Simulation of Associated Monthly Rainfall and Evaporation

George R. Herrmann, P.E., P.H.
Theodore Cleveland, Ph.D., P.E.

Why Monthly Accumulations?

- Captures seasonal variations
- Short enough to be of value, long enough to be practical
- Some rain does occur in the majority of months, as compared to shorter intervals

Why Simulate?

- Simulated monthly accumulations could be transformed into corresponding end-of-month storage in small reservoirs or water-harvesting facilities.
- Allows the comparison of storage/usage/management strategies and probabilistic assessment of water availability.

Evaporation

In arid areas, evaporation is a huge component of loss in water stored in open reservoirs. Evaporation prevents long-term storage in such areas.

Rainfall and Evaporation

- Monthly rainfall and monthly evaporation are inversely associated; months with large rainfall usually exhibit small evaporations, and vice versa. That makes some basic thermodynamic sense.

San Angelo, Texas

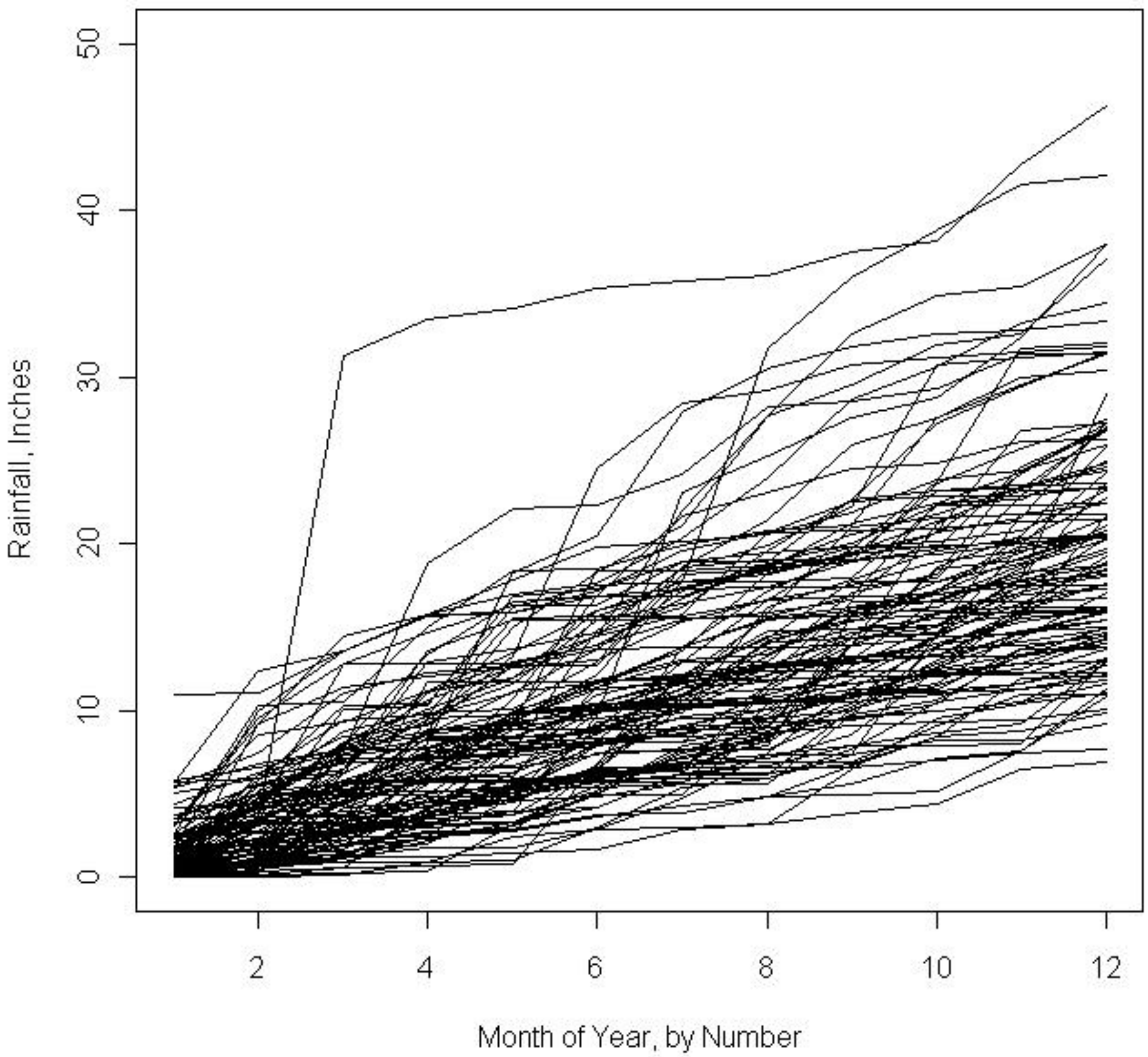
- 116 complete years of data, with some breaks.
- L-moments for each of the 12 months were computed.
- L-moment ratio diagram indicated that a Generalized Pareto distribution (GPA) was appropriate.

