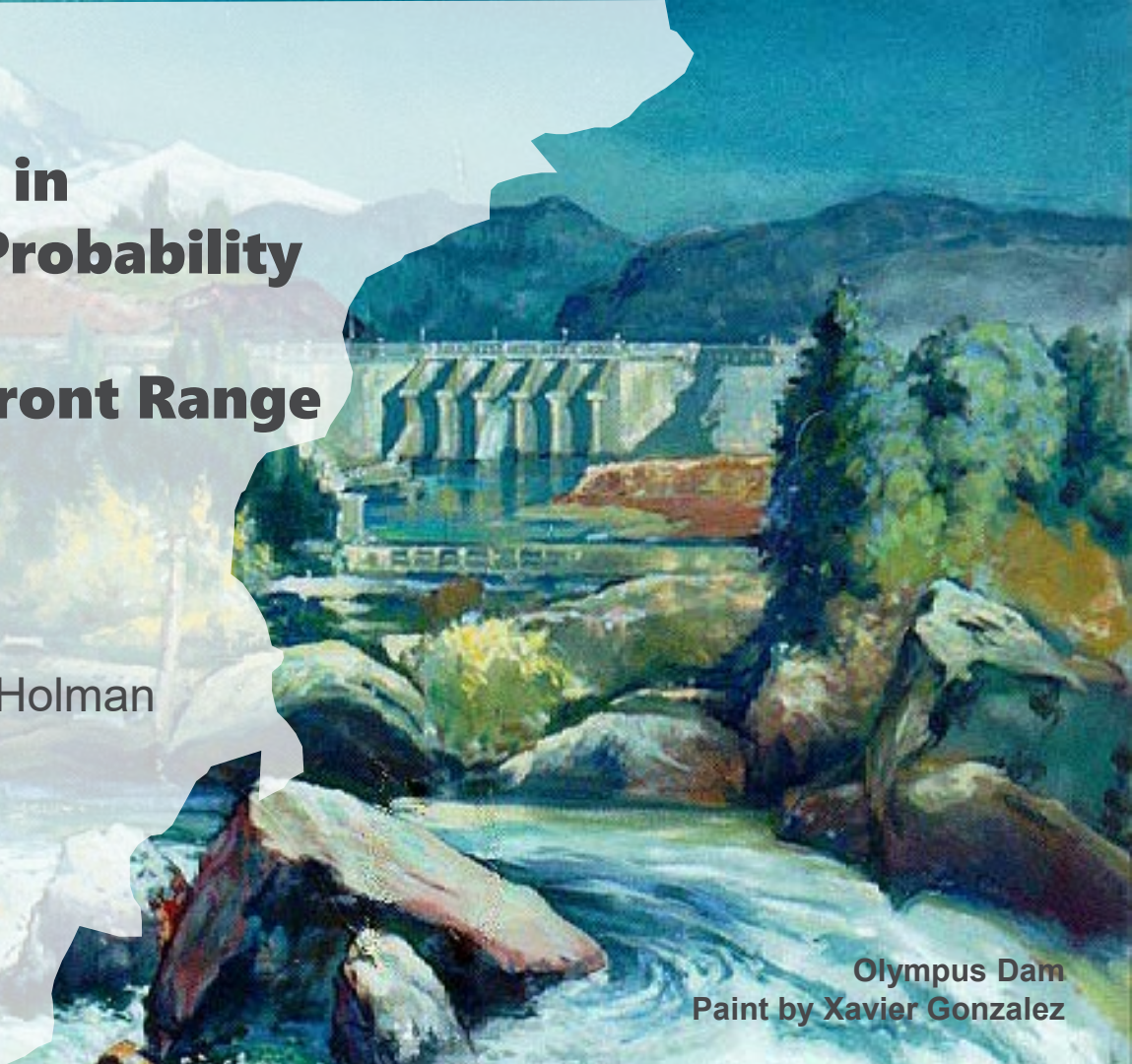
Land Surface Model Aids in Understanding the Low Probability Floods in the Mountainous Colorado Front Range

