

# ***Interactive comment on “A multi-sourced assessment of the spatio-temporal dynamic of soil saturation in the MARINE flash flood model” by Judith Eeckman et al.***

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Response to Reviewer N°2

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**HESSD**

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## Response to Reviewer N°2

November 3, 2020

We wish to thank the referee for his/her careful evaluation of the manuscript as well as its very useful and exhaustive corrections. Please find below the details responses to the comments (in bold). Some modifications of the manuscript are mentioned in italic.

### Major comments:

**\* The manuscript contains many grammar and spelling errors, which makes the manuscript rather difficult to read. The authors should correct these errors. A (rather long, but not exhaustive) list with proposed technical changes is appended at the end of the review. Also, some parts, especially in the introduction and results sections, need restructuring, as some statements are repeated quite often.**

The technical changes pointed below, as well as spelling errors have been corrected. The clarity of the paper have been improved by selecting essential information. The litterature review of the various satellite data source, the detail of the different soil layers in the LDAS-Monde product have been moved to an appendix section.

The introduction is completed and reformulated. The conclusion is shortened and reformulated.

**\* The authors use only one in situ soil moisture station per catchment for the study. Is this sufficient? Several studies show that the use of only one point location for the validation of gridded soil moisture products introduce large uncertainties.**

Is it possible to compare the absolute values of the different soil moisture datasets while not investigating the same spatial scale? The authors should clearly state the spatial differences between the point observations, model output, and satellite estimates. Also, the authors should explain how these difference in spatial scales affect the findings of the study. The comparison of soil measurements to gridded products obviously raises consistency issues. One of the main concerns of the paper is to address these issues. Additionnal soil moisture points measurement would indeed be valuable. But the SMOSMANIA network is the most dense soil observation network available for the south of France. The studied catchments are chosen because they contain one SMOSMANIA point. As stated by reviewer n°1, even if the uncertainties cannot be fully avoided, several studies have demonstrated that local soil moisture measurements are representative of larger areas and hence they can be useful to assess the temporal dynamic simulated by flood models (e.g., Brocca et al., 2009; Tramblay et al., 2010).

The absolute values of the different soil moisture data are not directly compared. A special attention is paid not to do so when comparing different data source. When comparing the MARINE soil moisture outputs from the different models (BM, SSF or SSF-DWF), the soil moisture values are compared in terms of absolute values. In this case, the absolute values are comparables because they represent the same physical

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variable. Yet, the soil depth considered in each model is specified.

A table (Table2), as well as the following lines are added in section 2.3. " Available soil moisture data " in order to clarify the spatial differences between the point observations, model output, and satellite estimates : The table 2 summarizes the five products compared in this work for soil moisture estimation: The SAFRAN-ISBA-MODCOU (SIM) root zone soil moisture, the LDAS-Monde root zone soil moisture, the CGLS Soil Water Index (SWI) and the soil moisture measurements provided by the SMOSMANIA network. For the SIM, LDAS-Monde and SMOSMANIA soil moisture data, the soil saturation degree is retrieve by dividing the soil moisture values by its saturation value in the respective product.

**\* The authors show an extensive analysis of various datasets. However, some analyses can be investigated more in-depth. As an example: P13, I308-309: “Despite being initially defined by Zoccatelli et al. (2011) to characterize rainfall fields, the delta1 and delta2 moments also appear to be particularly relevant when applied to soil moisture fields.” > Please explain how you calculate these moments and why they are relevant when applied to soil moisture fields. What is the consequence on the findings of the delta1 and delta2 moments? What do these results mean in context of the model and soil moisture products? I would like to see a discussion included in the manuscript. The same holds for the findings on the spatial variation in soil moisture.**

The spatial moments are initially developped by Zoccatelli et al. (2011) to be applied to precipitation fields. In this paper, we propose to apply them to soil moisture fields. This choice is an innovative way to assess the spatial variation of soil moisture fields and easily compare spatial patterns with different spatial resolutions.

The following lines are added in section 3.2 Indices, when introducing the spatial moments :

*'The exact formulation of the  $\delta_1$  and  $\delta_2$  spatial moments as functions of the spatially distributed field and of the distance to the river 'network can be found in equation 2 and equation 3 in Zoccatelli et al. (2011)'*

In addition, the paragraph 4.2 Comparison at the catchment scale is splitted into 2 paragraphs :

4.2.1 Catchment average behavior and 4.2.2 Spatial variability.

In section 4.2.2, the spatial variability of soil moisture fields, as well as the conclusion drawn from the spatial moments values are detailed.