San Angelo, Texas

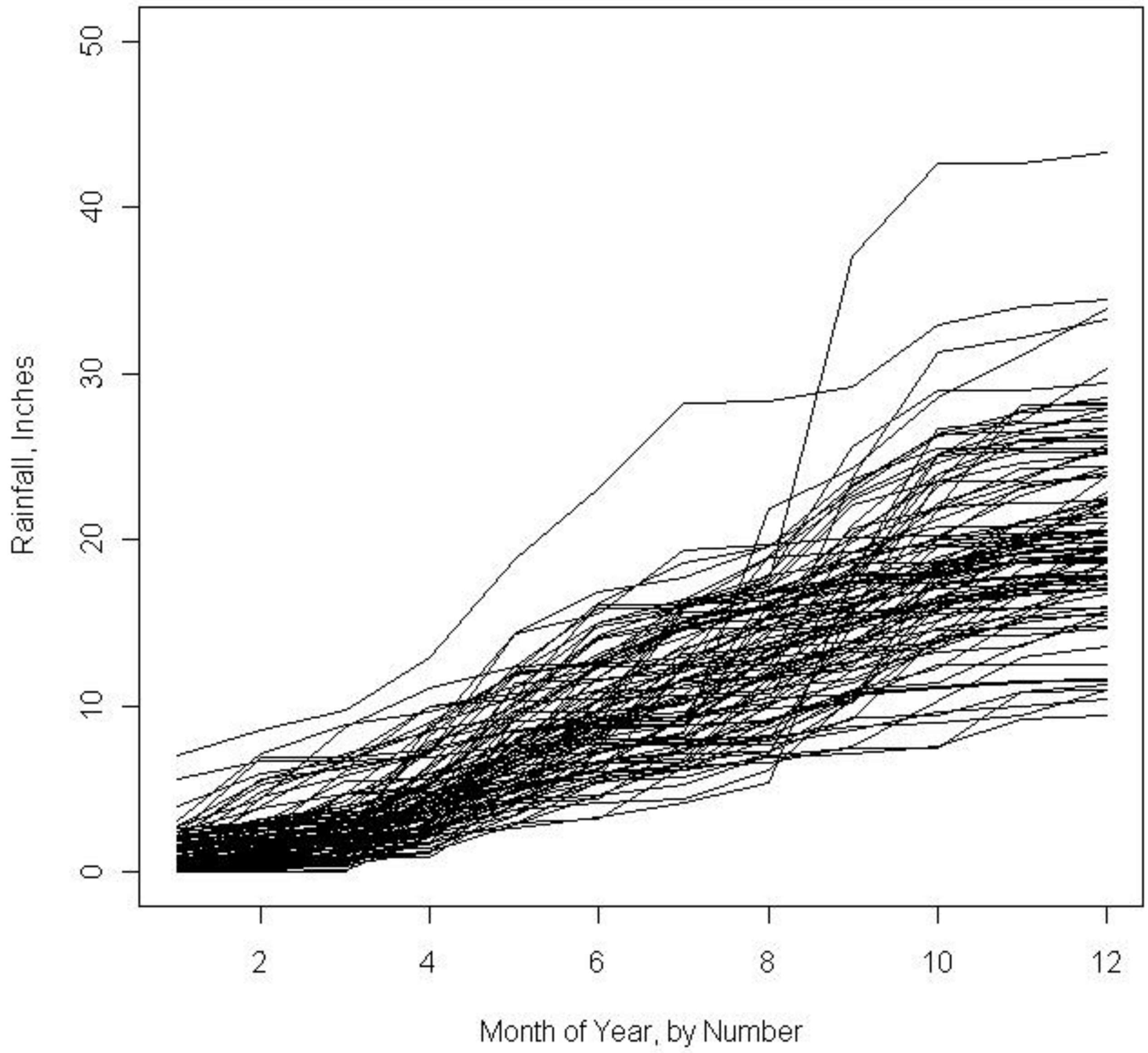
- 12 separate sets of GPA parameters were computed.
- Simulations were run assuming that each month was independent of the previous month.
- These simulations demonstrated much less variance than the real data.

