

Stochastic Hydroclimatic Modeling and Simulation (SHCMS)

Introduction

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Hydroclimatology and Hydroclimatic Phenomena

- Hydrology and climatology are two closely related areas of earth science. Hydroclimate is the scientific field that brings together hydrology and climate, including the impacts that water and its processes have on Earth's climate, and the impacts of climate patterns and change on the global hydrological (or water) cycle.
 - <https://www.weather.gov/safety/drought-hydroclimate>
- Hydroclimate phenomena such as drought, flooding, and precipitation can have societal impacts such as crop damage and loss of life.

- Hydroclimatic phenomena are inherently stochastic due to the random variability, both in space and in time, of hydrologic and climatic variables.
- In general, hydroclimatology provides a platform to analyze the relationship between climatic factors and hydrologic variables over space and time. Such relationship and their possible changes vary over time and space and are essential in the context of climate change.

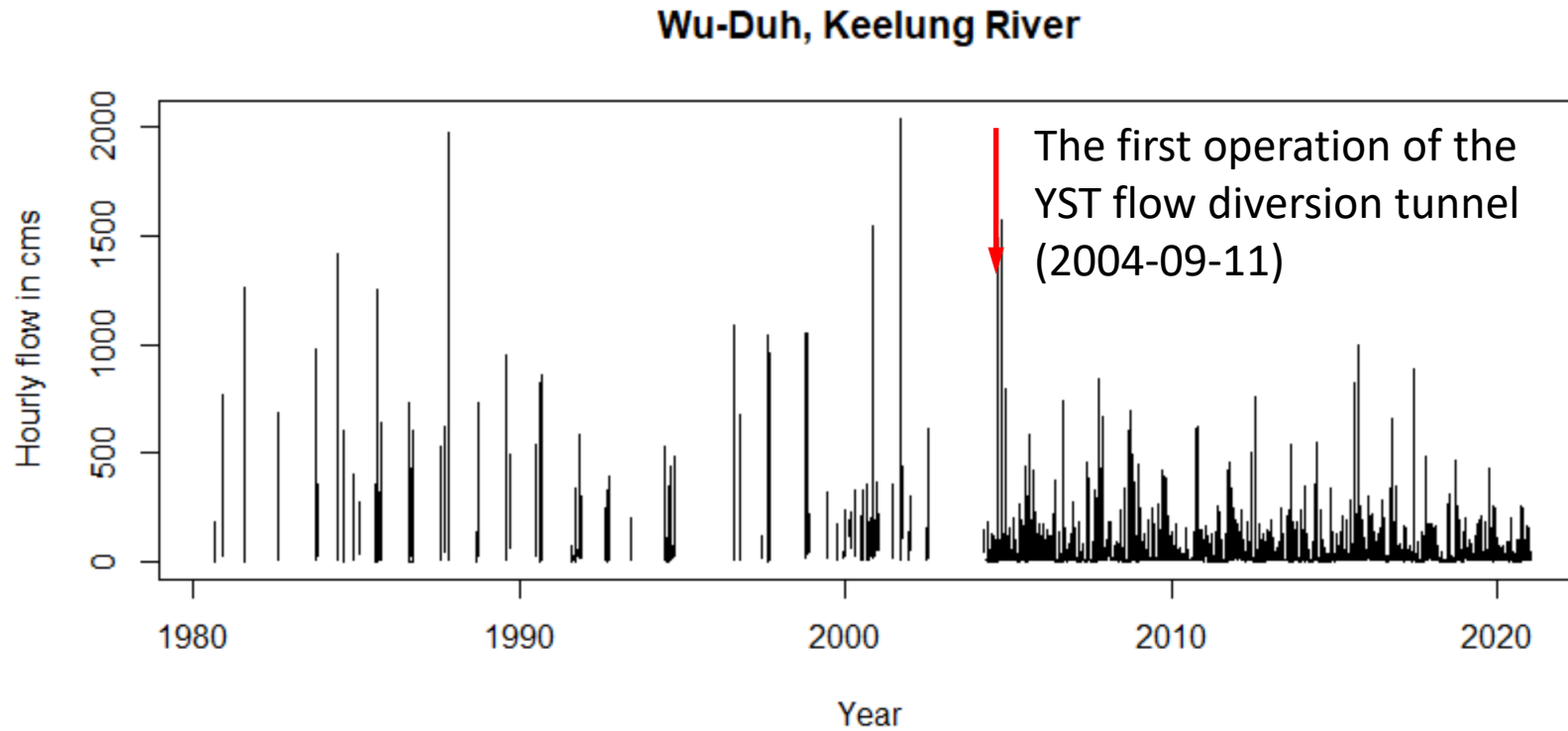
What is this course about?

- This course aims to introduce the fundamental theories and techniques for stochastic modeling and simulation of hydroclimatic **processes**.
- The focus of this course is on the uncertainty of hydroclimatic processes and the risk of hydroclimatic forecasting.
- We will use real-world data in in-class practices and discussions for modeling and simulation of hydroclimatic phenomena.

Examples of hydroclimatic processes

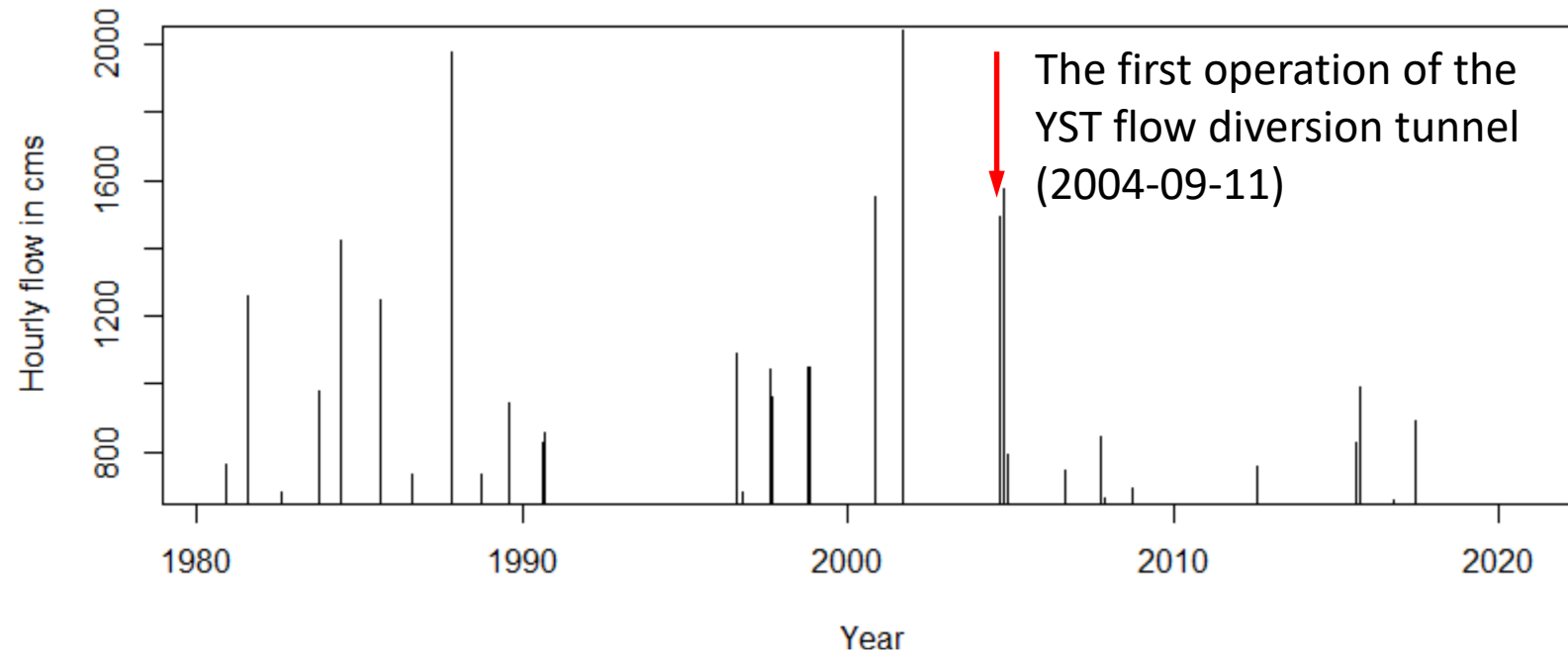
- Streamflow data series
 - Hourly streamflow at Wu-Duh
 - Daily streamflow at Xia-Yun
- Rainfall data series
 - Hourly rainfalls of storm events (Hyetograph)
 - Daily rainfall series
 - Monthly rainfall series
- Wind speed data series

