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Interactive comment on "The role of large-scale dynamics in an exceptional sequence of severe thunderstorms in Europe May/June 2018" *by* Susanna Mohr et al.

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#2 Review for WCD-2020-1 (RC1 from 23 Feb 2020) Overview: The paper presents a case study of a long-lasting thunderstorm series over France/central Europe in May/June 2018 that occurred south of a blocking high. The synoptic situation persisted for several weeks. The thunderstorms were associated with cut-off lows/potential vorticity filaments that formed on the south-west of the blocking high. As a result, numerous severe convective events such as flash floods, hail and wind gusts were recorded. The authors use multiple different data sets and methods to show how the large-scale dynamics contribute to the thunderstorm series and that this event was exceptional.

AC: We thank the reviewer for the time taken to review our manuscript and for his useful comments.

Overall, I like the author's idea of studying this event from synoptic down to the convective scales. Moreover, it is an interesting case. However, I think the manuscript was difficult to follow and can still be improved considerably. In the current form, it was unfortunately no pleasure to read through the study. My main criticism is that large parts of the paper (chapter 2,3,4, but also in the introduction) read like a collection of single parts which are not really connected with one another. A central theme seems to be missing. I think, the authors should restructure the paper or parts of it and follow a clear path, e.g. from large-scale to the small scale or the other way around. If this is not possible, they should at least clarify the purpose of each (!) chapter at the beginning (as it is done in chapter 5) to facilitate the reading.

AC: We will edit several text passages (linguistic and structural revision), in particular rewrite the introduction, better link the individual chapters and better highlight the interesting point of our study (description of a case study of a thunderstorm episode, which was particularly influenced by large-scale processes (blocking and enhanced cut-off frequency) resulting in the long lasting event). We believe that this will help to improve these points.

Moreover, in my opinion, the writing can be improved, too. Some sentences are too long, which makes the text hard to read. Just write necessary information and just reference to papers that are relevant for your topic. Make the sentences clear and concise. Please connect the single chapters and (sub)sections with one another!

AC: Long sentences are typical for Germans. We will take this criticism into account in the next script version and will endeavour to reduce long sentences, to make sentences clearer and more concise, and to connect the individual chapters better.

I will explain my criticism in more detail in the following:

(i) In the introduction, the authors switch strongly between different topics: first they introduce the case and its impacts in a few sentences. Then they describe convective development due to scale interactions (mainly lifting processes). Afterwards they describe the case again with focus on blocking which is described more general thereafter. In the successive part, the authors explain cut-off lows in the potential vorticity framework. Afterwards they switch back to the topic of blocking. However, these single parts are often unconnected with one another which is confusing for the reader!

AC: We will rewrite the introduction to clarify the points criticised and to better structure aspects necessary for the paper.

(ii) In the data and methods chapter (chapter 2), data sources are often introduced without clarifying why the authors will need the data. At least some overview at the beginning of this section – how the study was designed and/or what data satisfies which purpose – would help the reader tremendously!

AC: We will take this point better into account and integrate it in the relevant parts.

Are there any new methods? Please clarify!

AC: Please, see comments below.

(iii) The same applies for chapters 3,4, and partly 5! Try to connect the single parts, try not to jump unnecessarily between topics. In the current version, it is really confusing for the reader.

AC: We will edit several text passages to better structure aspects necessary for the individual chapters.

(iv) With respect to the methods my main concern is the usage of the 500hPa-wind instead of vertical wind shear. At least additionally analyzing shear had the advantage that your work can be compared more easily to the existing literature of convective events.

AC: We had made a conscious decision to show V500 and not the shear (although we had already examined both). One reason for V500 was the connection with the propagation speed of the cells (see also the comment on propagation speed below), since our focus in the work was not to analyse the organizational structure of the cells using wind shear. Since we have observed very low near-surface wind speeds in several cases, the wind at mid-tropospheric levels is more or less identical to wind shear. However, we will check this again. Perhaps, we will add the results for wind shear to one of the figures (where it will also become clear that there are only very few differences). A first idea would be Fig. 7, 8, or 14.

