

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

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**Contents of this file**

Text S1

Figures S1 to S8

**Additional Supporting Information (Files uploaded separately)**

None

**Introduction**

This supplementary file contains supplementary text S1 and Figures S1-8 that are referenced in the main text. Text S1 demonstrates a case study for a flash flood event in 2021. Figure S1 is based on the downloaded USGS stream gage time series from 1985-2020. Figures S2-6 are based on the Flashiness-Intensity-Duration-Frequency values processed (Li, 2023). They are presented from event durations 2-6 hours, with 1-hour event shown in Fig. 2. Figure S7 is the density plot of reported flash flood events from Li

et al. (2021), which is based on National Weather Service storm database. This database is subject to (1) imprecise event location, (2) times related to meteorological events, (3) relying on in-person witness accounts, and (4) limited information about the site exposure to antecedent conditions. Figure 8 depicts the time series of streamflow for six USGS gage sites as a case study for 2021 Tennessee flash flooding.

## **Text S1.**

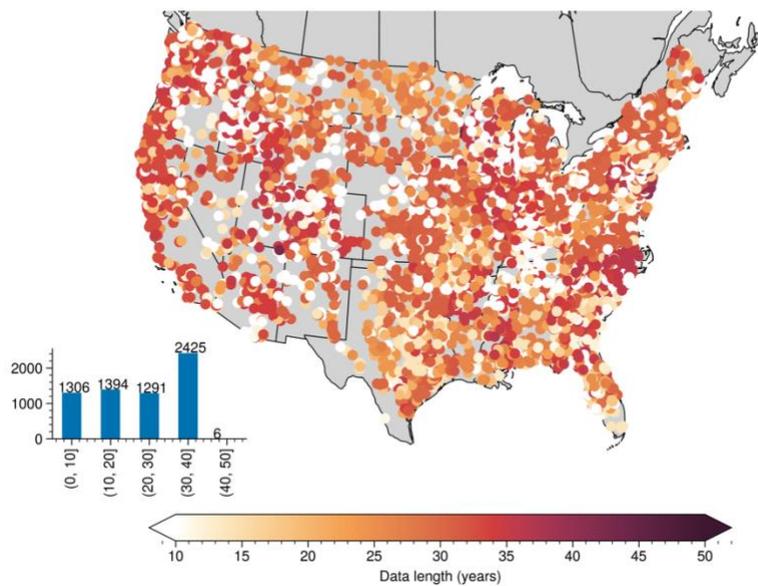
### Case studies – 2021 Tennessee Flash Flooding

The 2021 Tennessee flash flooding event resulted in 20 fatalities and thousands of homes flooded and even swept away (WKRN, 2021). A training thunderstorm in the early hours of August 21 produced very heavy rainfall total – 10 to 15 inches within 12 hours. Five counties received up to a quarter of normal annual rainfall within this period (Wikipedia, 2023). Excessive rainfall quickly generated fast runoff and triggered flash floods in the Tennessee Valley. To apply our newly introduced F-IDF curve in this disaster, we retrieved USGS stream gages within the storm extent as shown in Fig. S8. We plotted the accumulated precipitation overlaid with stream gages and flash flood frequency at six durations – one to six hours. The return periods of this flash flood event for each stream gage vary at different durations. Taking the gage site 03610200 as an example, the flashiness values do not surpass two-year thresholds for one-hour and two-hour events. However, for the duration from 3 to 6 hours, it suddenly becomes a 100-year event. It is also clear from the hydrograph shown in Fig. S8 that the rising limb is gradual instead of a spike. That said, longer-duration event becomes more extreme than that of short duration. In contrast, gage 03601990 experiences a 100-year flash flood event for durations of 1 and 2 hours while the return periods decrease to 10 years, 5 years, 2 years, and less than 2 years for durations of 3, 4, 5, and 6 hours, respectively. The hydrograph in Fig. S9 exhibits multiple spikes that diminish flashiness values for long-duration events. This case demonstrates that duration is a critical dimension in flash flood studies. Without duration, flash flood intensity forecast and responses could be misguided.

