General comment:
This study aims at producing and evaluating a new soil moisture dataset at 1 km spatial resolution, based on both SAR backscatter data and the normalized vegetation index (NDVI) from the Sentinel missions. To reach their objective the Authors adapted the S2MP algorithm, developed in El Hajj et al. (2017), to move from plot scale to 1 km spatial resolutions. To reach the target resolution the Authors investigate advantages on using NDVI from Sentinel-3 (S3) instead of Sentinel-2 (S2; higher resolution as compared to S3), used in previous works (El Hajj et al., 2017). This work is of interest for the journal. Despite this there are major gaps that should be filled. For instance, it would be helpful to elaborate more on the methodology and the Sentinel datasets used (i.e., pre-processing) as well as on the final objective of this study. The introduction section and the abstract need to be revised, focusing on the main target of this work. Finally, the title seems to be not appropriate for the analysis conducted.
Specific comments can be found below.

We truly thank the reviewer for his/her pertinent comments on the manuscript. We understand that the objective of this work was not clear enough in the current version.
Retrieving soil moisture is currently done globally at low spatial resolution (40 km) or over smaller regions at high (~1 km) or very high spatial resolution (10-100 m) as the original S^2MP algorithm does over croplands. The goal of this manuscript is to study how the S^2MP approach could be used to produce 1-km soil moisture maps over large regions using the synergies of different Sentinel satellites. Of course, the first step is to be able to use it over larger regions and to extend S^2MP to other land cover types than croplands. In addition, since for soil moisture mapping at large scale, 1 km is a high spatial resolution, using S3 instead of S2 becomes possible. In spite of the lower spatial resolution of S3, its higher revisit frequency with respect to S2 makes it possible to reduce uncertainties in the NDVI estimations used by S^2MP introduced by clouds and gaps in the optical time series.
In this context, we understand that comparing the S1+S2 vs S1+S3 results and continuing showing the performances of S1+S2 against those of other state-of-the-art datasets was a bad choice. In a revised version of the manuscript we will focus on the results for S1+S3 in addition to clarify the goal in the abstract and introduction as well as improve the structure and content of the data and method sections.

Specific comments:

RC1-Title: The Authors should consider another title. The actual version is misleading, suggesting that three products (S1, S2 and S3) are used together to derive the 1km soil moisture dataset, which is not the case considering that the algorithm only uses two of them.

The title will be turned into "Soil moisture estimates at 1-km resolution making a synergistic use of Sentinel data".

RC2-L74: Which is the main reason for using S3 dataset (i.e., NDVI) as compared to S2? Which is (or which should be) the major advantage? Which is the difference between the sensors? This aspect is not treated in detail. A description of the Sentinel missions (not only Sentinel-1) should be included, to better understand which is the usefulness of S3 (i.e., in terms of spatial and temporal resolution and/or processing computation timing). The usefulness of S3 in terms of temporal sampling is only mentioned at line 422. Clarifying this aspect would be useful to better frame the analysis.

Since 1 km spatial resolution is a high spatial resolution for large scale mapping of soil moisture, the full spatial resolution of S1 and S2 is not needed. S2 data used as input to the S2MP algorithm is NDVI. Therefore, for this target resolution, S2 could be replaced by S3.

The higher temporal revisit of S3 allows to retrieve more optical images without cloud conditions than those onboard S2. This results in a better estimation of the vegetation effect on the SM retrieval through a more precise NDVI computation.

However, the counterback of using S3 with respect to S2 is that the NDVI used comes from the 1 km^2 pixels while the backscattering from S1 will come only from croplands and herbaceous regions within the 1 km^2 pixel. The possible uncertainties introduced by this mismatch have to be evaluated. It is shown in the manuscript that actual differences in the output soil moisture estimates are low. This was somehow expected since the main predictor for soil moisture remains the microwave backscattering.

Of course, producing SM daily maps at 1 km resolution using S3 instead of S2 is easier and faster because there is no need to do all the previous preprocessing of S2 to analyze and aggregate the data from its original resolution to 1 km.

