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Geoscientific Instrumentation Methods and Data Systems Discussions

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.

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We would like to extend our sincerest gratitude to the reviewer for the very useful comments and suggestions. With regard to the reviewer's concern over language, we will employ a native speaker to review the final revised version of the manuscript. We will respond to the comments, concerns and questions below in the order that they were presented. We will submit a revised manuscript after the review period has closed.

[QUESTION 1]: Perhaps update the title to be more specific: "an example application to ESA CCI soil moisture product evaluation"

[RESPONSE]: Agreed; admittedly the reviewer's suggestion sounds much better and actually describes the article better – we will the title accordingly.

[QUESTION 2]: Abstract line 18 and throughout the text: how exactly is "top layer" defined? Here it says 5-10 cm, but later on the sensors appear to be installed at -5 and -10 cm. The measurement centralized at -5 cm is valid for a top layer of 0-10 cm, not 5-10 cm. Please be more precise throughout about the "top layer", because this also affects the comparison with the remote sensing data (which don't give information below 5 cm).

[RESPONSE]: This reviewer raises a valid concern. This is an issue that we've now sought to clarify in the revised manuscript. Defining the top layer of soil as strictly referring to a depth of e.g. 0-10 cm is in our view slightly restrictive. The reason we've deliberately referred to soil top layer vaguely instead of a particular depth, or range of depths is two-fold. First, the term soil "top layer" is vague by definition, and varies between soil types. This is seen for example in how soil horizons are defined in soil taxonomy classification systems. In these, the top layer of soil is usually referred to as the A-horizon, and the depth as well as thickness of this can vary significantly from soil type to soil type. Second, the absolute depth to which the ESA-CCI soil moisture data product refers to is not explicitly stated – and in-fact this could be a topic for another paper, and in-part something that this paper actually seeks to answer. Since the ESA-CCI soil moisture data product claims to present "top layer", soil moisture it is in our view appropriate to compare the data product to in-situ measurements made at depths that we consider to best represent (within reason) the vaguely defined term; "top layer" of soil. This is in-fact an important point; a depth of 5 cm for conducting top layer soil moisture measurements for e.g. Umbric Gleysol type soil (a semi organic soil type) can be argued to be inadequate, and to not be deep enough to actually capture soil moisture at all. The structure of soil typically at that depth usually consists of mostly porous vegetation and litter mixed with mineral soil particles. In this case it is in our view and through our understanding of local conditions more appropriate to

take top layer soil moisture measurements in Umbric Gleysol type soil from a depth of 10 cm instead. In this case strictly following a vaguely argued definition of 5 cm as an appropriate and correct depth for conducting top layer soil moisture measurements would be impractical. One could argue that in this case it is not necessarily valid to say that soil moisture values at 5 cm best represent top layer soil moisture for this particular soil type. However as stated, in order to alleviate any concerns, we will change the definition of soil top layer to mean 0-10 cm through-out the article, as this was the original intention anyway. This definition does however not apply to Umbric Gleysol soil moisture measurements, where we have taken the liberty of adjusting the definition to mean 5-15 cm.

[QUESTION 3]: I do not see any use in looking at the "weekly running" average values. Those weekly data points are sometimes made of no more than a handful of measurements and not really representative for "weekly" data, but instead simply filtered to remove noise, which evidently improves the statistics (except bias, as expected). Yet, the latter is no surprise and not very useful for remote sensing validation. I would not include that in a paper. Instead, I suggest to focus more on the spatial scaling and averaging, see below.

[RESPONSE]: We disagree with the reviewer on this point. We consider the use of temporally smoothed dataset as important and common practice, instead of irrelevant, as the reviewer suggests. Temporally smoothed data, in which identifying a particular trend, can be useful in various potential operational activities such as terrain trafficability analysis, inflow forecasting for hydropower production and flood forecasting. Therefore investigating the accuracy of this is important.