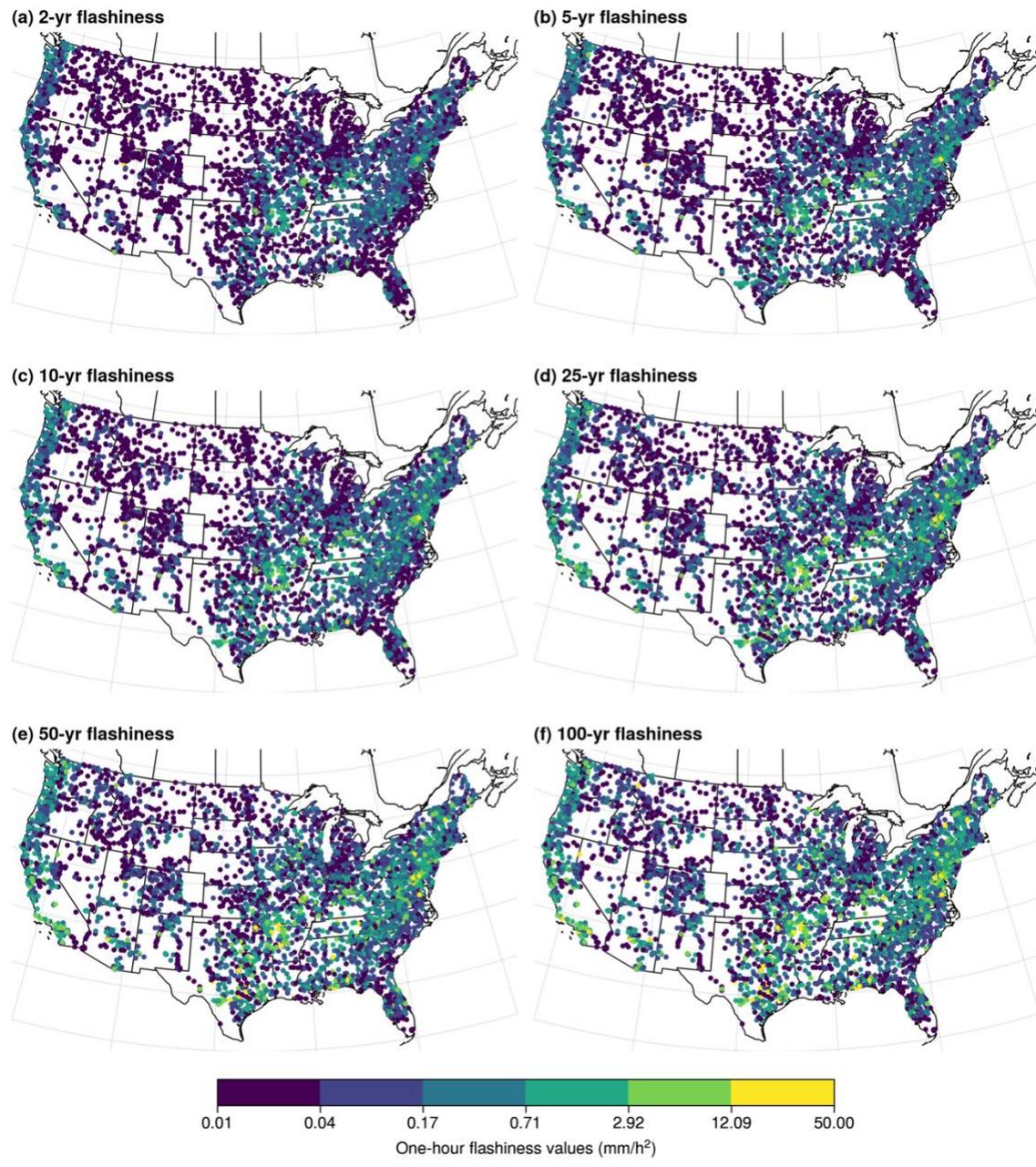
### Reference

WKRN (2021). Authorities: Multiple deaths reported after flooding in Humphreys County, Available from: <https://www.wkrn.com/news/local-news/sheriff-multiple-deaths-others-still-missing-after-flooding-in-humphreys-county/> (Accessed: August 4 2023).

