A joint probability approach to flood frequency estimation using Monte Carlo simulation

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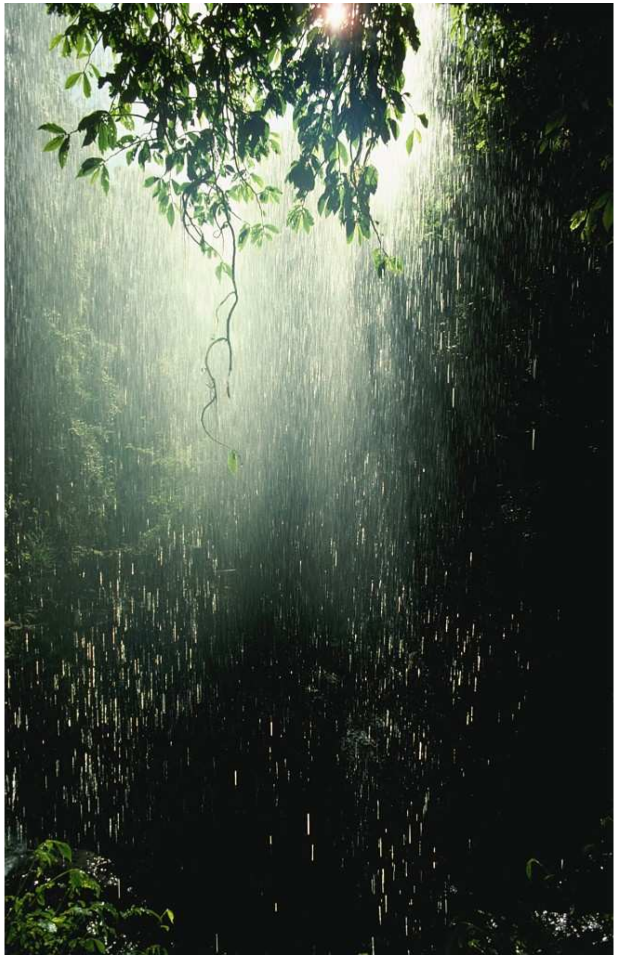
Presented by Cecilia Svensson

Outline of presentation

- Objective
- Current techniques for flood estimation
- Flood estimation using a joint probability approach
- Defining events
- Simulation methodology
- Results