There are several other studies in which satellite based soil moisture data is temporally smoothed. For example C. Champagne et al. (2010) state that; "The daily values extracted from the satellite-derived soil moisture contained considerable noise which made the interpretation of the soil moisture time series problematic. The raw data series was compared to dataset smoothed with a five-day average filter, described in

§2.2 (figure 3). The smoothed data from both retrieval algorithms visually have much better agreement with the in situ soil moisture measurements. Subsequent results are reported based on the temporally smoothed dataset only. An assessment of the unsmoothed data was also made, and the relationships reported here were relatively consistent, but with higher overall error and lower correlations with the satellite data products (results not shown). This indicates that the use of a temporally smoothed dataset is important for use of these datasets.". Further for example, C.S. Draper et al. (2009) state that; "Prior to the normalization, the AMSR–E data was filtered to reduce the noise using a 5-day moving average filter; while a 16-day filter would be more physical for treating the noise associated with the mapping technique, it would overly dampen short-term variability. The correlation (r) and Root Mean Square Difference (RMSD) between the in-situ data and the AMSR–E soil moisture for the original and normalized/ filtered AMSR–E data are provided in Tables 1 and 2, respectively. The benefit of the filter is demonstrated by the increase in correlation to the in-situ data: in most instances the correlation is increased (by up to 0.12; since the normalization is a linear transform it does not affect the correlation estimates).".

References:

Champagne, C., Berg†, A., Belanger, Mcnairn, H., and richard de Jeu, R.: Evaluation of soil moisture derived from passive microwave remote sensing over agricultural sites in Canada using ground-based soil moisture monitoring networks, International Journal of Remote Sensing, 31, 14, 3669–3690, 2010.

Draper, C., S., Walker, J., P., Steinle, P., J., de Jeu, R., A., M. and R.H. Holmes, T., R., H.,: An evaluation of AMSR–E derived soil moisture over Australia, Remote Sensing of Environment, 113, 703–710, 2009.

[QUESTION 4]: p.601, line 16: why are ECHAM and JSBACH mentioned? They do not strike me as 'well known' models.

[RESPONSE]: Perhaps using the term "well known" can be considered as a bit over-

stated, but nonetheless we consider both ECHAM and JSBACH to be at least relatively well known. Besides, to what degree something is “well known”, or not is largely up for subjective interpretation, depending on where someone is from or to which social groups one is connected to etc. Further, to our knowledge ECHAM is (still) a relevant climate model. It was e.g. included in the latest CMIP5 (Taylor et al., 2012) runs as the atmospheric part of MPI-M Earth System Model, CMCC-CESM, CMCC-CM, and CMCC-CMS. CMIP5 was the basis for the IPCC AR5 (Flato et al., 2013). MPI-M Earth System Model includes JSBACH (Reick et al., 2013) as Land Surface component. We agree that version 6 should be mentioned instead of version 5. We will update the version number and references.

[QUESTION 5]: p.601, line 27: SMAP has been launched more than a year now. That is not “just recently”.

[RESPONSE]: In our view, whether or not something is considered as recent or not is up for subjective interpretation. For example, research conducted a year or even two or more years ago can be considered as recent, depending on whom the considerer is, or what the subject field is etc. Nevertheless, we will remove this word completely from the revised manuscript.

[QUESTION 6]: p.602, line 19 (and other places in the paper): rewrite as “spatially weighted average of top layer (XX0-10 cm? See aboveXX) soil moisture”

[RESPONSE]: Good suggestion, we will re-word this through-out the article.

[QUESTION 7]: p.602, line 25: aren’t they using this site in SMAP CalVal as well?

[RESPONSE]: To our knowledge, the Sodankylä site is planned to be used as a CAL-VAL site for SMAP data, however no studies have so far been conducted at least with the same in-situ datasets described in our paper. Further, it is actually our intention to conduct soil moisture data comparisons against SMAP data using the in-situ observation network described in this paper in future studies.

[QUESTION 8]: p.604, line 21: “These measuring points. . . some ten meters. . .”: which points are you referring to? Are these the 2 additional “horizontal measuring points”? At what depth? Please clarify.

[RESPONSE]: We agree that this needs clarification. Clearly some text is missing. We will edit the sentence as follows: “The two additional horizontal measuring points have been installed some ten meters from the station in opposing directions, in order to catch small scale variations in soil moisture of the uppermost layer. Both of these measuring points have two sensors at depths of -10 cm and -5 cm.”

[QUESTION 9]: p.606, line 2: why is 2013 skipped in this discussion? (Table 2 shows that 2013 received an additional sensor)

[RESPONSE]: The establishment of the UG Forest 2 site in 2013 was only done to verify measurement results from the UG Forest 1 site. As such, this in-situ site is not very significant when considering its location and does not contribute to increasing the areal representativeness of the in-situ observation network. We are in-fact planning to discontinue measurements at this site and move the equipment to a new site during the summer of this year (2016). Despite these issues, we will add a sentence to the revised manuscript to clarify this.