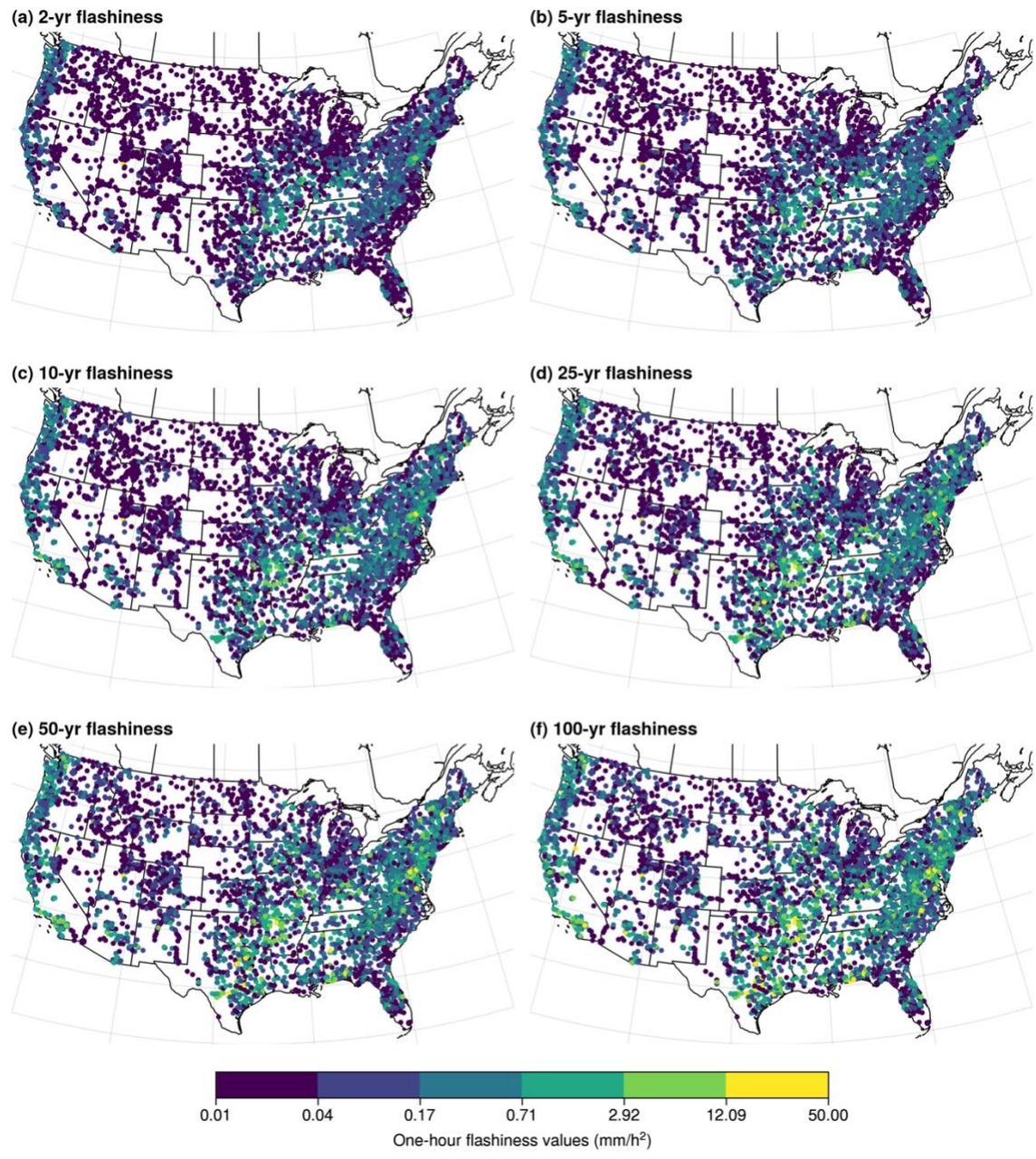
Wikipedia (2023). 2021 Tennessee floods. Wikimedia Foundation. Available at: [https://en.wikipedia.org/wiki/2021\\_Tennessee\\_floods](https://en.wikipedia.org/wiki/2021_Tennessee_floods) (Accessed: April 4, 2023).



