Modelling Mixed Populations

Flood Frequency Analysis PROSPECT

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Purpose

- Review "iid" random variables
- Identify mixed populations in flood frequency analysis
- Build a model for a mixed population

Overall: Take steps toward "homogenizing" frequency analyses

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Outline

1. Revisiting the “IID” assumption
2. Understanding mixed populations
3. Modelling mixed populations

IID

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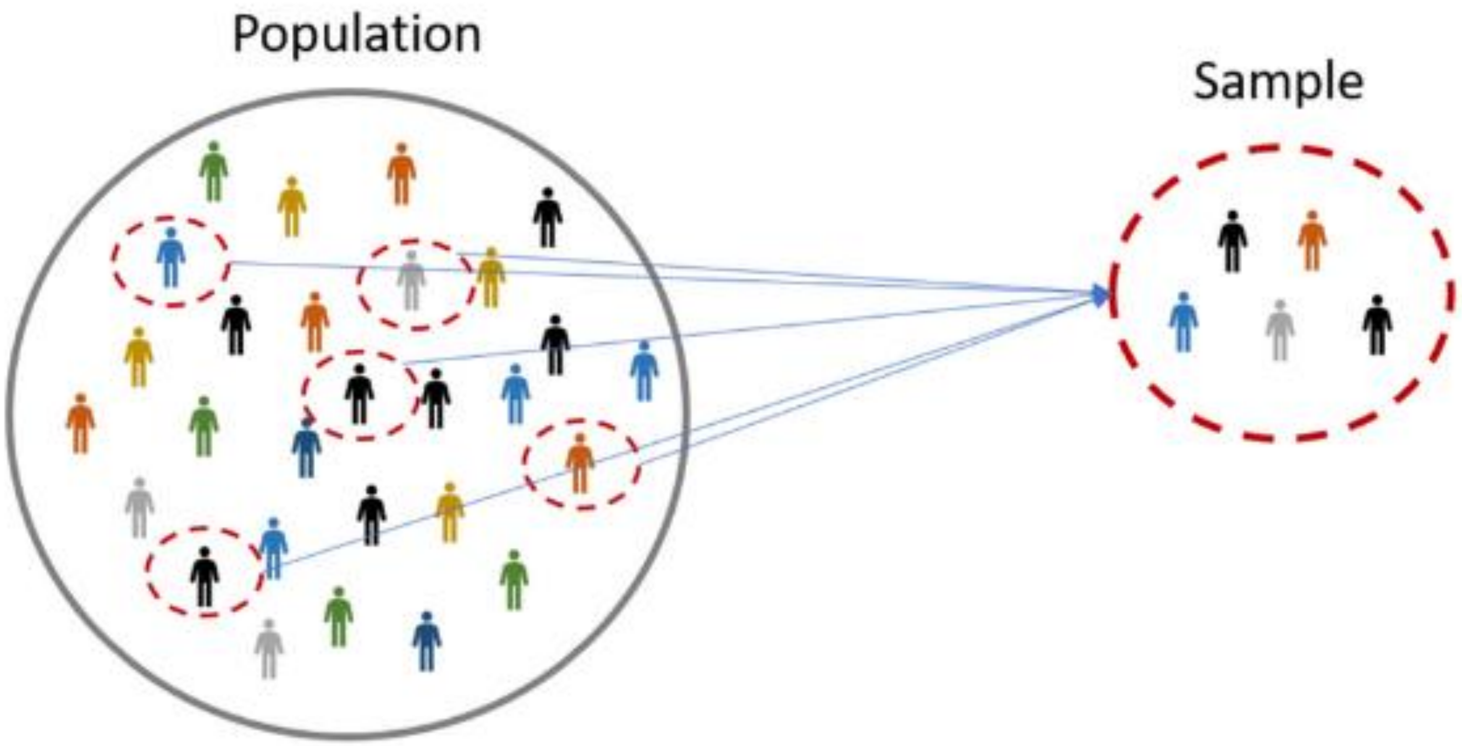
Populations vs. Samples



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Populations vs. Samples

Population

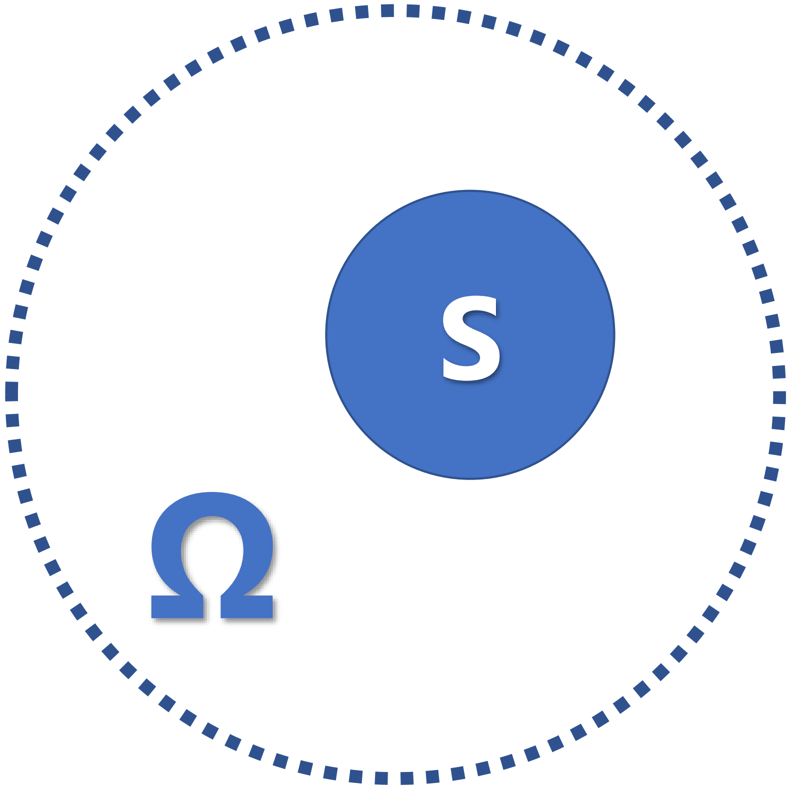
- Entire group you want to draw conclusions about
- May be unknowable
- Parameter
  - Example: all annual maximum flows on the Mississippi River at Vicksburg

Sample

- Part or subset of the population
- Data you have or can collect
- Statistic
  - Example: annual maximum flow observations on USGS/NWIS

Assumptions

- Sample is representative
- Observations are IID
  - Independent
  - Identically-Distributed



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Independence

VOL. 10, NO. 4 WATER RESOURCES RESEARCH AUGUST 1974

The Hurst Phenomenon: A Puzzle?

V. Klemeš

- Serial (in)dependence?
- Hydrologic processes have long memories
- "Overcount" certain ranges of observation

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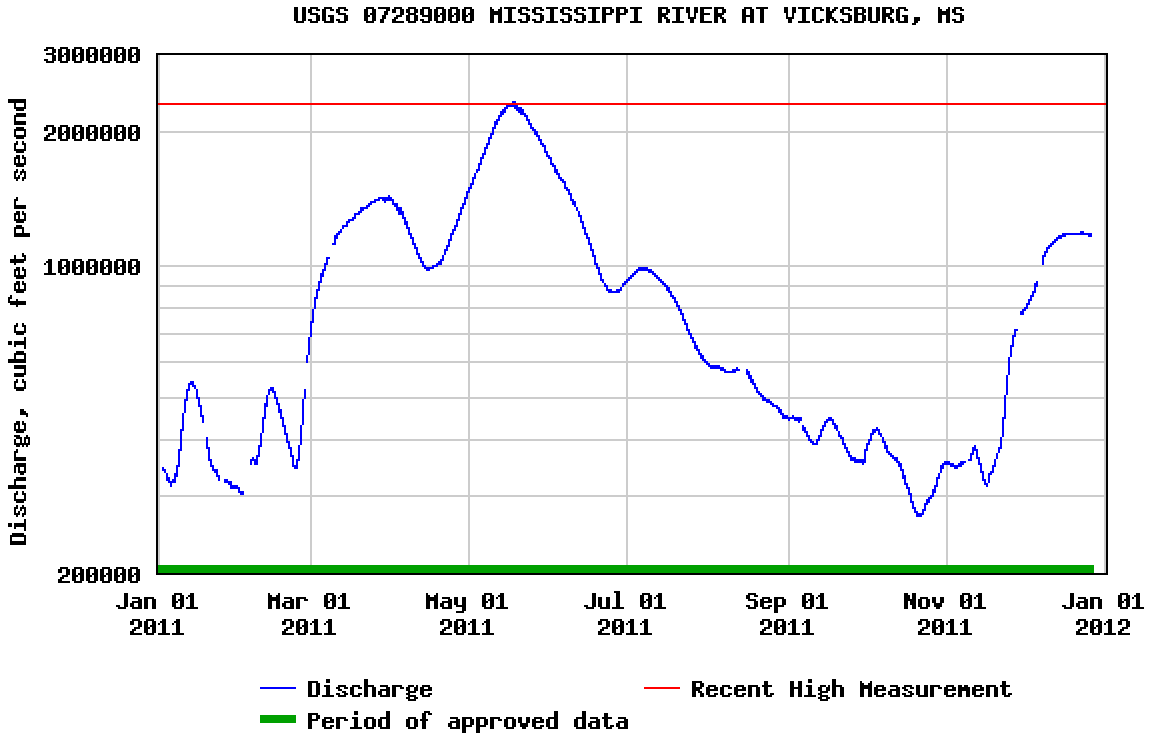
Independence

- Generally safe by using annual maximum series
- Consequence may be small
  - Depends on strength of serial dependence
  - Depends on the sample size



