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Interactive comment on "The Sodankylä in-situ soil moisture observation network: an example application to Earth Observation data product evaluation" *by* J. Ikonen et al.

J. Ikonen et al.

jaakko.ikonen@fmi.fi

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We would like to extend our sincerest gratitude to the reviewer for the very useful comments and suggestions. We will respond to the comments and questions below in the order that they were presented. We will submit a revised manuscript after the review period has closed.

[QUESTION 1]: The authors correctly state on P612L27 to P613L3 that: ". . . GLDAS-Noah model data to impose absolute soil moisture values to the CCI data product renders statistical comparison metrics such as root-mean-square-difference and bias somewhat scientifically meaningless. The CCI soil moisture product should in fact be

used, and considered as a reference product for computing correlation statistics, not as an absolute soil moisture content estimate ...". These statements should be made earlier by moving them to section 4 that describes the ESA CCI product. In addition, remove from the Abstract this sentence "All years exhibit a negative (dry) bias ranging from 0.0346 to 0.046".

[RESPONSE]: With regard to the statement that; "the CCI soil moisture product should not be considered as a direct soil moisture reference product", the reviewer raises a good point in that perhaps it should be mentioned much earlier. As suggested we will move this sentence into section 4. As part of our effort to reduce the length of the abstract we will remove this sentence; "All years exhibit a negative (dry) bias ranging from 0.0346 to 0.046" from the abstract, as suggested.

[QUESTION 2]: Please also provide statistics for the temporal correlation between the in-situ and ESA-CCI soil moisture anomalies.

[RESPONSE]: We have previously calculated temporal correlation statistics between in-situ and ESA-CCI soil moisture anomalies. The correlations for these were however small and therefore they were not included in the original manuscript as they hold very little new information. We have calculated anomaly correlations by compensating for standard deviation in three ways; 1) deviation from 7-day average, 2) deviation from 15-day average and 3) deviation from 31-day average. The correlations for these are;

Deviation from 7-day average: 0.15 (2012) 0.19 (2013) 0.22 (2014)

Deviation from 15-day average: 0.21 (2012) 0.24 (2013) 0.36 (2014)

Deviation from 31-day average: 0.18 (2012) 0.17 (2013) 0.29 (2014)

[QUESTION 3]: A number of verification studies convert the in-situ and remotely sensed soil moisture to soil wetness (rescaling to soil wetness using the time-series maximum and minimum values) prior to calculating bias and root mean square difference. These additional statistics would be very useful since the soil wetness is less

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affected by the high spatial variability of soil and vegetation types.

[RESPONSE]: We have now converted the in-situ and ESA-CCI soil moisture data into "soil wetness" by rescaling the respective soil moisture values to the entire time-series' maximum and minimum values. This comparison would be more useful if we were comparing results from several pixels, and in that case having the results on the same climatology would be valuable. These additional statistics however provide very little new information for this study and therefore we will not include these in to the revised manuscript. The resulting RMSE and Bias statistics are as follows;

2012: 0.16 (RMSE), -0.18 (Bias) 2013: 0.18 (RMSE), -0.09 (Bias) 2014: 0.25 (RMSE), -0.17 (Bias)

[QUESTION 4]: Please provide more information on the accuracy of the in-situ soil moisture measurements and the area-representative in-situ soil moisture average. Perhaps the field measurement campaigns data can be analysed to provide more information.

[RESPONSE]: We could have been clearer on this in the original manuscript. We will now include a more comprehensive descriptive analysis on the accuracy of the in-situ measurements and area-representativeness through, and by more detailed interpretation of the field measurement campaign results.

[QUESTION 5]: Microwave C-band AMSR2 and ASCAT derived soil moisture is representative of the top 1cm of soil. Often, an exponential filter is used to relate the remotely sensed soil moisture measurements to the in-situ measurements at a depth of 5cm. What is the representative soil depth for the ESA-CCI product? Does an exponential filter need to be applied to the ESA-CCI product?

[RESPONSE]: The reviewer raises a very good point. Since the ESA-CCI data product is derived from AMSR2 and/or ASCAT (in our case only ASCAT) data, we assume, although this has not been explicitly defined in the description of the ESA-CCI data

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product or definitively proved to be the case in other studies, that in-fact what is referred to as top-layer soil moisture, can in-fact be considered to refer to soil moisture at a depth of only 1 cm as the reviewer states. Other similar studies to ours, e.g. Nicolai-Shaw et al. (2015) and Dorigo et al. (2015), however support our initial assumption that the ESA-CCI data product represents soil moisture data at a depth of 0-5cm. Further, in both of these examples ESA-CCI soil moisture is compared to in-situ soil moisture observations made at depths of 5 or 10 cm.

