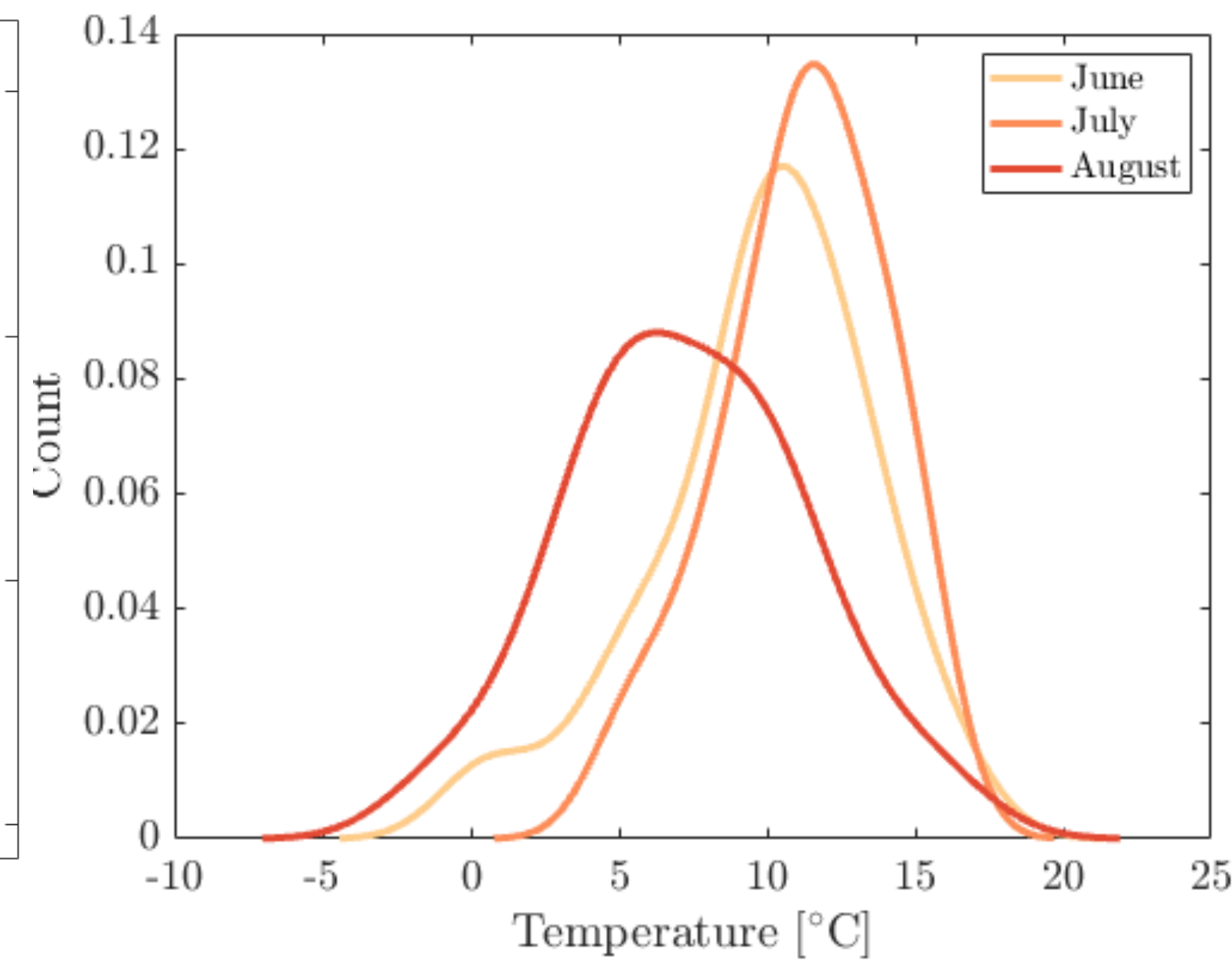


Runoff Response Rate to
Rainfall decreases between
June and August by 25%
decrease

