Review for WCD-2020-1

General Comments

This study describes an exceptional period of thunderstorm activity in western Europe during summer 2018 and explores the associated synoptic-scale conditions; in particular, the role of blocking and associated upstream cut-off lows. The event is also placed in a climatological context using long-term records from surface stations, upper-air soundings, and reanalysis.

This is an interesting, thorough and well-written piece of work, which I have no hesitation in recommending for publication, subject to a few minor revisions as detailed below. I would like to thank the authors for their efforts, which made for an easy and enjoyable review.

Specific Comments

1. My most significant comment relates to your conclusion regarding the slow movement of convective systems during the event. You provide clear evidence (in Fig. 9) that storm motion was, on average, much lower than is typically observed in this region and at this time of year and suggest that this was key to the extreme rainfall totals. However, storm motion is not the only relevant factor for heavy precipitation. As discussed by Doswell et al. (1996), accumulated rainfall depends on two things: average rain rate and total rainfall duration. Slow cell motion contributes to long rainfall durations, but one must also consider system size (in the direction or storm motion) and the existence of back-building convection, both of which may lead to echo training. Rainfall rates must also be considered. Given that you have hourly gauge data and radar observations, it should be possible to assess all of these things. While this might not be practical for the whole study period, you should consider doing so for the most extreme events noted in Table 1. One option would be to add an extra column to the table, providing a brief description of the storm(s) that caused the rainfall totals (including their estimated motion). At the very least, it would be good to demonstrate that the general characteristic of slow storm motion applies to some of the individual extreme events.

2. You state in your abstract that low vertical wind shear “prevented thunderstorms from developing into severe organized systems”. However, reports of hail up to 5 cm in diameter (L234; L239) suggest that this is not entirely true. Clearly, wind shear in certain areas and on certain days was sufficient for the development of organised convection (probably supercells). As such I think this statement needs revising.

3. Please provide some citations for reports of storm impacts (in the opening paragraph of the introduction and section 3.1). These could simply be links to online news or social media reports.

4. The second paragraph of the introduction doesn't really fit and has only limited direct relevance to your study. As such I would suggest removing it (although parts of it could potentially be incorporated elsewhere in the introduction).

5. I know that 1981–2010 is a standard 30-year climatology period, but for this study you should consider using the full ERA-Interim record (1979–2017) in order to provide a more complete historical context for the 2018 event. I believe the sounding data will go back this far as well.

6. On Line 140 you claim that surface-based lifted index (SLI) offers "the best representation of convective environmental conditions in central Europe". I would expect CAPE to provide a more robust measure of surface-based instability, given that it considers the full column rather than just a single level (see discussion in Doswell and Schultz 2006). Certainly it has been shown to usefully discriminate between severe and non-severe convective environments in various parts of the world, including Europe (Pucik et al. 2015; Taszarek et al. 2017). It is also available as a diagnostic from ERA-Interim, so could easily be analysed spatially as well as from the point soundings. I appreciate that repeating all of your instability analysis using CAPE would be time consuming and is likely to show comparable results, so I will not request this. However, you should provide some further justification for why you chose to use SLI over CAPE.

7. You use a very high reflectivity threshold (55 dBZ) for identifying and tracking convective storms. Such a value is more characteristic of hail than intense rainfall. As such I wonder if the majority of storms went undetected, leading to an unrepresentative velocity estimate. One simple way to check this would be to see if the storms that produce some of the extreme rain accumulations listed in Table 1 were detected. At the very least this should be noted as a limitation of your radar-based analysis.

8. It would be good to include a figure showing the different weather regimes discussed in section 2.3 (or, at least, the ZO, EuBL, and AR regimes that dominated during the study period). Perhaps this can be found elsewhere. If so please refer to the specific figure(s) in the relevant paper(s).

9. In discussing the persistence analysis in section 2.5, and the associated results in section 5.2, I found the reference to "cluster length" confusing, in part because K-Means clustering is used in the analysis of weather regimes. I would change this to just "event duration" or "event persistence".

10. Could you provide a few more details on the origin of the "basic" and "strict" criteria for SLI and mid-tropospheric wind speed, so that the reader doesn't have to go to PIP16 for this information? Also, I'm not a fan of the notation TH_{BC} and TH_{SC} for these and would argue that they can be eliminated (you can just refer to the basic/strict criterion).

11. I recommend using V500 (rather than v_{500hPa}) to indicate the 500hPa wind speed.

12. I suggest using “total” or “accumulation” when referring to precipitation amounts rather than “sum” (e.g. in Table 1 and on L260–261).

