Reply on RC3
Lorenzo Alfieri et al.

Author comment on "High resolution satellite products improve hydrological modeling in northern Italy" by Lorenzo Alfieri et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-632-AC3, 2022

Reply to Referee #3

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.

Thank you very much for considering me as a reviewer for the manuscript by Alferi et al., titled “High resolution satellite products improve hydrological modeling in northern Italy” (hess-2021-632). I find the title of the study appropriate, thus read with much interest the manuscript written and presented in high quality. The study deals with the integration of multi-sensor and multi-resolution satellite products into hydrological modeling based on different experiments/simulations. Against the background of the mentioned "Digital Twin" of the Earth, this approach is of high relevance to the scientific community and implies the potential for future investigations. To my understanding, the study's introduction provides sufficient background and includes relevant references. About the description of the research design and methods applied, I see some need for improvement to further specify. According comments/questions are listed below.

For the aspect of language and style, I do not see any serious flaws, thus only minor spell checking is recommended.

Reply:

We thank the reviewer very much for the overall positive evaluation of the manuscript. We have worked to improve the article following his/her recommendations and we believe it is now clearer and more readable. Replies to each point raised can be found in the following.
Line 14: Use the plural for resolution (i.e., spatial and temporal resolutions)

Reply:
Amended

Line 15: You write “high-resolution” here in this line, but in the title, you go for “high resolution”. This is minor; however, I recommend using consistent writing.

Reply:
Thank you for pointing this out. All occurrences have been uniformed to “high resolution”.

Line 16: As you have introduced EO as an acronym for Earth observation in line 13 already, I recommend using this acronym consistently.

Reply:
Amended as suggested.

Line 16: As the abstract acts as an “appetizer” to your study, I would prefer to read more specific information, thus recommend adding the number of experiments investigated (i.e., “In a set of six experiments, [...]

Reply:
Amended as suggested.

Lines 31 and 44: What is the order of your references listed? Alphabetical? Chronological?

Reply:
Following the journal guidelines, in-text citations can be ordered based on relevance, chronological or alphabetical listing, depending on the author's preference. We have opted for chronological order, with older references placed before and newer afterwards.

Line 66: No comma after Po River Basin.

Reply:
Amended.

Line 78: How was the spatial resolution of the DEM resampled from 90 m to 1 km spatial resolution?
Reply:

In the revised version we have clarified that “The DEM was upscaled at the chosen model resolution of 1 km through cubic resampling [...]”

Line 80: What is the reasoning for an upstream area larger than 240 km²? Did you choose?

Reply:

We have clarified in the text that “The river network is defined by cells with an upstream area larger than 240 km², following previous applications of Continuum in northern Italy.” In fact this threshold is very much related to the hydrological model used (Continuum) and its settings. Its physical meaning is related to a value where the effect of river routing along the river network becomes relevant in comparison to the effect of the slope runoff.

Line 81: What is the source of the high-resolution stream network of the main rivers?

Reply:

In the revised version we have specified that “To improve its spatial representation, the DEM was carved with a high resolution stream network of the main rivers taken from the Italian Institute for Environmental Protection and Research”

Line 83: The hydrological model Continuum used in the study is mentioned here for the first time. So far, the readership was not informed about the specifications of this model, thus reasoning why this model was chosen for the simulation experiments.

Reply:

Following the reviewer’s comment we have pointed out in the first occurrence of Continuum (except for the Abstract) that “[...] we test the influence of five new high resolution satellite-derived datasets on the performance of CIMA’s distributed hydrological model Continuum (Silvestro et al., 2013) set up for the entire Po River Basin in northern Italy”

Line 84: What do you mean specifically with a “hydrological soil type map”? What soil hydrological/hydraulic properties are provided?

Reply:

For consistency with the acronym of the database HYSOGs used we have rephrased it to “Hydrologic soil groups were extracted from the HYSOGs250m (Ross et al., 2018) [...]”. We have also clarified that such information then contributes to the estimation of Curve Number maps: “The Curve Number map used to model direct runoff and infiltration from rainfall excess, was derived from the ESA-CCI 2018 Land Cover map (ESA, 2017) at 300 m resolution, together with information on the soil characteristics. [...]”
Line 85: What do you mean specifically with “soil capacity”?

Reply:

This part has been improved to be more specific and with a more correct terminology. It now reads “[...] for soil texture identification, we applied the USDA method (Shirazi and Boersma, 1984) using the ISRIC SoilGrids (Hengl et al., 2017) global maps of the fractions of sand and clay [...]”

Line 86: Use plural for “fraction”, i.e., fractions of sand and clay.