(v) Furthermore, I am missing evidence, that the thunderstorms have been single cells rather than multicells, MCS or slow-moving (HP) supercells.

AC: Separating the convective cells among their organization form might be an interesting issue, but is far beyond the content and aim of our paper. Furthermore, we do not have an algorithm that allows us to adequately identify this. Instead, we suggest weakening the statement about the single cells. In addition, we will check the cases in 2018 (especially those mentioned in table 1) with radar images and add some comments in the text.

Specific minor comments:

Abstract, p.1 line 2: "80mm" - what is the temporal range? a few hours?

AC: See Table 1 Theoretically several time scales are possible (1 h, but also in 3 h). We will add an information.

p.2, line 25-36: I am missing the general ingredients of convection here: instability, moisture, lift and shear. The ingredients-based concept is first mentioned in the Discussion chapter (chapter 6), I think it would be fitting in the introduction, too. Moreover e.g. Markowski and Richardson, 2010 (their chapter 10.4) & Doswell III, C. A., Brooks, H. E., & Maddox, R. A. (1996): Flash flood forecasting: An ingredients-based method-

ology. Weather and Forecasting, 11(4), 560-581. treat flash flood events. Especially in the Markowski and Richardson book, you can find a very similar synoptic pattern that led to flash flood events in the US (please refer to the publications mentioned therein).

AC: We will include the suggested literature and some comments on this.

p.2, line 34: "all these mechanisms" - which ones are meant here?

AC: All those mentioned before; this paragraph will be completely revised anyway. We will take care not to make this point too general.

p.2, lines 51-61: There are some publications concerning the PV framework and convection: e.g. Russell A, Vaughan G, Norton EG. 2012. Large-scale potential vorticity anomalies and deep convection. Q. J. R. Meteorol. Soc. 138: 1627–1639. DOI:10.1002/qj.1875; Morcrette CJ, Lean H, Browning KA, Nicol J, Roberts N, Clark PA, Russell A, Blyth AM. 2007. Combination of mesoscale and synoptic mechanisms for triggering of an isolated thunderstorm: a case study of CSIP IOP 1. Mon. Weather Rev. 135: 3728–3749. Can you please put your work in context with the existing literature?

AC: Thank you for your literature suggestions; we will put these works in the context of our study (or introduction).

p.3, line 62: "A connection between atmospheric blocking and heavy precipitation events..." - Why again blocking? The sentence is almost identical to that on page 2, lines 49-50. Why don't you merge these parts?

AC: We will rewrite the introduction.

p.3, line 68-70: "[..] such situations are usually associated with weak wind speeds at mid-tropospheric levels (cf. PIP16), so that thunderstorms become almost stationary and usually do not develop into organized structures such as large mesoscale convective systems or supercells." – First: where is the wind weak? in the high, the low, at the western flanks?

AC: Over the investigation area in the mentioned paper, we will clarify this.

Second: What about HP-supercells (high precipitation supercells)? Can you please comment on HP-supercells.

AC: HP-supercells might have occurred. As we haven't investigated that, I'd suggest to change the sentence into "usually associated with weak wind speed at mid-tropospheric levels and, thus, weak vertical wind shear with the consequence that thunderstorms become almost stationary and rarely develop into organized convective systems."

p.3, line 83: What do you mean with "secondary effects"? Please elaborate.

AC: Their sub-perils (e.g., hail, heavy rain, wind gusts); we will clarify this.

p.3, line 85: "(May/June)" - These are the whole months (1.5-30.6)? It is confusing since you already stated two different periods in the text before.

AC: Yes, the whole month; we will add this information (1 May to 30 June).

p.4, line 87-93: Please clarify what the purpose of the ESWD data is. Do you use different quality levels or all? Why don't you show the reports also in e.g. Belgium or Italy?

