Attribution of precipitation to cyclones and fronts over Europe in a kilometre-scale regional climate simulation
wcd-2020-18

General comments

The aim of this study is to use high-resolution data to quantify the precipitation associated with different weather systems over Europe. In general, the authors have achieved this aim. The paper is clear, and the analysis well presented. However, the abstract does not reflect the quantitative aspect of the paper and simply lists the qualitative results, many of which are supported by previously published work in the literature. What is novel about this study is the development of a methodology which can be used to quantify the extent to which, for example, cold fronts produce more heavy precipitation than warm fronts. This kind of quantitative result should be included in the abstract. Furthermore, there is not enough motivation/context for the work, or inclusion of the wider implications. How might the methodology and results impact forecasting, model development, understanding of precipitation? How might the methodology be used in the future to investigate precipitation in a changing climate? Finally, while the conclusions contain a nice summary of the methodology and its limitations, no such caveats are applied to the discussion of the climatological results. This study is based on only 9 years of data and there are many studies that have shown that decadal variability in cyclone frequency and location exists. Therefore, these caveats must be included in the discussion since conclusions based on 9-years of data may not represent a longer climatology.

Specific comments

1. Lines 70-75. Regarding the interaction with orography, it seems amiss that reference to the seeder-feeder mechanism for generating localised heavy precipitation is missing (e.g. Browning et al. (1973).
2. Line 117. The authors state that the model is free to evolve precipitation systems that may differ from reality despite being forced at the boundaries by re-analysis data. Have they performed analysis of individual precipitation events? Are convective rather than synoptic scale events more likely to be different from reality? Does this affect the conclusions?
1. Line 143. How frequently are the boundaries forced by ERA-Interim data?
2. Line 145. Is the model orography at different resolution for the 12km and 2.2km resolution simulations? If so, does this affect the results?
3. Line 158. What do the authors mean by ‘Paste’ these into the 12km fields?
4. Line 176 and 241. What is the width of the Gaussian filter? Was this an arbitrary choice or was some sensitivity testing performed to gain an optimal choice?
5. Line 208. Which input fields are the authors referring to? Could they be more specific please?
6. Line 225. Why are short-lived fronts discarded in this study? Do they contribute to local precipitation, for example precipitation can sometimes be seen at the leading edge of sea-breeze fronts which are short lived?
7. Line 231. I didn’t follow the reasoning for defining local fronts by their size and stationarity. Surely it would be more logical to present the definition of synoptic fronts as large and non-stationary and thus assume the remainder are local (if they occur close to orography or coastlines) rather than the other way around.
8. Line 267. For the far-frontal precipitation, do these features need to be also within a cyclone mask, or are both local and synoptic fronts included in this classification?
9. Line 273. During the subjective evaluation of the distance thresholds, was any seasonality identified? I.e. did similar thresholds capture the frontal precipitation in both winter and summer?
10. Figure 2. This schematic implies that cyclonic and cold frontal precipitation are mutually exclusive. I guess this is not necessarily true, especially during the early stages of cyclone evolution. Also, given the cyclone is part of a larger-scale wave pattern, the location and shape of the high-pressure region in the schematic seems a little odd. What is the reasoning behind the shape and position of the high-pressure region in the schematic?

11. Figure 3. This figure is too small to see the detailed frontal precipitation features.
12. Line 289. I do not see the warm front identified in figure 3b. If I understand correctly, this would be a red filled black contour. Where is this feature on the figure?
13. Lines 295-300. In figures 3b and 3c there is a lot of precipitation that would generally be associated with the occluded/bent-back warm front which is not associated with frontal features using the objective criteria, nor within the cyclone feature contour. Which classification does this precipitation fall into? From figure 4 it looks to fall into the residual. This does not seem correct to me but is not referred to by the authors.
14. Figure 5. Similar to the comment above, in figure 5a there is a lot of precipitation close to the developing cyclone centre along a bent-back warm front. However, because this cyclone does not have a closed contour it is not captured by the cyclonic criteria. Would this just be assigned to the residual?
15. Line 327. What do the authors mean by the 'dry gap region between the fronts'? Is this the warm sector of the cyclone?
16. Line 330. Browning and Roberts (1997) has a nice description of these cold frontal line features.
17. Line 340. It would be interesting to speculate if any of the precipitation occurring along the northern flank of the Alps was enhanced by precipitation from the frontal clouds falling through orographically generated clouds.
18. Line 362. There are also large precipitation amounts over fairly modest topography in the domain. For example, in the UK.
19. Figure 9 and lines 410-415. In this section the relative contribution from different features to the total precipitation climatology is discussed. This quantitative analysis is surely one of the most novel parts of this work and should be reflected in the abstract.
20. Lines 420-425. The difference between the regions dominating heavy precipitation and overall precipitation is very interesting.
21. Line 436. Do the authors have a hypothesis for why cyclonic precipitation is not enhanced by topography in contrast to cold frontal precipitation?
22. Figure 7d. Does the lack of heavy precipitation associated with collocated fronts mean that ascent of warm conveyor belt over the warm front does not lead to heavy precipitation? This is surprising to me.
23. Lines 495-508. This section is a repetition of your results and not a conclusion. I suggest removing this text.
24. Lines 510-550. This section is interesting but should be strongly caveated by the fact that only 9-years of data has been used to create the climatologies. For example, there are many studies demonstrating decadal variability in the latitude of the storm track which would have a large influence on these conclusions.

Technical corrections

1. Line 110. Why does period have a – afterwards rather than a comma?

Browning, K.A., Hardman, M.E., Harrold, T.W. and Pardoe, C.W., 1973. The structure of rain bands within a mid-latitude depression. *Quarterly Journal of the Royal Meteorological Society*, *99*(420), pp.215-231.
Browning, K.A., Roberts, N.M. and Illingworth, A.J., 1997. Mesoscale analysis of the activation of a cold front during cyclogenesis. *Quarterly Journal of the Royal Meteorological Society*, *123*(544), pp.2349-2374.