Hourly flow series at Wu-Duh

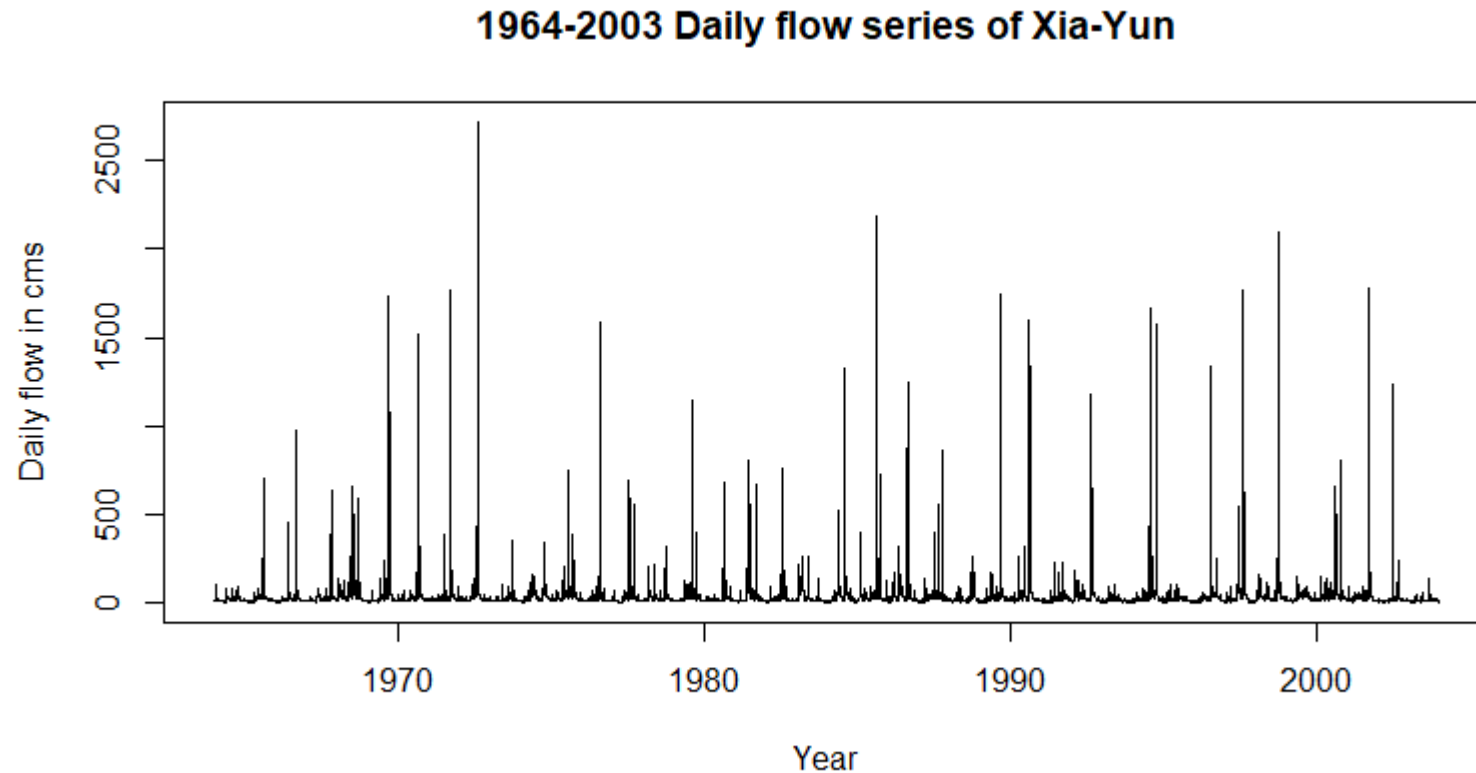


Hourly flow exceeding 700 cms

Wu-Duh, Keelung River

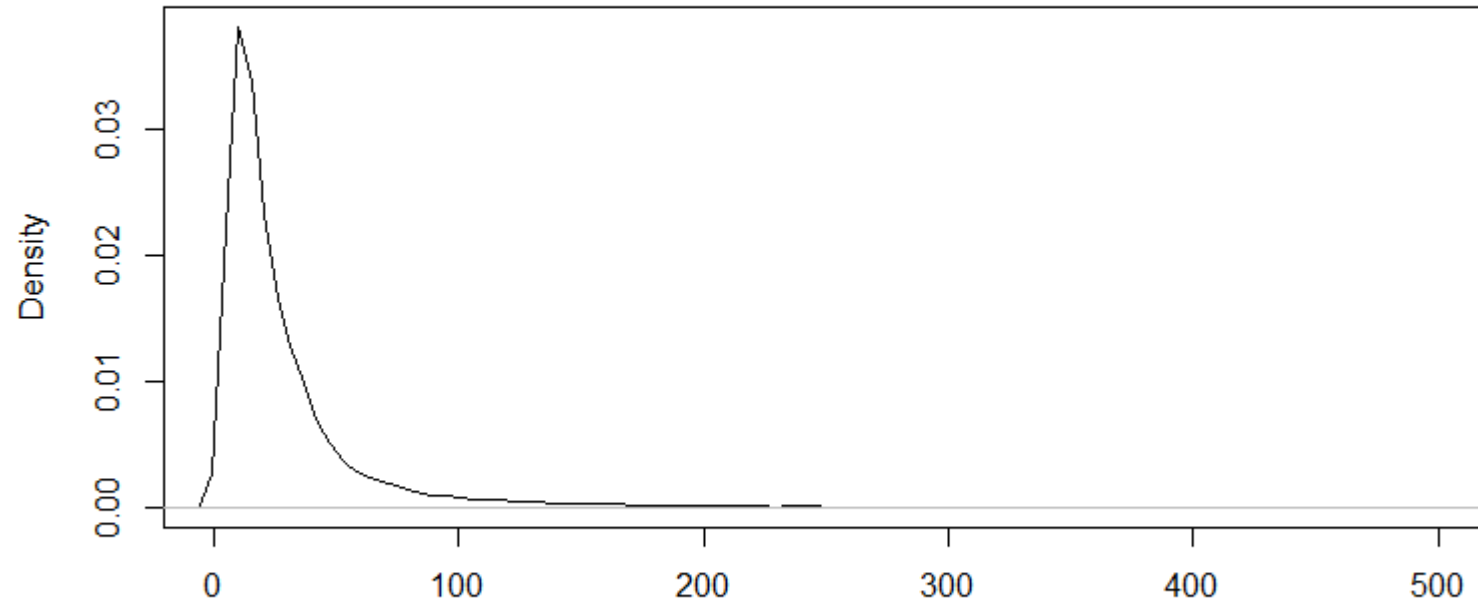


Daily flow series at Xia-Yun



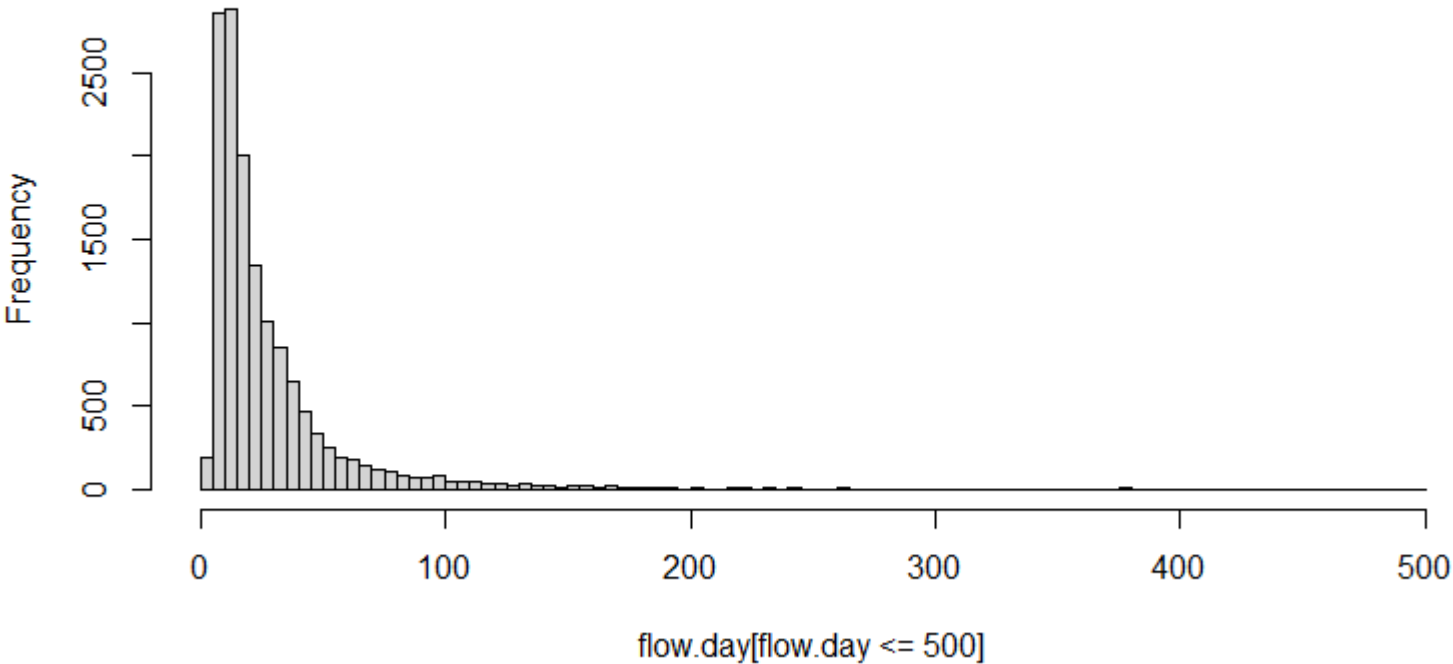
Daily flow represents the average flow rate of the same day.

density.default(x = flow.day)

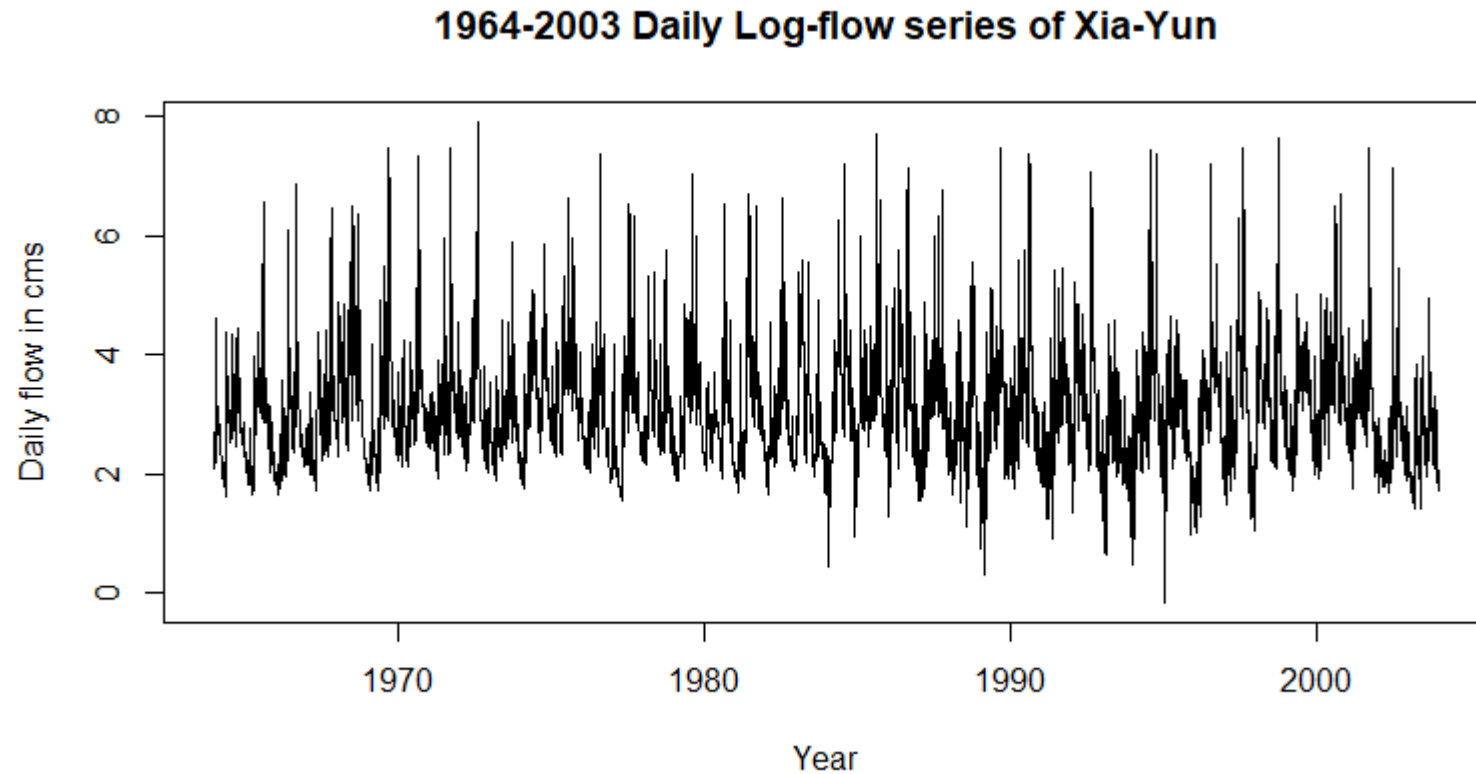


N = 14600 Bandwidth = 2.241

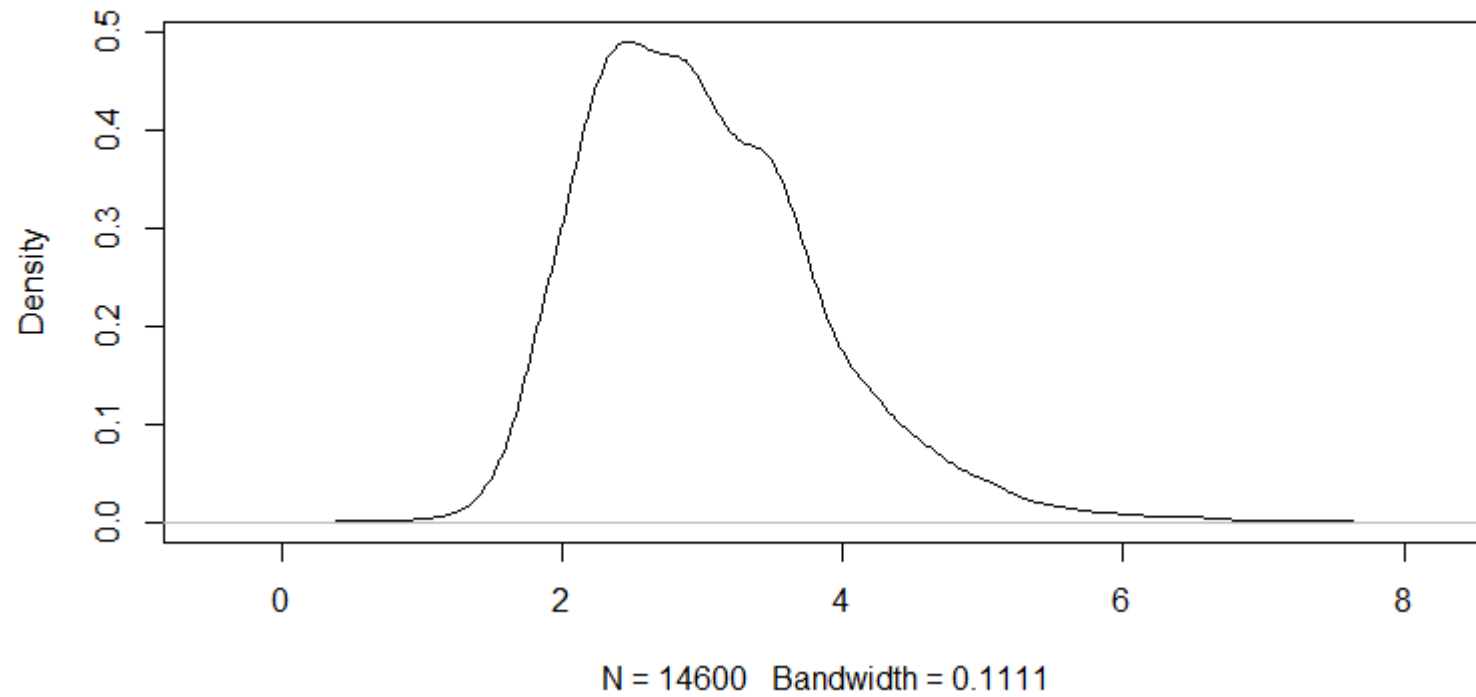
Histogram of flow.day[flow.day <= 500]



