



# Introducing Flash-Intensity-Duration-Frequency (F-IDF) curve: A New Metric to Quantify Flash Flood Intensity

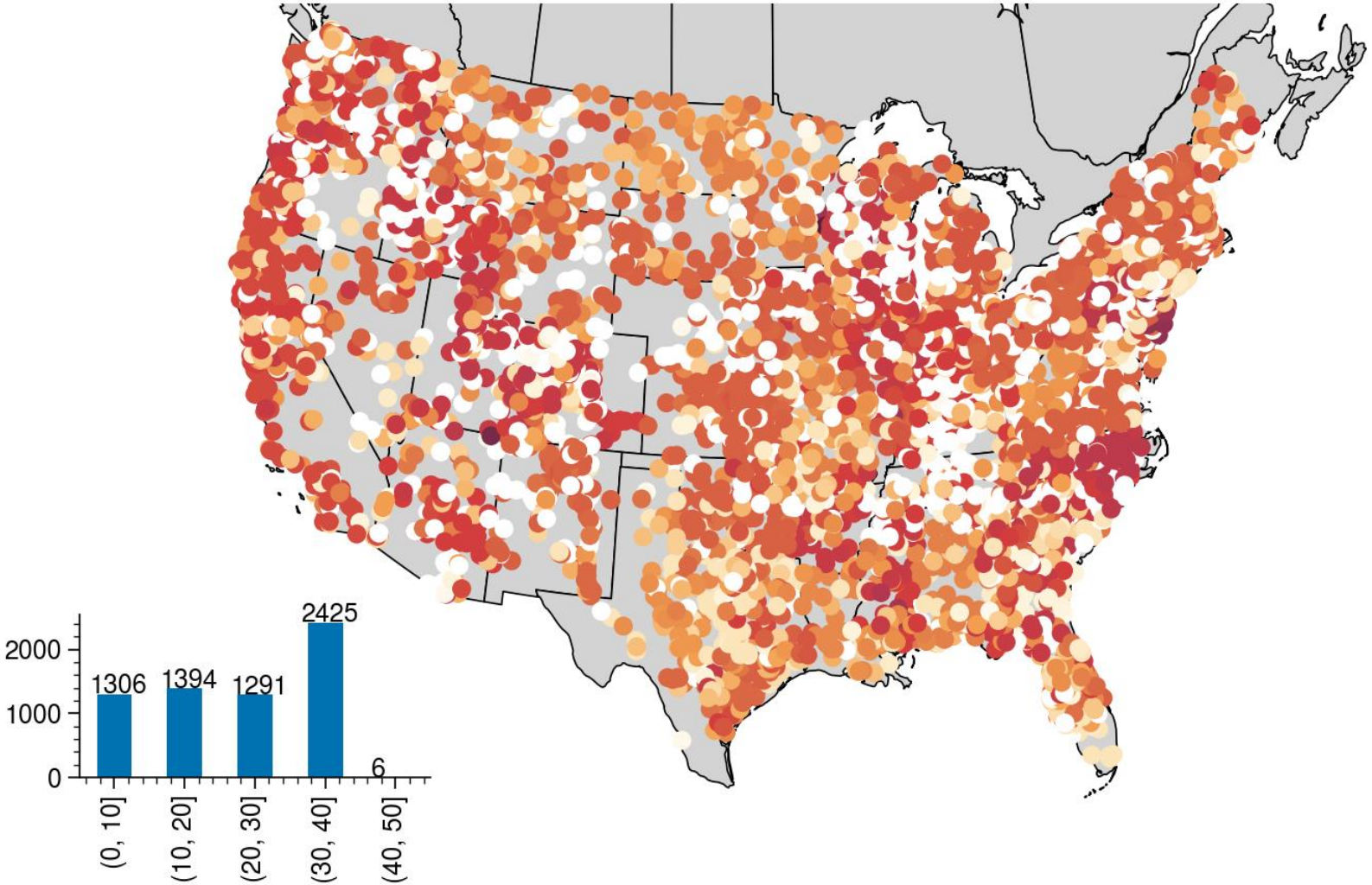
HYDROLOGY & WATER SECURITY PROGRAM
The UNIVERSITY of OKLAHOMA

# Context

- How to identify basins or parts or the country that are “flashy” and thus respond quickly to rainfall and with high magnitudes?
- If flashiness variables can be identified using observed discharge, can they be used in a forecasting context?
  - Proposal: Compute Flashiness-Intensity-Duration-Frequency Curves
  - Apply in 5,116 USGS gauges at 15-min resolution



# Data record length for USGS gauges



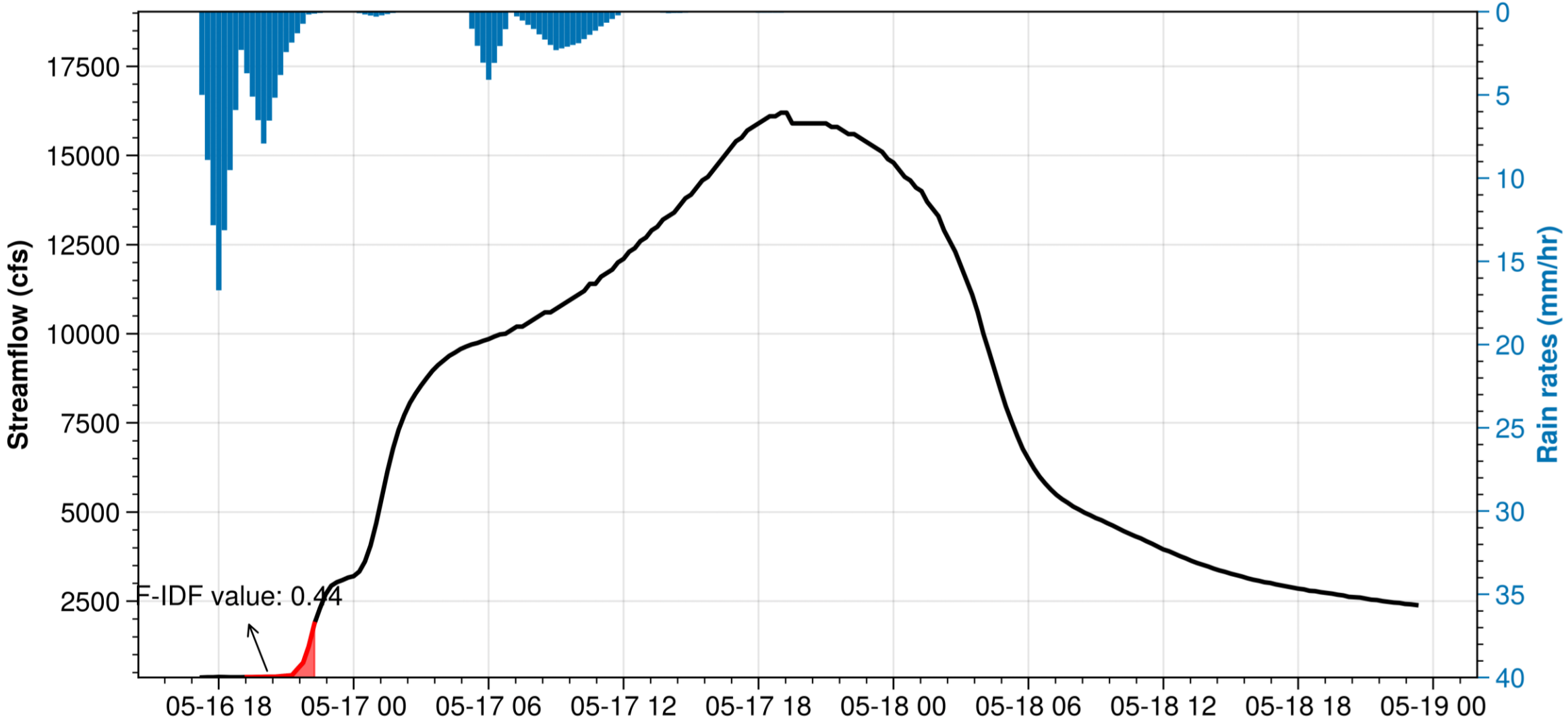

HYDROLOGY & *The* UNIVERSITY *of* OKI

# Fit extreme value distribution

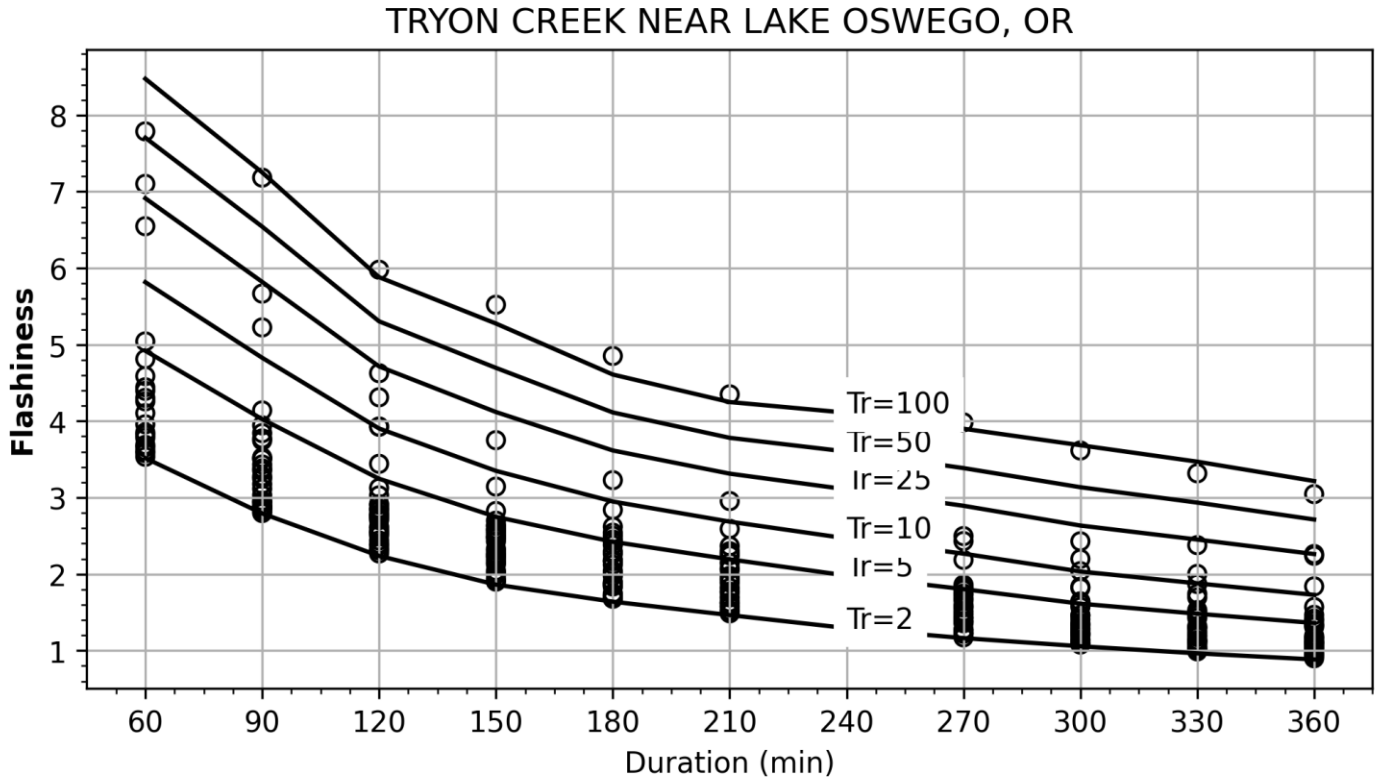
- Find maximum slope of hydrograph over a moving time window (D=1hr, 2hr, 3hr, 4hr, 5hr, and 6hr)
- Extract the annual maximum
- Fit into general extreme value distribution and logPearson Type III distribution
- Find an optimal fit based on the BIC (Bayesian Information Criterion)
- Find flashiness values at different frequency 2-yrs, 5-yrs, 10-yrs, 25-yrs, 50-yrs, and 100-yrs

