Response to Referee Comments on "Heavy Precipitation Events of Various Durations Across Germany: A Station-Based Assessment of Spatial and Temporal Variability Using the Block Maxima Method" (egusphere-2026-1067)

- **Referee:**

  Contents The study examines heavy precipitation events in Germany using spatially dense station-based high resolution 5-minute rain-gauge data for durations from 5 minutes to 7 days. Results show that the variability of annual maximum precipitation strongly depends on event duration: short events are more evenly distributed and highly variable, while longer events are more influenced by topography and show more regional consistency. Positive trends are more common for events lasting 1 to 7 hours, whereas longer events (3 to 7 days) show mixed or slightly negative trends, though statistically significant trends are generally rare.

  Recommendation substantial revisions required

  Justification The topic of this paper is relevant as it analyses data that has not been available before which is potentially very interesting. In general I enjoyed reading the manuscript, it confirms and supports several things already found for surrounding regions. It is a pity that the interpretation of the very short durations is hampered by data problems. I am not sure if it is a good idea to show the trend results at all for these time granularities – you should motivate this a bit better, if you keep them. In addition, I think that the manuscript could be shortened in several places (esp. the introduction and see details below). I am also not sure if all multi-panel maps shown (Figs. 2, 4, 5, 8, 9 10) are necessary or some could probably be moved to an appendix or supplementary material file. The readability of some figures need to be improved (see details below). I think that the paper is suited for HESS after substantial improvements of the abstract, changes of several parts of the text and some improvements of the figures and their annotations. My comments below are intended to strengthen the paper.

  Response:

  We thank the referee for this constructive assessment of our manuscript and sincerely appreciate the time and effort invested in providing detailed and helpful comments. We also appreciate the referee's recognition of the relevance of the topic and the value of the underlying high-resolution dataset. At the same time, we acknowledge the concerns raised regarding the interpretation of trend analysis results for very short durations as well as those related to the length and structure of the manuscript, the selection and presentation of multi-panel figures, and the overall readability of the figures.

  In the revised manuscript, the former issue will be addressed by relocating and expanding the description of the 5-minute data and associated challenges (e.g. jump detection and limitations of their correction) to Section 2.1, while omitting the interpretation of the corresponding trend analysis results for very short durations from Section 3.2, given their limited reliability. In addition, we will revise and shorten parts of the text, in particular Section 1, to improve clarity and conciseness, as well as reassess the necessity of the multi-panel maps, moving selected figures to the Appendix or Supplementary Material where appropriate. For all figures retained in the revised manuscript, including those in the Appendix or Supplementary Material, we will carefully revise their design, improve their readability, and adjust the figure captions.

  In the following, we provide a detailed point-to-point response to the referee's comments.

- **Referee:**

  Title. I would shorten the title by deleting "Using the Block Maxima Method". This is a methodological detail not needed in my view.

  Response:

  We agree that the reference to the block maxima method in the title is not essential and will revise the title accordingly: *"Heavy Precipitation Events of Various Durations Across Germany: A Station-Based Assessment of Spatial and Temporal Variability"*.

- **Referee:**

  Abstract. L16: Consider shortening to "Using the block maxima method, we confirmed that the spatial and temporal variability of annual maximum precipitation totals (AMPTs) is strongly duration dependent." The usage of AMPTs is implying the method, or not? L21f: There is also no hint on the time periods used for the trend analyses. Please add, also esp. the end year.

  Response:

  - We will revise the sentence in L16 to: *"We confirmed that the spatial and temporal variability of annual maximum precipitation totals (AMPTs) is strongly duration-dependent."* We agree that the use of AMPTs already implies the application of the block maxima approach, therefore, an explicit reference to the method in this sentence is not necessary.

  - In addition, we will revise the sentence in L21 to: *"The duration-dependent nature of AMPTs was further reflected in their long-term variability, which was assessed using station records of at least 30 years, with the end year fixed at 2020 and start years varying according to data availability at individual stations".* We believe that this provides a clearer indication of the temporal framework of the trend analyses, including the specification of the end year.

- **Referee:**

  Introduction. Is with almost 100 line too long in my view. Some details but could be easily shortened. It is not necessary to mention the project a paper was based on (L75). An important point is related to the super-CC scaling discussion (L79f). Da Silva & Haerter (2025) is mentioned a bit misleading here, because their main message is that "the present data unambiguously show that there is no exceedence of the CC rate at the scale of individual convective cells. To the contrary, the CC rate is a robust predictor of the change in convective precipitation intensity with temperature. Super CC changes with temperature are found only as a statistical superposition of distinct rainfall types". Also Estermann et al. (2025) doi:10.1029/2024JD040901 suggest that there is hardly any super-CC scaling. I would thus suggest to make more clear that super-CC-scaling is not necessarily a physical feature in some cases. I think it could also make sense to additionaly consider mentioning the results by Haslinger et al. (2025) doi:10.1038/s41586-025-08647-2 as it studies a very similar topic in Austria.