We also agree that information about the S2 and S3 missions are lacking in the manuscript. Please find below a full description of the Sentinel missions and the data used for the production of the S^2MP_{S1S2} and S^2MP_{S1S3} SM maps.

- The Sentinel-1 mission is the first satellite constellation mission of the Copernicus program and was conducted by ESA. The mission is composed of a constellation of two satellites sharing the same orbital plane. S1A was launched on 3 April 2014, and S1B on 25 April 2016. They were placed in a near-polar, sun-synchronous orbit. The revisit frequency is 12 days (6 days using both satellites) with crossing time at equator at 6:00 pm for the descending overpass. S1A and S1B carry onboard a C-band (wavelength 6 cm) SAR imaging instrument, enable to acquire imagery regardless of the weather and the time of the day. Four imaging modes with different resolution (down to 5 m) and coverage (up to 400 km) are available with this instrument, which allow a continuous radar mapping of the Earth. S1B has now retired.
  For the production of the S^2MP SM maps, S1A and S1B SAR images were collected over each region of study. S1 images are accessible from the Copernicus website (https://scihub.copernicus.eu/dhus//home). The S1 images (10 m x 10 m) were acquired in the Interferometric Wide-swath (IW) imagining mode with VV and VH polarizations and the S1 Toolbox (S1TBX) developed by ESA was used to calibrate the images. This calibration aims to

convert digital number values from S1 images into backscattering coefficients in a linear unit and ortho-rectifying the images using the Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM).

- The Sentinel-2 mission aims at monitoring variability in land surface conditions and was developed by ESA in the framework of the Copernicus program. S2A and S2B were launched on 23 June 2015 and 7 March 2017, and were placed in a near polar, sun-synchronous orbit. The revisit frequency is 10 days (5 days with 2 satellites) and the descending orbit crossing time at equator is at 10:30 am. The spatial coverage ranges from 56° S to 84° N. The satellites carry onboard a multi-spectral instrument with 13 bands: 4 bands at 10-m spatial resolution, 6 bands at 20-m and 3 bands at 60-m spatial resolution. The orbital swath width is 290 km.
  For the production of the S^2MP SM maps based on S1 and S2, optical images from S2A on dates close to S1 SAR images (less than 2 weeks) were downloaded from the French land data service center (Theia) website (https://www.theia-land.fr/). The S2A optical images (10 m x 10 m) are corrected for atmospheric effects and ortho-rectified.
- The Sentinel-3 satellites were launched by ESA to answer the operational needs of the Copernicus program by measuring sea-surface topography, sea- and land-surface temperature, ocean and land color with high-end accuracy and reliability. The main objectives are to support ocean forecasting systems as well as environmental and climate monitoring. S3A and S3B were launched on 16 February 2016 and on 25 April 2018, respectively. The S3 satellites orbit is a near-polar, sun-synchronous orbit with crossing time at equator at 10:00 am for the descending overpass. They carry onboard an optical instrument payload, the Ocean and Land Color Instrument (OLCI), that samples 21 spectral bands ([0.4-1.02] µm) with a swath width of 1 270 km and a spatial resolution of 300 m. They also carry a dual-view scanning temperature radiometer at 500-m spatial resolution: the Sea and Land Surface Temperature Radiometer (SLSTR). The revisit frequency of these instruments is 2 days when both satellites are used together.
  In this study, the S3 10-days synthesis NDVI at 1-km spatial resolution were used for the production of the S^2MP SM maps based on S1 and S3. These data are accessible in the SY_2_V10 product and were downloaded from the Copernicus website (https://scihub.copernicus.eu/dhus//home). The data from this product rely upon the synergistic use of the OLCI and SLSTR instruments. The product provides a 1-km VEGETATION-Like dataset including 10-day synthesis surface reflectances and NDVI. The NDVI values correspond to a maximum NDVI value composite of all segments received for 10 days.

We will revise the data and method sections to better present the essential information concerning the Sentinel missions and the data used as inputs to the S^2MP algorithm.

