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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.

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Point 1: You have used two distrometers in the same locations (considering the whole UK study area) and in the same elevation ranges (low elevation), but they differ considerably. What about the high elevation then? And how much they are representative of the whole UK?

Response 1: The current studies showed that DSD and ke-I relationships changes with geographical locations and weather systems, including climate, altitude and terrain (Van Dijk et al., 2002; Angulo-Martínez et al., 2016). Both the two disdrometers located in southern England, have the similar oceanic climate. The focus of this study is not to use disdrometers to estimate rainfall erosivity. On the contrary, we chose the

two disdrometers in similar locations to illustrate the spatial uncertainty of the ke-I relationship exactly. The results indicated that it is inappropriate to rely on an empirical formula in a large scale. The widely used (R)USLE approach to predict ke-I relationships based on measurement at a single location only (Wischmeier et al., 1978; Renard et al., 1997). Therefore, the proposed method based on NWP DSD is expected to effectively improve large-scale rainfall KE and rainfall erosivity estimation.

Angulo-Martínez, M. and Barros, A. (2015). Measurement uncertainty in rainfall kinetic energy and intensity relationships for soil erosion studies: An evaluation using PARSIVEL disdrometers in the Southern Appalachian Mountains. Geomorphology 228: 28-40.

Renard, K. G., Foster, G. R., Weesies, G., McCool, D. and Yoder, D. (1997). Predicting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE), United States Department of Agriculture Washington, DC.

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.

Wischmeier, W. H. and Smith, D. D. (1978). Predicting rainfall erosion losses-a guide to conservation planning. Department of Agriculture, Science and Education Administration, US.

Point 2: Could you use the recently published and open access Disdrometer Verification Network of UK (Disdrometer Verification Network (DiVeN): a UK network of laser precipitation instruments, https://amt.copernicus.org/articles/12/5845/2019/) to support the finding of your study and refine better the findings?

Response 2: This study used two disdrometers in Chilbolton and Bristol to calibrate R results derived by WRF model. Both two disdrometers have long running periods and have been fully studied and calibrated from a series of research work by our team (Islam et al., 2012; Dai et al., 2014; Yang et al., 2019). The DiVeN disdrometer network may provide an interesting support for our follow-up research, such as finding an empirical formula that is most suitable for the UK as a whole. However, for this study, DiVeX has less overlap with the period studied here, which has limitations for verifying. The following text has been added at the end of Section 5:

"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."

Dai, Q. and Han, D. (2014). Exploration of discrepancy between radar and gauge rainfall estimates driven by wind fields. Water Resources Research 50(11): 8571-8588.

Islam, T., Rico-Ramirez, M. A., Thurai, M. and Han, D. (2012). Characteristics of raindrop spectra as normalized gamma distribution from a Joss–Waldvogel disdrometer. Atmospheric Research 108: 57-73.

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.

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

Point 3: The performance (R2) of equations of the relationship between Ke-I presented in Table 1 are low and very similar (except ID-III). The exponential (ID-I) and power-law (ID-V) are exactly the same, and did not support the statement given in Line 73 where the exponential relationship is used in preference. Would you discuss this in detailed and how much these values are in line with former investigations?

Response 3: Figure 1 below replaced Figure 2 in the manuscript, expressed the number of minutes per intensity class (x-axis) and ke class (y-axis). It clearly showed how the five equations performed, plotted on linear and logarithmic intensity scales, re-

spectively. Figure 4 in manuscript also changed to a similar expression. A detailed discussion about the comparison of relationships has been added in section 4.1 as follows:

"Figure 2 shows the ke–I relationship and five fitted curves at Chilbolton station. It can be seen that the two logarithmic curves (Equation II and IV) invariably overlap. The logarithmic form has been used for a long time in USLE (Wischemier and Smith, 1978). It describes ke well at both low and high I, but does not have an upper limit. The power law curve (Equation V) can predict ke well at lower I but overestimates ke at high I. The exponent-based relationship (Equation I) is widely used in the literature and in forecast models such as RUSLE (Renard et al., 1997), which fits the data particularly well in Figure 2. Even though ke in exponential curve has a minimum value at very low I, it also should be noted that higher rainfall intensities are much more important in determining overall storm energy than lower intensities. Therefore, we adopted it here as the empirical formula to estimate rainfall erosivity in the UK."

Point 4: The Discussion section is one of the most exciting parts of any study and preferably to be presented separately from the Results section. Add the Discussion section and compared the study finding with previous studies.

Response 4: 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 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 WRFâĂŘ3DVar 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.

Point 5: What about ground truthing validation of your results in the whole UK or using previous studies with experimental and in-situ data?

