Dear Reviewer#3,

Thank you for your detailed comments about our manuscript. All your suggestions have been considered, and we propose the following changes to address the questions you raised in your review.

In the following point-by-point responses, RC denotes a referee comment (in black), AR denotes the author response (in blue), and PM denotes the proposed modifications (in green).

Hoping that the proposed improvements will fulfill your expectations,

Best regards,

Lionel Benoit, Mathieu Vrac and Gregoire Mariethoz.

RC: The authors need to take the study to the end and show that the suggested rain types are indeed modelled easier separately than together, and that this approach is actually operationally feasible. From Figures 2 and 5 it shows that rain types can transition directly to one another, meaning that having individual models for each rain type could be very challenging.

AR: The interest of using rain types to improve stochastic rainfall generation has been demonstrated in a previous paper (Benoit et al, 2018). Hence, the main aim of the present study is rather to propose a new framework to simulate rain types conditional to meteorological covariates in order to ensure climate coherence. However, the reviewer is right when pointing out that the aim of the paper must be better stated. To this end, we propose to improve the introduction by adding a figure showing how the proposed rain type simulation method can be embedded into the framework of stochastic rainfall simulation. In particular, this new figure illustrates that realistic transitions can be simulated when a rain type switch occurs within a single rain storm. The end of the introduction will be revised as follows to better define the target of the paper.

PM [Same modification than the reply to Reviewer#2. We repeat it here for easier readability]: PM: "*In this context, the main goal of this paper is to propose a new approach to leverage the use of rain types for encoding rain non-stationarity in the framework of stochastic weather generators. However, the finality differs from that of classical weather generators (Richardson, 1981; Wilks and Wilby, 1999; Peleg et al., 2017) since we aim at simulating rainfall conditional to already known meteorological covariates, instead of simulating jointly the whole weather (i.e., all variables). More precisely, we develop a method for stochastic simulation of rain type time series conditional to the current state of the atmosphere, i.e. conditional to meteorological variables such as pressure, temperature, humidity or wind (Fig 1a). These meteorological covariates are assumed to be known beforehand, either from observations, numerical weather model outputs, or from other stochastic simulations. The advantage of the proposed approach is twofold: firstly, using a stochastic simulation to generate rain types allows to properly reproduce the natural variability of rain type occurrence, and thereby to indirectly model the non-stationarity of rain statistics observed in historical datasets. Secondly, the conditioning of the stochastic rain type model to the state of the atmosphere preserves the relationships between rain type occurrence and climatological drivers. Once realistic rain type time series have been simulated (i.e. the core of this study, Fig 1a), high-resolution rain fields can be simulated conditional to rain types using any high-resolution stochastic rainfall generator (e.g., Vischel et al., 2011; Leblois and Creutin, 2013; Paschalis et al., 2013; Nerini et al., 2017; Benoit et al., 2018a) as illustrated in Fig 1b. Using rain types to guide the stochastic generation of synthetic rains has been shown to improve the realism of the resulting high-resolution space-time simulations (Benoit et al., 2018b).*