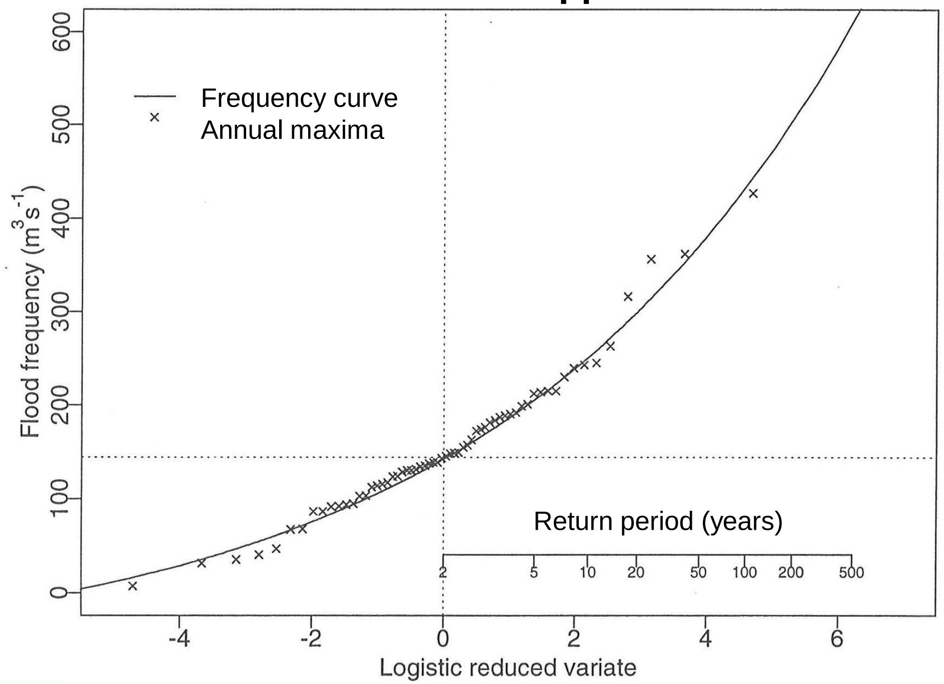
Objective

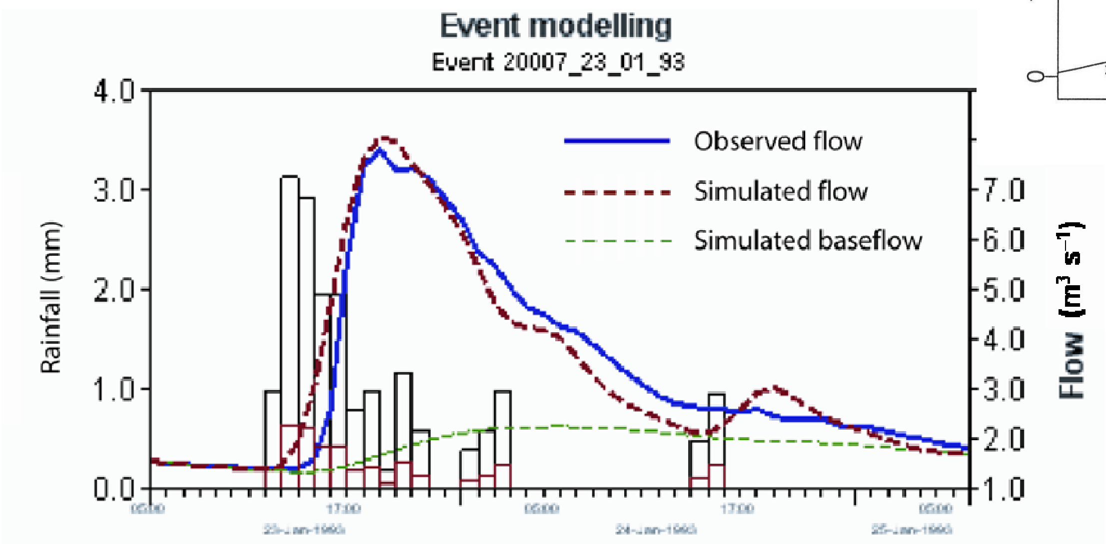
- To conduct an exploratory analysis of observed flood events to identify suitable joint probability models and to detect any seasonal, geographical and/or flood-size related effects which need to be included in these models

Current techniques for flood estimation

- Flood Estimation Handbook – statistical approach
- Flood Estimation Handbook – event approaches
- Continuous simulation

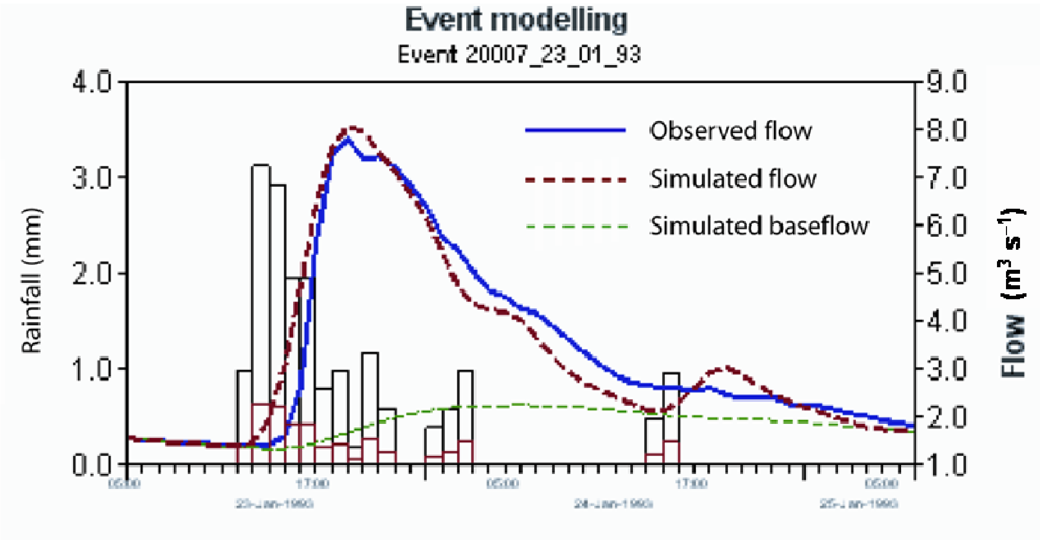
Statistical approach

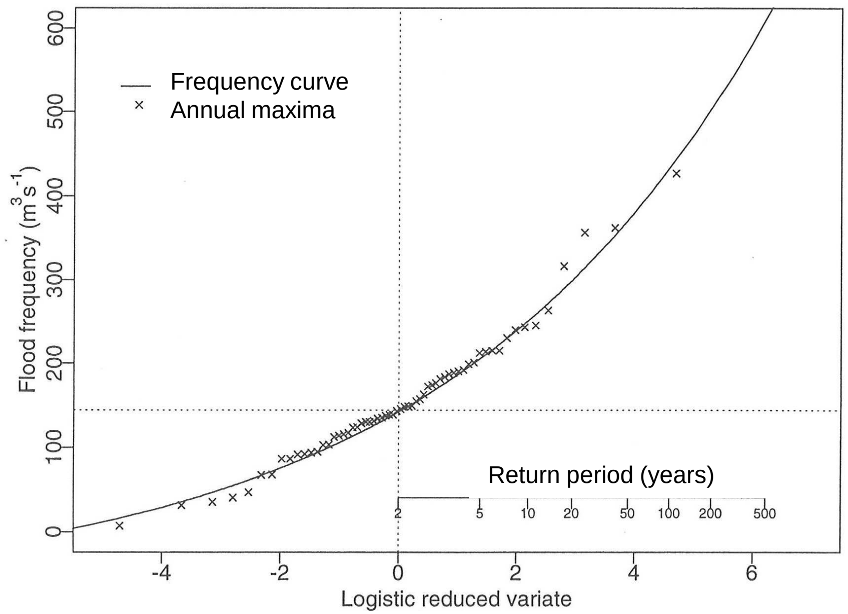




Avoiding bias in event modelling

- Full probability distributions for input variables
- Monte-Carlo simulation of flow events
- Frequency analysis of output peak flows

