Stochastic investigation of the streamflow adjusted in human impact

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1. Introduction

The streamflow process plays a major role not only in water management, but also in prosperity of any aquatic ecosystem.

Until now, large numbers of scientific studies have dealt with the stochastic framework of the river flow and not so much with the influence of human intervention on it. The following study attempts to investigate the cross-correlation and statistical similarities between the streamflow in natural conditions and that with anthropogenic alterations.

To this end, we collected and examined several data sets from numerus locations with differences in topography, geomorphology, catchment attributes and climate regimes.

The detection of the statistical similarities or cross-correlation between the natural flows and those with human interventions could be useful in studies related to the ecosystem of the river, sediment transportation, as well as water management and environmental impact.

Aim?

2. What is the Aim of the study?

Its reasonable that nowadays, dam construction and water pumping systems become more urgent due to both urbanization and climate change. Human intervention in river regime can bring irreversible changes and affects the entire ecosystem surrounding it. This is the reason why it is important to further investigate this field.

In this research, we consider as "human intervention" water uses ranging between industrial, irrigation, domestic and drinking water, as well as hydroelectric power.

Human alteration at the river flow regime can be attribute to the regulation of a dam or the water directly pumped from a river. Previous analyses showed that the total long-term average river discharge into the oceans and internal sinks has been decreased due to water with-draws and dams. [1]

Furthermore, according to Camila Alvarez-Garreton et al. [2], the substantial human interventions can lead to the decrease in annual streamflow, runoff stations, the flashiness of runoff, especially in drier catchments and they can influence the elasticity of runoff with respect to precipitation.

Therefore, by investigating the statistical similarities between the natural river flows, which represent the stochastic variability, and the flow with human intervention, which reflects the deterministic one, we expect to see differences.

Stochastic parameter - natural flow

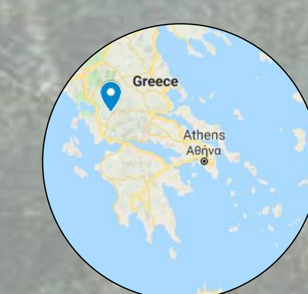
VS

Deterministic parameter - human behavior

3. Where was the data gathered from?

674 stations in U.S.A.

517 stations Chile



2 stations in Kremasta, Greece

Specifications

- Above some indicatively stations from our research are presented to illustrate the stations' spatial distribution .
- We did not include in our research further time series from other countries due to the fact that are few data sets in which the human impact has been determined
- The two stations in Kremasta, Greece were selected due to the fact that they described a inflow and outflow system of two reservoirs.

4. Statistics tools

➢ Moments

Moment number	Name	Measure of	Equation
1	Mean	Central tendency	$\bar{X} = \frac{\sum_{i=1}^{N} X_i}{N}$
2	Variance	Dispersion	$\sigma^2 = \frac{\sum_{i=1}^{N}(X_i - \bar{X})^2}{N}$
3	Skewness	Symmetry	$skew = \frac{1}{N}\sum_{i=1}^{N}\left[\frac{(X_i - \bar{X})}{\sigma}\right]^3$
4	Kurtosis	Shape	$Kurt = \frac{1}{N}\sum_{i=1}^{N}\left[\frac{(X_i - \bar{X})}{\sigma}\right]^4$

Why the Climacogram?

- In a programming environment, it requires less operations and storage space
- Its bias can be estimated through a simple and analytical expression
- The climacogram has the smallest estimation error in estimating the true values

