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Hydrology and Earth System Sciences
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Discussions

Interactive comment on "Estimation of rainfall erosivity based on WRF-derived raindrop size distributions" *by* Qiang Dai et al.

Qiang Dai et al.

qiangdai_nnu@163.com

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Point 1: Statement of the third key point is not very clear. After reading the manuscript, I know the main point is the west coastal area, but the statement is not emphasizing this.

Response 1: Agreed and the following text has been added in the Section 4.4:

"The highest rainfall erosivity regions in the UK are concentrated in the mountainous areas along the western coast, related to their rainfall system. The moist air brought by the prevailing westerly wind from the Atlantic Ocean moves from west to east across the UK and rises when it encounters the mountains of western England. Therefore, the mountainous regions along the UK western coast have the highest rainfall amount and rainfall erosivity in the UK. In addition, western Scotland is under the subpolar oceanic climate, which enhances its humidity. On the contrary, eastern Scotland and northeastern England are more likely to expose continental polar air mass, which brings dry and cold air and lower rainfall erosivity."

Point 2: For interpolation of rainfall in section 4.1, CEH also published 1km gridded rainfall datasets for the whole UK, have you compared your interpolation rainfall with theirs? The reason I'm asking it is because rainfall interpolation is important in the following analysis of erosion, it's worthy to ensure that the interpolation is reliable.

Response 2: CEH is a dataset with 1 km gridded estimates of daily and monthly rainfall for the whole UK derived from the Met Office. The natural neighbour interpolation methodology, including a normalisation step based on average annual rainfall, was used to generate the product (Tanguy et al., 2019). The method for calculating EI30 requires hyetograph data for individual storms (Wischemier and Smith, 1978). Therefore, the monthly or daily rainfall data generated by CEH are hard to distinguish rainfall events and estimate EI30, although some studies have proposed methods related daily rainfall data to estimate rainfall erosivity using statistical models.

The study area has the little climatic variability with same climate type named temperate oceanic climate, and the 304 hourly rain gauges are distributed throughout the UK evenly. Therefore, ordinary kriging interpolation was expected to produce realistic results. It should be noted that refined interpolation for rain gauges is not the focus of this research. Instead, we tried to propose a methodology based on the numerical weather prediction model for estimating rainfall erosivity anywhere around the world, especially those regions with sparse instruments.

Tanguy, M.; Dixon, H.; Prosdocimi, I.; Morris, D.G.; Keller, V.D.J. (2019). Gridded estimates of daily and monthly areal rainfall for the United Kingdom (1890-2017) [CEH-GEAR]. NERC Environmental Information Data Centre. (Dataset)

Wischmeier, W. H. and Smith, D. D. (1978). Predicting rainfall erosion losses-a guide

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to conservation planning. Department of Agriculture, Science and Education Administration, US.

Point 3: The empirical equation in table 1 and figure 1 did not perform very well with R2 not over 0.50, how well is the relationship in other studies? Is this acceptable based on previous studies?

Response 3: The Figure 2 in the manuscript has been replaced with the following figures, which is clearer in showing the method performance. Van Dijk et al. (2002) compared the three forms of ke-I relationships including exponential, logarithmic and power-law equations, based on the same observed data. The R2 values are 0.53, 0.52 and 0.53, respectively. The R2 values in this study is surely acceptable that many studies have obtained R2 value between 0.45-0.50 (Laws and Parsons, 1943; Kinnel, 1980; Brandt, 1988). Angulo-Martínez et al. (2016) compared simulated ke from 14 different exponential ke–I relationships with respect to the disdrometer-observed values, found that R2 was low at 1 min resolution (∼0.25). The low R2 of empirical equations also indicate the large variability of DSD in nature. Therefore, we believed that the study of large-scale rainfall energy and rainfall erosivity based on NWP-derived DSD is of great significance.

Angulo-Martínez, M., Beguería, S. and KyselÃ¡, J. (2016). Use of disdrometer data to evaluate the relationship of rainfall kinetic energy and intensity (KE-I). Science of the Total Environment 568: 83-94.

Van Dijk, A., Bruijnzeel, L. and Rosewell, C. (2002). Rainfall intensity–kinetic energy relationships: a critical literature appraisal. Journal of Hydrology 261(1-4): 1-23.

