Authors' response to comments from Referee #2

The authors would like to thank the second reviewer for the positive overall evaluation and the constructive general comments. Suggestions and specific remarks on English usage and grammar are greatly appreciated and will be thoroughly accounted for.

In what follows in *Italic* are the comments provided by the Referee, and in **bold** fonts the authors' response. Changes to the manuscript are quoted and reported in **"*bold italic*"** font. Please consider that text here reported is still undergoing for the check from a professional native English speaker.

The title of the manuscript is not informative of its content. I suggest "Monte Carlo investigation of the power of parametric and non-parametric tests for trend detection in annual maxima series", or something similar.

We thank the reviewer for this comment and for the suggested title we slightly changed it "Numerical investigation on the power of parametric and non-parametric tests for trend detection in annual maxima series"

Lines 29, 147 and other parts of the manuscript: The statement attributed to Salas (1993) (see line 29) is theoretically incorrect. Stationarity is an attribute of stochastic processes (i.e. models) not of time-series (i.e. their realizations). More precisely, a stochastic process is said to be stationary, if and only if:

$$X_t \overset{\mathrm{d}}{=} X_{t+\tau},\ \forall\ t, \tau$$

where $\overset{\mathrm{d}}{=}$ *denotes equality in all finite-dimensional CDF's* $F_{X,n}$, $n = 1, 2, ...$ *For example,* $F_{X,1}(x; t) = F_{X,1}(x)$, $F_{X,2}(x_1, x_2; t_1, t_2) = F_{X,2}(x_1, x_2; |t_2-t_1|)$, $F_{X,3}(x_1, x_2, x_3; t_1, t_2, t_3) = F_{X,3}(x_1, x_2, x_3; |t_2-t_1|,|t_3-t_1|)$ *and so on.*

In the above context: a) lack of trends shifts and periodicities in a timeseries does not necessarily mean that the parent process is stationary, b) the wording in the manuscript should be properly modified to avoid use of the terms: "stationary timeseries" and "non-stationary timeseries"

We thank the reviewer for this important comment. The statement which is recognized as "theoretically incorrect" is a literal quote from Chapter 18 of Handbook of Hydrology (Maidment, 1993). As mentioned by Koutsoyiannis and Montanari (2015), in their paper section "Semantic and historical review" about the concept of stationarity, this is not the only case. Also the Kendall and Stuart's book make reference to "stationary series", for not counting the large number of papers that may arise from such a keyword search in a database such as Scopus. While we recognize the huge importance of semantic consistency in the scientific literature, we observe that in our paper there is little chance for misconception if considering that we are working in the framework of a Monte Carlo experiment by using time series generated from theoretical models. Nevertheless, in order to avoid any possible confusion, we accepted the reviewer's suggestion by removing the quoted sentence in the

introduction (line 29) and introducing a more formal definition of stationarity. Then, we have checked throughout the manuscript for the use of "stationary (and nonstationary) time series". We found, besides the line 147 that was indicated by the reviewer, only one other "suspicious case" at line 264. In lines 147 we rephrased "if the time series is non-stationary, […]. Vice versa if the time series is stationary" into "if the time series arises from a non-stationary process, […]. Vice versa if the process is stationary"; Line 264 "the generation of stationary series …" into "the generation of series from a stationary model…".

The results presented in Figures 7-13 need to be discussed in more detail.

We have introduced some more description of such results, nevertheless, following comment 15) from Referee #3, we have also reduced the number of figures and subplots, limiting their display to representative selected cases.

The following comment was added to the revised manuscript

Subplots show that the presence of a strong trend coefficient may produce significant loss in the estimator efficiency probably due to deviation from normal distribution of the sample estimates also for long samples. This suggests the need of more robust estimation procedures which provides higher efficiency for estimates of ϵ and σ in case of strong observed trend. It should be highlighted that efficiency in parameter estimation increases with sample size for ε=[0,0.4], while it decreases for both ε and σ, in the case ε=[-0.4], where the trend of the location parameter implies a shift in time of the distribution upper bound.

See response to comment 15) from Referee #3 regarding the reduction of figures and subplots.

As a final remark, I think that in the concluding section, the Authors should at least comment on an important aspect related to the presented analysis: When inferring the properties of a stochastic process from data, one needs to analyze the available time-series assuming ergodicity.

Since a non-stationary process is (by definition) non-ergodic, the stationarity assumption is central to any type of time-series analysis. Hence, non-stationary modeling of physical processes based on data (i.e. a single realization of a stochastic process) is theoretically inconsistent. That said, I believe that the findings of the Authors regarding uncertainty aspects of parametric and non-parametric tests in detecting non-stationarities, significantly underestimate those emerging when real world data is used.

Also this comment is particularly welcome because it provide us with the possibility to share our general perspectives on issues concerning real data analysis. Ergodicity, in fact, is not only an important theoretical property of stationary stochastic processes but it also affects practical inferential tasks. Then, we added a final remark about different sources of uncertainty and perspectives about data usage and exogenous information exploitation to be used in environmental change modeling.

The following lines were added in conclusions:

"*As a final remark, concerning real data analysis, in our numerical experiment we showed that, in some cases, even a weak linear trend in the mean suffices to reduce power to unacceptable values. Yet we explored the simplest nonstationary working hypothesis by introducing a*

deterministic linear dependence on time of the location parameter of the parent distribution. Obviously, when making inference from real observed data other sources of uncertainty may affect statistical inference (trend, heteroscedasticity, persistence, nonlinearity, etc), and moreover, if considering a nonstationary process with underlying deterministic dynamics, the process turns out to be non-ergodic, implying that statistic inference from sampled series is not representative of the process's ensemble properties (Koutsoyiannis and Montanari, 2015).

As a consequence, while considering a nonstationary stochastic process as produced by a combination of a deterministic function and a stationary stochastic process, other sources of information and deductive arguments should be exploited in order to identify the physical mechanism underlying such relationships. Even in such a case observed time series have a crucial role in order to calibrate and validate deterministic modeling or, in other words, for confirming or disproving the model hypotheses.

In the field of frequency analysis of extreme hydrological events, considering the high spatial variability of sample length, trend coefficient, scale and shape parameters, etc, we believe that physically based probability distributions could be further developed and profitably exploited for selection and assessment of the parent distribution in the context of non-stationarity and change detection in annual maximum series. Physically based probability distributions we refer to are: (i) those arising from stochastic compound processes introduced by Todorovic and Zelenhasic (1970), which include also the GEV (see Madsen et al., 1997) and the TCEV (Rossi et al., 1984), and (ii) the theoretically derived distributions following Eagleson (1972) whose parameters are provided by clear physical meaning and are usually estimated with support of exogenous information in regional methods (e.g. Gioia et al., 2008; Iacobellis et al., 2011; see also for a more extensive overview Rosbjerg et al., 2013).

Hence, we believe that "learning from data" will remain in future years a fundamental task for hydrologists facing the challenge of consistently identifying both deterministic and stochastic components of change. This involves crucial and interdisciplinary research to be developed in order to exploit as much information as possible while finding consistent frameworks for enhancing data analysis and physical knowledge to reduce uncertainty of prediction in a changing environment."