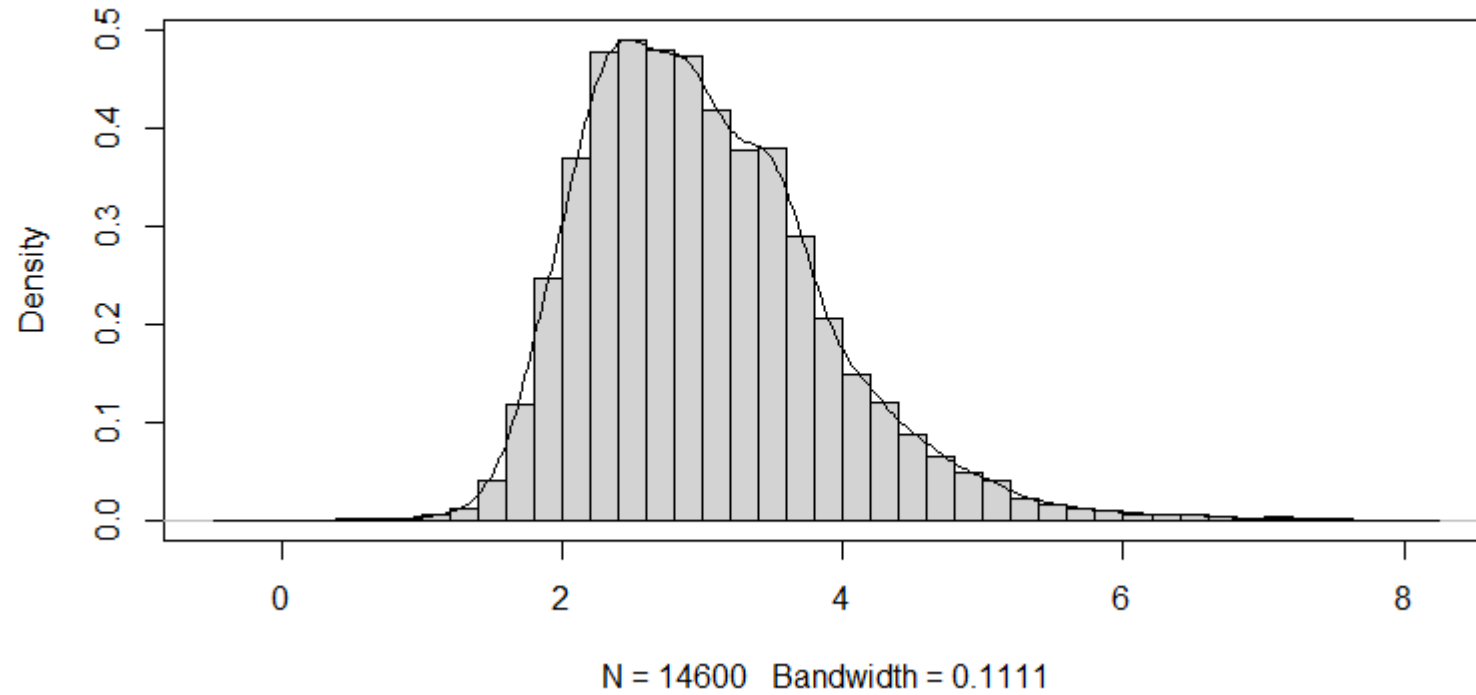
Daily log-flow series at Xia-Yun



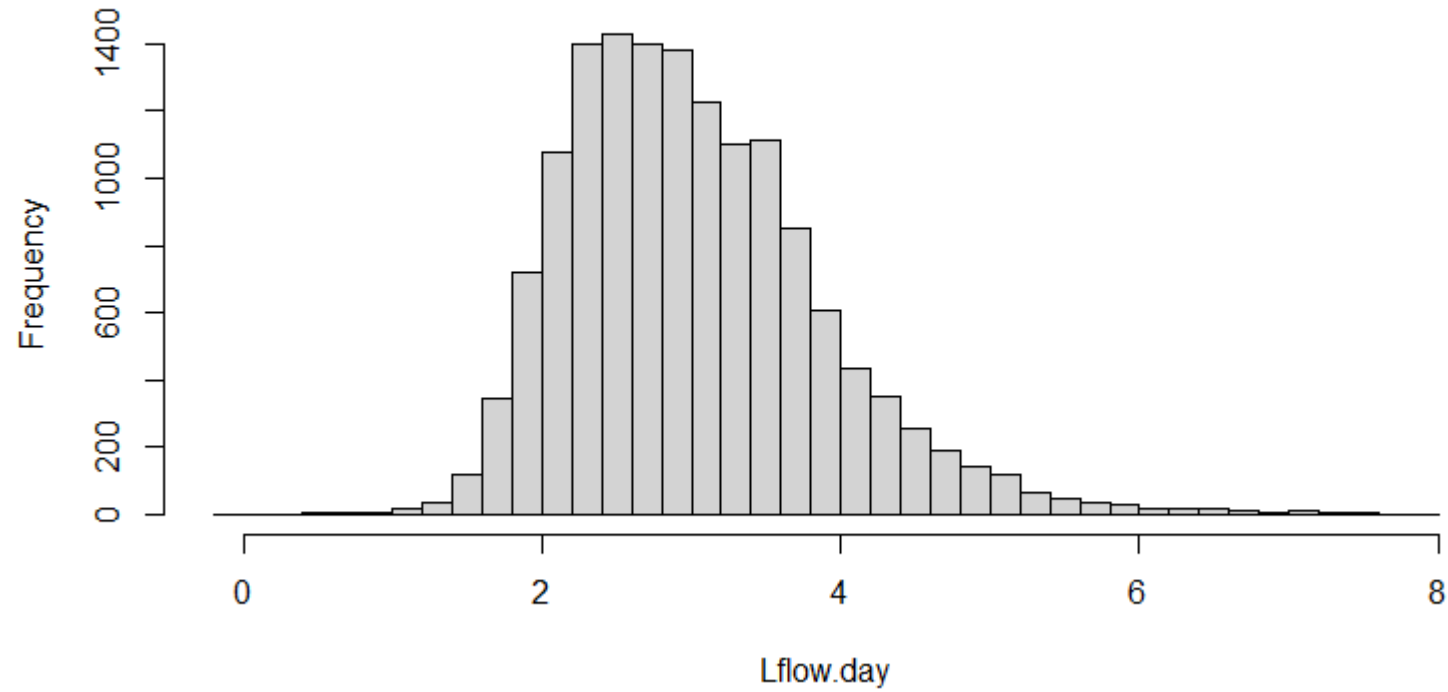
density.default(x = Lflow.day)



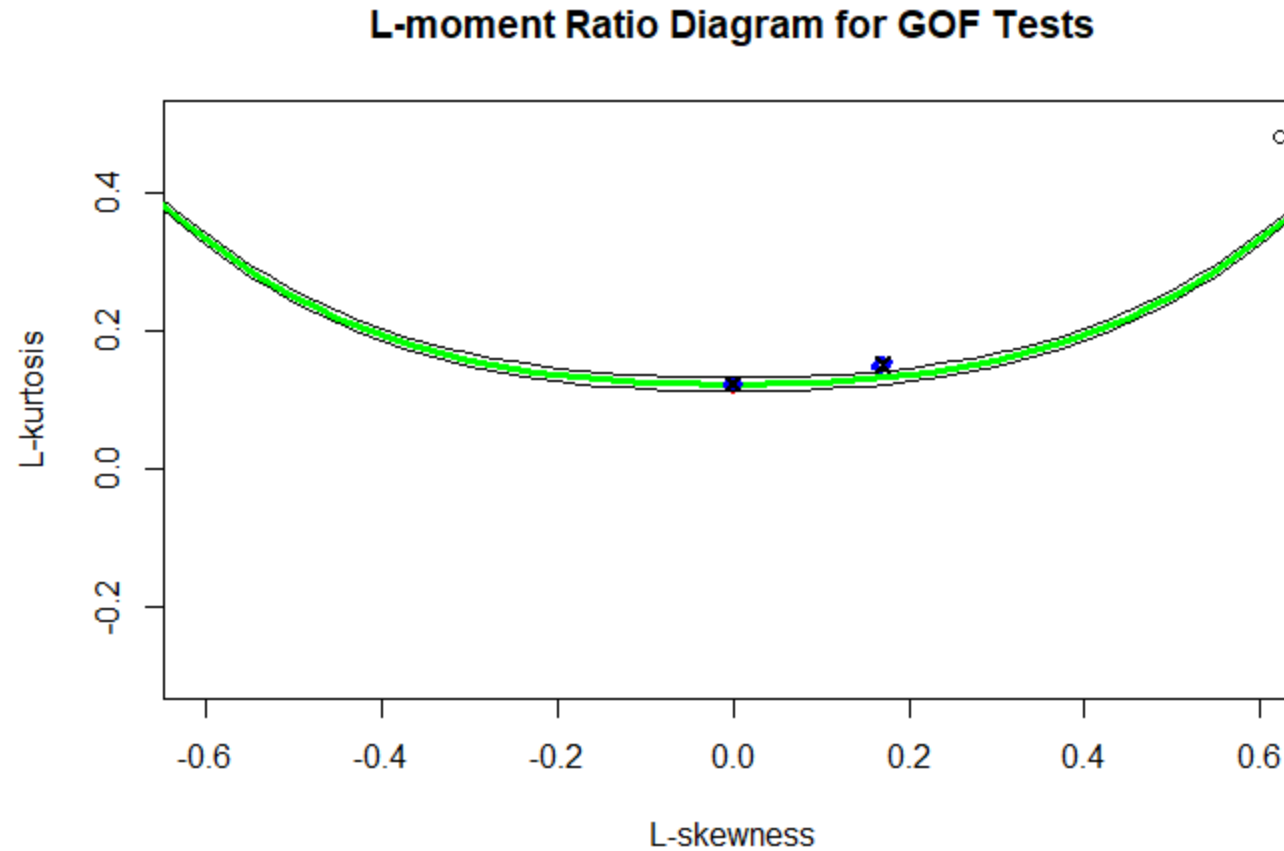
density.default(x = Lflow.day)



