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Hydrology and Earth System Sciences Discussions

Interactive comment on "Soil parameters estimation over bare agriculture areas from C-band polarimetric SAR data using neural networks" *by* N. Baghdadi et al.

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Dear Editor Dear Referee The authors found the reviewer comments extremely helpful, and these have been taken into account in the revised version. Our specific responses to the comments are detailed below. We hope that we have adequately addressed the concerns of the reviewer.

Anonymous Referee #1 Received and published: 23 April 2012

General comments: This paper demonstrates the use of artificial neural networks for retrieving soil moisture or soil roughness information instead of using well known

backscattering models. In the exercise, it is investigated whether a priori information on soil wetness state or roughness condition may improve the retrieval. I enjoyed reading the paper and only have some minor comments. It is not completely clear to me why the authors opted for neural networks: what was the reason not to work with classical backscatter models such as the IEM? Such reasoning should be included in the paper. An innovative aspect of the paper is that it tries to include a priori information on the soil condition (being moisture content or roughness state). However, previous works also tried to include such information in the retrieval (using soil moisture info (e.g. Mattia et al. (2006), or soil roughness (e.g. Satalino et al. 2002, Verhoest et al. 2007)). The paper could refer to such previous work and document how the approach of this paper differs from the other papers.

Response: Concerning the following comment "It is not completely clear to me why the authors opted for neural networks: what was the reason not to work with classical backscatter models such as the IEM? Such reasoning should be included in the paper":

This paper uses the IEM model for estimating soil moisture content. It uses the empirical calibration as proposed in Baghdadi et al. (2006b; 2011). The most popular statistical models as those developed by Oh et al. (1992; 2002), Oh (2004), and Dubois et al. (1995) were not used because the discrepancies often observed in several studies between experimental measurements and SAR data (e.g. Zribi et al., 1997; Baghdadi et al., 2006b).

Before the use of Neural Networks technique, we tested an algorithm based on the least squares method where the objective was to minimize the cost function defined as:

Q=(f1+f2+f3)/3

With f1= (hh_sim(rms, mv) - hh_mes)^2 f2= (hv_sim(rms, mv) - hv_mes)^2 f3= (vv_sim(rms, mv) - vv_mes)^2

pp_mes=measured backscattering coefficient at pp polarization (IEM simulation + noise) pp_sim=IEM simulations (Look Up Table) at pp polarization pp=hh, hv and vv mv=soil moisture rms=rms surface height

Normally, the minimum of the cost function Q (Qmin) gives the estimated values of mv and rms but with our wide range of rms (between 0.3 and 3.6 cm), several minima (Qmin1, Qmin2…) with close values were often found for the cost function (Qmin1≈Qmin2…). The minimum minimorum does not correspond always to optimum values of mv and rms.

The authors have added in the revised version the following sentences: The use of simple inversion technique based on simulated Look-Up Tables (IEM model), which minimizes a mean distance (cost function) between the simulated and the measured backscattering coefficients (HH, HV and VV polarizations) does not lead to estimate correctly the soil parameters. Indeed, several minima are sometimes found for the cost function with very close values. Thus, the minimum minimorum does not correspond always to optimum values of soil moisture and surface roughness.

Concerning the following comment "The paper could refer to such previous work and document how the approach of this paper differs from the other papers", the authors have added in the revised version an analysis of previous works:

Inversion approaches using a priori information on soil parameters were developed to improve soil moisture retrieval from SAR data. Satalino et al. (2002) developed an algorithm to retrieve soil moisture content over smooth bare soils from ERS-SAR data (VV-23°). The method consists of inverting the IEM model for a restricted roughness range (rms between 0.6 and 1.6 cm), by using neural networks. Results indicate that only two soil moisture classes, i.e., dry and wet soils, can be retrieved using ERS data. It is mainly because a same measured radar backscattering coefficient corresponds to several combinations of soil moisture and surface roughness conditions. Mattia et al. (2006) also use a priori information on soil moisture through water balance model

and surface roughness by means of an empirical approach, to constrain the inversion of theoretical radar backscattering models. An accuracy of approximately 5% on retrieved soil moisture is obtained. A possibilistic inversion approach which uses the soil roughness uncertainty for retrieving bare surface soil moisture from SAR data was developed by Verhoest et al. (2007). Accuracy less than 0.06 cm3/cm3 was obtained for study cases with low surface roughness (rms surface height less than 1 cm).

Other minor comments:

Comment 1: doesn't sound good (soil parameters estimation): maybe rephrase to "Estimation of soil parameters over bare agricultural areas…"? Response 1: As suggested "Soil parameters estimation over bare agricultural areas …" was changed in "Estimation of soil parameters over bare agricultural areas …"

Comment 2: Page 2898 âĂć Sometimes the volumetric moisture content is written as cm3/cm3 (e.g. line 16), in other places it gets no units (e.g. line 18), please make it consistent throughout the paper. Response 2: As suggested, the unit was added.

Comment 3: Page 2898 âĂć Line 16: mention that surface roughness concerns the rms height. Response 3: As suggested we added "root mean square surface height lower or higher …"

Comment 4: Page 2898 âĂć Line 23: an RMSE Response 4: OK

Comment 5: Page 2900 âĂć Line 2: IEM: also add Fung et al. (1992) Response 5: The reference of Fung et al. (1992) was added Fung, A.K., Li, Z., and Chen, K.S.: Backscattering from a randomly rough dielectric surface. IEEE Transactions on Geoscience and Remote Sensing, vol. 30, no 2, pp. 356-369, 1992.

