Hydrology and Earth System Sciences Discussions

Hydrol. Earth Syst. Sci. Discuss., author comment AC2
https://doi.org/10.5194/hess-2021-563-AC2, 2022

Reply on RC2

Paolo Filippucci et al.

Author comment on "High-resolution (1□km) satellite rainfall estimation from SM2RAIN applied to Sentinel-1: Po River basin as a case study" by Paolo Filippucci et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-563-AC2, 2022

The paper titled "High resolution (1 km) satellite rainfall estimation from SM2RAIN applied to Sentinel-1: Po River Basin as case study" explores how precipitation estimates can be retrieved by inverting the precipitation necessary to produce the soil moisture signal measured in both ASCAT and S1. They compare their results between the 12 km ASCAT product and the target 1 km product. The end result shows that the overall performance of the higher resolution soil moisture product is mostly similar to the coarser resolution ASCAT one. However, there are large difference in performance depending on the topographic/land cover domain. Overall, the study is well presented and relevant to the community. I recommend the paper be accepted after moderate revisions.

We thank the reviewer for the valuable suggestions that helped us to clarify and improve the manuscript. A detailed answer to each comment is reported in the sequel.

My main comment is that the paper would be well served by a large enhancement of the discussion. The paper shows how the finer detailed SM1-derived precipitation estimates are at best equal to the ASCAT product which at first glance is a discouraging result. However, the correlation maps tell us a much more interesting story. As is noted in the paper, valley vs peaks seems to be playing an important role in the retrieval accuracy. The authors then present arguments of why this might be the case but I believe these arguments could be further developed. Here are some relevant questions that could be discussed accordingly.

- *What could be done moving forward to address the weaknesses observed over these regions? What are the reasons for these weaknesses?*
- *What other precipitation datasets could be used to evaluate the product? Since there are large errors over the high mountainous regions, this is most likely strongly driven by errors in the precipitation product. I believe that the use of an algorithm such as that used in PRISM over the US would be interesting to improve these estimates.*
- *How much of the error is attributed to the SM2RAIN model parameters and how much to the noise of the retrieval?*

I am not suggesting that the authors solve these issues in this paper, but I do think a comprehensive discussion around these ideas would be very useful. In many ways, the appendices already include many of these ideas; when creating a discussion section, I *would suggest scavenging from these sections and then eliminating the appendices. The paper could handle more figures, so some in the appendices could be added in here.*

We thank the reviewer for their suggestion, we agree with it. We will add a "Discussion" section in the revised manuscript using as the basis the appendix A, appropriately modified to address the highlighted issues. The main modifications to the text are reported in the follow:

...The obtained results show that the high resolution information from S1 sensors allows to increase the accuracy of SM (and thus of rainfall) in areas where coarse resolution data are not able to obtain reliable estimates. Conversely, over some region the rainfall obtained from the application of SM2RAIN to S1-RT1 SM shows worse performance with respect to the one obtained when the algorithm is applied to ASCAT data, as it happens over many mountainous areas. Finally, the analysis highlighted In some areas, **in which** the accuracy of the rainfall obtained from the application of both the calibrated and parameterized SM2RAIN to ASCAT or S1-RT1 SM products is stably low, as discussed in section 4.2. This issue can depend by multiple factors, as SM signal quality, failure of the model **SM2RAIN algorithm hyphothesis** or accuracy of the benchmark rainfall product. In this appendix, a An attempt to identify those area is **here** made, by highlighting the pixels in which the Pearson's correlation between the 30 days accumulated rainfall from MCM and the four SM2RAIN derived products is always less than a threshold, fixed at 0.65, as shown in Fig. A-1**8**. Multiple areas of stable low performances can be distinguished in the figure, highlighted in blue. Two main reasons of this behaviour can be identified: issues with the SM sensing and issues with the benchmark product.

In particular, the blue areas located in mountainous region in Fig. A-1**8**, in the North and the West of the map, should be affected by both the source of error, since on topographically complex areas SM retrieval is difficult and weather radar accuracy drops. **Notwithstanding this, ASCAT performance are still higher than those of S1-RT1 in these areas (compare with Fig. 4). This fact has a threefold explanation: first, S1-RT1 SM estimations are obtained without considering any snow masking, thus their accuracy over mountain region regularly affected by snow cover is limited; second the low quality of ASCAT SM retrieval over topographically complex area is mitigated by the presence in each ASCAT pixel of valleys and/or plateau in which SM accuracy is higher; third, SM2RAIN algorithm hypothesis could be not valid over these areas since the runoff rate should be not negligible. Indeed, SM2RAIN conditions states that the runoff rate is negligible during the rainfall event, but the low temporal resolution of S1 overcomes the duration of most of the events, questioning the condition's validity.**

Instead, Tthe areas **in Fig.8** within the light blue rectangles, are characterized by the presence of paddies and water bodies: here the low performance should be caused by low SM quality, due to the impossibility of retrieve SM information over flooded areas **with active microwave sensors**. Finally, the **remaining** remnant blue regions should be affected by low quality of the benchmark product. This can be related either to "bad" performing gauge stations, recognizable through the central position of a gauge with respect to the low performing area (e.g. the two regions in the Center-East black rectangles), or to issues with weather radar **and raingauges** measurements, where the blue patterns are concentrated between two or more raingauges (e.g. the region within the black rectangles on the South-West).

In order to better analyze this aspect, three stations located in within the three black rectangles in Fig. A-1**8** were selected, together with the nearest neighbour stations. The MCM timeseries of the pixels that includes the stations were extracted, in order to compare them and assess the quality of the considered**selected** raingauges. The qualitative comparison of the stations is shown in Fig. A-2**9**, where the scatter plots for each pair of raingauges is shown together with their position in the map (Fig. A-2**9**a). In particular, a clear issue with the raingauge named A1 can be appreciated in Fig. A-2**9**b, with this sensor measuring rainfall peaks up to 300 mm/day, absent from the nearest gauges. The issue can be confirmed by the low Pearson's correlation between its timeseries and the one of the nearest raingauge, equal to 0.53, that is significantly lower than the mean Pearson's correlation calculated between each couple of nearest stations within the study area, equal to 0.87 (standard deviation equal to 0.1). Also Fig. A-2**9**c shows strange patterns of rainfall: even if there are no large peaks, several rainfall events are sensed with different magnitude by the two stations named B1 and B2, as can be noticed by looking at the number of points that tends to the x and y axis which indicate severe over- or underestimation. Also in this case, the measured Pearson's correlation is lower than the average, equal to 0.71. Finally, the station C1 **(Fig. 9d)** measures several peaks of rainfall that are higher than those sensed**recorded** by the nearest raingauge, C2. Notwithstanding this, in this case the variation between the two sensors seems to be caused by the natural **rainfall** spatial variability of the rainfall, as demonstrated by the high Pearson's correlation between the two timeseries, equal to 0.88. This was expected since the low performing region is not located around one of the stations, but in between them, over a hilly area that could affect the weather radar measurements.

Errors in the selected benchmark product are a known limitation of the direct validation of rainfall datasets. This fact is also the proof of the need of further research in the rainfall measurement fields, since the merging of different rainfall products, each with its limitation, often complementary, can be beneficial, allowing to obtain a more reliable estimate.

The following sentence will be also added to conclusion, to underline the results obtained in this section:

Some areas with stable low performance of rainfall estimation were also identified (Fig. 8), caused by the limitations of SM2RAIN algorithm (e.g., areas in which runoff rate is not negligible), of the SM remote sensing (areas in which SM estimation is impossible, e.g., flooded or snow covered areas) and of the benchmark product (e.g., topographically complex areas).