Meyer et al. 2021, "More frequent flash flood events and extreme precipitation favouring atmospheric conditions in temperate regions of Europe"

Summary: This study investigates changes in the frequency of flash flood events in central Europe and concomitant changes in extreme precipitation and atmospheric variables promoting heavy rainfall. The database of flash flood events is compiled from reinsurance, literature review, and personal communication and connected with heavy rainfall events using a radar network across Germany to determine ERA5 grid cells in which the radar indicated rainfall exceeds 40 mm h^{-1}. ERA5 grid cells containing and neighboring the precipitation event are then used to study changes in atmospheric variables promoting heavy rainfall using instability indices, moisture, and storm motion values. While the number of flash flood events show a slight increase over time, precipitation events and their rainfall characteristics exhibit little change. These precipitation events are often associated with some CAPE, high moisture, and weak winds. Of these variables, moisture shows the largest and most significant increase over the study period, while CAPE and CIN showed a loss noticeable increase, and storm motion/shear in some places exhibits decreases. Therefore, while the authors showed that flash flood events are increasing in frequency over time, they could not link this to changes in rainfall, but rather more favorable rainfall environments. This is an interesting study, but several major points need to be addressed before publication.

General comments:

- A major limitation of this study is the lack of flash flood events, particularly before 2006, and how they are identified. While the authors acknowledge this limitation in lines 332-333, I wonder if this is not an issue of a lack of flash flood events in the past, but a limitation of the observational record they use to define flash flood events. Flash floods are defined by news reports, prior literature (I am guessing case studies?), water agency reports, and reinsurance data, which are all prone to human error, including the need for people to observe the flood and report it as noteworthy. I wonder if they can incorporate any physically based indications of a flood event by including streamflow observations. This could address the dearth of floods prior to 2006 and remove some of the inherent bias in the human-based indications of flooding.
- The connection between the flash flood events and extreme rainfall is unclear in the present form of the manuscript. The only description of how these events is linked are in lines 172–173 where the authors state that they include all floods that directly follow extreme precipitation. What is the temporal scale used to determine what "directly follows" means? Is this an hour, several hours, or a day? Please be explicit in stating this. Also, what is the spatial requirement for a flood event being connected to an extreme precipitation event? Please describe this in more detail. Finally, the independence of flood and precipitation events must be discussed. For example, if a flood event occurs on two consecutive days, is that considered the same event? Again, please discuss this in more detail.
- It seems odd to me that despite an increase in more favorable rainfall environments over time, little trend is observed in changes to extreme rainfall. While the authors discuss

possible reasons why this is in the discussion section, I wonder if it would be helpful to include other sources of rainfall data (like rain gauges or even ERA5, despite their limitations), to see if the same lack of a trend is reproduced.

Specific comments:

- Lines 59–62: There are some contradictions in these lines as to how you refer to precipitation events that trigger floods. In line 59, you state that they are characterized by high rainfall amounts over a short period of time, while in the next few lines, you say that the rainfall also lasts over longer periods of time. What do you mean here? Please be clear if these are short or long duration rainfall events. Perhaps providing typical durations could be helpful here.
- Lines 67–70: I am not sure I understand what you are saying here–which processes are you referring to? Do you mean the upscale growth of convective cells into organized convection, like a mesoscale convection system? Please be more specific.
- Line 80–81: I would also cite Schroeder et al. (2016) regarding a larger warm cloud depth leading to higher precipitation efficiency.
    - Schroeder, A., et al., 2016: Insights into atmospheric contributors to urban flash flooding across the United States using an analysis of rawinsonde data and associated calculated parameters. *J. Appl. Met. and Clim.*, **55**. Doi: https://doi.org/10.1175/JAMC-D-14-0232.1
- Lines 83–84: Large rainfall systems can also result in long duration storms (Doswell et al. 1996).
- Line 88: I would start a new paragraph here at "Proxy parameters.." since this paragraph is already quite long.
- Lines 91–93: The results of this study seem to contradict your previous sentence stating that bulk wind shear can be used to estimate precipitation efficiency if heavy precipitation occurs over a variety of DSL values. How do you reconcile this conflict?
- Line 114: Please also cite Rasmussen et al. (2017), as they were among the first to discover the increasing CAPE/decreasing CIN paradigm:
    - Rasmussen, K. L., A. F. Prein, R. M. Rasmussen, K. Ikeda, and C. Liu, 2017: Changes in the convective population and thermodynamic environments in convection-permitting regional climate simulations over the United States. Climate Dyn., 55, 383–408, https://doi.org/10.1007/S00382-017-4000-7.
- Line 175–176: Are this 8 neighboring grid cells centered around the precipitation event grid cell? What if the precipitation event takes up multiple grid cells?
- Lines 205–215: Did you perform a sensitivity test to see if taking the RH or winds at different pressure levels aside from 700 hPa affected your results?
- Line 240: how would your results look if you omitted the year 2016? Would it still be an increasing trend?
- Line 258: what does "all hourly values" refer to? Is it the time of the precipitation event and the flood event combined or something else? This needs to be described in more detail. Also, how long, on average, are the precipitation events and the flood events?

- Lines 261–262: Half of the distribution is above 100 J Kg^{-1} of CIN, which is moderate CIN, so I do not believe saying high values of CAPE are often accompanied by low values of CIN is entirely accurate.
- Lines 273–274: Given the low wind speed and weak DSL, this likely indicates that these storms are slow-moving single-cell thunderstorms. This is interesting, because many flood-producing storms tend to be larger and more organized mesoscale convective systems (Ashley and Ashley 2008; Schumacher and Johnson 2006):
    - Ashley, S. T., and W. S. Ashley, 2008a: The storm morphology of deadly flooding events in the United States. Int. J. Climatol., 28, 493–503, https://doi.org/10.1002/joc.1554.
    - Schumacher, R. S., and R. H. Johnson, 2006: Characteristics of U.S. extreme rain events during 1999–2003. Wea. Forecasting, 21, 69–85, https://doi.org/10.1175/WAF900.1.
- Line 282: CAPE at or exceeding 100 J kg^{-1} is not high, but rather weak. I recommend you edit language throughout the paper to reflect this.

Technical corrections:

- Line 66: I would consider using a different word rather than “neglected” such as “slowed” or “halted”.
- Line 228: I would replace “prove” with “test”.
- Figure 3: Please describe what each of the panels are showing.
- Line 281: I believe you meant to stay Table 2 instead of Table 1, correct?