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Interactive comment on "Which rainfall metric is more informative about the flood simulation performance? A comprehensive assessment on 1318 basins over Europe" *by* Stefania Camici et al.

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General comments

The authors propose the evaluation of satellite rainfall products with different metrics and compare the results to the performance of a hydrological discharge model. The aim is to determine which rainfall accuracy metrics are suitable in describing satellite rainfall accuracy in regard to flood simulation performance. The authors compare the performance of a hydrological model forced with a benchmark rainfall dataset with the performance of the same model forced with three different satellite rainfall products. In my opinion the work described is novel and worthy of publication. The results presented

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Discussion paper

support the conclusion reached. The findings of the study will be very relevant for future research. However, there are several minor issues that need clarification, which are outlined below.

R: We thank the reviewer for his/her supportive review. In the revised version of the manuscript the following changes will be implemented:

1. the title will be changed in “Which rainfall performance score is more informative about the river discharge simulation? A comprehensive assessment on 1318 basins over Europe”.

2. Any reference to flood will be removed and modified with river discharge to highlight that the purpose of the study is to investigate the performances between rainfall and discharge time series (without specific focus on high and/or low flows);

3. a discussion about the quality of the E-OBS rainfall data and the impact of its density network on river discharge simulation will be added to the revised manuscript;

4. to avoid misunderstanding between KGE of rainfall and discharge throughout the manuscript (and in the figures) KGE will be replaced by KGE-P and KGE-Q, to indicate the KGE index referred to precipitation and the one referred to discharge respectively;

5. more information about why only the KGE-Q index has been selected for the analysis will be added to the revised manuscript;

6. Tables and figures will be modified according to the reviewer’s suggestions.

Specific comments

1. The authors claim in the title, introduction and methodology that satellite rainfall performance is evaluate in regard to flood modelling. However, no high flow specific analyses are performed and in their conclusions the authors them-selves state that the focus was on the entire discharge time series. I therefore propose to remove any reference to flood simulation and instead refer to runoff or discharge simulation.

R: According to the reviewer suggestion, the title and the manuscript will be changed to outline that the analysis is not specifically oriented to floods but it is related to the simulation of the entire river discharge time series.

2. The title can be perceived as misleading, since “rainfall metric” generally refers to rainfall statistics (e.g. spatial and temporal distribution, amount, seasonality, ... etc.). Please change the title (and mentions in the paper, for example L135) in a way that reflects to focus on satellite rainfall product performance metrics.

R: We thank the reviewer for raising this issue. Accordingly, the terms “rainfall metric” will be changed as “rainfall performance score” throughout the revised manuscript. In particular, the title, by considering also the comment n1 will be modified as: “Which rainfall performance score is more informative about the river discharge simulation? A comprehensive assessment on 1318 basins over Europe”.

3. Please discuss what effect the station density of the benchmark dataset (E-OBS) has on the results. Similarly, please mention if any quality checks have been performed on the discharge data.

R: A discussion on the station density will be added to the revised manuscript to highlight that “E-OBS station density significantly varies across Europe (see Haylock et al., 2008; Cornes et al., 2018): for some regions the station density is sufficiently low to expect a strong tendency for interpolated daily rainfall and temperature values to be underestimated with respect to the “true” area-average stations (Hofstra et al., 2009; Hofstra et al., 2010; KyselÃ¡ and Plavcová, 2010). As the smoothing is greatest for higher percentiles, an underestimation of peak floods is expected if E-OBS rainfall data are used for rainfall-runoff modelling (Hofstra et al., 2010). However, as this product is composed by time series thoroughly checked both in terms of quality and homogeneity (Klok and Tank, 2009) and it is continuously available from 1950 up to now at daily time step, it can be considered a good benchmark for the analysis of long rainfall time series, without any special attention to extreme events.” Similarly, some sentences will

be added to the revised manuscript to describe the quality checks performed on the discharge data. In particular, it will be specified that “to ensure quality on discharge observations, the following steps have been followed: 1) visual hydrograph inspection, which is probably the most thorough method (Crochemore et al., 2020); 2) check on data availability; 3) check the presence of outliers; 4) check the presence of inhomogeneities. Only stations with less than 20

4. In Line 185 the authors very briefly mention that they developed and used a catchment delineation algorithm. Since this is a new approach, please elaborate on the methodology and quality checks used. Do et al. (2018) applied a catchment delineation procedure to a global river dataset and found only 68

R: We thank the reviewer for the very relevant comment. In the manuscript we will add details about the adopted procedure and associated quality checks: “The procedure is based on the following steps: (i) we select cells having contributing area larger or equal to 4 km2 over the entire study area, (ii) we move the discharge measurement locations from the coordinates reported in the original metadata to the closest cells of the river network, (iii) we delineate the catchments. Adopting the method used by Do et al. (2018), we evaluated the quality of the products comparing the area of the delineated catchment (Ad) with that available from the original metadata (Am). The absolute percentage difference (Dp) was calculated according to the following formula Dp =| Ad - Am)/ Ad *100 |. Median and 75th percentile of the distribution of the Dp values were, respectively, 2.67

5. L62: Please clarify what do you mean with “gaining ground”? Are satellite rainfall observations used more often? Do they improve in accuracy?