Guo Yu, Daniel Wright and Katie Holman

DRI

WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON

BUREAU OF RECLAMATION



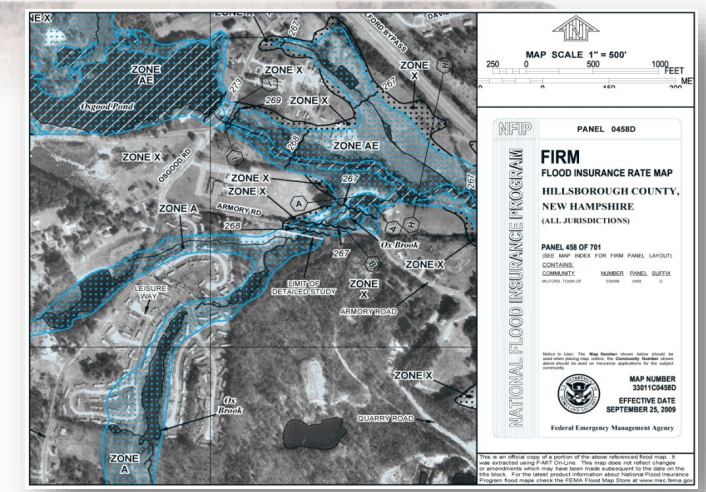
Olympus Dam
Paint by Xavier Gonzalez

Flood Frequency Analysis (FFA)

What is the 100-year flood?

Why does it matter?

- **X-year storms/floods are critical:**
  - Infrastructure design, planning
  - Floodplain mapping
  - Flood insurance
- **High costs if X-year storm/flood is wrong:**
  - Infrastructure has long lifespans and high price
  - Issues with climate and land use change

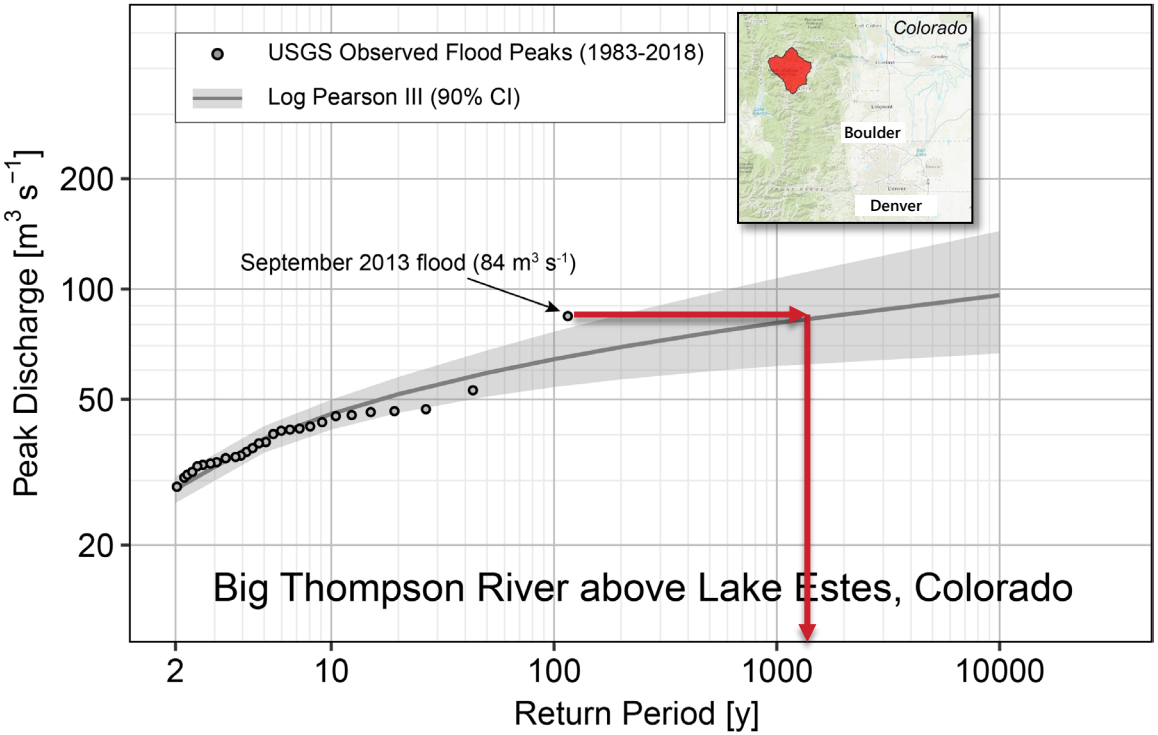


Flood Frequency Analysis (FFA)

What is the 100-year flood?

