Reply to Referee #3

The main research question of this study, as presented by the authors in Line 64, is "What is the impact of rainfall seasonality anomalies on annual-average (or seasonal-average) water supply, and what happens if the Alento River catchment (ARC) will experience several consecutive years of lower-than-expected rainfall events?" The authors use SWAT (Soil Water Assessment Tool) to assess the changes in the different catchment water fluxes in response to changes in rainfall seasonality, using ARC as a study site. The changes in rainfall seasonality is simulated through two different approaches: (i) a "static" approach based on the SPI (Standard Precipitaiton Index) and (ii) a "dynamic" approach by decomposing seasonality into a magnitude, timing, and duration components following Feng et al. 2013. While simulating the changes in rainfall seasonality via a Monte-Carlo approach, the length of the seasons are set across multiple years but varied across the 3 case scenarios ("reference," "dry," and "wet") for the "static" approach, whereas for the "dynamic" approach, the duration of the wet season in each year is randomly drawn from a normal distribution (line 220 – 222).

GENERAL REPLY: We thank this reviewer for her/his comments and suggestions. In the following sections we have tried to provide a few preliminary replies to clarify her/his major concerns.

To me, the set of main questions is at once too broad ("the effect of rainfall seasonality on the annual catchment water yield") and too specific (effects on one catchment, ARC). The presentation is overall loose and acutely needs focusing. By this I mean that it's not clear to me what conclusions to be drawn from this study other than "by changing rainfall seasonality under scenario X, we simulated a reduction in water yield at this Mediterranean catchment by Y amount," which does not give much scientific insights into how this particular Mediterranean catchment might function (in response to the second part of the main question), nor how the results may be able to be generalized to other Mediterranean catchments around the world (in response to the first part of the main question). Perhaps this is just an issue of having to refine the main question a little more. At one point the authors also state "the goal of this study is to characterize the rainfall seasonality and its anomalies by using two approaches (Line 84)" – to what end? Not only do I find this goal to be a little aimless, but it's also not clear to me how this would help advance the overall research question stated earlier. I understand that this relates to the methodology through which the main questions were interrogated, but why two different approaches? And what did the authors learn from adopting the two different approaches?

REPLY: Honestly, the first part of this reviewer's comment is not completely clear to us. Firstly, "rainfall seasonality" represents a clear and specific change in the input forcing, whereas "water yield" is a clear and specific output response of a catchment. On the other hand, almost all of the papers we read in the literature refer to a general problem or concern that then is investigated in one specific area where a good amount of quality data is available to elucidate somehow the question at hand. Moreover, especially in recent years, it is a desire to be able to compare outcomes from different sites, an exercise made difficult since only in very few cases the experimental sites are instrumented in similar ways. One eventually tries to get the most from the own site and hopes that these outcomes can be exported to similar sites.

Whereas we do agree with this reviewer that the main research question we pose in this paper should be refined somehow and better worded, an issue relevant to the Mediterranean rainfall seasonality but that does not seem to be well explored yet, at least as we are aware, using the SPI approach is the following: What happens to the water budget if the transition season becomes dry or wet? The "dynamic" approach, instead, identifies two seasons and sets two parameters that characterize the wet season, namely the centroid and spread. The spread of the wet season varies from year to year (inter-annual variability). Therefore, we posed a similar question: what happens to the water budget if the spread of the wet season becomes small (short duration of the wet season, meaning drought) or large (long duration of the wet season)?

By exploiting a long-term rainfall time series, an element of novelty of this manuscript is to assess the impact of wet season duration on the water budget in a river catchment having the UARC features. However, a longer-than-average duration of the wet season does not "always" imply a wetter-than-

average mean annual rainfall. We do have to take into account also for rainfall magnitude of the wet season. The strategy is to analyze rainfall data and properly characterize the duration and magnitude of rainfall seasons through a Monte-Carlo approach since we want to obtain water budget results within a probabilistic framework.

The authors claim that the questions of how the catchment water balance plays out in Mediterranean question remains largely unaddressed ("As far as we are aware, there is still a lack of knowledge about the effects of possible changes in rainfall seasonality on the water balance of a catchment subject to a Mediterranean climate, and the analyses presented in this paper aims primarily at contributing to fill this gap." (Lines 84 – 86) I find this statement to be surprising and again, vague and unrefined, since there is already a large body of work that already attempts to address this question in one fashion or another, via theoretical and empirical approaches, that remains uncited:

- Potter et al. 2005 "Effects of rainfall seasonality and soil moisture capacity on mean annual water balance for Australian catchments" WRR.
- Hickel and Zhang 2006. "Estimating the impact of rainfall seasonality on mean annual water balance using a top-down approach" JoH.
- Viola et al. 2008 "Transient soil-moisture dynamics and climate change in Mediterranean ecosystems" WRR.
- Gentine et al. 2012 "Interdependence of climate, soil, and vegetation as constrained by the Budyko curve." GRL
- Andersen et al. 2012 "Assessing regional evapotranspiration and water balance across a Mediterranean montane climate gradient." AFM
- Williams et al. 2012 "Climate and vegetation controls on the surface water balance: Synthesis of evapotranspiration measured across a global network of flux towers" WRR
- Feng et al. 2015 "Stochastic soil water balance under seasonal climates" PRSA
- Viola et al. 2019 "Impacts of hydrological changes on annual runoff distribution in seasonally dry basins" WRM

The authors do not make an attempt to contextualize the results of their work against a larger set of studies on water balance in seasonal and Mediterranean climates, and I find this disappointing. My goal in listing these references is not to encourage the authors to simply cite them, but also to use them (amongst others that I have certainly missed) as a starting point to actually pinpoint where the existing knowledge gaps are, and articulate clearly how, using the current approach, they are able to fill them. For example, the fact that we need to account for climate seasonality and non-stationarity when considering annual water balances, to me, does NOT constitute a knowledge gap – this has been the conclusion of many previous papers.

