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Interactive comment on "Gap-Free Global Annual Soil Moisture: 15 km Grids for 1991–2018" *by* Mario Guevara et al.

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1. Limited usefulness of an annual average soil moisture. Some gap filled values i.e. over areas of permanent ice are not physically realistic.

RESPONSE: We respectfully disagree with this comment. There are multiple applications of annual soil moisture estimates that can be related with annual estimates of other variables of ecological importance. We have made our work available to the community through the Hydroshare database and we are monitoring the use of our datasets by other scientists . Our datasets (years 1991-2016 and 1991-2018) have been downloaded nearly 300 times demonstrating interest from the community. Another example of broad interest by

the scientific community is our estimates of annual soil moisture across the conterminous United States, which have been downloaded nearly 3,000 times (see:https://www.hydroshare.org/resource/b8f6eae9d89241cf8b5904033460af61/). We believe these metrics are a solid indicator of the impact and relevance of our datasets. Examples for uses of annual average of soil moisture include topics related to soil health, trends in the carbon cycle, response of ecological communities in terrestrial ecosystems, changes in ecosystem functions, among others. We will include text in the discussion to highlight these and other potential applications. We agree with the Reviewer that values in permanent ice are not physically realistic. In the revised version of this manuscript we will not present soil moisture estimates across Antarctica or the Arctic.

2. Incorrectly referenced CCI dataset i.e. L51, 72 (as per terms&conditions https://www.esa-soilmoisturecci.org/node/236) + manuscript does not specify which CCI product was used (passive, actice or combined). In L96: I believe the authors meant v4.7, there is no CCI SM v4.9.

RESPONSE: We will revise the manuscript for consistency in data versions, and we will include the references associated with the development of the ESA-CCI according to the policy listed in the webpage. We clarify that we used ESA-CCI version 4.5.

3. Unnecessary level of detail in the abstract, numerical results could be saved for the end.

RESPONSE: We respectfully disagree with the Reviewer; we believe that quantitative results are important information in the abstract to facilitate readers in identifying the key contributions of the paper. That said, we will revise the abstract for clarity in the revised version.

4. The number of used in situ ISMN records (n=13,376) seems very high, nowhere does the manuscript state which sensor depths from ISMN records were selected for the validation. (As acknowledged in L65, satellited soil moisture represents 0-5cm and

so only relevant in situ records should be included).

RESPONSE: This number does not represent in situ monitoring stations but corresponds to the number of globally available soil moisture records from all ISMN stations between 1991 and 2018. In other words, we aggregated all available soil moisture values for each station contributing to the ISMN on a yearly basis between 1991 and 2018. We will revise the manuscript for clarity. Furthermore, we want to emphasize that the validation only with information within 0-5 cm from the ISMN is consistent. Here, we present examples of our validation approach using only information within 0-5 cm from the ISMN (Figure R1).

5. The overall correlation with in situ records of the original CCI dataset (L25-27 again, no product specified) is said to be 0.3 which is much lower than the correlation values available from the official CCI product website, validation report and what a quick validation (https://qa4sm.eu/result/8098cf4a-726b-4f56-a4cb-fb180c884c5c/) all suggest (r=âĹij0.5). If annual mean values were validated, how were the means taken, was there a number of available observations threshold for a pixel in the CCI dataset before a mean was taken? Or could annual means be computed with at least a single observation? The same goes for in situ reference data. The selection of included in situ sensor depths would also affect the correlation metrics.

RESPONSE: We will include in the revised discussions potential issues for this discrepancy. For example: the correlation presented in the ESA-CCI website represents a calculation using a different time period (between 1978 and 2020). In this study we only use data between 1991 and 2018, and we perform our comparison using the ESA-CCI on a yearly basis. We did not consider a minimum number of observations threshold for a pixel in the CCI dataset or the in situ reference data (i.e., the ISMN) before calculating global yearly means. More information on gaps (e.g., pixels with only one observation during each year) will be provided in the revised version of our manuscript.

6. The 10-line Fig 2 caption repeats the preceeding text exactly; repetitive wording in other figure captions (i.e. Fig 5).

RESPONSE: We will revise the text and remove repetitive wording.

7. Section 2.2 it is unclear to me whether the model was entirely built around annually aggregated CCI values.

RESPONSE: We built a model for each year using all available data for that specific year aggregated on an annual basis. We will revise the methods section to clarify this point.

8. Section 2.4: not sure if validation against a mixture of soil moisture and rainfall observations is a good approach... Later L372-373 read "The use of precipitation data for areas of the world where no in situ soil moisture validation data is supported by work of Gruber et al., (2020)." - I found no such information in the quoted paper, moreover Fig 1 shows that the used in situ rainfall stations often overlap with the soil moisture ones, contradicting that statement (unless they all don't overlap temporally). I believe 'available' is also missing from the quoted sentence.

RESPONSE: We clarify that our results represent independent validations: one only with soil moisture data and a second one only with precipitation data. We will revise the methods section to clarify this point. We will also revise the text in lines 372-374 following the suggestion of the reviewer.