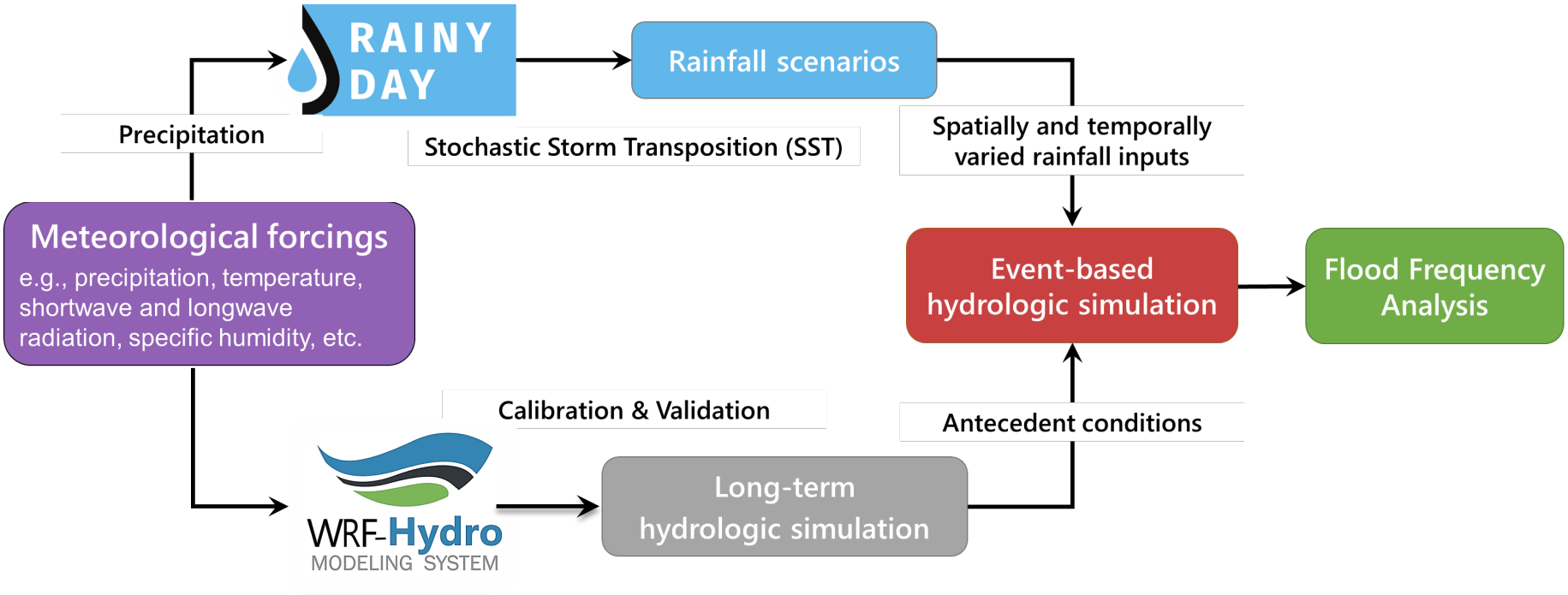
Conventional assumptions

- Extrapolating the tail of the distribution (i.e., rare events) based on common flood peaks;
- The observed sample is from a single population (i.e., a single flood regime);
- Stationarity;
- Ignore the physical processes.



Process-based flood frequency analysis (FFA)

"Monte Carlo" simulation



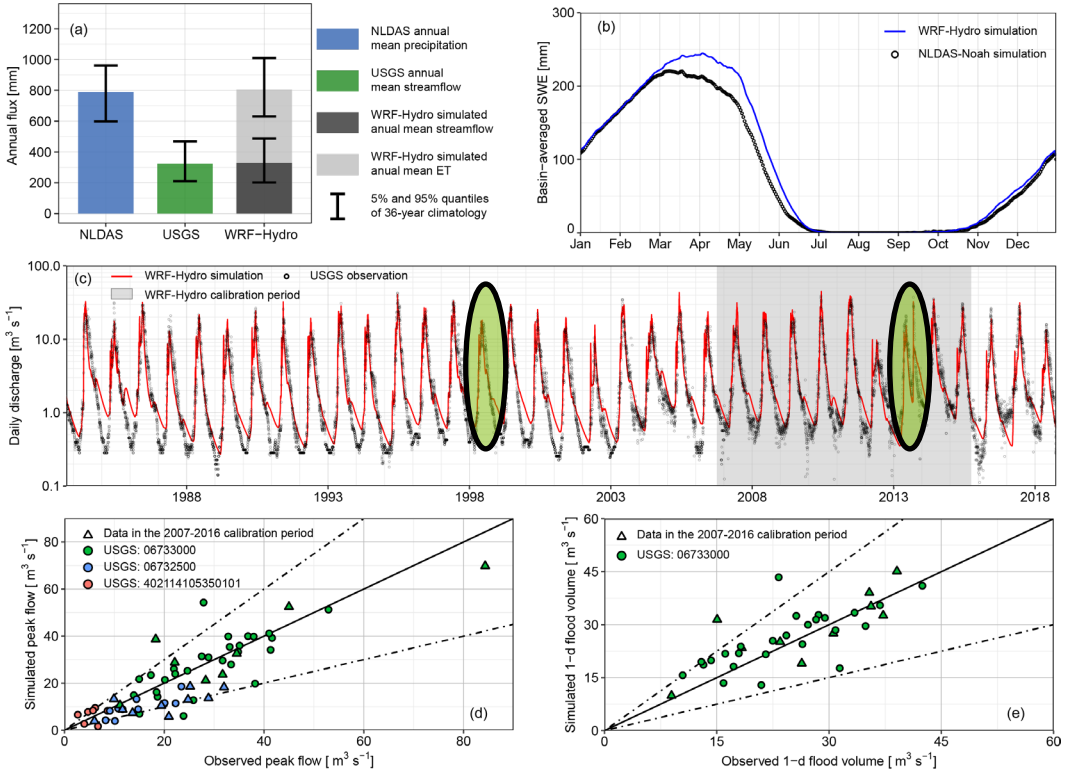
Process-based flood frequency analysis (FFA)

