Responses to the comments of reviewer #2: An assessment of the accuracy of global rainfall estimates without ground-based observations

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This paper presents a novel approach to estimating surface precipitation using retrieved soil moisture. The authors then apply their soil moisture estimates to understanding the uncertainties in satellite rainfall estimates, and indicate which potential rainfall products perform better in different regions of the CONUS and globally. The applicability to the hydrologic modeling community makes it appropriate for publication in HESS. I recommend publication with minor revisions, many of which deal with adding additional clarification for the reader.

We would like to thank the reviewer for appreciating the value of the paper and for her/his valuable comments.

1. Page 3, Line 5: certainly not certainty

We will correct the text.

2. Page 4, Section 2.1.2: I think that the flow of the paper would be improved by including the description of SM2RAIN with the description of ASCAT (or as a sub- section to it) as opposed to the current arrangement of describing the instrument here and the product several sections later.

We thank the reviewer for this suggestion. However, we prefer to separate the methodology section from the data description. SM2RAIN can, in fact, be applied to any type of satellite soil moisture observation, and we would not like to not give the false impression that it can run only with ASCAT soil moisture data.

3. Page 4-5, Section 2.1.3: Readers familiar with the 3B42 product will recognize that you are using the "Real Time" rather than the "Research" version. In the CMORPH description you mention using the raw version that lacks gauge information, this justification should be included as to why you use 3B42RT as well.

We will add the following clarification to the revised paper at line 27 of the Introduction section:

"Note that both 3B42RT and CMORPH (raw version) do not include gauge information in their retrieval algorithms."

4. Page 5, line 8: SSM/I instruments are operated by the US Department of Defense, not NOAA.

We will correct the text.

5. Page 5, line 23: 1st

We will correct the text.

6. Page 6, Line 11: should the second i in the square root also be subscripted?

Yes, it should be subscripted because it is referring to a diagonal element of the covariance matrix.

7. Page 9, Line 19: "use" instead of "have utilize"

We will correct the text.

8. Page 9, Line 24: You indicate that equation (8) is only valid for liquid precipitation, and in the concluding remarks mention that the SM and combined satellite products are less reliable in cases of frozen precipitation/snow cover/frozen surfaces. Are you using the entire 2012-2015 time period, or only the warm seasons? If you are using the entire period, how are you dealing with the winter months?

We thank the reviewer for rising this important point. We used the entire period 2012-2015; however, we removed periods of snow cover/frozen soil by masking data where the surface state flag (SSF) of the ASCAT product indicates frozen (SSF=2), temporary melting/water on the surface (SSF=3) or permanent ice (SSF=4). In particular, given that the analysis was carried out at a 1-degree spatial resolution, grid cells were masked if more than 50% of their sub-grid areas consisted of ASCAT observations characterized by a SSF equal to 2, 3 or 4. Moreover, data points where we observed solid precipitation from ERA-Interim were also excluded. The latter, in addition to the consideration of the SSF, helped to reduce the probability of having snowy periods and consider only liquid precipitation. Thus, the results of the paper are not affected by snow.

This will be clarified in section 2.1.2:

"ASCAT points characterized by a surface state flag (SSF) of the ASCAT product that indicates frozen (SSF=2), temporary melting/water on the surface (SSF=3) or permanent ice (SSF=4) were excluded from the analysis."

Page 5 line 30:

"Note that, we considered only liquid precipitation in the analysis. Solid precipitation were

excluded by masking out periods experiencing snowfall (using the "large-scale snowfall" variable of ERA-Interim)."

And at page 9 lines 11:

"Given that the analysis was carried out at a 1-degree spatial resolution, grid cells were masked if more than 50% of their sub-grid areas consisted of ASCAT observations characterized by a SSF equal to 2, 3 or 4."

8. Page 9, Line 28: Remove the word "values"

We will remove it.

9. Page 10, Line 19, "are", not "ae"

We will correct the text.

10. Page 10, Lines 27-28, and Page 12, Line 3: This may be arguing semantics a bit, but the results don't indicate that not using SM2RAIN yields unreliable results. The results indicate that not adhering to the assumptions of the TC method (specifically with respect to having estimates with uncorrelated errors) produces unreliable results. Table 1 indicates that triplets D and E do just as well without SM2RAIN.

The reviewer is right. The sentence is misleading. We will correct it as:

"This suggests those triplets (where not gauge-based observations are used) not containing SM2RAIN provide unreliable results."

11. Page 10, Line 32: Sentence needs revising

We will modify the sentence to read:

"It is often important to understand which is the best available rainfall product among those available in a specific area"

12. Page 11, Lines 15-21: It would be nice to have some context as to why the statistics for the multiplicative error are different from the additive. This comes up a bit later (line 32), but could be more up front.

This will be clarified via new text added after line 20:

"One reason of the lower SC for the multiplicative error model assumption could be the necessary removal of zeros from the time series which potentially creates a different

precipitation signal with reduced sampling power."

13. As a general comment, it might be interesting to look at the CMORPH and 3B42 with gauge-adjustment in the global comparison. Presumably this would improve their results in data-rich areas and result in no change in data sparse regions. Comparing triplets using the same product both with and without gauge adjustment might also provide some indication of how much improvement the gauge adjustment provides.

While we agree that this would be an interesting extension, it would require a substantial modification of the existing paper and would entail a substantial departure from the specific goal of this analysis (i.e., to demonstrate that the availability of independent SM2RAIN-based rainfall estimates enables rainfall validation without ground-based observations). However, we fully agree that this suggestion would be a valuable topic for future research.