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Global investigation of the multi-scale probabilistic behaviour of dry spells from rainfall records

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Abstract:

Understanding and modelling the rainfall process at fine timescales has been a classic endeavor of hydrology, particularly because of its importance in everyday life, hydrological design and water resources management. At fine timescales, the rainfall process alternates between wet and dry states exhibiting pronounced clustering behavior. Herein, we employ a probabilistic characterization of rainfall intermittency as a two-state process and estimate the probability-dry across a range of timescales from minutes to months. **To model the resulting multi-scale behavior, we employ a stochastic model derived from an entropy maximization framework at a multi-scale setting, which was previously found to successfully describe sub-daily rainfall in single case studies. We investigate whether the proposed model is able to capture the wide range of rainfall regimes observed worldwide and discuss its potential generality.** Furthermore, we show how such a modelling approach of rainfall intermittency can prove valuable for practical purposes, such as the derivation of ombrian (intensity-duration-frequency) curves.

Premises of the stochastic model used :

- Stochastics is the language of **uncertainty**.
- **Entropy** is the quantified measure of uncertainty.
- The **principle of maximum entropy**, which reflects entropy maximization in nature, can help to construct parsimonious probabilistic representations of natural phenomena.

About the Stochastic Model used:

In this attempt, we use a model of maximum entropy proposed by *Koutsogiannis* and it's formulated as followed :

$$p^{(k)} = p^{[1+(\xi^{-\frac{1}{\eta}}-1)(k-1)]^{\eta}}, \quad \xi \geq \frac{1}{2^{\eta}}$$

with η and ξ ranging in the interval of [0,1].

Important to note :

- For η = 1, the resulting dependence structure is Markovian.
- For η=1 and ξ=0.5, the independence model emerges.

About the Application:

- U.S. 15 Minute Precipitation Data from National Climatic Data Center (NCDC) were used for our analysis. The data used are **15-minute precipitation data (**reported 4 times per hour, if precipitation occurs).
- The weather stations picked for our analysis are located in the states of **Alabama, Arkansas and Arizona**. The exact position of the weather stations used are shown in the following figures.
- The **criteria** used for the dataset are : (a) record **length of over 50 years**; (b) **percentage** of missing values and flags for suspect quality combined is **less than 2%.**

About the States involved:

- Arizona has an average annual rainfall of **323 mm**, which comes during two rainy seasons, with cold fronts coming from the Pacific Ocean during the winter and a monsoon in the summer.
- Alabama has very hot summers and mild winters with copious precipitation throughout the year. This state receives an average of **1400 mm** of rainfall annually.
- Arkansas generally has a humid subtropical climate; Annual precipitation throughout the state averages between about **1000 and 1500 mm**.

