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Interactive comment on "Data-driven distinction between convective, frontal and mixed extreme rainfall events in radar data" *by* Emma Dybro Thomassen et al.

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Dear Reviewer, thank you for a thorough review of our article. In the following we have done our best to reply to your comments and suggestions as point to point answers. The review is copied and all our comments start with an asterics to ease reading. ... Major comments: The main difficulty with this study is that it is not clear what is the research question that triggered the analyses conducted. It is stated that: "This study aims to quantify and describe spatial rainfall as a function of temporal and spatial dynamics, rainfall types and seasonal variation". At the preceding paragraph it is written: "Here we apply a broad range of spatio-temporal characteristics in order to develop

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an automatic classification scheme of different event types and provide a better understanding of actual precipitation processes". These are two different objectives, neither of them mention the word "extreme" which seems to be a main focus. In addition, the Introduction section goes through urban hydrology, design storms, gauge vs. radar rainfall, but not much on topics related to either of the potential objectives mentioned above.

* We see one of the sentences the reviewer cites as an aim and the other as a means. We will rewrite the introduction with a clearer motivation, aim and methods keeping the above comment in mind as well as comments from the second reviewer.

Assuming the main goal is event classification, which also better matches the paper's title, then there are three missing components. The first is validation. I guess the authors could ask some experts to (subjectively) classify the 39 events according to "convective", "frontal" and "others" and test the clustering results against the expert classification. Without validation what we get is cluster analysis with a potential interpretation, not more than that.

* We have done our best to validate the results by considering the events ourselves but agree with the reviewer that this approach is questionable and that a more independent validation is preferable. A classification by a meteorologist is still subjective, so we suggest instead to make a classification based on the ERA5 reanalysis product that includes variables (e.g. CAPE) that other studies have shown to be important for event classification. We hope that the reviewer agrees such a comparison/validation this will further add to the novelty of our study.

Second, I would expect a much deeper analysis/discussion of the space-time properties of each type and how is it related to precipitation processes associated with the event type (which was part of the declared objective).

* We will elaborate on the event types identified with the cluster method (section 4.4.2, second paragraph) as well as the comparison with ERA5 in order to derive a more

in-depth discussion of the spatio-temporal characteristics. This will also include visualization using the methods shown in Ochoa-Rodriguez et al., 2015, as discussed also with the second reviewer.

Lastly, classifying events is still far from developing an automatic classification scheme, so it is better to remove this part from the goal definition.

* We agree and will rephrase to a “data-driven classification scheme”.

Other comments: Event definition is not clear and I have several related questions: 1) the threshold intensity is per pixel or averaged over the area (with size depends on the sampling strategy)? if the former then how does it generalized for the entire area, if the latter then it is a problem because 1 mm/h for 1 kmˆ2 and 38x48kmˆ2 is very different.

* The threshold intensity is per grid cell. When considering more than one grid cell, rainfall occurs when at least one grid cell has an intensity above 1mm/hr. We will clarify this in a revision of the text on P5 L10-16.

2) for what duration the 1 mm/h threshold is applied? I guess that for 5-min, but it is not written clearly.

* Yes; we will clarify this in the revised version of the manuscript.

3) what is the minimal dry duration required for event separation? the authors provided the threshold to separate between dry and wet segment, but can 5-min separate two events? usually a minimal dry duration is set for event separation.

*We use a dry weather period of 24 hours as specified on P5 L7. We understand the comment as a reference to section 3.1 and will move the specification to this section.

4) why 1 mm/h was set as a threshold? it is described as a “drizzle” threshold, but I think this is not a very low intensity. What percent of 5-min rainfall intensity is above this threshold?

* Thank you for this comment. We use a threshold of 1mm/h in the analysis of the

sampling strategies in order to get a high separation into separate events. However, having chosen the sampling strategy SS1 we relax the threshold to a “drizzle” threshold of 1mm/d in the subsequent classification analysis since this is a sufficient threshold to ensure a clear separation into different rainfall types. Table 2 shows number of events with the 1mm/hr threshold for all sampling strategies to be able to compare number of events between strategies while subsequent results use another threshold. We will make this clear in the revised manuscript.

Radar rainfall estimation: I am not clear what Z-R relation was used. It is written that the relation could be described by Z=256Rˆ1.42. Was this the relation used? Another point is that the error reported is on annual basis while the data analyzed are for 15 min, 1h, 24h. So it would be much better to report the error for 24h, using cross-validation procedures (or daily rain gauges that are not participate in the gauge adjustment).