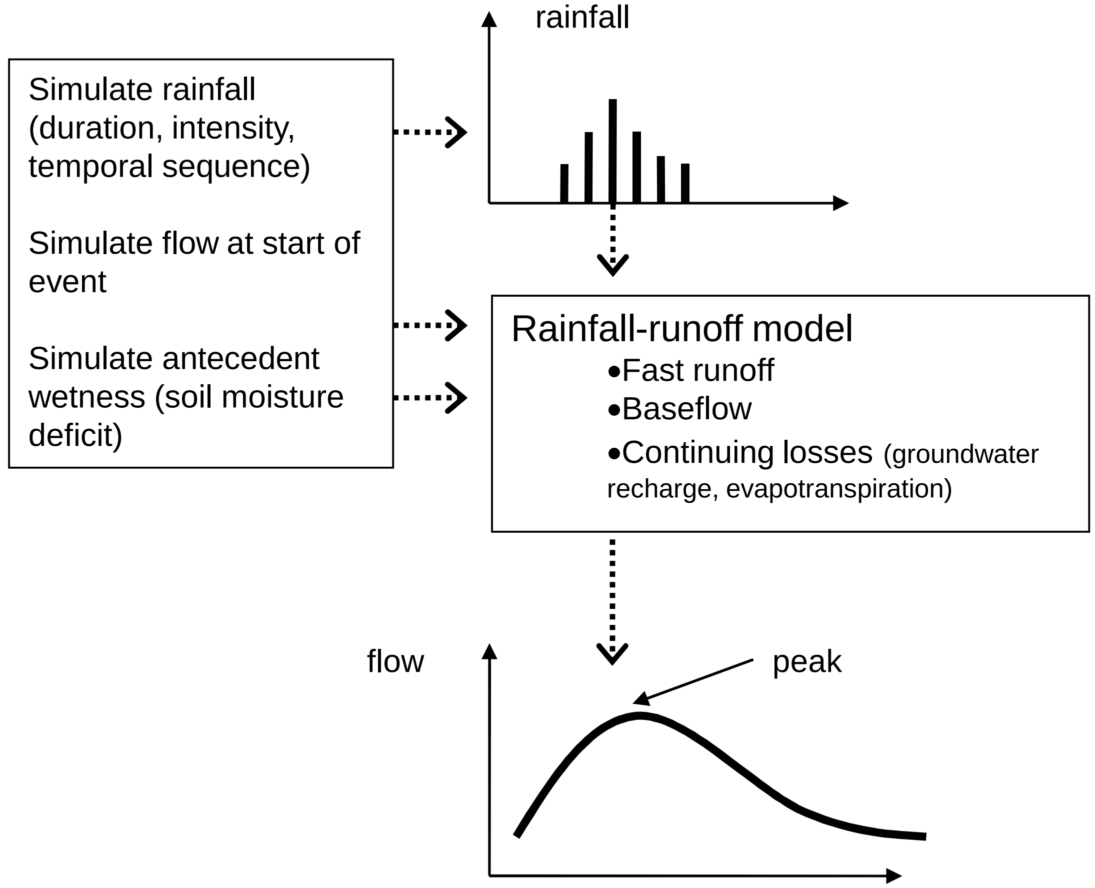




Joint probability approach

Simulate events taking into account:

- Seasonality
- Serial dependence
- Conditionality: strong relationship between
  - Rainfall duration and rainfall total
  - Flow at start of event and soil moisture deficit



Data

- Five study catchments
- Various climates and response times
- About 17-year long hourly series
  - rainfall
  - river flow
  - SMD

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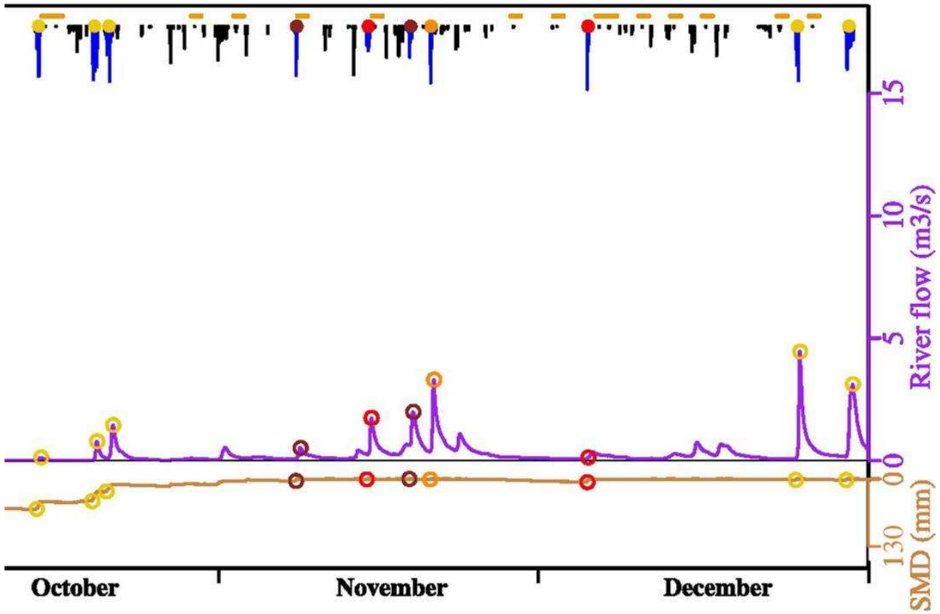
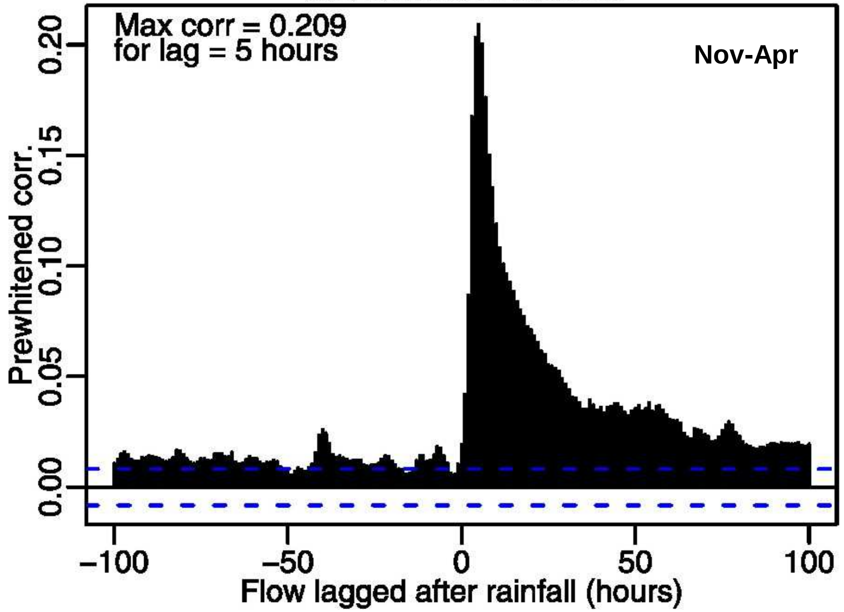
Defining events

