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Hydrology and Earth System Sciences Discussions

Interactive comment on "Effective roughness modelling as a tool for soil moisture retrieval from C- and L-band SAR" *by* H. Lievens et al.

H. Lievens et al.

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Anonymous Referee #1 Received and published: 8 October 2010 General comments

An interesting study that proposes an empirical statistical model to reduce the illposedness in soil moisture retrieval from SAR by the integrated equation model?. The model is calibrated and tested using SAR and in-situ observations from various dedicated campaigns. For me, the study would have been even more interesting if the method had also been tested on simulated data, representing a wider range of possible scenarios. In this way you could also make a direct comparison between C and L-band, without any other disturbing influences related to site or other observation characteristics.

Reply: We agree with the reviewer that the use of synthetic data is in many cases opportune for analysing a wider range of scenarios. However, in our case, the use of synthetic data is not possible. Our study presents a method to solve for the discrepancies between roughness parameters as measured in the field, and the roughness parameters that are actually needed by the IEM in order to obtain accurate soil moisture retrieval results. In this sense, it is not possible to first use the IEM (the same holds for any other theoretical backscatter model) to generate the artificial data needed for a synthetic study, as such exercise would be completely determined by the roughness parameters used to generate the backscatter data. This study therefore focuses on real backscatter and soil moisture observations only.

specific comments p4999.l21: RADARSAT does not have very low incidence angles, only ESAR does

Reply: The incidence angle is the angle between the incoming radar signal on the surface and the local surface normal. A low incidence angle thus corresponds to a steep sensing geometry, as is the case for Radarsat-1 S1 and S2 modes. To the contrary, E-SAR operates at high incidence angle.

p5000.l20-21: Explain why measuring a larger soil profile leads to better correspondence with in situ measurements: the reason is that in situ soil measurements are not performed at the surface but over a small depth interval (e.g. 0-5 cm)

Reply: Based on Fig. 1, showing the correlation between soil moisture and backscatter, we did not have the intension to formulate a strong conclusion on the favourable soil moisture retrieval capability of L-band in comparison with C-band. We believe that such comparison would require both C- and L-band data of the same fields, under similar circumstances. Therefore, we adjusted the text by mentioning that the higher correlation at L-band highlights the potential of lower frequency SAR for soil moisture retrieval.

p5000.l27: "...may have been processed..." The author should know, and report, the way the imagery was processed.

Reply: We agree with the referee that authors should know about the processing. However, not all data was processed by us. Giving a detailed overview of the processing of all data would make the description exhaustive. We therefore commented that standard processing techniques were performed for all imagery, basically comprising image calibration and geocoding, and referred to Table 1, in which references are provided for most data sets. As such, interested readers can have more information on the specifications of a particular data set, including the collection of the ground data and processing of the imagery.

p5003.l18: Explain in a little bit more detail what you do. I assume you invert IEM using Mv values measured in situ as input?

Reply: This is correct. We invert the IEM using in situ soil moisture measurements and a predefined roughness value (s or l) as input. To make this clear, the text has been adjusted.

p5003.l18: Are the different effective roughness lengths (i.e. not the real roughness lengths) really a failure of IEM? Theoretically, I would expect that effective roughness lengths would increase at larger wavelengths (i.e. for L-band).

Reply: The scaling of surface roughness is a very complex phenomenon and still not well understood. Currently, a comprehensive description of natural surfaces is lacking. The IEM addresses the scaling with the wavelength by multiplying the correlation length (l) and the RMS height (s) by the wave number (k). As such, from a theoretical point of view, a specific correlation length measured in the field should be valid as input to the IEM irrespective of the SAR frequency applied. The fact that the retrieved correlation

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length, based on the IEM, in situ soil moisture measurements and a predefined RMS height, differs between frequencies in our opinion illustrates a failure of the IEM in describing the scale-dependency of surface roughness, and highlights the importance of effective parameters. Please note that very similar conclusions were already drawn e.g. by Baghdadi et al., 2004, and Zribi et al., 1997.

p5005.l1-4: Is this really shortcoming of IEM or is it due do the fact that you are dealing with "effective" roughness lengths and not with "real" roughness lengths? Additionally, it would be interesting to see what happens with the RMS slope (p5001.l7) when both roughness parameters are left free. Judging from the trends found in your plots I would expect this ratio to be almost constant. This would be an indication that we are dealing rather with a model inversion problem than with a shortcoming of IEM. A better model parametrization in IEM would not necessarily lead to better retrievals.

Reply: If the model would be perfect, there would be no differences between effective and real roughness parameters. The fact that it is not, enforces the need for effective roughness parameters. Therefore, in our opinion, this really is a shortcoming of the IEM. Once again, we refer to Baghdadi et al., 2004 (also referred to in the manuscript), who identified similar shortcomings of the IEM in the description of roughness and incidence angle effects on radar backscattering. The RMS slope was found not to be constant. For instance, based on Fig. 2 (b), RMS slopes equal 0.11, 0.06, 0.04 and 0.02 for RMS heights of 1, 1.5, 2 and 2.5 cm, respectively. Hence, model inversion is not the only concern.

p5005.l23-24: Explain why you use these reference angles. I suppose these should be sensor specific.

Reply: The 23° for C-band corresponds to the standard ERS configuration, whereas the 40° for L-band corresponds to the average value of the incidence angle of the L-band imagery. This has been added to the text. Please also note that our method is certainly not limited to the use of these specific reference incidence angles.