* The Z-R relationship is a function which is variable with the reflectivity, inspired by the one used by the German Weather Service (DWD, 2004). This relationship here, as a difference to the DWD function, uses a true convective formula (Z=256Rˆ1.42) for values above 36 dBZ, and a formula for stratiform rainfall (Z=200Rˆ1.6) below this threshold. Thus, it is considering the type of event, at least in an indirect manner. Thank you for the remark on the reported error: it is indeed described incompletely. The error is counting the number of differences of 5 mm (10 mm) per daily sum over 13 years of data, analysed on independent gauges which were not used for adjustment. We will clarify this in the text.

P5,L28: “Extreme events from five independent grid cells are sampled with SS1”. In what sense these are independent and how do you know this? surely some events cover more than one pixel out of the five.

* Thank you for this comment. We will change “independent grid cells” to “different grid cells”.

P9,L20: “In order to use the knowledge about extreme events from rain gauge data

and be able to compare the results obtained to studies using rain gauge data, SS1 is chosen as the sampling strategy for this study". I don't understand why is it important to compare the results to rain gauge? it does not seem a part of any of the potential objectives.

* Our study originates out of past research that compares point rainfall estimates with spatial estimates and sampling strategy SS1 is close to this research environment, as reviewer two also points out. We will clarify and justify why this is important as a part of revising the introduction (motivation, aim and methods).

Event selection: in relation to the above point, I am not convinced of the advantage of SS1 sampling strategy. Surely, as shown later in the paper, there are un-sampled extreme events that did not pass over the central sampling pixel with the highest rain intensity. Why not use the entire area?

* We see two established practices for analysis of extreme rainfall; one is based on point rainfall and the other on tracking meteorological events in the atmosphere with little consideration of the catchment below. We have not identified an established practice for sampling of spatial rainfall over a catchment which is the justification of our analysis. Additionally is it common in urban hydrology to use point data which the second reviewer points out should receive more attention in the manuscript. We will make sure to be more accurate in both the justification of studying sampling strategies and the choice of best strategy for the bulk of the analysis.

P10,L1: "It is believed that the most severe extreme events in the case area is sampled for all grid cells, even though the ranking could be different between the grid cells". Why it has to be "believed" and cannot just to be checked? I am not sure this belief is correct. Since only 3 events per year are selected, considering the e-folding correlation distance of 5 km reported later, it can certainly be the case that the largest event in one pixel would be ranked more than 3 in another pixel and would not be selected.

* We agree, and indeed the sampled events will in general vary between grid cells due

to the short e-folding distance. The text refers to the 2-3 most severe extreme events, which are more widespread extremes and hence sampled over a large part of the case area. We will clarify this and check our assumption.

Rain cell properties are not really discussed. It seems like “overkill” to detect and track rain cells without later on relate these properties to storm dynamics.

* The rain cell properties with be used as a part of the missing discussion on physical properties of the different cluster.

Minor comments: P2,L2: Another rain gauge strength: direct measurement (much more accurate at the point)

* Thank you, this will be added.

P2,L5: Deriving spatio-temporal properties of the storm: the problem is not with the rain gauge instrument itself but with the rain gauge network that is often too sparse to represent these properties. In principle, a very dense rain gauge network could provide the relevant information on these properties (e.g., the Walnut Gulch gauge network in Arizona).

* This will be clarified.

P.4,L2: 1.4 in percent or as a fraction (i.e., 140%)?

* We will clarify that we mean 1.4 cases per station per year, equivalent to 0.38% of the days. so extremely rare.

P6,L16: why Dt = 11h?

* We used the same value as reported by Gregersen et al., 2013, that apply the samemethod. We will add a reference to this study here.

Rain cell properties are not really discussed

* We will add this to the discussion on physical properties of the different clusters.

daily (abstract) vs. 24 h

* Thank you, we will make sure this is consistent throughout the manuscript.

Relevance to urban hydrology is not explored at all, so do not mention in abstract and in introduction

* Thank you for the comment. Based on the comments by reviewer 2 we will instead make the links to urban hydrology clearer in the revised manuscript.

Reference Ochoa-Rodriguez S, Wang LP, Gires A, et al (2015) Impact of spatial and temporal resolution of rainfall inputs on urban hydrodynamic modelling outputs: A multi-catchment investigation. J Hydrol 531:389–407. https://doi.org/10.1016/j.jhydrol.2015.05.035

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