RC3-L70-85: I struggle to see the final objectives of this work. Want the Authors to demonstrate which NDVI product is more advantageous between S2 and S3? Do the Authors think that in the future they will move to S3 NDVI? In theory, if good agreement was found between S1+S2 and S1 +S3 (line 425), why not using S3 for the following analysis? I think the Authors should elaborate more on their objective and provide insights on what pushed them to use S3 and later on staying with the initial S2 product. This should be clarified in both the introduction section and in the abstract.

As said above, we agree with the reviewer. Since a good agreement was found between S1+S2 and S1+S3 we continued showing more results on S1+S2 but we understand that it was a bad choice and that it confused the readers. It would have been a better choice to continue the discussion using the S1+S3 retrievals. The reviewer is right in the goal and more details on the interest of S3 with respect to S2 have already been given in the answer to RC2-L74, we will not repeat them here again.

Please find below figures showing the comparison between the S^2MP_{S1S3} SM maps and those of the other HR datasets in terms of bias, STDD and R.

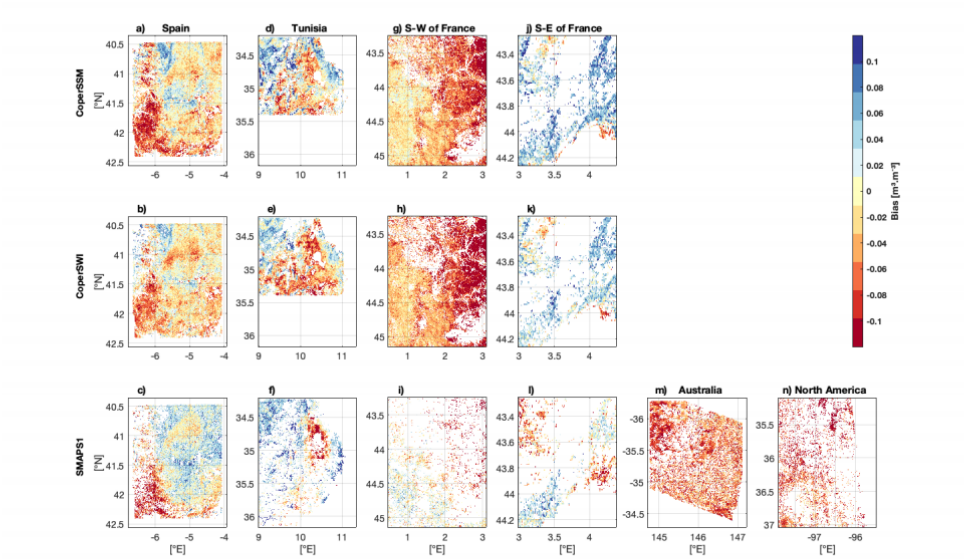

Figure 5. Comparison of S^2MP_{S1S3} with respect to $CoperSSM$ (S^2MP_{S1S3} minus $CoperSSM$), $CoperSWI$ (S^2MP_{S1S3} minus $CoperSWI$) and $SMAPS1$ (S^2MP_{S1S3} minus $SMAPS1$) over the regions of study in terms of bias in $m^3\,m^{-3}$. The analysis was performed from January to December 2019.