State of Alabama

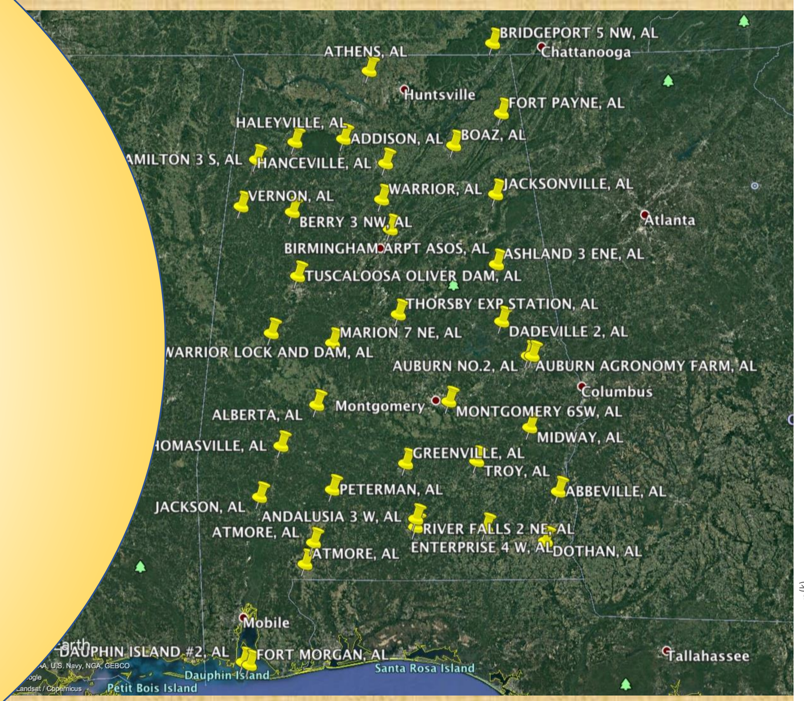