San Angelo, Texas

- The difference was interpreted as being due to a non-random "persistence" or conditional association from one month to the next. It was decided to attempt to represent this association with a simple copula.



Rainfall, Inches
0
10
20
30
40
50
2
4
6
8
10
12
Month of Year, by Number



Rainfall, Inches
0
10
20
30
40
50
2
4
6
8
10
12
Month of Year, by Number

Evaporation

- The same simple copula (Plackett) was used to simulate the association between rainfall and evaporation. These associations were fairly strong. The result was a set of random variates, with a component of association to the rainfall.

Evaporation

- L-moment analysis had indicated that evaporation for each month of the year was appropriately represented by a Generalized Extreme Value (GEV) distribution. 12 sets of parameters were computed.

Sequence of Operations

Read all available monthly rainfall data,
Compute monthly GPA parameters

Read CONTIGUOUS monthly rainfall data
Compute Spearman's rho values and copula parameters for month-to-month dependence

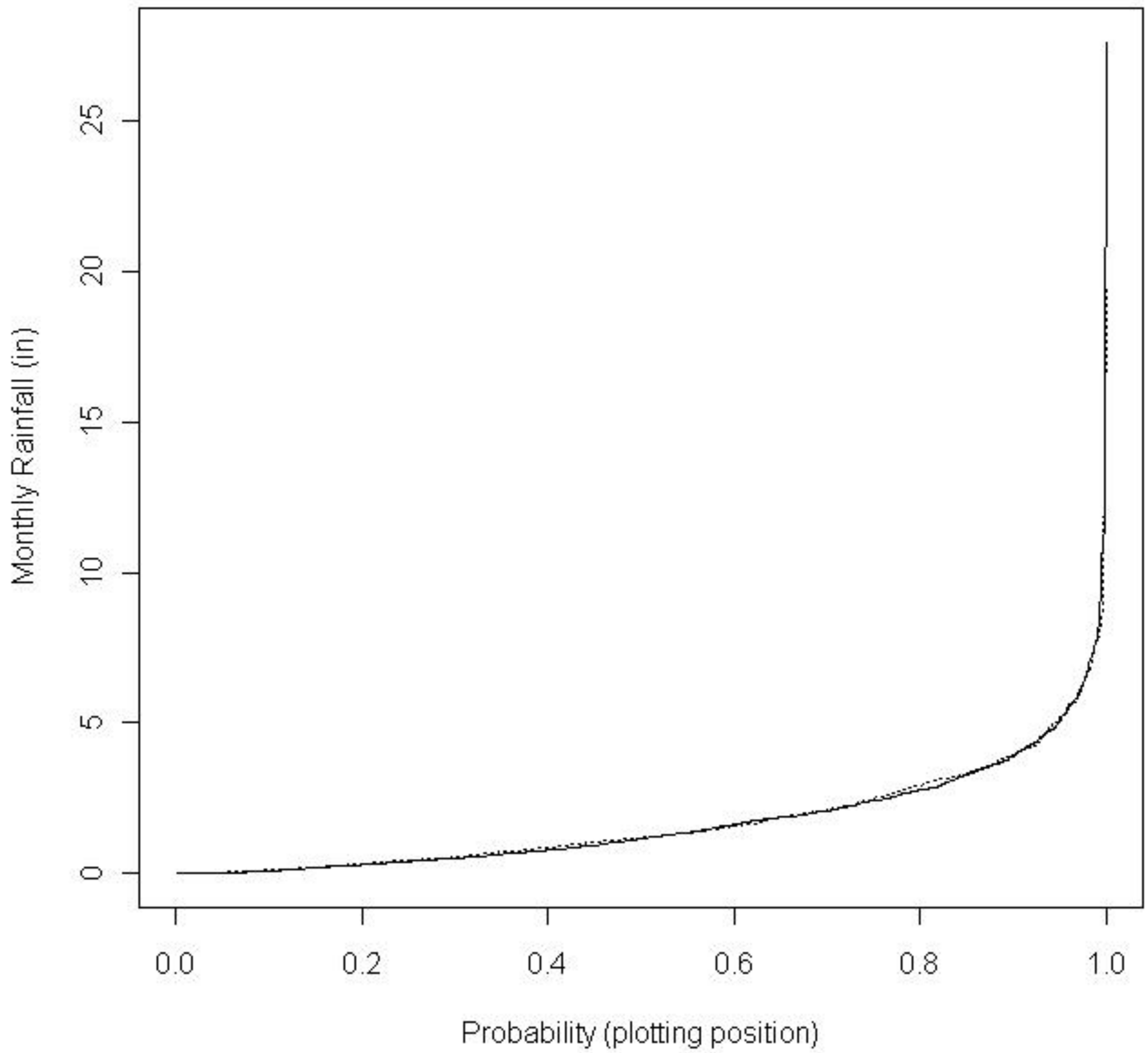
Read ASSOCIATED monthly rainfall and evaporation data
Compute monthly GEV parameters for evaporation
Compute Spearman's rho values and copula parameters for rainfall/evaporation association

Generate a series of random variates by cycling through month-to-month copula parameters, using the previous value and a uniform random variate as marginal values through the copula
The number of variates is 12 months times a desired number of years