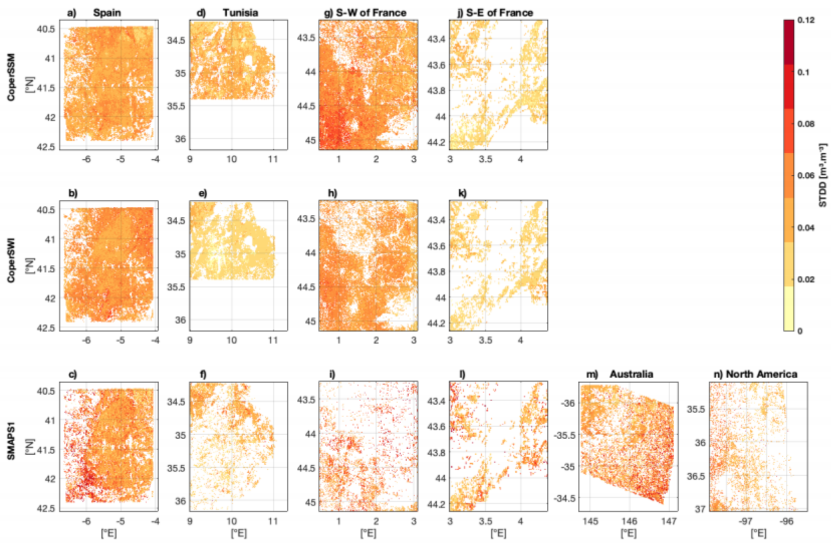

Figure 6. Comparison of S^2MP_{S1S3} with respect to $CoperSSM$, $CoperSWI$ and $SMAPS1$ over the regions of study in terms of standard deviation of the difference ($STDD$) in $m^3\ m^{-3}$. The analysis was performed from January to December 2019.

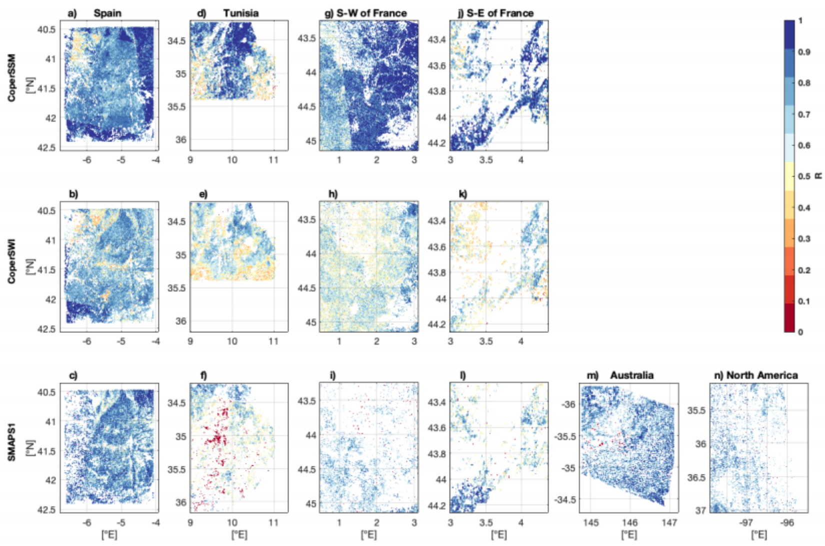

Figure 7. Comparison of S^2MP_{S1S3} with respect to $CoperSSM$, $CoperSWI$ and $SMAPS1$ over the regions of study in terms of Pearson correlation (R). The analysis was performed from January to December 2019.

In a revised version of the manuscript we will replace the original Figure 5-7 (S^2MP_{S1S2} maps versus the other HR maps) by these new figures in the revised version of the manuscript. Sections results and discussion will be updated accordingly.

RC4–Section2: I did not find a proper description of the Sentinel products used to run the S2 MP algorithm (S1, S2 and S3). The S2 MP section 2.1.1 should go in the method while a subsection to describe the Sentinel datasets used in S2 MP (i.e., original spatial and temporal resolution) should be added. As an additional suggestion, the HR and CR products used for evaluation could go in another sub-section (i.e., Satellite products used for evaluation) reducing the detailed description and directly referring the reader to the reference work. For instance, at section 2.1.2 both the 1-km and 3-km SMAP+S1 L2 products are described but only the 1-km product is then used.

We understand that there is a lack of information concerning the description of the S^2MP algorithm and the Sentinel data used as inputs. This information can be added to the Data section. Otherwise, the suggestions of the reviewer of moving the S2MP description to Methods and regrouping and reducing the text on the other SM data sets used for the evaluation make fully sense and we will take it into account in a manuscript revision

Please find below a full description of the S1/2/3 data used to produce the S^2MP SM maps.