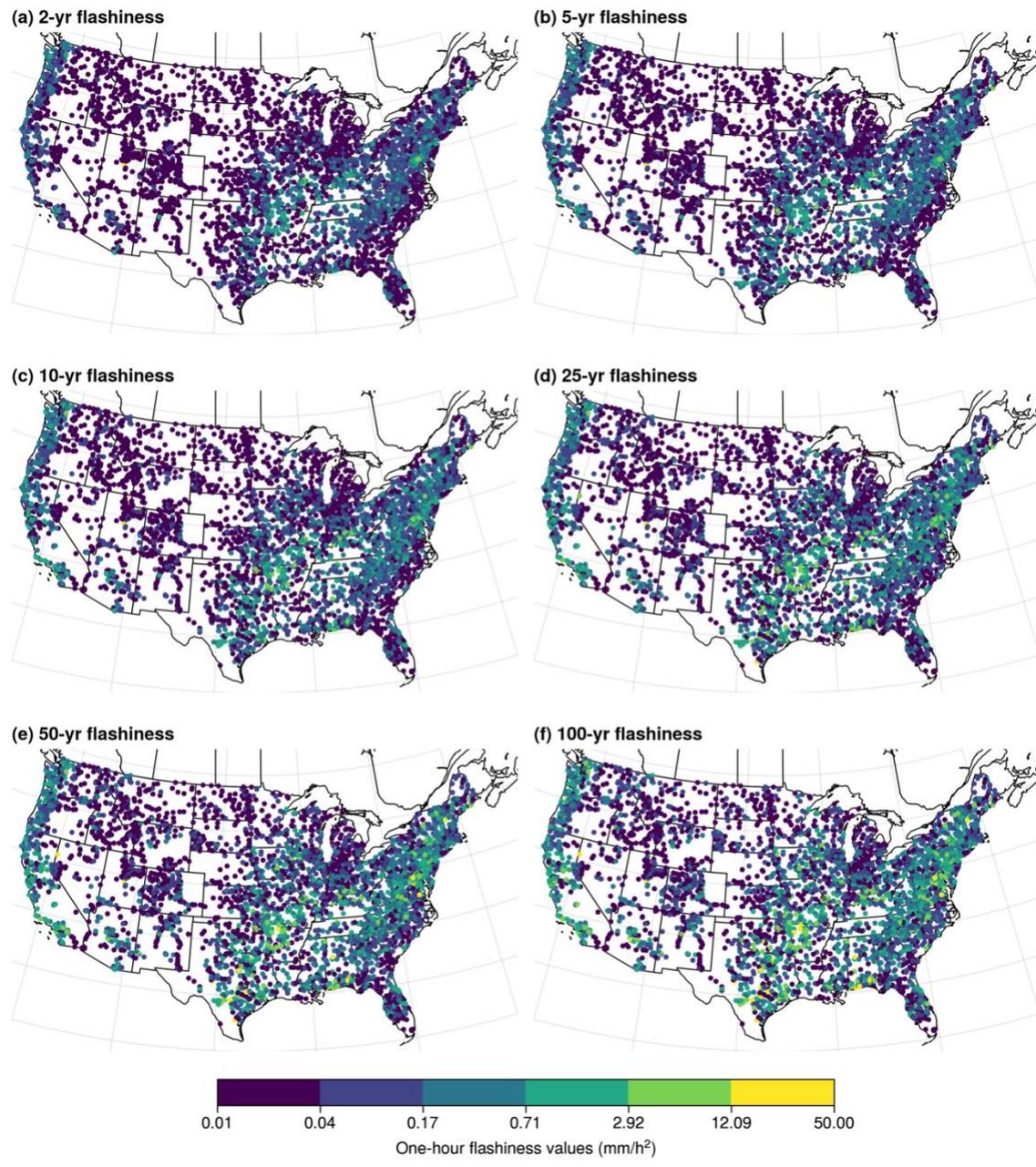
**Figure S1.** Map of 15-min stream gage data length.