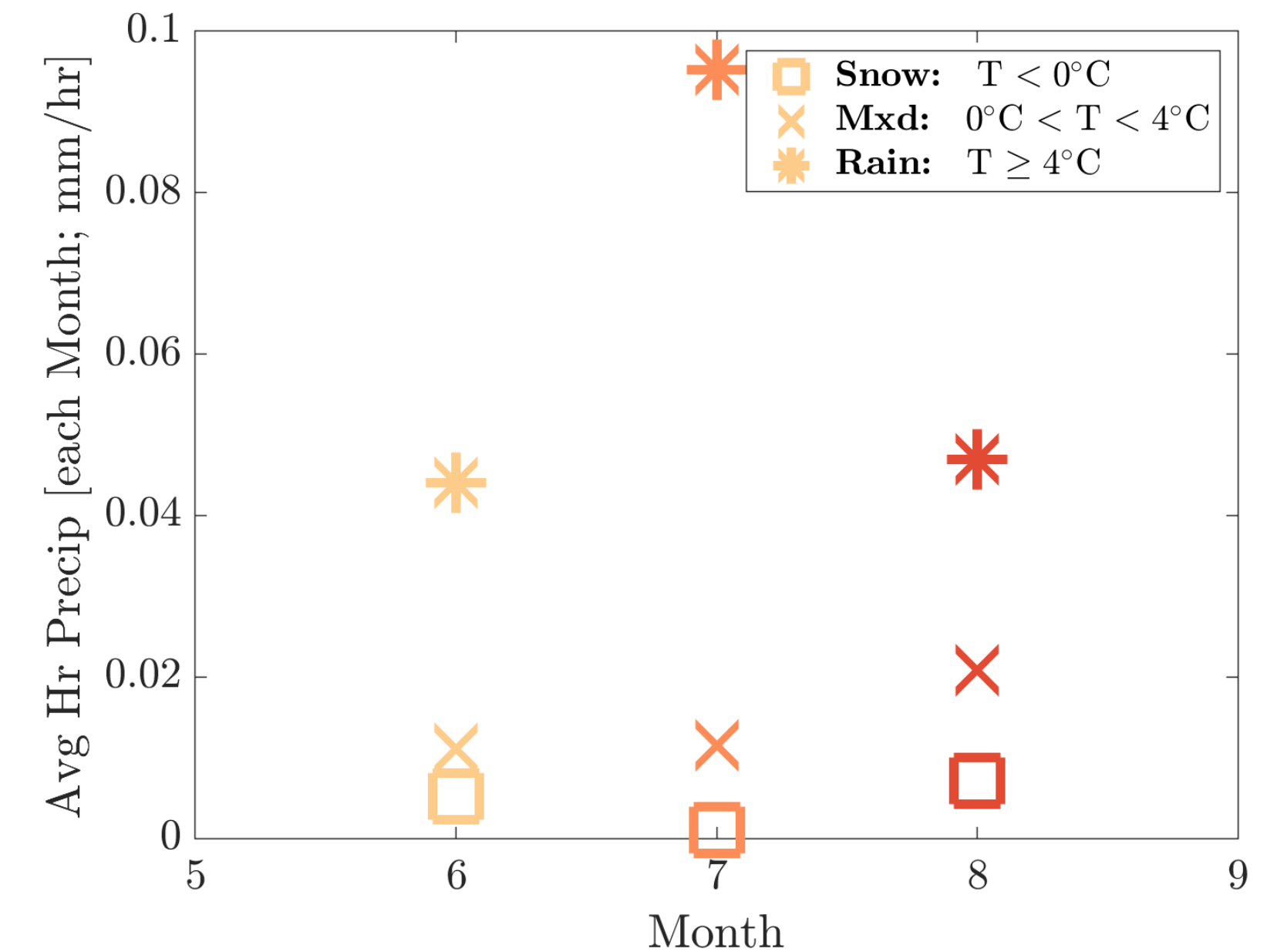
Precipitation intensity and evaporation do not explain this decrease