The paragraph detailing the  $\delta_1$  dynamics is reformulated as :

*" The general behavior of the  $\delta_1$  spatial moment when computed on the SSD is that the  $\delta_1$  increases when precipitation happens and then decreases at a variable rate. Indeed, as precipitation necessarily flows towards the outlet,  $\delta_1$  values are bound to increase (i.e. the SSD fields get closer from the outlet after a precipitation event. The  $\delta_1$  time series obtained with both the SSF and the SSF-DWF models are significantly closer to 1 than the  $\delta_1$  values obtained with the base model. This means that the SSD fields simulated with the base model are globally closer from the outlet than with the SSF and the SSF-DWF models, that is to say that the propagation of the water through the drainage network in the upper soil layer is faster for the base model than for the SSF and the SSF-DWF models. The analysis of the  $\delta_1$  time series allows to quantify the impact of the calibration of lateral transfers on the SSD distribution."*

The paragraph detailing the  $\delta_2$  dynamics is reformulated as :

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*" The  $\delta_2$  values for the SSF and SSF-DWF models are globally closer to 1 than for the base model, that is to say that the SSD fields simulated with the SSF and SSF-DWF models are globally more uniform than for with the base model. This can be explained by the fact that the SSD is globally higher for the SSF and SSF-DWF models than for the base model (see figure ??), the difference between the SSD and saturation in the drainage network (i.e. 100 %) is stronger for the base model than for the other two models. This leads to SSD fields more uniform for the SSF and SSF-DWF models than for the base model. This result is particularly observed for the Orbieu catchment. The analysis of the  $\delta_2$  time series allows to quantify the differences between one the one side, base model, and on the other side the SSF and the SSF-DWF models. "*

The following synthetic sentence is added at the end of 4.2.2:

*" The analysis of the delta1 and delta2 spatial moments provides an inovative way to assess the spatial variability of the SSD fields. The reaction of the SSD fields to precipitation are quantified. The difference between the spatial repartition of the ouputs of the base model on the one side and the SSF and SSF-DWF models on the other side, is highlighted. "*

## Specific comments:

**-Title: either use dynamics or variability instead of dynamic**  
'dynamic' is remplaced by " dynamics "

**Abstract, l17-18: "The opportunity of improving the two-layers model calibration is then discussed."** Please provide a summary of the discussion instead of

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## referring to the discussion.

Reformulated as : ' *Finally, the soil moisture simulated by the two-layers model for the deep layer is compared to the soil moisture provided by the LDAS-Monde product at corresponding depths.* '

## - Reference section: please provide doi for each reference if available.

The references are provided under the style required by the editor.

## -The introduction can be improved by including a concise discussion on the relation between soil moisture content and flash floods.

A paragraph describing the processes is inserted (see below) and the paragraph on representation of the subsurface in the models is reformulated as:

*" Several mechanisms generate the partition between infiltration and surface runoff. Surface runoff can happen when rainfall intensity excess the maximum infiltration rate of the soil (infiltration excess), or when the precipitation volumes exceed the storage capacity of the soil (saturation excess). Then, the generation of surface runoff directly rely on the water content of the subsurface. Within the subsurface, both vertical infiltration flows and lateral transfers take place. These flow are controlled by the physical characteristics of the porous media, such as its hydraulic conductivity or its capacity at saturation. In addition, preferential flows happen through macropores or fractured aquifers. "*

## - Can you add a short section to the introduction on flash floods and why it is important to model them in France?

Lines 21-29 are dedicated to this purpose

Inserted l24 :

*" In particular, modeling systems for short term predictions represent valuable tool for decision making and organization of emergency systems. "*

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**- Can you be more specific about assessing the performance? What exactly do you mean with performance? Accuracy of model output? Model efficiency?**

When referring to the performance of the simulated soil moisture, with respect to reference products (SIM, LDAS-Monde or SMOSMANIA measurements), 'performance' is replaced by 'efficiency'. When referring to 'model performance', 'performance' is used in a more general way, including simulated discharge and simulated soil moisture accuracy. In this case, 'model performance' is replaced by 'model accuracy'. When referring to 'performance criteria' (NSE, etc..), 'performance' is kept.