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Identical Distribution

- A probability distribution represents the relative likelihood of all outcomes in a population
- Each sample in a record of streamflow is assumed to come from the same population
- Identical distribution = same population

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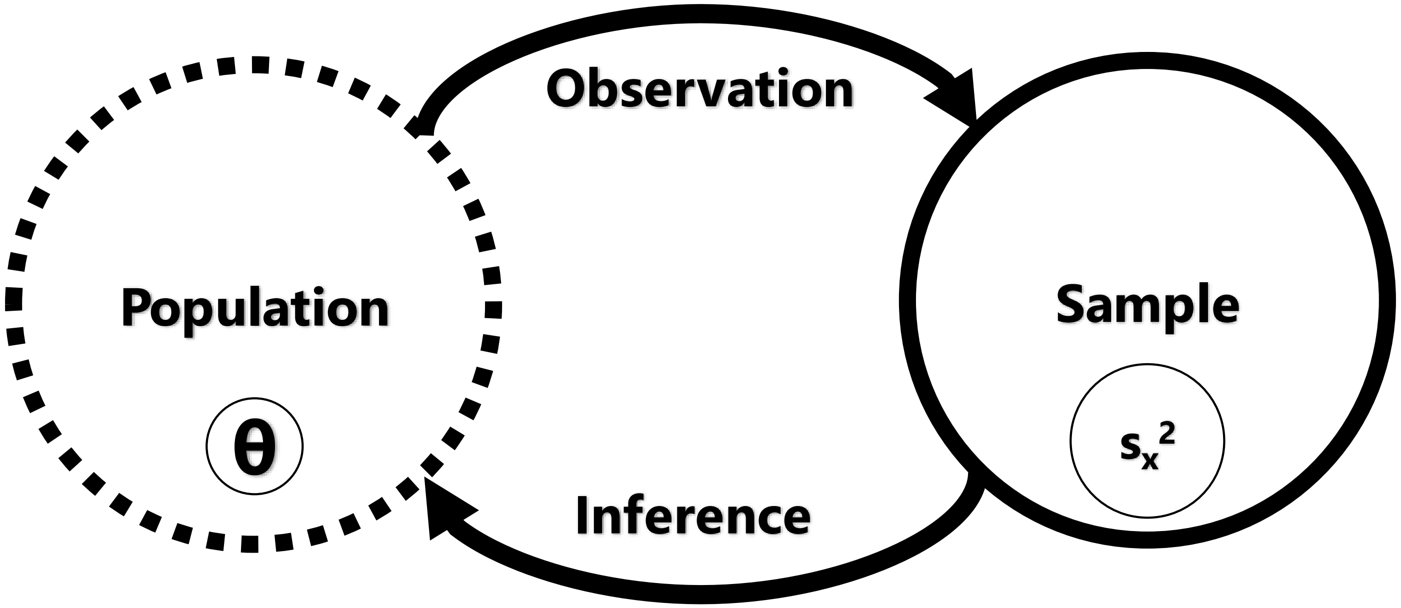
Inference

- We want to ask questions of an unknowable population
- We use sample statistics to estimate population **parameters**



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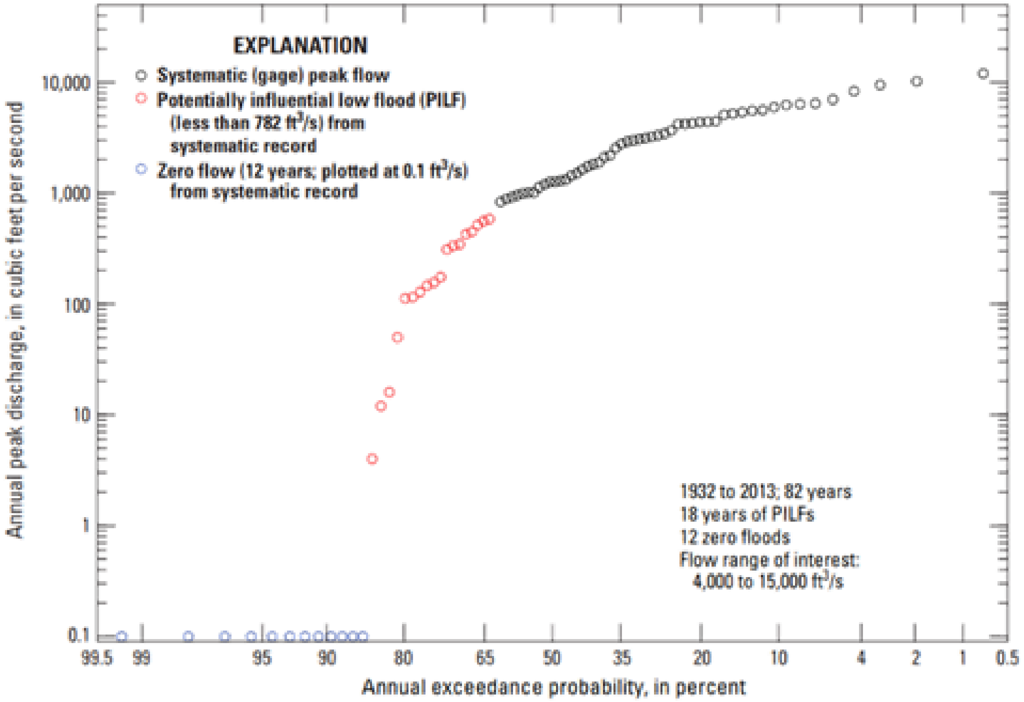
Identical Distribution

- **Are all floods created equal?**
- Just because a flow is an annual maximum, does not guarantee it was created the same way as the others



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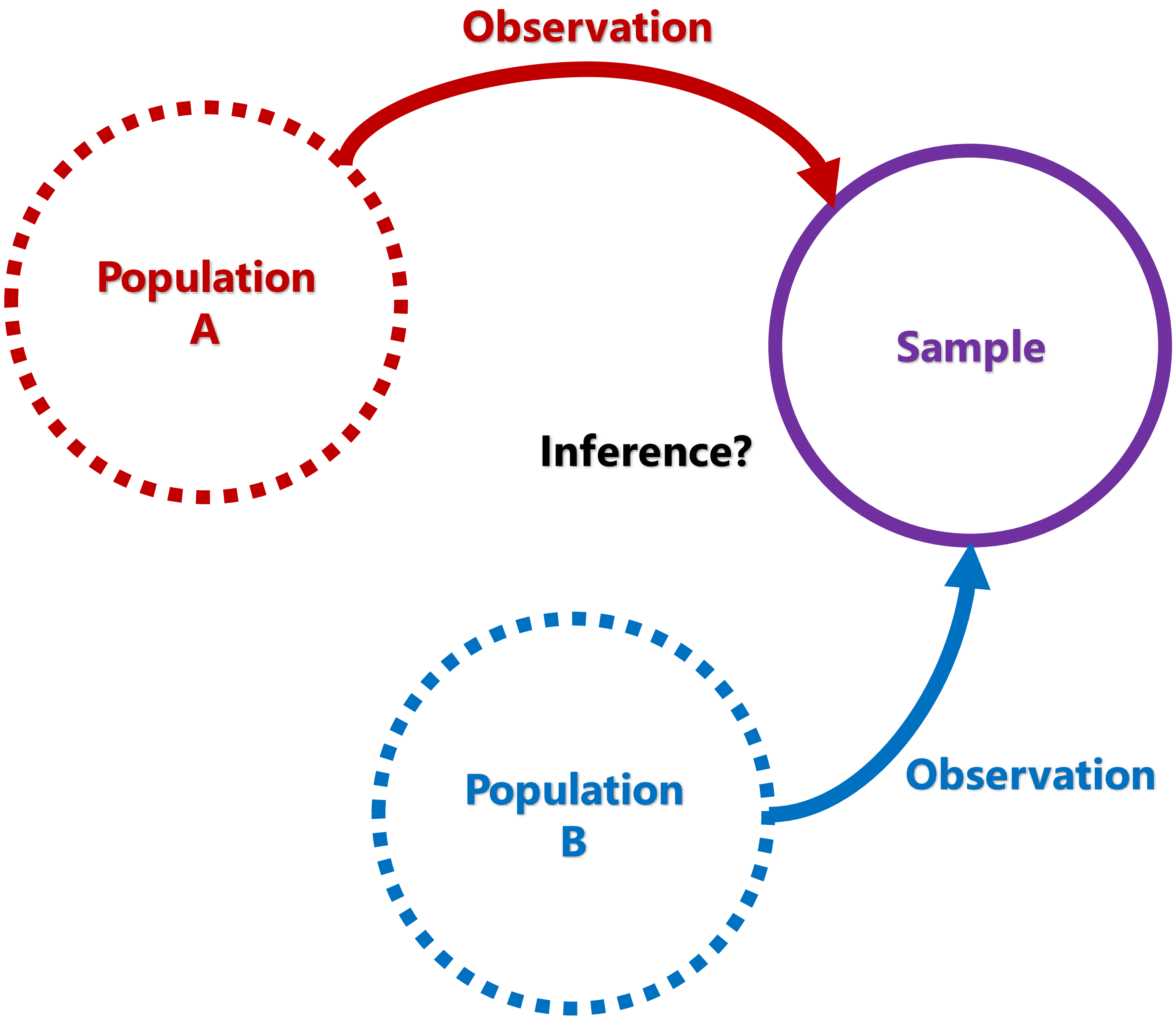

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Mixed Populations

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Mixed Populations

Flooding in some watersheds is caused by different types of meteorological events associated with distinct physical processes. For example, flooding at some locations may arise from snowmelt, rainstorms, or by combinations of both snowmelt and rainstorms (Jarrett and Costa, 1988). Such a record may not be homogeneous and may require special treatment. This mixed population results in flood frequency curves with abnormally large skew coefficients reflected by abnormal slope changes when plotted on logarithmic normal probability paper. In some situations, the frequency curve of annual events can best be described by computing separate curves for each type of event and then combining the results.