- Find events using continuous hourly series
  - rainfall
  - associated SMD, initial flow and peak flow
- Relate definitions of events to catchment characteristics
  - time-to-peak
  - 1-hour areal rainfall of 2-year return period
- Select on average 10 events per year

Bumpstead Brook



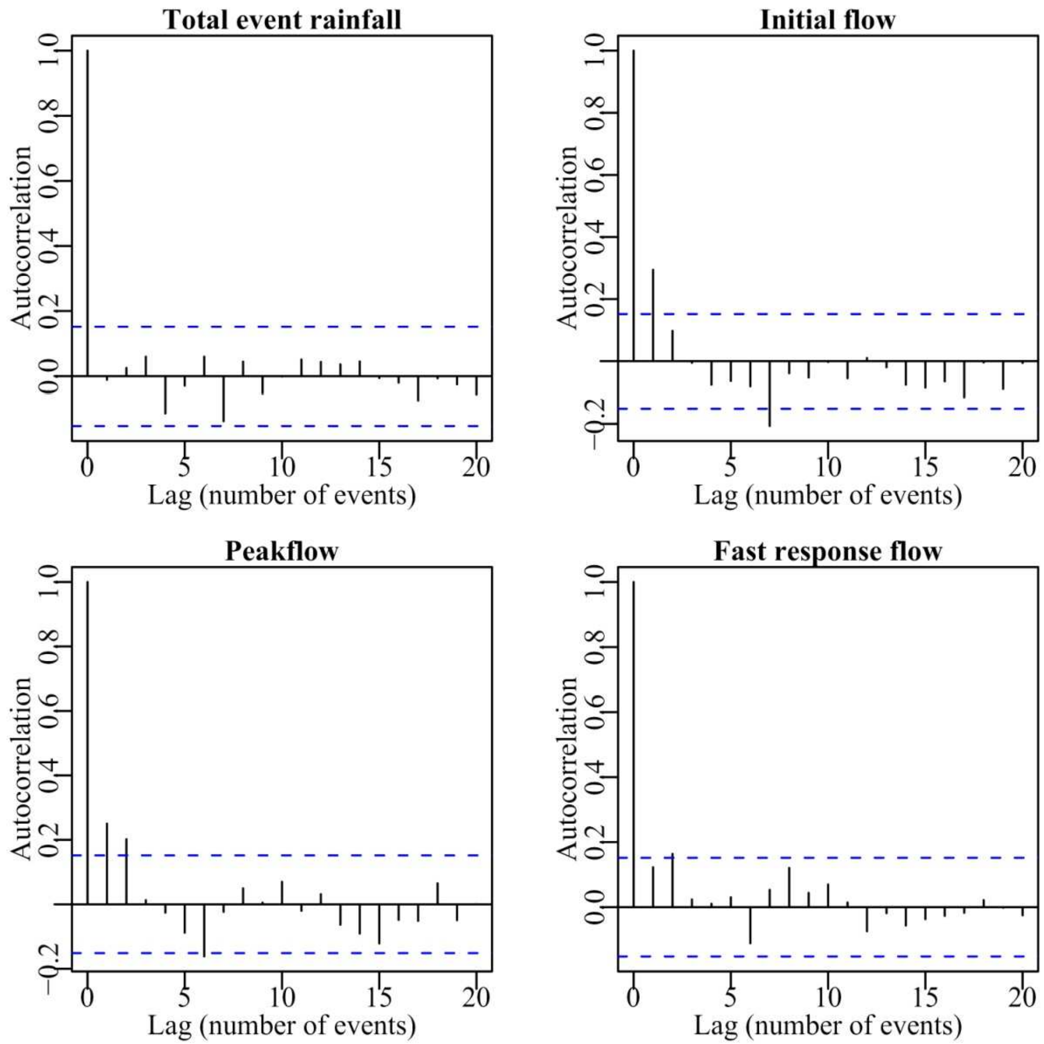
Bumpstead Brook