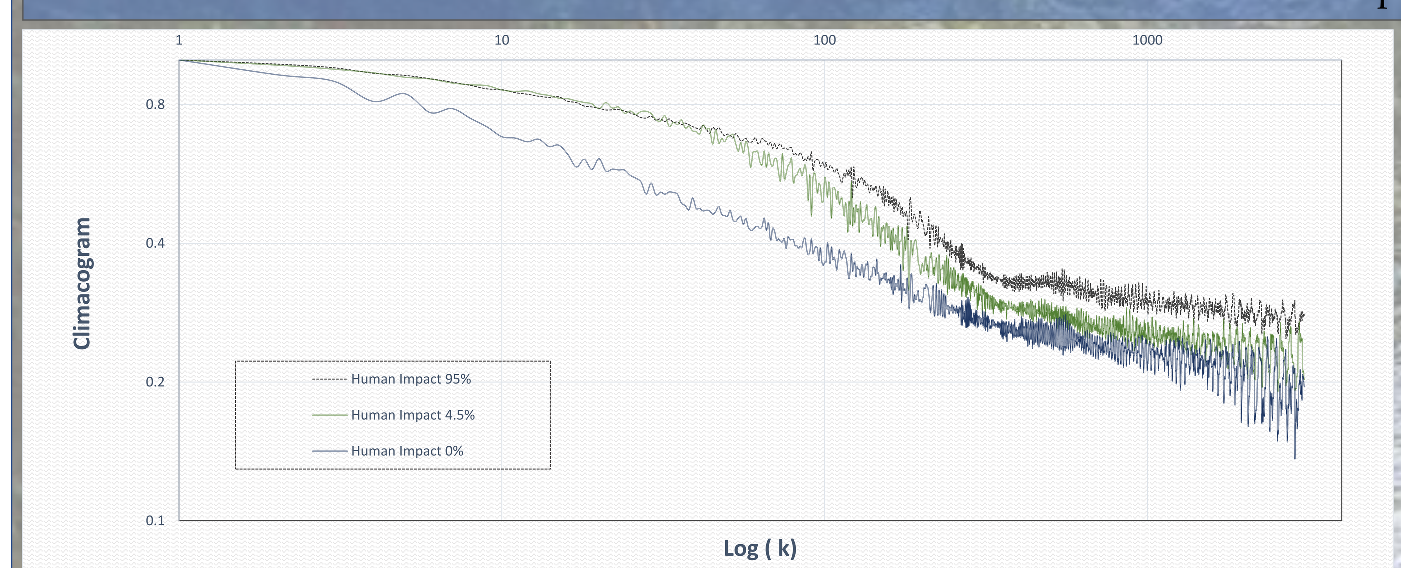
➢ Correlation

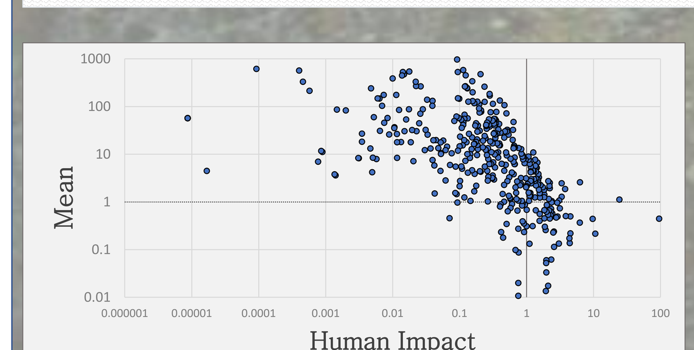
In order to cumulate the cross - correlation in the nature streamflow (stochastic one) and the cross - correlation in the streamflow with the human impact (deterministic one) we use the **Climacogram.**

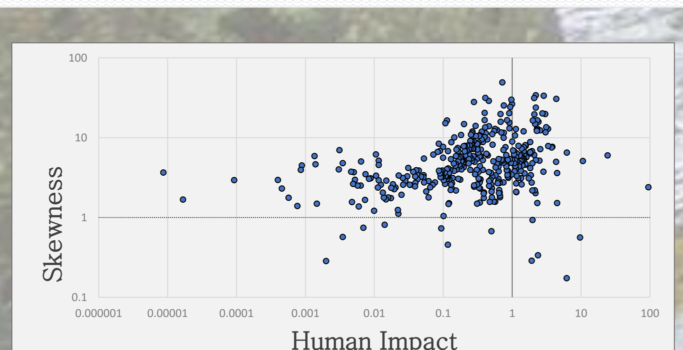
The Climacogram comes from the Greek word climax (meaning scale). It is defined as the (plot of) variance of the averaged process $\underline{X}(t)$ (assuming stationary) versus averaging time scale m and is symbolized by $\gamma(m)$. The climacogram is useful for detecting the long term change (or else dependence, persistence, clustering) of a process. This can be quantified through the Hurst coefficient H, which equals the half of the slope of the climacogram in a log-log plot, as scale tends to infinity, plus 1. For sufficiently large scales, if $0 \leq H < 0.5$ the process is anti-correlated (for more information see e.g., Koutsoyiannis, 2010), for $0.5 < H \leq 1$ the process is positively correlated (most common case in geophysical processes) and for $H = 0.5$ the process is purely random (zero autocorrelation, thus white noise behavior) at these large scales. [3], [4]