Histogram of Lflow.day

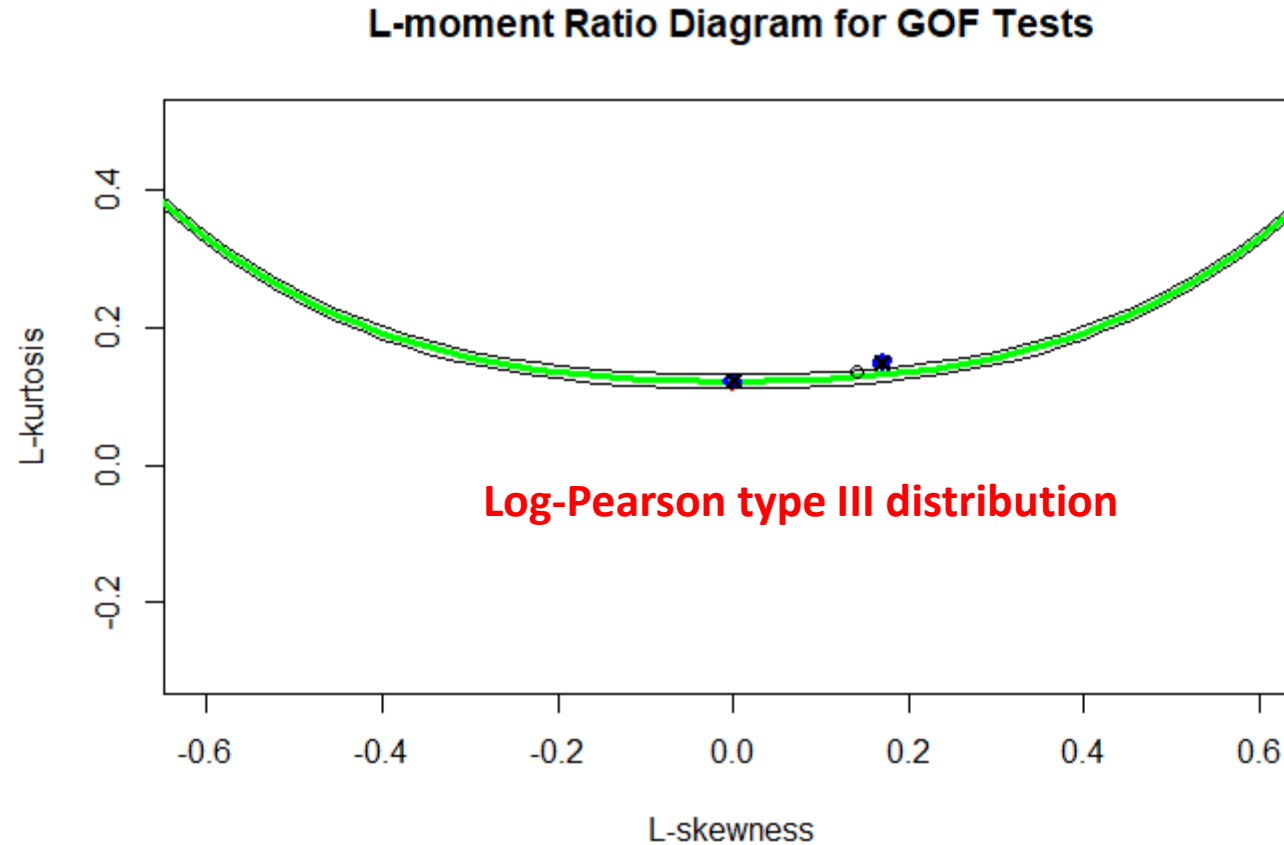


LMRD GOFT for Daily Flow



The goodness-of-fit test for normal, Gumbel, and Pearson type III distribution.

LMRD GOFT for Log-Flow



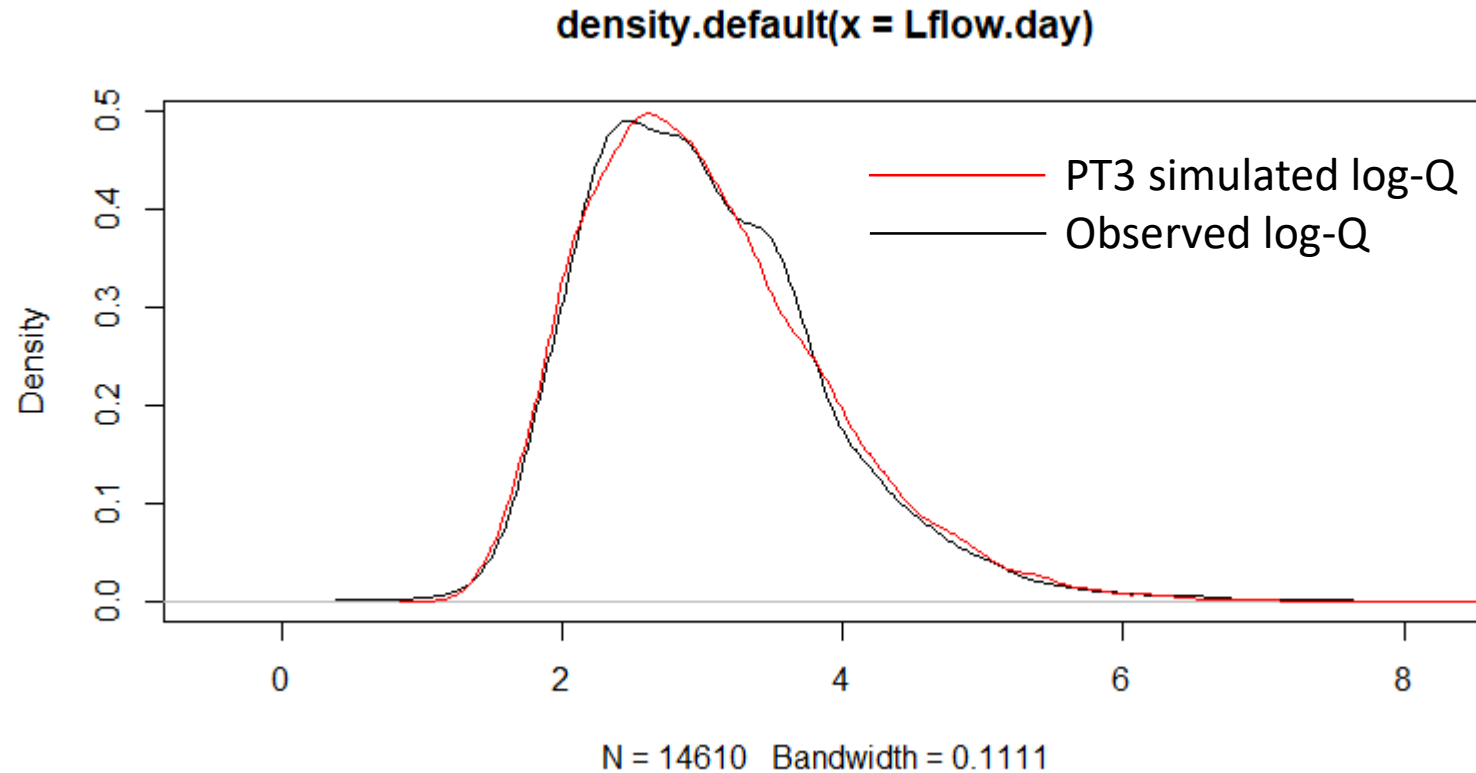
The goodness-of-fit test for normal, Gumbel, and Pearson type III distribution.

Parameter estimation for daily log-Q using the method of L-moments

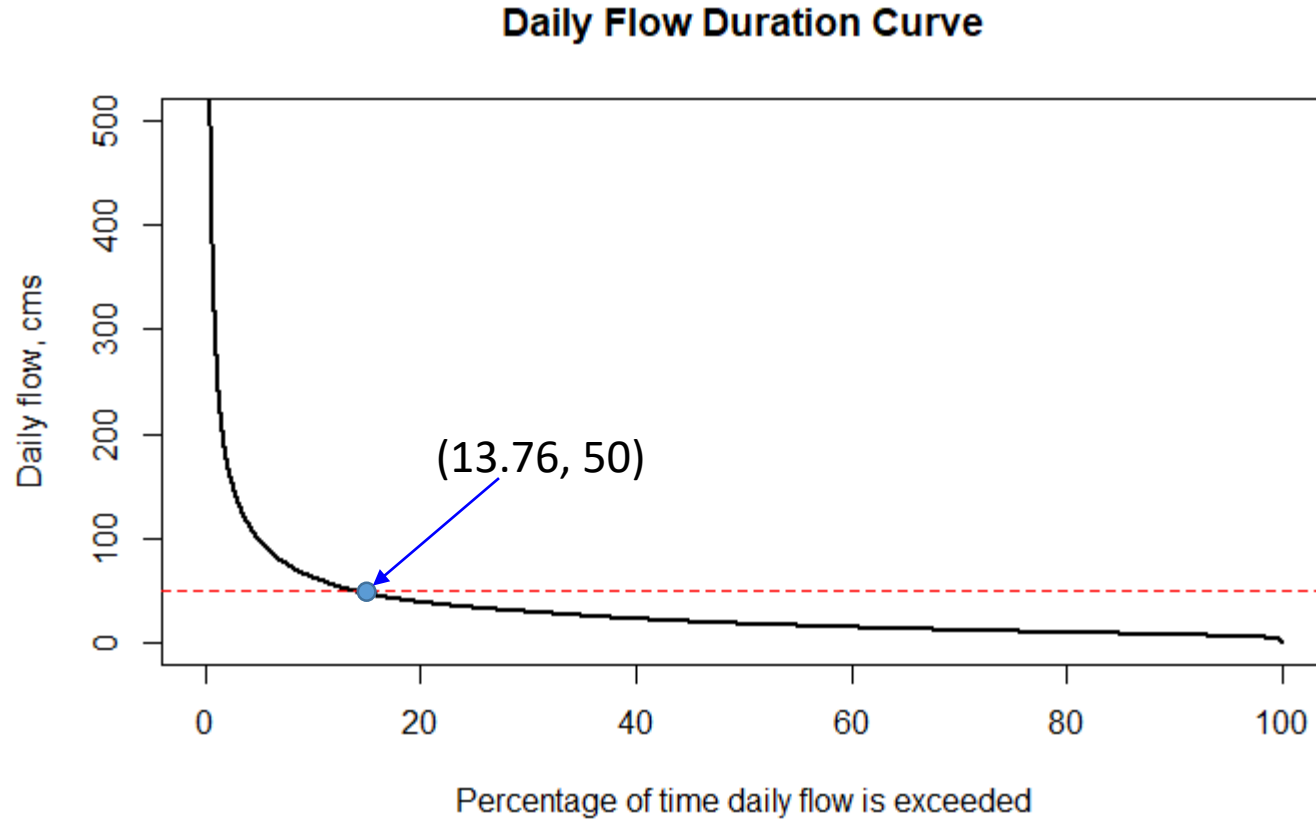
- Pearson type III distribution with the following parameters
 - Location: 1.0199710
 - Scale: 0.3698756
 - Shape: 5.4165063

```
> parm.lmom
      mu      sigma      gamma
3.0234044 0.8608258 0.8593506
```