One example of mixed population is rainfall-runoff mixed with snowmelt. In the Sierra Nevada region of California, hydrologic factors and relationships operating during general winter rain floods are usually quite different from those operating during spring snowmelt floods or during local summer cloudburst floods. In this region, peak flows are primarily caused by winter rainfall at lower elevations, whereas at higher elevations, peak flows are generally caused by spring snowmelt or rain-on-snow events (Parrett and others, 2011). Frequency studies in the Sierra Nevada have been made separately for rain floods, which occur principally during the months of November through March, and for snowmelt floods, which occur during the months of April through July. Peak flows were segregated by cause—those predominately caused by snowmelt and those predominately caused by rain (Crippen, 1978). Likewise, in the Colorado Front Range, peak flows are caused by both rainfall and snowmelt during the spring and summer (Elliott and others, 1982), especially in the lower elevation of the foothills zone (Jarrett and Costa, 1988).

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Mixed Populations

- Some locations unfortunate enough to have multiple causes for flooding
- What are hydrological and meteorological factors for explaining flood variability?

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Flood Variability

- Snow vs. rain
- Meteorological scale
- Moisture source
- Season
- Long-term climatic impacts
- Wildfire

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Snow vs. Rain

- Boreal or high-elevation watersheds may accumulate snow
- Warmer regions in same watershed may have rain floods at the same time
- Snow melts later
- Sometimes, rain falls on snowpack

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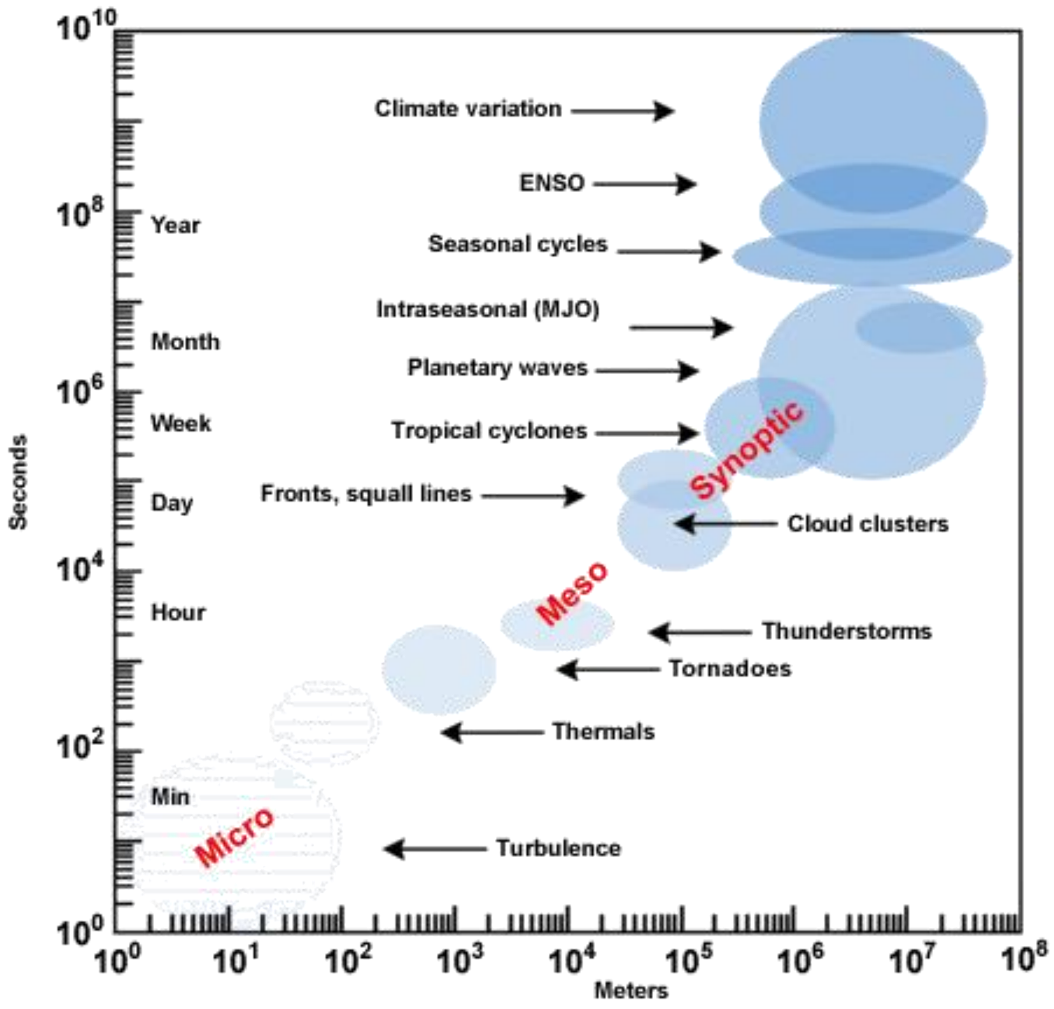
Meteorological Scale



Storm Duration
Mesoscale ~6 hour
Synoptic ~48 hour

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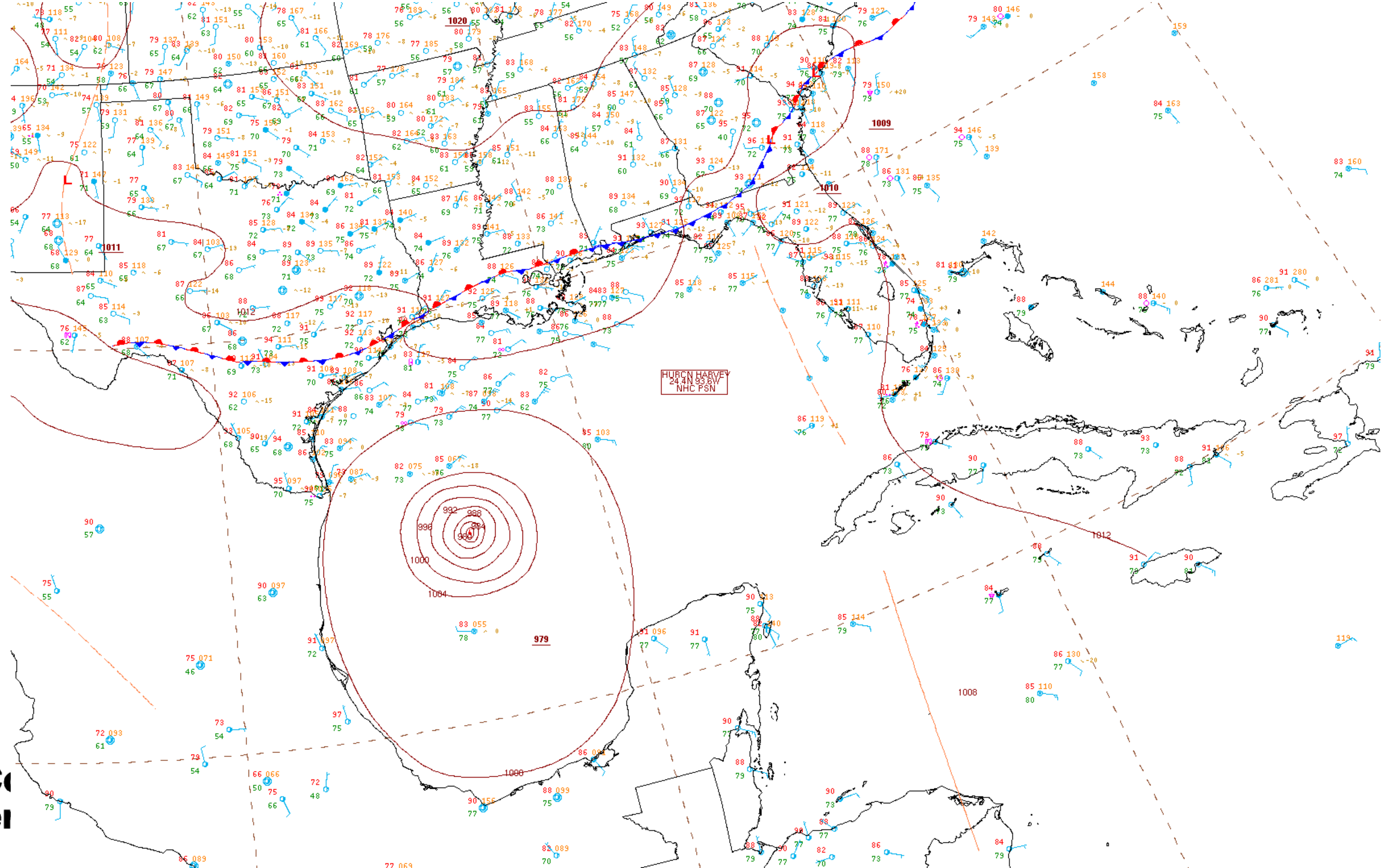
Moisture Source