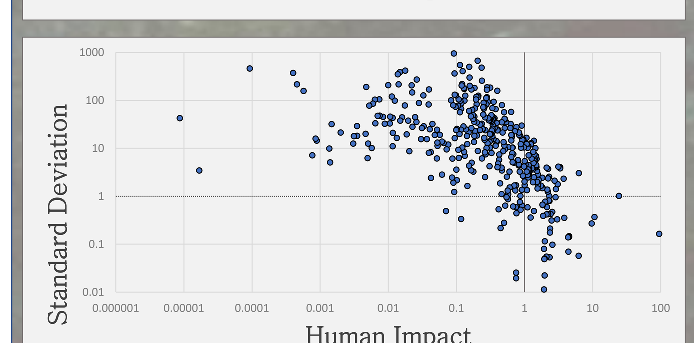
5.Results

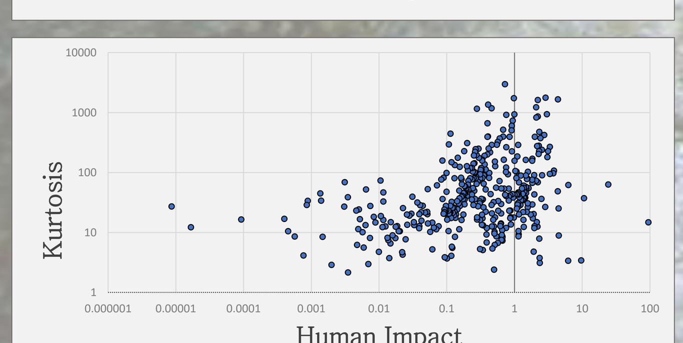
Data with and without human impact - Chile











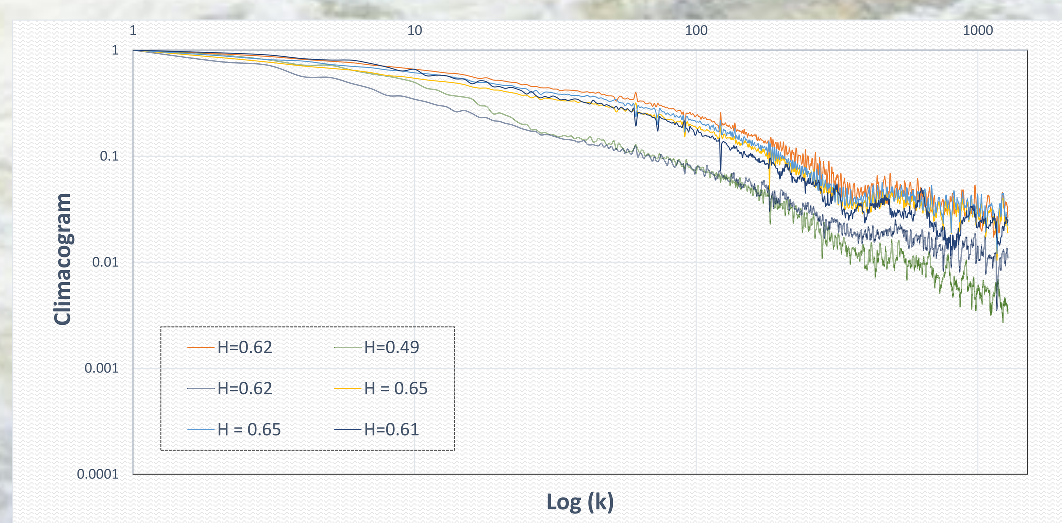
Human Impact [2]

- The human impact percentage describes the degree of anthropic intervention within the catchments by relying on publicly available water rights data for the Chile. The type of rights it will be either for consumptive or non-consumptive proposes and its use could be for industrial, irrigation, domestic and drinking water, hydroelectric power, pisciculture, mining etc. Is calculated as the ratio between the annual surface flow allocated within a catchment, and the catchment annual runoff. This indicator describes how much of the annual average runoff produced within a catchment, corresponds to the water volume allocated as consumptive surface rights.