[QUESTION 10]: p.606, line 15: “within the area”. Which area? The area covered by the ESA CCI pixel, 25x25 kmËĘ2? Related to this, p.600 line 21 says that the CCI pixel ‘encapsulates’ the Sodankyla observation sites, but figure 1 shows that the pixel excludes 2 CalVal sites. Please clarify.

[RESPONSE]: The area that is referred to is the ESA-CCI pixel area. This will be stated more clearly in the revised manuscript. Regarding the usage of the word “encapsulates” is admittedly technically incorrect when also considering all of the new in-situ observation sites, even though they were not used in determining the comparison results presented in our paper. We will also re-word this.

[QUESTION 11]: p.606, line 17: what is meant by “continuously redistributed”? continuously in time? I think this word can be removed here. In general, it does not seem a good idea to create a time series with varying number of sensors, because it will alter the climatology of the time series. It can be compared to the ESA CCI product: they applied CDF-matching to each individual period to get all data in the same climatology. Similarly, the in situ data should be made ‘consistent’ if additional sensors are included. In order to do so, we’d need to look at the time series with and without the additional sensors and then match the climatology to be consistent across all years.

[RESPONSE]: The reviewer is correct in that using the word continuously in that sentence is perhaps a bit confusing. We will reword this sentence. With regard to the issue of inconsistency in the in-situ time series, we acknowledge that the reviewer raises a valid point. With regard to this issue please see response to comments #18 and #19.

[QUESTION 12]: p.607: the weighting happens based on soil types. What about terrain (e.g. slope) and vegetation?

[RESPONSE]: Although we agree that ideally the weighting of in-situ observations should also take into account slope and vegetation, in practice in our case, it is a) not possible to do and b) not a very significant issue. The maximum slope within the CCI-ESA pixel is 12 degrees and although this is quite high, the mean slope is only 1.2 degrees and the standard deviation of slopes is only 1.3 degrees. The Sodankylä ESA-CCI pixel in question is thus relatively flat, and while terrain surely has an effect on soil moisture, the areas underneath slopes are rather small. Further, no in-situ stations are located at the bases of significant slopes. Concerning vegetation, we have calculated areal coverage percentage shares for the 6 primary land cover types based on Corine 2006 data. The areal coverage percentage shares are; forest (67.5%), open areas (6.2%), bare rock (4.1%), bogs (21.6%) and water (0.5%). Based on this data it can be stated that the ESA-CCI pixel area is primarily covered by forests and bogs (accounting for 89.1% of the area). Our in-situ observations are all either in forests (in various soil types) or bogs. Taking into account other land cover classes is in our opin-

ion thus not required. Further, in Sodankylä the soil type tends to determine the type of vegetation present. Ideally we would like to divide the largest soil type (Haplic Podzol) into 2 subcategories, one covering dense forests (in practice fine Haplic Podzol) and the other spare forests (in practice coarse Haplic Podzol). Our field campaign data shows that there is a slight difference in soil moisture in the two. Unfortunately at the moment we do not have in-situ observations in coarse Haplic Podzol (sparse forest), consequently new in-situ site installations are being planned. This issue is discussed at length in section 3.2.

[QUESTION 13]: p.609, line 2: one example of several English issues: “does not have an effect” instead of “affect”.

[RESPONSE]: Agreed, we will fix these mistakes.

[QUESTION 14]: p.609, line 15: ASCAT passes over at specific time steps. When the ‘daily’ values are compared to in situ data, did you match up the exact overpass time steps? Please clarify in the text.

[RESPONSE]: In our study comparisons were made with daily average ESA-CCI soil moisture data (if more than one overpass occurred on that day) against daily average in-situ observations. We also conducted comparisons where ESA-CCI soil moisture data was compared against in-situ observations at the time of overpass. This did not however result in significant differences in statistical scores. For the sake of article length and simplicity we decided not to present these results in our paper. We will attempt to state this more clearly in the revised manuscript.

[QUESTION 15]: p.610, line 3: “apparent” noise? That is not apparent, that is real noise. . .

[RESPONSE]: Agreed; we will remove the word “apparent”.

