

Review for WCD-2020-1, Revision 1

General Comments

The changes and additions made by the authors have further improved what was already a very good piece of work. However, reading the revised manuscript I felt that the text could be improved in a number of ways. I have tried to cover these in my suggestions below, but I would encourage all coauthors to give the paper a thorough read through before the final submission to make sure that things are clearly explained, particularly when it comes to the methodology. I also have a concern regarding the use of the word “triggering” to describe the role of cut-off lows and PV filaments in the event, which I believe needs to be addressed. As such I am recommending further minor revisions.

Specific Comments

My only significant comment relates to your repeated use of the word “triggering” to describe the role of the cut-off lows and PV filaments in this event. In general, convective triggering refers to the process whereby air parcels are lifted to their level of free convection and subsequently rise through buoyant accelerations. For an individual convective cell (thunderstorm) this process occurs on the scale of a few kilometres to ~100km (i.e. the meso- β or meso- γ scale following Orlanski 1975; see also Markowski and Richardson 2010, section 1.1). On the other hand, lifting associated with cut-off lows and other synoptic-scale disturbances occurs on length scales of 100s of kilometres to ~1000km (meso- α scale). It is generally accepted that this lifting contributes indirectly to convective initiation (triggering) through the generation of CAPE and the removal of CIN, via changes in lapse rate (see Markowski and Richardson 2010, section 7.1) - in other words large-scale ascent *primes* the atmosphere for convective initiation. However, the initiation process itself is typically associated with phenomena such as convergence lines, thermally driven circulations (sea/lake/vegetation breezes), orographic lifting, and boundary-layer thermals, at least for surface-based convection (some elevated MCSs may be directly triggered by large-scale ascent). I think it is important that this distinction is clearly articulated in your paper. As such you need to modify the text in several places, including L56-59, L425, L433-434, L460-462, and L584.

L27-34: You should restructure this part of the paragraph so that the three ingredients for deep moist convection are listed together. State the ingredients first and then discuss the scale of the processes they are associated with (synoptic for instability and moisture; mesoscale to storm scale for the lifting mechanism).

L31: Latent and conditional instability are one and the same (see, for example, http://glossary.ametsoc.org/wiki/Latent_instability). Also, potential instability is generally not considered to be a major factor in the preconditioning of convective environments (see section 3.1.3 of Markowski and Richardson 2010). There are also various other forms of

instability (centrifugal, inertial, symmetric, shear). As such I would just state conditional instability as the first of the three ingredients for deep, moist convection.

L62: It should be “fully” not “full” here. However, I would actually recommend deleting this sentence as it is a bit “hand wavy”.

L78: I would say “mesoscale cut-off lows and PV filaments”.

L82: Get rid of “and their accompanying phenomena”

L84: “prior to”

L87: Get rid of “The next” and add “then” after “Section 4” (i.e. “Section 4 then puts the results in a historical context...”)

L94: Rather than “secondary effects” I would say “associated hazards”.

L103: You need to say “allow us to investigate” or, alternatively, “permit/facilitate an investigation of”.

L126: I think it should just be “Météo-France”, not “the Météo-France”.

L128-129: Here and elsewhere I would use the term “1-hour extreme rainfall events” rather than “hourly extreme rainfall events”. Generally I would take “hourly” to mean “occurring every hour” rather than “lasting for 1 hour”. This is also consistent with “3-hour extreme rainfall events”.

L135: Since “the RR collective” isn’t mentioned again, you can get rid of the statement in parentheses.

L147: “location and scale parameters, respectively”

L150: I think you mean “standard deviation” not “derivation”

L152: You can either just say “return period” here or use the symbol t_{RP} ; you don’t need both as this definition is already given in the previous sentence.

L158: Suggest changing to “12 equidistant vertical levels extending from 1 km to 12 km above ground level (AGL)”.

L169-170: I’m not sure it is fair to assume weaker cells “cannot move at higher speeds” than those above 55 dBZ. I would instead simply note the caveat that your use of a high reflectivity threshold means that the resulting storm-motion estimates may not be representative of weaker convective cells.

L189-190: Suggest modifying the end of this sentence as follows: "...to describe the large-scale meteorological conditions and define weather regimes (see Sect. 2.3), perform kinematic backward trajectories (see Sect. 2.4), and identify cut-off lows (see Sect. 2.5)."

L193: Here and throughout your analysis you should say "bulk wind difference (BWD)" rather than "bulk wind shear". Shear has units of s^{-1} as it is the BWD divided by the layer depth.

L198: Rather than using Z500' for 500 hPa geopotential height anomalies, I suggest using Z500 to represent 500 hPa geopotential height and explicitly stating when you are talking about an anomaly. For example, on L206 you would say "dominated by a negative Z500 anomaly".

L199: Why did you choose the first seven EOFs? What percentage of the total variance do they collectively explain?

L217-218: Presumably, the five "surrounding" grid points are the nearest grid point to the sounding site and its immediate neighbours to the north, south, east and west; however, this should be stated explicitly.

L220: Get rid of "where the air masses relevant for the thunderstorm development are located". Air below 950 hPa and above 600 hPa is certainly relevant for thunderstorms!

L224: Rather than "the literature" I would say "previous studies" (or work or research).

L245-257: This description of the persistence analysis is quite difficult to follow, particularly the first paragraph. As such I would recommend completely rewriting it. Also, as stated in my original review, you should avoid using the term "cluster" here (and in Fig. 15) to avoid confusion with the actual cluster analysis used to define weather regimes.

L257: What do you mean by "the maximum of the daily minima"? Please rephrase.

L268: Get rid of "an area" before "twice the size of Germany"

L275: I think you mean "evolution" rather than "evaluation" here.