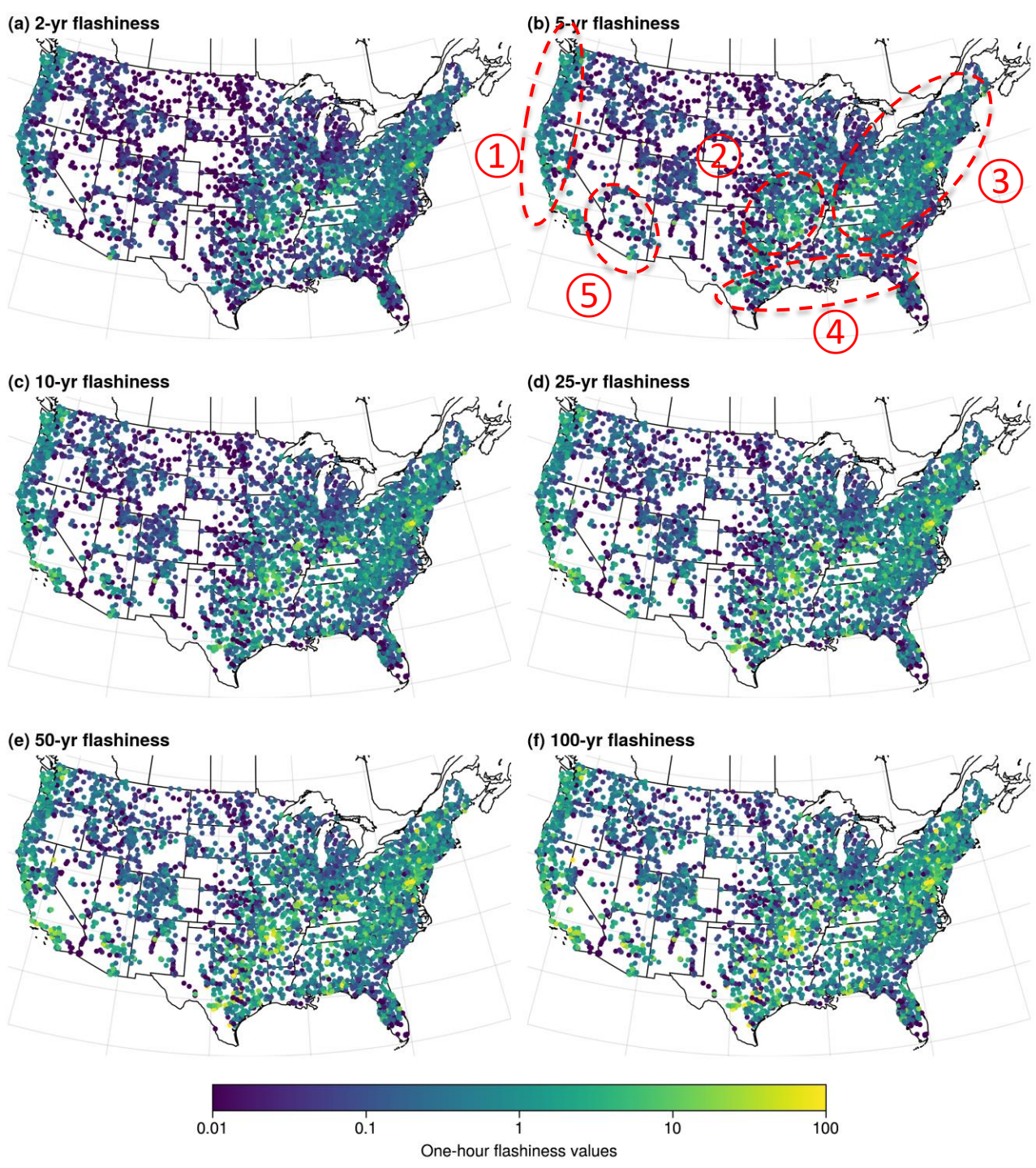


# Illustration – 3hour FIDF



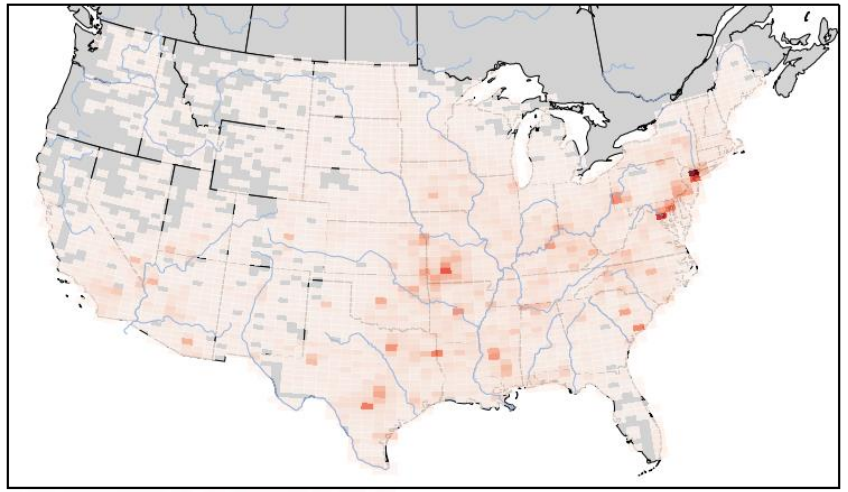
# Flashiness-Intensity-Duration-Frequency (F-IDF) curve