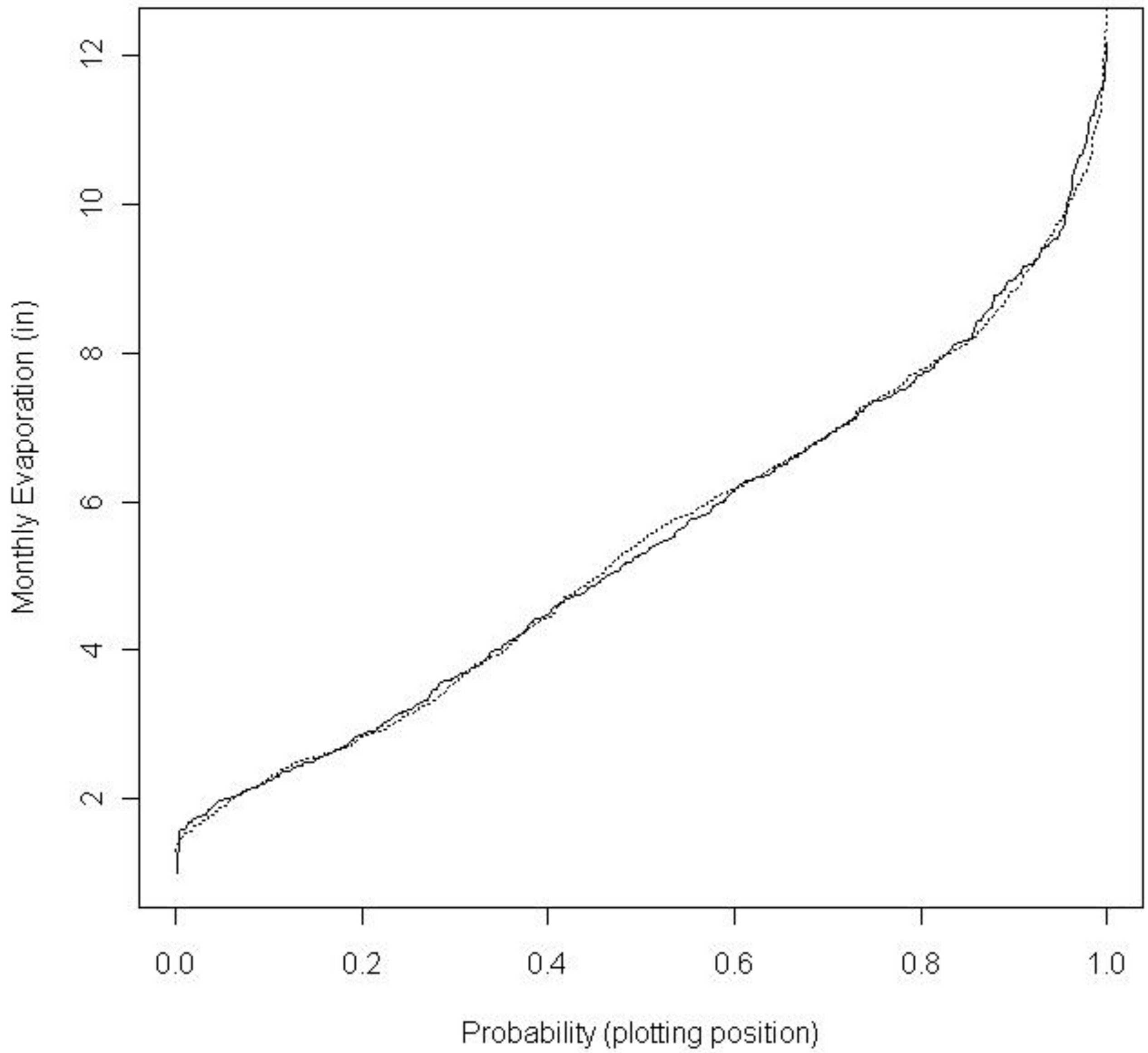
Generate associated evaporation probabilities by cycling through the monthly rainfall to evaporation copula parameters, using the rainfall probabilities and a uniform random variate as marginal values through the copula

Compute simulated rainfall depths and evaporation depths from the vectors of probabilities by passing probability values to the quantile functions, cycling through the monthly parameter values for rainfall (GPA) and for evaporation (GEV)