13. I’m confused as to why you focus the opening paragraph of section 3.3.1 and the first three panels of Fig. 4 on the two weeks before your main study period. In my view it would make more sense for Fig. 4 to show more regular snapshots from the study period, so that the reader can more easily see the temporal evolution described in the subsequent two paragraphs. In particular, it would be good to include one snapshot that shows the second cut-off low (C2) and one close to the end of the study period.

14. In section 5.1, you note that several of the rainfall return period maxima in Fig. 13 “have an almost circular shape with the highest value located in the center” and suggest that this characteristic “reflects the very slow propagation of the thunderstorms”. However, could it instead be an artefact of insufficient gauge density? If only only one gauge recorded the event, this information would be spread laterally by the gridding procedure, giving the impression of a small circular shape. It might be worth overlaying the gauge locations on this plot to check how many gauges are associated with each maximum.

15. The description of Fig. 14 at the start of section 5.2 is rather confusing and should be revised. In particular, I found it hard to understand how the distributions for the climatological period were derived.

16. Several of the figures could be improved in a few ways. Specifically, I recommend the following changes:
    - Fig. 3: The top and bottom rows could arguably be combined. In this case, rather than colouring the symbols on the map by rainfall amount you could just make them blue for > 35 mm/h and red for > 60 mm/3h; then use these same colours for the bar plot (with red bars overlaid on blue bars).
    - Fig. 7: I don’t think it’s necessary to state the two thresholds within the plots; this information can be provided in the caption (with reference to the dashed lines).
    - Fig. 12: I would get rid of the hatching showing the objectively identified cut-offs and use a darker contour for the pressure vertical velocity.
    - Fig. 14: It would be helpful to use different colours for the box-and-whisker plots corresponding to the study period and the 1981–2010 climatology. Use the same colour convention for Fig. 9.
    - Fig. 15: In the legend, rather than putting “(2018: N days incl. M skip days)” for each station I would just put “(N/M)” and then explain what these numbers indicate in the caption. So, for example, for Essen you would put “(17/3)” instead of “(2018: 17 days incl. 3 skip days)”.
    - Fig. 16: Rather than plotting the percentage difference from the climatological frequency (which is confusing because it is a percentage of a percentage), I recommend expressing this difference in terms of the standard deviation of the climatological frequency. This will highlight whether the 2018 frequencies were exceptional in the context of typical year-to-year variability.

Technical Corrections

1. There are a few issues with tenses in the text. For example, the opening sentence of the introduction is written in the present perfect tense (use of “has been”), but should be in the past tense (“was”). The same goes for L261. The last sentence of the opening paragraph of section 3.3.3 is written in the simple present tense but should be in the past tense.

2. L23: Parentheses are (are not) for references and clarification (saving space) (Robock 2010). Please modify this sentence accordingly.

3. L36: “...serve to precondition the thermodynamic environment.”

17. L39–42: To which event are you referring here: 2018 or 2016? I suggest rewording this paragraph to make this clear. Similarly, you should state explicitly the event you are referring to on L71.

18. Line 60: Lifting will only lead to the release of CAPE (i.e. convective initiation) if it is sufficient for parcels of air to reach their level of free convection; however, it may still act to destabilise the column (increase CAPE) and erode lids (reduce CIN).

19. Line 90–91: Suggest revising the end of this sentence as follows: “...based on reports from storm chasers, eyewitnesses, voluntary observers, meteorological services, and news media.”

20. L97–98: “...~~the~~ Météo-France (1223/1935 stations with hourly/daily data)...”

21. Line 100: These are the national meteorological services of all the countries in your study so I don’t think you need this last part of the sentence.

22. Line 132: “wind speed and direction”

23. L146: What is the altitude of the lowest level?

24. L199: Change “fewer” to “less”.

25. L239–240: Suggest revising this sentence as follows: “Many of the record-breaking 1h and 3h rain totals occurred within this period (see Sect. 3.2).”

26. L255–256: “...the latter on the day with the second most ESWD severe weather reports (cf. Sect. 3.1).” Rather than referring to the previous section here please specify the actual date.

27. L257–258: You deal with the variations in large-scale forcing for convection later in the paper so I don’t think it is necessary to include this here (unless you want to explicitly refer to the relevant sections).

28. L271: Change “were” to “where”.

29. L272–273: This sentence is confusing and should be revised.

30. L357: Change “vast parts of” to “much of”.

31. L362: Change”exemplarily shown for” to “exemplified by”.

32. Line 380–381: Change “and was already mentioned at the end of Section 3.2” to just “(Section 3.2)”.

33. L510: Advected where?

34. L526: Get rid of “(global/regional)”.