“Monte Carlo” simulation

Long-term hydrological simulation

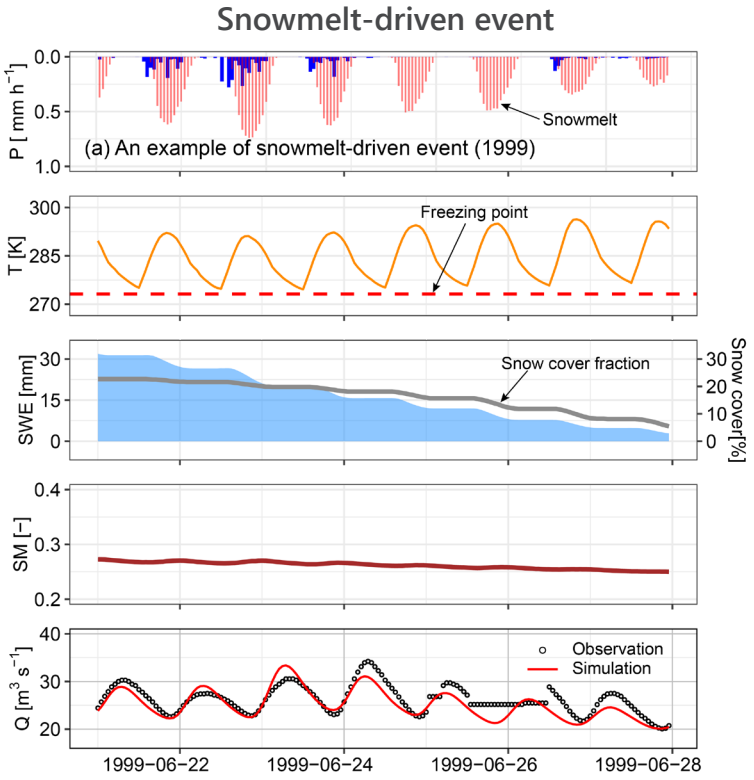
Model calibration/validation as a physics problem

- Long-term water balance;
- Basin-averaged snow water equivalent;
- Long-term daily hydrograph
- Peak discharge at 3 USGS gages (1 outlet and 2 inner gages);
- 1-day flood volumes at watershed outlet.