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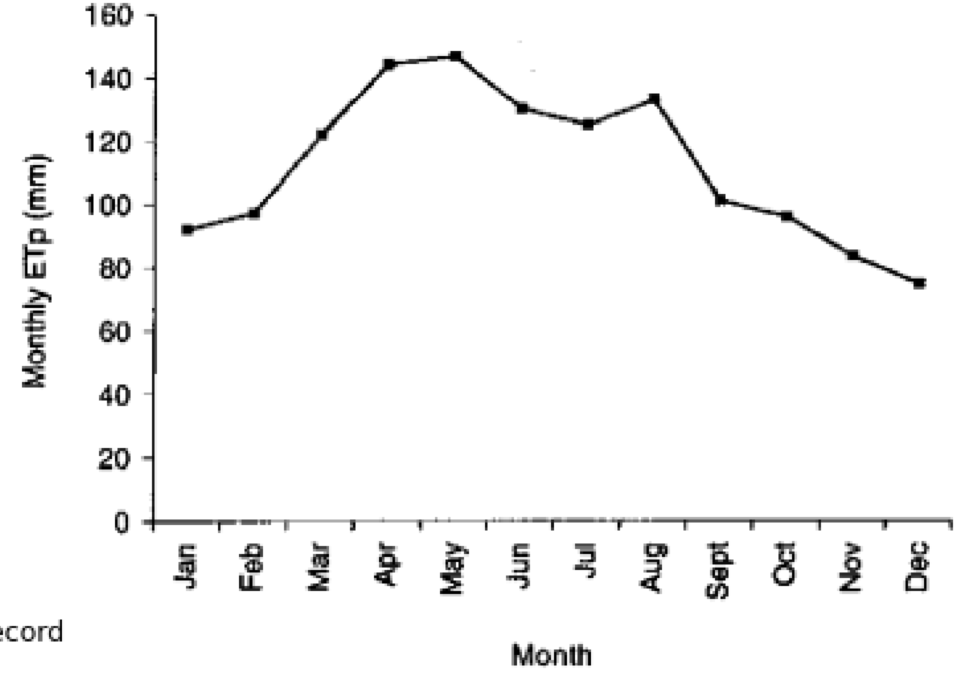
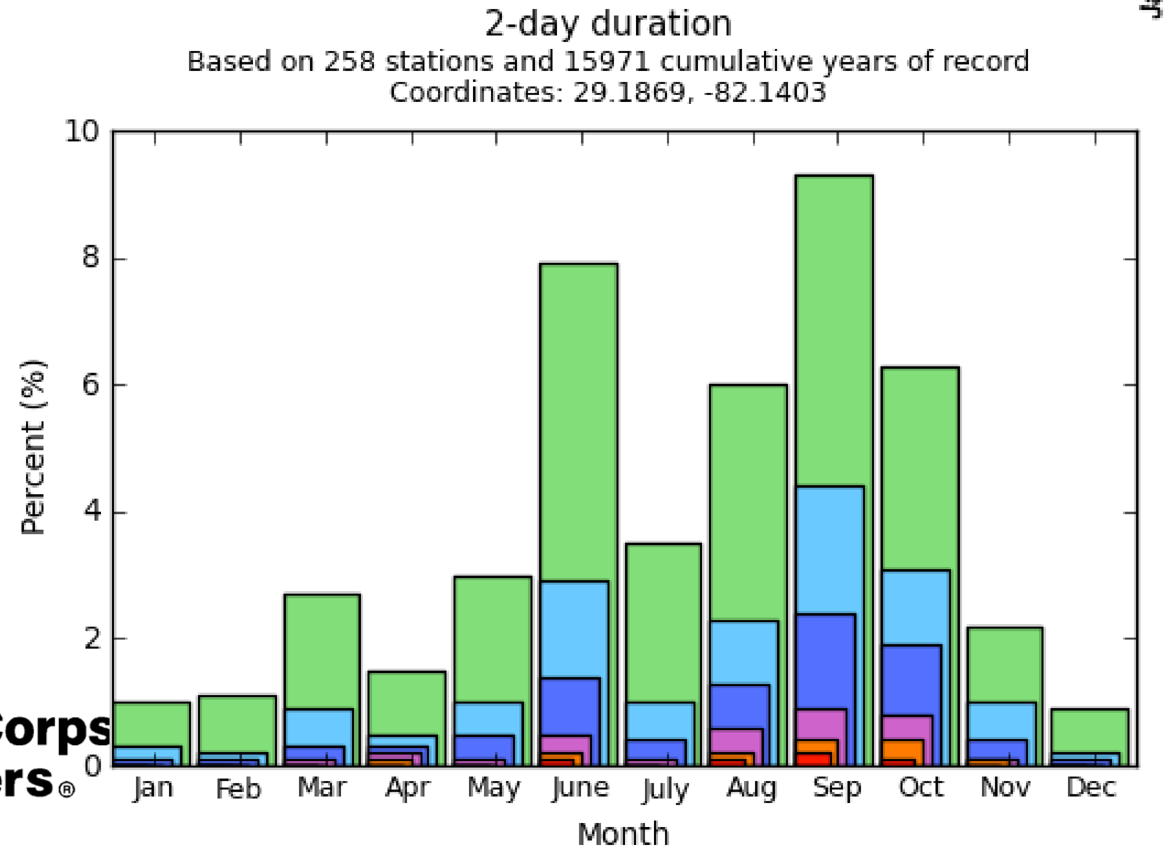
Season





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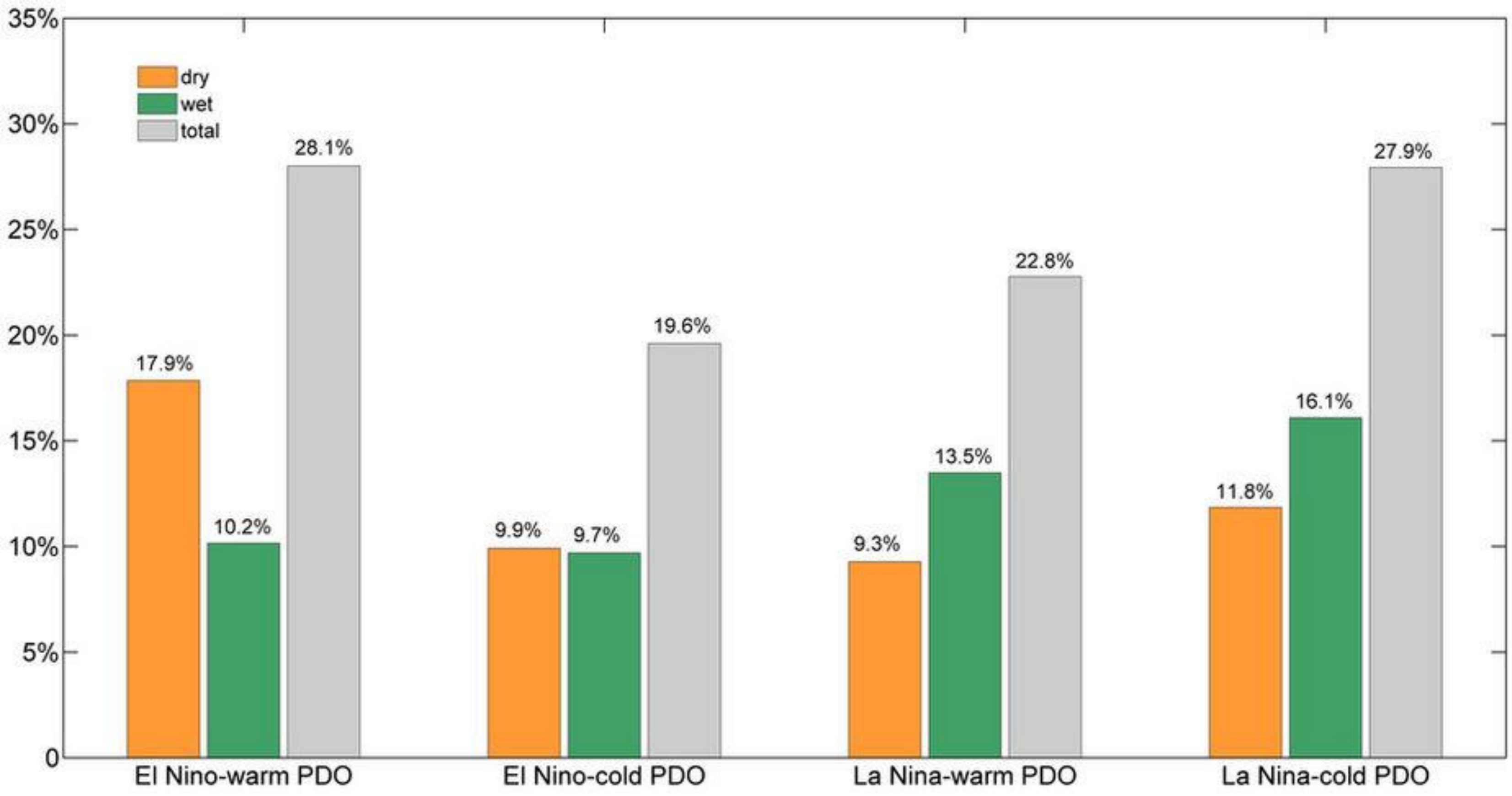
Climatic Cycles



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https://www.nature.com/articles/srep06651/figures/3

Post-Wildfire Hydrology & Debris Flow:
Significant Long-Term Effects on Hydrological Processes

- Burned Canopy/Vegetation
  - Decrease roughness & canopy storage capacity
  - Early snowmelt by reducing canopy shade areas
- Hydrophobic Soil Layer
  - Decrease the soil infiltration loss rate
  - Increase the surface runoff volume
  - More rapid runoff
- Radically change the Hydrologic response: Rapid Runoff/Flash Floods & Large Runoff Volume
  - Peak Timing, Flow, and Discharge Volume including Debris
  - Double Impacts: Rain on snow on burn areas
  - Subsequent Issues: Streambank Erosion, Reservoir volume Reduction, Water Quality, & Ecosystem
- Hydrologic models are used to estimate post-wildfire hydrology and debris yield/flow