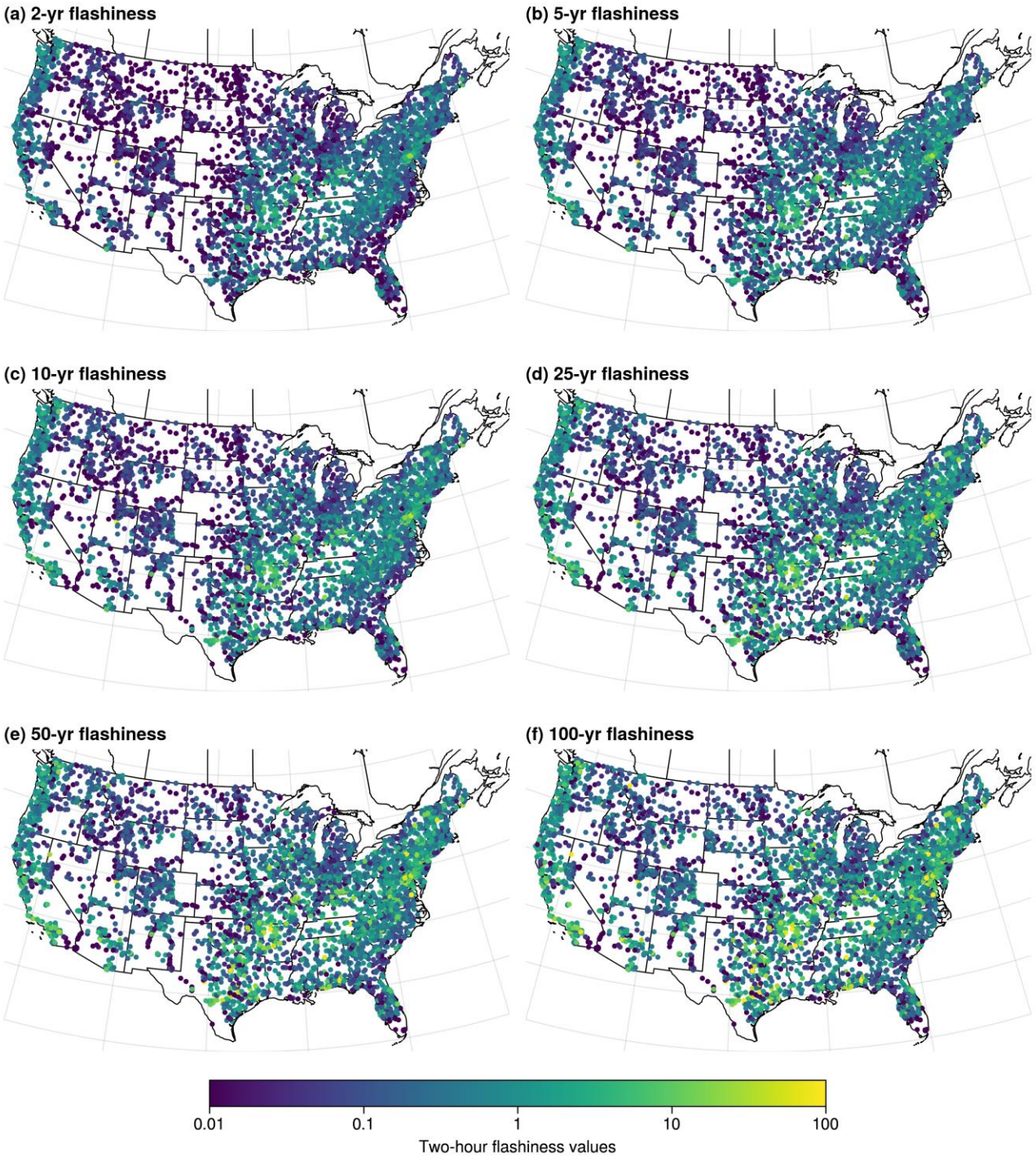




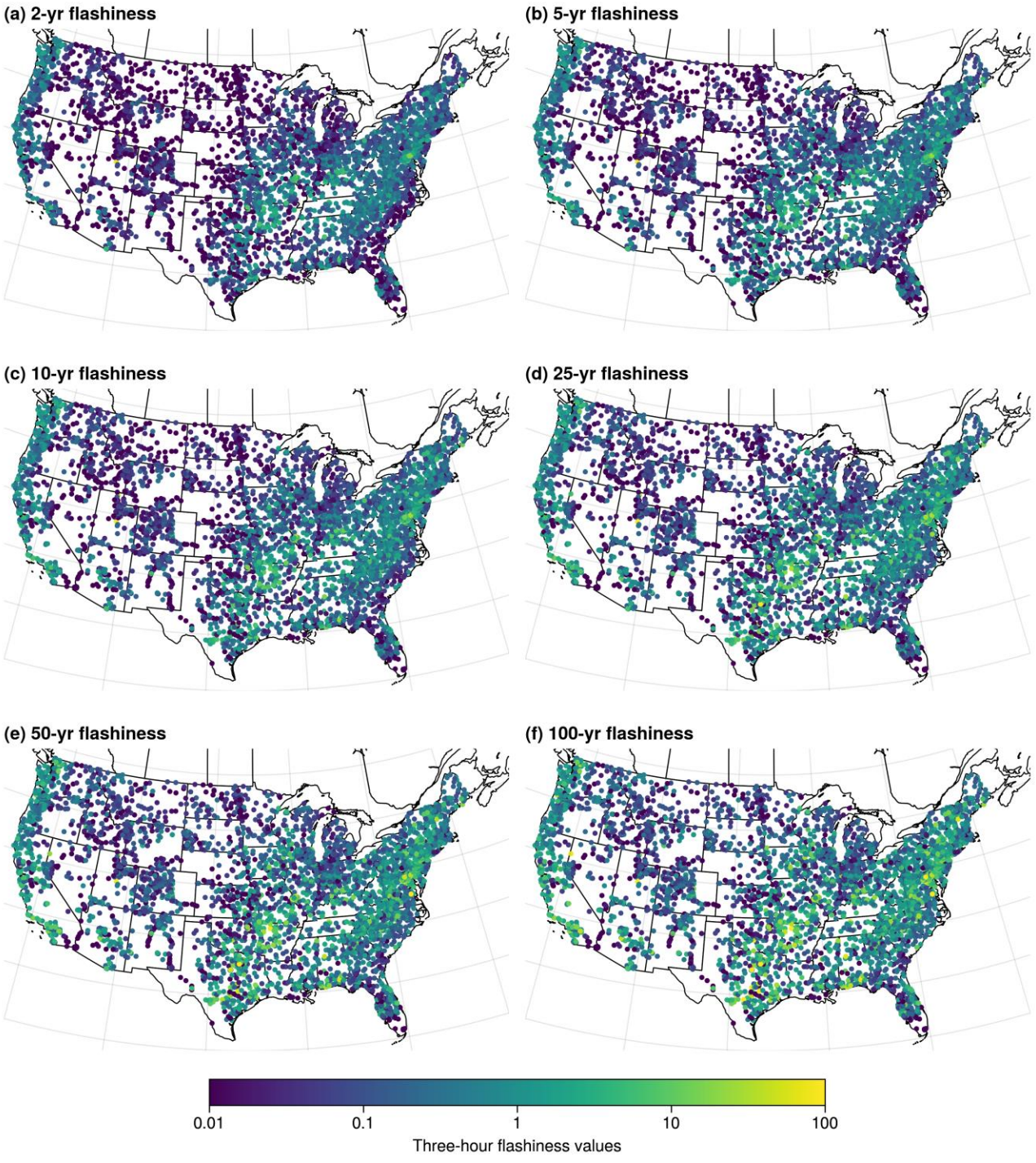

# Flash flood frequency values at 1-hour duration

Flash flood occurrence density plot (based on Storm Events)