  Response:

  - We agree that the introduction can be shortened and will streamline several parts accordingly. In particular, we will shorten the description of the INTENSE project in L75 to focus only on its most relevant aspects.

  - We appreciate this important comment on the discussion of super-CC scaling and agree that the current wording may be misleading. We will revise this part to better reflect recent findings, emphasizing that apparent super-CC scaling does not necessarily represent a physical scaling at the level of individual convective cells. Instead, it may arise from *"the statistical shift from low-intensity stratiform rainfall to higher-intensity convective rainfall"* and that, *"when considered in isolation, both stratiform and convective precipitation extremes increase at the Clausius-Clapeyron rate"*, as highlighted by Da Silva & Haerter (2025). In addition, we will further revise the paragraph to incorporate the studies by Estermann et al. (2025) and Haslinger et al. (2025), as both provide valuable model- and observation-based insights for Central Europe.

- **Referee:**

  Data and methods. Fig. 1: y-axis could be limited to 1000. Fig. 2: Readability should be improved. Maps should probably be bigger, legend in panels a)-c) is only needed once. Legend dot colours difficult to see. Test transparent of colours? L165f (LOESS smoother): probably add reference Scherrer et al. (2024) doi:10.1016/j.cliser.2023.100428.1

  Response:

  We appreciate these helpful suggestions.

- Fig. 1: We will limit the y-axis to 1000.

- Fig. 2: We will revise the figure to improve readability by increasing the size of the individual maps, simplifying the legend (displayed only once for the panels showing the number of years in the data series), and improving the visibility of the legend colours. We will also explore adjusting the colour transparency where appropriate.

- L165f (LOESS smoother): We will add a reference to Scherrer et al. (2024) to support the methodological description as follows: "*In addition, Locally Estimated Scatterplot Smoothing (LOESS) was applied to visualise gradual changes in AMPTs over time and to identify potential non-linear and non-monotonic trends that may not be adequately captured by the Mann-Kendall test (Scherrer et al. 2024).*"

- **Referee:**

  Results. Fig. 3: Hard to read, especially combination of box plot and violin plot does visually not work (distribution not visible). Please improve. Also everywhere in text and figures: I suggest to change 60 Min to 1h, 180 Min to 3h, 420 Min to 7h, 720 Min to 12h, 1440 Min to 1d, 4320 Min to 3d. This would make things much more readable. Fig.5: Consider moving to Appendix or suppl. material. Units in Fig. 5 are wrong: [%] instead of [mm]. As for other maps, not all points are readable (transparency?, bigger maps). 3.2 Long-term variability and Fig. 6: The more than 50% of sign. positive trends for 5' values is really troubling. It is good that you made additional tests but I think there should be a bit more quantitative information about that or you should omit the trend analysis results for the very short time granulation in Fig. 6 and following. Additionally for Fig. 6: I see that there is no fixed period for the trends but you could at least give a statistic (min year, mean/median year, max year) or so to make things a bit more objective here Fig. 7: What is the min. number of years used to compute trends? Please mention. There is a strange behaviour in panel "420 min". Only 0, 50 or 100% is shown until 193X. Why is this the case? Please explain. Are there only 2 stations available? If yes, I would omit results based on less than X stations (e.g. X=10 or so). Legend: "Only stations with at least 90% data availability for AMPTs in the respective time periods are included." appears twice in legend. I would reduce the start year analysis to two periods (e.g. 1951-2020 and 1991-2020 or 1951-2020 and 1971-2020) to reduce the number of maps shown. 1991-2020 is very short for a trend analysis though. L314-315: How was this shown? Please give more details here. Legends of Fig. 8-10 are the same except for the period, shorten to "Same as Fig. X, but for period XXXX-YYYY". Fig. 11: some colours are hard to read or too dominant (station >1750 m), please ameliorate.

  Response:

  We appreciate these detailed and helpful comments and will revise the results section and figures accordingly.

  - Fig. 3: We agree that the combination of boxplots and violin plots reduces readability. In the revised figure, we will remove the violin plots and retain boxplots only to improve clarity.

  - Notation of durations: We agree that the current notation reduces readability and will consistently replace durations expressed in minutes (60, 180, 420, 720, 1440, 4320, 10080 min) with more intuitive units (1 h, 3 h, 7 h, 12 h, 1 d, 3 d, 7 d) throughout the manuscript and all figures.

  - Fig. 5: We will move Fig. 5 to Appendix or Supplementary Material. The unit in the figure will be corrected to [%] instead of [mm]. In addition, we will improve the readability of the maps by adjusting symbol visibility (e.g. by modifying transparency or reducing point size) and by increasing the size of the individual panels.