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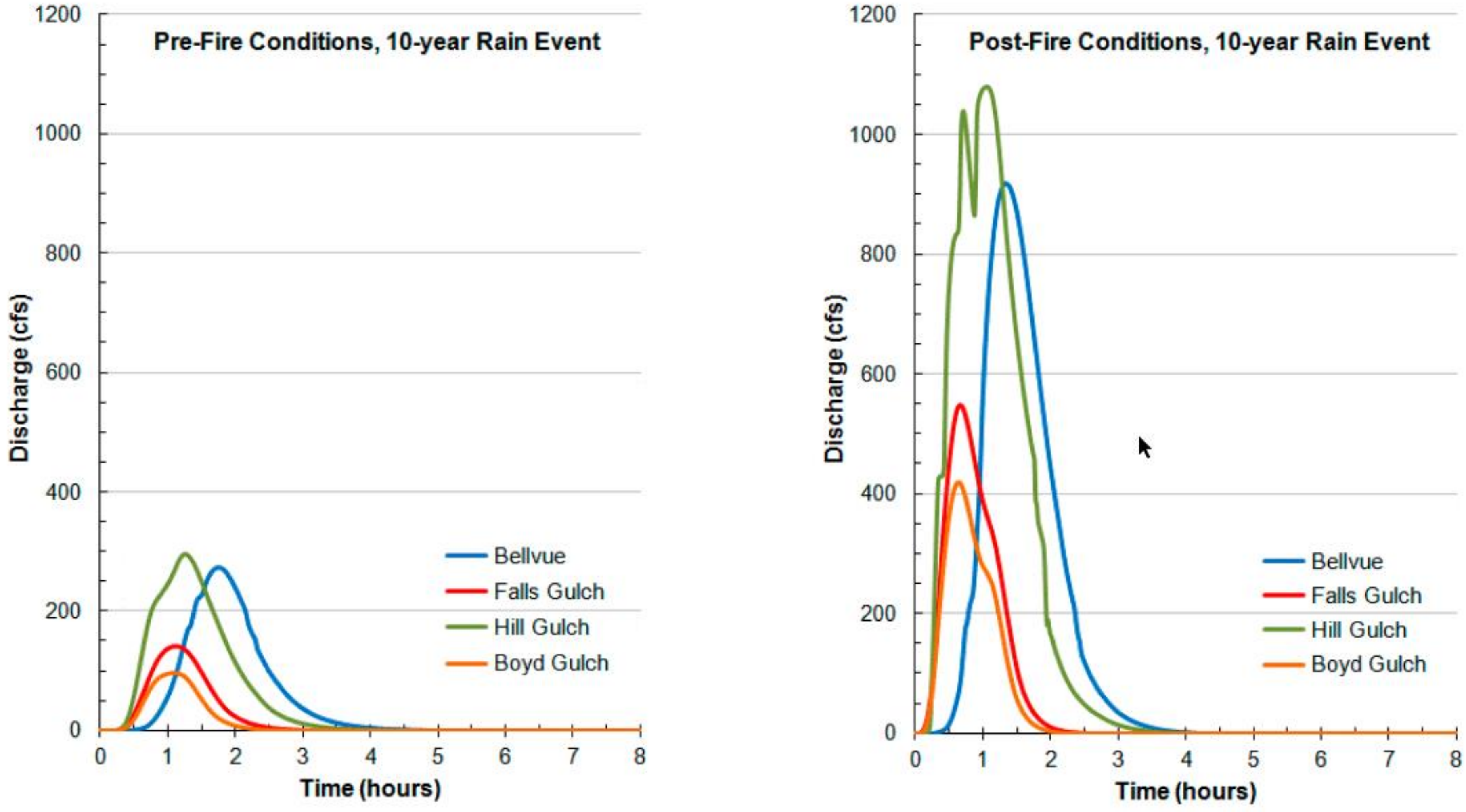
High Park Fire (June-July, 2012), Colorado
Estimated pre-and post-fire hydrographs



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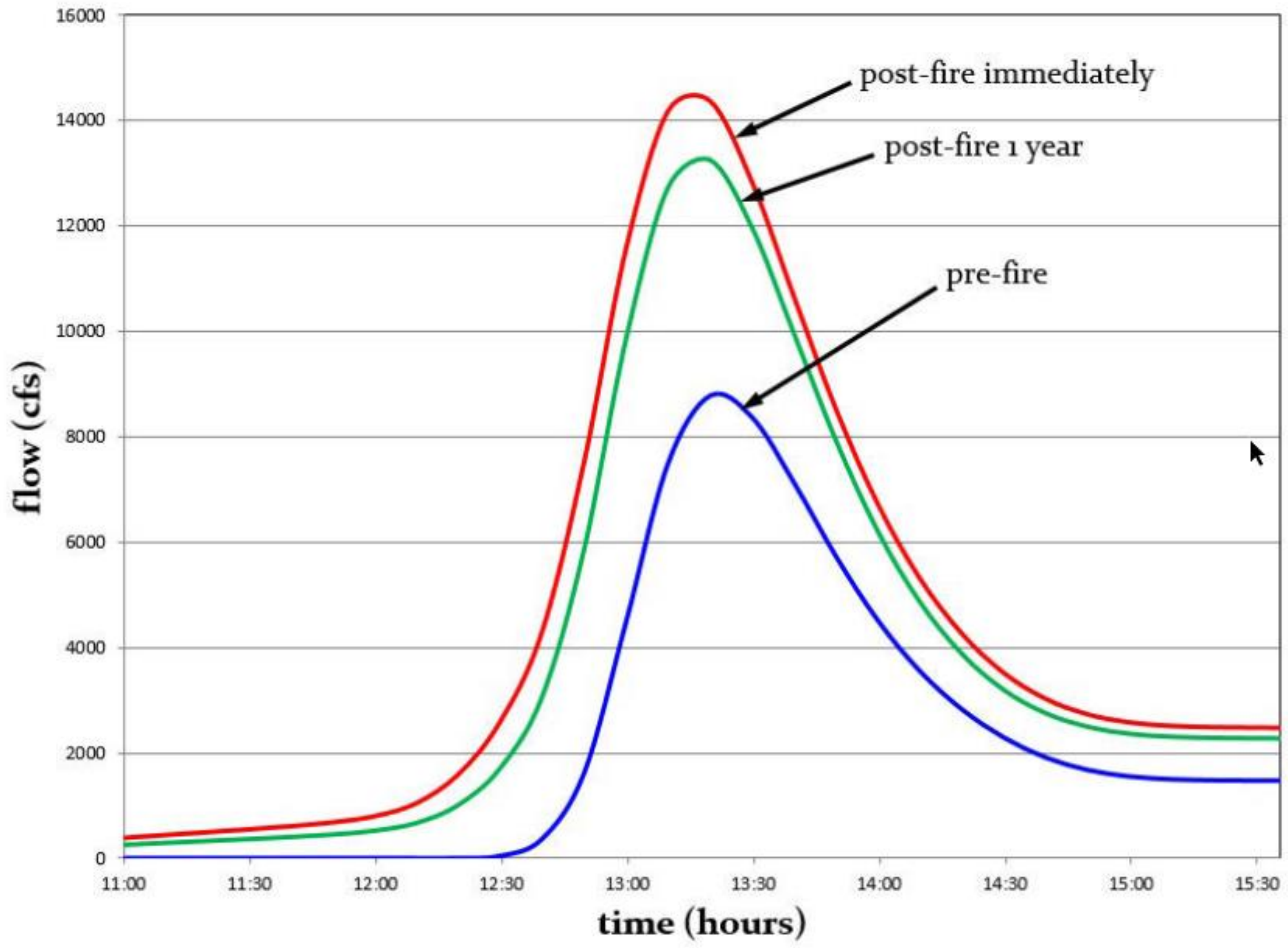
Source: USGS NRCS Hydrology Technical Note 4 -Hydrologic Analyses of Post-Wildfire Conditions, August 2016

HEC-HMS results, 100-year peaks at Glenwood (NM), areal reduction 6-hm centerir



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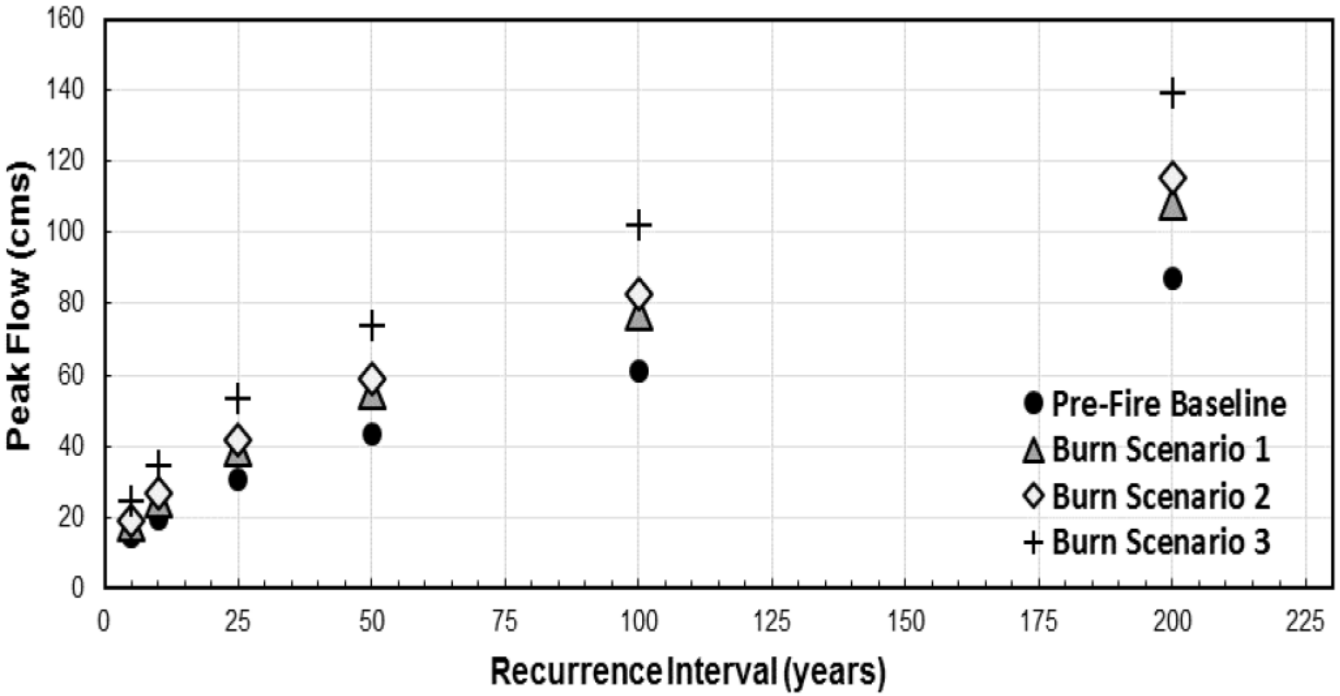