AC: The purpose of the ESWD data is to show the sub-perils associated with the thunderstorms, and that these were preferably heavy rain events. We use all data above QC0+ (we will add this). ESWD Data from Belgium have already been used (see Fig. 2). Maybe you mean the precipitation data from Belgium (here we were not able to get any). Data from Italy are not included because Italy is not included in our study area (see L: 81/82 "The study area includes parts of central and western Europe - France, Benelux (Belgium, Netherlands, Luxembourg), Germany, Switzerland and Austria (see Fig. 1) – for which data were available").

p.4, line 88: It is good to know that the ESWD collects data about heavy rain, hail and

wind gusts. However, what data did you use for the analysis?

AC: All these three sub-perils. We will add a comment.

p.4, line 90: better: "[..] mainly based on reports of storm chasers, [..]"

AC: We will correct this.

p.4, line 108: Is there a description of the REGNIE data in English for non-Germans, too?

AC: Not really, but about HYRAS, which uses the same methodology and which is already cited (Rauthe et al., 2013).

p.4, line 104-111: Why did you decide to use the REGNIE data. The data seems to interpolate measured precipitation on a regular grid. Is the REGNIE data suitable to analyse extreme convective precipitation which might be short in duration and small in scale? Or might these extremes be smoothed during the interpolation process? Did you consider to use a highly-resolved reanalysis data set for comparison reasons?

AC: We used REGNIE data only for the estimation of return periods because of their long-term availability of approx. 70 years, and the large number of approx. 2,000 climate stations used in the regionalization method. RADOLAN data (merger between Radar and station data) would be a better choice, but are available only for 20 years and, thus, not suitable to estimate return periods. Reanalysis also tend to underestimate precipitation totals. We will explain in the new version of the text, why we used REGNIE data (in addition to other station data).

p.4, line 109-111: "Note that the REGNIE time series are affected by temporal changes in the number of rain gauges considered by the regionalization. For our purpose, the homogeneity of the data are sufficient." – Can you please give a reference here? Did the number of stations change in the analysed period?

AC: We will included the reference Rauthe et al. (2013). Unfortunately, there is no

recent reference available; also the exact number of stations for the regionalization is not known (it was approx. 2,000 stations in 2011).

p.4, line 115: "[..] appropriate for precipitation statistics [..]" - can you please give a reference here and explain a bit more in detail what was done in the previous literature with the Gumbel distribution.

AC: That's right, "precipitation statistics" is a little too generic. We will change this sentence into: "The Fisher-Tippett Type I distribution, also known as the Gumbel distribution (Gumbel, 1958; Wilks, 2006), has been extensively used in various fields including hydrology for modelling extreme events, i.e. to estimate statistical return periods or return values (Sivapalan and Blöschl, 1998; Rasmussen and Gautam, 2003). The Gumbel cumulative distribution function (CDF) is given by:"

p.4, line 112-123: General comment: Is this method new? If so, please state here, otherwise, please write something like: "we follow the methodology used in..."

AC: No, is not new. We will clarify this and add a reference (e.g. Wilks, 2006).

p.4, line 116: R is not explained.

AC: That's correct. We will add this (R is the investigated variable, here precipitation values.)

p.5, line 117: Can you please give a reference for the "Method of Moments". If it is also explained in the Wilks-book, maybe you can add the chapter to the reference here.

AC: Yes; it is explained in Wilks (2006) in Chapter 4 (Parametric Probability Distributions).

p.5, chapter 2.1.3: What will you use the data for?

AC: To show the affected area in our study region. Lightning data are the best direct observation data for the thunderstorm detection, as they provide the best spatial (complete) coverage (but without reference to the respective sub-peril and no direct relation

to intensity of the event. For this, we use ESWD data and rain measurements. We will add a comment on this.

p.5, line 132: what parameters will be taken into account to estimate the "atmospheric conditions"?