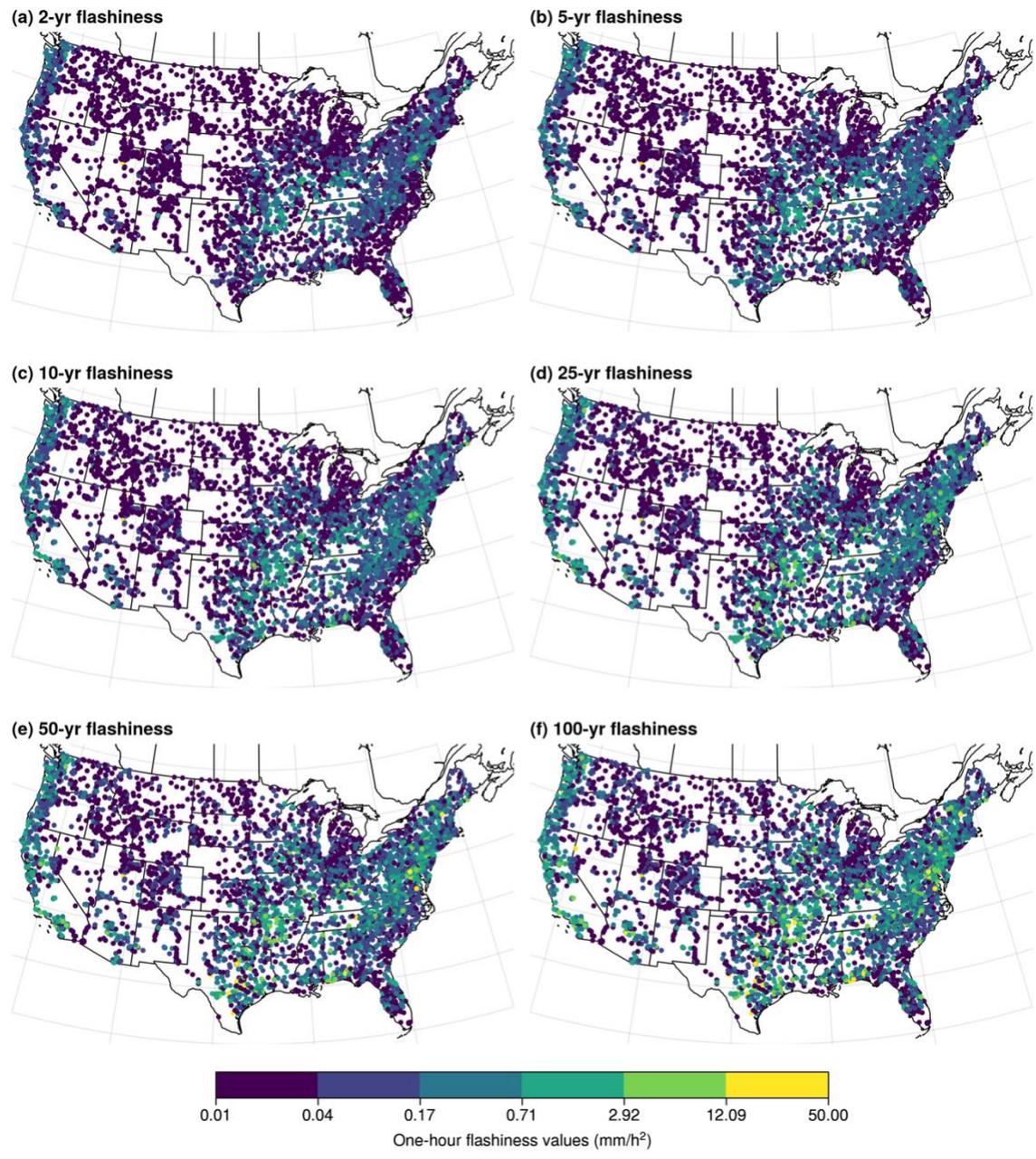
**Figure S2.** Similar to Figure 2, but for flashiness values at two-hour duration.