Comments

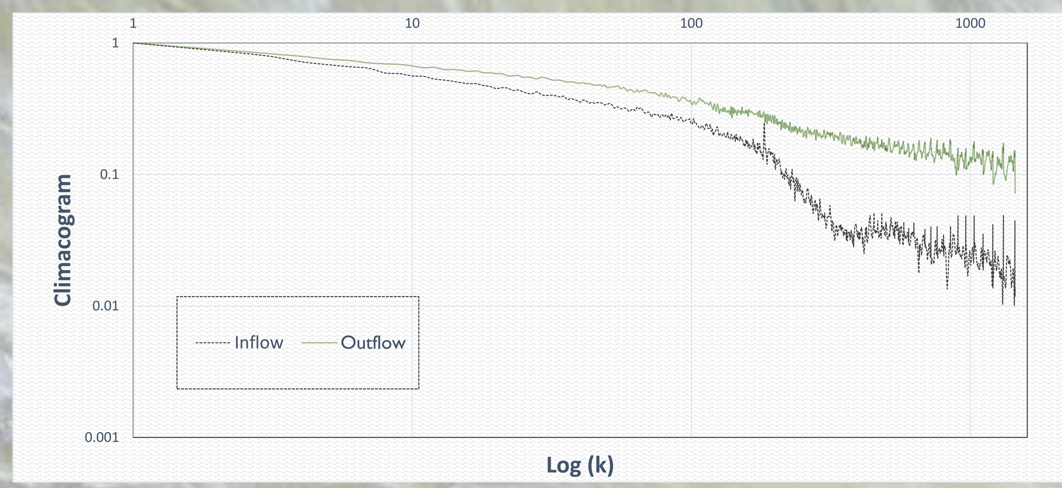
- As we see in the diagram for Chile, that the climacogram with deep grey colour which describes the time series with the biggest human influence has a "gap" after the completion of one year (365 days).
- That "gap" weakens as the human impact decreases in streamflow
- Also the three climacograms seems to have the same Hurst coefficient which is calculated near 0.8
- In the next diagrams we compare the human impact index with the first four moments (mean, standard deviation, kurtosis, skewness)
- Additionally, it seems that the skewness and kurtosis increase and lose theirs initial low values as the human impact index become larger

USA - Data without human impact



- The next diagram contains the climacograms of the time series produced by the stations in USA in which the human impact have been filtered
- As it is indicated by this scenario the slope of the climacogram is smoother and the 'gap' decreases

Kremasta, Greece - Data with human impact



- Its seems that in this scenario of dam regulation the results differ from the previous ones
- This indicates, that on a short-term scale the type of human intervention may influence the behavior of time series

6.Conclusions

- On long-term scale the data variability is absorbed and the Hurst coefficient is stabilized
- On long-term scale both, the stochastic variability of natural flow and the flow with the deterministic human interference seem to have the same behavior
- The Hurst coefficient appears to be independent and unaffected by the differences of the data in topography, climate regime or geomorphology
- It is also observed that, on a short-term scale, the type of human intervention in streamflow (dam regulation, pumping etc.) may somehow affect of the time series behavior

Links

1. https://www.usgs.gov/
2. http://www.cr2.cl/
3. https://www.itia.ntua.gr/en/

References

[1] P. D¨oll, K. Fiedler, and J. Zhang, Global-scale analysis of river flow alterations due to water withdrawals and reservoirs, December 2009

[2] Camila Alvarez-Garreton at all, The CAMELS-CL dataset: catchment attributes and meteorology for large sample studies – Chile dataset, February 2018

[3] P. Dimitriadis, D. Koutsoyiannis, and Y. Markonis, Spectrum vs Climacogram, EGU General Assembly 2012, Geophysical Research Abstracts, Vol. 14, Vienna

[4] P. Dimitriadis, and D. Koutsoyiannis, Climacogram versus autocovariance and power spectrum in stochastic modelling for Markovian and Hurst–Kolmogorov processes, August 2015

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