AC: As already mentioned the SLI; others are V500 (perhaps shear). We will add a comment on this.

p.5/6, chapter 2.1.5: Can you conclude from the radar data, if the thunderstorms rotated? For example by comparing the direction of the mean tracks to the investigated severe thunderstorms?

AC: For proper detection of rotation in radar data you need the Dual-Doppler wind fields, which we do not have. And even with that the detection or rotation is very difficult (we didn't even detect rotation in the radar data of the severe supercell on 28 July 2013; cf. Kunz et al., 2018). Because the track direction depends – in addition to vertical pressure disturbances - on various effects such as the vertical extent of the cells relative to the wind shear or the formation of new cells (particularly in case of multicells), a comparison between the two as suggested would not allow to give any conclusions about the rotation of the cells.

p.6., chapter 2.2: What fields will you use?

AC: We will add a more detailed description (e.g., SLI, V500, PV, Z500, IWV, . . .).

p.6, line 172/173: "[..] but reflects important seasonal differences." - What do you mean here?

AC: Classical weather regime definitions typically distinguish summer and winter regimes. Our year-round definition contains these seasonal different patterns and therefore has more regimes than classical definitions. Still these patterns kann occur in any season and are important for local weather conditions.

A figure showing the weather regimes would be nice, at least later in the text, where you analyse the data, you could show the typical patterns of the prevailing regimes.

AC: The illustration of the Atlantic-European weather regimes can be found in Grams et al., 2017 – in the Supplementary information (Supplementary Figure 1) for the winter season. We will provide the typical patterns (for the summer season) as supplementary material for faster availability.

p.7, chapter 2.4: Is this method new or does it already exist? Please clarify.

AC: Similar approaches have been used to relate surface weather to weather objects in earlier work (e.g., Pfahl and Wernli 2012, 2014; Pfahl et al. 2014). We will clarify this now in the text. Still as far as we know this is the first study matching lightning data to cut-off cyclones. Pfahl, S., and H. Wernli, 2012: Quantifying the Relevance of Cyclones for Precipitation Extremes. J. Climate, 25, 6770–6780, doi:10.1175/JCLI-D-11-00705.1. Pfahl, S., and H. Wernli, 2012: Quantifying the relevance of atmospheric blocking for co-located temperature extremes in the Northern Hemisphere on (sub-)daily time scales. Geophys. Res. Lett., 39, L12807, doi:10.1029/2012GL052261. Pfahl, S., E. Madonna, M. Boettcher, H. Joos, and H. Wernli, 2014: Warm Conveyor Belts in the ERA-Interim Dataset (1979–2010). Part II: Moisture Origin and Relevance for Precipitation. Journal of Climate, 27, 27–40, doi:10.1175/JCLI-D-13-00223.1.

p.7, line 197: general comment: The Brunt-Vaisala frequency is smaller in summer, too, due to decreased stability.

AC: Here we aim to provide a physical justification for the scale of our buffer radius not an exact estimation which would depend on each specific case. We think our scale analysis yields a reasonable estimate of a remote influence and that seasonal variation in stability would not change the order of magnitude. In addition, we tested the sensitivity to a range of buffer radii with now impact on our qualitative interpretation.

p.7, line 199-203: You could add a table to the supplementary material showing the

change in associated lightning.

AC: Good suggestion; we will include a table in the supplementary materials.

Moreover, it would be nice to see this "buffer zone" in the figures.

AC: However, showing the additional buffer zone can be problematic – it is probably only possible as an example. We will check this.

p.8, line 211-214: Why do you use the wind speed at 500hPa instead of the deep-layer shear? Additionally, deep-layer shear is a widely used variable and the results would be better comparable to the existing literature. I do not understand the motivation here, especially since the authors later in the paper discuss the importance of shear on the organization of thunderstorms.