**- The authors often refer to "spatially extended data". Consider rephrasing this to "spatially distributed data".**

The occurrences of "spatially extended data" are replaced by "spatially distributed data"

**- The authors should be more clear on the use of the word soil moisture. An example is shown on page 11, line 275: "the MARINE soil moisture is compared to the moisture of the surface layer". Please indicate whether volumetric soil moisture content or soil saturation degree is considered.**

For each data source, the meaning of the word "soil moisture" is detailed in the text :

- P9, L207, for the SIM product : *'The soil saturation degree of the root zone (i.e. the volumetric soil water content divided by its value at saturation) is directly provided by the SCHAPI for this work.'*

- P9, L224, for the LDAS-Monde product : *'LDAS-Monde provide both the soil water content and the maps of soil water content at saturation for each of this 11 layers. For each layer, the soil saturation degree is retrieved by dividing its soil water content by the soil water content at saturation.'*

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- P11 L251 for the SMOSMANIA network : " *For each sensor, the soil saturation degree is retrieved by dividing the measured soil water content by its value at saturation estimated at the location of the point of measurement.* "

When referring to soil water content, the word 'soil moisture' is replaced by 'soil water content'. When referring to soil saturation degree, it is replaced by 'soil saturation' (SSD). When referring to either soil saturation or soil water content, 'soil moisture' is kept.

- **Please move references in the middle of a sentence to the end of that sentence. As an example (P8, l 184): "LDAS-Monde (Albergel et al., 2017) assimilates satellite derived data into the ISBA land surface model."**

The edits are done

- **P2, I25: Please define what an integrative discharge variable is.**

The sentence is reformulated as : *'.. the discharge variable, that integrates all the processes taking place at the subsurface and the surface of the catchment.'*

- **P2, I34: "controlling coefficients". Do you refer to the parameters of the discussed representations of infiltration?**

Yes. Reformulated as : *" parameters controlling the representation of infiltration.. "*

- **P2, I36-37: "This variety.. ..during flood events" This sentence can be removed for clarity.**

The sentence is removed

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**- P2, I42: “the lack of underground flow measurements” → I believe you want to refer to soil moisture measurements rather than underground flow measurements. Is that correct?**

Reformulated as : *“ In addition, both the lack of soil and deep ground description and the uncertainties associated with soil moisture estimations lead to an hazardous validation of the model outputs ”*

**- P2, I44: please define event-based hydrological models.**

" event-based models " are set up on short time period, typically a flash flood, and only represent the short-term processes that are not neglectible compared to the intensity of precipitation. In particular, the evapotranspiration is commonly not represented in the event-based models. " event-based " models are opposed to " continuous models ". For clarity purpose, " event-based " is removed from the text.

**- P2, I45-47: I do not fully agree with this statement. If you simulate soil moisture using a 1D-soil column model, point measurements provide valuable information. Could you clarify this sentence?**

This part of the introduction is reformulated : *“ local ground measurements provide locally accurate estimations of soil moisture at shallow depths. Several studies have demonstrated that local soil moisture measurements are representative of relatively larger areas and hence they can be compared to spatially distributed simulation outputs around the point of measurement (Brocca et al., 2009; Tramblay et al., 2010). ”*

**- P2, I48: “continuous models” → what do you mean with a continuous model in this context?**

Replaced by ‘land surface model and distributed models ‘

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- **P2, I50-53: please clarify why using these products lead to structural model uncertainties.**

Any model output is necessarily associated with uncertainties due to the assumption and parametrization (necessarily reductive compared to real, complex systems). For clarity purpose, the sentence is removed.

- **P2, I53-61. This part needs support of references (use of data-assimilation to improve RZSM representation.**

The three references are added.

- **P3, I63: Isn't MARINE an abbreviation of Model of Anticipation of Runoff and INundations for Extreme events?**

Yes, the edit is done

**P3: can you include more details on the recent developments of the MARINE model in the introduction? Briefly explain how the representation of subsurface flow was improved? Also, please briefly discuss the findings of Douinot (2016) after line 68.**

The following lines are added in the introduction :

*" On the other hand, the soil column is divided into two layers, which represent respectively the upper soil layer and the deep weathered rocks (SSF-DWF model). These developments enhance the degree of refinement of the soil physics described in the model. "*

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**P3, I76: “upper soil moisture hourly measurements” → what’s the meaning of upper in this context?**