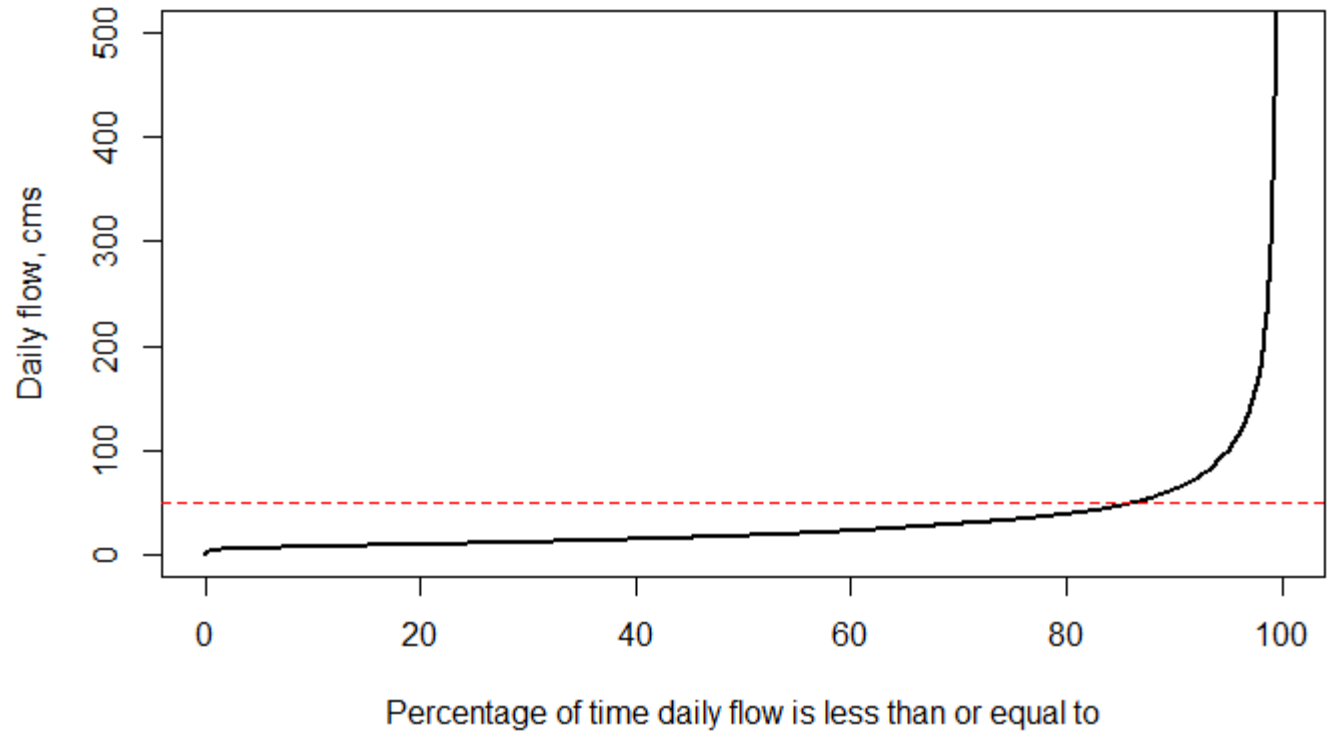
Density functions of the observed and PT3-simulated log-Q



Daily flow duration curve (using daily flow data of 1964 – 2003)



Daily Flow Cumulative Time Percentage Curve



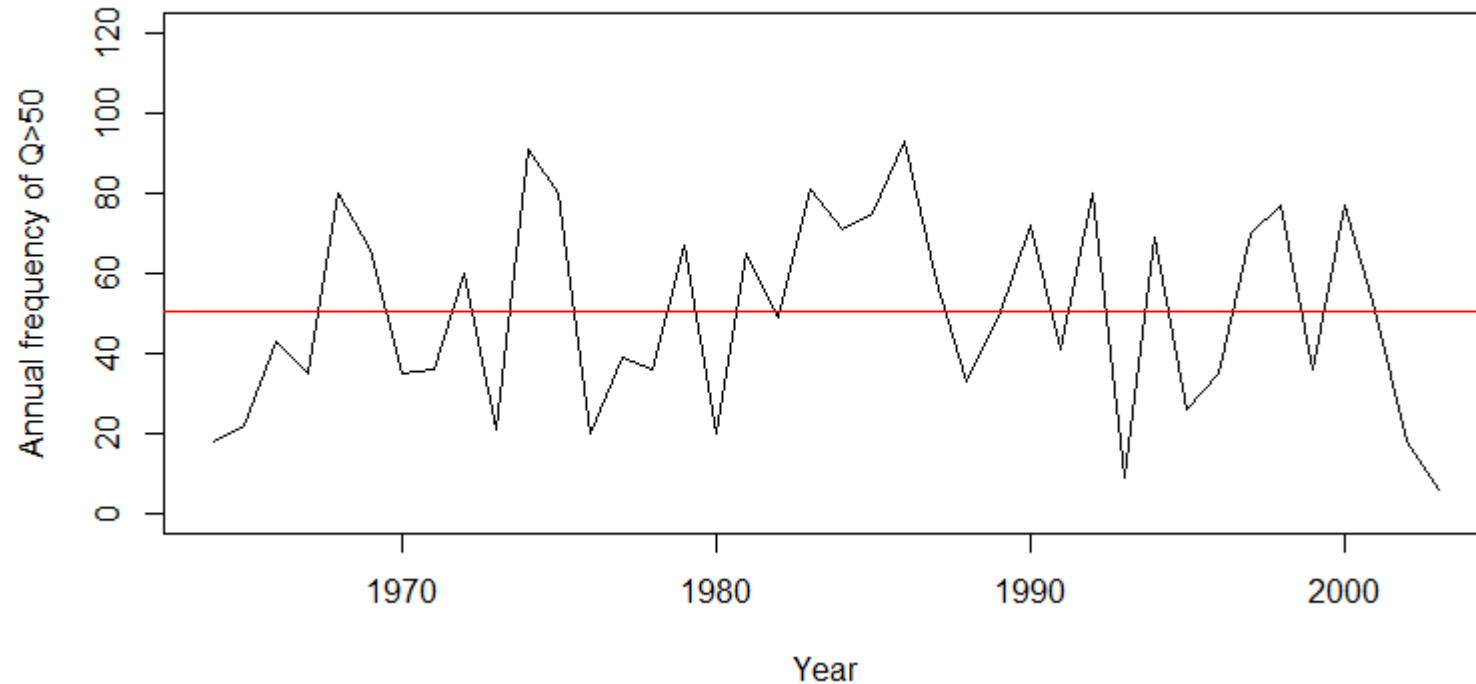
Duration curve (DC) and empirical cumulative distribution function (ECDF)

- A duration curve is usually established using a long time series of **autocorrelated** data.
- An empirical cumulative distribution function is established using a random sample of size n (**IID**).
- Based on the Xia-Yun daily flow series, **13.76%** (2010/14610) **of time** has a daily flow exceeding 50 cms.

Interpretation of the flow duration curve

- Based on the Xia-Yun daily flow series, **13.76% (2010/14610) of time** has a daily flow exceeding 50 cms.
- Are the following interpretations appropriate?
 - **On average, approximately 50 days in a year (0.1376×365) have a daily flow exceeding 50 cms.**
 - **Approximately 4.13 days in a month (0.1376×30) have a daily flow exceeding 50 cms.**
 - **There is a 13.76% of chance that a daily flow exceeds 50 cms.**

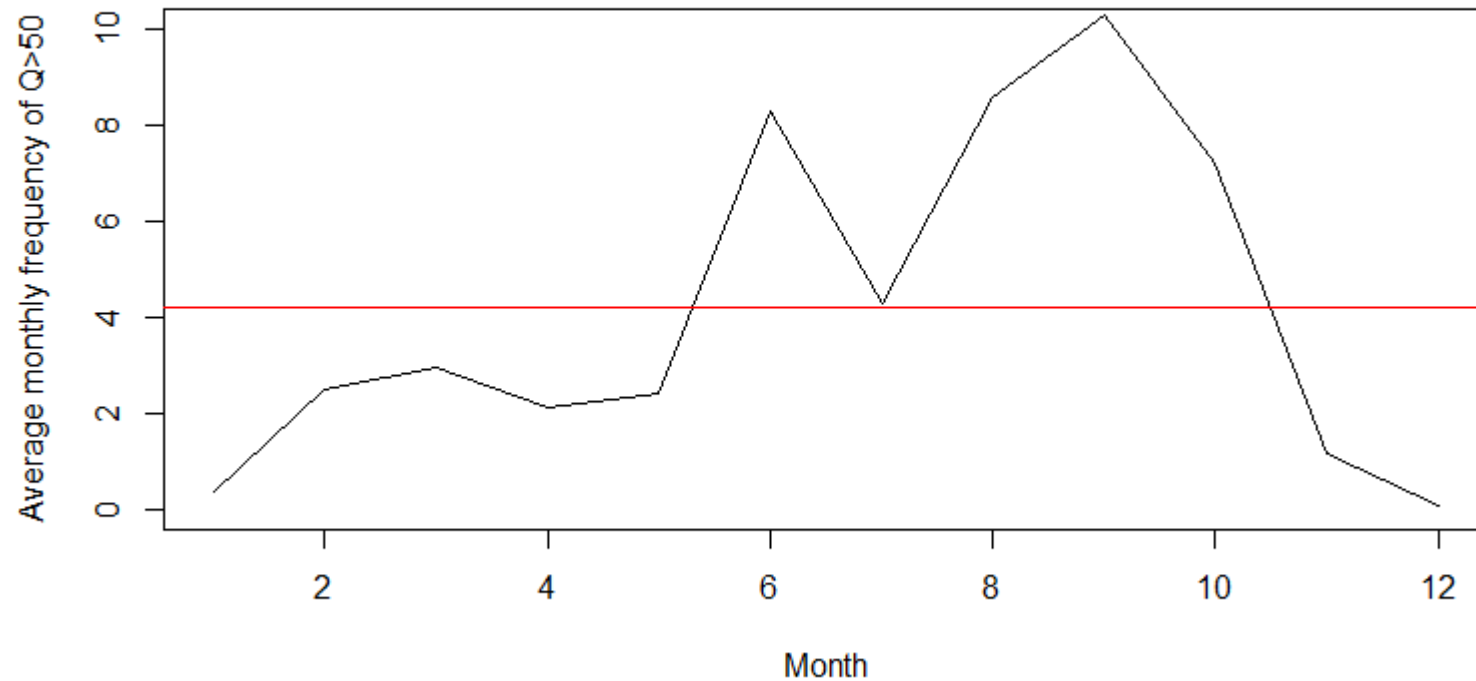
- On average, approximately 50 days in a **year** (0.1376×365) have a daily flow exceeding 50 cms.



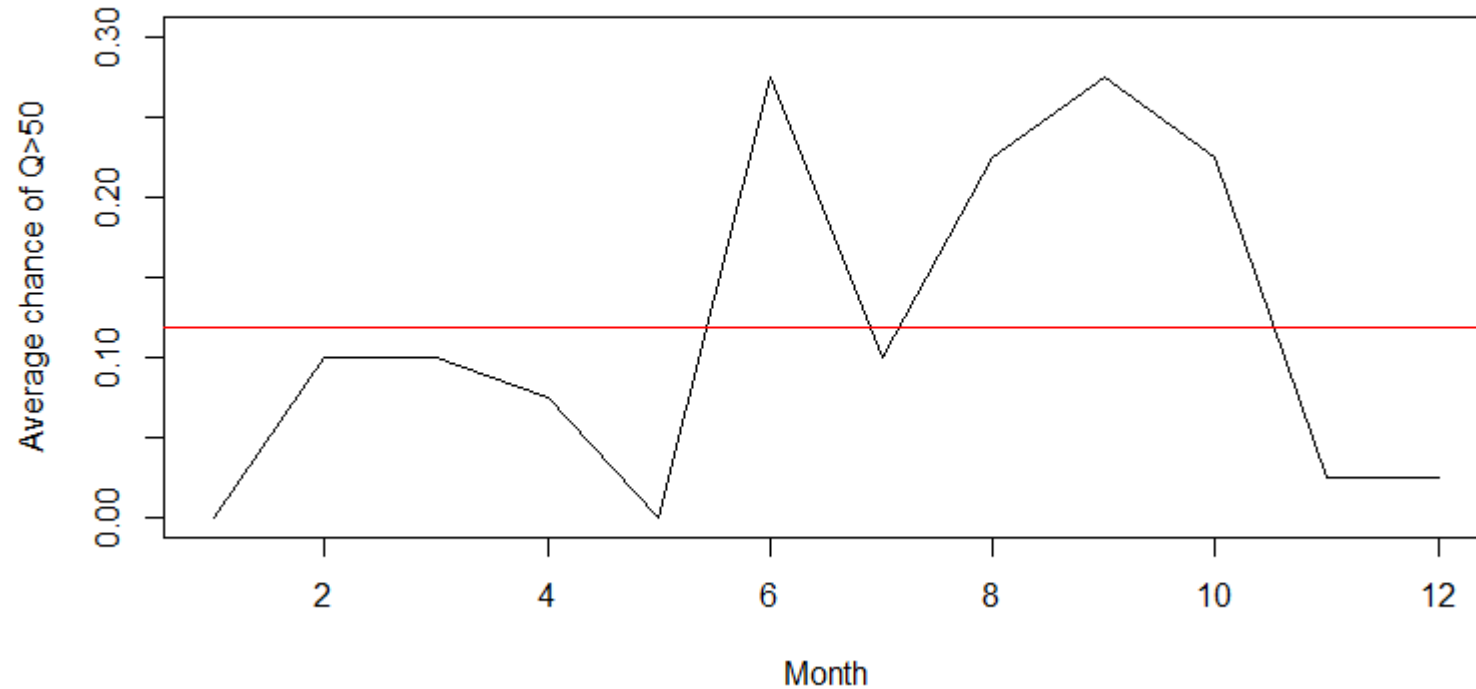
Seasonal non-stationarity

- **Approximately 4.13 days in a month (0.1376×30) have a daily flow exceeding 50 cms.**
 - # of days in August having daily flow higher than 50 cms
 - # of days in February having daily flow higher than 50 cms
- **There is a 13.76% of chance that a daily flow exceeds 50 cms.**
 - Chance of $Q > 50$ cms on August 15
 - Chance of $Q > 50$ cms on February 15