AC: We had made a conscious decision to show V500 and not the shear (although we had already examined both). One reason for V500 was the connection with the propagation speed of the cells (see also the comment on propagation speed below), since our focus in the work was not to analyse the organizational structure of the cells using wind shear. Since we have observed very low near-surface wind speeds in several cases, the wind at mid-tropospheric levels is more or less identical to wind shear. However, we will check this again. Perhaps, we will add the results for wind shear to one of the figures (where it will also become clear that there are only very few differences). A first idea would be Fig. 7 or 8.

p.8, line 216: "Overview" - Can you please be more precise, there is another chapter which is also called overview. What is you intention of this whole chapter?

AC: A first description if the event episode in 2018 based on direct observation (lightning data, ESWD) to demonstrate the severity. We will rename the section title. Perhaps, we will combine the Section with Section 3.3.2 and called it “(Overview of) direct observations” during the thunderstorm episode.

p.8, line 222/223: "The three-week period from 22 May until 12 June was the most

active thunderstorm episode with a total of 868 heavy rain, 144 hail, and 145 convective wind gust reports based on the ESWD." - do you mean "the most active thunderstorm episode" in the year 2018 or inother period?

AC: During our extended study period (1 May to 20 June) or also in May / June 2018. We will clarify this point.

p.8, line 223/224: "An average area of 715,000 km2 was affected by lightning per day" - is that much, what is the average value for Europe?

AC: Yes, this is twice the area of Germany per day, that’s much! Do you really think it’s necessary to give an average value? I’d suggest to include the relation to the area of Germany.

p.8, line 227/228: "As shown in Figure 2b, most of the severe weather reports came from the western part of France, Benelux, central and southern Germany, and the easternmost part of Austria." - Can you explain the gap in central/eastern France? From your Fig. 8 Lifted index was negative, too. Moreover, the mean wind was not much different from western France?

AC: This could depend on the availability of storm chasers, eyewitnesses, or voluntary observers. In addition, the orography could also have an influence in Central France (Massif Central) on thunderstorm activity and/or the reports possibilities. We will verify this by investigating the (spatial) lightning density (or thunderstorm days) during the whole study period/area and add a comment.

p. 8, line 241: Isn’t the number of ESWD reports depending on the number of people reporting events? Is there a difference if you just use some of the quality levels?

AC: Right. And the quality levels can’t fix this. The reports in the ESWD are absolutely controlled by the activity of the different people. Here, the population density plays a significant role or where the most active "reporters" live and what their area of investigation is. There are very severe events, which have smaller number of reports that

less severe events. But what/how exactly defines severe events?

p.9, line 252: "low wind speed [..] slow propagation" - You could mention here, that you will give more details later in the text. While first reading through the text, I wondered if these statements will be verified later or just stated as a fact here?

AC: We will follow the suggestion and add a reference.

p.9, line 257: What is meant with "The strength and spatial extent of the lifting forcing varied from day to day, [..]"? Can we see this in one of the figures?

AC: Not directly. We will delete the sentence.

p.9, line 260-273: Just write about the events that are explained in more detail. All other numbers will just lead to confusion and can be seen in the table.

AC: Ok, we will follow the suggestion.

p.10, chapter 3.3: It would be reader-friendly if you explained what the intention of this chapter is. Please give an introductory sentence.

AC: We will do this (between Sect. 3.3 and Sect. 3.3.1).

p.10, lines 292-303: It would be a helpful addition if you overlayed the ESWD data. This would make it easier to follow your arguments.

AC: We will check whether this is graphically implementable (e.g., only precipitation reports as small points for each time step/panel).

p.11, lines 312-313: Can you please plot the typical patterns of the Zonal regime and the European Blocking.

AC: We will provide the typical patterns (for the summer season) as supplementary material.

p.11, lines 315-323/line 330: Can you plot in Fig 6/7a+b additionally to the regimes/sounding data, the lightning activity (out of Fig. 2a) for easier comparisons.

AC: We will implement this.

p.12, line 348/349: "Because of the low wind speed in the mid-troposphere, most of the thunderstorms moved very slowly or even became stationary." - The motion of thunderstorms is not necessarily determined by the wind at 500 hPa – can you please give a reference that shows that the storm motion correlates with 500 hPa winds.