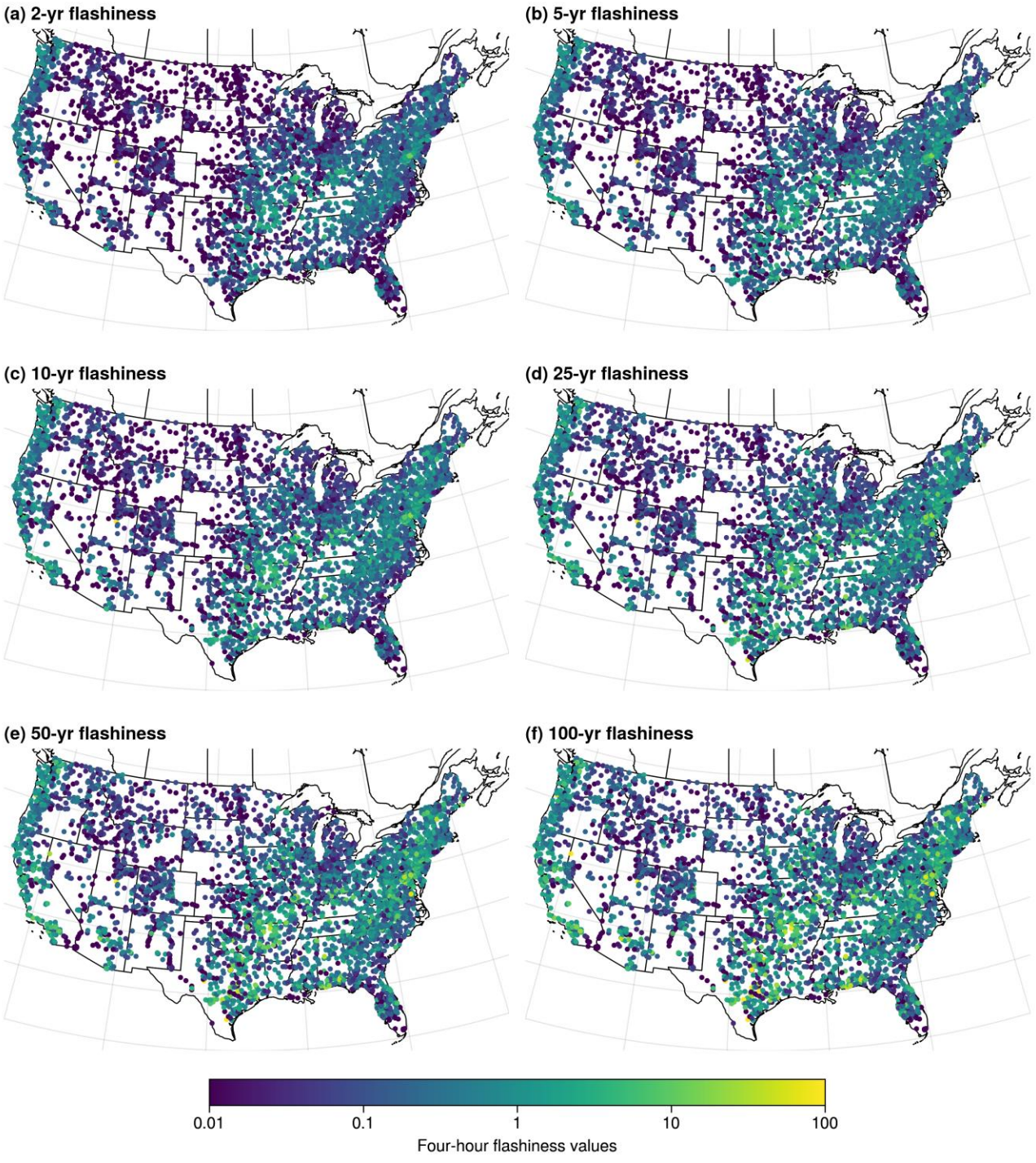




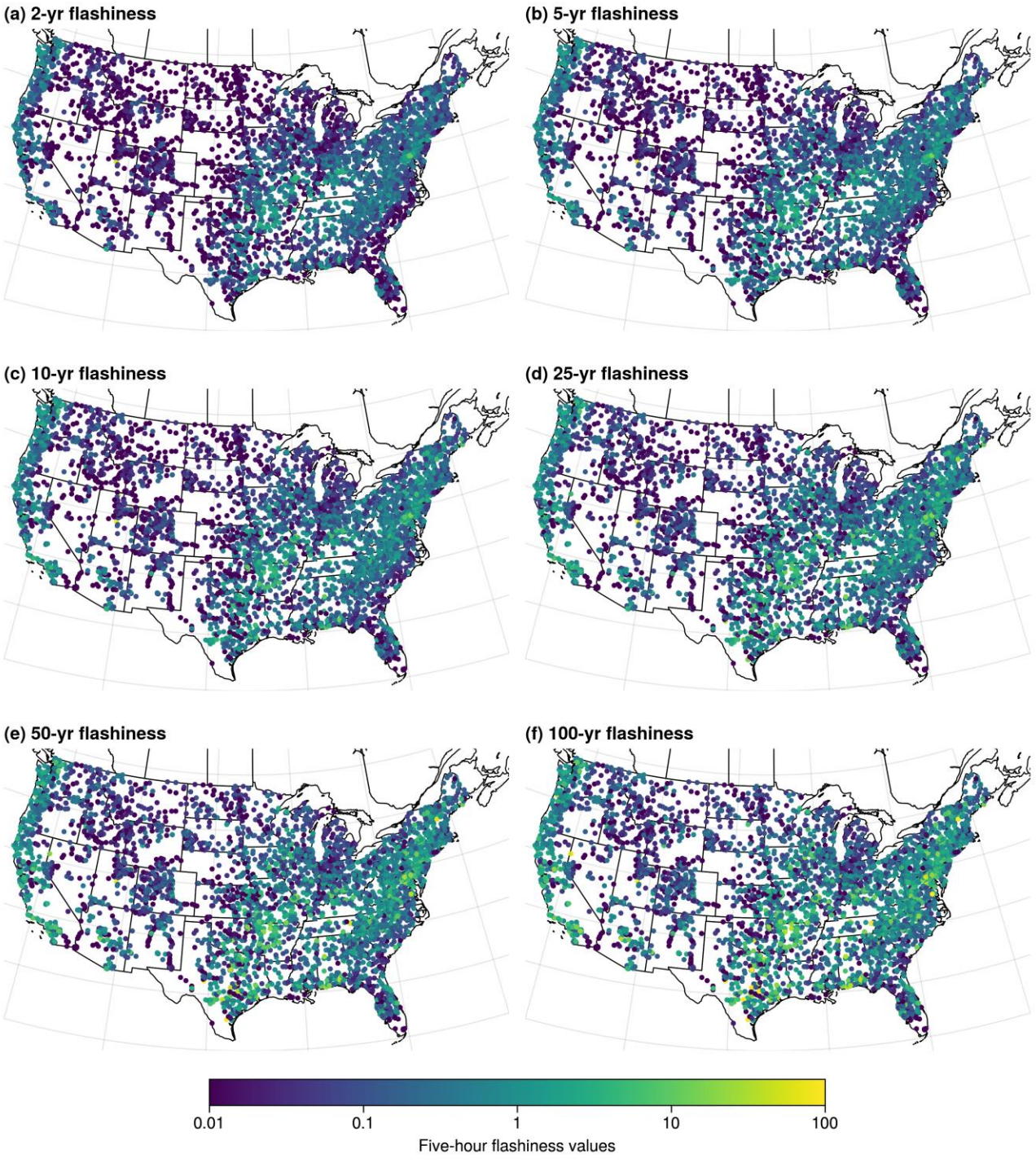

# Flash flood frequency values at 2-hour duration



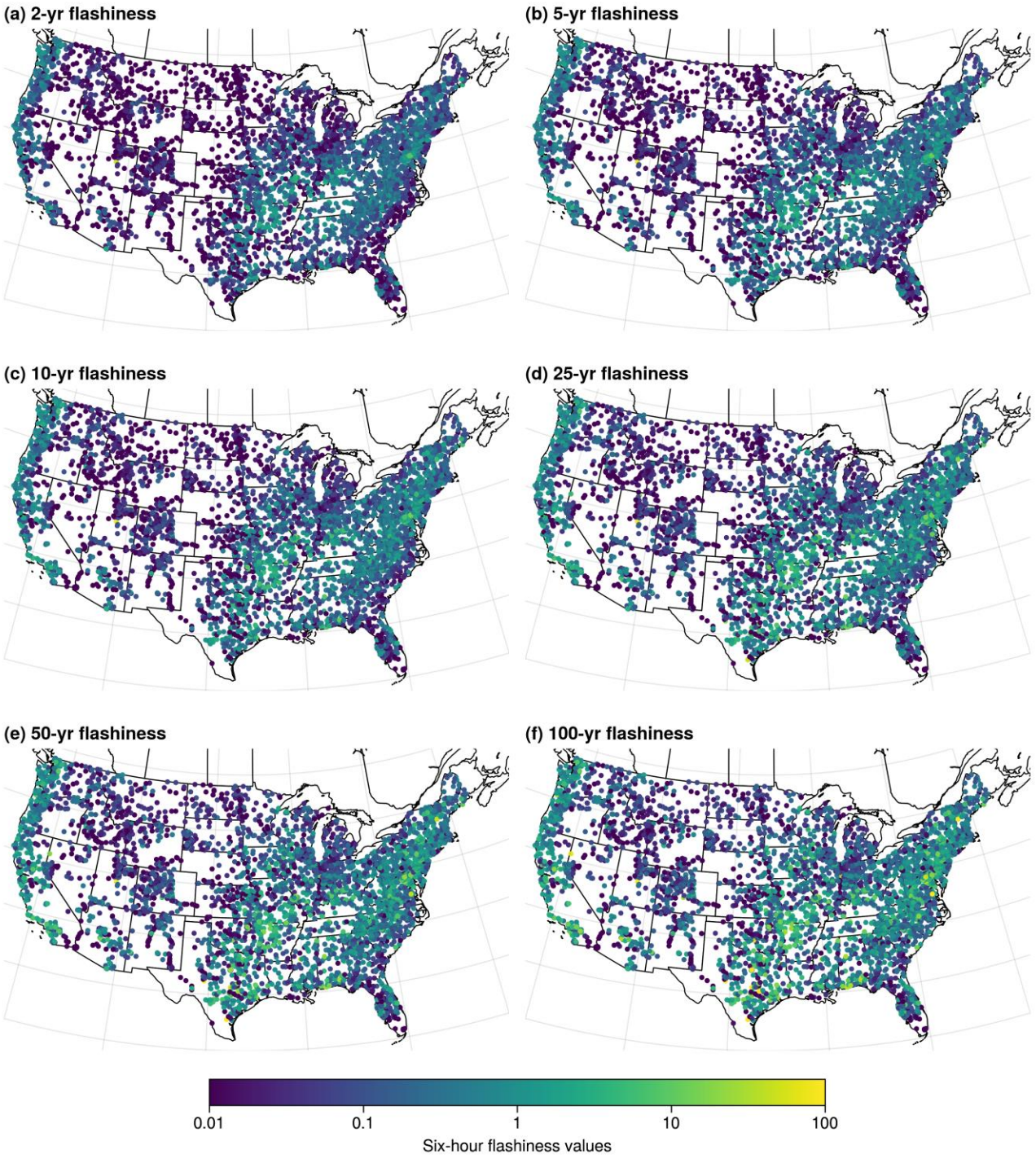

# Flash flood frequency values at 3-hour duration




# Flash flood frequency values at 4-hour duration

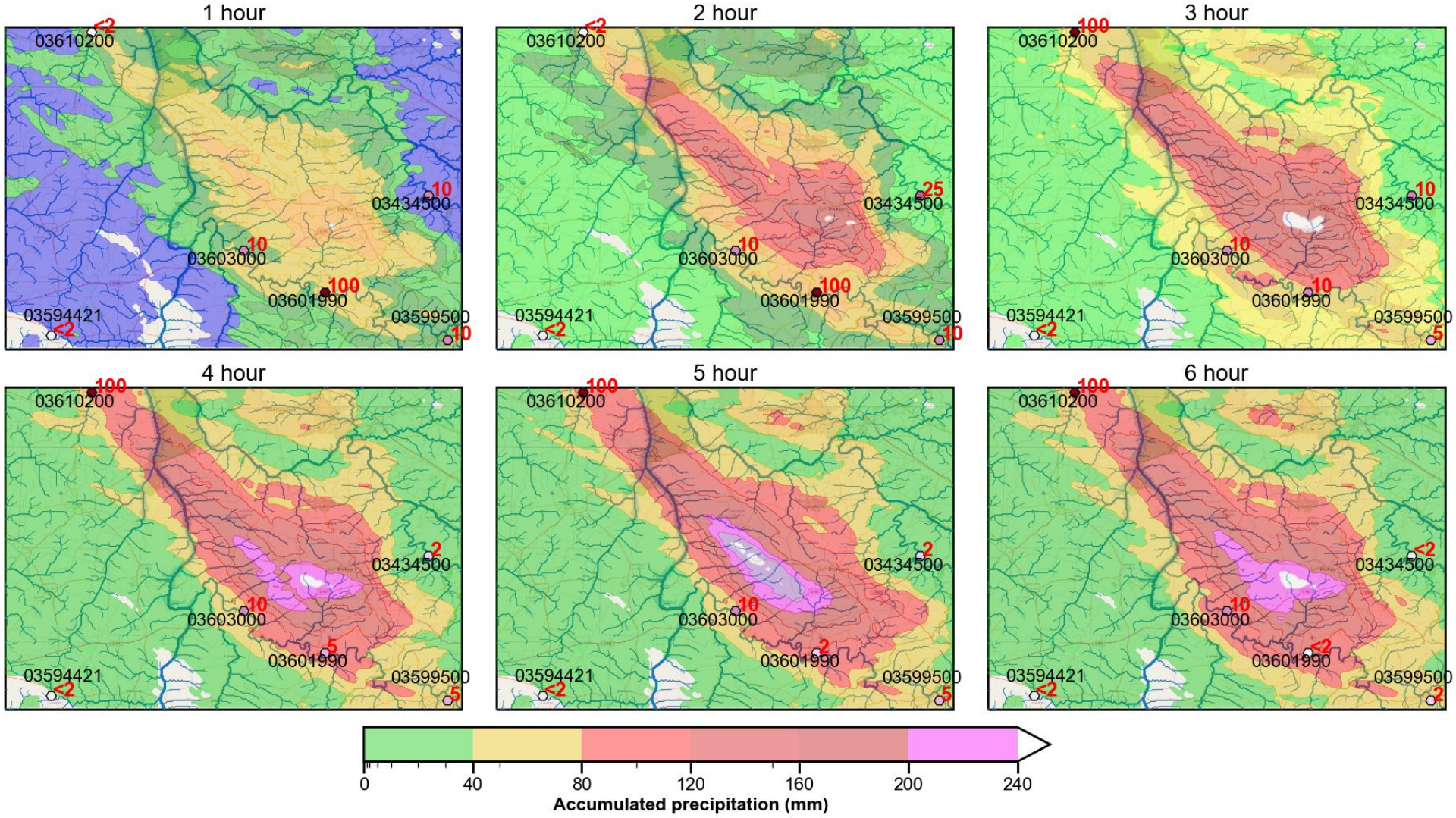


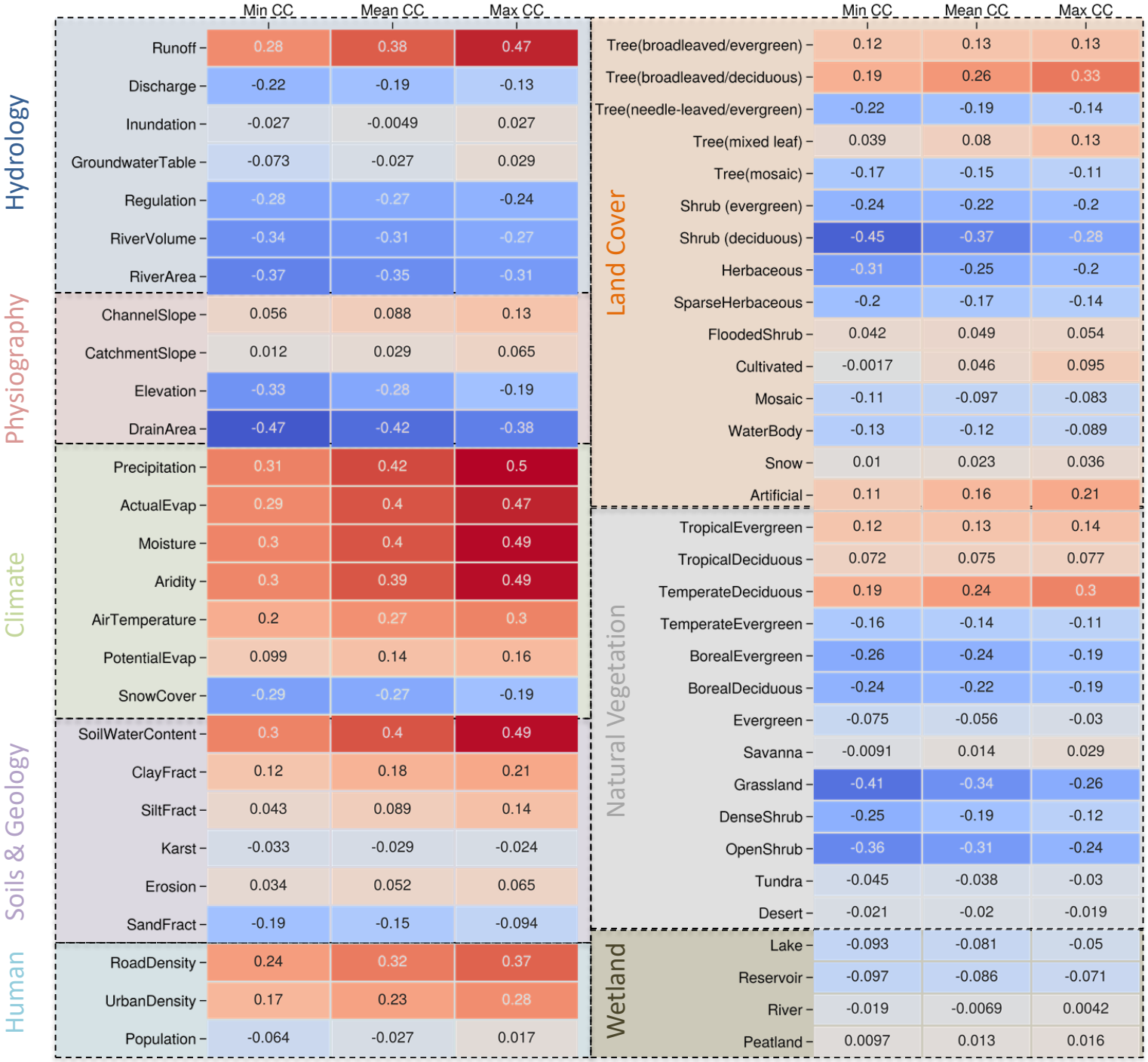

# Flash flood frequency values at 5-hour duration




# Flash flood frequency values at 6-hour duration

# 2021 Tennessee flash flooding

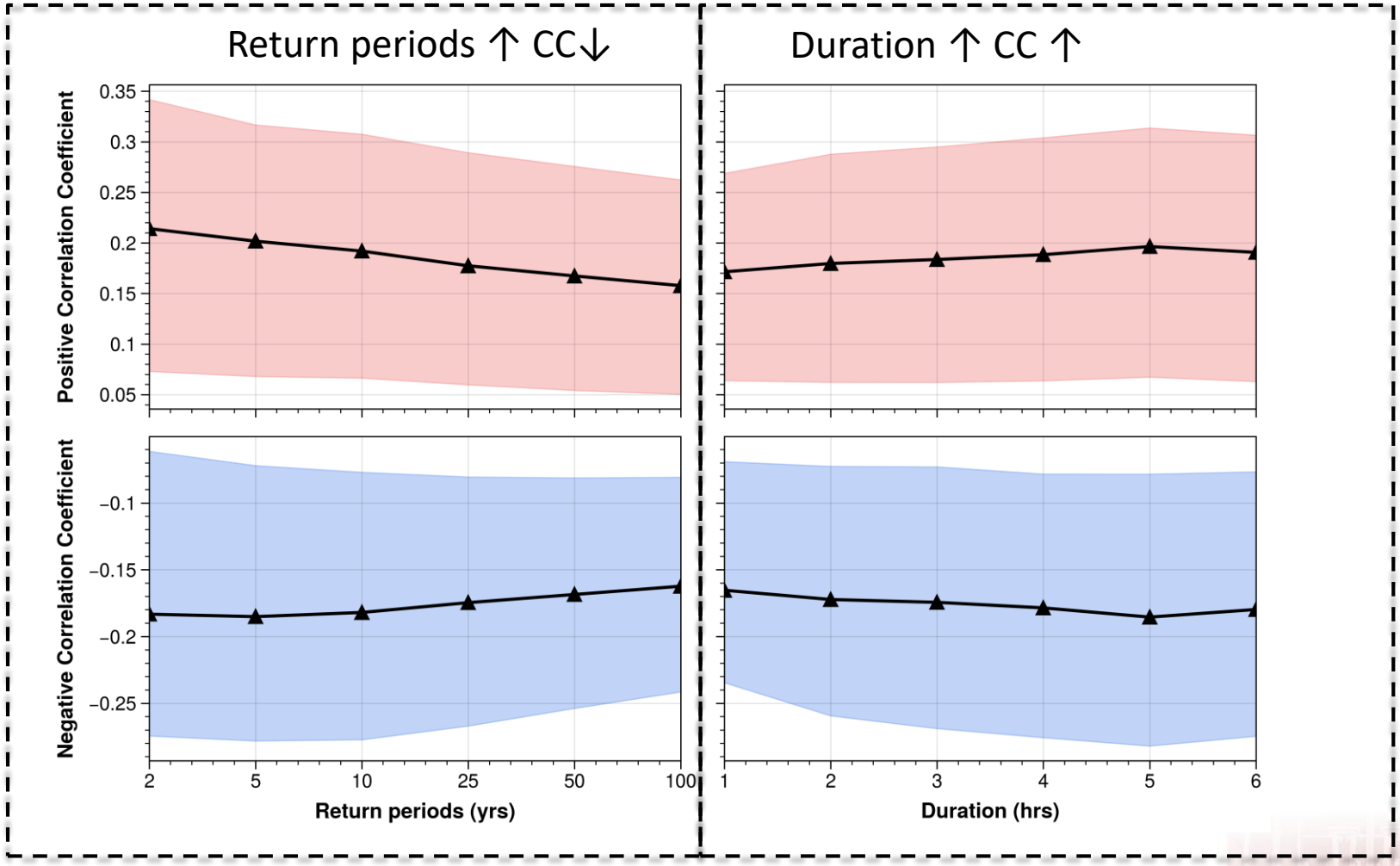





# Factors

1. ↑ Flashiness -> ↓ discharge, river area/volume: small reaches tend to have higher flashiness values
2. ↑ Flashiness -> ↓ regulation: flood structures impede flash floods
3. ↑ Flashiness -> ↑ land runoff, air temperature, aridity index, evaporation, climate moisture index: flashiness is a weather-dependent variable not dependent on climate
4. ↑ Flashiness -> ↓ snow cover extent: flash floods are not typically snow-driven
5. ↑ Flashiness -> ↑ clay, ↓ sand: clay soils help generate flash floods
6. ↑ Flashiness -> ↑ soil water content: wet soils help generate flash floods
7. ↑ Flashiness -> ↑ urban density, road density: impervious surface area help generate flash floods

# Correlation changes regarding return periods and duration




We reason:

1. When return period increases, flash flood event becomes less dependent on climate variables but rather on weather such as intense rainfall rates, etc.
2. When return period increases, the event is less dependent on a single factor (e.g., rain), but rather a joint factor (e.g., rain + wet antecedent soils + steep channels)

# A distributed F-IDF curve over the CONUS

HYDROLOGY & WATER SECURITY PROGRAM
*The* UNIVERSITY *of* OKLAHOMA

# Research goals & Objectives

- Goal: offer a distributed F-IDF curve over the CONUS
- Objectives:
  - Produce CONUS-wide F-IDF curves based on (1) CREST (physical) and (2) AI (statistical)
  - Cross-compare the two approaches with regard to (1) flashiness representation, (2) limitations

Cross-compare

**CREST-based FIDF**
(gridded)

MRMS reanalysis data

Pre-calibrated parameters

CREST hydrologic model

Streamflow from 2001-2012 @ 1km/15 min

Calculate annual max. flashiness

Fit Extreme Value Distribution

Dynamic (event-based)

**ML-based FIDF**
(reach-based)

RiverAtlas data

59 attributes

Training/testing

20 ML models

Gage-based FIDF

Extrapolation

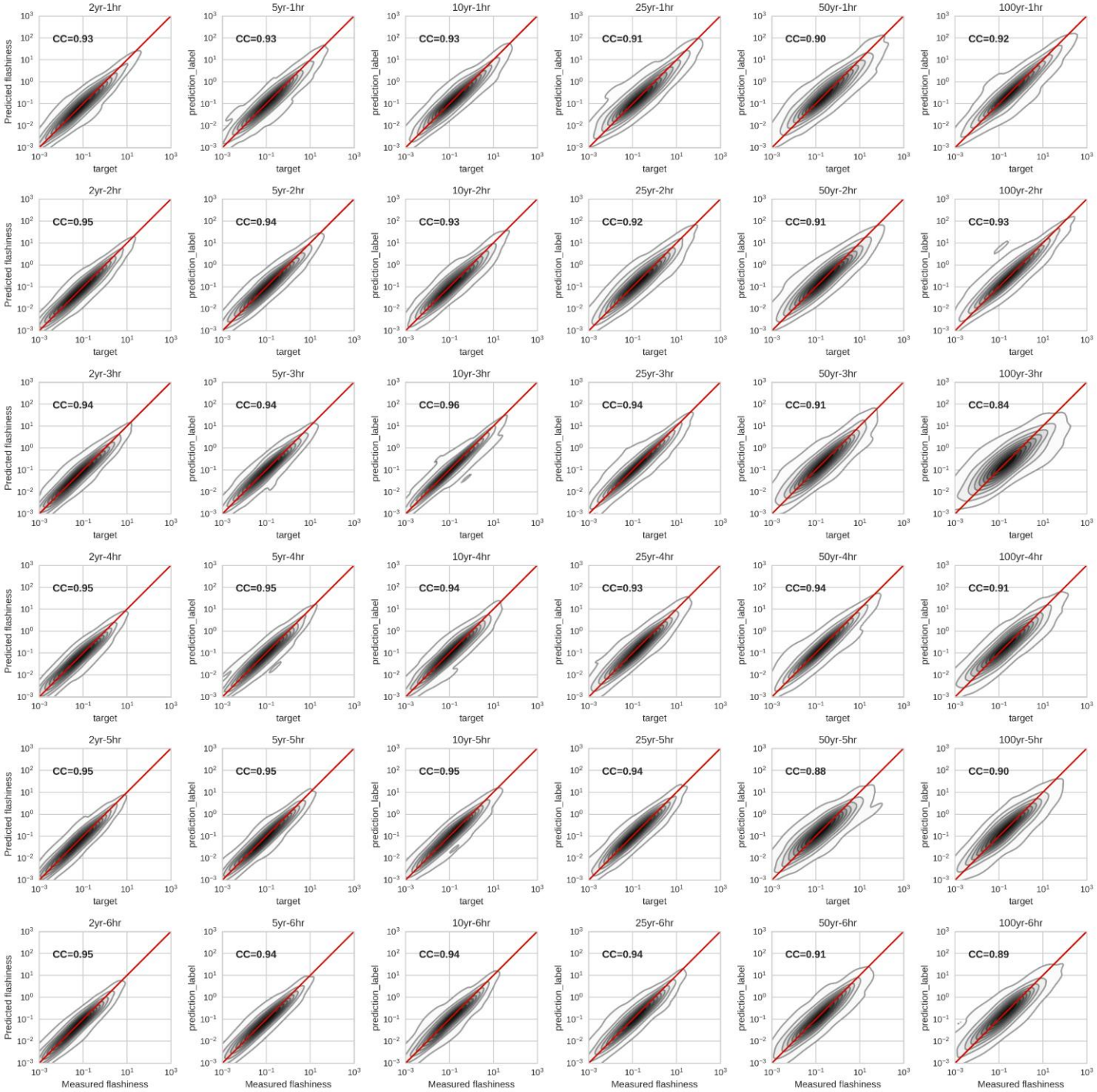
556,711 CONUS river reaches

Annual streamflow (cms
0 - 1
1 - 10
10 - 100
100 - 1,000
1,000 - 2,000
2,000 - 5,000
5,000- 10,000
Lakes