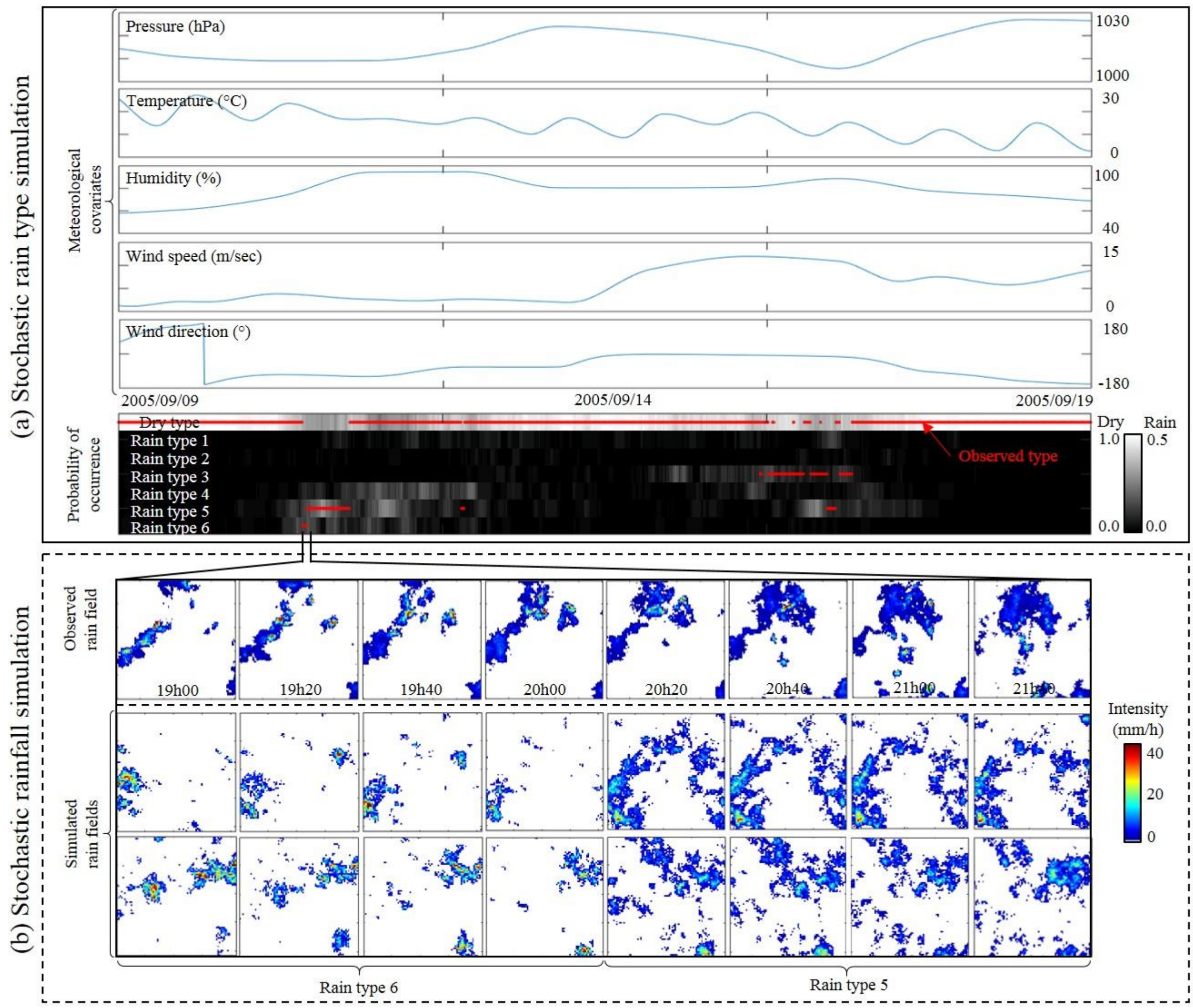

Figure 1. Overview of stochastic rain type generation (core of this study), and its application to simulate high-resolution synthetic rain fields whose statistical properties depend on meteorological conditions. (a) Rain type simulation framework developed in this study. (b) Illustration of stochastic rainfall simulation conditioned to changing rain types. In the bottom line of (a), the observed rain types are in red, and the gray shaded background denotes the probability of rain type occurrence derived from stochastic rain type simulations conditioned to the meteorological covariates displayed in the 4 top lines. In (b), the upper row displays actual rain fields observed by radar imagery, and the two bottom rows display two stochastic simulations of synthetic rain fields for the same period (Benoit et al., 2018a)."

RC: Also, the two stochastic rain types models compared both seem extremely cumbersome to work with, without showing really convincing results.

AR: The parametric model was indeed a bit complex, and following a comment from Reviewer#2 it will be moved in appendix. This will hopefully make the methodological part easier to follow. Regarding the non-parametric model (based on Multiple-Point Statistics), it is nothing but a resampling of an historical dataset that preserves patterns. It is therefore quite easy to work with this model, especially because the software used to perform simulations is freely available with an extensive documentation (https://gaia-unil.github.io/G2S/). In the present application of rain type simulation, a basic call (i.e. without complicated options) of the G2S software allows to get all the results shown in the paper.

PM: The parametric model will be moved in appendix and overlooked in the main text. This will hopefully make the 'Section 3: Stochastic rain type model' simpler.

RC: Convincing results could only be to actually model not only the sequence of rain types, but go the step further and model the weather.

AR: The main aim of this study is to simulate rain types conditional to meteorological covariates, and therefore to pave the way to stochastic rainfall simulations which are coherent with the co-occurring climate conditions. Hence, the target is not to design a stochastic weather generator, but to focus on 'meteorologically realistic' rainfall simulations. We believe that the frequent mentions to 'weather generator(s)' throughout the first version of this paper were misleading. We will therefore remove most of these mentions in the revised manuscript, and modify the title to better state our objectives.

PM:

- Reduce the number of mentions to stochastic weather generators.

- Improve the introduction to better define the target of the paper [cf reply to comment#1 above].

- Change the title to: Non-stationary stochastic rain type generation: accounting for climate drivers.

RC: It is very unclear how the final results could actually look. Could this approach be used to make stochastic rainfall output resembling the radar data used for the rain type data? That would indeed be impressive.

AR: The new figure 1 shows that it is indeed possible to simulate synthetic radar images resembling the radar data used for model calibration. In addition, it will be better specified in the introduction that using a stochastic rainfall model conditioned to rain types has been proved to improve the final simulations (Benoit et al, 2018).

RC: It would also be very interesting to compare such result to state-of-the-art 2D weather generators (like e.g. the AWE-GEN-2D).

AR: The way synthetic radar images have been simulated in the new Fig 1b is almost identical to the rain generation module of AWE-GEN-2D (i.e. truncated and transformed multivariate Gaussian field, cf Benoit et al, 2018a, Peleg et al, 2017 and Paschalis et al, 2013). In that respect, very similar results are expected. The other aspect that could be compared is the realism of the relationships between meteorological covariates and rainfall simulations. However, the philosophy of the two approaches is fundamentally different, which prevents a fair comparison. In AWE-GEN-2D, rainfall is simulated first, and the other meteorological parameters are simulated conditional to rainfall. Here we do the opposite, and condition rain types (and in turn rain intensity) to the state of the atmosphere. This is justified by the different aims of the two approaches, the focus of the present paper being to propose a stochastic parametrization of rainfall conditional to climatic conditions.

RC: As a standalone item, this manuscript is not very interesting. The fact that radar images can be used to make rain types has already been published elsewhere, and showing that you can get a 7-state Markov model to work is not very novel. You claim that it will improve stochastic modelling of rainfall, you need to also show it.

AR: We hope the above answers convinced you that stochastic rain type simulation is an interesting topic, and can improve stochastic rainfall modelling. We also hope that clarifications about the aims of the paper, and how our contribution fits within the context of stochastic rainfall (and not weather) generators respond your inquiries about practical applications of the proposed approach.

References:

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Peleg, N., Fatichi, S., Paschalis, A., Molnar, P. and Burlando, P.: An advanced stochastic weather generator for simulating 2-D high-resolution climate variables, Journal of Advances in Modeling Earth Systems, 9, 1595-1627, doi:10.1002/2016MS000854, 2017.