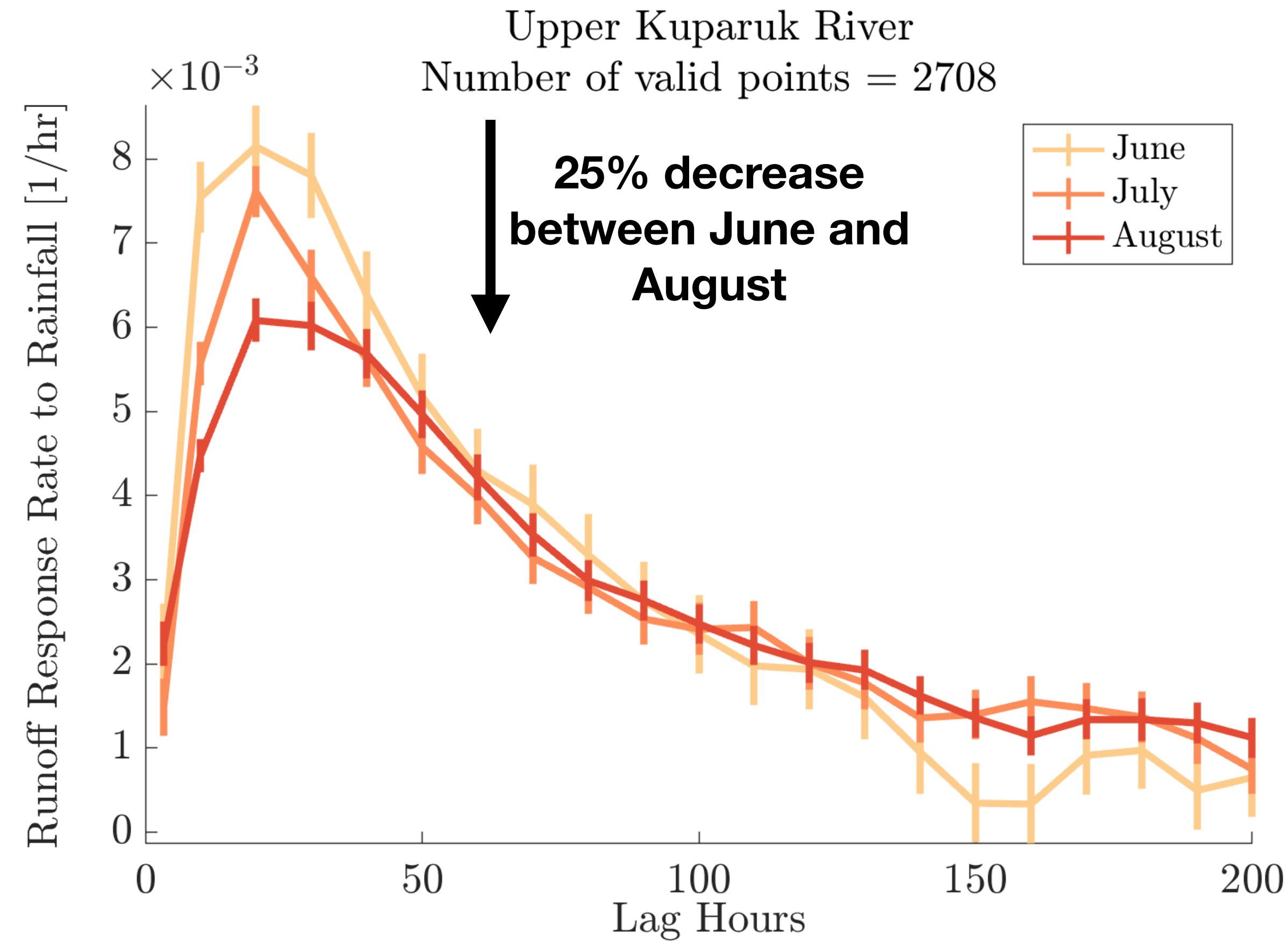
Precipitation does not decrease



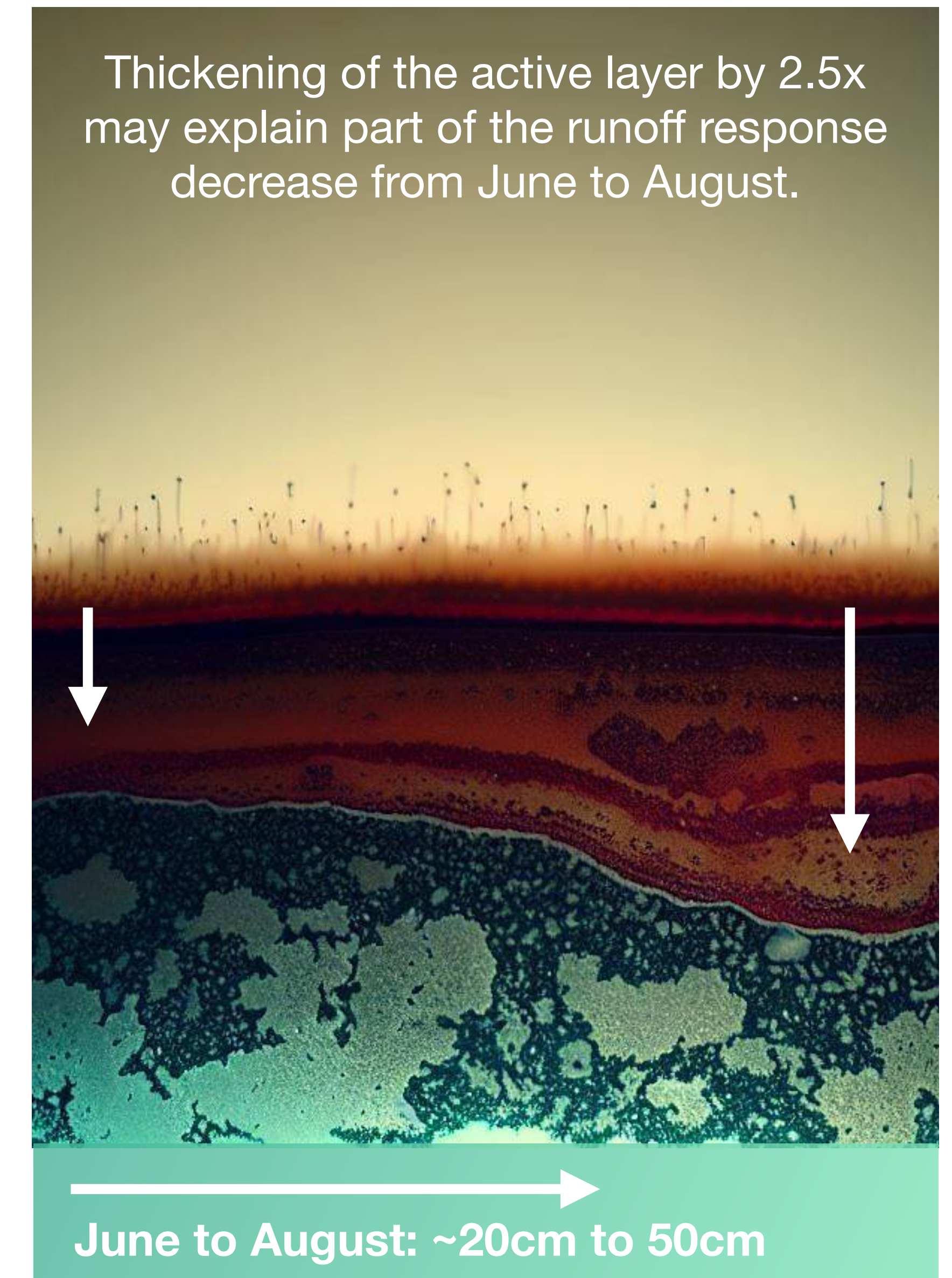