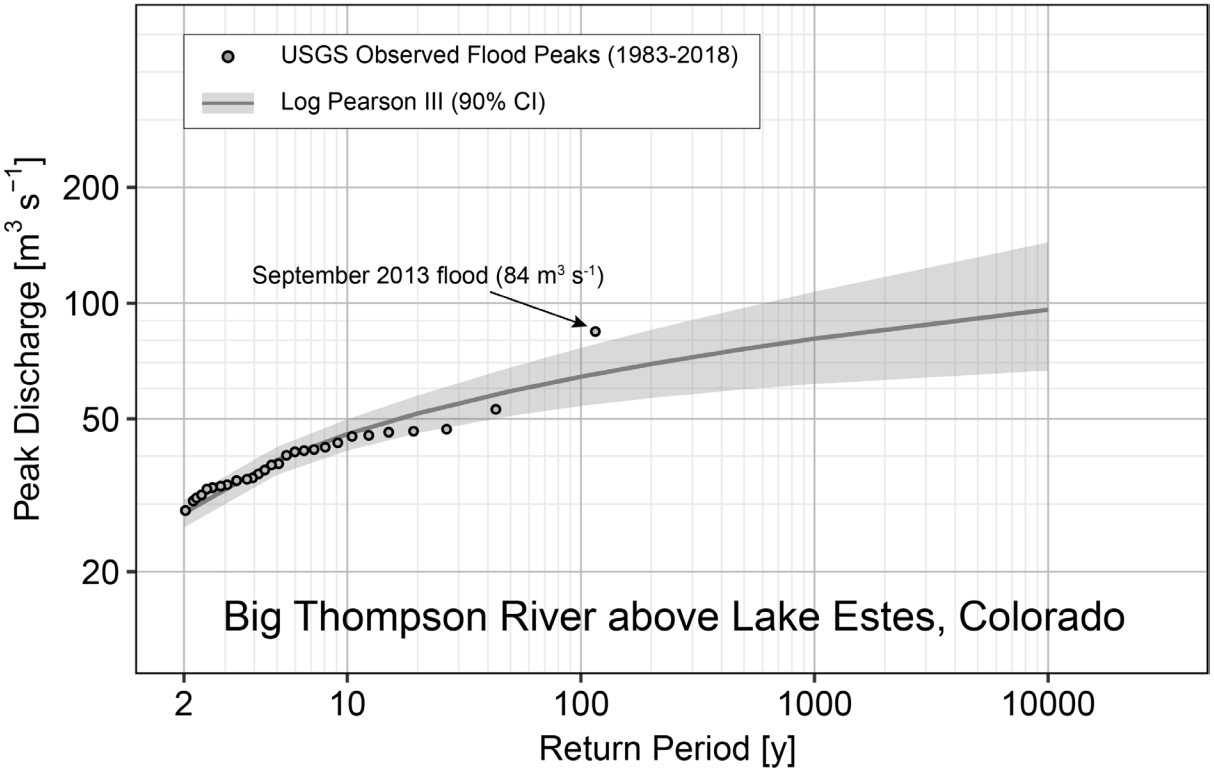
Long-term hydrological simulation

Model calibration/validation as a physics problem



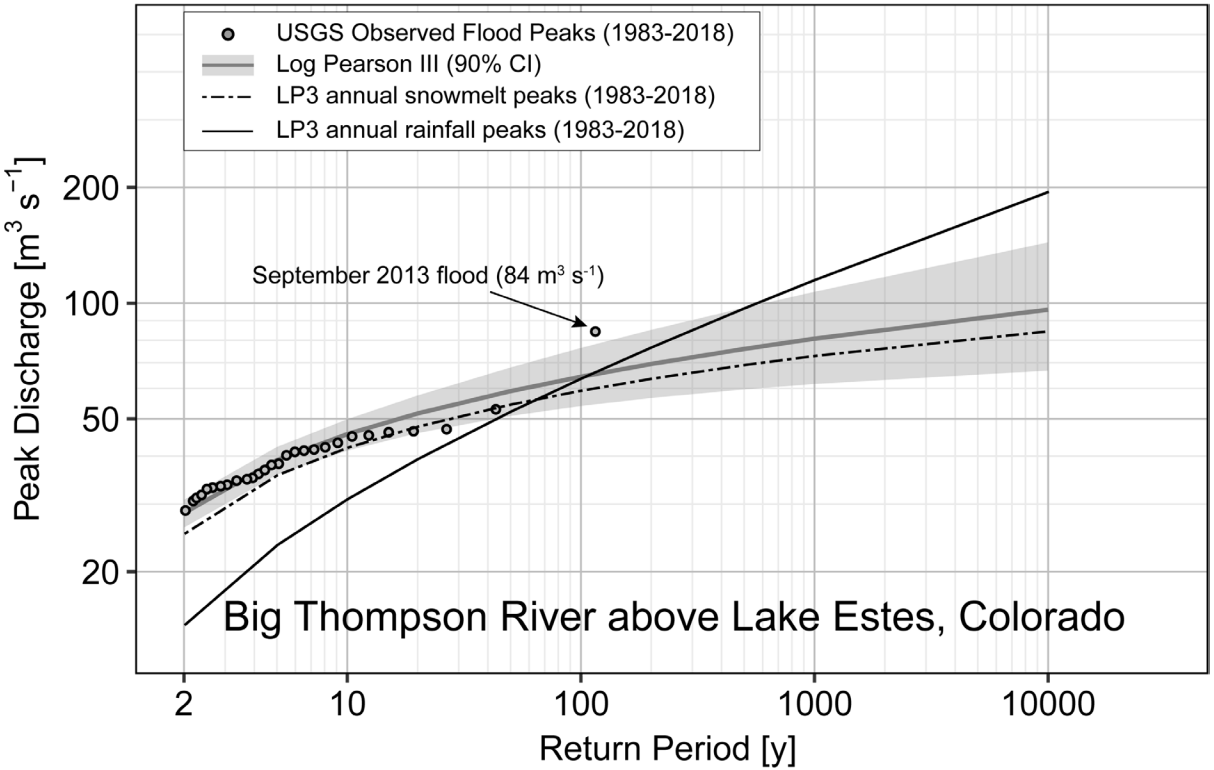
FFA for Big Thompson River watershed