R: Yes, the meaning of the sentence was “satellite rainfall observations are potential alternative to classical rainfall monitoring methods, thanks to their global availability and increasing accuracy”. The manuscript will be modified, accordingly.

6. L122: Please specify that “best performing” in this context is meant in regard to

hydrological model performance and not in regard to rainfall accuracy in comparison to a benchmark rainfall product.

R: In the revised version of the manuscript this part will be modified as, according to the suggestion of reviewer 1, all the questions raised throughout the manuscript will be moved here. For that this sentence will be modified as follows: “The following research questions are addressed: is there any link between rainfall and river discharge performances? is it possible to find a rainfall performance score to select a priori the best SRP to obtain reliable river discharge simulations? Are R and RMSE, generally used to characterize the rainfall accuracy, informative about the hydrological modelling performance? how small/large should be these rainfall scores to obtain good hydrological performances, i.e., KGE greater than 0.5?”. We hope that in this way the misunderstanding highlighted by the reviewer will be solved.

7. L150-152: Please improve your description of the rainfall distribution over Europe. The Alps receive high rainfall amounts (not just the surrounding areas), as does the coast of Croatia (which is at the edge of the Mediterranean Sea).

R: Accordingly, the description of the rainfall distribution over Europe will be improved. The sentence will be modified as follows: “The north Atlantic coast of Spain, the Alps and Balkan Mediterranean countries generally receive higher rainfall amounts while along the west edges of the Mediterranean Sea, in northern Europe and in northern Scandinavia, lighter rainfall is common.”

8. L204-208: Since the SM2RAIN-ASCAT product is relatively can add a brief explanation of the SM2RAIN algorithm.

R: Accordingly, in the revised version of the manuscript a brief description of the SM2RAIN algorithm will be given. Specifically, it will be added to the manuscript that “SM2RAIN is an algorithm based on the concept that the soil acts as a “natural rain gauge”: by inverting the soil water balance equation the algorithm allows to estimate the accumulated rainfall from soil moisture observations.”

9. L249: Can you elaborate what you mean with “QE-OBS is used as reference for parameter values calibration”

R: The sentence will be modified to better explain that “QE OBS is used as benchmark to calibrate the parameters of MISDc model.”

10. L312/313: Please move this thought to the discussion.

R: The authors would prefer to leave this sentence in section 5.1, focused on rainfall assessment, instead of to move it in the discussion section, focused on the relationship between rainfall and discharge performances.

11. L341-343: Please check these values. They do not match the values reported in Table 4.

R: We thank the reviewer. The values in the manuscript will be modified in accordance with Table 4.

12. L394/395: Please check the reference to the Figure. RRMSE is Figure 4c) and R is Figure 4b).

R: The text will be changed accordingly.

13. L394/395: Please elaborate how you differentiate between strong increase/decrease and how the individual increase/decrease might be related to the definition of the individual metric.

R: To differentiate between strong increase/decrease, the authors verified the increasing trend between both KGE-Q with rBIAS and KGE-Q and KGE-P. Although a difference in the magnitude and correlation of the relationship between KGE-Q vs rBIAS and KGE-Q vs KGE-P can be noted, i.e., the slope coefficient is equal to 1.07 (R2= 0.98) and 0.80 (R2= 0.81) for KGE-Q vs rBIAS and for KGE-Q vs KGE-P, respectively, the sentence in the revised manuscript will be smoothed. Concerning how the individual increase/decrease might be related to the definition of the individual metric, the meaning

of each score will be recalled in the revised manuscript. Specifically, the sentence in line 394/395 will be modified as “SRP hydrological performances decrease by increasing the absolute value of rBIAS, |rBIAS|, and the RRMSE values (higher |rBIAS| and RRMSE values indicate lower rainfall performances, Figure 4a and c) whereas KGE-Q increases with R and KGE-P (higher R and KGE-P values indicate higher rainfall performances, Figure 4b and d).”