Summer Temperatures do not increase



Average monthly rainfall does not decrease



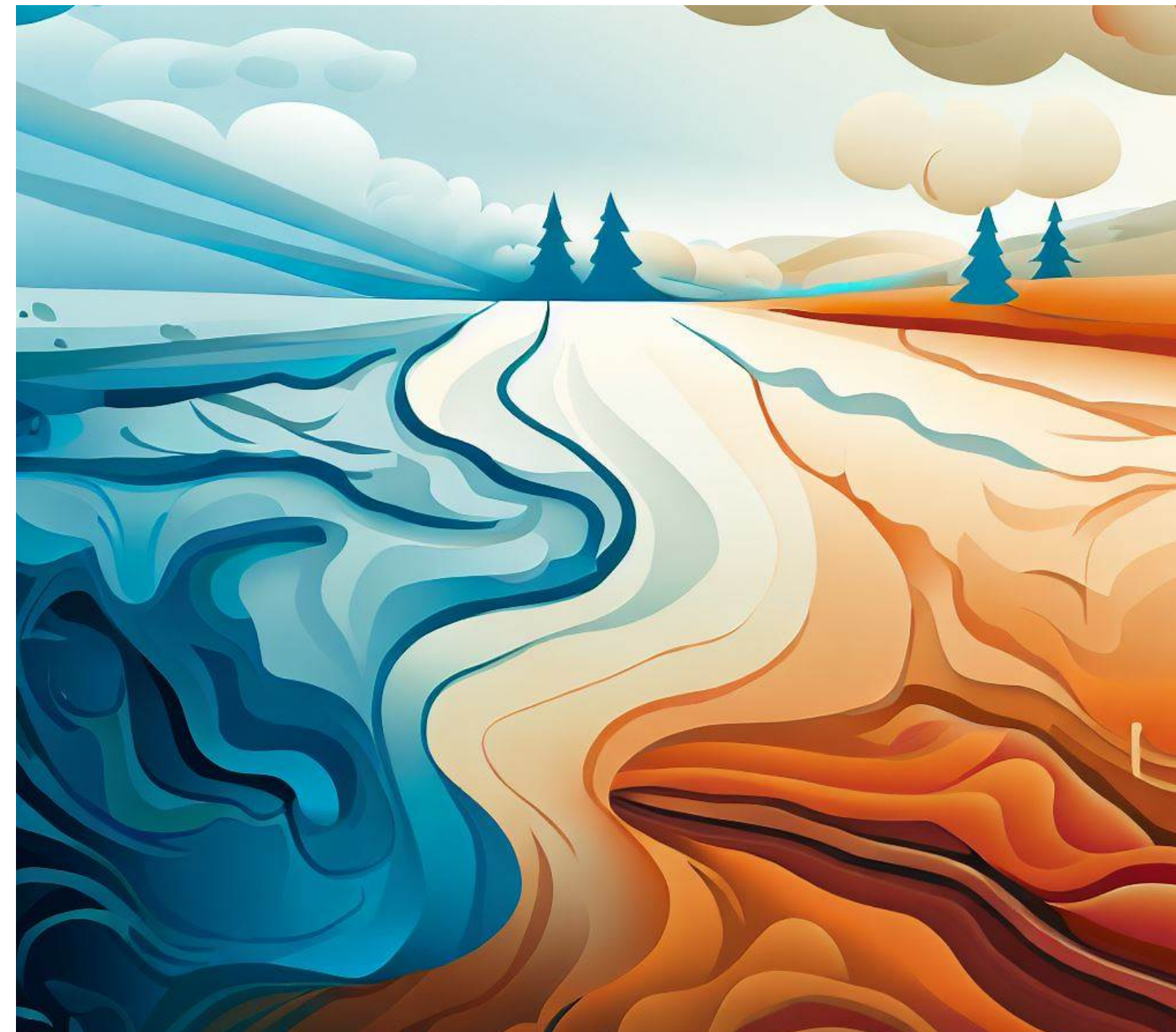
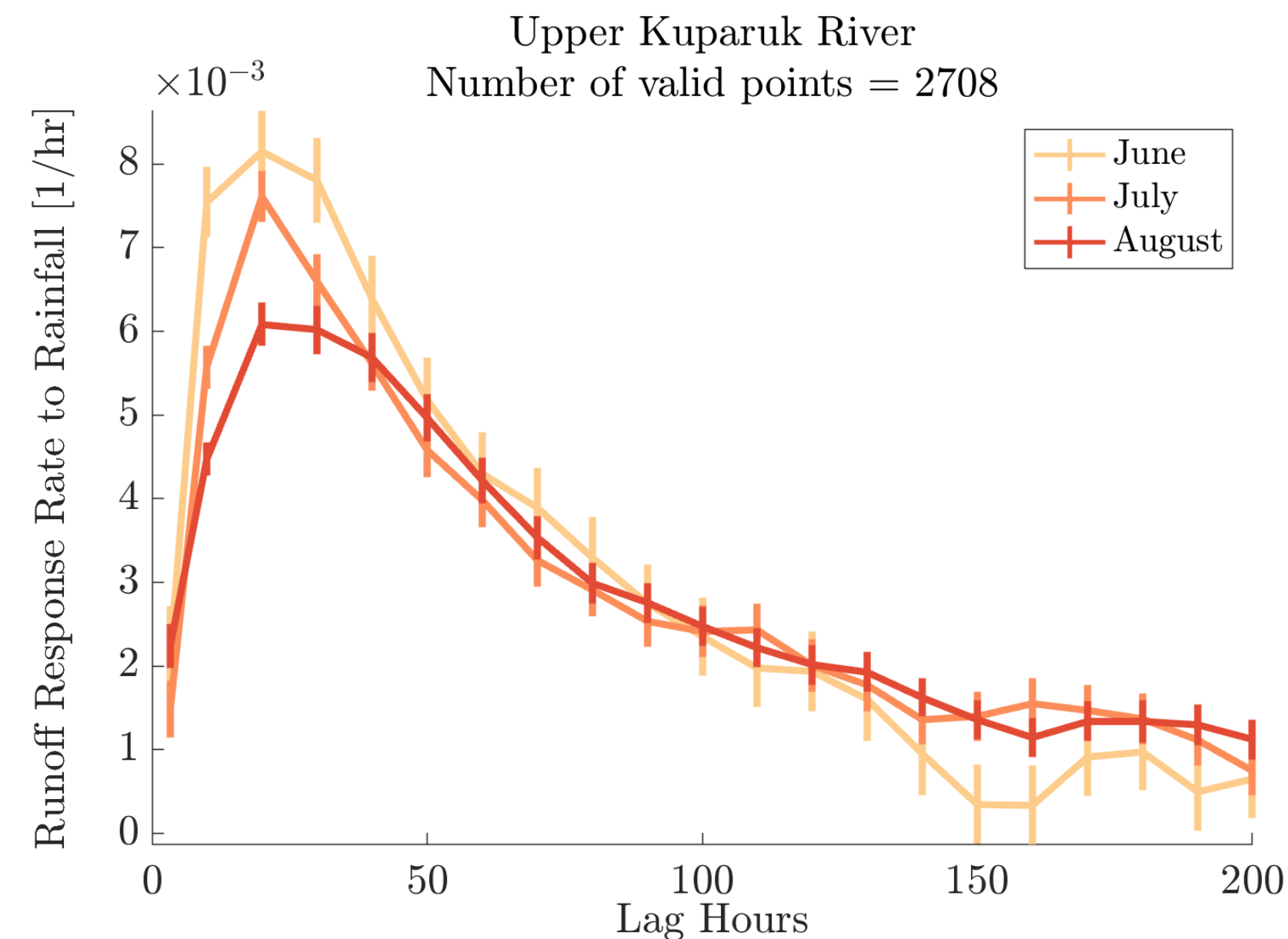
Runoff Response Rate to Rainfall decreases by 25% between June and August, maybe because of active layer thickening