Comment 6: Page 2901 âĂć Line 10: IEM: also add Fung et al. (1992) Response 6: OK

Comment 7: Page 2902 âĂć Equations 1 to 3: are these newly derived for this paper, or are they taken from Baghdadi et al.? If new, then please provide some statistics with respect to their fit. Response 7: In Baghdadi et al. (2006b-2011) the expressions of Lopt2 for each polarization were given as a function of rms surface height and incidence angle. In this paper, these expressions were improved in using additional SAR datasets. As suggested, some statistics were added in the revised version: ïĆšïĄś is in degree, Lopt and rms are in centimeters. The coefficient of determination R^2 is 0.98 for HH, and 0.96 for both HV and VV. A small difference between calibrated IEM simulations (using Lopt2, equation 1) and SAR data (less than 1dB) was observed, with a standard deviation better than 2dB.ïĆš

Comment 8: Page 2904 âĂć Lines 1-14: please give some information on the error that is expected Response 8: As mentioned in page 2904, the accuracy of roughness parameters should be better than $\pm$ 10% for rms and between $\pm$ 10% and $\pm$ 20% for large and small correlation lengths, respectively (Baghdadi et al., 2012). For our dataset, the error on the rms surface height is about 0.09 cm for rms=0.9 cm (lower rms-value) and 0.4 cm for rms=4.0 cm (higher rms-value).

Comment 9: Page 2904 âĂć Line 8: dependent (typo) Response 9: OK

Comment 10: Page 2904 âĂć Line 19: Levenberg-Marquardt (not Marquart) (typo) Response 10: OK

Comment 11: Page 2906 âĂć Case 2: an overlap of 10% is found between both classes, not 5%. Is two classes sufficient, or wouldn't it be better to have had three classes (dry, intermediate and wet)? Response 11: OK for the overlap. Concerning the choice of two soil moisture classes and not of three classes (dry, intermediate and wet), of course the inversion result will be much better in using three soil moisture classes but that complicates the work of the expert who will have to choose for a given SAR acquisition (given date) the a priori knowledge on the soil moisture. The choice among our two classes of soil moisture (very wet soils or dry to wet soils) will be easier. Moreover, as this paper aims to test the contribution of polarimetric parameres on the soil moisture estimation and that Baghdadi et al. (2012) have shown that the alpha

angle allows to separate only two soil moisture classes (very wet soils with mv>0.30 cm3/cm3from the rest), the choice is thus doubly justified.

Comment 12: Page 2906 âĂć Case 3: an overlap of 1 cm is found between both classes, not 0.5 cm. The smooth class includes roughness up to 2 cm: can this still be considered as smooth? On the contrary, the rough class includes roughnesses of 1 cm, which is quite smooth Response 12: OK for the overlap. As suggested, we changed the names of roughness classes. For soils with rms surface height lower than 2cm, "smooth soils" was changed in "smooth to moderate soils". For soils with rms surface height higher than 2cm, "rough soils" was changed in "moderate to rough soils"

Comment 13: Page 2906 âĂć Lines 24 and equation 4: bias is not equal to mean absolute error. Equation 4 now defines the bias. For the mean absolute error, one should take the absolute value of Ei -Mi. Response 13: We agree with you. Only Bias and RMSE were used.

Comment 14: Page 2908 âĂć Line 3: please rephrase ''slightly behind": it is unclear what is exactly meant (underestimating?) Response 14: The sentence is changed in "The performance of the algorithm is slightly lower at incidence angle of 35°."

Comment 15: Page 2908 âĂć Line 6: an intermediate (typo) Response 15: OK

Comment 16: Page 2908 âĂć Line 9: up till now, it is not clear how the a priori information is being fed to the neural network. Response 16: As suggested, we added clarifications. The following paragraph has bee added in the revised version: ïĆšFor each studied case (case 1 to case 4), only the sub-datasets corresponding to rms and mv values defined by the a priori knowledge are used in the training and the validation phases. For example, for the case 2, with a priori knowledge on mv, two neural networks were developed and validated in using the corresponding sub-datasets : sub-dataset_1 corresponding to data with mv<35% and sub-dataset_2 corresponding to data with mv>25%.ïĆš

Comment 17: Page 2909 âĂć Lines 25 and 26: overestimation and underestimation (instead of resp. overestimate and underestimate) Response 17: OK

Comment 18: Page 2912 âĂć Line 23: an RMSE Response 18: OK

Comment 19: Page 2913 âĂć Line 1: an RMSE âĂć Line 24: an NDVI Response 19: OK

Comment 20: Page 2916 âĂć It is unclear to me why the last sentence (lines 19 to 21) is stated: although it is true, the link with the paper seems to lack. If this sentence is really needed in the conclusion, then please better frame it such that it fits the research that was presented. Response 20: The last sentences could be removed.

References: Fung, A. K., Z. Li, and K. S. Chen (1992), Backscattering from a randomly rough dielectric surface, IEEE Transactions on Geoscience and Remote Sensing, 30, 356–369.

Mattia, F., G. Satalino, L. Dente, and G. Pasquariello (2006), Using a priori information to improve soil moisture retrieval from ENVISAT ASAR AP data in semi-arid regions,IEEE Transactions on Geoscience and Remote Sensing, 44, 900–912.

Satalino, G., F. Mattia, M.W. J. Davidson, T. Le Toan, G. Pasquariello, and M. Borgeaud (2002), On current limits of soil moisture retrieval from ERS-SAR data, IEEE Transactions on Geoscience and Remote Sensing, 40, 2438–2447.

Verhoest, N. E. C., B. De Baets, F. Mattia, G. Satalino, C. Lucau, and P. Defourny (2007), A possibilistic approach to soil moisture retrieval from ERS synthetic aperture radar backscattering under soil roughness uncertainty, Water Resources Research, 43, W07435, doi:10.1029/2006WR005295.

These references were added and discussed in the paper.