Point 4: The two disdrometers are located in the same region, but the relationship is significantly different. Is it common in previous studies or any explanation about it?

Response 4: The current studies have showed that DSD and ke-I relationships changes significantly with geographical locations and weather systems, including climate, altitude and terrain (Van Dijk et al., 2002; Angulo-Martínez et al., 2016). Both disdrometers located in southern England, have the similar oceanic climate. However, there are still differences between the two stations in altitude, topography, land cover, etc. For instance, Chilbolton Observatory is located on the edge of the village of Chilbolton, at an attitude of 86m, while University of Bristol is an urban campus, at 77m attitude. The former is 11 kilometers from the coastline and the latter is above 37 kilometers. From the revised Figure 2 and Figure 4, the difference in the ke-I relationship between the two stations can be clearly observed. Moreover, the significant difference also shows that DSD-based estimation methods are needed to reflect rainfall microphysical characteristics on large-scale, which is the goal of this work.

Van Dijk, A., Bruijnzeel, L. and Rosewell, C. (2002). Rainfall intensity–kinetic energy relationships: a critical literature appraisal. Journal of Hydrology 261(1-4): 1-23.

Point 5: In figure 7, can you change the x axis tick to the real month, e.g. Jan/2013, so that seasonable patterns can be observed and analyzed?

Response 5: Agreed and amended. Figure 7 in manuscript has been changed and the following text has been added in the Section 4.3. We also added a figure (Figure 8) to show how monthly patterns performed.

"Based on the four-year data, the study area is rainy throughout the year with little R monthly, or seasonal patterns change (Figure 8), influenced by the temperate oceanic climate. Figure 8 also indicated that through the perspective of monthly average results, RW-WDM6 values are low, RW-TAA has a good similarity with low RD, and RW-Morrison is the closest to RD in value."

Point 6: Discussion part is weak in the manuscript, more discussions can be added in the result section or a separate section by comparing with previous studies and discussing about the potential limitations and applications of this approach.

Response 6: Discussion part is mainly contained in the conclusion section. The following text has been added in the Section 5 to enrich the discussion:

“The reliability of the WRF model is heavily dependent on the model-driving initial data provided by mesoscale or global models and complicated scheme setting and parameter adjustment (Liu et al., 2013; Thompson and Eidhammer, 2014; Kumar et al., 2017). However, numerous uncertainties are observed in the parameterization of the WRF simulation, and the choice of microphysical schemes has a significant influence on the inverted DSD (Ćurić et al., 2009; Yang et al., 2019). Therefore, combining the DSDs obtained by an increasing number of disdrometers and the WRF model is valuable. For example, the Disdrometer Verification Network (DiVeN) in the UK (Pickering et al., 2019) started in Feb 2017 can be introduced to support and improve our estimation in future studies.”

“Soil erosion in the UK is dominated by water erosion (10–30 t km−2 yr−1), especially in areas with abundant rainfall in Scotland, where the soil loss rate is approximately 5–10 times that of dry areas (Duck, 1996). Thus, it is significant to estimate rainfall erosivity to elucidate the microphysical characteristics of rainfall and rainfall–soil interactions. Benaud et al. (2020) collated empirical soil erosion observations from UK-based studies into a geodatabase. However, there is a limitation that this database does not cover the entirety of the UK, especially the limited records in northern Scotland. In our future work, we propose to compare the soil loss database with our estimated soil loss using WRF DSD based rainfall erosivity and a soil erosion model (such as RUSLE). We believe that not only can we better analyze the impact of rainfall and rainfall erosivity on the UK soil loss, but also help to better understand microphysical rainfall–soil interactions to support the rational formulation of soil and water conservation planning.”

Benaud, P., Anderson, K., Evans, M., Farrow, L., Glendell, M., James, M. R., ... & Brazier, R. E. (2020). National-scale geodata describe widespread accelerated soil erosion. Geoderma, 371: 114378.

Ćurić, M., Janc, D., Vučković, V. and Kovačević, N. (2009). The impact of the choice of

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the entire drop size distribution function on Cumulonimbus characteristics. Meteorologische Zeitschrift 18(2): 207-222.