- For the production of the S^2MP SM maps, S1A and S1B SAR images were collected over each region of study. S1 images are accessible from the Copernicus website (https://scihub.copernicus.eu/dhus//home) and the revisit frequency is 12 days (6 days using both satellites). The S1 images (10 m x 10 m) were acquired in the Interferometric Wide-swath (IW) imagining mode with VV and VH polarizations and the S1 Toolbox (S1TBX) developed by ESA was used to calibrate the images. This calibration aims to convert digital number values from S1 images into backscattering coefficients in a linear unit and ortho-rectifying the images using the Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM).
- For the production of the S^2MP SM maps based on S1 and S2, optical images from S2A on dates close to S1 SAR images (less than 2 weeks) were downloaded from the French land data service center (Theia) website (https://www.theia-land.fr/). The S2A optical images (10 m x 10 m) are corrected for atmospheric effects and ortho-rectified. The revisit frequency is 10 days (5 days with 2 satellites).
- The S3 10-days synthesis NDVI at 1-km spatial resolution were used for the production of the S^2MP SM maps based on S1 and S3. These data are accessible in the SY_2_V10 product and were downloaded from the Copernicus website (https://scihub.copernicus.eu/dhus//home). The data from this product rely upon the synergistic use of the Ocean and Land Color Instrument (OLCI) and Sea and Land Surface Temperature Radiometer (SLSTR. The product provides a 1-km VEGETATION-Like dataset including 10-day synthesis surface reflectances and NDVI. The NDVI values correspond to a maximum NDVI value composite of all segments received for 10 days.The OLCI samples 21 spectral bands ([0.4-1.02] µm) with a swath width of 1 270 km and a spatial resolution of 300 m. The SLSTR works at 500-m resolution. The revisit frequency of these two instruments is 2 days when both satellites are used together.

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RC5–L106: SMAP provides passive measurements of *brightness temperature* (passive sensor) in vertical and horizontal polarization and not measurements of land surface SM. This part should be edited.

This sentence will be corrected.

RC6–L178: *"The Dynamic Land Cover Map product … provided by CGLS was used to evaluate the different HR and CR data sets"*? In my understanding the objective should be to evaluate the new S2 MP product and not the other HR and CR SM products. Please comment on that.

The reviewer is fully right. The goal is to evaluate the S^2MP product by comparison to other SM (HR and CR) data sets. The formulation used is misleading and hence, it will be edited and clarified.

RC7–Figure 1: It's difficult to locate the different test sites. I suggest to add an inset in Figure 1 summarizing where the test sites are located. Additionally, it would be useful to add in the maps the in situ soil moisture sensors location (this would help also the discussion section – line 386).

Please find below a new version of Figure 1. As advised, it has been modified to help the reader to better locate the different regions of studies. Locations of in-situ stations have also been added. This new figure can replace the original Figure 1 into the manuscript.