How does the runoff response to rainfall change year-year and month-month?

<—>

Months



Runoff response to rainfall
decreases over the **summer
months**.

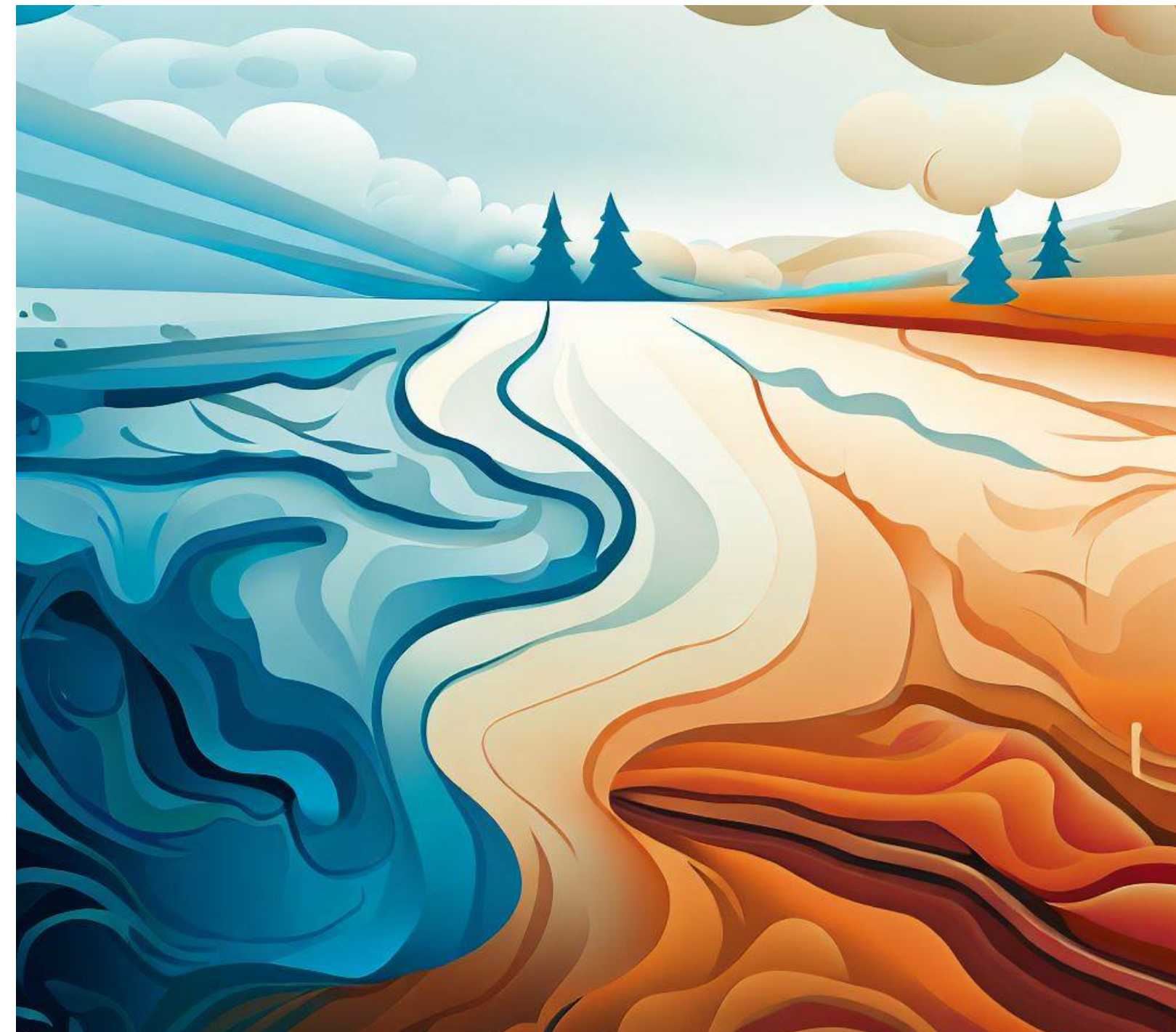
How does the runoff response to rainfall change year-year and month-month?

Years



Months

Runoff response to rainfall shows a **positive** correlation with the **summer precipitation** and **negative** correlation with **average winter temperatures**.

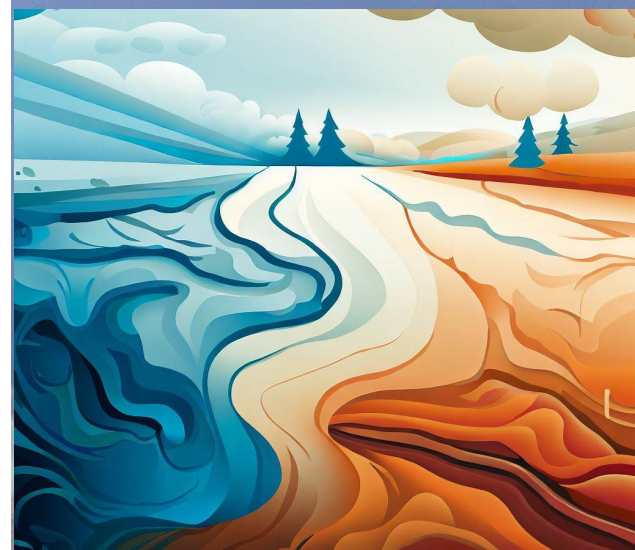


Runoff response to rainfall **decreases** over the **summer months**.

**Have rainfall-runoff time
series data?**

Please reach out!

Thank you.



Cansu Culha

Email:

cansu.culha@gmail.com

ETH zürich