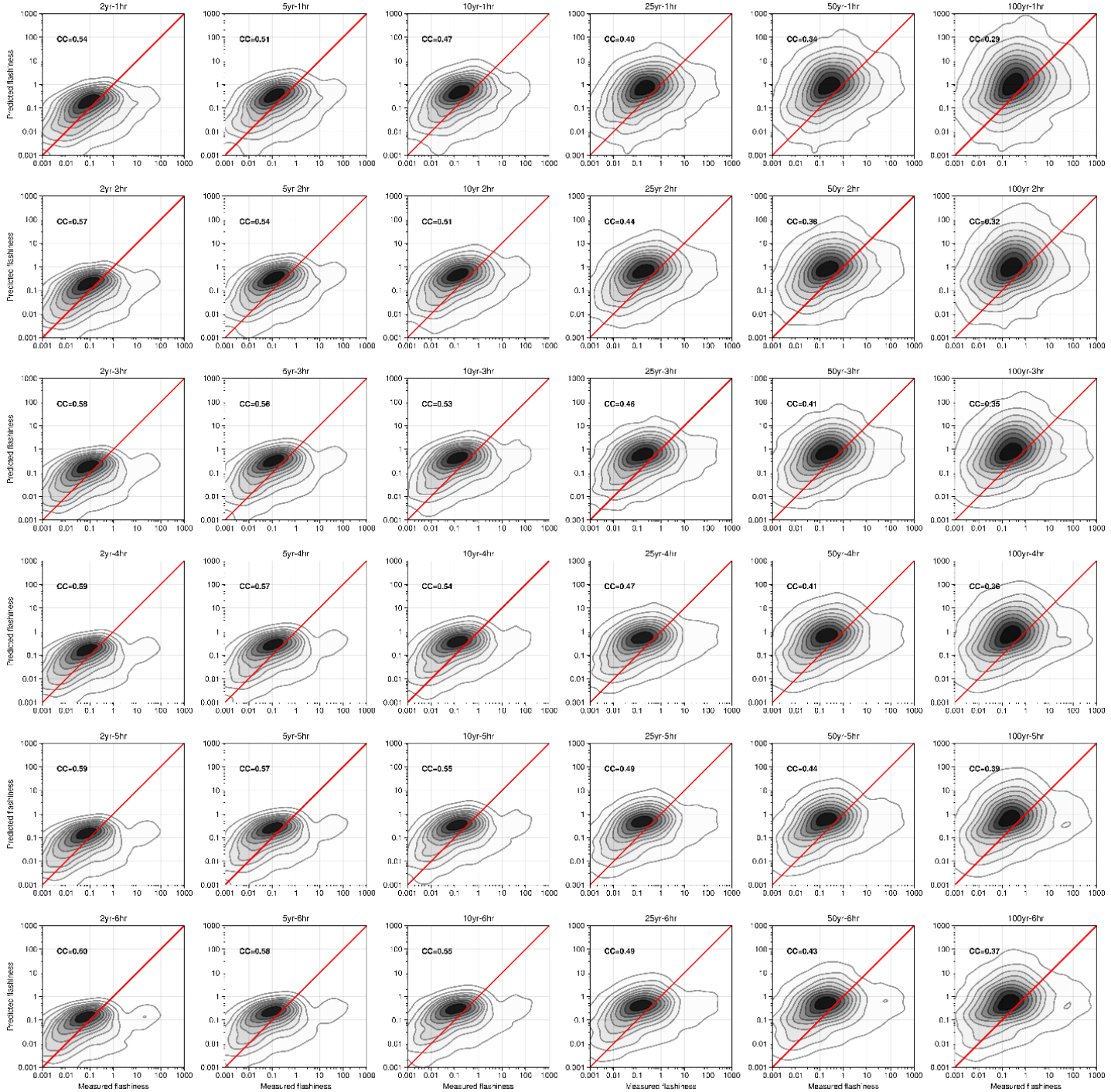
Static

Validate

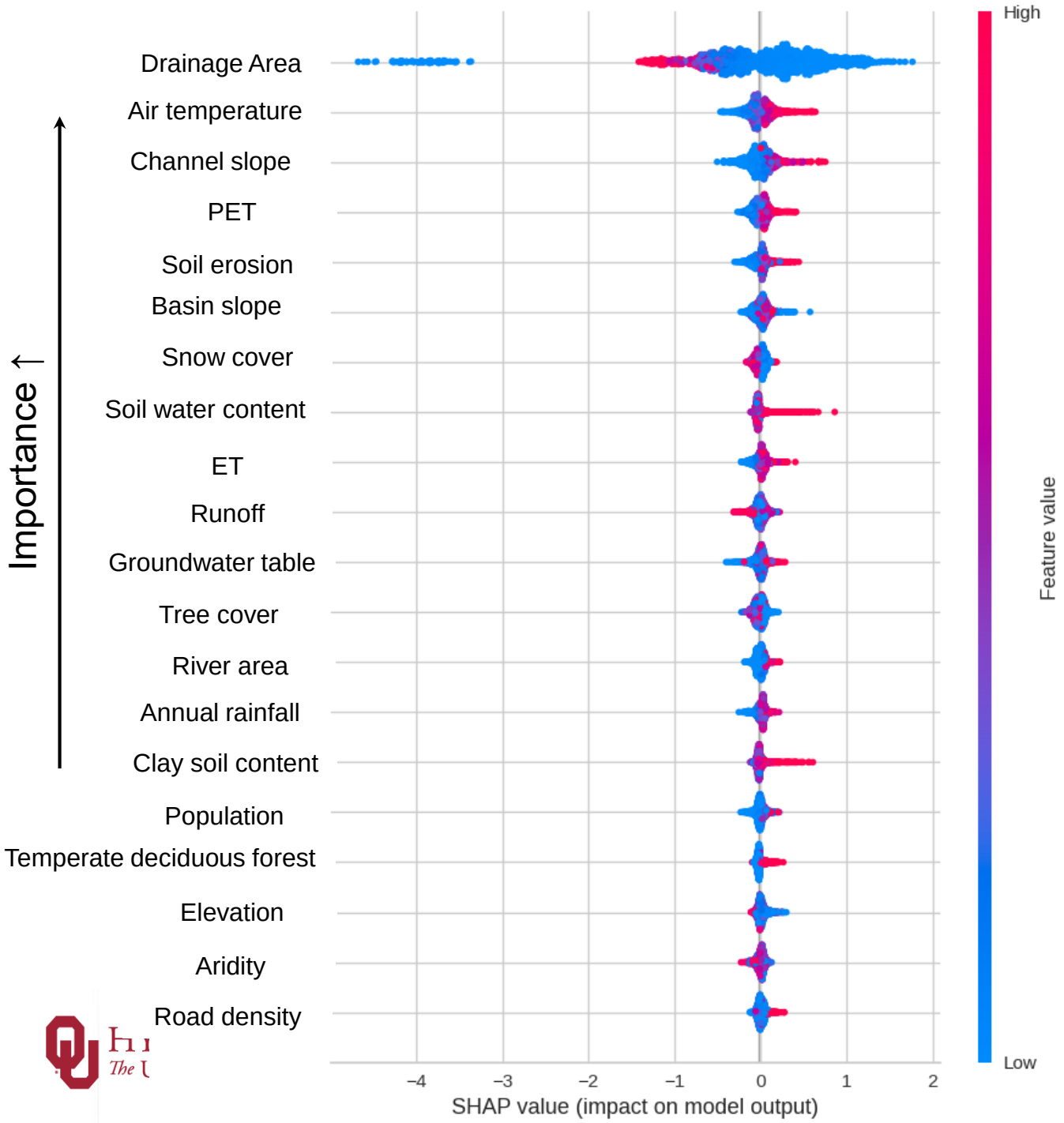
Gage-based FIDF




ML-based testing (validated on gauges)



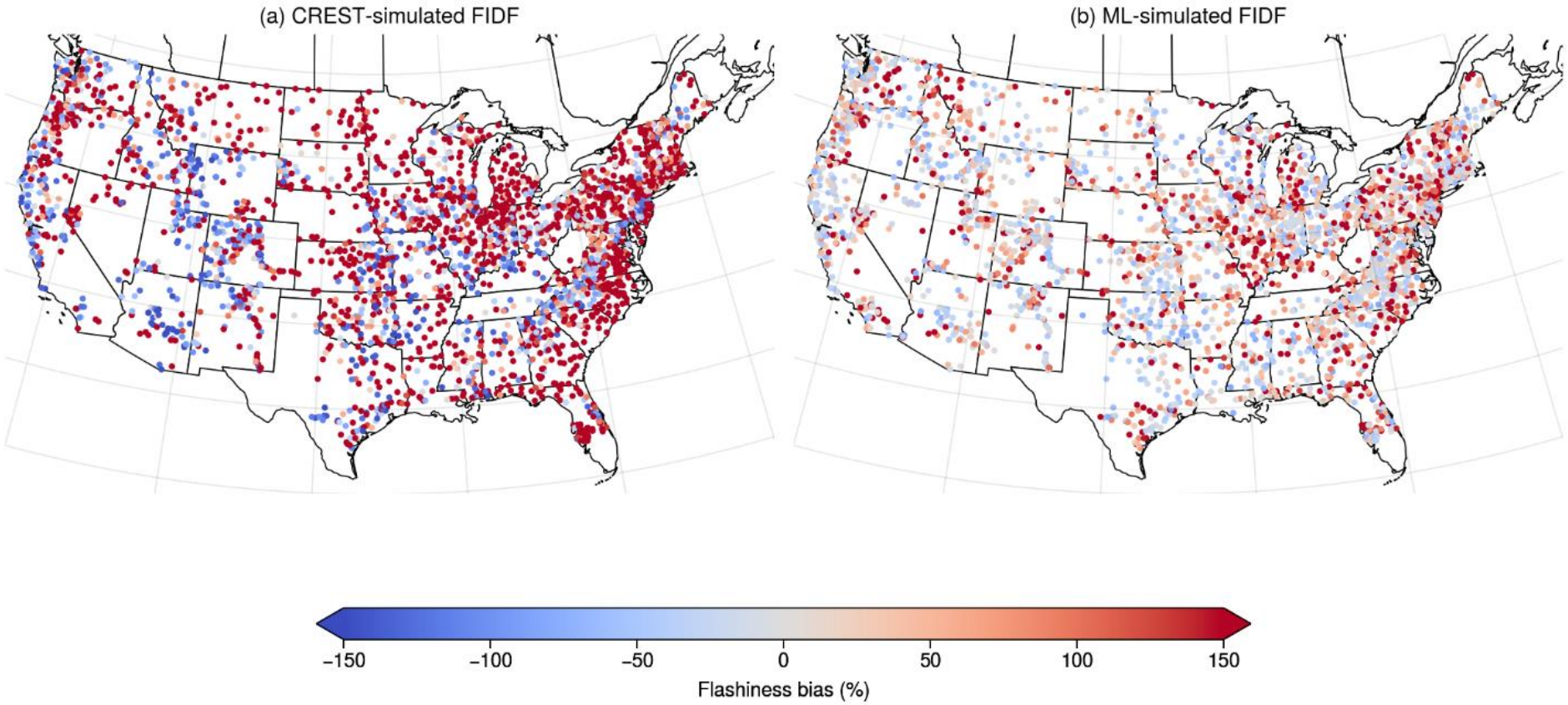

# CREST-based testing

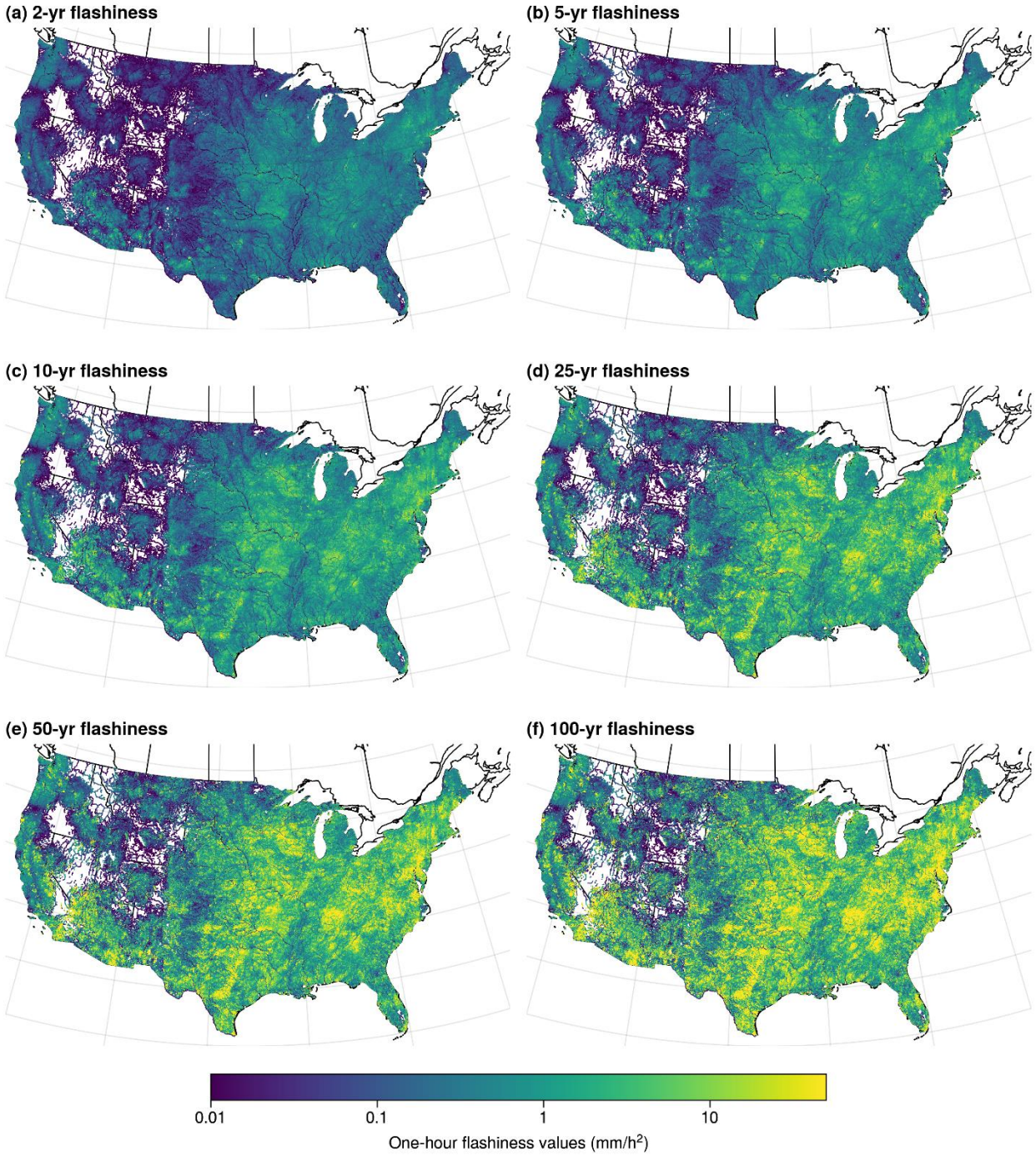



Variable importance ranking from ML-based model

Drainage area has the greatest impact on the model prediction (lower values impact positively on the model prediction)

