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Interactive comment on "Return levels of sub-daily extreme precipitation over Europe" *by* Benjamin Poschlod et al.

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The paper presents 10-year sub-daily rainfall return levels over Europe based on climate model simulations from the 50-member ensemble of the Canadian Regional Climate Model version 5 (CRCM5). The model estimates are evaluated based on observation-based rainfall return levels from 16 European countries. In terms of bias and spatial correlation, the model provides acceptable return level estimates; the longer the duration, the better the model performance. The bias is, however, large for regions with a complex topography such as the Alps and Norway, as expected considering the relatively coarse spatial resolution of the climate model (0.11°). The extreme precipitation data of hourly to 24-hourly durations provided in this paper are valuable for a wide range of applications over Europe, particularly for countries without any sub-daily

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Discussion paper

rainfall records and those with a sparse gauging network. The manuscript is overall well written and presented and the limitations of the study were well acknowledged and discussed. However, certain methodological aspects need to be explained more clearly, which I detail below.

Major comments:

1- The uncertainties of the used observational data were well discussed in section 5.1. There are still some limitations regarding the conversion of point measurements to the areal estimates of precipitation to make a fair validation of the CRCM5 estimates. As mentioned in lines 265-266 of this paper from Sunyer et al. (2016), Areal Reduction Factors (ARFs) are dependent on the temporal and spatial resolutions as well as the local climate. Berg (2019) also attributed the differences between their obtained ARFs and those of Wilson (1990) to differences in local precipitation climate. The influences of the temporal and spatial resolutions on ARF were taken into account in this study; however, the effect of local climate was not considered. That's to say, the same ARFs were applied on extreme precipitation of the entire Europe with diverse climates. In this regard, the ARFs developed by Berg (2019) for Sweden, which was used in this study, might not be applicable, for example, for Spain.

2- Because the 50 members of the CRCM5 only differ due to the internal variability of the climate system, the results quantify the internal variability on the return level values. How would the return level estimates change by changing the atmospheric forcing or the dynamics, physics and structure of the climate model. It needs to be discussed in section 5.

3- The Pearson correlation method was used to compare the spatial patterns between observed and modeled return level values. The Pearson method is appropriate for light-tailed distributions, while the Spearman method is preferable in the case of heavy-tailed distributions or the presence of outliers. The methods respectively measure the degree of linearity and monotonicity between two series. The Spearman method thus appears to be more suitable for this study.

4- The 10-year rainfall return level was estimated from 30 annual maxima values. It should be clarified why a theoretical distribution was used for this purpose, while 10 year rainfall could be more accurately derived from an empirical distribution, excluding the fitting errors of theoretical distributions. Furthermore, the Extreme Value Theory (EVT) consists of two fundamental methods of block maxima (BM) and peak-over-threshold (POT). BM was selected as it ensures the independence of extracted extremes. The method, however, has some well-known drawbacks which need to be acknowledged, such as sampling only one event per year which may result in a loss of information or inclusion of some lower observations that are still the maximum value in the year.

5- As expected, the performance of the CRCM5 improves with duration expect the 24-hourly duration. For the same observational datasets, the rainfall intensity of the observed return level is within the intensity range of the 50 CRCM5 simulations in 52 %, 77%, 79%, 84% and 81% of the domain for hourly, 3-hourly, 6-hourly, 12-hourly and 24-hourly durations, respectively. The Pearson correlation coefficients between the median return level of the CRCM5 and the observational data also show a similar pattern: correlation coefficients of 0.79, 0.82, 0.85, 0.86 and 0.71 for hourly 3-hourly, 6-hourly, 12-hourly and 24-hourly durations, respectively. The possible reasons for such exceptional behavior of the CRCM5 for 24-hourly duration need to be discussed.

Minor comments:

Title: “10-year return levels of sub-daily extreme precipitation over Europe” better reflects the aim and the content of the work.

L122: It is an hourly moving window?

L124: There are different versions of the Mann-Kendall test: e.g., original method without considering autocorrelation, modified methods to consider autocorrelation using

Effective Sample Size (ESS) or Trend Free Pre-whitening (TFPW). Which one was used here?

L128: Is 30 data used in this study considered a very high sample size?

L133: There exist several extreme value index estimators such as Probability Weighted Moment, Maximum Likelihood, Pickands and Moment. It might be clarified why the authors chose the L-moments for estimation of the GEV parameters. It is probably because of the limited sample size of the data in this study as the previous studies (e.g., Kharin and Zwiers, 2000) showed that when the sample size is limited, the L-moment theory offers more accurate estimates.

L277: It is not clear. Is the return level based on the ensemble median? Do 5% and 95% quantiles refer to the 5% and 95% quantiles of the ensemble?

L322-323: The sentence on the meaning of the correlation coefficient value is not necessary and can be removed.

L380: A higher standard deviation of higher rainfall intensity seems to be trivial.

Used reference: Kharin V, Zwiers F (2000) Changes in the extremes in an ensemble of transient climate simulations with a coupled atmosphere-ocean GCM. J Climate 13:3760–3788.

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