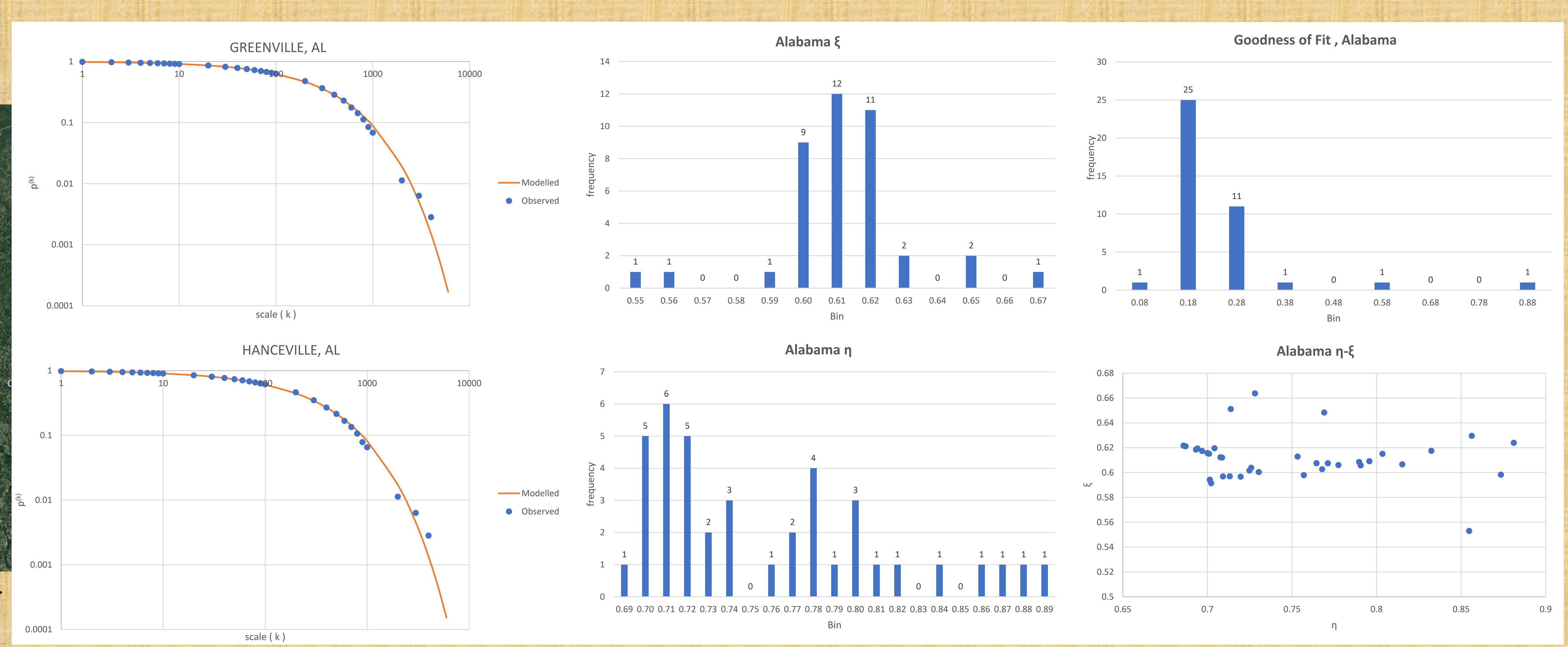
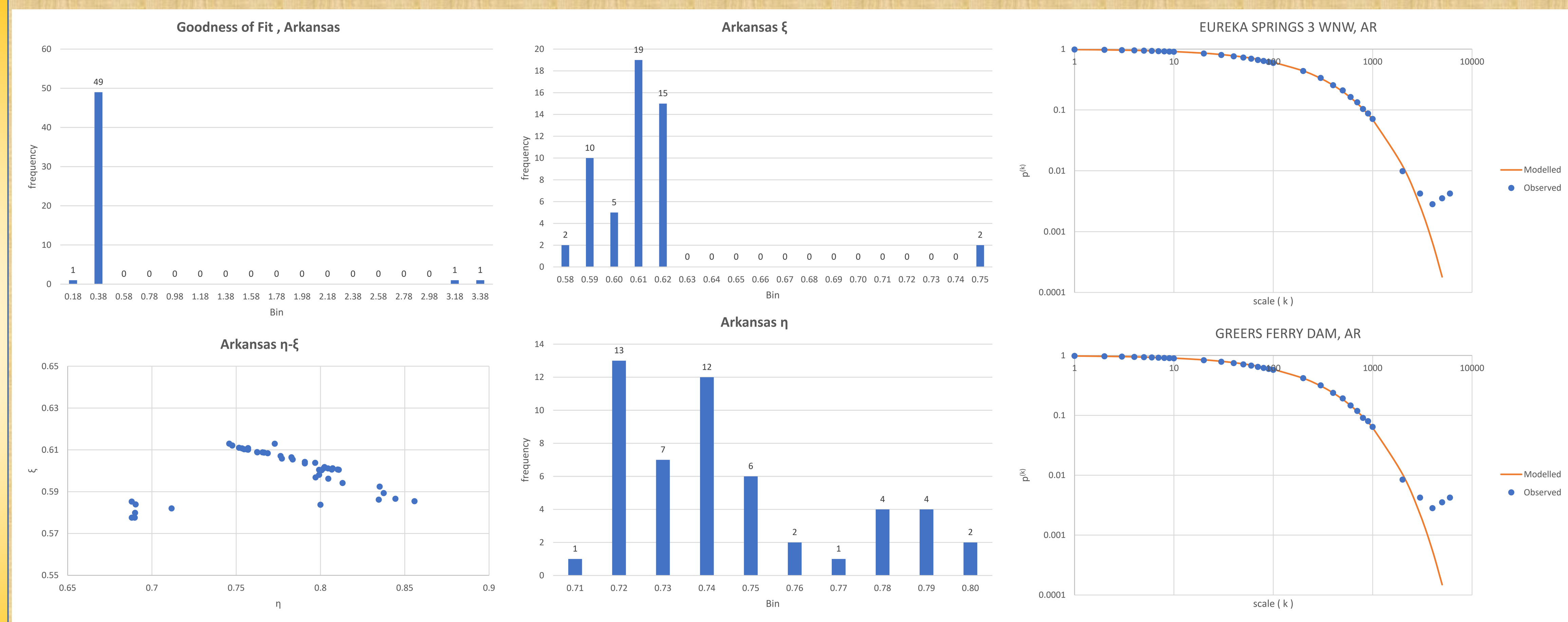