Average monthly frequency of $Q > 50\text{cms}$



Average chance for the 15th day in a month having $Q > 50$ cms

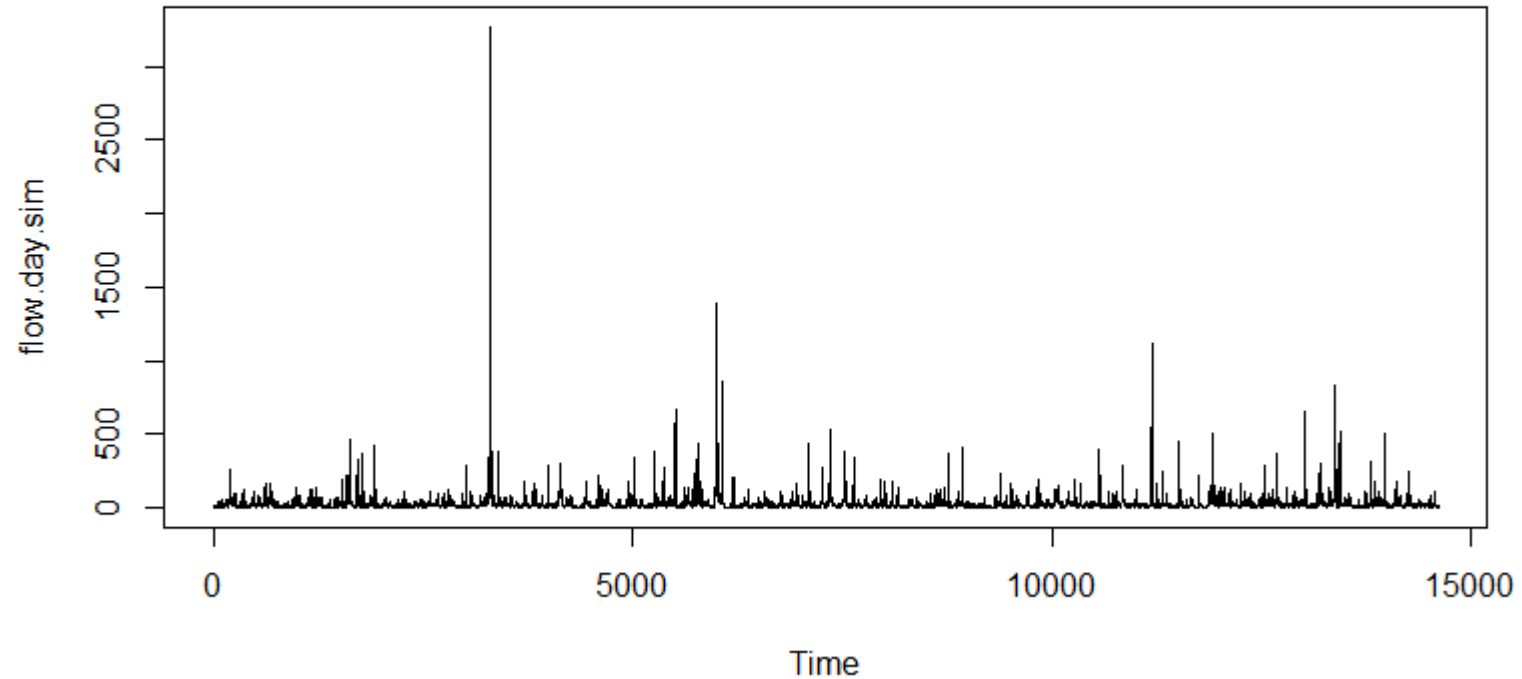


Simulation of an AR(1) log-PT3 time series

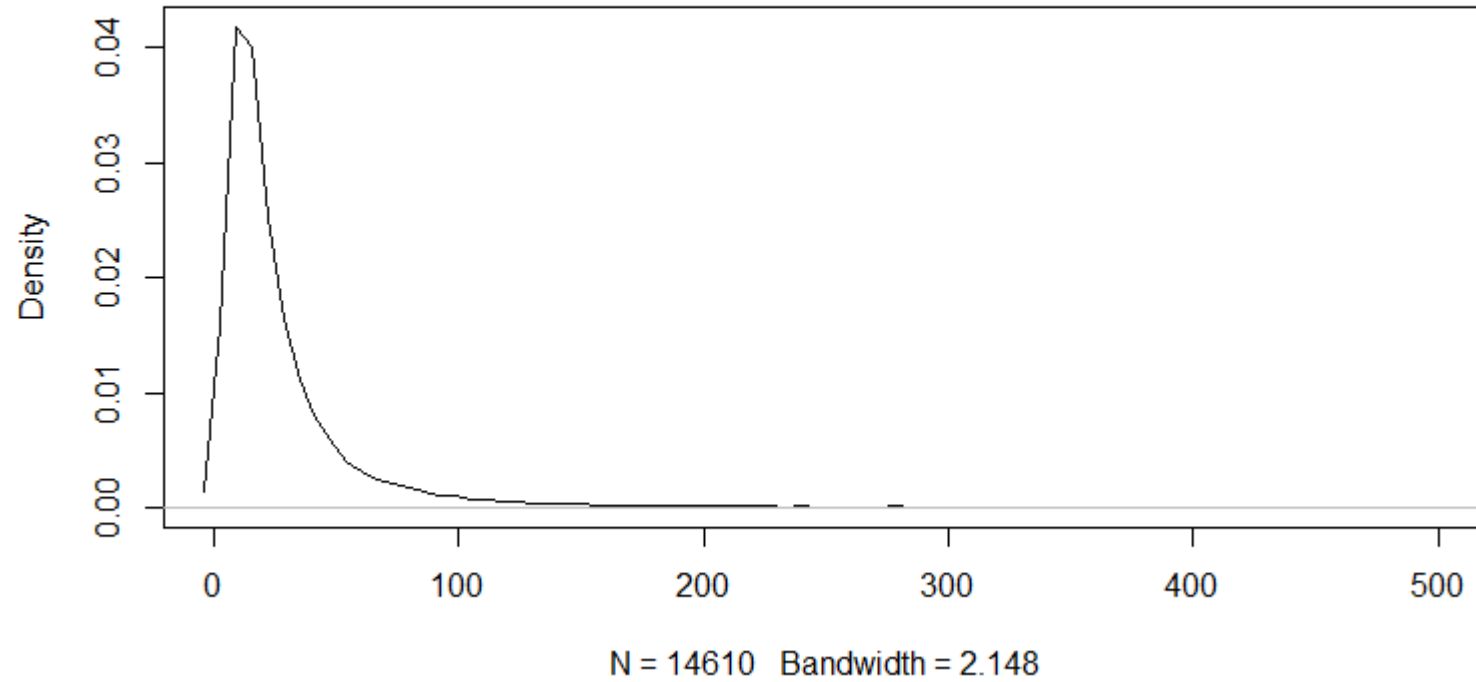
- The daily flow at Xia-Yun has a log-PT3 distribution.
- Assuming a stationary AR(1) non-Gaussian random process for the daily flow.
- Ignore the seasonal non-stationarity of the daily flow series.

AR(1) log-PT3 random process

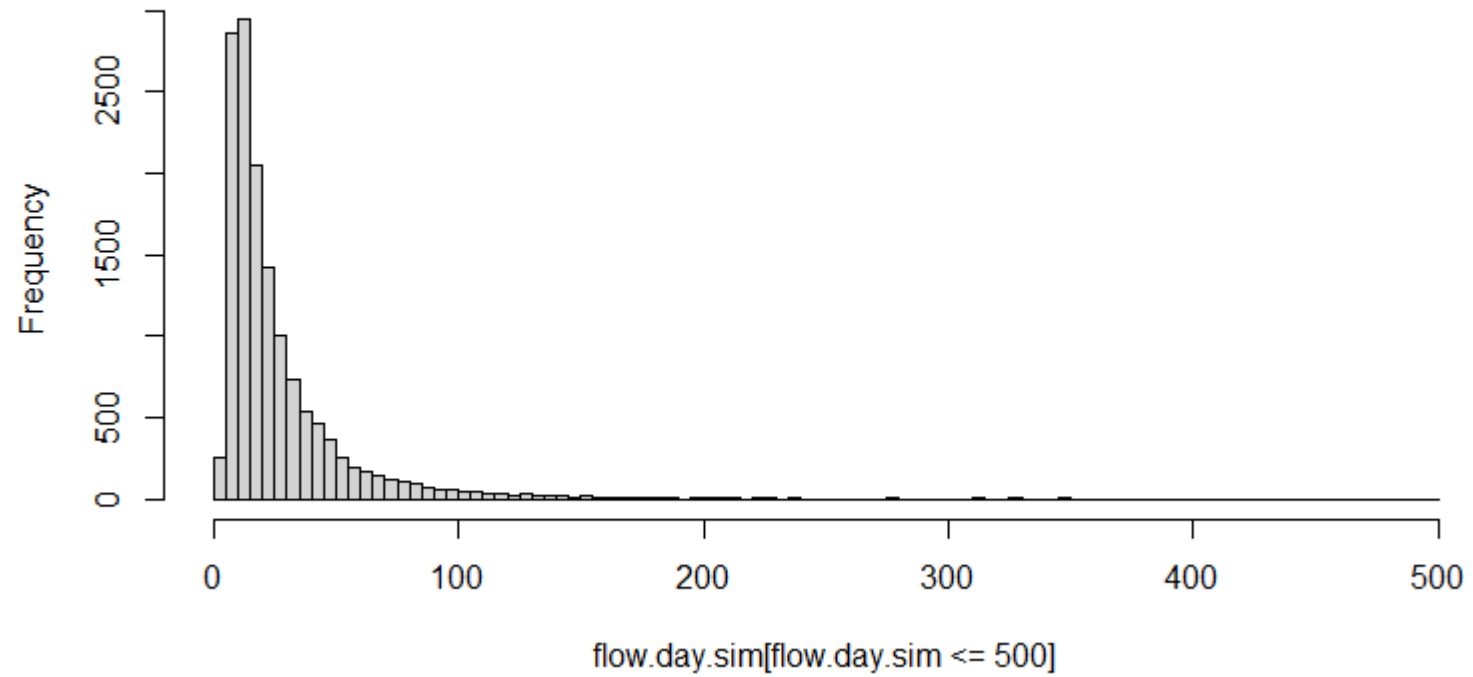
Simulated log-PT3 daily flow series



density.default(x = flow.day.sim)