Serial dependence

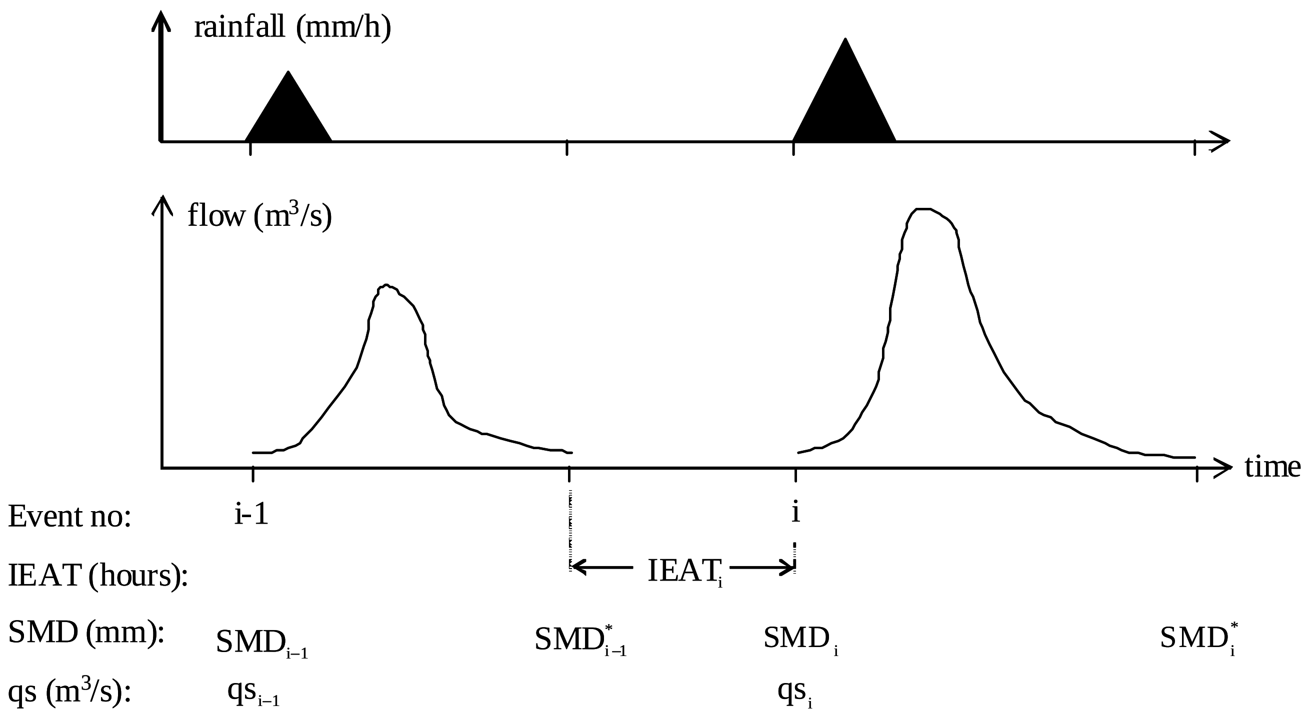
- Serial independence for total event rainfall, but not for flows and SMDs

Taf at Clog-y-Fran



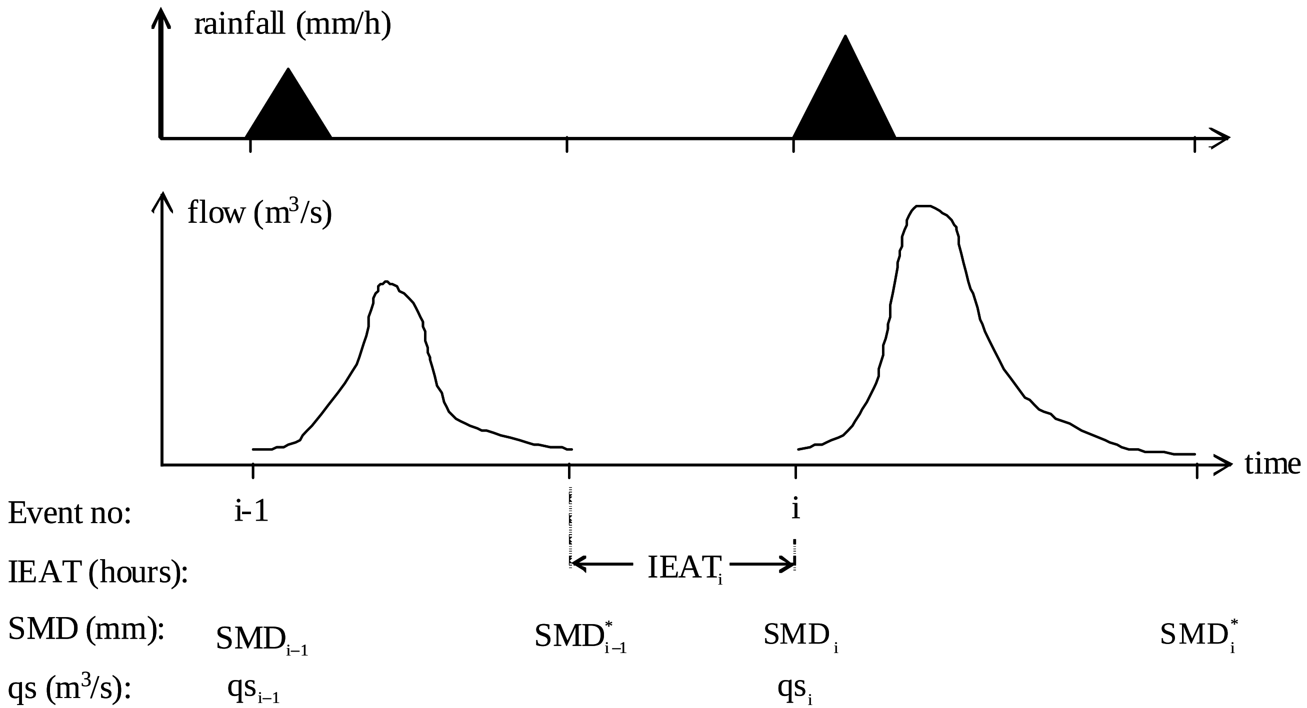
Simulation methodology

- Simulate a string of events
- Stochastic model for inter-event arrival times (IEAT)
- On average 10 events per year