AC: The propagation of convective cells is driven by various factors such as gust-front lifting in case of multicells and vertical pressure gradients extending over a deep in case of supercells. For single cells, however, no such processes occur or are relevant and the propagation is related to the mean flow, i.e. the vertically average winds. We took the 500 hPa wind as a proxy because proper determination of the vertical extent – even though possible – would be out of the context of this paper. We will modify this statement and include a reference. For example Houston and Wilhelmson (2012) & Markowski and Richardson, 2010). @Article{houston12, author = {Houston, Adam L and Wilhelmson, Robert B}, title = {The impact of airmass boundaries on the propagation of deep convection: A modeling-based study in a high-CAPE, low-shear environment}, journal = {Mon. Wea. Rev.}, year = {2012}, volume = {140}, pages = {167–183}, doi = {doi:10.1175/MWR-D-10-05033.1},}

p. 12, lines 358-360: "The fact that relatively high PV cut-off frequencies expand over a larger region of western Europe underlines that multiple individual PV cut-offs form on the upstream flank of the blocking ridge, and intermittently move across Iberia, France, the British Isles, the North Sea, and Germany [..]" - How do you distinguish between a stationary cut-off low and newly-formed moving ones in Fig. 10? Please clarify.

AC: We concur that this statement was misunderstandable. We here only refer in the first half of the sentence to Fig. 10 (now reference included after ". . . western Europe (Fig. 10) underlines that . . .". The occurrence of multiple cut-offs was explained in the synoptic overview Fig. 4. The references "(see Fig. 4)" is now earlier in the sentence ". . .of the blocking ridge (see Fig. 4), and intermittently . . ."

p. 13, line 396: better: "To estimate the severity of the rainfall with respect to the rainfall climatology, [..]"

AC: We will change this.

p. 13/14, chapter 5.1: I wonder if the return periods are dependent on the REGNIE data and how it is designed. Is it possible to get higher precipitation amounts than observed at the stations? Can you please comment on this?

AC: Yes of course, all extreme value estimates depend upon the used data set. REGNIE certainly underestimate the precipitation peaks, but this is the case for both the observation period and the reference period of 50 years. We will add a comment on this.

p. 14, chapter 5.2: If I understand it correctly, the only thing one can directly compare in Fig. 14 - left vs. right boxes-and-whiskers - is the median on the left with the complete box-and-whiskers on the right? Maybe you could add the median of the actual period as an extra symbol to the right box-and whiskers.

AC: We will implement the suggestion in Fig. 14.

p. 14/15, lines 435-448: Although, your main intention is presumably, that the investigated storm period is a rare event. From your text, I could not understand how Fig. 15 was produced. Can you please rewrite the text passage and clarify.

AC: We will rewrite this description to make it more understandable.

What is meant by skip days and why do you use 3 instead of 1 as in the referenced paper? Please explain.

AC: One skip day per (started) week; already PIP16 used 2 skip days for two weeks. Since in this study, the persistence is longer – at least three weeks – three skip days are possible.

p. 15, lines: 463-466: "A further relevant condition for the evolution of deep moist

convection is the vertical wind shear or, more generally, the wind at mid-tropospheric levels, which is decisive not only for the organizational form, the longevity and thus the severity of the convective storms (e.g., Weisman and Klemp, 1982; Thompson et al., 2007; Dennis and Kumjian, 2017), but also for their propagation (Corfidi, 2003)." - As far as I know, all the cited papers talk about the vertical wind shear, but not about the wind at mid-tropospheric levels (although they might mention storm-relative winds, but this can be quite different from the mid-tropospheric wind). Of course, I can be mistaken, hence, please cite the text passages of the papers, where the mid-tropospheric wind is mentioned in your authors's response.