At 5cm, 10cm, 20cm and 30cm depth. For clarity purpose, ‘upper’ is removed

**P3, I77: “kilometric resolution” this is a bit ambiguous, please use same definition of spatial resolution as used in lines 73 and 75.**

“kilometric resolution” is replaced by ‘1-km’ resolution

**- The relationship between the various model components was not directly clear to me. You might consider to add a figure in section 2.1 showing the connections between the model components.**

A figure is added in the 2,1 section to summarise the main state variables and flux regarding soil processes for the three soil models. A figure presenting the connections between the MARINE components can be found in Roux et al, 2011. This sentence is added in section 2.1.1 : *“ The connections between the model components are extensively described in Roux et al, 2011 ”*

**- Although the structure of the manuscript is good, the authors provide a lot of information on models and datasets. The readability of the manuscript would greatly improve when a figure showing the research methodology and a table summarizing all data and models used in the study would be added.**

In order to clarify the description of the three models, a figure (Figure 1) presenting a scheme for the soil module of each model is added in section 2.1, as well as the following lines :

*“ This section presents the base version of the MARINE model as propose by Roux et al. (2011), together with the two evoluted versions of the model implemented by*

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*Douinot et al. (2018) for soil processes description. The figure 1 summarizes the main state variables and flux regarding soil processes for the three versions of MARINE. "*  
In addition, the table 2, presented before, summarizes the data used in the study.

**- P4, I116: What exactly are the hypotheses here? Do you mean the model developments? I would not consider that a hypothesis.**

" hypotheses " is replaced by " developments "

**- P5, I131-135: Do you have any references for these datasets?**

For the IGN 25m DEM : IGN- BD Topo

([https://geoservices.ign.fr/ressources\\_documentaires/Espace\\_documentaire/BASES\\_VECTORIELLES/BDTOPO/DC\\_BDTOPO\\_3-0.pdf](https://geoservices.ign.fr/ressources_documentaires/Espace_documentaire/BASES_VECTORIELLES/BDTOPO/DC_BDTOPO_3-0.pdf)) \\

For the INRA soil data base :Robbez-Masson, J., Barthes, J., LEGROS, J., et al.: Bases de données pédologiques et systèmes d'informations géographiques. L'exemple de la région Languedoc-Roussillon., Forêt méditerranéenne, 2000.

These references are added in the text.

**- P5, I141, p6, I153: please add reference to reference list.**

The references for the soil, land cover and DEM data are given in lines 131-135

**- P5, I143-145: How did you define these depths? Also, what exactly do you mean with a shallow depth (for Orbieu)?**

The soil depth values are taken from the INRA soil database, quoted before. " Shallow soils " stands for soil depths around 1cm (no altered soil). These databases

have been established for agronomic uses and do not document deep weathered rock horizons (i.e. pedologic horizons of type C and deeper) (Vannier et al., 2014).

**- P6, I152: What is the context of criticized in this sentence?**

"criticized discharges" are defined as discharge measurements that have been corrected from known biases. In particular, in the case of flood events, high water heights are difficult to extrapolate from the rating curve. Direct measurements have then to be criticized and corrected according to human expertise. This analysis is carried out by the forecasters of the French national flood forecasting services.

**- P6, I158-159: Can you discuss why the response of discharge to precipitation during this flood was so fast?**

A very specific pattern of precipitation occurred during this event. The precipitation field was oriented along the main axis of the river, resulting in intense and devastating surface runoff. This may explain such a speed for this flood. The recent paper of Caumont et al. (2020) extensively describe this flood event. This reference is added to the text.

**- It was not clear to me why you introduce the various soil moisture products in section 2.3. Please clarify at the start of this section why you need these products.**

The aim of this paper is to assess the performances of three soil representation for the representation according to five products available for soil moisture estimation : the SIM product, the LDAS-Monde product, the CGLS Soil Water Index product and the SMOSMANIA measurement. Therefore, these products are data used for the study. As a consequence, they are presented in the data section. A table is added in section

2.3 to summarize these five soil moisture data source.

**- P7, I174: what is the depth of the root layer in SIM?**

In ISBA-3L (used for the SIM1 version of SIM), the root zone moisture corresponds to the humidity of the second soil layer. This depth is spatially distributed and it is parametrized with the soil maps given as entries of the model. In ISBA-DIF (used for the SIM2 version of SIM), the humidity of the root zone is considered as the sum of the humidities of the ISBA-DIF layers between 10 cm and 30 cm deep.