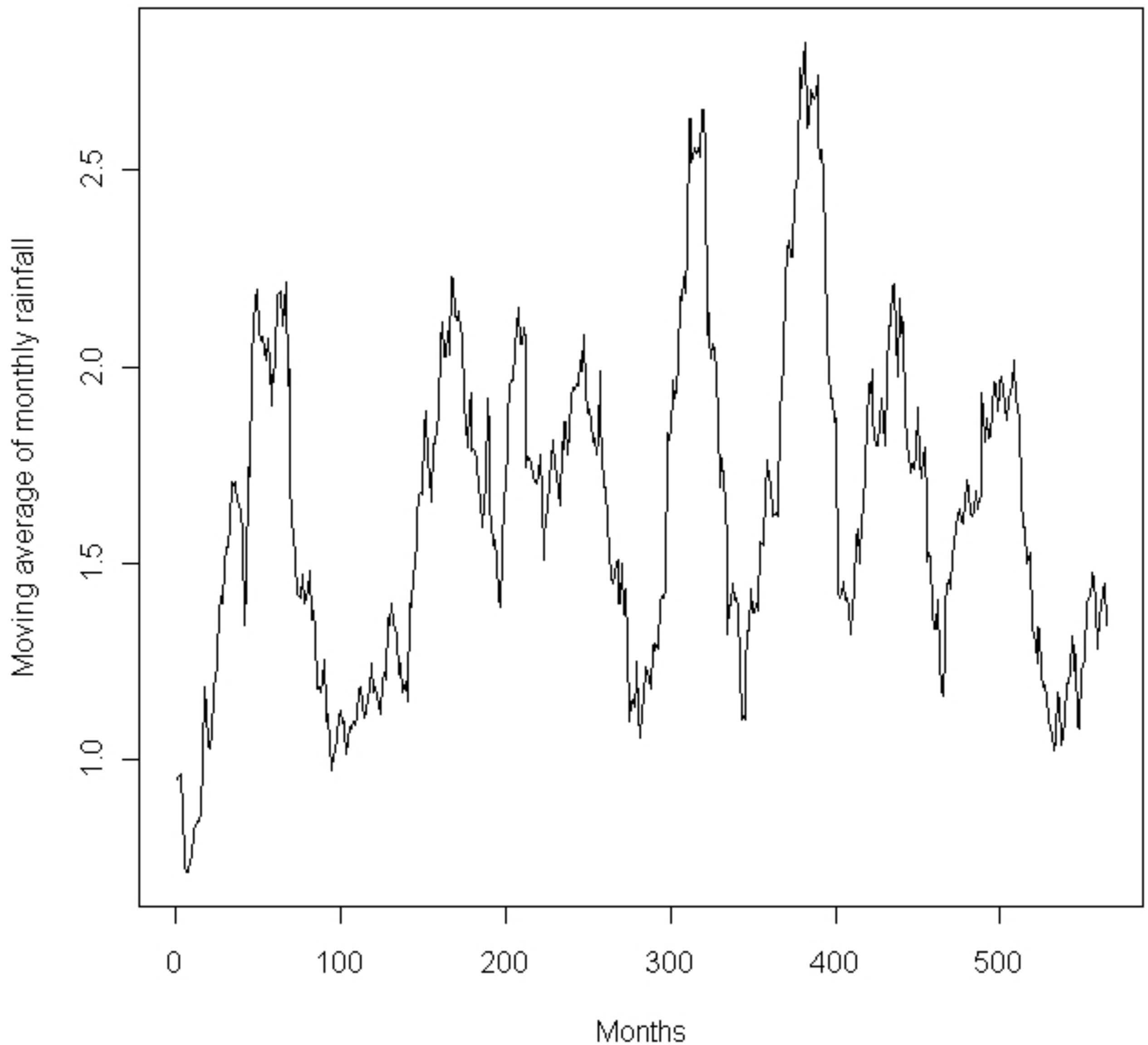
RESULTS
Two vectors (number of elements divisible by 12) representing simulated monthly rainfall depths associated serially through a copula, and evaporation depths associated with them, also through a copula