14. L400/401: Can you explain how the categorical values are different than expected? Higher (= better) POD and TS scores lead to better performance. Only FAR behaves differently than expected (but only for rainfall >0.5 and rainfall >5 mm). It even seems like not very high values of TS and POD are necessary to still get high KGE.

R: The reviewer is right, only FAR behaves differently than expected and only for small and moderate rainfall events. This sentence will be modified according to the reviewer suggestion: “Indeed, it has been found that higher (= better) POD and TS scores lead to better performance whereas the relationships between KGE-Q and the FAR for small and moderate rainfall are different (i. e, inverse) from what can be expected.”

15. L410-418: Could the difference in which range reaches high KGE performance be due to differences in how these metrics are calculated? This will impact what is considered a “large range” of values. This makes the interpretation of the plot slightly subjective. Please elaborate how you came to the conclusion that “rBIAS and RRMSE [...] seem to have a stronger link with the hydrological performance”. In regard to this, please also see the comment on Figure 4 below.

R: According to the authors this result could be linked to the hydrological model structure and to the parameters calibrated into the model. Indeed, it has been largely demonstrated in the scientific literature (e.g., Zeng et al., 2018) that the impact of imperfect precipitation estimates on model efficiency can be reduced to some extent through the adjustment of model parameters. In this case, it is clear that the hydrological model calibration step is able to correct the rainfall time shift, allowing to obtain

good hydrological performances (KGE-Q) for a large range of R values. A similar consideration holds for KGE-P, largely influenced by the correlation coefficient. A sentence highlighting this aspect will be added in the revised manuscript (in the discussion section): “In particular, it has been noted that R and KGE-P rainfall scores seem to have a small impact on KGE-Q as for R ranging from 0.5 to 0.8 and for KGE-P ranging from 0.4 to 0.8, it is possible to obtain high KGE-Q values. As the meaningful range of R (KGE-P) is between 0 and 1 (-0.41 and 1), we can conclude that R and KGE-P are not suitable scores to define a criterion able to discern between good/bad hydrological simulations. This result could be linked to the hydrological model structure and to the parameters calibrated into the model. Indeed, it has been largely demonstrated in the scientific literature (e.g., Zeng et al., 2018) that the impact of imperfect precipitation estimates on model efficiency can be reduced to some extent through the adjustment of model parameters. In this case, it is clear that the hydrological model calibration step is able to correct the rainfall time shift, allowing to obtain good hydrological performances (KGE-Q) for a large range of R values. A similar consideration holds for KGE-P, largely influenced by the correlation coefficient.”

16. Tables/Figures: If possible, the authors might want to consider including the supplement figures in the main text.

R: Thanks for this suggestion, but we think that to make the manuscript more readable it would be better to not increase the number of figures and related comments.

17. Table 1: This table is not necessary. Instead a plot showing catchment area distribution might be more useful.

R: In the revised version of the manuscript, the table will be removed and, according the reviewer suggestion, in Figure 1 a plot showing catchment area distribution will be added.

18. Table 3: KGE is missing in the list of metrics mentioned in the caption. For better readability, can you add the information from this sentence "The more R, rBIAs,

RRMSE and KGE values goes to-ward 1, 0, 0, 1 respectively, the higher is the agreement between E-OBS and SRPs. "to the table caption?

R: The caption of the table will be improved according to the reviewer suggestion, specifying also that “the more R, rBIAs, RRMSE and KGE-P values goes to-ward 1, 0, 0, 1 respectively, the higher is the agreement between E-OBS and SRPs.”

19. Figure 2: Please add column headings. Although using the same colour scale is aesthetically pleasing, it makes it difficult to compare the different metrics, since “best” value varies. E.g. for rBIAS a diverging colour scale would be more appropriate.

R: Figure 2 will be modified in the revised version of the manuscript, adding a column heading for each product and modifying the colour scale for rBIAS and RRMSE. Specifically, as suggested by the reviewer a diverging colour scale would be used for rBIAS whereas for RRMSE an inverse colorbar with respect to R and KGE will be used.

20. Figure 3: Plots d, e and f are mentioned in the caption but are not part of the Figure.

R: The caption of the figure will be modified deleting any reference to plots d, e, f that are not part of Figure 3.

21. Figure 4: There is a high density of points. Can you use empty (e.g. transparent) filling of the points, so that the points do not cover each other. Otherwise the distribution, particularly of the TMPA points, is not visible. (Same for Figure S2). Also, can you clarify if the boxplots are for all products together? S1: Please add which values are considered better (e.g. higher for POD and TS and lower for FAR) to the figure caption.

R: Figure4, Figure S2 and caption of Figure S1 will be modified according to the reviewer suggestion.