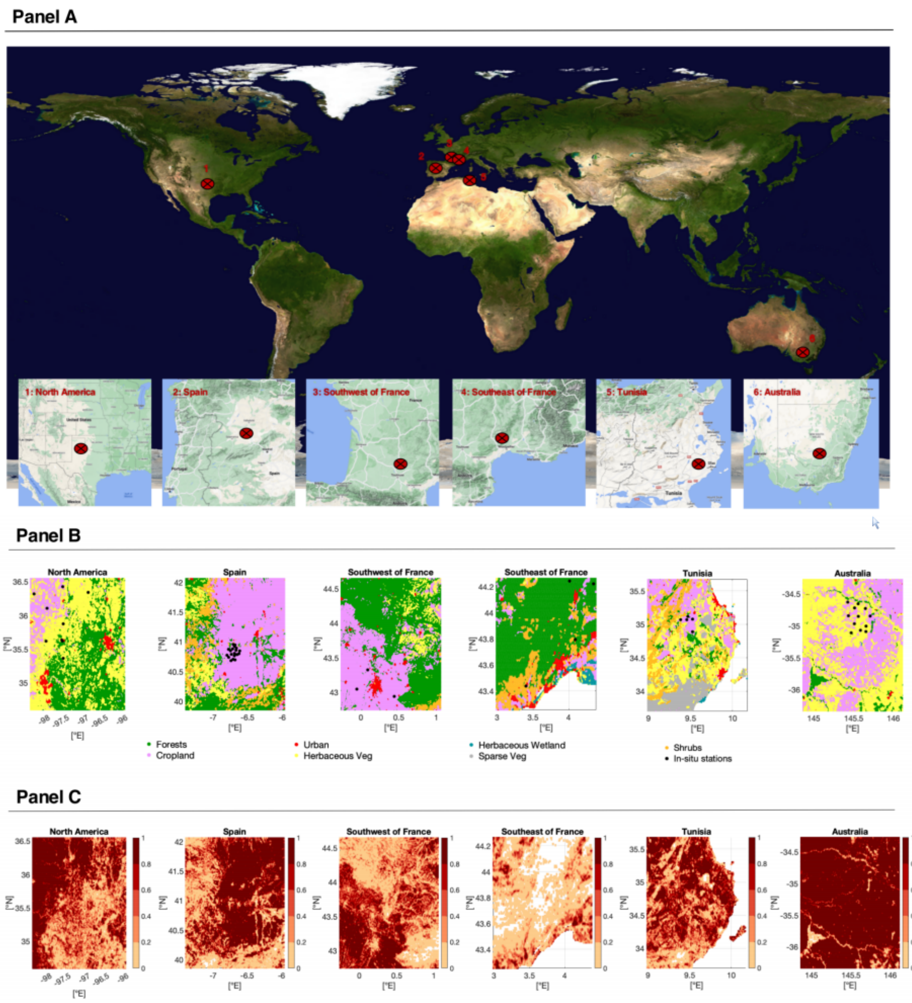

Figure 1. Panel A: Global locations of the 6 regions of study. **Panel B:** Copernicus land cover maps of the 6 regions of study aggregated at 1-km spatial resolution. Only the dominant land cover type within a 1-km^2 pixel is shown. For instance, a pixel characterised as forests can contain 27% of forests, 26% of croplands, 24% of herbaceous vegetation and 23% of shrublands, or 90% of forests and 10% of herbaceous vegetation. The in-situ stations are shown as black dots. One black dot can correspond to several sensors since some of them have the same coordinates. **Panel C:** Proportion of croplands and herbaceous vegetation within each 1-km^2 pixel for the 6 regions of study. The proportion is expressed as a percentage ranging from 0 to 1. Pixels with no cropland or herbaceous vegetation at all are shown as white areas.

RC8–L194-195: This part was already mentioned in Section 2.1.1. I suggest to merge the two sections and, as in my previous comment (RC4), to describe the Sentinel products in the data section instead of the S2MP algorithm.

We understand that the structure of the data and method sections could be improved. The section data will be revised to only present the description of the Sentinel missions, the Sentinel data used for the production of the S^{2}MP SM maps, and the other HR and CR SM products used in this study. The section method will describe the S^{2}MP algorithm and SM maps, as well as how the evaluations were carried out. Hence, the initial S^{2}MP description from the section data will move to the section method.

RC9–L201-208: It is only mentioned that the Authors used S3 at 1 km spatial resolution while that S1+S2 SM is obtained moving from a 100 m resolution to a 1 km spatial resolution. S3 images should have an original spatial resolution of 300m (please check at line 208). How were the images processed? (If a specific product was used it should be cited). Does the S3 NDVI take into account different land uses as the S2 NDVI product? In any case it could be useful to have an idea of the average percentage of crop and herbaceous vegetation for each product over the study areas. Please comment on that.

Regarding the 300m to 1 km question, in this study, the S3 10-days synthesis NDVI at 1-km spatial resolution were used for the production of the S^2MP SM maps based on S1 and S3. These data are accessible in the SY_2_V10 product and were downloaded from the Copernicus website (https://scihub.copernicus.eu/dhus//home). The data from this product rely upon the synergistic use of the OLCI and SLSTR instruments. The product provides a 1-km VEGETATION-Like dataset including 10-day synthesis surface reflectances and NDVI. The NDVI values correspond to a maximum NDVI value composite of all segments received for 10 days.
Regarding the different land covers within the 1 km pixels, this is the goal of the S3 vs S2 NDVI comparison in the Results section.

RC10–L203: It is mentioned that only croplands and herbaceous vegetation are used to derive *S2 MPS1S2*. However, in Figure 1 (land cover processed at 1 km spatial scale) over some specific regions (i.e., Southwest and Southeast France or North America), forests are the dominant land use. If the Authors are focusing on cropland and herbaceous vegetation, I am wondering why those areas where not masked (i.e., line 331-332 "*As discussed above, the correlation maps show some features related to the dominant land cover class, in particular, higher correlations are found for areas dominated by croplands and herbaceous vegetation*"). Please comment on that.