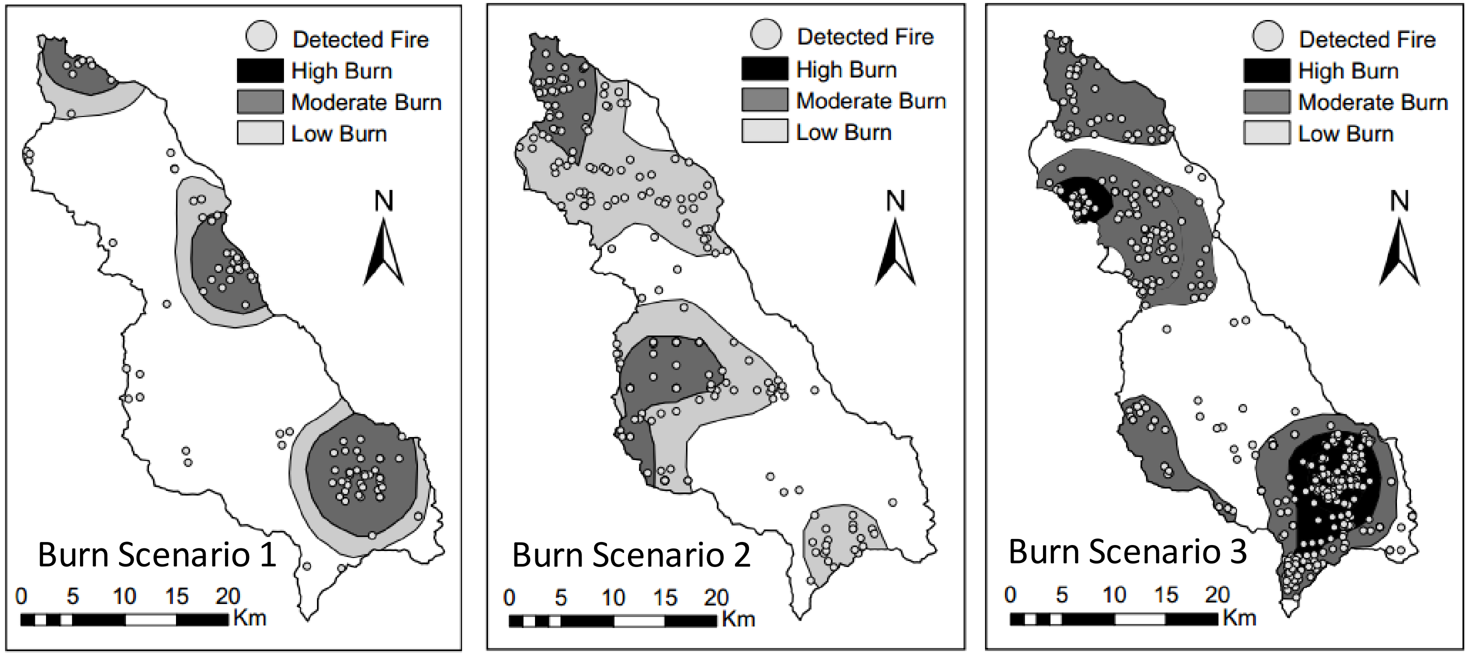

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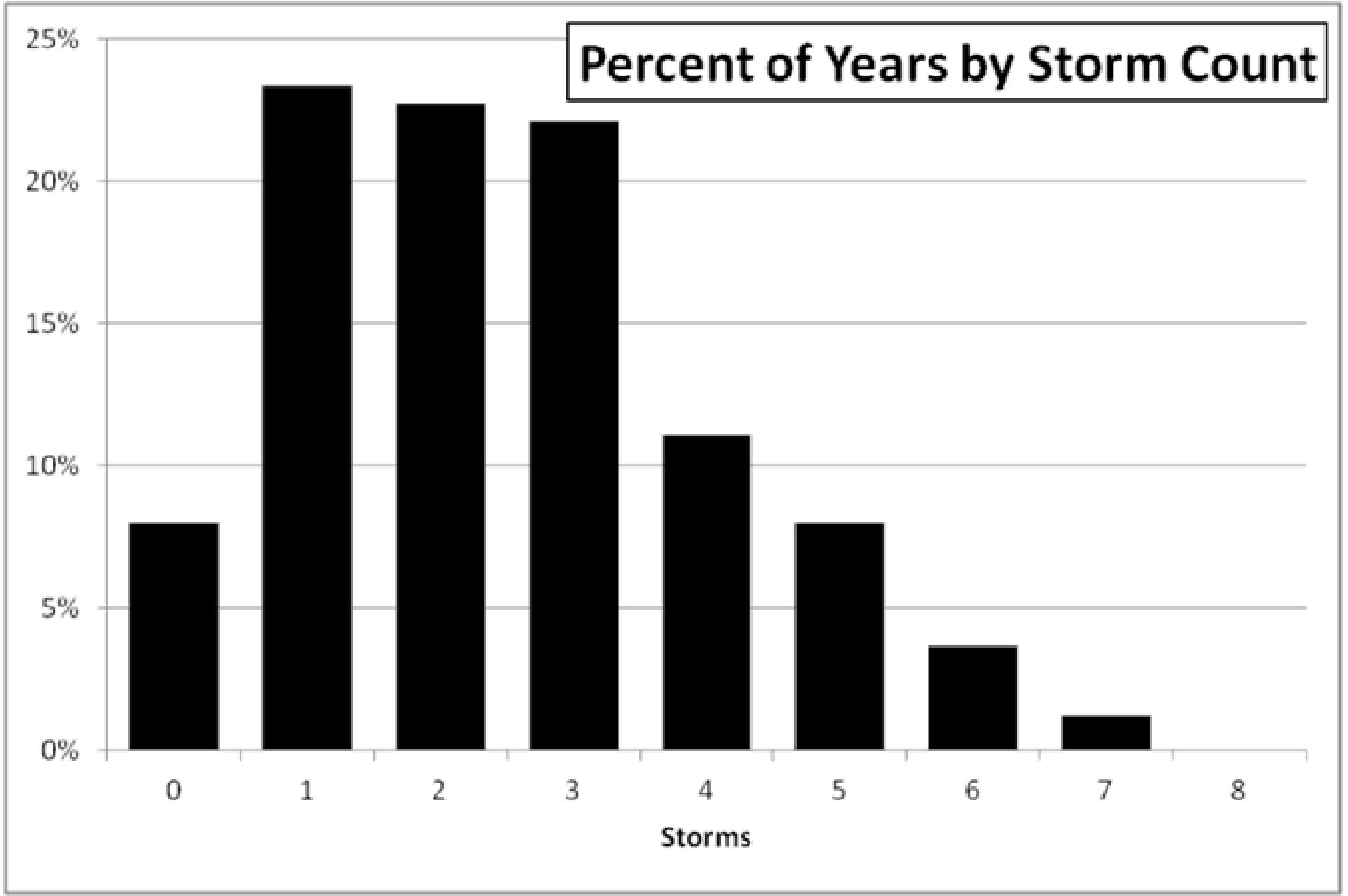
Source: Modeling The Impacts of Wildfire On Surface Runoff In The Upper [illegible] River Watershed Using HEC-HMD, JUEE, v.11, n.1, p.88-98