**- P8, line 184: Is LDAS-Monde a data-assimilation framework? Please make this clear.**

The following sentence is added : "*LDAS-Monde is a data-assimilation framework that assimilates satellite derived data into the ISBA land surface model* "

**- P9, line 214: SMOS remote data → please clarify that these data are obtained using the SMOS satellite.**

Reformulated as : " from the SMOS satellite data "

**- Figure 2 is not clear to me. The labels are too small and not in English. Please make a clear distinction between SSM and SWI. Also, the difference between 1km and 25km resolution is not clear. In addition, the precipitation data is not visible, consider adding them in a subplot. Furthermore, according to the manuscript, the figure also shows the respective fraction of missing values. I do not see this in the figure.**

The graphical appearance of this figure is enhanced. The figure is sent to the appendix section.



**- P9, I233: How do you define the very local scale?**

Reformulated as : " at the catchment scale ".

**- P11, I256: the authors state that the ADES locations are situated in the study area. However, according to figure 1, the ADES stations are situated outside the catchments. Why do you consider these stations?**

The ADES station measure the piezometric level of the water tables that infiltrate and exfiltrate within the studied catchments. Despite the ADES station are located outside of the catchment, the associated water tables influence the hydrology of the catchments. The use of the piezometric measurements had been attempted in order to add more validation data source. However, according to reviewer n°1 comments, the reference to the ADES data, as well as the values in the tables and graphics are removed. The ADES network is only quoted in the last paragraph 4.2.3 Water content of the deep layer, as a possible opening for further works.

**- P11, I257-258: What is meant with “the water table is 110 km<sup>2</sup> large”? Is this the size of that specific aquifer? If so, what is the relation with the in situ soil moisture station? According to figure 1, the groundwater and soil moisture stations are located quite far away from each other.**

As stated above, the reference to the ADES data, as well as the values in the tables and graphics are removed. The respective sizes of the water tables are provided by the ADES national database. The groundwater and soil moisture stations do not measure the same variable : the ADES stations measure deep ground water using piezometers, whereas the SMOSMANIA stations measure the upper soil water content.

**P11, I265-266: Please describe the eleven soil layers of the LDAS-Monde**

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## product in the data section.

The following sentence is added in section 2.3.2 :

*" For the two considered catchments, the soil column is discretized into 11 layers, with fixed depths. The depth of the total soil column is 300 cm for the two catchments. "*

**- P11, I275: "is compared to the moisture of the surface layer" → Do you mean compared to the surface layer of LDAS-Monde?**

The synthese variables 'surface layer' and 'deep layer' moisture for the LDA-Monde product are defined line 273. For clarity purpose, the following sentence is added :

*" The moisture of the surface layer is noted  $HU_{surf}$  and it is computed as the average of the layer 1 to 5, weighted by their respective depths. The moisture of the deep layer is noted  $HU_{deep}$  and it is computed as the average of the layer 6 to 11, also weighted by their respective depths. "*

**- P12, I286-289: I don't understand your argumentation here. Why would you consider the drainage network in averaging of a grid/mesh? Also, do you have 16 different grids for the analysis and you choose to exclude 4 of them? Or are you referring to individual cells of the grid? Could you rephrase and clarify?**

The question is to compare the local SMOSMANIA measurements with the gridded outputs of MARINE. It could be possible to directly extract the grid cell corresponding to the SMOSMANIA point. However, since the LDAS-Monde cells are 1km large, it is more consistent to average the MARINE cells over the same surface. Among the MARINE cell, some are part of the river network (drainage cells). Soil saturation in these cells is very high because the exfiltration law is not the same than is other 'regular' cells in order to better correspond to the exchange between river water and

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groundwater. In consequence, the cells corresponding to the river network are not considered in the averaging.

For clarity purpose, L287-289 are reformulated as :

*" In addition, among the MARINE grid cells, some are part of the river drainage network. As the physics of the soil saturation in the drainage network are not the same than over hillslope cells, the cells corresponding to the MARINE drainage network are excluded from the 1 km<sup>2</sup> area around the measurement point. For the Ardeche catchment, 4 drainage cells are excluded from the 16 cells around the measurement point. For the Orbieu catchment, no drainage cells are located within 1 km<sup>2</sup> around the measurement point, so no cells are excluded. "*

**- P13, I291: Add reference for NS-efficiency criterion. Also, is LNP index an abbreviation? Furthermore, please add the units of each term in equation 1.**

The reference for NSE is added. LNP is the acronym of " Likelihood using Nash and Peak " but is not quoted as so in the original paper. In equation 1, each term is adimensional. The unit of the discharge and time variables are added in 3.1.3.