Concerning the boxplot, they are evaluated for all products together. This aspect is clarified in the manuscript at lines 388-390: “to extract useful information from Figure 4 and Figure S2, the scores obtained separately for each product have been grouped

and the KGE-Q data points have been binned into uniform ranges (with step 0.1) of rainfall scores".

Technical corrections

I want to compliment the authors for communicating a complex topic very well, however the manuscript would benefit from a thorough grammar and spell check to improve understanding.

22. L25: "understanding how uncertainties[...]"

R: In the correct version of the manuscript the sentence will be correct.

23. L42: "Results suggest that, among [...] are not reliable scores to select the best performing rainfall product for hydrological modelling[...]"

R: In the correct version of the manuscript the sentence will be correct.

24. L58: "Generally, rainfall observations [...]"

R: In the correct version of the manuscript the sentence will be correct.

25. L63: "[...] (SRPs) has boosted their use [...]"

R: In the correct version of the manuscript the sentence will be correct.

26. L72: "is used to simulate a discharge time series [...]"

R: In the correct version of the manuscript the sentence will be correct.

27. L86: "Generally, this comparison [...]"

R: In the correct version of the manuscript the sentence will be correct.

28. L98/99: Missing bracket

R: In the correct version of the manuscript bracket will be added.

29. L108: "by using the MIKE SHE model[...]"

R: In the correct version of the manuscript the sentence will be correct.

30. L112: “it is difficult to find literature [...]”

R: In the correct version of the manuscript the sentence will be correct.

31. L140/141: “is composed of 1318 basins[...] over the whole of Europe [...]”

R: In the correct version of the manuscript the sentence will be correct.

32. L142: “The European continent [...]”

R: In the correct version of the manuscript the sentence will be correct.

33. L145: “gently slopes towards [...]”

R: In the correct version of the manuscript the sentence will be correct.

34. L150: “the Alps generally has higher rainfall amounts [...]”

R: In the correct version of the manuscript the sentence will be correct.

35. L154: “prevailingly subject to [...]”

R: In the correct version of the manuscript the sentence will be correct.

36. L155: “according to the latitude[...]”

R: In the correct version of the manuscript the sentence will be correct.

37. L157: “and for about11

R: In the correct version of the manuscript the sentence will be correct.

38. L161: “basin characteristics.”

R: In the correct version of the manuscript the sentence will be correct.

39. L175: “an European daily dataset [...]”

R: In the correct version of the manuscript the sentence will be correct.

40. L190: “period in 2012[...]”

R: In the correct version of the manuscript the sentence will be correct.

41. L201:” provided by the CPC [...]”

R: In the correct version of the manuscript the sentence will be correct.

42. L219-221: “applied to carry out[...] model composed of a component [...] of soil moisture and a rainfall-runoff model[...]”

R: In the correct version of the manuscript the sentence will be correct.

43. L233/234: “allow us to consider the model suitable for the purpose of this analysis.”

R: In the correct version of the manuscript the sentence will be correct.

44. L236: “analysis regards the quality assessment [...]”

R: In the correct version of the manuscript the sentence will be correct.

45. L270/271: “The more R [...], respectively, the higher is [...]”

R: In the correct version of the manuscript the sentence will be correct.

46. L275: “(TS). POD reports [...]”

R: In the correct version of the manuscript the sentence will be correct.

47. L278: too many dots

R: In the correct version of the manuscript dots will be removed.

48. L356: “This is the first notable result [...]”

R: In the correct version of the manuscript the sentence will be correct.

49. L368: “for the CMOR product[...]”

R: In the correct version of the manuscript the sentence will be correct.

L371/404. As amusing as it is, it might be better to refer to FAR and TS as TS/FAR instead of the other way around.

R: In the correct version of the manuscript the sentence will be correct.

50. L372: “of this product in terms [...]”

R: In the correct version of the manuscript the sentence will be correct.

51. L380: “in terms of RRMSE[...]”

R: In the correct version of the manuscript the sentence will be correct.

52. L454-457: This sentence would benefit from commas.

R: In the correct version of the manuscript the sentence will be correct.

53. L456: “errors in rainfall [...]”

R: In the correct version of the manuscript the sentence will be correct.

54. L498: “limitation, this study contributes to the better understanding of the propagationof [...] simulations. This could be very [...]”

R: In the correct version of the manuscript the sentence will be correct.

References Do, H.X., Gudmundsson, L., Leonard, M. and Westra, S., 2018. The GlobalStreamflow Indices and Metadata Archive (GSIM)-Part 1: The production of a dailystreamflow archive and metadata. Earth System Science Data, 10(2), pp.765-785.C4 Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2020-31, 2020

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