Multiple Events

- Sequencing of events may cause the biggest floods



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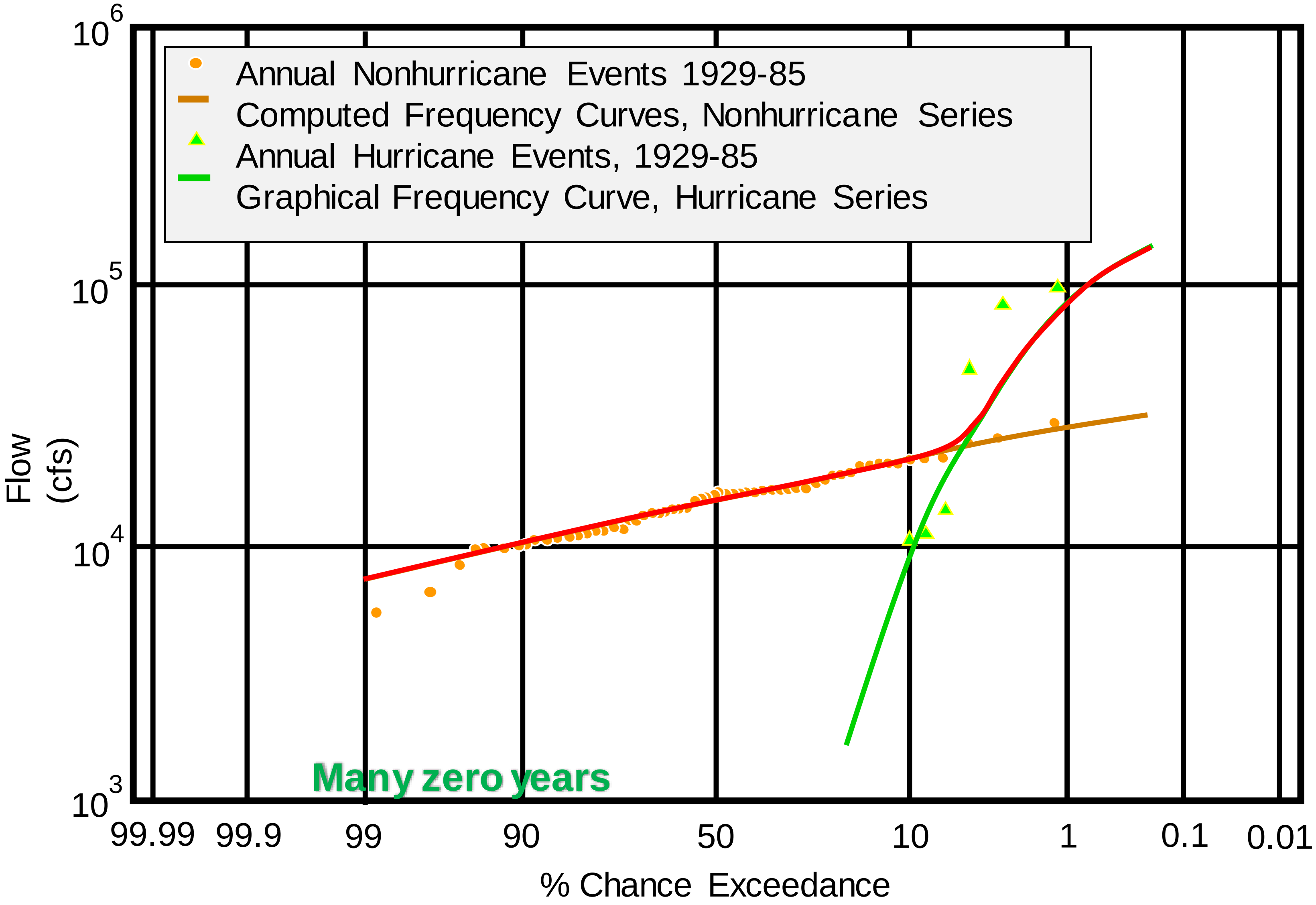

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Identifying Mixed Populations

- Streamflow data by itself usually not enough information
- Need additional data to identify causal mechanism
- Climatological data most important
- Sometimes simple rules work well

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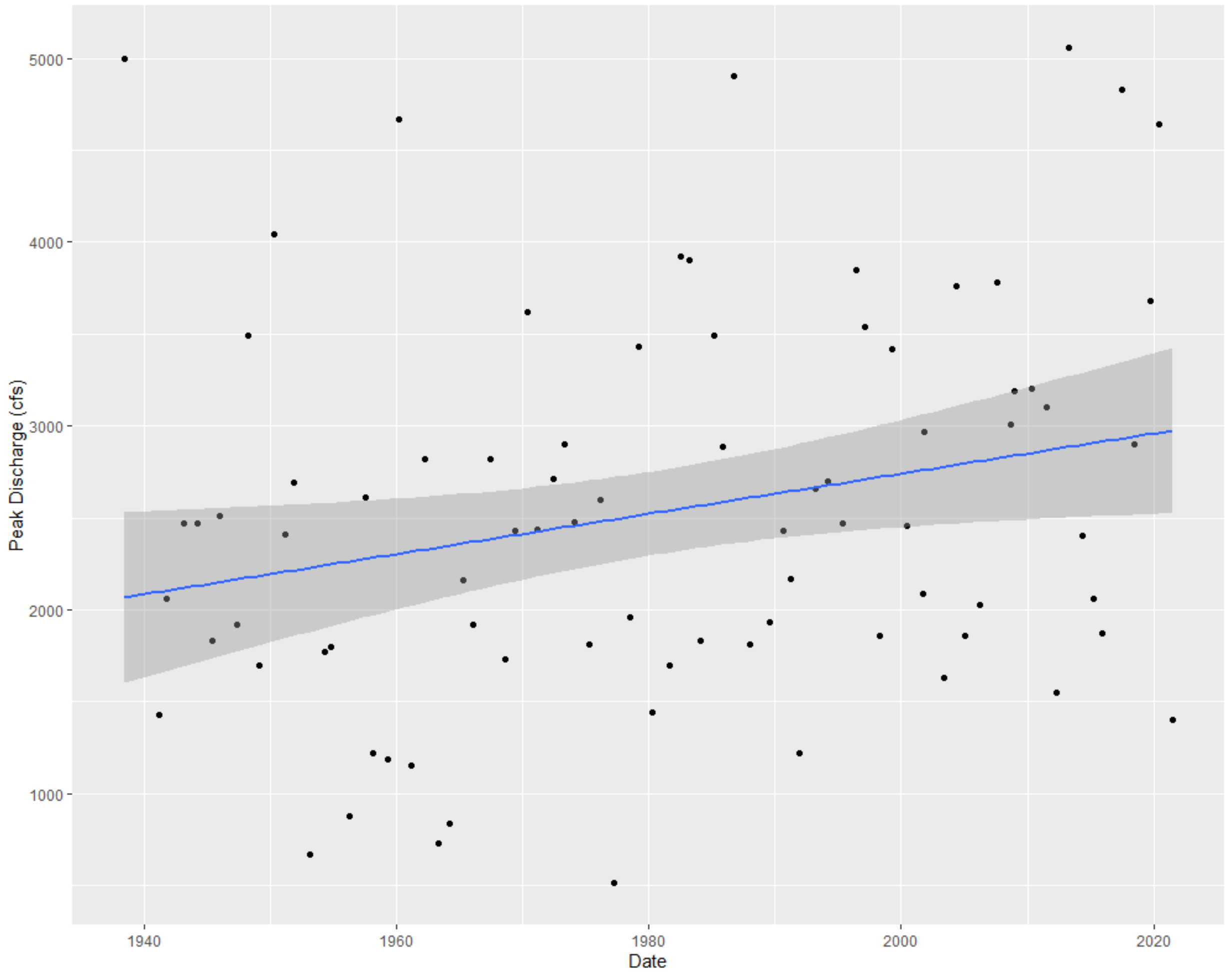
Nonstationarity

- Both mixed populations and nonstationarity deal with differences in the properties of floods
- Key difference: nonstationarity is a one-way process



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Modeling Mixed Populations

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A Model for Mixed Populations

- If C = max(A,B), then:

CDF → $$F_C(c) = F_A(c)F_B(c)$$ ← Any flood magnitude

- A: largest rain flood in a year
- B: largest snow flood in a year
- C is the larger of the two
- Thus, C is the annual maximum

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A Model for Mixed Populations

- What does this require?
  - Determining the dominant flood mechanisms/types
  - Identifying the annual maximum series for each type
  - Fitting a distribution to each AMS

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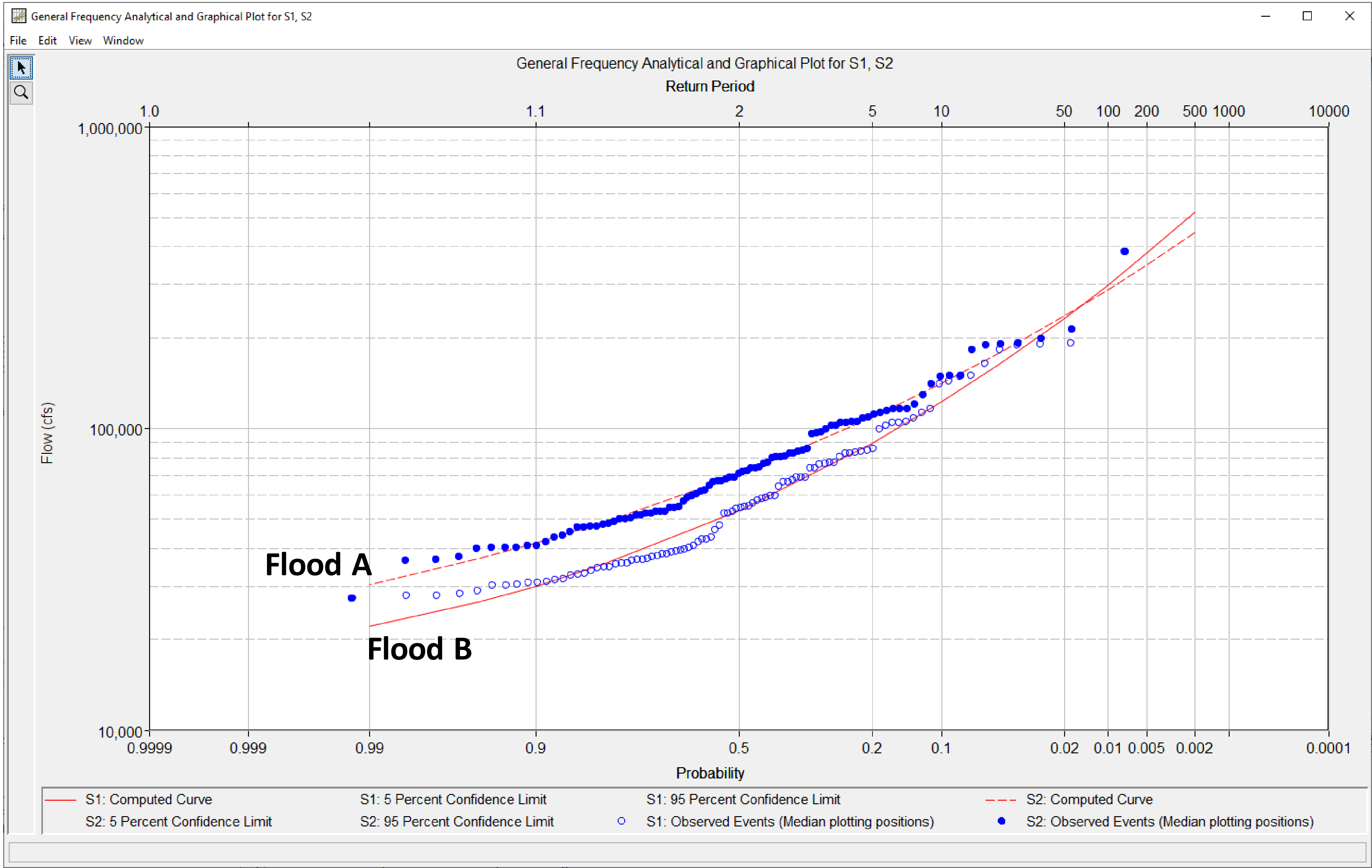