This work extends the S^2MP algorithm including herbaceous regions with respect to the croplands used by El Hajj et al. However, for the evaluation we think it is interesting not to limit ourselves to homogenous regions with only herbaceous and cropland classes. The final goal of course is to have good soil moisture retrievals at high resolution over all types of surfaces. Certainly, we are not there yet but evaluating the performances on mixed land cover pixels with state of the art algorithms helps to understand the work that remains to be done.

RC11–L218: Why did the Authors select a threshold of 5%? Please comment on that.

The 2.5% lowest and 2.5% highest values are discarded from the scaling reference, (the in-situ measurements here) to remove the potential outliers that can be caused by instrumental noise. This is a threshold advised in Brocca et al. 2011. The sentence in line 218 is not clear and will be rephrased. Of course, the above reference will be cited into the manuscript.

Brocca, L., Hasenauer, S., Lacava, T., Melone, F., Moramarco, T., Wagner, W., Dorigo, W., Matgen, P., Martínez-Fernández, J., Llorens, P., Latron, J., Martin, C., and M, B.: Soil moisture estimation through ASCAT and AMSR-E sensors: An intercomparison and validation study across Europe, Remote Sensing of Environment, 115, 3390–3408, 201.

RC12–L212: Why only ascending orbits from SMOS and descending orbits from SMAP were used? It is not explained in the text or at least I did not find it. Please comment on that.

During the night and early in the morning, the soil skin layer is closer to thermal equilibrium, meaning that the vegetation temperature is closer to the soil temperature. During the afternoon, the balance is lost and the vegetation temperature is closer to the air temperature leading to more uncertain soil moisture retrievals of lower quality. This is often reflected by lower performances against in-situ measurements for the afternoon SM estimates than those of the morning (Leroux et al., 2014). Also, in some regions, convective precipitation in the afternoon makes more complex the soil moisture retrieval with afternoon orbits.
This is the reason why only morning orbits from SMOS (ascending overpasses) and SMAP (descending overpasses) were used. This justification will be added to the manuscript.

RC13–L242-244: *"The S2 NDVI at 1 km grid ... and compared to the S3 NDVI obtained at 1km"*. This sentence is clearly part of the method. I suggest to remove it from the results section.

As advised, this sentence will be removed and moved to the section method.

RC14–L273-274: Considering the original spatial resolution of S3 an explanation on how this product was processed would be very helpful to understand the results. See my previous comment RC9.

Please see our response to RC9 for more details concerning the description of the S^2MP SM data production. As already explained before, the section data of the revised manuscript will present all the different types of Sentinel data used as inputs to the S^2MP algorithm and the way how they have been processed will be explained in the section method.

RC15–L276: *"However, taking into account the overall very good agreement of S2MPS1S2 and S2MPS1S3 maps, for the sake of simplicity and clarity, in the following sections only S2MPS1S2 is compared to the other HR data sets"*. This choice makes it difficult to understand the objective of the paper. Which is the point to use the S3 product? This aspect should be clarified throughout the text.

As mentioned in RC3, we understand that this was a bad choice and that it would be more logical to pursue the analysis with the S1+S3 SM maps after showing there is a good agreement between the S1+S2 and S1+S3 maps. The results of the comparison

between the S1+S3 SM maps and those of the other HR datasets in terms of bias, STDD and R can be seen in the answer to RC3.
We will replace the original Figure 5-7 (S1+S2 versus the other HR maps) by these new figures in the revised version of the manuscript. Sections results and discussion will be updated accordingly.

RC16–L369: The Authors should edit the first line of the discussion section. It suggests that four HR soil moisture dataset were produced and evaluated. Whereas, the product evaluated here should be S2MP against the other data sets.

This sentence will be rephrased.

RC17–Section 4.4: The manuscript does not show any time series analysis. It could be interesting to see some time series of the S2MP product against in situ data and the other HR-CR soil moisture products.