AC: We will clarify that when in cases with very low near-surface wind speed the wind at mid-tropospheric levels is more or less identical to the wind shear. This is clumsily expressed in the sentence quoted.

p. 16, lines 475/476: "[..] air masses were trapped [..]" - Is it possible to show, that the air masses were trapped over several weeks (e.g. by using trajectories)?

AC: Good suggestion; we will check this (by working with the Lagrangian Analysis Tool, LAGRANTO from Wernli & Davies, 1997) and comment/include the results. Wernli, H., H. C. Davies (1997): A Lagrangian-based analysis of extratropical cyclones. I: The method and some applications, Q. J. R. Meteorol. Soc., 123, 467–489, doi:10.1002/qj.49712353811.

p. 16, lines 484-485: "In our investigated case, thunderstorms were often triggered by large-scale lifting associated with upper-level cut-off lows or filaments of high PV that separate from the main PV cut-off" - I am convinced that the cut-off lows provided good environmental conditions for convection, however I doubt that the cut-off lows triggered the thunderstorms directly. What about (older) outflow boundaries? Can you please comment on that?

AC: That's correct. Thunderstorms are triggered by a variety of mechanisms. Large-scale uplift by itself won't bring air-packets up to LFC height, speeds are too low (resp.

time scales would be too long for that). Rather, it is the decrease in CIN and the increase in CAPE that are relevant here. We will specify the wording, e.g., we will not speak of trigger (in the direct sense), but of large-scale conditions.

p. 16, lines 490-496: Especially since the precipitation amounts are so high, how do you know that the thunderstorms were mainly single cells? Moreover, did you mention at any point in your paper, how you differentiate between single cells and other convective thunderstorm types like multicells? Maybe you can put the radar movies for one of the extreme cases you talked about to the supplemental material?

AC: Only by visual observation from radar data (we do not have an algorithm which allow to identify the various organisational structures (see also comment above (v)). But we will comment the cases in Table 1 (by naming the type observed). Furthermore, we will check how many days (during the study period) we observed mainly single cells (but also only visually).

Figures:

Fig. 2b: Please do not use the rainbow color scale. It is hard to differentiate between some days. Maybe if you switch to a sequential scale, it might be possible to see some temporal clustering?

AC: We will modify the colorbar.

Are there really no events in northern Italy, the Czech republic or Poland?

AC: Data from Northern Italy, the Czech republic or Poland are not included because these are not part of our study area (Homogeneity reasons) (see L: 81/82 "The study area includes parts of central and western Europe - France, Benelux (Belgium, Netherlands, Luxembourg), Germany, Switzerland and Austria (see Fig. 1) – for which data were available").

Fig. 3b: I cannot see any difference between the blue colors here.

AC: We will modify the colorbar.

Fig. 4: Is it possible to add the locations of the ESWD reports of the associated day to maps?

AC: We will check whether this is graphically implementable (e.g., only precipitation reports as small points for each time step/panel).

Fig. 6: It is impossible to differentiate between ZO/SCTr, EuBL/SCBL and AT/GL.

AC: We will change the colours to make these regimes better distinguishable in Figure 6.

Can you add the affected lightning area (from Fig 2a) to the curves.

AC: We will implement this.

Fig. 7: Is it possible to add the lightning data from Fig 2a?

AC: We will implement this.

Fig. 12: There is no red hatching (in my print it looks black?). Is it possible to add the buffer zone?

AC: Oh, sorry in an older version of the Figure the PV on the 325 K isentropic surface was red. Thanks, we will change this. However, showing the buffer zone can be problematic / to much information in one figure– it is probably only possible as an example. We will check this (for example, a contour filled with small points).

Fig. 14: Can you please add the median from the left box-and-whiskers as an extra symbol to the right ones?

AC: We will implement the suggestion in Fig. 14.

Please also plot the deep-layer shear.

AC: The point with the deep layer wind shear we will check if there is an added value

in this figure (or is the same/to similar; see comments above/beginning if the review)

Interactive comment on Weather Clim. Dynam. Discuss., https://doi.org/10.5194/wcd-2020-1, 2020.