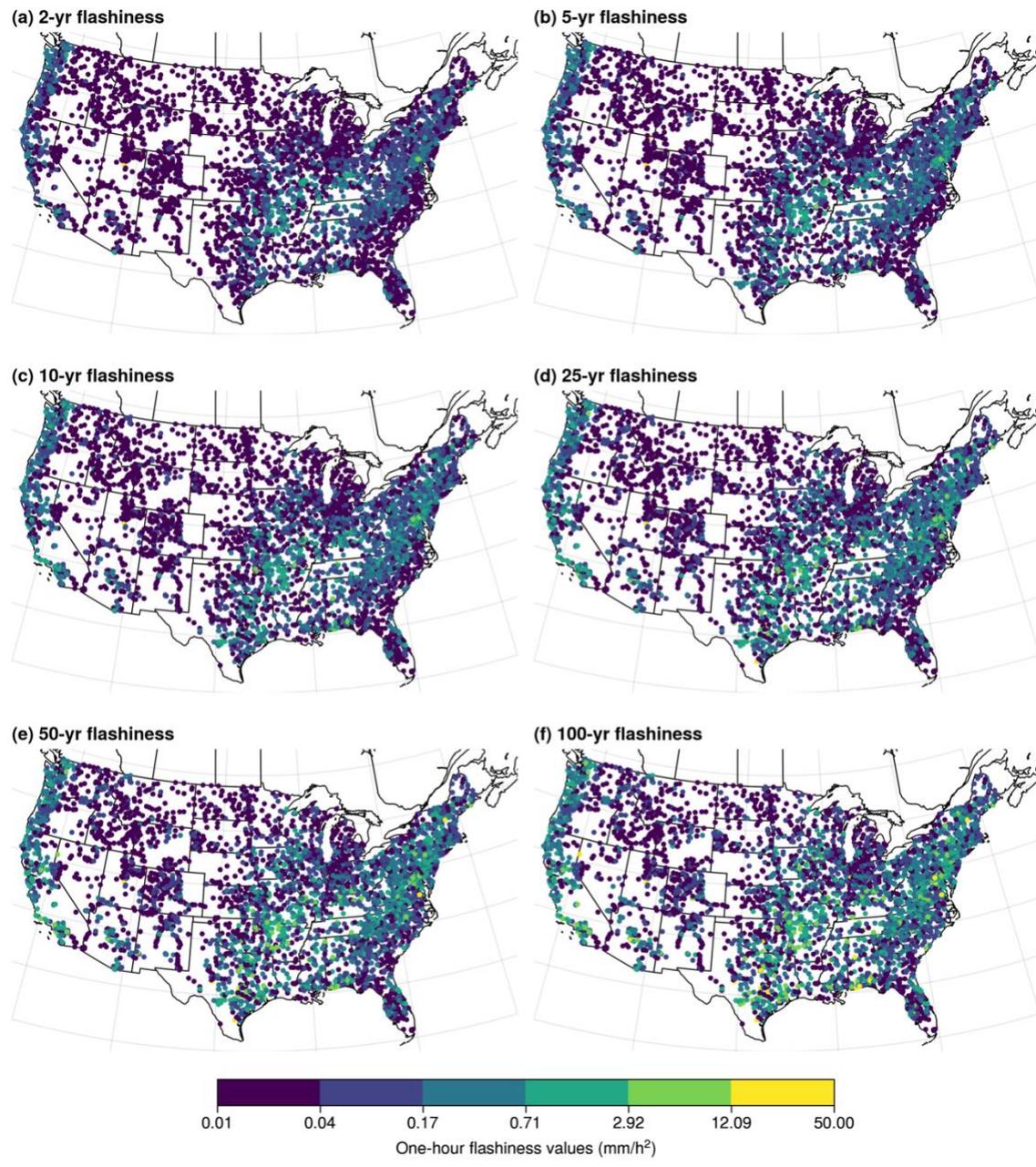
**Figure S3.** Similar to Figure 2, but for flashiness values at three-hour duration.