Actually, the computation of the different statistical metrics (R, bias, STDD) with respect to the other datasets or the in-situ measurements is a time series analysis. However, we clearly understand the interest of showing time series from the different datasets. The figure below shows time series from each dataset at 6 in-situ stations. The revised version of the manuscript will include this new figure.

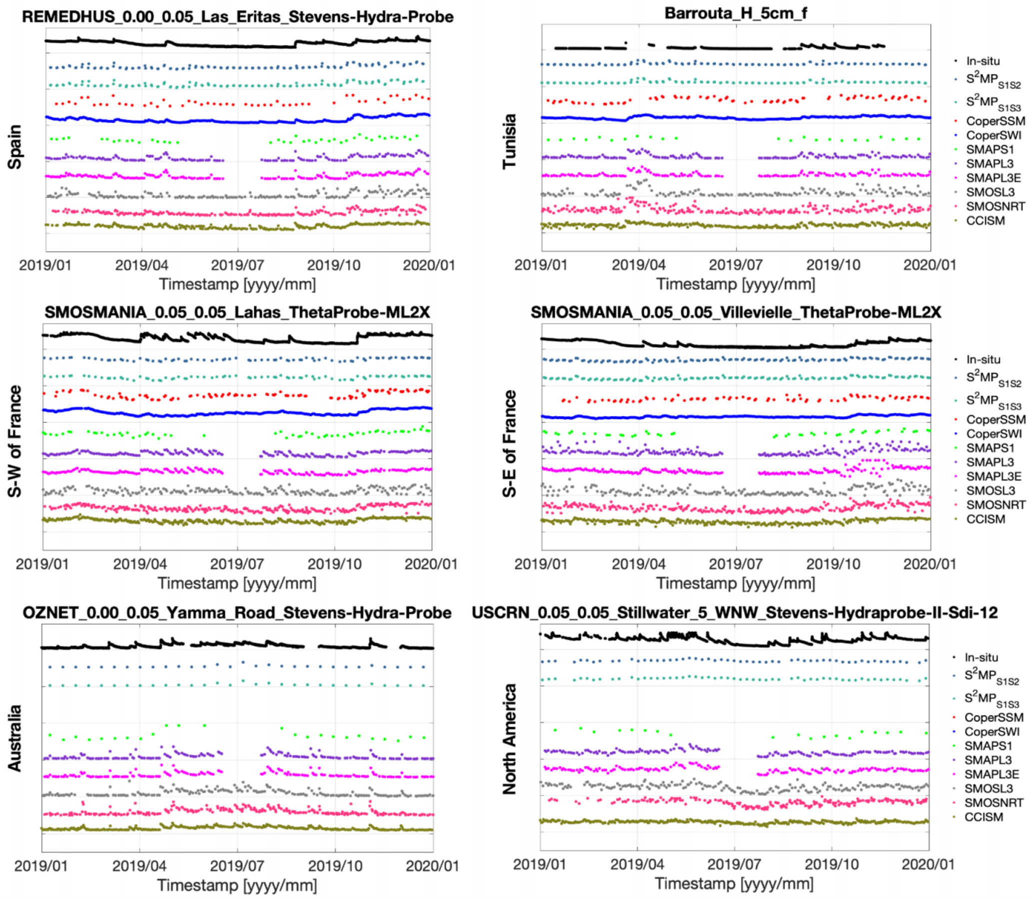

Figure 8. Examples of SM time series from the different HR and CR datasets at 6 in-situ stations (one for each region).

RC18: The Authors should check for the acronyms in the abstract section as well as throughout the text. The notation should be uniform. For instance, at line 5 the Authors write NDVI (Normalized Difference Vegetation Index) but it should be the opposite considering other notations (i.e. Soil Moisture [SM]). Another example is at line 194 where the notation “soil moisture” should be edited to “SM”.

All the acronyms will be checked and explained as follows: Full Name (FN). For example: European Space Agency (ESA).

RC19–L130: Maybe the Authors can mention that T is the *“characteristic time length”*.

As well pointed out, the definition of the T value is not written in the manuscript. It will be added in the revised version.

RC20-L118: The term *“estimation”* before images should be removed.

The related sentence will be edited.