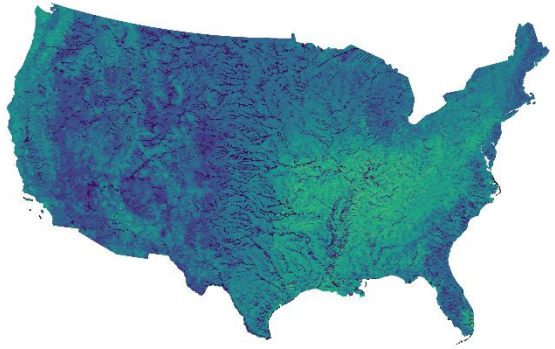
Comparing both CREST-based and ML-based FIDF on all the stream gages



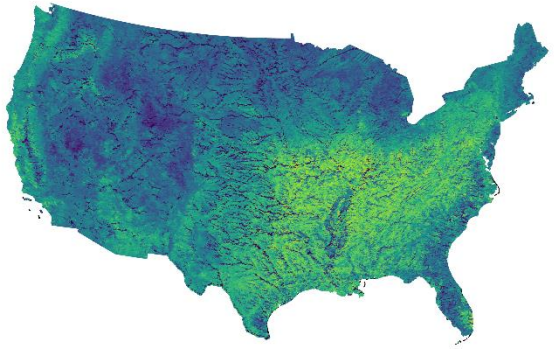



CREST-based distributed FIDF

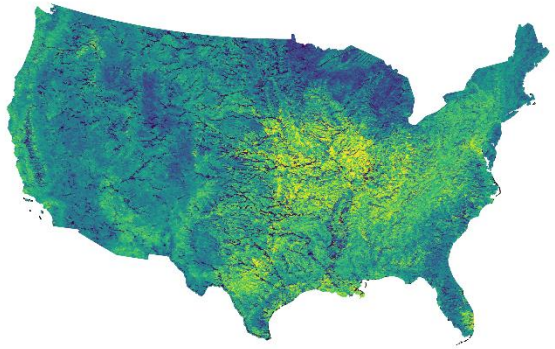
(a) 2-yr flashiness



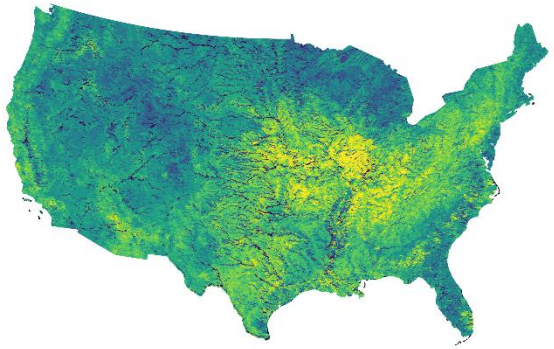
(b) 5-yr flashiness



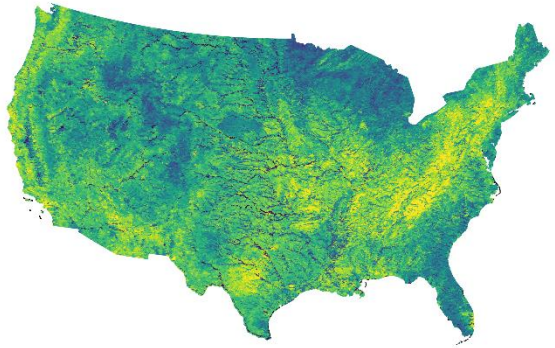
(c) 10-yr flashiness



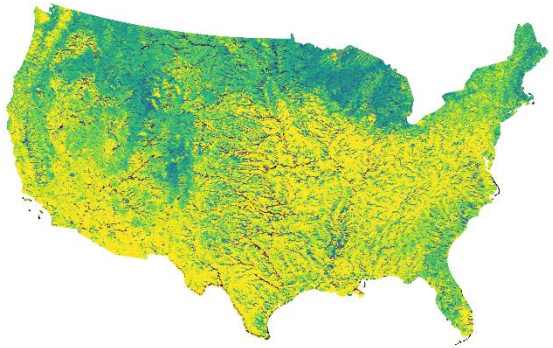
(d) 25-yr flashiness



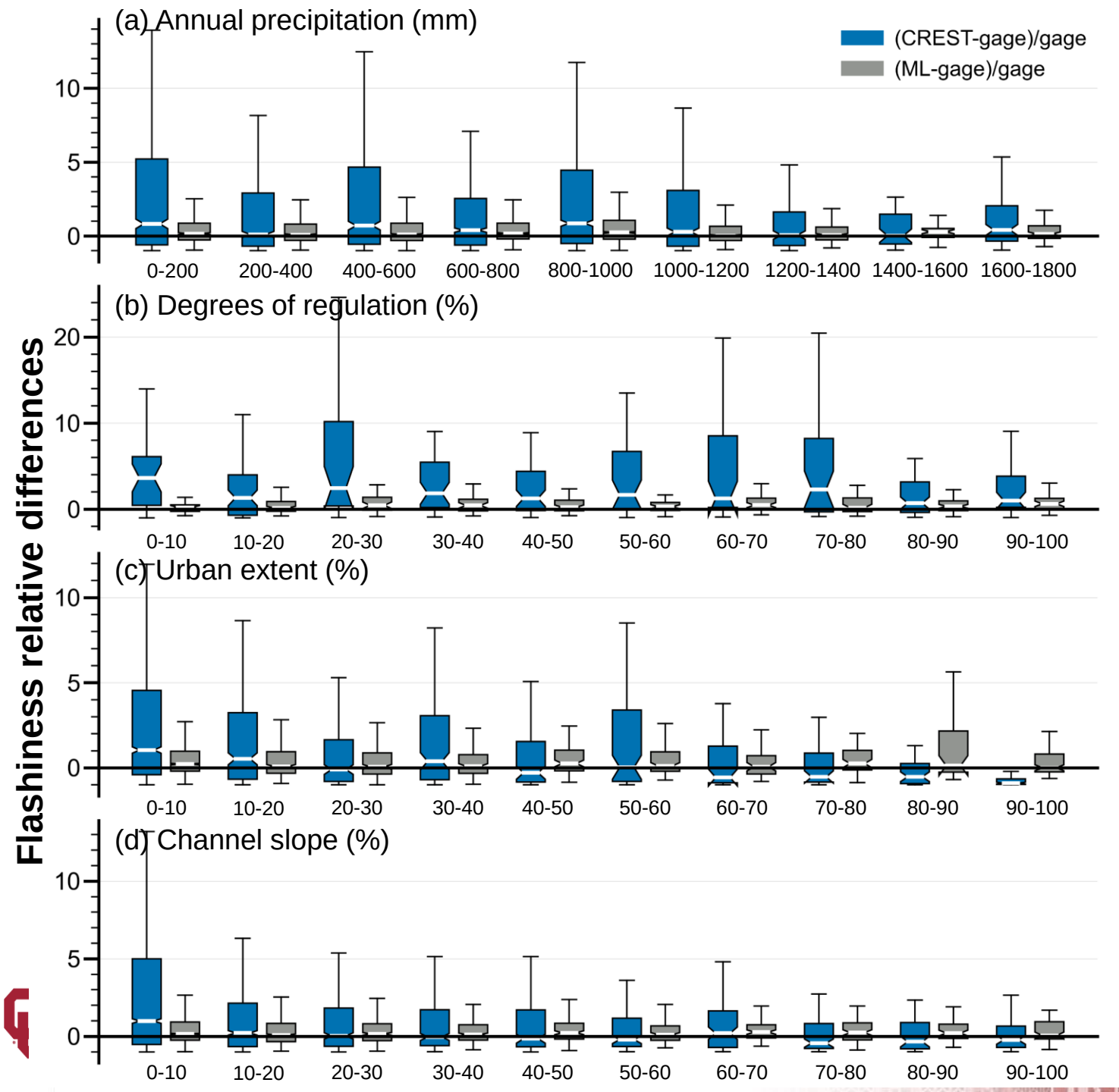
(e) 50-yr flashiness



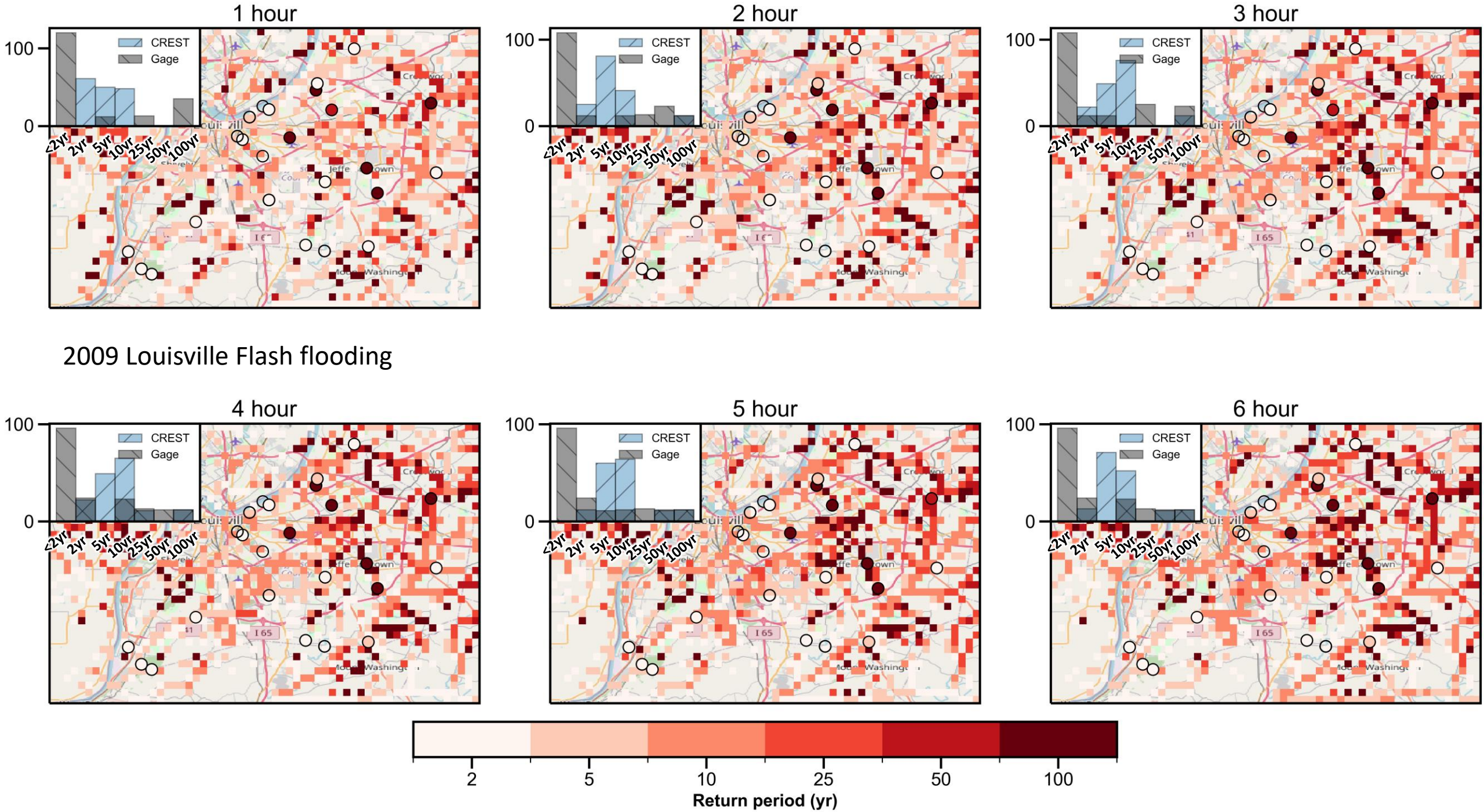