**- P13, I317-318: Why do you consider two grids with different spatial resolution? Can you discuss the impact on your results? Also, why do you have a computational time step of 5 minutes while the precipitation input data has a hourly time step? Please explain.**

The Orbieu catchment is significantly smaller than the Ardeche catchment, so the use of a finer resolution is reasonable. In addition, the calibrations of MARINE used in this work have been performed Garambois et al. (2015) for the Orbieu catchment, using the 200 m resolution and by Douinot (2016) for the Ardeche catchment using

the 250 m resolution. The resolutions used for the calibrations have to be kept for the consistency of simulations using these calibrations.

These lines are reformulated as :

*" The model is set up over a regular mesh. The spatial resolutions applied by Garambois et al. (2015) and Douinot et al. (2018) for the calibration are kept. For the Orbieu catchment, the spatial resolution is 200 m and 250 m for the Ardeche catchment. Despite the precipitation information is given at the hourly time step, the sub-hourly processes are simulated using a 5 minutes computation time step and results are aggregated at the hourly time step. "*

**- Section 3.2.2: Shouldn't this section be part of the results section?**

As the calibration of the models are taken from previous study, the discharge simulations are not considered as results from this current work, but rather as part of the methodology applied for model inter-comparison on soil moisture simulation.

**- Table 4: maybe a figure would visualize these data better, or add the numbers in figure 5.**

We found no satisfactory option to plot all this amount of values on a single plot as the figure 5 is already over crowded.

**- P15, I334-336: I don't understand the argumentation here. Is your argument here that you use the same parametrization for the BM, SSF, and SSF-DWF model variants? However, the SSF and SSF-DWF model variants contains more parameters, so how do you cope with that?**

The model set-up used in the publication is based on the calibration of the base model BM. The following sentence is added to the text :

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*" As the SSF model doesn't involved additional parameters, the same calibration is used for the SSF and the base model, given by Douinot et al. (2018) for the Ardeche catchment and Garambois et al. (2015) for the Orbieu catchment. The SSF-DWF model involves to also calibrate the depth of the deep layer. Therefore, the calibrations of the SSF-DWF model performed by Douinot et al. (2018) for both the Orbieu and the Ardeche catchment are used."*

**- Although you state otherwise on p19, I405-407, the initialization grid shown in Figure 8 is still visible in the flood rising stages of the SSF and SSF-DWF models. Is the model able to reach an equilibrium after initialization or is the model still in a spin-up stage? Did you had a look at this?**

As the model is event-based, it only runs for time windows of the duration of the flash-flood, that is to say from several hours to a few days. There is no spin-up stage possible for that kind of models and it is therefore likely that the initialization does have an impact on the simulation results. That is why a systematic initialization has been chosen for all the models using the spatial soil saturation outputs from Météo-France's SIM (Safran-Isba-Modcou, Habets et al., 2008) operational chain : the initial soil moisture is not calibrated.

**- P20, I432-433: "The computation of spatial moments for the CGLS SWI might not lead to robust conclusions." Ok, so what is the consequence for your message? Why even considering these data in the manuscript then?**

As mentioned in the text, the amount of missing pixels is important in the CGLS SWI product, in particular for the Ardeche catchment. In consequence, this data source is not reliable to assess the spatial repartition of the soil moisture. However, the CGLS SWI remains valuable to assess the dynamics of the catchment average soil moisture. Indeed, the available pixels are informative when the data is averaged over

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the catchment.

**- P23, I454: “Additional research regarding the deep layer calibration should be led.” Please rephrase and explain why additional research should be performed.**

A more robust calibration is needed for the deep layer, ideally based on the knowledge of the characteristics of the flow in the weathered bedrock. A sentence has been added in this direction : *" Additional research regarding the deep layer calibration should be led. In particular, the Height Above Nearest Drainage (HAND) method would offer the opportunity to take into account the terrain physical characteristics in the deep layer parametrization (Nobre et al., 2011). "*

**- Figure 11: I am not convinced that you can use the piezometric observations for validation of the deep layer of the SSF-DWF model. (1) please explain why you validate soil moisture simulations with groundwater observations. Or do you investigate groundwater simulations here?(2) the groundwater observations are located outside the study area. Are they valid to use?**

As mentioned before, despite the ADES station are located outside of the catchment, the associated water tables influence the hydrology of the catchments. The use of the piezometric measurements had been attempted in order to add more validation data source. However, the authors agree that the time scale of the variations of the water table does not allow to use piezometric values to asses the simulations of ground water here. The reference to the ADES data, as well as the values in the tables and graphics are removed. The ADES network is only quoted in the last paragraph 4.2.3 Water content of the deep layer, as a possible opening for further works.