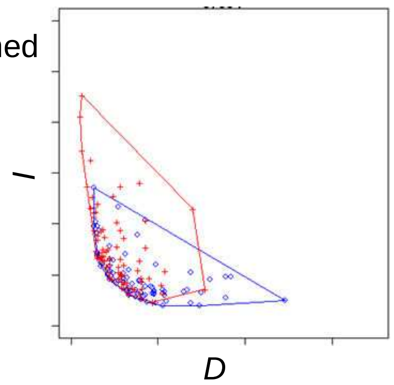
Simulation methodology

- Boundary conditions from stochastic models:
  - rainfall duration (D) [h]
  - rainfall intensity (I) [mm/h]
  - soil moisture deficit at onset of rainfall event (SMD) [mm]
  - initial flow (qs) [m^3/s]
- Soil moisture deficit at the end of each flood event from PDM (SMD*) [mm]



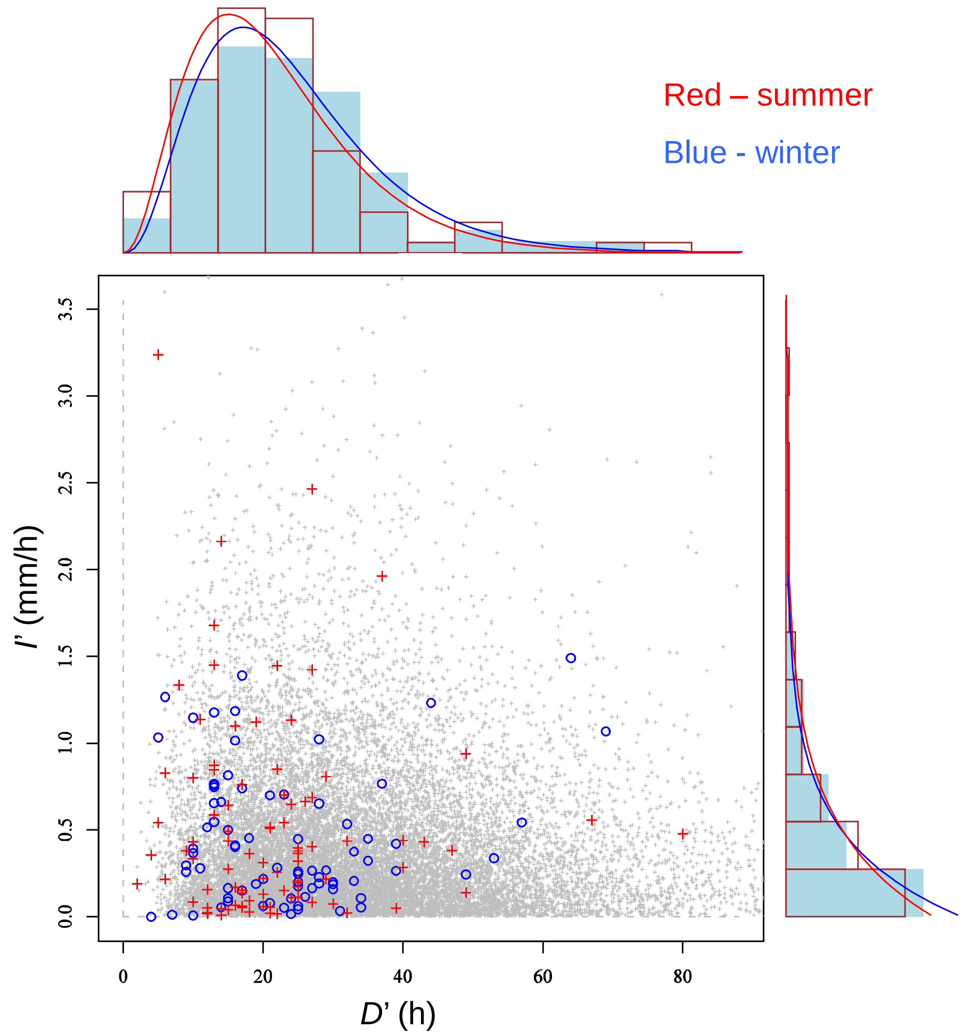
Rainfall

Untransformed variables



- Rainfall duration and intensity show
  - dependence
  - artificial lower bound (due to selection of events on total rainfall depth, *P*)
- Transformed variables
  - duration (gamma): $D' = D - 1$
  - intensity (exp) : $I' = (P - P_{min})/(D - 1)$
- Two seasons
  - May – October, November – April
- Triangular profile