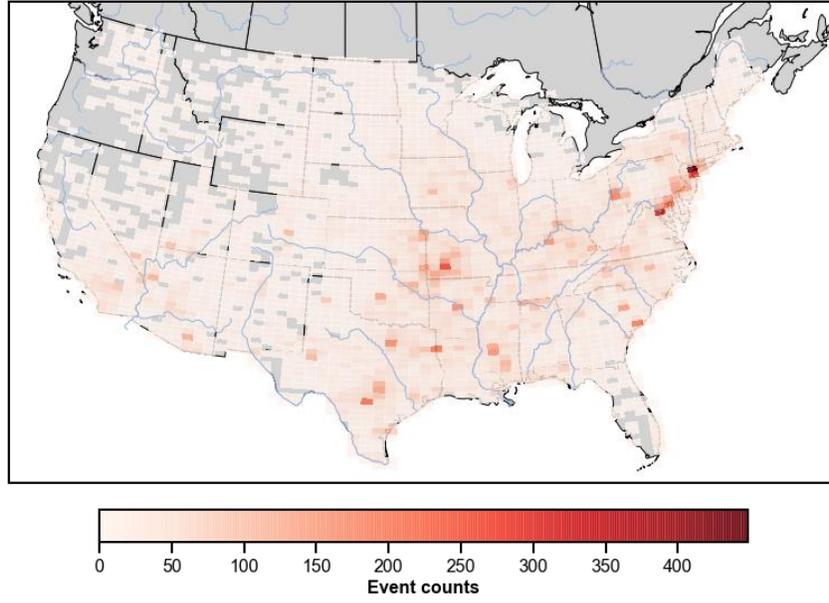
**Figure S4.** Similar to Figure 2, but for flashiness values at four-hour duration.



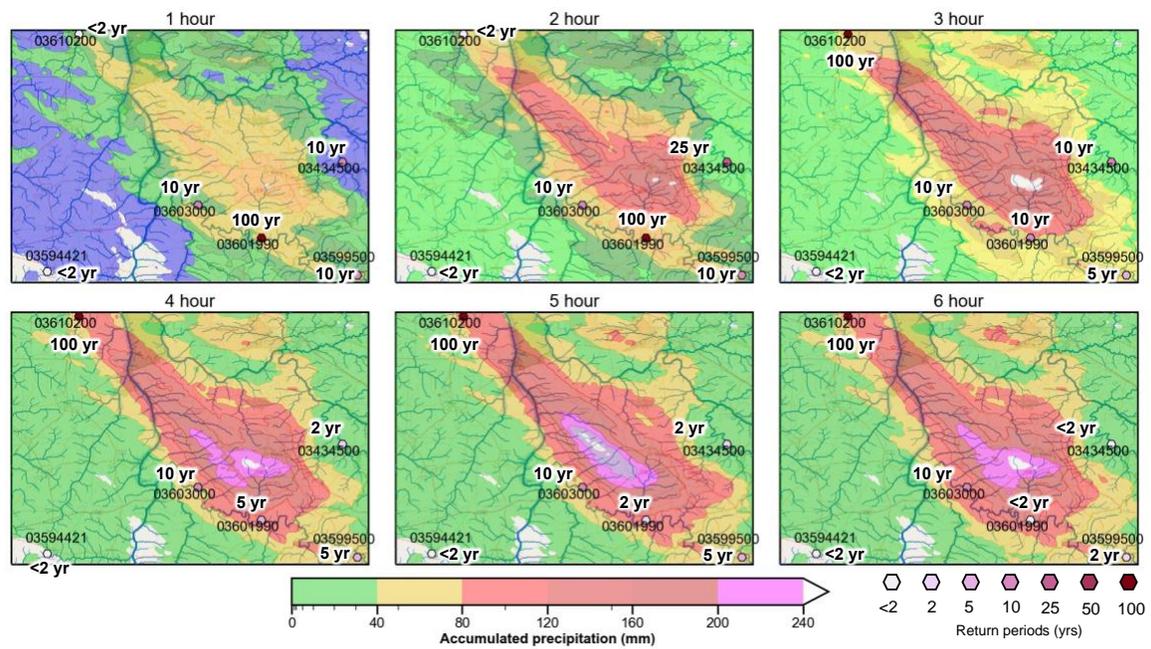
**Figure S5.** Similar to Figure 2, but for flashiness values at five-hour duration.