- A conventional approach



FFA for Big Thompson River watershed

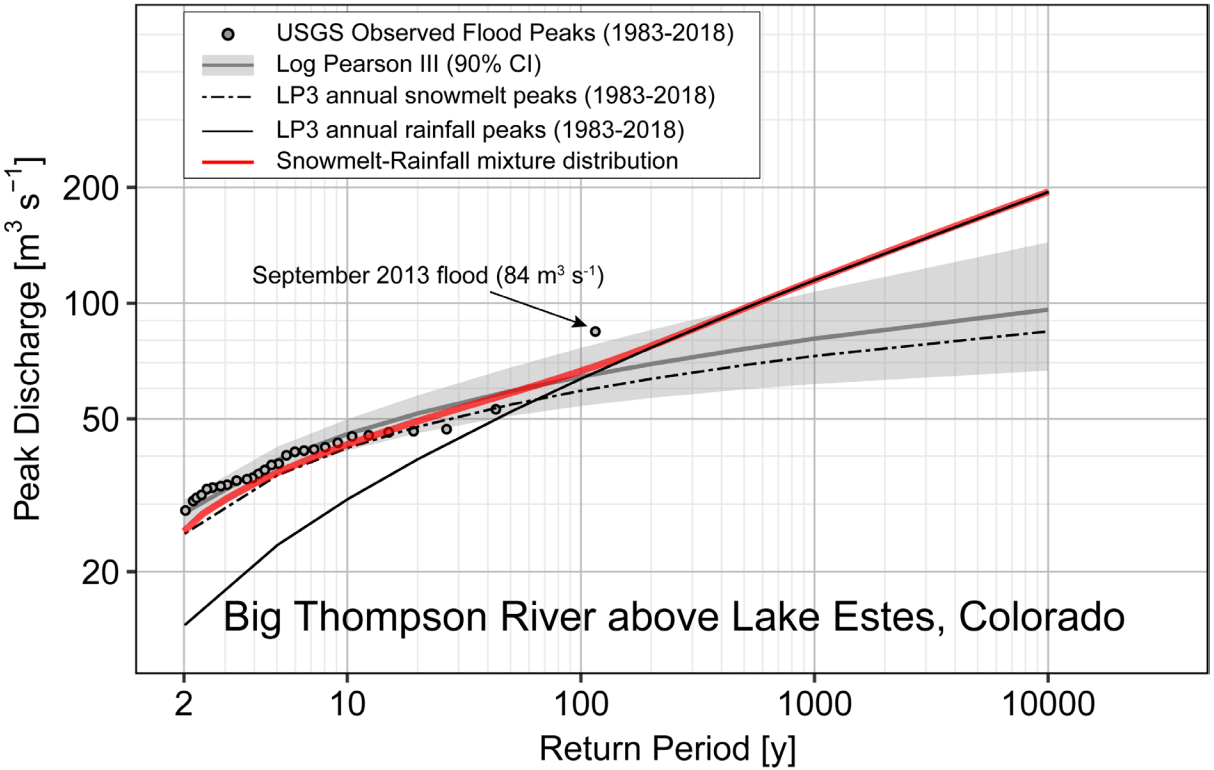
- A conventional approach
- Two LP3 distributions fitted to snowmelt- and rainfall-driven peaks