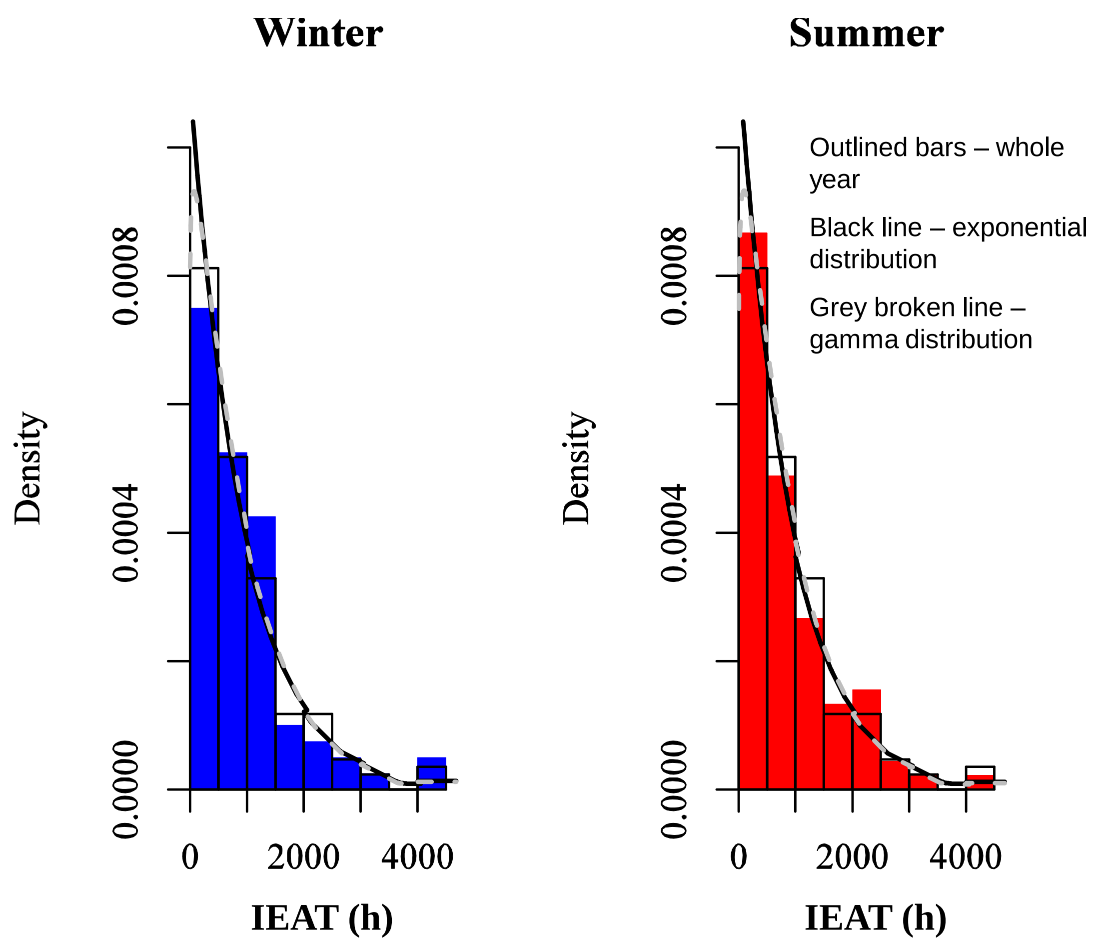
Blyth at Hartford Bridge



Inter-event arrival time

- Gamma or exponential distributions
  - Not much difference
  - Exponential distribution chosen
- Two seasons

Blyth at Hartford Bridge

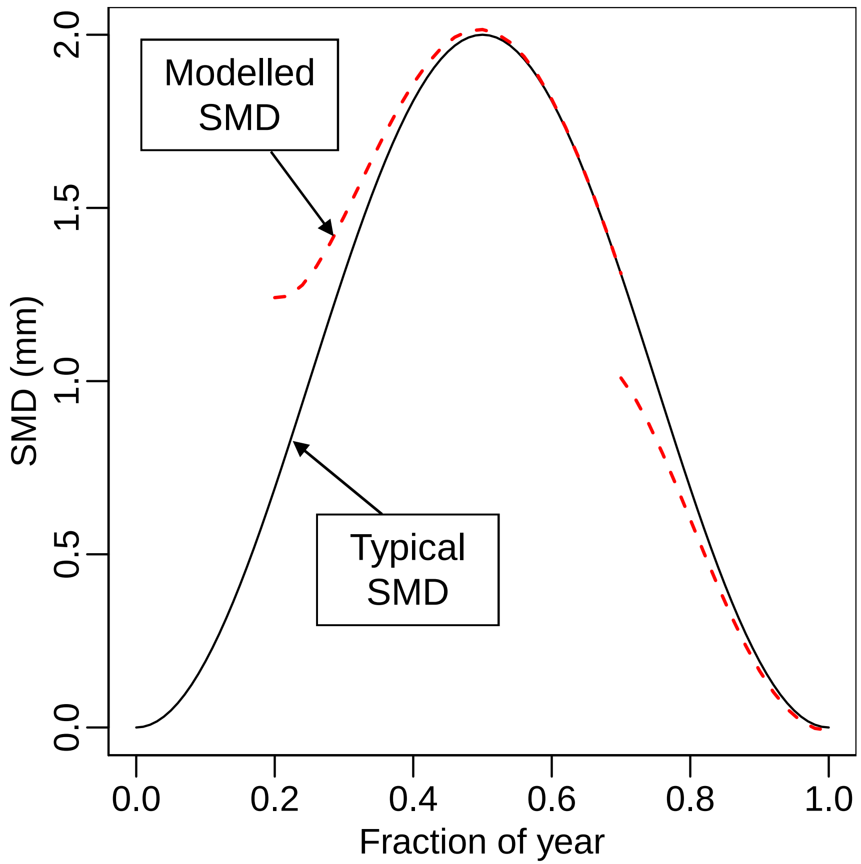


Exponential distributions' parameters

	Winter	*Summer*
Scale (hours)	910.95	881.10

Soil moisture deficit

- SMD at the start of each rainfall event
- Sinusoidal seasonal variation of SMD, with deviation depending on:
  - time elapsed since the previous event (IEAT)
  - the SMD at the end of the previous event