Duck, R. W. (1996). Regional variations of fluvial sediment yield in eastern Scotland. Erosion and Sediment Yield: Global and Regional Perspectives: Proceedings of an International Symposium Held at Exeter, UK, IAHS.

Kumar, P., Kishtawal, C. and Pal, P. (2017). Impact of ECMWF, NCEP, and NCMRWF global model analysis on the WRF model forecast over Indian Region. Theoretical and Applied Climatology 127(1-2): 143-151.

Liu, J., Bray, M. and Han, D. (2013). Exploring the effect of data assimilation by WRF-3DVar for numerical rainfall prediction with different types of storm events. Hydrological Processes 27(25): 3627-3640.

Pickering, B. S., Neely III, R. R., & Harrison, D. (2019). The Disdrometer Verification Network (DiVeN): a UK network of laser precipitation instruments. Atmospheric Measurement Techniques 12: 5845-5861.

Thompson, G. and Eidhammer, T. (2014). A study of aerosol impacts on clouds and precipitation development in a large winter cyclone. Journal of the Atmospheric Sciences 71(10): 3636-3658.

Yang, Q., Dai, Q., Han, D., Chen, Y. and Zhang, S. (2019). Sensitivity analysis of raindrop size distribution parameterizations in WRF rainfall simulation. Atmospheric Research 228: 1-13.

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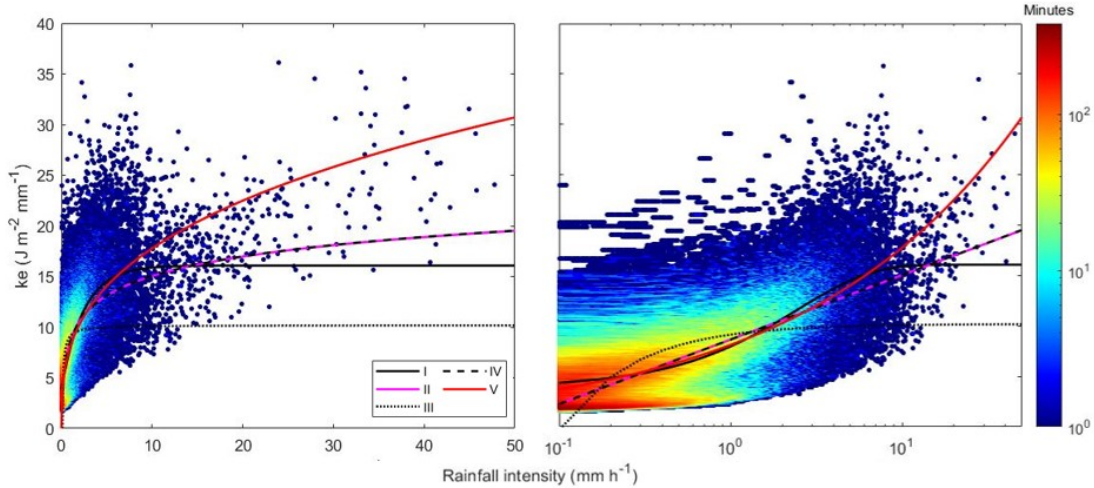

Fig. 1. (new Figure 2 in manuscript). Minutes number per intensity class (x-axis) and ke class (y-axis) with five fitted ke–I curves at Chilbolton station (2004–2013), plotted on linear (left) and logarithmic