FFA for Big Thompson River watershed

- A conventional approach
- Two LP3 distributions fitted to snowmelt- and rainfall-driven peaks
- Combine two LP3:

$$F(X \leq x) = F_{snow}\,(X \leq x) * F_{rain}\,(X \leq x)$$

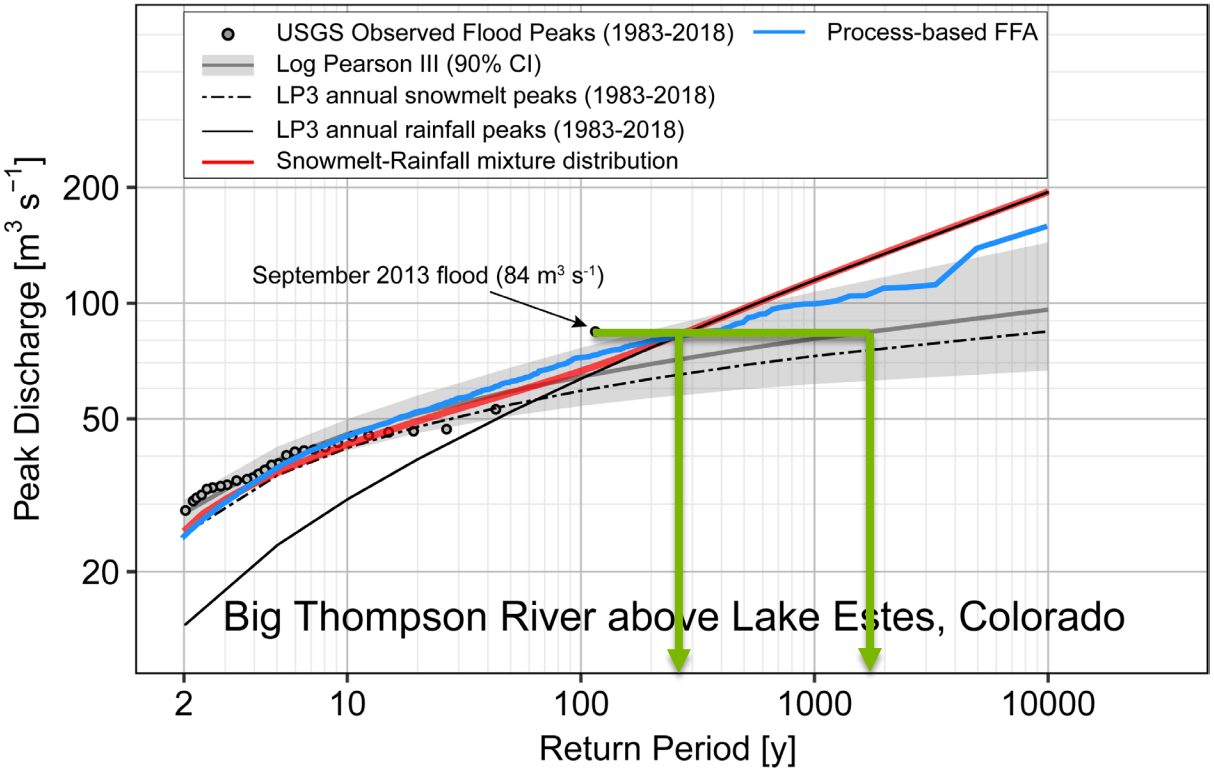


FFA for Big Thompson River watershed

- A conventional approach
- Two LP3 distributions fitted to snowmelt- and rainfall-driven peaks
- Combine two LP3:

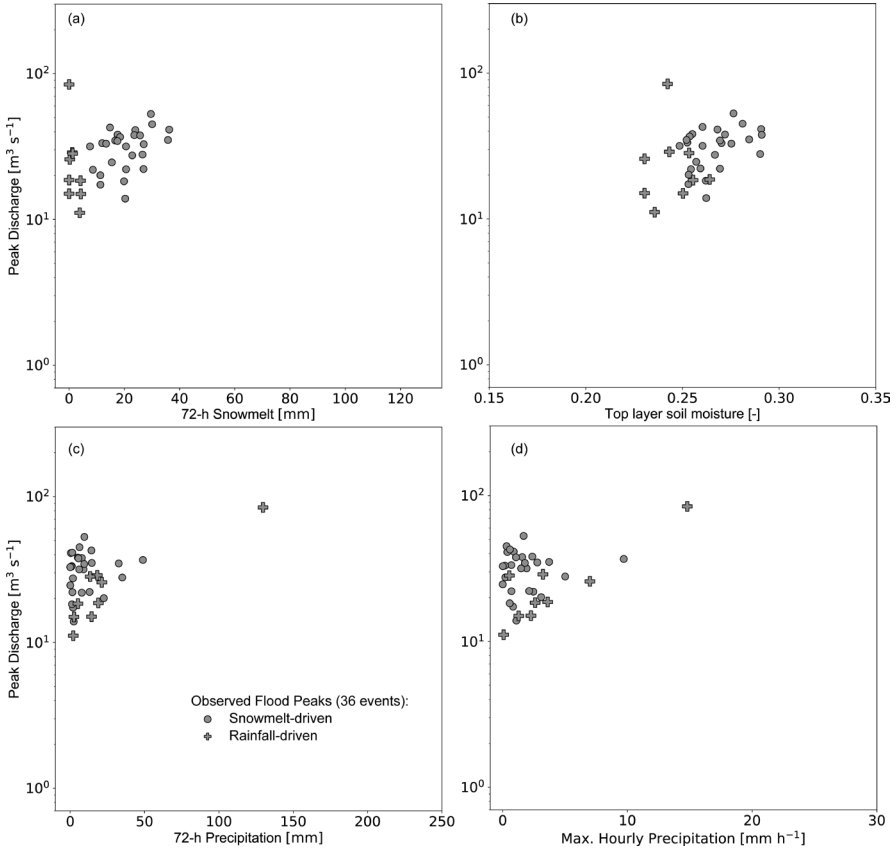
$$F(X \leq x) = F_{snow}\,(X \leq x) * F_{rain}\,(X \leq x)$$

