Assessing the spatial impact of the skewness-ratio originating from the time irreversibility and long-range dependence of streamflow in flood inundation mapping

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ABSTRACT

The skewness-ratio (i.e., standardized skewness of the differenced process) is shown to have a high impact to the average (over all inundated cells) of flood-related variables, such as depth and velocity, when is originated from a streamflow process exhibiting time-irreversibility (i.e., its joint distribution changes after reflection of time about the origin) and/or long-range dependence (i.e., power-law asymptotic decay of its autocorrelation function). A simple way to quantify time-irreversibility is through the skewness coefficient of the differenced process, while the long-range dependence behaviour can be identified through the climacogram estimator (i.e., adapted for bias variance of the averaged process vs. scale). In this work, the spatial distribution of the skewness-ratio is assessed and quantified through a real case scenario of flood mapping. It is found and discussed that depending on the distance from the river, different degrees of skewness-ratios may exist and have an impact on the temporal distribution of the flood-momentum and the increase of flood-risk.

Keywords: stochastics, flood, streamflow, dependence, irreversibility

1. Introduction, Methods and Application

The long-range dependence (also known as long-term persistence or the Hurst phenomenon; Hurst, 1951) is related to the asymptotic power-law behaviour at large scales of the autocorrelation function of a stochastic process. It is shown that it can be efficiently simulated through the explicit preservation of the climacogram (i.e., adapted for bias variance of the averaged process at the scale domain; which is preferred to the more traditional autocovariance and power-spectrum at the lag and frequency domains, respectively; Dimitriadis and Koutsoyiannis, 2015) along with the probability distribution function of the process expressed through any number of its marginal moments (Koutsoyiannis and Dimitriadis, 2021). Interestingly, most of the key hydrological-cycle processes are shown to exhibit the long-range dependence behaviour (Dimitriadis et al., 2021).

The time-irreversibility is a model attribute of a stochastic process related to its distribution in time, which is shown to be efficiently simulated through the preservation of the skewness coefficient of the differenced process (Koutsoyiannis, 2019). Although for most of the key hydrological-cycle processes, time-irreversibility can be assumed negligible at fine scales (and is often apparent in high-resolution timeseries), for the streamflow process its impact can last even for several days (Vavoulogiannis et al., 2021).

Both the long-range dependence and the time-irreversibility can highly increase the variability of the streamflow process, and therefore, to any related processes such as the ones involved in flood inundation mapping (e.g., flood depth and water velocity). In this work, the impact of time-irreversibility and long-range dependence is assessed through the spatial distribution of the skewness-ratio (i.e., standardized skewness of the differenced process) of the depth and velocity through a Monte-Carlo application of flood mapping at the Peneios river in Greece (Fig. 1).

2. Results and Discussion

To test the impact of both behaviours (i.e., time-irreversibility and long-range dependence) in the flood mapping, a Monte-Carlo experiment is performed at the area of interest (Fig. 1). Particularly, 100 synthetic streamflow timeseries are generated by preserving the important stochastic properties of a daily recorded timeseries of more than 10 years of length at an upstream station at the area of interest. For the simulation of the streamflow, the Asymmetric Moving Average (AMA) scheme (Koutsoyiannis, 2020) is employed, where the observed skewness coefficient of the timeseries and the differenced timeseries is estimated as 3.9 and 1.3, respectively, the Hurst parameter (indicative of the strength of the long-range dependence) is estimated as *H* = 0.8, and the Pareto-Burr-Feller probability distribution is used (more information will be provided at the main paper). For the flood inundation, the dynamic-wave scheme of the HEC-RAS 2D model (www.hec.usace.army.mil/software/hec-ras/) is applied with a rectangular grid of 50×50 m^2 pixel area.

It is found that the skewness-ratio of both the flood depth and water velocity are affected by the explicit preservation of time-irreversibility and long-range dependence, but in a different degree and dependent to the distance from the river, which carries the longitudinal momentum of the flood, and therefore, it is expected to also have an impact on flood-risk.

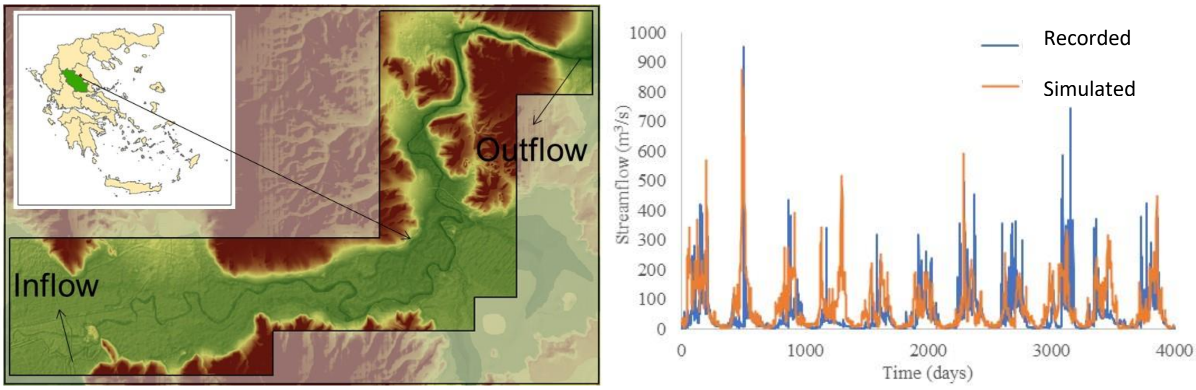

Fig. 1. The area of interest at the Peneios river in the Thessaly plain (Greece) [left]; A recorded timeseries at the upstream station (inflow) and a simulated one preserving time-irreversibility and long-range dependence.

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