Gruber et al (2020) provide a validation framework for soil moisture and recognize that in the absence of ground data, other variables related to soil moisture could be used as alternatives for a validation strategy. We assume that precipitation data is a closely related variable to soil moisture and we will clarify this assumption in the revised manuscript. We used precipitation data as a complementary approach for validation and comparison of ESA-CCI and our data products. We will make edits in the methods section and discussion section to clarify this approach.

9. The source of the precipitation records is not explained until L366 even though these data are mentioned several times before. As they are mentioned and mapped (Fig 1) together with in situ soil moisture it is easy to assume the authors refer to in situ precipitation measurements from ISMN. L162 and L368 seem to be using 'records' and 'sites' interchangeably, which is incorrect.

RESPONSE: We will improve consistency in this narrative and will clarify that precipitation data is not from the ISMN, but from another database. We specifically used data from the soil respiration database, which reports annual precipitation associated with locations of soil respiration measurements around the globe (Bond-Lamberty and Thomson, 2018). We will revise the manuscript for consistency of terms and avoid redundancy on how we refer to the datasets.

10. ISMN is a dynamic dataset and access/download data would be useful. What are the 8,080 ISMN tables mentioned in L361? Confused by this number. From how many stations were the 13376 records derived? Which networks were selected and why. Again, what reference depths were included.

RESPONSE: We will add more information about the ISMN version in the methods. The full ISMN dataset provides over 10,000 tables including climate, soil temperature, and soil moisture data (downloaded in August of 2019). We identified 8,080 tables with 13,376 soil moisture records across the green sites illustrated in Fig. 1. These records are available with high temporal resolution (e.g., hours to daily). Between 0-5 cm depth, we use information available from 987 sites (Figure R2) and provide this dataset along with the soil moisture predictions. We will clarify this in a revised version. Finally, we plan to include additional figures as supplementary material to show the availability of ISMN data using only information between 0-5 cm depth (Figure R2).

11. L68- there is also 1km surface soil moisture over Europe https://land.copernicus.eu/global/products/ssm2020

RESPONSE: We will include this reference in the introduction

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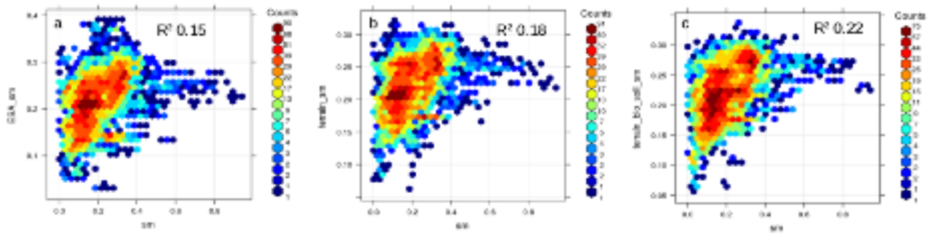

Fig. 1. Fig R1 Validation plots: a) ISMN 0-5cm and soil moisture data from the ESA, b) ISMN 0-5cm and predicted soil moisture using terrain covariates, c) ISMN 0-5cm and predicted soil moisture using terrain,

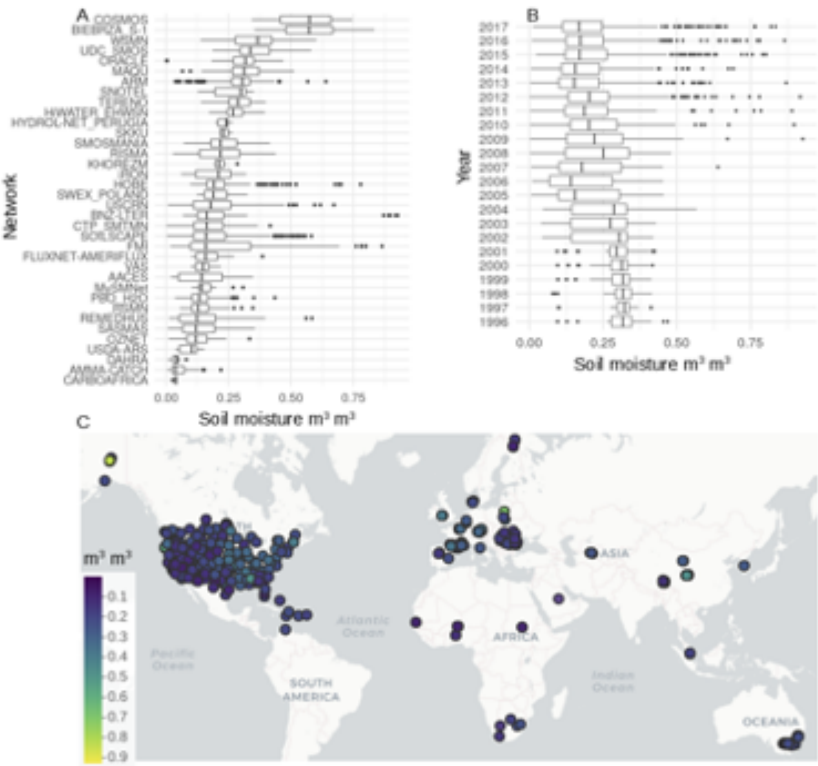

Fig. 2. Fig. R2 Statistical distribution of A) soil moisture values at 0-5 cm depth according to each contributing network in the ISMN, B) years of available data and C) the spatial distribution of available