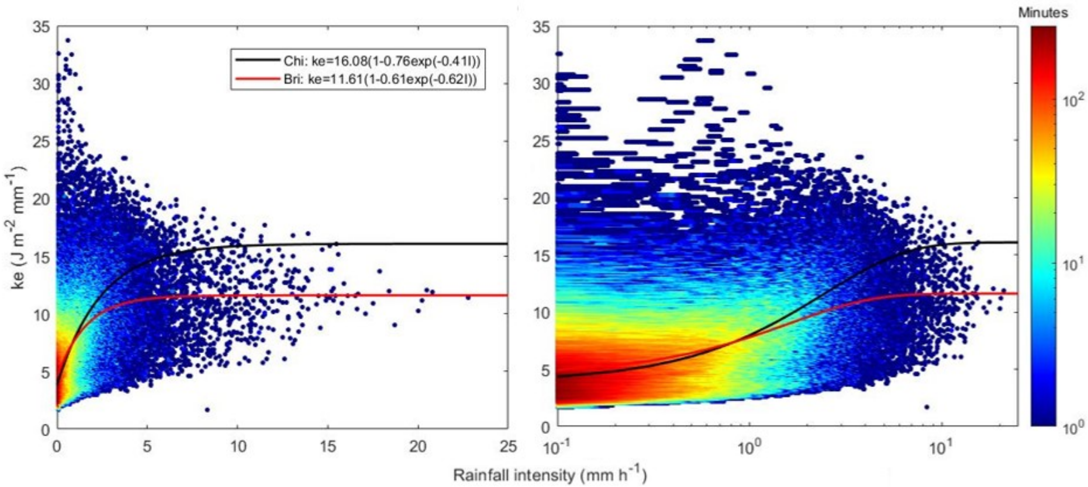

Fig. 2. (new Figure 4 in manuscript). Minutes number per intensity class (x-axis) and ke class (y-axis) with fitted ke–I curves at Bristol station (2015–2018), plotted on linear (left) and logarithmic (right)

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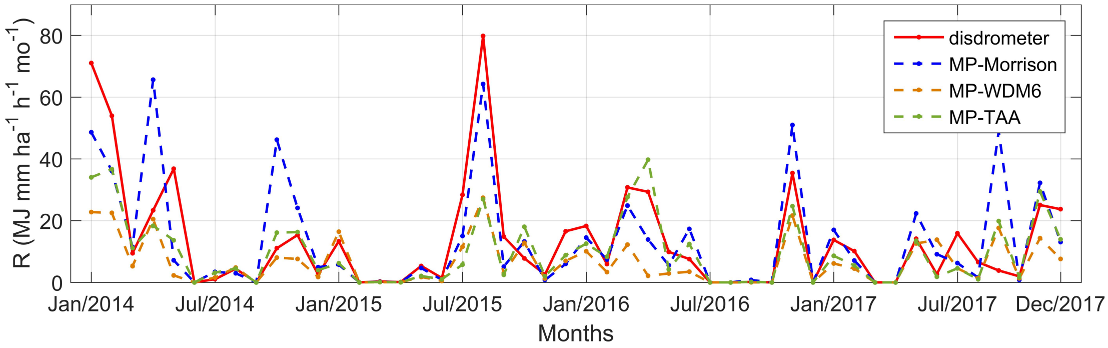

Fig. 3. (new Figure 7 in manuscript). Comparison of disdrometer- and WRF-derived monthly rainfall erosivity estimations at Chilbolton station (2014–2017).

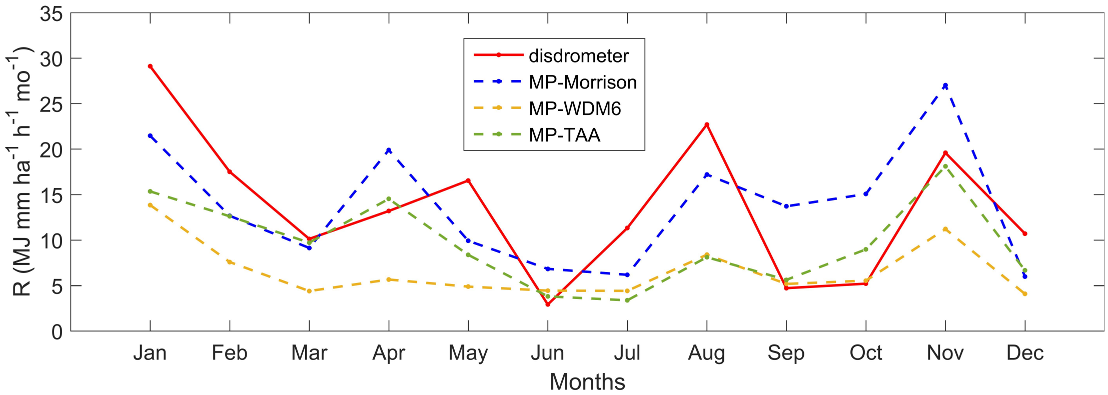

Fig. 4. (added as Figure 8 in manuscript). Comparison of disdrometer- and WRF-derived average monthly rainfall erosivity estimations at Chilbolton station (2014–2017).

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