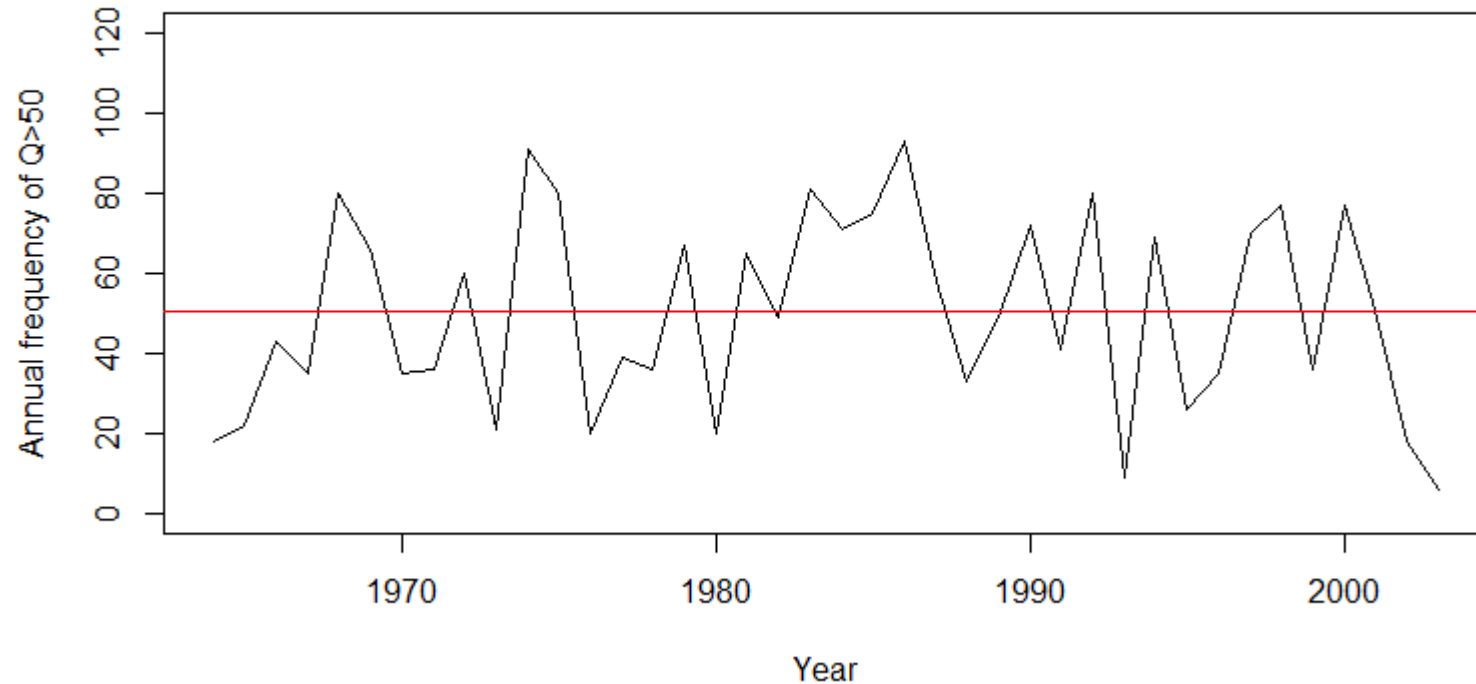


Histogram of flow.day.sim[flow.day.sim <= 500]

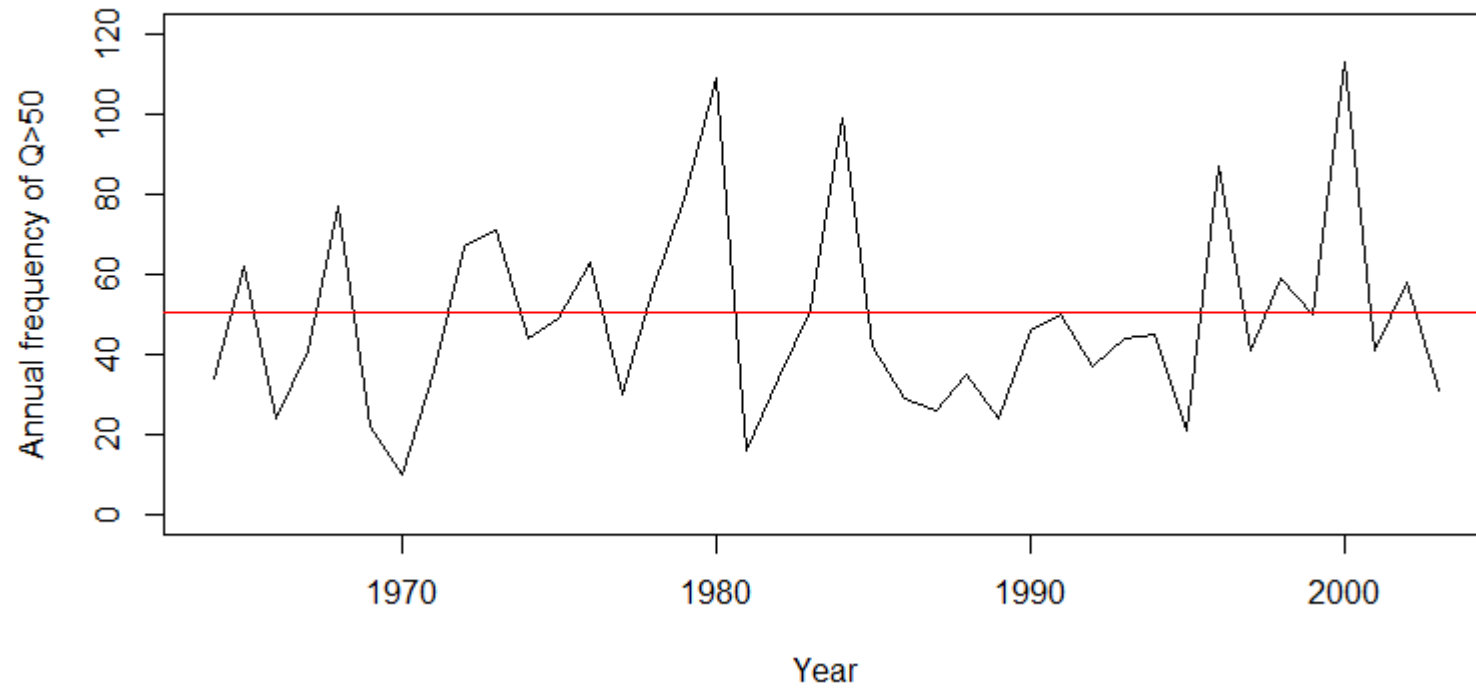


- On average, approximately 50 days in a **year** (0.1376×365) have a daily flow exceeding 50 cms.