Typical seasonal variation at time *f* (fraction of a year):

$$\ln\left[\frac{SMD_i}{S_{\max}-SMD_i}\right]=\mu(f)=\theta_1+\theta_2\sin(2\pi f)+\theta_3\cos(2\pi f)$$

SMD at start of event *i*:

$$\ln\left[\frac{SMD_i}{S_{\max}-SMD_i}\right]=\mu(f)+\exp(-\theta_4 IEAT_i)\left(\ln\left[\frac{SMD^*_{i-1}}{S_{\max}-SMD^*_{i-1}}\right]-\mu(f^*)\right)+\varepsilon_i$$

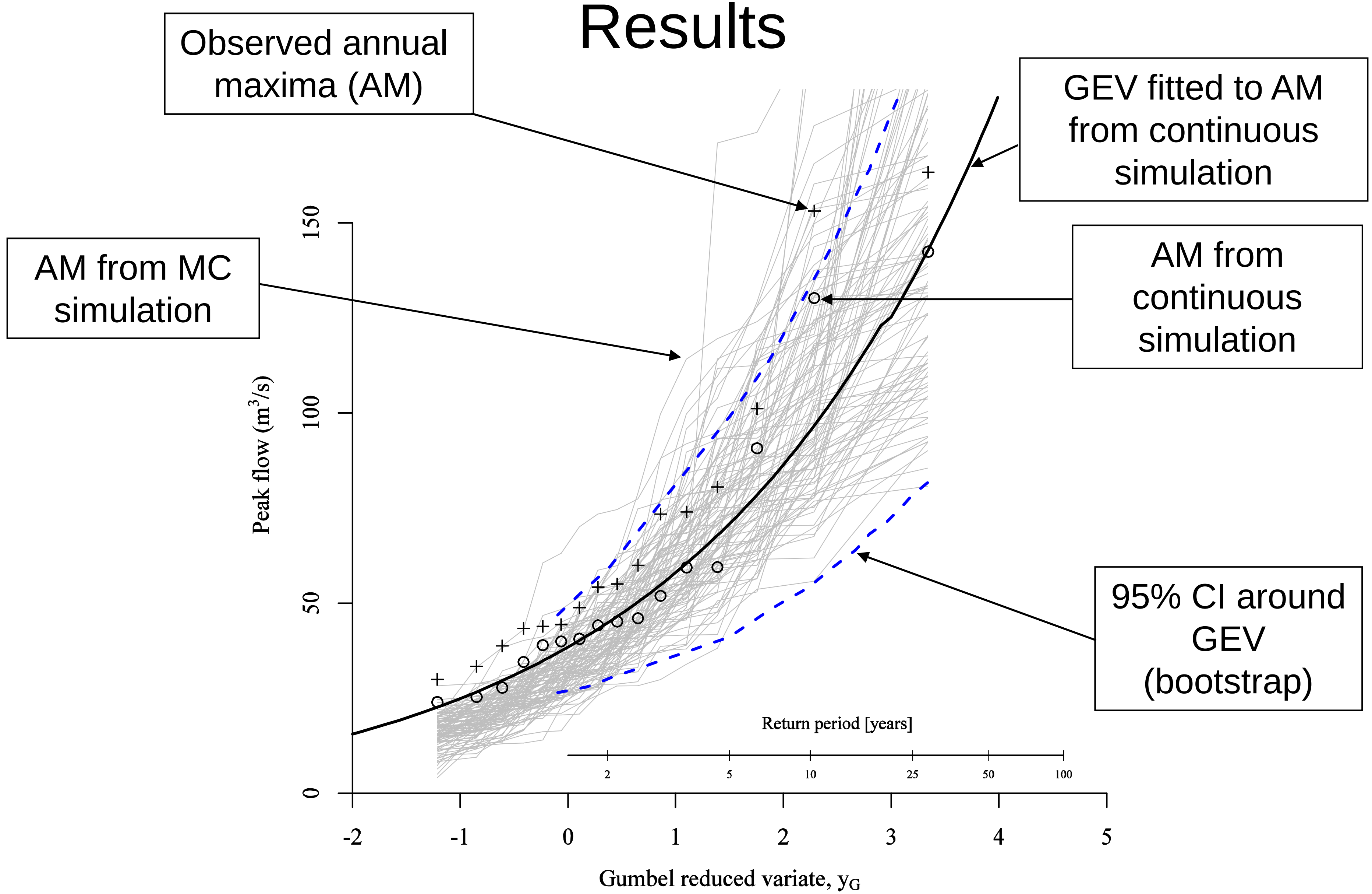
Initial flow

- Initial flow at the start of each rainfall event
- Sinusoidal seasonal variation, with deviation depending on:
  - the SMD at the start of the event

Initial flow, *qs*, at start of event *i*:

$$\ln[qs_i] = \phi_0 + \phi_1 \ln[SMD_i] + \phi_2 \sin(2\eta f) + \phi_3 \cos(2\pi f) + \eta_i$$

Results



Blyth at Hartford Bridge

Summary

- Design values in current event modelling approaches may cause bias in the flood frequency estimate
- Instead: a joint probability approach using Monte Carlo simulation
- Preliminary results fit well to data from continuous simulation

Thank you!