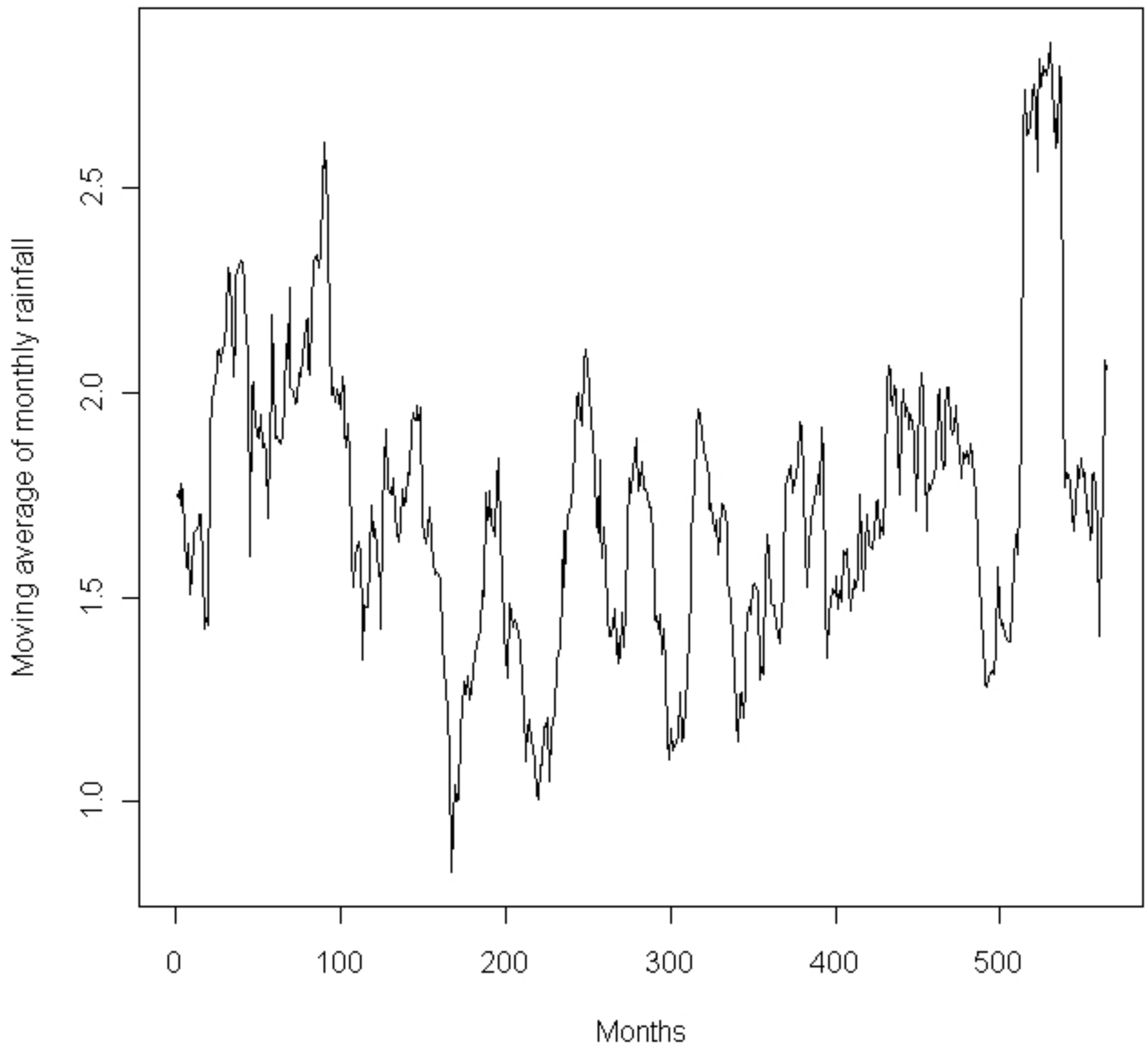


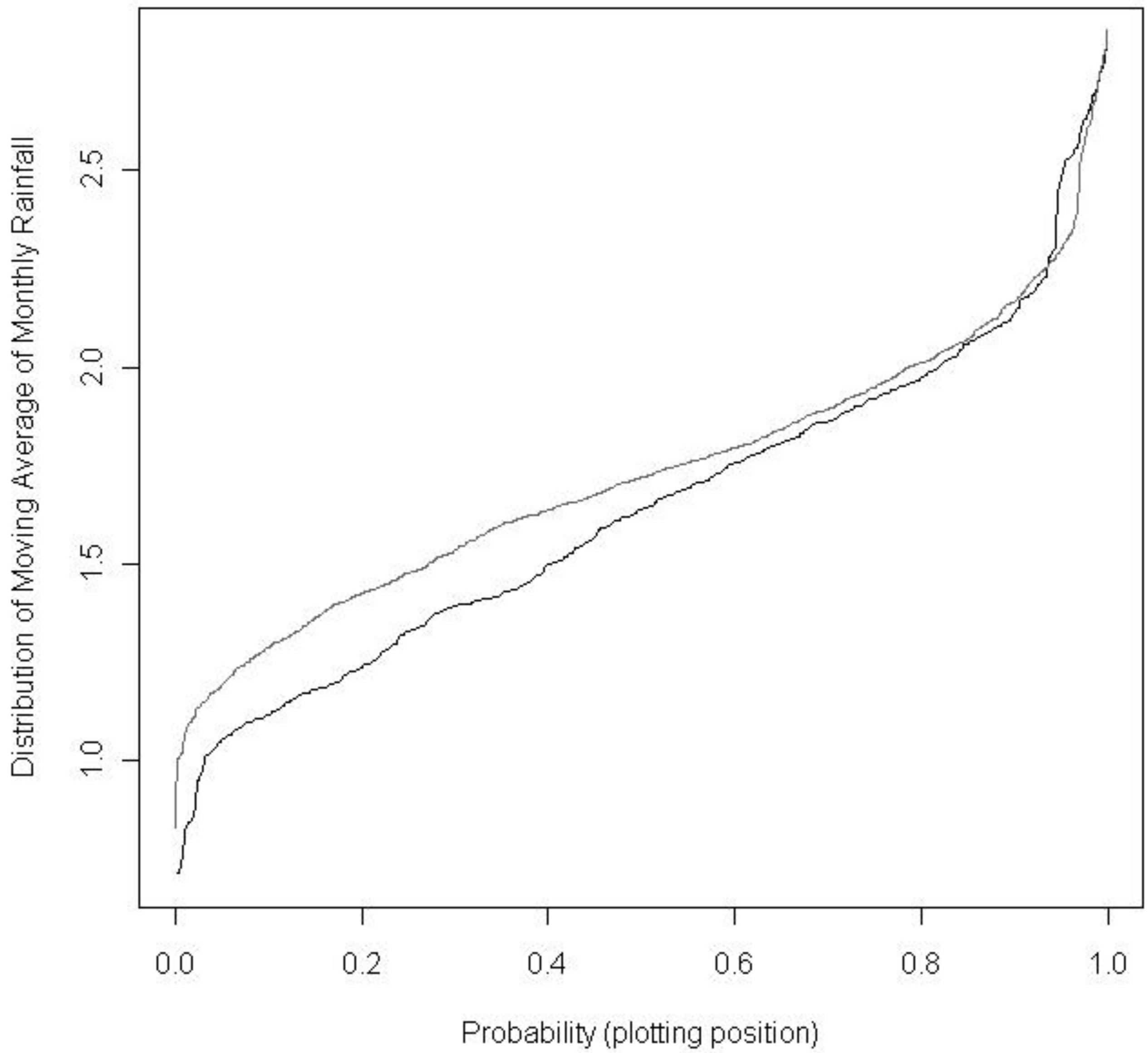
Monthly Rainfall (in)
0
5
10
15
20
25
0.0
0.2
0.4
0.6
0.8
1.0
Probability (plotting position)



Monthly Evaporation (in)
2
4
6
8
10
12
0.0
0.2
0.4
0.6
0.8
1.0
Probability (plotting position)


Moving average of monthly rainfall
1.0
1.5
2.0
2.5
0
100
200
300
400
500
Months


Moving average of monthly rainfall
1.0
1.5
2.0
2.5
0
100
200
300
400
500
Months



Distribution of Moving Average of Monthly Rainfall
1.0
1.5
2.0
2.5
0.0
0.2
0.4
0.6
0.8
1.0
Probability (plotting position)

Conclusions

- Beginnings of a tool to run long-term studies of the expected yield from water harvesting activities, based on historical data.
- Allows iterative trials of reservoir geometry and how that affects yield.
- Lots of fun!