Despite this, we acknowledge that applying an exponential filter to ESA-CCI soil moisture data provides valuable additional information. We will include these additional results to our revised manuscript using an exponential soil moisture filter proposed by Wagner et al. (1999). In our application we have used a simple recursive formulation of this method. The results show significant improvements in daily correlation against in-situ observations. There exists however a possible drawback in its application related to the need of an additional parameter, T (temporal variation of soil moisture within the root-zone profile, in days). Ideally this parameter needs to be regionalized and should possibly be dynamic, in that the value of T should ideally change according to soil moisture conditions below the target filtering depth. The uncertainty of the T value brings along with it new potentially undesirable characteristics in that it can mistakenly be used to fit EO based soil moisture data to observations. In order to reduce uncertainty and the potential for fitting, a physical significance needs to ideally be attached to this value. Despite our concerns, we will include daily average comparison results assuming a T value of 1 and 3.5 days (as suggested in Brocca et al. (2011)). The issue of applying an exponential filter to adjust EO based soil moisture data and proper T parameter value assignment could perhaps be a topic for an entirely separate article.

References:

Dorigo, W. A., Gruber, A., De Jeu, R. A. M., Wagner, W., Stacke, T., Loew, A., Albergel, C., Brocca, L., Chung, D., Parinussa, R. M., and Kidd, R.: Evaluation of the ESA CCI soil moisture product using ground-based observations, Remote Sens. Environ., 162,

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380–395, 2015.

Nicolai-Shaw, N., Hirschi, M., Mittelbach, H. and Seneviratne, S.: Spatial representativeness of soil moisture using in situ, remote sensing, and land reanalysis data, Journal of Geophysical Research: Atmospheres, 120, 19, 9955–9964, 2015.

Wagner, W., Lemoine, G., and Rott, H.,: A method for estimating soil moisture from ERS scatterometer and soil data. Remote Sensing of Environment, 70, 191–207, 1999.

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 Bittelli, M.: Soil moisture estimation through ASCAT and AMSR-E sensors: An intercomparison and validation study across Europe. Remote Sensing of Environment, 115, 3390–3408, 2011.

[QUESTION 6]: The verification suggests high temporal correlation between the in-situ soil moisture average and the ESA-CCI product for the years 2012 and 2013. However, for 2014 the temporal correlation is much smaller. To properly investigate this difference, verification statistics should be calculated for the individual components of the ESA-CCI product: ASCAT, AMSR2 and GLDAS-NOAH. The LPRM algorithm provides estimates of VOD, is there much inter-annual difference in VOD? Is there much inter-annual difference in snow cover during the years 2012, 2013 and 2014?

[RESPONSE]: It is stated on page 609, lines 10-13; “For the Sodankylä region only active microwave data is used, since from the perspective of the CCI product merging algorithm, the Sodankylä region falls within a region with moderate vegetation density exceeding the predefined threshold value.”. This means that, although through-out the article we refer to the ESA-CCI soil moisture product as a merged product, in practice the merged ESA-CCI soil moisture product for the Sodankylä pixel only consists of ASCAT soil moisture data that has been scaled by GLDAS-NOAH data - arguably this could be stated much more clearly. Therefore comparing the AMSR2 data component is irrelevant. Comparing against GLDAS-NOAH soil moisture data is in practice not

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possible, since the original GLDAS-NOAH data used in producing the ESA-CCI soil moisture product has not been and is not made available by the ESA-CCI soil moisture data product providers. Further, it is stated on page 608, line 26 and page 609, lines; "In step 3 the active and passive datasets are blended together by re-scaling both to GLDAS-Noah soil moisture data values with a cumulative distribution function (CDF) matching approach. This imposes GLDAS-Noah model based absolute value ranges on the original EO observations, but does not have an affect on the original EO data dynamics (Chung et al., 2014b)." This renders in-situ data comparison, in terms of effect on correlation, at least in theory, irrelevant. In reference to the VOD value, the VOD value itself only determines whether or not active or passive data is used. In our case for all of the years, only the active product is used to produce the ESA-CCI soil moisture product. Therefore inter-annual differences in the VOD value are irrelevant to this study.

[QUESTION 7]: Please improve the caption for figure 5 and provide a clearer explanation of what the figure shows. What do the vertical bars represent?

[RESPONSE]: Duly noted, and a new improved explanation of figure 5 and improved caption will be provided in the revised manuscript.

Interactive comment on Geosci. Instrum. Method. Data Syst. Discuss., 5, 599, 2015.