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p5007.l7: Please insert both formula to avoid confusion caused by the Rmod variable.

Reply: If both formulae would be provided, problems arise with defining the regression parameters a and b. From a mathematical point of view, the same parameters cannot be used in the two equations. The use of different parameters would cause problems in the further description of the procedures. Therefore, we would like to preserve one equation with Rmod, however, we have extended the explanation of this equation to avoid any confusion.

p5008: "The validation is somewhat meager as the cross validation like performed in this paper does not really show the robustness of the model. Only using two distinctive training and a validation data sets would show this.

Reply: With respect to this comment, we agree with the referee that setting aside a validation set can be a good strategy to assess the performance of a prediction model. However, the latter is only true if one would have enough data, e.g. a data set of 500-1000 samples. As this is not the case, the most plausible and most widely used method is cross validation (see Hastie et al., 2009 for a more detailed explanation about cross validation). Furthermore, as two cross validation strategies are used in this paper, a leave-one-out and a leave-field-out cross-validation, the method's robustness with respect to a possible effect of the geographical location of the samples is checked (i.e. to check whether or not there is an influence of measurements sampled within the same agricultural field). Only by comparing the results of such cross-validation strategies, this can be verified. Using the (standard) methodology as proposed by the reviewer cannot provide the desired result, given the small size of the data set. Therefore, such exercise is not included in the manuscript. However, a brief justification on the methodology used with a reference to the book of Hastie et al. is provided.

Technical corrections p4996.l3: remove either "yet" or "at present" Reply: “yet” has been removed p4996.l8: Insert a break after "... in Europe" Reply: OK p4996.l16: I am not familiar with the symbol Mv being used to indicate volumetric soil moisture Reply:

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There have been several studies using Mv or mv, e.g. Verhoest et al., 2007 and Mattia et al., 2009. p4997.l5: Please rephrase or specify "input use" Reply: “Input-use” has been replaced with “the use of” p5000.l16: "Mv-observations - add "in situ" Reply: “in situ” has been added p5003.l4: "...one solution..." Use "... a unique solution..." instead. Reply: OK p5004.l18: "... than C-band". Add "(Fig. 6)" Reply: We believe that this cannot be derived from Fig. 6 p5008.l18: leave-field-out validation: on p5000.l16-17 you say that you calculate Mv at field level. Therefore, what is the difference between cross validation at data point level and that performed at field level? Reply: The leave-field-out validation retains all data observed on a given field, i.e. data acquired on different dates on one field. The leave-one-out validation only retains one field observed on one date. A short sentence is added to make this clear. Furthermore, the relevance of this validation has been described into more detail, as explained in the specific comment dedicated to this concern.

Table 1: in the column "sensor" you do not list the sensors (e.g. ASAR) but the platforms. Reply: We have changed the title in the table to “SAR data” and have added the sensors as well, e.g. ASAR and PALSAR.

It would interesting to know how many samples you take per field. Reply: The number of soil moisture measurements per field ranges from 3 (for some of the Demmin field campaigns) to 40 (for the Dijle and the Alzette campaigns) samples. However, because of the large variability in the number of samples per field and per campaign on the same field, such information is not considered meaningful. Therefore, it was decided not to present this in Table 1; however, the range of the number of measurements per field has been added in the text.

Table 3: Please add a column with relative errors.

Reply: We agree with the referee that in some cases relative errors reveal complementary information to absolute errors. However, since we have data covering a large range of soil moisture conditions, relative errors would be very different for dry com-

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pared to wet in situ observations. For example, a 5% error on an in situ soil moisture measurement of 5% gives a 100% relative error, whereas the same error on a soil moisture measurement of 45% would only result in a relative error of about 10%. The same absolute accuracy of soil moisture retrieval results for wet and dry moisture conditions will thus lead to very different relative results, according to the number of wet and dry observations of a given data set, and making the average of the relative error is therefore not informative. Nevertheless, for most hydrological applications it is the absolute error that is of most importance; dry in situ observations do not require a more accurate retrieval for many applications. To our knowledge, there are only very few studies providing relative errors, most of them which have no large range of in situ soil moisture conditions. As this is not the case here, we prefer not to add such information.

Figure 1: Include number of data points in the plots (applies to most tables and figures, e.g. fig 11 and fig 12). Add "measured in situ" to soil moisture. Reply: The numbers of data points have been added to Fig. 1. The same numbers apply to all other figures and tables, distinguishing between C-band HH, C-band VV, and L-band HH. Therefore, they are not repeated. The expression “in situ” has been added in the figure captions.

Baghdadi, N., Gherboudj, I., Zribi, M., Sahebi, M., King, C., and Bonn, F.: Semi-empirical calibration of the IEM backscattering model using radar images and moisture and roughness field measurements, Int. J. Remote Sens., 25, 3593–3623, 2004

Zribi, M., Taconet, O., Le H′egerat-Mascle, S., Vidal-Madjar, D., Emblauch, C., Loumagne, C, and Normand, M.: Backscattering behavior and simulation comparison over bare soils using SIR-C/X-SAR and ERASME 1994 data over Orgeval, Remote Sens. Environ., 59, 256–266, 1997.

Hastie T., Tibshirani R. and Friedman J., 2009, The Elements of Statistical Learning, Springer, NY, 745 pp.

Verhoest et al., A possibilistic approach to soil moisture retrieval from ERS synthetic aperture radar backscattering under soil roughness uncertainty, Water Resources Re-

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search 43, 2007.

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