Response 5: Rainfall erosivity are difficult to measure, because they refer to erosive potential of rainfall, not the amount of soil erosion that rainfall specifically causes. In RUSLE, soil loss can be estimated by multiplying the rainfall erosivity factor (R-factor) by five other factors: soil erodibility (K-factor), slope length (L-factor), slope steepness (S-factor), crop type and management (C-factor), and supporting conservation practices (P-factor). For ground verification, we believe that disdrometer is the most accurate measurement instrument currently for rainfall erosivity estimation. Results derived by disdrometers are sufficient as a reference to support this study. Moreover, DiVeN you pointed out in Point 2 may be a great data source for ground verification in our future in-depth work.

Point 6: How much your study can be compared or can support the very recently published research entitled "National-scale geodata describe widespread accelerated soil erosion" https://doi.org/10.1016/j.geoderma.2020.114378. The latter publication can enrich the discussion part of the study.

Response 6: Thanks for your kind advice. As mentioned in the Point 5, rainfall erosivity and soil erosion caused by rainfall are completely different concepts. The publication you pointed out collected all readily available and empirically-derived soil erosion data from UK-based studies into a geodatabase. However, the database did not cover the entire UK completely. For instance, compared to England data, Scotland has very few soil erosion records in the database. Based on the analysis of existing records, authors found that there was a weak positive relationship between the total annual precipitation and soil erosion rates in some areas. We believe that putting the rainfall erosivity estimation based on WRF DSD into a soil erosion model (such as RUSLE) and estimating large-scale soil loss can enrich the UK soil loss database. In this way, not only can we better analyze the impact of rainfall and rainfall erosivity on UK soil loss, but also help to better understand microphysical rainfall–soil interactions to support the rational formulation of soil and water conservation planning.

The corresponding text has been added (see Point 4).

Point 7: Avoid using the abbreviation in the abstract and key points.

Response 7: Agreed and amended.

Point 8: Enrich the Figures and Tables captions, ensuring selfexplaining to the readers without referring to the main text and avoiding abbreviations.

Response 8: Agreed and amended.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2020-187, 2020.

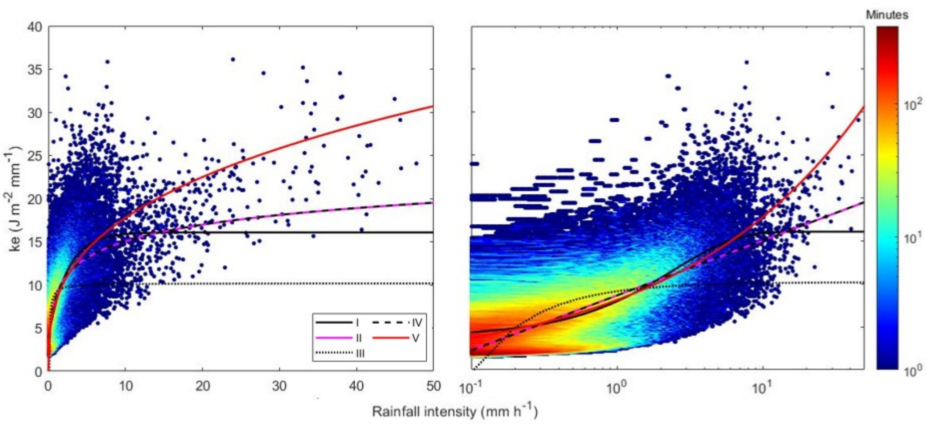

Fig. 1. (new Figure 2 in manuscript). Minutes number per intensity class (x-axis) and ke class (y-axis) with five fitted ke–I curves at Chilbolton station (2004–2013), plotted on linear (left) and logarithmic

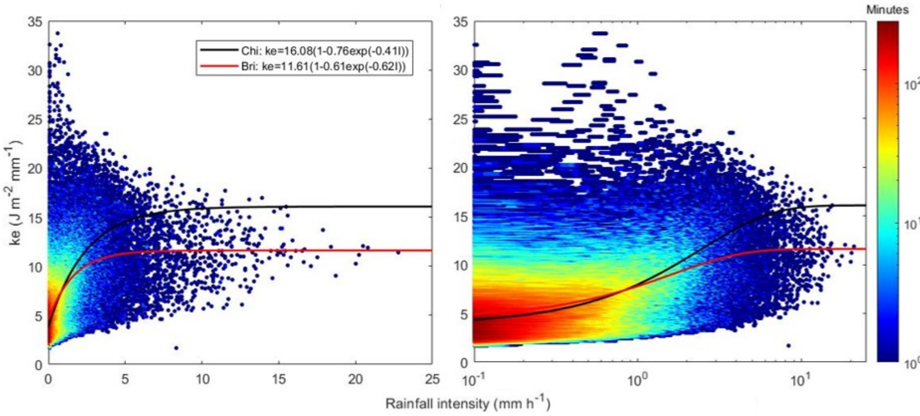

Fig. 2. (new Figure 4 in manuscript). Minutes number per intensity class (x-axis) and ke class (y-axis) with fitted ke–I curves at Bristol station (2015–2018), plotted on linear (left) and logarithmic (right)