Reply:

Amended

Line 87: So far, the datasets provided are represented by grids. I assume that the spatial data on the glacier areas is provided in vector data. If so, how was the data implemented?

Reply:

That is correct. Polygons of glacier areas were turned into a raster at the model resolution using the criterion of dominant class within each output cell. Being a standard approach we opted for omitting such a methodological detail, to allow the reader focusing more on the key datasets and research strategy.

Line 89: Your information on the vegetation coverage originates from the ECOCLIMAP dataset with 1 km spatial resolution. What is the reasoning for using this dataset whilst you have used the ESA CCI Land Cover product (300 m) for deriving your curve number?

Reply:

In our modeling experience, the ECOCLIMAP dataset proved to work well and gives additional information in comparison to the ESA dataset, including stomatal resistance, mean canopy height, as well as over 200 vegetation classes, hence for this work we opted for using a combination of the two land cover datasets.

Lines 92-95: You write of a set of variables relating to the dam reservoirs and natural lakes. How do those variables go into the parameterization of Continuum, particularly specific information on the weir length? This parameterization and the reasoning are not getting clear.

Reply:

Here we did not go into the details of how dams and lakes are modeled for multiple reasons. First because they do not play an active role in the different model experiments (no related model parameter is calibrated; dam/lakes parameters are not changed from
one experiment to another). Second, no further analysis specific to their output is carried out, while the article is rather oriented to showing the influence of different dynamic input data, especially those derived from satellite data. Finally, we included in the “Code and data availability” section that “S3M and Continuum are open source models and their code is available at https://github.com/c-hydro”, so that all modeling features can be seen in details, favoring transparency and the reproducibility of experiments. In particular, as can be read in the related Github page, information on the weir length is used to model the maximum outflow that can be drained from a reservoir in high flow conditions, using weir flow equations.

Sub-chapter 2 “Data”: Before reading extensive information on the various datasets, I would prefer to have information on the temporal domain (i.e., observation period) considered for your study. Moreover, I am missing information on the study area (area size, climate, physical properties, land cover) that would support the readability and interpretation of the further information provided and results.

Reply:

Upon the reviewer’s comment we have added the observational period (2017-2019) at the end of the introduction section, to anticipate this information. Moreover, an entirely new section (~280 words) has been added (now Sect. 2.1 entitled “Case study – the Po River basin”), which gives several information on the case study and its key features for the purpose of hydrological modeling.

Line 110: What is the specific reasoning for selecting 22 stations for cal and five stations for val? What were your criteria for selection (position in the Po River Basin?, Data coverage? Data density?)?

Reply:

We thank the reviewer for this comment which helped us improve this part. We decided to move here a sentence initially placed in the discussion section, though not ideal in such place. Now it is clarified that “Validation stations were chosen to represent different areas of the Po basin, including a mix of small and large sub-catchments with varying influence of lakes and reservoirs.”

Figure 1: Your figure looks very appealing. However, up to now, the meaning of the virtual stations (black dots) is not clear. Maybe you can add a general study workflow leading into this subchapter? Also, I am wondering if a smaller “overview map” (e.g., placed in the upper left corner of Fig. 1) would be meaningful.

Reply:

To avoid producing additional figures we decided to put all point information in Figure 1, including the location of virtual stations, even if described specifically in a later section. However, this is in compliance with the submission guidelines. Also, to optimize the use of space in the figure we favored latitude and longitude bars at the borders over an overview map.
Line 129: How were the two datasets rescaled? What is the common reference? What are the relative systematic differences between the products?

Reply:

Upon the reviewer’s comment this part has been considerably enhanced with the following text (including an additional reference to Crow et al., 2015): “TC was applied to the triplet: SM2RAIN-ASCAT, IMERG-LR and the MCM radar-gauge precipitation dataset. Note that, unlike the use of random error variances as in Crow et al. (2015), weights calculated as in (2) do not require the assumption of null systematic differences between the datasets, thanks to the self-consistency of the signal-to-noise ratio (see Gruber et al., 2017 for further details). Before the weights can be used to merge the data sets, relative systematic differences (i.e., long term bias) have to be corrected to make weights obtained by (2) converge to the optimal weights in a least square sense (Crow et al. 2015). Given the nature of the precipitation signal (containing many null values) this rescaling has been done by means of a multiplicative factor to the mean with respect to MCM.”

Line 132: Add the acronym “GPM” after “Global Precipitation Measurement” in line 117 to introduce this abbreviation.

Reply:

Added as suggested

Figure 2: When comparing Fig. 1 to Fig. 2, I recommend using the same “spatial extent” for both figures to increase the figures’ readability.

