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Hydrology and Earth System Sciences Discussions

Interactive comment on "Error characterisation of global active and passive microwave soil moisture data sets" *by* W. A. Dorigo et al.

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General comments:

[Comment] The triple collocation technique requires data sets to be independent. However, if I am not mistaking, SSM/I radiances have been assimilated for the development of the ERA-interim product? This could cause an interdependence, through argue the use of SSM/I may not be justified, and should be verified.

[Reply] This comment is principally correct. SSM/I is one of many datasets used in the atmospheric analysis of ERA. However SSM/I radiances are only assimilated over the ocean and to our knowledge only in the case when no rainfall is detected. The relative

contribution to the land surface soil moisture analysis is therefore indirect and negligible. We can therefore work with the assumption that the data sets are independent. This assumption is also confirmed by the robustness of the error fields using different combinations of datasets. In case the errors are significantly correlated the derived error fields would depend on the combination of datasets. But the reviewer raises an interesting issue, that of correlated errors in general. This should be further studied using a fourth source of independent data, e.g. in situ observations from a dense ground station network. We however believe that this would go beyond the scope and objectives of this paper. We will point to this issue in the conclusion.

[Comment] I think the interpretation of the results could be improved by explaining in more detail the motivations and particularly the consequences of using soil moisture anomalies instead of absolute values, for instance in Section 3.2. Which information can or cannot be revealed by this type of error analysis, e.g. in terms of bias, the dynamic range of the soil moisture products, soil moisture variability, etc., and what are the differences with an error analysis based on absolute moisture levels. Such information could be particularly useful since the results are compared with those of Scipal et al. (2008b). Besides, I am not completely convinced that differences between anomaly errors and absolute value errors are always small (p5632.l21). This should be further elaborated, or reference should be provided.

[Reply] The reviewer is making a good point here. One could argue that the error is composed of two different terms, a random error (e.g. influenced by instrument noise) and a systematic error (e.g. influenced by model simplifications) While using absolute values provides information on the total error, i.e. the capability of the soil moisture products to estimate absolute soil moisture levels, the anomaly-based approach gives us more information on random error, i.e. the ability of the different datasets to capture single wetting and drying events (e.g. due to rainfall). As a consequence, the anomaly-based approach tells us less about absolute deviations between datasets, e.g. like induced by a deviating seasonality. The choice of an anomaly-based approach in this study is motivated by the fact that the LPRM soil moisture product from SSM/I at many locations shows a seasonality that is different from the other datasets considered in this study. This is caused by the higher sensitivity of the Ku-band to atmospheric water vapour and vegetation. Whereas the use of absolute values would only tell us that the SSM/I product deviates from the other datasets (i.e. would show high errors), the use of anomalies still provides us meaningful information about the capability of this product in capturing single events. As the systematic differences between datasets (e.g. differences in seasonality) can be mostly corrected for, anomaly-based error estimation of SSM/I provides us a realistic insight on the usability of SSM/I-based soil moisture, e.g. in dataset merging (see Liu et al, 2009, Liu et al, 2010). We will address the differences between errors obtained from using absolute values and anomalies, respectively, in Section 3.2 and throughout the discussion of the results and the conclusion.

Specific comments:

[Comment] P5626-5627: Please add a few details in the explanation of the soil moisture products, i.e. make sure you mention for each product: the polarization, the incidence angles, time span of data availability, spatial and temporal resolution, and some details on the climatology (e.g. dynamic range or choices on the minimum and maximum soil moisture). Most of these items are given, but not consistently for all products. If the authors wish, this could be summarized in a Table, simplifying a comparison between products.

[Reply] For each product (satellite and land surface model) we will provide consistently the details relevant for this study

[Comment] P5627-5628: are there any references for the ERA-Interim and GLDAS-NOAH datasets?

[Reply] Official references will be added to manuscript: ERA-Interim: Simmons, A., Uppala, S., Dee, D., and Kobayashi, S.: ERA-I : New ECMWF reanalysis products 20

from 1989 onwards, ECMWF Newsletter, 110, 25–35, 2007. GLDAS-NOAH: Rodell, M., Houser, P. R., Jambor, U., Gottschalck, J., Mitchell, K., Meng, C. J., Arsenault, K., Cosgrove, B., Radakovich, J., Bosilovich, M., Entin, J. K., Walker, J. P., Lohmann, D., and Toll, D.: The Global Land Data Assimilation System, Bulletin of the American Meteorological Society, 85, 381-394, 2004.

[Comment] P5630.l5: Is the seasonality observed for all data sets, or only for the SSM/I Ku-band? Now, it seems there are only such effects for SSM/I.

[Reply] The seasonality of each dataset is calculated and subtracted from the original observations. We will describe this more clearly in the text.