**- Conclusions: please remove references from conclusion section. too much**

**information is provided in the conclusion section. Please make the section more concise and to the point.**

The summary of the method is removed from the conclusion. The conclusion is shortened and some parts are reformulated as :

*The local comparison of the MARINE outputs for surface soil saturation with the SMOSMANIA measurements, as well as the comparison at the basin scale with the gridded LDAS-Monde and CGLS data lead to the same conclusions: SSD simulated with the base model significantly differs from the simulations using the SSF and the SSF-DWF models. When no precipitation happens, the soil layer empties faster with the base model, leading to a simulated SSD significantly lower with the base model than with the two other models. This behavior can be physically explained by the fact that, in the SSF and the SFF-DWF models, the lateral transfers are computed as a function of the volumetric soil water gradients, whereas in the base model, they are computed as a function of the water height gradient. Indeed, since the water height gradient between two cells depends on the slope between the cells and the cells textures, water height gradients are larger than volumetric soil water gradient when no precipitation happens. Consequently, lateral flows based on the water height gradients are larger than lateral flows based on the volumetric soil water gradient. In addition, the dynamics as well as the amplitudes of the SSD simulated in the SSF model and for the upper layer in the SSF-DWF model are better correlated with both the SMOSMANIA measurements and the LDAS-Monde data than the outputs of the base model. Considering that the dynamics of the LDAS-Monde  $HU_{surf}$  are of satisfying accuracy, this assessment leads to the conclusion that the SSF-DWF model improves the simulation of the dynamics of the surface layer moisture, compared to both the SSF and the base models. This results appears to be particularly reliable, since it is observed both a the point measurement scale and at the catchment scale.*

*In the SSF-DWF model, the simulation of the moisture in the deep layer is also compared to LDAS-Monde moisture data provided for deeper layers. However, the*

*simulation of the deep layer water content strongly depends on the calibration of the deep layer thickness, the deep layer porosity and the vertical and lateral hydraulic conductivities in the deep layer. These results illustrate the difficulty to represent the hydrological dynamics of the deep soil layers, with limitation due to the lack of knowledge concerning the physical description of the subsurface water storage. Further conclusions concerning the simulation of deep SSD would then require an extensive work to enhance the parametrization of the deep layer in the SSF-DWF model.*

*In conclusion, this work exposes that computing the infiltration flow as a function of the soil saturation degree instead of the water height in the MARINE model enhance the soil moisture simulation during flash floods, with respect to both local measurements and spatially distributed products.*

**- P27, I529: the HAND method is introduced in the conclusions, but not discussed in the rest of the manuscript. Either discuss the HAND method in the discussion or remove this line from the conclusions.**

The HAND method is quoted in the 4.2.2 Result section :

*" Additional research regarding the deep layer calibration should be led. In particular, the Height Above Nearest Drainage (HAND) method would offer the opportunity to take into account the terrain physical characteristics in the deep layer parametrization (Nobre et al., 2011). "*

**- P27, I531-534: "In conclusion, this work exposes that enhancing the degree of refinement of the soil physics for the representation of subsurface flow in the**

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**MARINE model appears to enhance the upper soil moisture simulation during flash floods, with respect to both spatialized model outputs and satellite-based data, as well as with respect to local soil moisture measurements.” → This final statement is difficult to read and follow, although I believe this sentence is strong in summarizing the entire manuscript. The authors should clearly rephrase this sentence.**

This sentence is reformulated as : *" In conclusion, this work exposes that computing the subsurface flow as a function of the soil saturation degree instead of the water height in the MARINE model enhance the soil moisture simulation during flash floods, with respect to both local measurements and spatially distributed products. "*

**- The authors refer to several articles written in French, such as PhD theses. Is the work of these theses not published in English journal articles or other works written in English?**

When possible, the references to PhD are replaced by the reference to the corresponding paper.

### Technical comments:

All the technical comments and spelling errors have been corrected in the text.

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