REPLY: We are a bit puzzled over that comment. Actually, in the original manuscript we do have cited Potter et al. (2005) (see line 73) and Williams et al. (2012) (see line 393). Other than that, we have cited the papers related to the studies presented by Viola et al. (2019) (see the citations of Viola et al., 2017; Caracciolo et al., 2017 at line 369). Viola et al. (2008) focused on seasonal soil moisture dynamics impacting on plant water stress by using a zero-dimensional bucket-filling model, while ignoring the topographical effect on the lateral distribution, and where the authors identify two seasons and set rainfall parameters arising from a Poisson process. The paper by Anderson et al. (2012) seems a bit on the boundary of the topic of rainfall seasonality. The remaining suggested citations are based on the Budyko approach, but do not focus on the assessment of rainfall seasonality.

Therefore, we aware of the state-of-the-art in the literature and here confirm that, actually, only a few studies (such that of Viola et al, 2008) have dealt in the past with rainfall seasonality issues. Only recently we are witnessing an increase in the number of studies dealing with that topic, and our submission is also heading in this direction. Unless the few previous studies (as for example the paper by Viola et al., 2008), our study proposes a new approach for assessing the impact of observed rainfall data on a water budget. In doing so, we generate new random daily rainfall data as input in a hydrological model (such as SWAT) under a Mediterranean climate. It is therefore fundamental to group rainfall seasons adequately in order to

properly calculate the statistical parameters belonging to a Poisson process. Even when the user has a short-term rainfall data set.

Other comments:

Line 47: "The amount of rainfall in each season can be suitably decomposed and simulated considering the following three main components." It's not clear to me how this statement fits in with the rest of the introduction. Why is intra-annual variability discussed at this point, when the focus of the study is on inter-annual variability of seasonality? I suggest the authors move this into the method section when discussing the Monte Carlo simulations for daily rainfall. Also, the representation of rainfall via a stochastic Poisson process (which this set of criteria is describing) should be associated with more foundational studies than those of Van Loon et al. 2014 and Feng et al. 2013 – this was introduced first by Rodriguez-Iturbe et al. 1987 "Some models for rainfall based on stochastic point processes" in PRSA and more widely disseminated in Rodriguez-Iturbe et al. 1999, PRSA.

REPLY: The parameters describing the intra-annual variability of rainfall identify timing, duration, and magnitude of the rainfall seasons (intra-annual variability) that nevertheless change with time (inter-annual variability). We agree with this comment about the seminal paper by Rodriguez-Iturbe et al. (1987), but we did not cite it since it is actually embedded in the papers by van Loon et al. (2014) and Feng et al. (2013).

The presentation of Budyko's curve as a conceptual and unifying framework is commendable, but it that it is too rushed. This may be a widely used concept in hydrological sciences, but it does not make a first appearance until the results section (starting on line 367!!) and need to be motivated better in the introduction and methods section.

REPLY: This is a good point and we thank this reviewer for that. Honestly, we should admit that presenting our outcomes even within Budyko's framework is something that was discussed among us only shortly before submitting the manuscript to HESS-D. The revised version of our study will definitely keep this reviewer's suggestion.

Additionally, description for each of the "static" scenarios ("reference" "dry" and "wet") also only makes first appearance in the results section (lines 265-270) and need to be moved to the methods section.

REPLY: We agree on that point that helps improve the readability of our paper. A short description will be included in sub-section 4.1 ("Static approach based on the SPI drought index").

SWAT model calibration has not been adequately described. While the performance is shown to be good at the monthly scale (line 141), there could still be compensating model parameters. It would be helpful to see a table of calibrated values for the list of model parameters in lines 137 – 141.

REPLY: This concern was raised also by Reviewer#1. Below we report our reply:

Nasta et al. (2017 STotEnv) calibrated a few model parameters by comparing measured and simulated monthly water yield values recorded at the dam. Numerical simulations were run at daily time step (the only time step allowed in SWAT). In this study, we followed the same criterion, we run numerical simulations at daily time step (rainfall was randomly generated at daily time step) and aggregated the output fluxes at monthly time resolution. We are aware that calibrating at monthly time-scale might lead to a potential misfit between measured and simulated values at daily time-scale (e.g. Adla et al., 2019). However, our analysis is based on the monthly aggregation of fluxes and we analyzed seasonal patterns of monthly aggregates. This is an important point that requires to be clarified in the revised manuscript (Adla, S., S. Tripathi, M. Disse, 2019. Can we calibrate a daily time-step hydrological model using monthly time-step discharge data? Water 11, 1750; doi:10.3390/w11091750).