  - Section 3.2 and Fig. 6 (short durations): We appreciate this important comment regarding the interpretation of trend results for very short durations. As noted above, we will address this by relocating and expanding the description of the 5-minute data and associated challenges (e.g. jump detection and limitations of their correction) to Section 2.1, while omitting the interpretation of the corresponding trend analysis results for very short durations from Section 3.2. In addition, we will remove all panels representing very short durations from Figs. 6-11, as they are prone to misinterpretation. Regarding the differences in the time periods used for the

trend analysis shown in Fig. 6, we agree that additional quantitative information is required. In the revised manuscript, we will therefore incorporate summary statistics describing the temporal coverage of the station records (minimum, median, and maximum start years) into the text in Section 3.2. A preview of these statistics is provided in the table below.

Table: Summary statistics (minimum, median, and maximum) of start years of station records used for the trend analysis shown in Fig. 6, by duration (end year fixed at 2020).

Duration	1 h	3 h	7 h	12 h	1 d	3 d	7 d
Minimum	1946	1946	1905	1946	1901	1091	1901
Median	1956	1956	1951	1956	1948	1948	1948
Maximum	1991	1991	1991	1991	1991	1991	1991

- Fig. 7: As described in Section 2.1, only stations with at least 30 "representative years" are included in the study. These "representative years" are defined based on data completeness criteria following the KOSTRA-DWD-2020 methodology – in Section 2.1 we stated: *"To support the main aim of this study, we selected 237 stations with continuous 5-minute precipitation data series ending in 2020 […]. These stations met the following two data availability criteria: (a) data completeness was assessed for each year at a given station following the KOSTRA-DWD-2020 methodology and only years with at least 70 % available 5-minute precipitation data between March and October or at least 75 % available 5-minute precipitation data between April and September were considered representative; and (b) only stations with at least 30 such representative years were included in this study"*. For the trend analysis, this requirement is slightly relaxed to account for occasional gaps in the AMPT series. Specifically, stations are included if they provide at least 30 years of AMPTs within the analysed period, with no more than 10 % of AMPT values missing (i.e. at least 90 % data availability, as stated in the captions of Figs. 7-10). Also, we have investigated the behaviour observed for the 420 min duration and confirmed that it results from the very small number of stations available for the pre-1951 time periods, which leads to discrete values (e.g. 0%, 50%, or 100%). To avoid such misleading effects, we will revise Fig. 7 by introducing a minimum threshold for the number of stations required for plotting and will exclude periods with insufficient station coverage. In addition, the duplicated sentence in the legend will be removed.

- Number of analysed periods (Figs 8-10): We agree that the number of start-year periods can be reduced. In the revised manuscript, we will focus on two representative periods (e.g. 1951-2020 and 1971-2020), while omitting the shortest period (e.g. 1991–2020), as it is indeed relatively short for a robust trend analysis. In addition, we will consider moving selected figures to the supplementary material to further streamline the presentation. The figure descriptions will be revised accordingly.

- L314-315: We thank the referee for this comment. We agree that this statement is not sufficiently supported by a quantitative analysis. As it is further limited by the uneven spatial distribution of stations across different altitude ranges, we will remove it from the revised manuscript to avoid overinterpretation.

- Fig. 11: We will revise the colour scheme to improve readability and reduce the dominance of certain classes.

- **Referee:**

  Conclusion. With ~60 lines too long for conclusions. It is also rather a discussion of the most important results (e.g. lines L395-406), so either rename to "Discussion and conclusions" or divide into a discussion chapter and add a conclusion of less than half a page.

  Response:

  We agree that the current conclusions section is too long and contains elements that are more appropriate for a discussion. In the revised manuscript, we will restructure this part by separating it into a dedicated Discussion section and a concise Conclusions section. The Discussion will focus on the interpretation of the main findings, including their relation to previous studies, as well as the limitations and uncertainties of the applied methods. The Conclusions section will be shortened to provide a clear and concise summary of the key results.

- **Referee:**

References. Please check if all listed references are cited and if all citations are listed in the reference list. For example, I did not find an entry for Papalexiou & Montanari (2019) in the reference list. There might be more such cases.

Response:

The reference to Papalexiou and Montanari (2019) is included in the current reference list (see lines 588-589). However, to ensure consistency and completeness, we will carefully review all in-text citations and the reference list in the revised manuscript and correct any inconsistencies where necessary.

- **Referee:**

Typos. L427: Scherer → Scherrer; L439: Scherer → Scherrer

Response:

We thank the referee for pointing out these typographical errors. The spelling will be corrected to "Scherrer" throughout the revised manuscript.