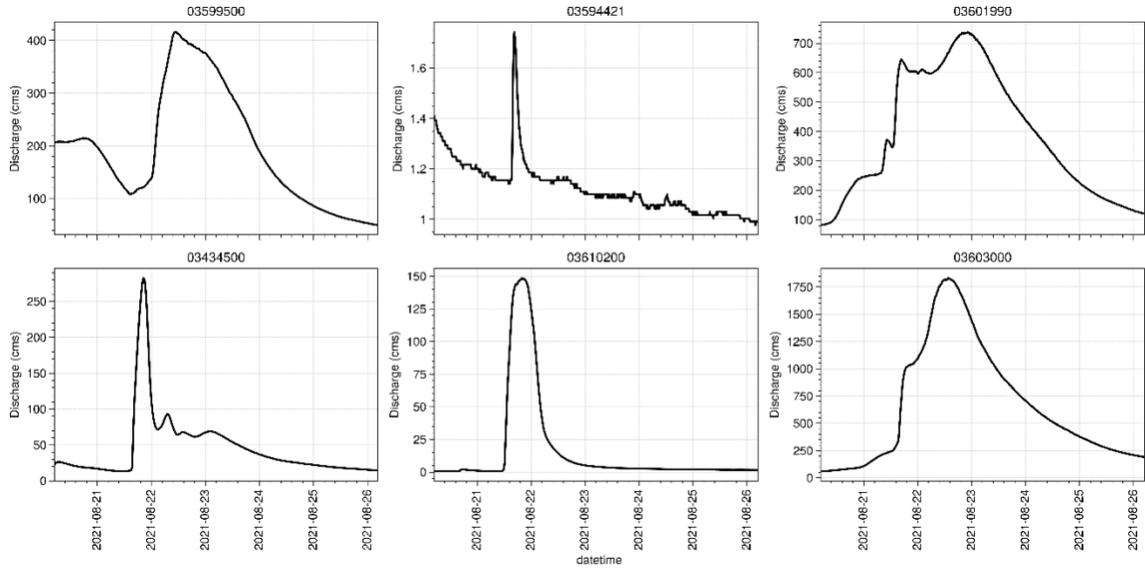
**Figure S6.** Similar to Figure 2, but for flashiness values at six-hour duration.



**Figure S7.** Map of flash flood event density with data collected from Li et al. (2021).



**Figure S8.** Maps of accumulated precipitation overlaid with event frequencies for each stream gages at six durations. Numbers shown for each stream gage are return periods of this event.



**Figure S9.** Hydrographs for the 2021 Tennessee flooding, corresponding to stream gages shown in Fig. 5.