Reply:

The two figures have almost the same spatial extent, which is centered on the Po River Basin. All maps have lat and lon labels, to identify locations univocally. As the reviewer may understand, it is rather challenging to coordinate at such a level of detail with a relatively large group of contributors from different institutes. Hence unless the reviewer or the editor believe this slight difference is a major limitation we would prefer to keep the current version.

Lines 150 and 151: It is minor again, however, I recommend using the same style for writing the spatial resolutions (1 km vs. 1-km).

Reply:

Agreed. All instances were uniformed to the "1 km" version.

Figure 3: I recommend adding the boundary of your spatial domain into Fig. 3 a (left). If possible, I would prefer to see subfigure Fig. 3b (right) a bit enlarged to enhance readability.
Figure 3 has been remade following the reviewer’s suggestions.

Line 176: How is the “natural vegetation” composed? (e.g., woodland, grassland, etc.).

Reply:

We have added some details about the natural vegetation: “[...] with a median Pearson correlation of 0.55 for croplands and 0.65 over areas primarily covered by natural vegetation (i.e., tree, shrub, herbaceous cover)”

Line 177: Where is the Oltrepo station located? As you write of different stations many times, I am wondering if their positions can be indicated in Fig. 1?

Reply:

As a general choice, stations used to validate the satellite products are kept separated from the others used in the hydrological model. Otherwise we should add to Figure 1 also snow and ET stations, though that would make the figure less readable. Hence, being only one station for soil moisture validation, we decided not to include a dedicated map, but rather to show its geographic coordinates (lon / lat) in the figure, under the title. In addition, upon the reviewer’s comment, we have added the name of the municipality where the station is located: “Validation was performed using in situ soil moisture for the Oltrepo station (Bordoni et al., 2019) located in Canneto Pavese (PV, Italy) [...]”

Figure 4: In your caption, you mix between writing "full wording” (i.e., Surface Soil Moisture) and abbreviations (i.e., SM). I recommend choosing one style to make the caption(s) a more stand-alone version. For the shading indicating the SD, I found it very hard to “read” in both digital and color printed format. Maybe you can decrease the opacity a bit?

Reply:

We have improved the use of abbreviations in line with the reviewer’s comment. I’ve double checked the figure and in the original version the shading is adequately visible. Perhaps it’s an issue with a lower resolution version for peer-review. Anyway, we thank the reviewer for pointing it out. We will make sure that the figure can be interpreted well in the final print layout.

Line 194: When you write that the observed snow data were processed, what do you mean specifically? How were they processed? How was their aggregation towards a daily resolution done (median or mean)?

Reply:

We have added some details on the processing, which now reads “Observed snow-depth data were processed by (1) setting to missing any negative value, (2) applying
climatological thresholds for maximum and minimum snow depth to remove spikes, and (3) using a threshold on the 6-hour moving coefficient of variation to detect periods with grass interference (Avanzi et al., 2014). Data was then aggregated at daily resolution, and C-SNOW data were extracted for the same locations and data range. “

Figure 5: I would prefer reading measures of performance (R2, RMSE) in the scatterplot (Fig. 5d).

Reply:

RMSE and Pearson’s correlation coefficient have been added to the scatter plot, as suggested.

Line 214: I would prefer seeing the position of the five stations indicated in a map to support orientation and interpretability. How did you deal with the fact of cloud coverage and its impact on the availability of the reflectance data?

Reply:

These are the virtual stations shown in Figure 1. This has now been clarified in the text. For conciseness, in the article we focus only on the main product features and its use in the described experiments, while specific questions and details can be addressed in the cited literature.

Figure 6: As you have provided the averaged NS and KGE in the paragraph, I would additionally prefer to see those station-based metrics in the according sub-figures. For the left column of Fig. 6 (a-e), a slight increase in the gaps between those sub-figures is recommended.

Reply:

The figure was remade following the reviewer’s suggestions.

In line 226, your description of the methods applied starts. For the previous sub-chapters providing information on the datasets for integration, also methods and results are provided. I am wondering if this was part of your analysis too and part of other or previous studies. I find this part hard to follow and would therefore prefer having clarification. Also, since now the reader got a lot of information on your different EO satellite datasets, an overview table stating the spatial resolution, temporal resolution, and purpose (model parameterization, data assimilation) would be helpful. As your spatial target model resolution is 1 km, more specific information on the resampling techniques from all different spatial resolutions (< 1 km and > 1 km) might be helpful.

Reply:

We are not sure we understood the reviewer’s point correctly. However, all numerical results shown in this article, resulting from model runs or product validation is part of this study. Instead, everything produced previously (methods, ancillary information) is duly
cited in the related literature.