Figure 1 : Position of the weather station used in Alabama. *(backround : GoogleEarth image)*



Charts 1, 2 : Probability $p^{(k)}$ dry versus scale (*k*)



Charts 3, 4 : Probability $p^{(k)}$ dry versus scale (*k*)

State of Arkansas

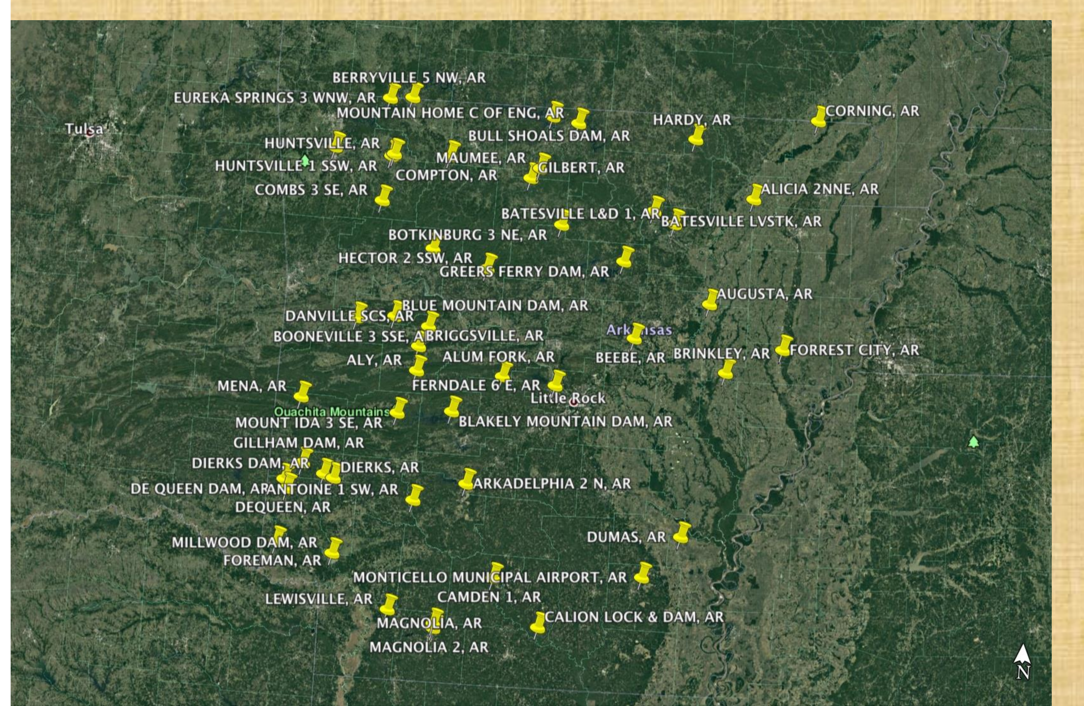
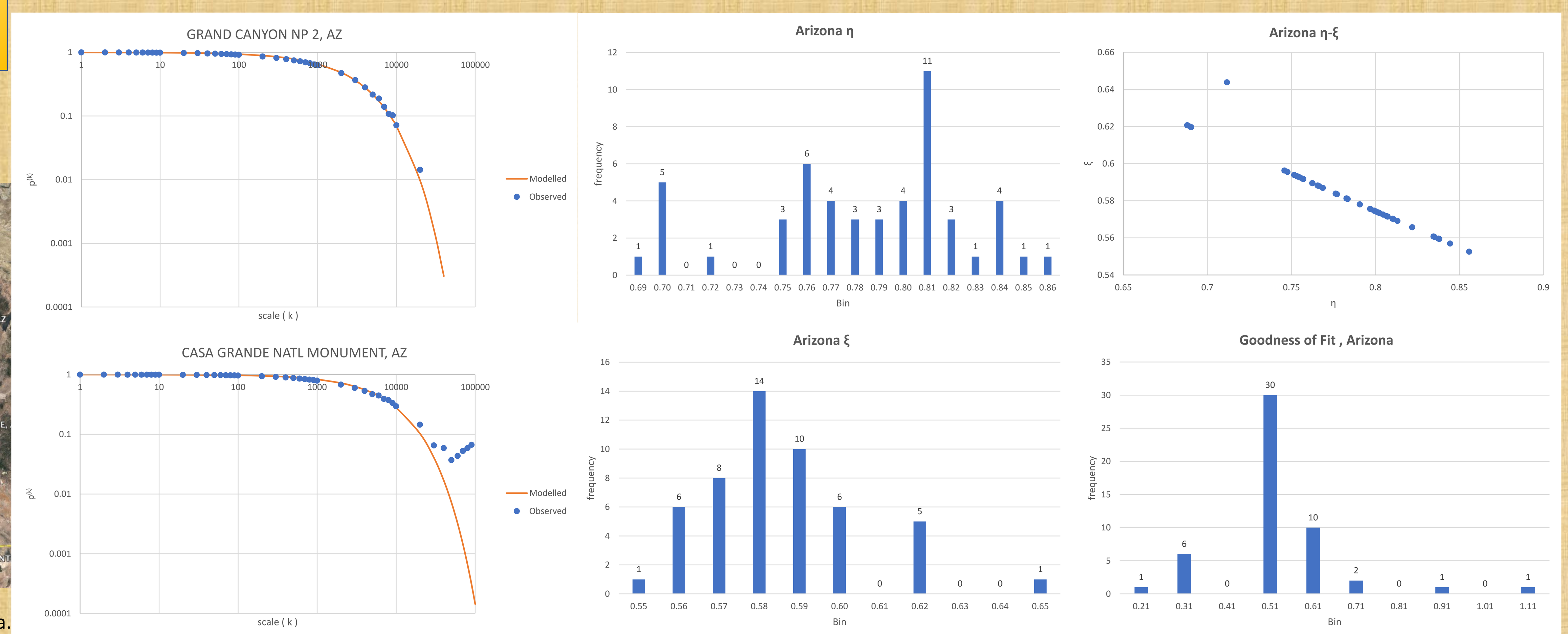


Figure 2 : Position of the weather station used in Arkansas. *(backround : GoogleEarth image)*

State of Arizona

Figure 3 : Position of the weather station used in Arizona. *(backround : GoogleEarth image)*



Charts 5, 6 : Probability $p^{(k)}$ dry versus scale (*k*)

Conclusions

- Application of this model indicates good agreement of theoretical predictions and empirical data at the entire range of scales for which probabilities dry and wet can be estimated (from 15 min to a few months).
- The values of η range in the interval **[0.68 , 0.88]**, the values of ξ range in the interval **[0.55 , 0.75]** , which indicates that the phenomenon is neither a **Markovian structure** nor a **independence model**.

References :

[1]D.Koutsogiannis, Uncertainty, entropy, scaling and hydrological stochastics. 2. Time dependence of hydrological processes and time scaling Hydrological Sciences–Journal–des Sciences Hydrologiques, 50(3) June 2005.

[2]D.Koutsoyiannis, An entropic-stochastic representation of rainfall intermittency: The origin of clustering and persistence. Water Resources Research, 42(1) ,(2006)