Observed

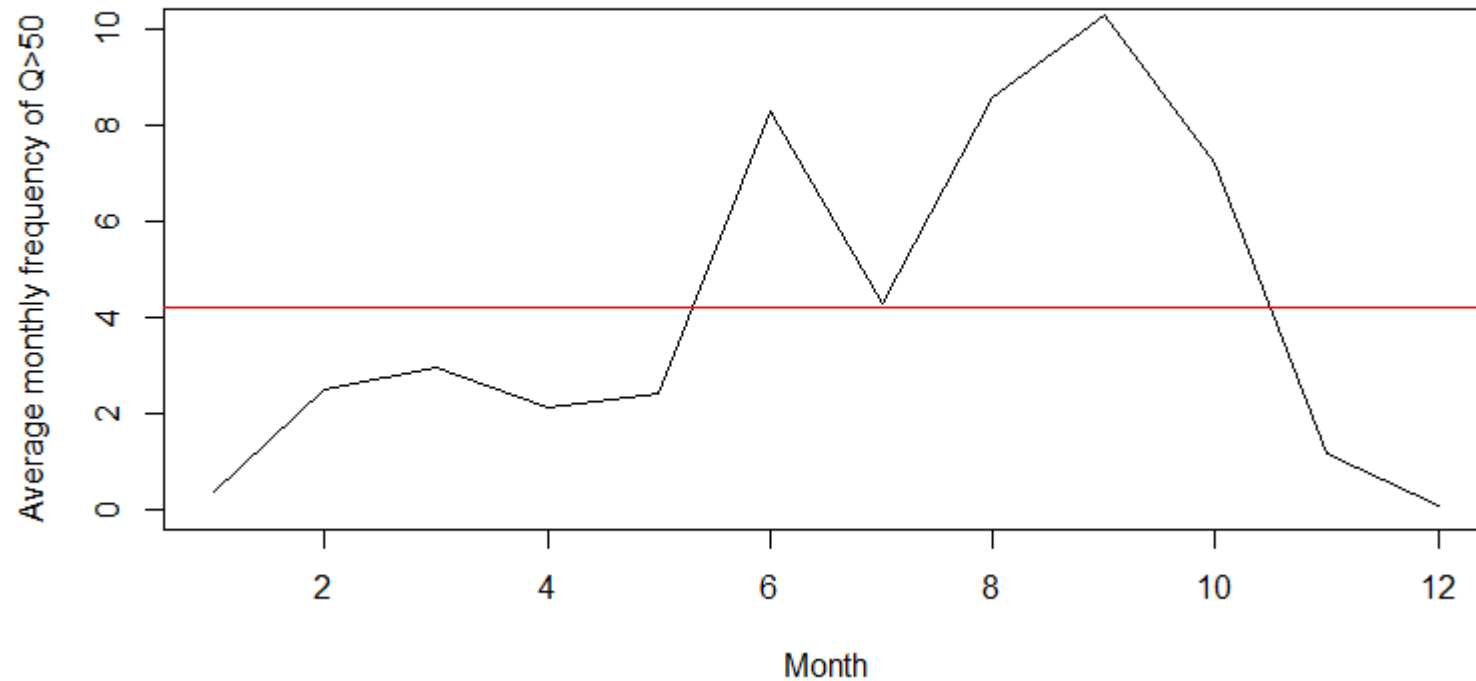


Simulated

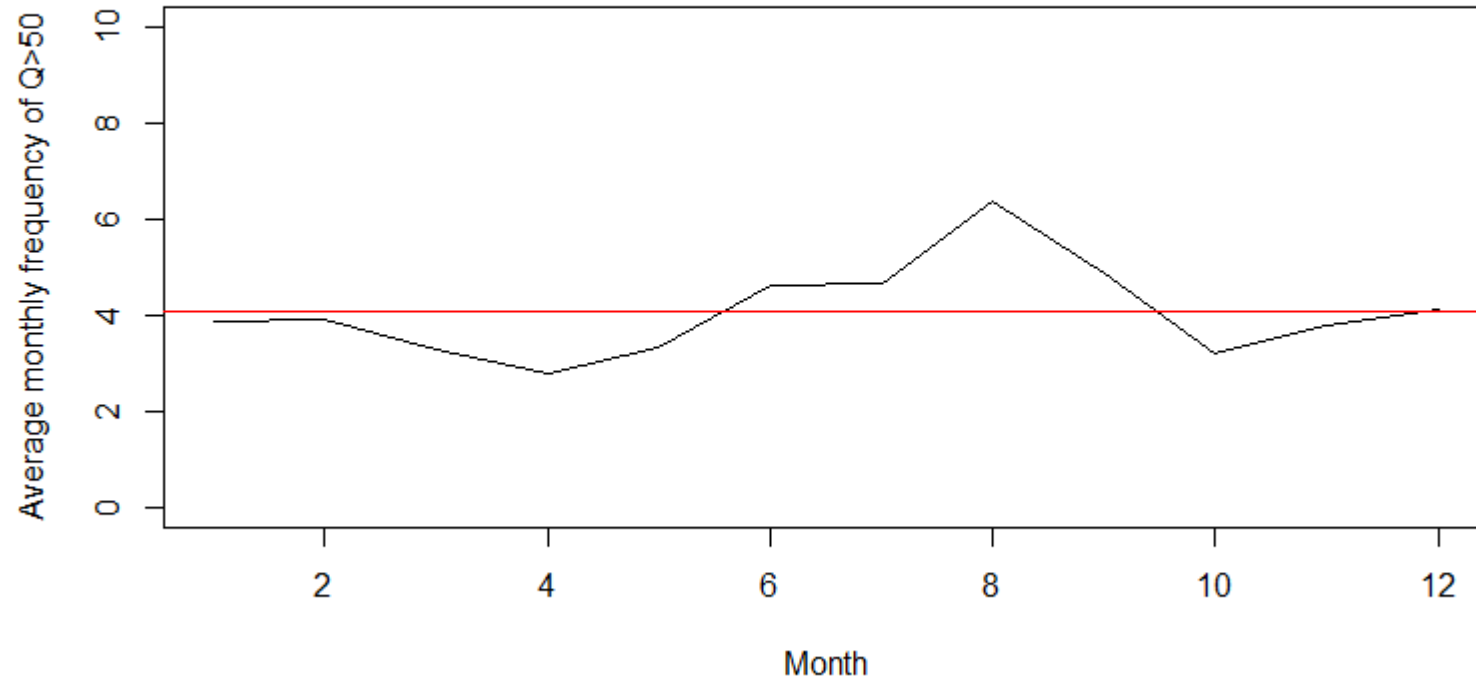


Average monthly frequency of $Q > 50\text{cms}$

Observed

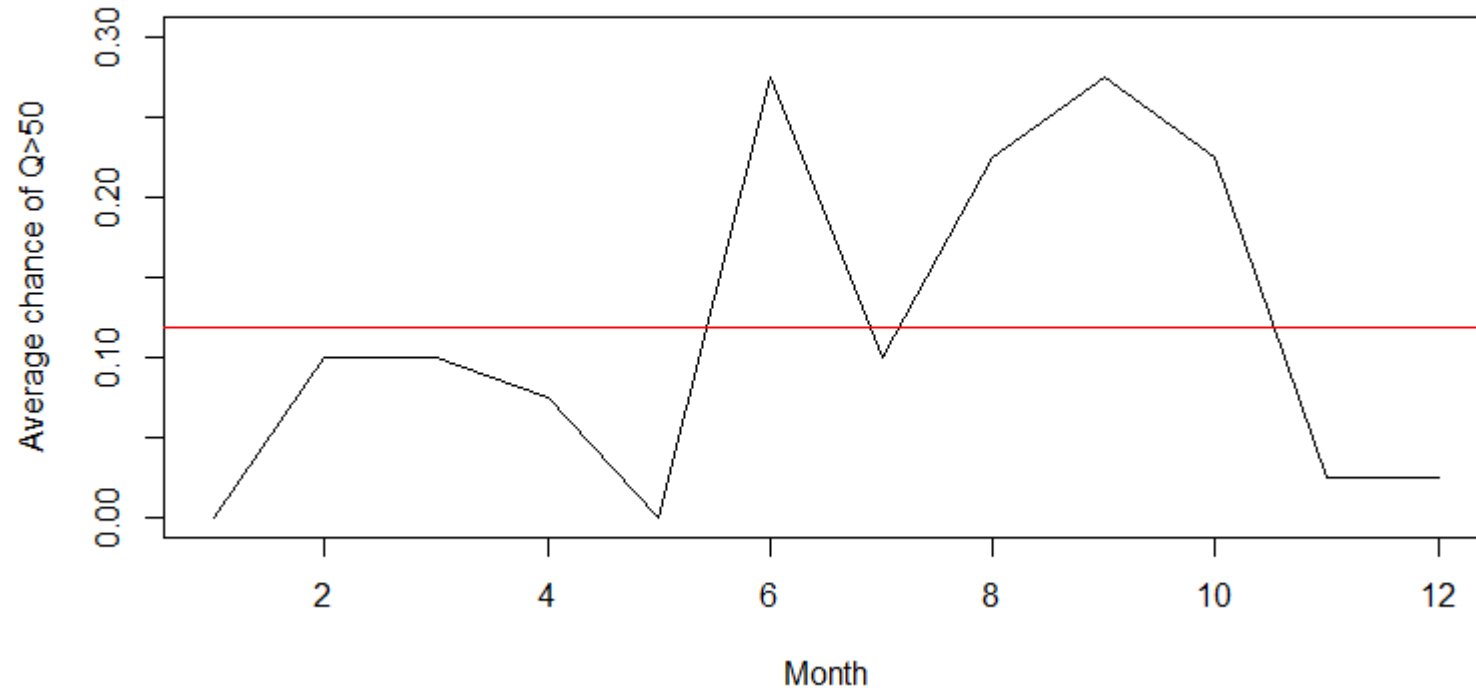


Simulated

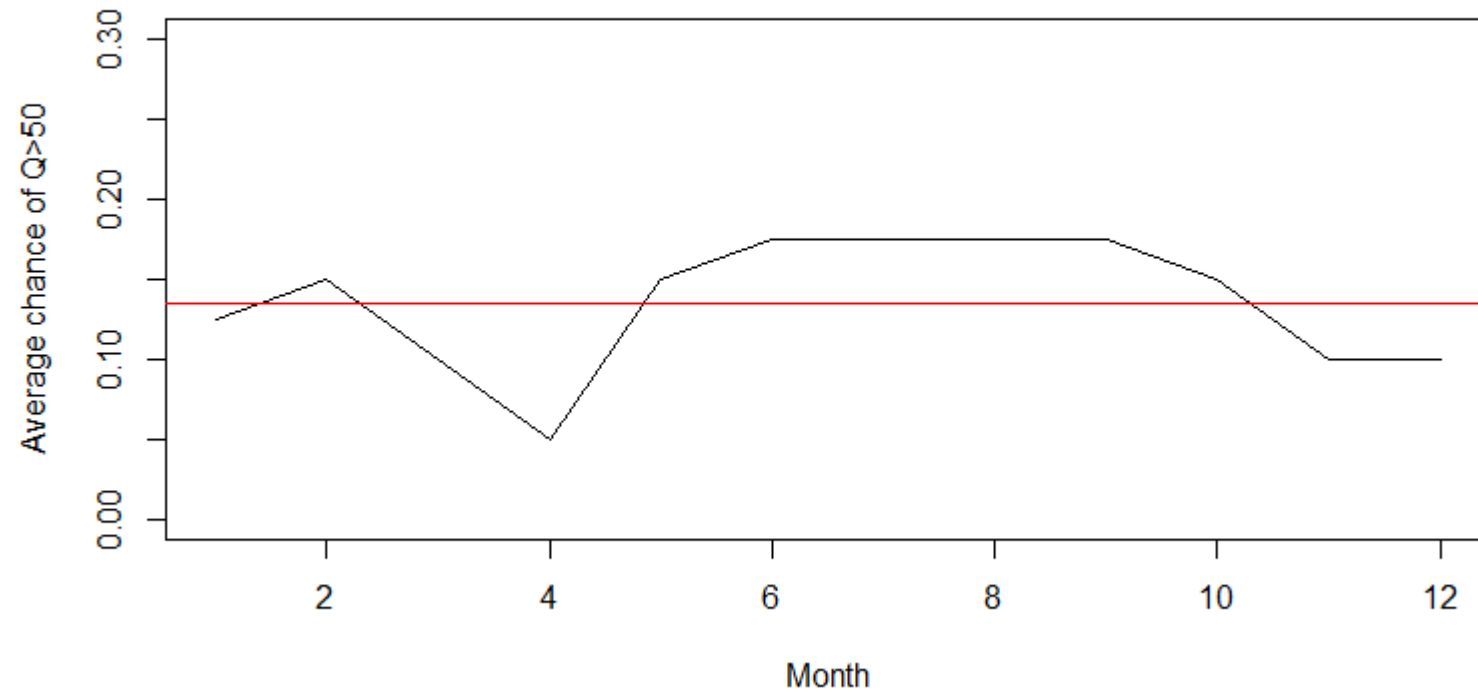


Average chance for the 15th day in a month having $Q > 50$ cms

Observed



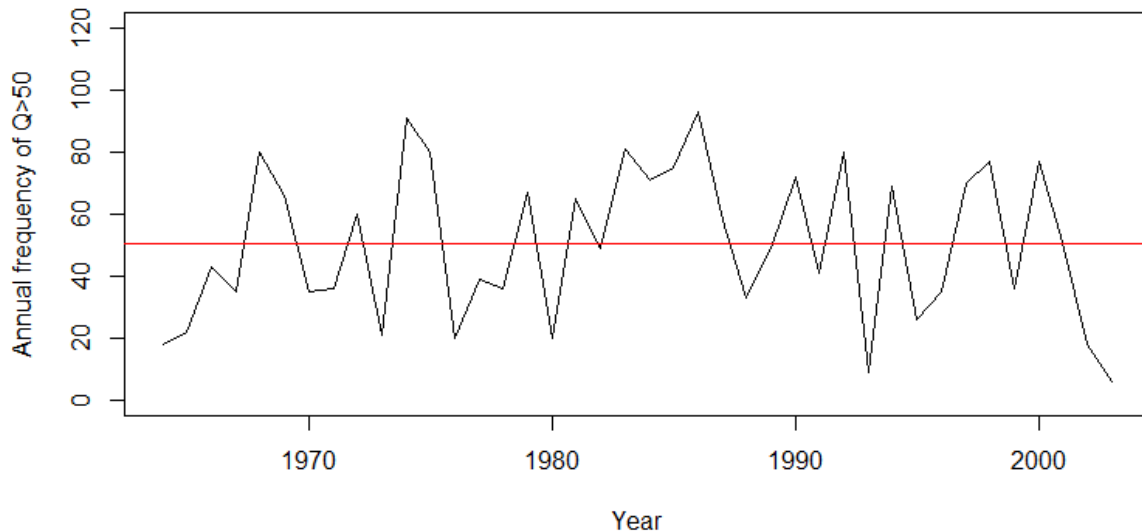
Simulated



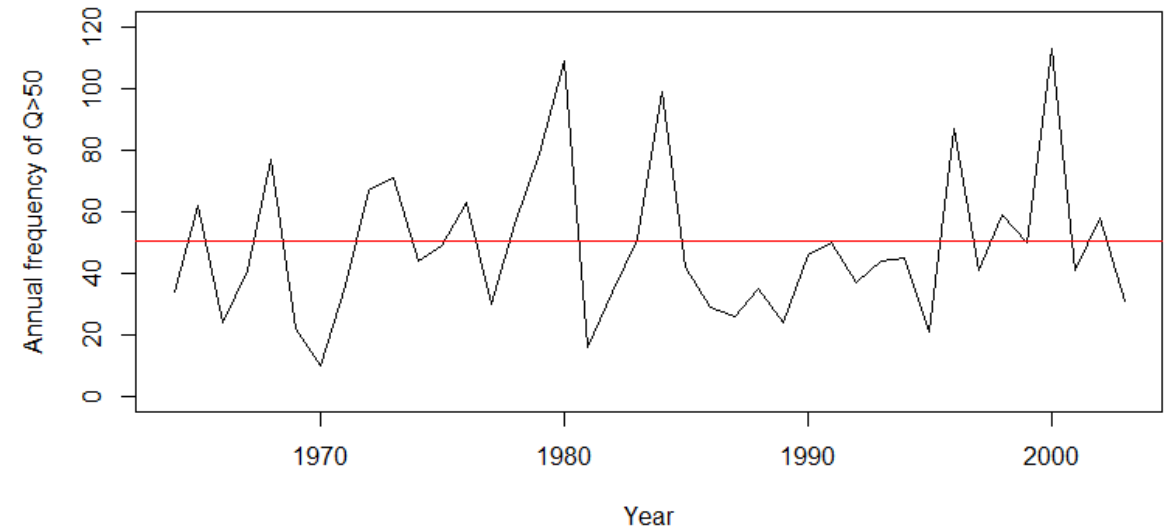
Cyclo-stationary Random Process

- A non-stationary random process with a periodic component.
 - Stationary intra-annual variation

Observed



Simulated



Rainfall-runoff process