Line 248: What are your performance measures to evaluate the “best match”? Maybe add in brackets.

Reply:

This information is described in more details a few lines below “The cost function, based on the Kling-Gupta Efficiency (Gupta et al., 2009), computes an error between the duration curves at each percentile, weighted with the logarithm of the upstream area, to give higher weight to the downstream stations without neglecting the contribution of the most upstream ones”. We have also added a piece of text in the line commented by the reviewer to clarify the reference to the objective function described in the lines below: “We deployed a multi-site calibration procedure that iteratively searches the model parameterization that best matches the available discharge observations over the calibration period at the 22 considered calibration stations (Figure 1), through minimization of a cost function”.

Line 250: I recommend adding the figure reference for Figure 1 in brackets after “[…] at the 22 considered calibration stations” to support orientation.

Reply:

Amended as suggested (see reply to comment above).

Lines 252-253 (and beyond): Personally, I prefer seeing those “feature symbols” (i.e., cf, ct, CN, ws) in italic letters.

Reply:

Amended as suggested, in line with submission guidelines. Mathematical symbols are now all typeset in italics.

Line 261: Specify "J".

Reply:

The sentence was modified to “The point that minimizes the cost function is used as the centre of the following iteration, until the algorithm converges to an optimal solution.”

Line 264: Again, this is minor, but choose on consistent style (Sentinel 1 vs. Sentinel-1).

Reply:

All occurrences were turned to “Sentinel-1” as of the official naming on the European Space Agency website.
Lines 270 and 272: Unfortunately, it is not getting very clear to me if G here refers to the same or two different variables (kernel function and gain). Please specify if needed.

Reply:

It is the same variable. In the revised version it has been clarified by keeping only one naming (Kernel function), while the term "gain" has been removed.

Figure 7: I would prefer knowing the locations of the basins and having more information available (e.g., land cover) to increase understanding of the interpretation.

Reply:

Labeling the 27 stations is not so straightforward. In addition to the 5 stations shown in Figure 7, the other 22 hydrographs are shown in the Supplement material. Hence we prefer avoiding such attempts and leave the connection between hydrographs and respective location through its name and the upstream area shown in the title of each panel.

Line 311: Specify towards potential evaporation (?).

Reply:

All experiments were run using (actual) evaporation, as required by the model, rather than potential evaporation. We have clarified that “For this work, GLEAM was applied over the entire Po River Basin to produce both potential and actual evaporation estimates at 1 km resolution.” However, potential evaporation, when provided as input, is only used to estimate actual evaporation from lakes and reservoirs. This notion has been added in the text. The use of actual evaporation in Figure 3 has also been specified in the figure caption.

Figure 9: I very much like your figures in the entire manuscript. However, I am wondering if you could change the color code of the KGE in Figure 9 towards more purple (or else) colors to allow for better differentiation from the background (e.g., stream network).

Reply:

We have used a palette which follows recommendations for color blindness impairments (https://www.color-blindness.com/coblis-color-blindness-simulator/). Colors look interpretable and circles can be easily distinguished from the white background and from the river network (also thanks to a gray contour around each circle and from the fact that the river network is a line feature). Of course it has the limitations of a relatively small set of figure panels when printed on an A4 paper (yet, in the electronic version one can zoom in). Hence, we would prefer keeping this version if possible.

Figure 11: Please see my comment for Figure 9. Also, I would rather see a stand-alone
version of Figure 11’ caption instead of “like Figure 9”.

Reply: See previous reply. The caption was modified as suggested.

Line 368: So far, the abbreviation PE (potential evaporation) was not introduced. Please do so in an adequate position.

Reply:

PE stands for precipitation and evaporation, either coming from conventional sources or from satellite products. In the revised version this has been clarified in the caption of Figure 10.

Figure 13: The legend placed in one of the subfigures (upper row, middle) is valid for all sub-figures, right? I would rather see it in a more meaningful position.

Reply:

Correct. Given the distribution of the scores obtained, the best placements (i.e., with enough space to make it readable) were in the top-middle and top-right position, hence we think that top-middle is a reasonable choice. It is probably quite subjective, though we don’t see any clear disadvantage of such a choice.

Discussion: How is the river discharge affected by different land covers/land uses in your study area (e.g., upstream). I am missing a more critical discussion on this effect, as the effect of the land cover also on soil moisture should be more highlighted in terms of uncertainty (effect of vegetation, surface properties).

Reply:

This was not investigated in detail, because despite being of sure interest it is well covered by the existing literature and it is not among the research questions set out for this work. Given the already large number of analyses we decided not to include it in the article.