- Process-based FFA



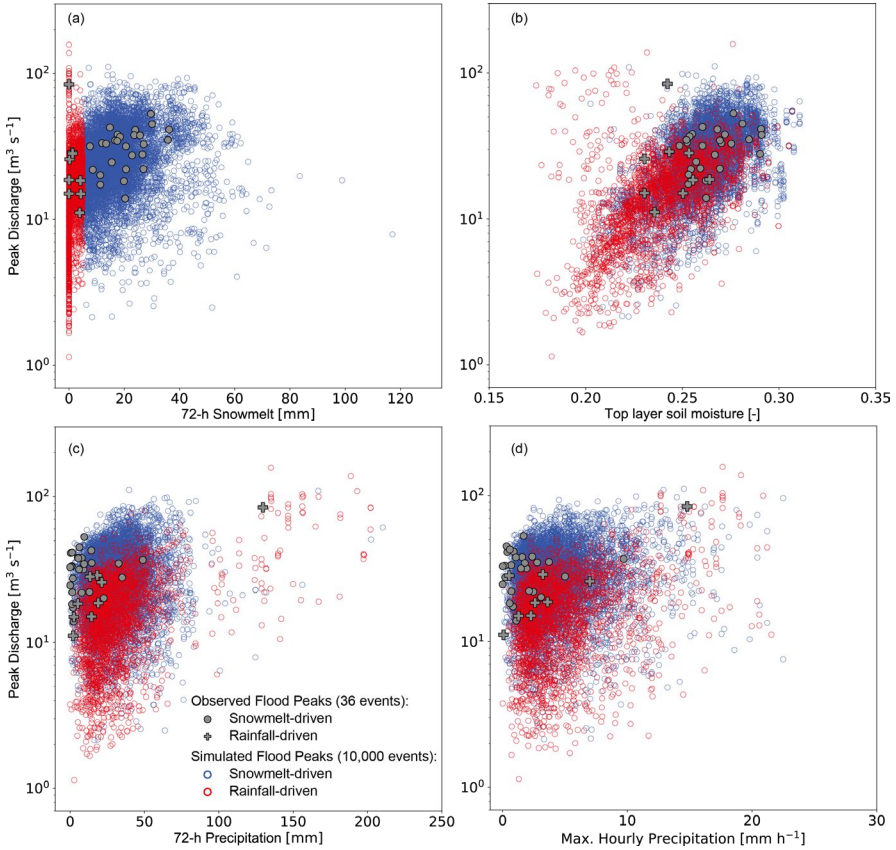
FFA for Big Thompson River watershed

- Process-based FFA can provide insights into the relationship between flood drivers and flood magnitudes
- The simulation is consistent with observation
- 36 observed vs. 10,000 simulated peaks



FFA for Big Thompson River watershed

- Process-based FFA can provide insights into the relationship between flood drivers and flood magnitudes
- The simulation is consistent with observation
- 36 observed vs. 10,000 simulated peaks



Conclusions:

- WRF-Hydro/Noah-MP continuous simulation can provide process-based insights into understanding historical events;
- Process-based FFA can help to understand the relationships between flood driving processes and flood peaks.
- If we can understand the watershed processes ***without using Machine Learning***, please do it !