L285: What does "(radar visibility)" indicate? Are you saying that the cells were only visible on radar for 30 minutes? Please explain or delete this if it isn't important.

L290: As stated in my original review, you should avoid using parentheses to save space as the resulting sentences are much more difficult to read and comprehend.

L312: This sentence has some grammatical errors. I suggest revising as follows: "However, this rain fell in a period of 3 hours, with 60 mm falling in just 50 min."

L320: Put "indicating wind speeds between 25 and 31 $m s^{-1}$ " in parentheses.

L324-327: This sentence would also benefit from rewording. Something like “In a few cases, deep-layer shear magnitudes were sufficient (BWD up to 20 m s^{-1}) for the development of severe storms, with large hail up to 5 cm in diameter recorded in Southwest France on 26 and 9 June and in southern Germany on 11 June.”

L359: “(Fig. 6a)”

L367: Why introduce the abbreviations “ZO” and “EuBL” here if you aren’t going to use them in the text?

L379: I would say “a pronounced decrease in convective activity”

L385: Get rid of the first instance of “values”

L396: Since your analysis considers geopotential height on constant pressure surfaces you should say “weak geopotential height gradients”.

L403: One way to highlight the strong relationship between V500 and BWD would be to compute the correlation coefficient between the two. You could do this both for the sounding data and the ECMWF analysis over the domain shown in Fig. 8. Just a thought.

L405: Get rid of “squall lines” (MCS covers this).

L407: Not sure what you mean by deep-layer shear. In my experience this is another name for the 0-6 km (or surface-500 hPa) BWD. As noted above, shear has units of s^{-1} , not m s^{-1} .

L409-422: I recommend using the term “air parcels” rather than “air masses” in this section, since the former is more consistent with what a back trajectory represents.

L469-470: Suggest rewording this sentence as follows: “This analysis is restricted to Germany due to the availability of long-term (> 50 years), high-resolution (1 km^2) gridded rainfall data.”

L479: What do you mean by “partly with new all-year records”? Maybe rephrase this.

L480-481: Suggest rewording this sentence and connecting it with the next one (getting rid of the paragraph break in the process) as follows: “This does not appear to be an artefact of insufficient gauge density, as most events are represented by multiple gauges (not shown). Instead, it likely reflects the very slow propagation of storms...”

L493-494: Suggest getting rid of (or moving) the sentence beginning “Recall that...” as it breaks up the flow between the preceding and following sentences. Also, in the next sentence, suggest changing “In doing so” to “Thus”.

L504: Here and elsewhere in this section, change “event persistence(s)” to “CE duration”.

L508-509: Change “event persistences of CE with long duration” to “long-duration CEs”. You might consider completely rewording this sentence as follows: “To put these numbers in context, Fig. 15 shows the relative frequency of CEs in May/June as a function of their duration for the period 1981 to 2010.”

L510-515: This additional explanation of the procedure is confusing and unnecessary. I recommend getting rid of it and the subsequent paragraph break.

L541: Change “convective” to “convection”

L581: Change “due to several reason” to “in several respects”

L611: I’m not sure what you mean by “(e.g. jet stream)”. Please either elaborate or delete this.

Table 1: I don’t think the track length and area are particularly informative, so these can probably be removed. The information on rainfall intensity and storm speed are more useful, but you don’t actually discuss them anywhere in the text.

Figure 2: Rather than saying “the extended study period” I would give the dates explicitly (i.e. 1 May to 20 June).

Figure 3: What do you mean by “total maximum”? Also, as stated in my original review you should say “accumulation” rather than “sum” when referring to rainfall amounts in mm.

Figure 4: I don’t think it is necessary or appropriate to apply a spline filter to the distributions here. Just plot the raw data as histograms (c.f. Fig. 11).

Figure 6: For some reason your color bars have more ticks than colours. Also the number of ticks per color varies and the tick labels don’t always align with changes in the color level. Please make it so that the ticks and labels occur at the boundaries between the colors; otherwise it is difficult for the reader to extract quantitative information from the figure. The caption for this figure also needs revising for clarity. Here is my suggestions: “Mean anomalies during May/June 2018 of (a) 500 geopotential height anomaly (shaded in gpm) and (b) integrated water vapour anomaly (shaded in kg m^{-2}), together with the mean 500 hPa geopotential height (contours every 40 gpm). Data are from ERA-Interim and anomalies are computed with respect to the 1981-2010 climatology.”

Figure 7: Panel (a) needs to be better explained in the caption. In particular you should state the meaning of the bold sections of the curves and the colours along the x axis. Also, in panel (c) the y axis should be labelled as “ $V500 (\text{m s}^{-1})$ ”.

Figure 8: Add “at 12 UTC” before “averaged over the study period” and get rid of “12 UTC” from the parentheses at the end.

Figure 9: Please explain either in the caption or the main text how the ellipses were defined. Also, I suggest using “distance along trajectory” instead of “total distance”.

Figure 13: Change “Return periods” to “Return period” (singular).

Figure 14: I think you mean “2nd and 3rd quartiles” (not “1st and 3rd”). Also, I would recommend making the whiskers and outliers the same colour as the boxes and using solid rather than dashed lines for the whiskers.

Figure 15: As noted above (and in my original review) you should avoid using the term “cluster” in this analysis. Instead I recommend using “CE duration” (this should also replace “event persistence”). Also, it should be “May”, not “Mai”.

Figure 16: I believe this information could be better presented in Fig. 10, by replacing the Z500 contours (which are already shown in Fig. 6) with the climatological cut-off low frequency. This way the reader can directly compare the climatological and 2018 cut-off low frequencies without the need to consider anomalies of percentages. You can then get rid of Fig. 16.