[Comment] P5630.l13: Is the long term mean at a specific DOY calculated over a large time period, and over the same time interval for each product? Changes in time of the mean at specific DOYs (e.g. through climate change) could have an influence on the calculation of anomalies. Such changes have for instance been reported Australia (subject to frequent droughts since 2000, ref: Liu et al. 2007 in Geophys Res Lett).

[Reply] This is a good argument posed by the reviewer. Indeed, seasonalities are calculated for periods that deviate between the various datasets (ERS/ASCAT: 1991-2008; ERA-Interim: 1989-2008; GLDAS-NOAH: 2000-2008; AMSR-E: 2002-2008; SSM/I: 1987-2008). In fact, there is increasing evidence that slight changes in mean soil moisture may have occurred in the last 3 decades as a result of climate change or ocean oscillations (e.g. Liu et. al, 2009 (WRR); Dorigo et al., 2010 (ESA Living Planet Symposium). Nevertheless, we consider the errors resulting from the varying periods of observation smaller than those that would have occurred when the number of observations is not large enough to reliably calculate the seasonality (e.g. this would have happened when only considering the 2 years of observation of ASCAT). In addition, for largest part of the time series used for calculating the seasonalities, 2002-2008 (i.e. the period of frequent droughts in Australia reported by Liu et al (2007)), observations are available for all datasets and hence eventual changes in seasonality affect all datasets in a similar way. We will raise this issue in the discussion/conclusion

[Comment] P5630.l27: ‘assuming errors in both variables to solve for the calibration constants’: please explain in a bit more detail.

[Reply] More detail will be given at this point

[Comment] P5631.l18: please clearly mention that the errors refer to anomaly values and are not related to absolute soil moisture errors. In the present form, the reported mean global errors could be easily confused with absolute soil moisture errors.

[Reply] Like stated in the “general comments” sections we will clearly address the differences between the anomaly-based errors and the errors that would have been obtained when using absolute soil moisture values.

[Comment] P5631.l22: Is it the dynamic range of ERA-Interim in terms of range between wilting point 0.17m3/m3 and saturation 0.472m3/m3, or in terms of observed soil moisture variability for each specific DOY that most affects the errors?

[Reply] The low dynamic range between wilting point and saturation is meant here. We will clarify this in the manuscript.

[Comment] P5633.l13-21: in general I am a bit sceptic about the assumed better sensitivity of active C-band radar to soil moisture under dense forest stands. In the active case, soil backscatter is also attenuated by vegetation, whereas the latter reflects also a part of the incoming signal directly toward the sensor. In dense forest stands, the radar signal will probably not even reach the ground. In spite of this, it might be that the retrieval technique in the active case is better adopted to vegetation and forests?

[Reply] We fully agree with the reviewer that vegetation interaction takes place in a very similar fashion for active and passive microwave observations. Very recently, Crow et al. (2010; IEEE Geoscience and Remote Sensing Letters) pointed out that first order radiative transfer models are not able to accurately describe radiation attenuation in denser vegetation, in particular for larger incidence angles. This most likely explains

the poorer retrieval capability of LPRM which is based on a simple linear radiative transfer model. We will therefore dedicate an extra paragraph to issue.

[Comment] P5635.l28: there is a large difference between the results expressed in the climatology of ERA-Interim (previous sections) and the one of AMSR-E C-band. Is this because of the low dynamic range of ERA?

[Reply] In fact, this is due to the limited dynamic range of the ERA-Interim dataset compared to the AMSR-E C-band dataset that is used as a reference in this section. We will discuss this at the end of this section.

[Comment] The use of only three data sets for triple collocation is a bit scarce. This may have an influence on the results of the error analysis and should be mentioned in the (conclusions of the) paper.

[Reply] The reason for using three data sets is mathematically well justified. It can easily be shown (Scipal, 2008) that a minimum of three datasets is sufficient to estimate the errors. We agree that including a fourth dataset would be interesting as it would allow parameterising error covariances (currently these are assumed to be 0, i.e we assume independent errors). Unfortunately there exists no forth independent soil moisture dataset with global coverage. The only choice would be in situ observations which only exist locally and would not allow a global evaluation. A potential way to use different datasets with correlated errors (e.g. from different passive microwave satellites) is to run the analysis for different combinations of datasets. In Section 4.3 we illustrated this by exchanging the modelled data set. As was shown in Figure 3, using a different dataset hardly affects the errors obtained for the AMSR-E C-band dataset, except for the cases where statistical conditions are not met, like in areas where soil moisture variability is large or where the signal-to-noise ratio of soil moisture is low (like in desert areas and densely vegetated areas). We suggest discussing this in more detail in Section 4.3.

[Comment] Figures 1-3 should be larger in order to enhance interpretation

[Reply] The figures are available in a larger size. At the stage of final typesetting we will discuss with the editor how the figures can be published at a suited size.

Technical corrections:

[Reply] We will perform all technical corrections as suggested by the reviewer.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 7, 5621, 2010.