[QUESTION 16]: Figure 7 and (8, 9) show the same information. It is sufficient to show the time series (Fig 7) only. Give units to all axes.

[RESPONSE]: We disagree with the reviewer on this point. Although the figures show the same data, a timeseries and scatter plot show different aspects of the comparison. Further, in our opinion the reader can get an improved visual sense by comparing the timeseries and the scatter plots. In our view this issue is a matter of subjective preference rather than an objective concern .Therefore we have not removed the figures from the article. We will however add the missing y-axes units in the timeseries plots as suggested.

[QUESTION 17]: p.605, line 17 and Table 2: The last 2 sensors are not calibrated, so why include them in the analyses of this paper?

[RESPONSE]: One of the purposes of this paper is to present the Sodankylä in-situ soil moisture observation network and as such we feel that it is relevant to mention these new stations as well. Data from these stations is however not used in the comparison results since they were installed in 2015. This is due to the fact that the ESA-CCI soil moisture data product does not at the time of writing extend out to the year 2015. Regarding the issue of calibration, we have found that factory calibration is adequate enough when measuring soil moisture on mineral soil, as is the case with these two stations. Further, careful inspection of table 1 would reveal that the same factory calibration has been used for the other stations as well when measuring soil moisture on mineral soil.

[QUESTION 18]: Table 3: no need to discuss the "weekly filtered" statistics, they do not add any value. Instead, I would suggest looking at the statistics for 2015 with its 8 sensors (adequately spatially averaged), then with its 6 sensors (same as in 2013-2014) and then with its 5 sensors (same as in 2012). Then discuss the impact of the additional sensors. Same for 2013-2014: compare the results for 5 (as in 2012) and 6 sensors. So, in short, discuss the effect of the spatial averaging in more detail, rather than the weekly filtering.

[RESPONSE]: We agree with the reviewer in that ideally we would like to look at statis-

tics for 2015 and discuss the impact of adding new sensors to the comparison results. However, the ESA-CCI product is not yet available for the year 2015; therefore conducting comparisons is not yet possible. In-fact only 1 new sensor (G Forest 2) was added between the years 2012-2014. The impact of adding the UG Forest 2 station in 2013 is very insignificant as it is located on the same type of soil and vegetation as the UG Forest 1 station. Adding the UG Forest 2 site to the comparison does not change daily correlation for 2013 but for 2014 adding the UG Forest 2 station increases daily correlation from 0.17 to 0.19. Overall daily correlation for the years 2012-2014 does not change. In future studies, once new data becomes available, we will conduct a more thorough analysis on the impact of adding additional sensors.

[QUESTION 19]: Ultimately, if I want to validate a product over a longer time period, I will want to use a consistent time series of in situ obs, that is, one with just the 6 sensors going from 2012 through 2015 (unless some clever CDF-matching would have been performed to bring the various chunks of data to the same climatology).

[RESPONSE]: We agree that ideally adjusting for new stations should be conducted. However, since in our comparison results we have only actually added a single new station, and the one added is on the same soil and vegetation type (Umbric Gleysol, Mixed Forest) as another one used in the timeseries, we consider doing this rather inconsequential. Further, as can be seen from our response to the reviewer's question #18 the impact of adding the new station is in practice very insignificant. As stated in our response to the reviewer's question #18, in future studies, once new data becomes available, we will conduct a more thorough analysis on the impact of adding additional sensors.

[QUESTION 20]: Figure 1: perhaps enlarge the spatial map to focus on the CCI pixel and only the few sensors outside of it.

[RESPONSE]: This is a good suggestion and we will include a complimentary map focusing on in-situ observation site locations.

[QUESTION 21]: Instead or complimentary to Fig 2-4, can you provide a spatial map with the areas (weights) attributed to each sensor based on soil types in “the area” (assuming the CCI pixel), rather than over this big region?

[RESPONSE]: This is a good suggestion and we will include a complimentary map of in-situ observation site locations and respective weights (see our response to question #20).

[QUESTION 22]: Figure 7: remove the connector lines between the observations to clarify that the data points are only taken at times when satellite data are available and not interpolated.

[RESPONSE]: The reviewer is quite correct in that there is no information between the ESA-CCI soil moisture observation points, and in that sense the connector lines may not be appropriate. We will remove these from the daily value representations in the timeseries plots.

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