

Hydrol. Earth Syst. Sci. Discuss., author comment AC2  
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## Reply on RC2

Lorenzo Alfieri et al.

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Author comment on "High-resolution satellite products improve hydrological modeling in northern Italy" by Lorenzo Alfieri et al., Hydrol. Earth Syst. Sci. Discuss.,  
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### Reply to Referee #2

We thank the reviewer for his/her time in reading our manuscript and for the overall positive evaluation received. We do not disagree with any of the reviewer's comments so the vast majority of those have resulted in an addition to the text or to a change. Our reply to each comment is shown below, interspersed with the reviewer's comments. We noted that a revised manuscript version is not yet required at this stage, hence to make replies clearer we include below portions of modified/updated sentences that will be used in the revised manuscript version.

- While the results are presented in terms of statistical measures, the goodness in simulating high flows and low flows are obviously very different for different gauging stations. This is a major issue that needs attention and at least a discussion and some additional supplementary materials are required.

### Reply:

We understand the reviewer's comment and agree that further work would help give more insight on the model behavior. We have added at the end of the Discussion section that "Given the number of experiments presented, focused on the role of different input data and model parameterization, results are only shown through overall statistics of each model run. Future work will investigate detailed model behavior over specific hydrological processes, regimes, seasonality and quantiles of the flow duration curve, to better disentangle strengths and weaknesses of the considered satellite products in specific hydrological conditions". In the work hereby presented, this would be outside the main focus, given the already large amount of information shown, and which may therefore distract the reader from the novelty aspects that we want to pass, which are:

- We show recent advances in the development of five different high resolution satellite products.
- Those satellite products are fed into a hydrological model (as forcing input and through data assimilation), first individually and then all together, and results show skillful results also compared to those of the same model driven by high quality ground observations.

- We take early steps towards fully satellite-driven hydrological applications, by calibrating a hydrological model using satellite-based forcing input and optimizing the objective function using satellite-derived discharge estimates at five virtual stations as benchmark.
- This work is part of the development of a Digital Twin Earth focused on the water cycle and hydrological processes, and contributes to the Destination Earth program launched by the European Commission.
- L88-89, the ECOCLIMAP (2013) was used for the vegetation coverage. There are obviously more recent data for the period of the simulations. A comparison and quantification of the uncertainty is needed.

Reply:

Upon the reviewer's comment we have added in Sect. 2.1 "In the choice of spatial information, large scale datasets were deliberately used over more detailed local data, in line with the concept of the Digital Twin Earth and in view of the plan to extend the simulation area for a continental or global application". In addition, in our modeling experience, this dataset proved to work well and gives additional information in comparison to alternative datasets, including stomatal resistance, mean canopy height, as well as over 200 vegetation classes, hence we preferred not to perform major changes to the static layers used, given the already wide range of model configurations tested in this work.

- The MS needs to report the used signal to noise ratio that determines the weights in eq. (1-2).

Reply:

Upon the reviewer's comment we have added after Eq. 2 some details on the estimation of the signal to noise ratios used to calculate the weights. It reads: "SNR is estimated as the ratio between the variance of the true signal and that of the considered satellite product, multiplied by a parameter representing the systematic error (see Gruber et al. 2017), where the subscripts 1 and 2 refer to the SM2RAIN-ASCAT and IMERG-LR datasets, respectively". Also, following a comment by Reviewer #3, this part has been considerably enhanced with additional methodological details and an additional reference, which led to a more understandable text on how the satellite precipitation product was produced.

- Datasets of different spatial resolution are mentioned, but what is the used spatial resolution in the hydrological modeling, 10km? How are they converted to the same resolution?

Reply:

We have slightly modified the sentence at the end of Sect. 3.1, which now reads: "For this work, S3M and Continuum were set up and run over the entire Po River basin (drainage area of 74,000 km<sup>2</sup>), with a constant grid spacing of 1 km and time resolution of 1 hour." As mentioned in the manuscript, all dynamic input is generated at 1 km resolution except for the SM2RAIN precipitation. For the latter we have added in Sect. 1.2.1 the sentence "The 10 km resolution dataset thus generated was resampled at 1 km resolution through bilinear interpolation for use in the hydrological model."

- L163-165: The used RT1 model for soil moisture retrieval uses auxiliary Leaf Area Index (LAI) time series provided by ECMWF ERA5-Land reanalysis dataset to correct vegetation effects, but ERA5- Land assumes a fixed land cover and static monthly leaf area index (LAI) climatology. How does the actual LAI change, in particular in agricultural areas, impacts the soil moisture and the subsequent use of it in the hydrological modeling?

Reply:

The scope of the article does not aim to investigate optimal soil moisture assimilation schemes but rather to use assimilation techniques and implementation strategies developed in previous research. Here, we agree with the concern raised by the reviewer and added a comment in the discussion section, which read "Our findings confirms the challenges in implementing a semi-automated assimilation of satellite soil moisture already pointed out in previous research (Laiolo et al., 2016; Wanders et al., 2014), where a range of factors affect and often decrease the assimilation performance, including the presence of complex topography, snow cover, frozen soil, urban areas, as well as differences between modeled and actual vegetation cover and leaf area index".

- In eq. (4), G is assumed as 0.45, meaning the observation carries 45% information and the simulated background 55% information for all grids. This seems a gross simplification for different land cover types and needs at least a discussion and justification.

Reply:

The text in Sect. 3.3 was improved, with the addition of some relevant details. It now reads: "In this application we used a constant value of  $G=0.45$ , following the recommendations by Laiolo et al. (2016), who estimated optimal G values from a test on four different satellite-derived soil moisture products. In addition, we used  $G=0$  in areas with low Pearson correlation coefficient ( $r<0.7$ ) between satellite-derived and modeled soil moisture in the simulation period."

- L314-316: 'Results denote a generally skillful reconstruction of river discharges for all experiments, with mean KGE at the 27 stations ranging between 0.13 (SM2RAIN+GLEAM) and 0.53 (C-SNOW), all well above the no-skill threshold of  $KGE_0 = 1-2^{1/2} \approx -0.41$  (see Knoben et al., 2019).' Please explain how  $0.13 > -0.41$ ?

Reply:

The no-skill threshold according to Knoben et al. (2019) is equal to  $-0.41$ , being calculated as  $1 - \sqrt{2}$ , that is  $1 - 1.41 \approx -0.41$ . Perhaps in the article preprint this is slightly misleading because the minus sign is in line 315 while the 0.41 is in the following line due to page justification. We are confident that this will be solved in the final article version.