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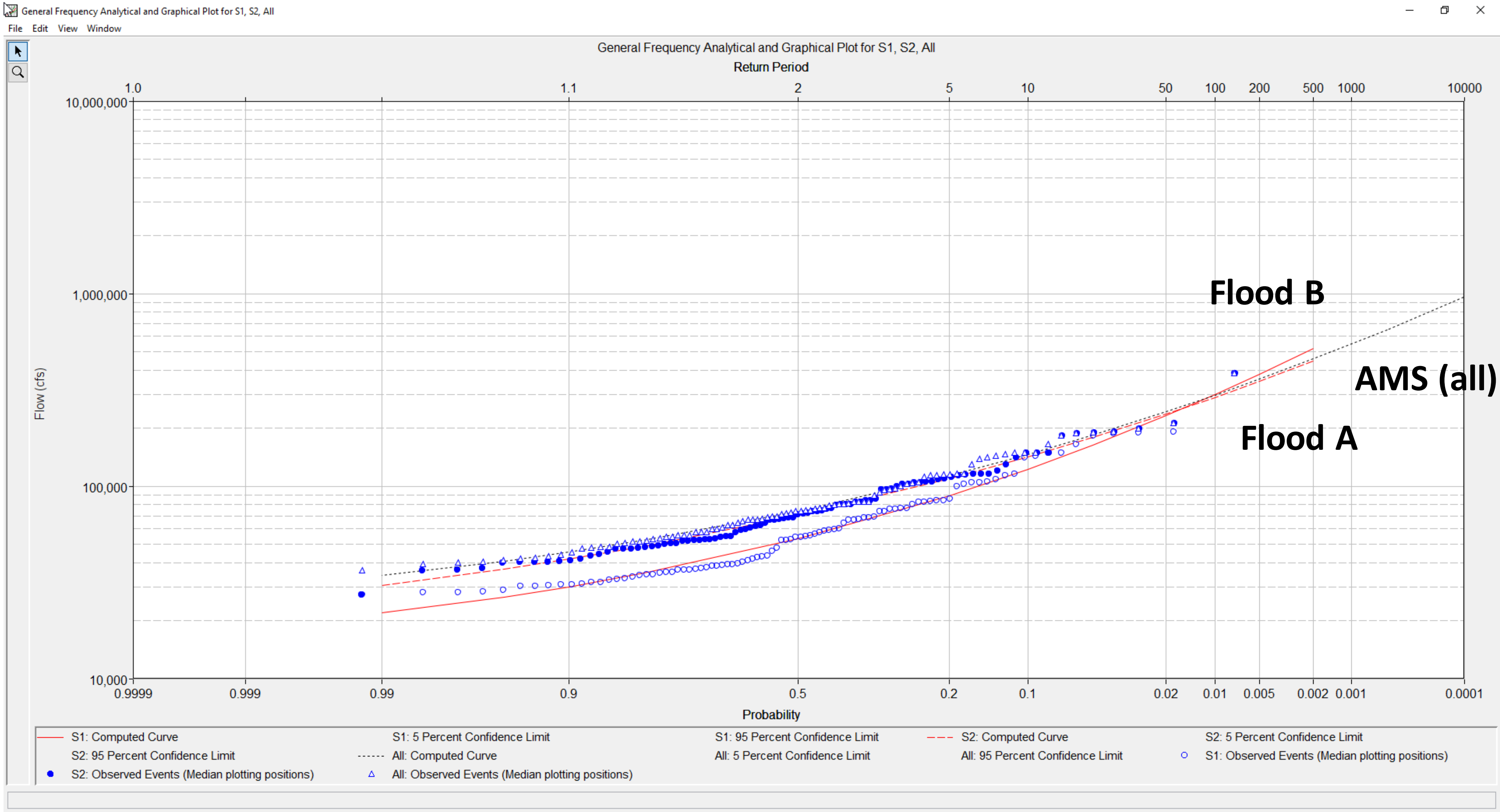

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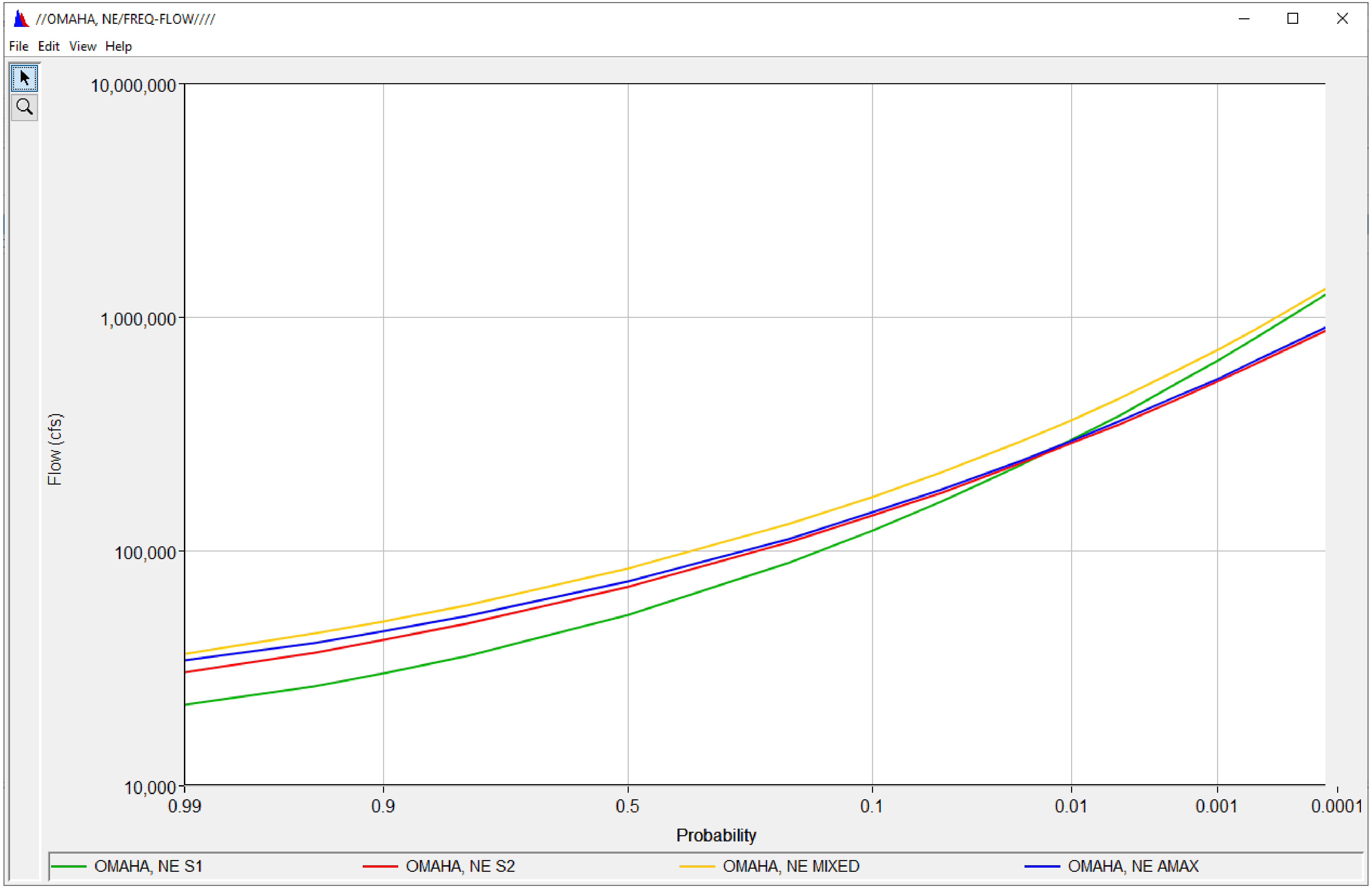

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Sample Sizes

- Splitting the annual maximum series by type can result in small sample sizes for each flood type
- Consider applying peaks-over-threshold

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Questions?

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