(f) 100-yr flashiness



ML-based distributed FIDF

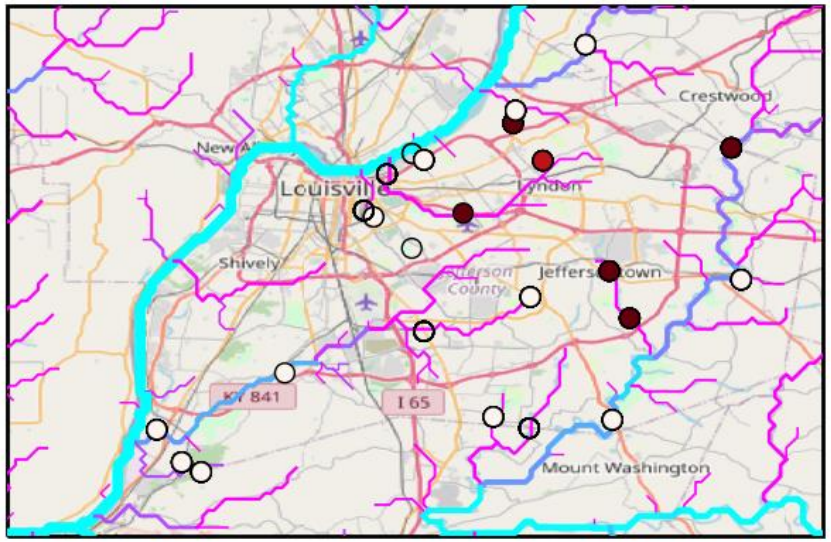



Conditional bias on different influential factors

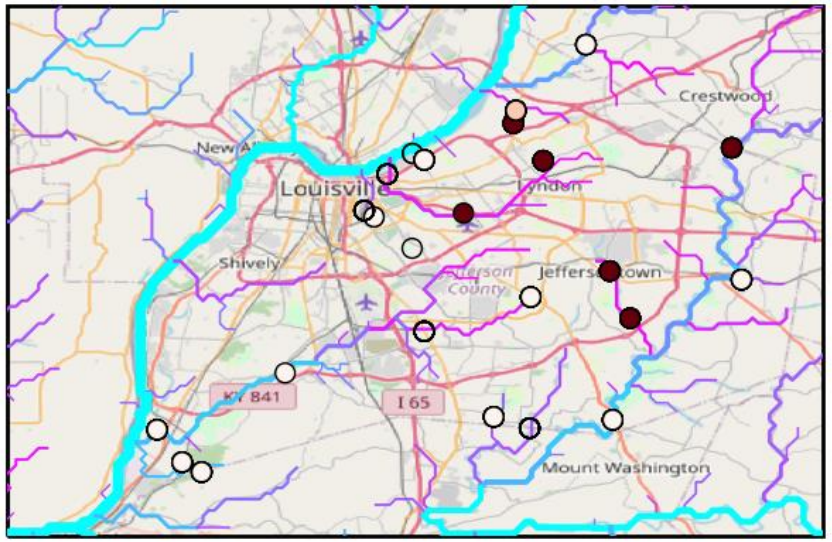



2009 Louisville Flash flooding

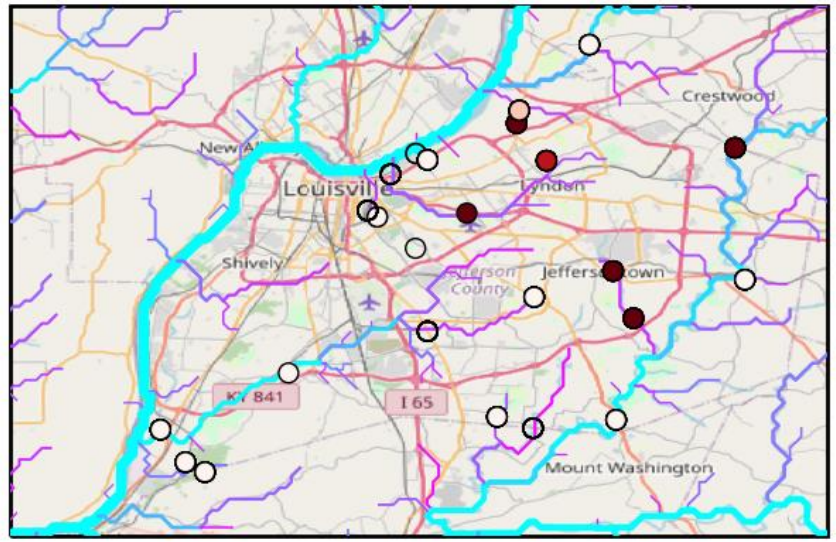
1 hour



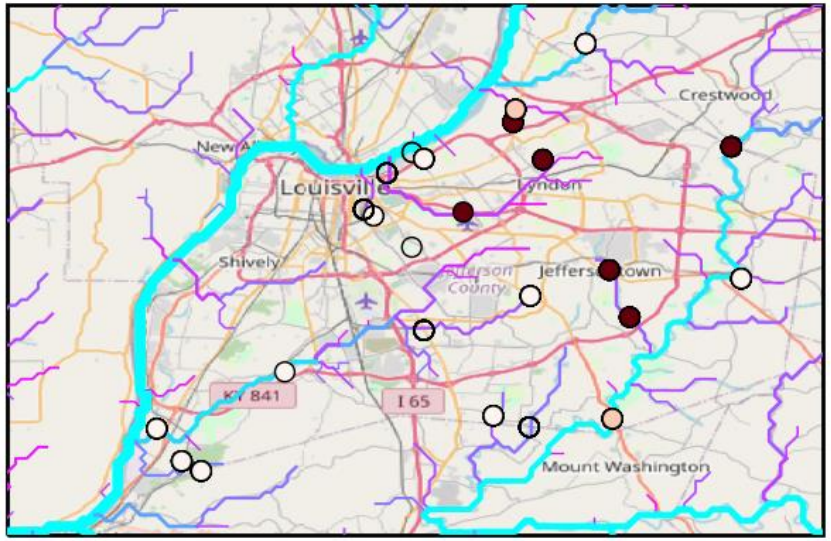

2 hour



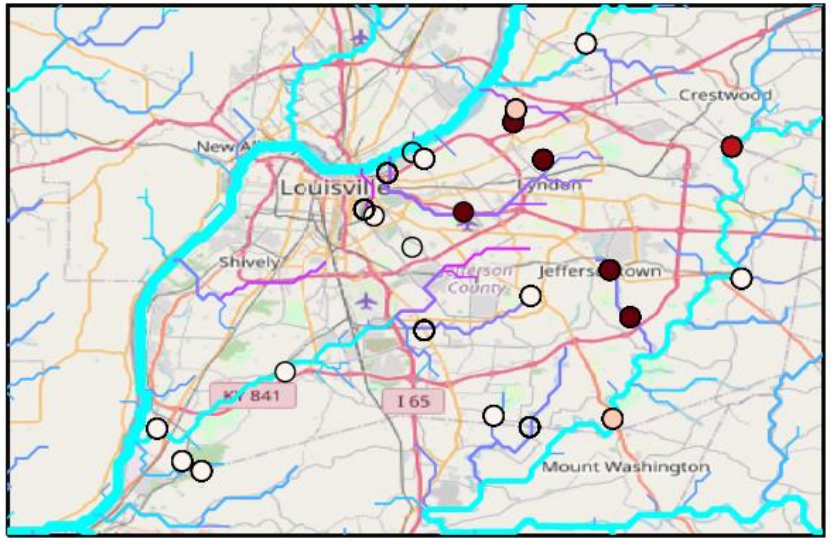

3 hour



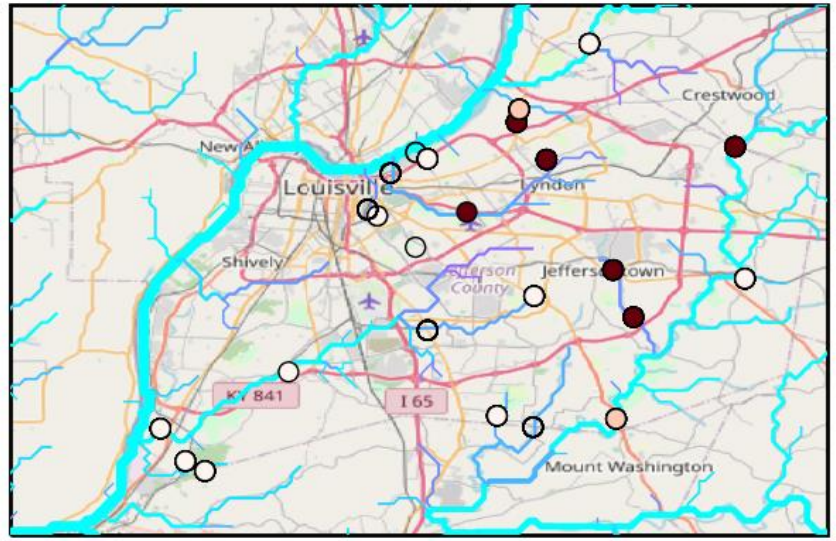

4 hour




5 hour




6 hour




HYDROLOGY & WATER SECUR
The UNIVERSITY of OKLAHOMA

Flashiness