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Hydrology and Earth System Sciences Discussions

Interactive comment on "On the derivation of soil surface roughness from multi parametric PolSAR data and its potential for hydrological modelling" *by* P. Marzahn and R. Ludwig

Anonymous Referee #2

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The present paper compares three techniques to retrieve surface RMS height from polarimetric SAR (PolSAR), namely based on the anisotropy *A*, the complex circular coherence $|\rho_{RRLL}|$ and the real part of the coherence $Re\,[\rho_{RRLL}]$. The results are validated with *in situ* measurements of RMS height by means of photogrammetry. The obtained roughness parameters are then used to derive information for hydrologic models, such as micro-depression storage capacity (MDS), bulk density, soil porosity and void ratio. The performed scientific research is very interesting and deserves being published, however, after revision and corrections for English language and style.

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Interactive Discussion
Discussion Paper

General comments

In my opinion, the methods used for the retrieval of roughness information are very sound, however, the discussion of the methods and results needs to be extended. Regarding the potential of the retrieved roughness information for hydrologic modeling, the MDS is not validated or qualitatively evaluated, which is a shortcoming. The results on the retrieval of bulk density may be discussed in more detail. Maybe it is better to focus the paper on the parts that are well established and for which you have ground truth information, i.e. the roughness retrieval and the correlation with bulk density.

Section 2.2

If three estimators of roughness are compared, there should be a short but more clear discussion of the background, advantages and shortcomings of each of the estimators, as well as the conditions for which their use is allowed. Readers that are not really familiar with polarimetry should be briefly informed about what is anisotropy and what do the eigenvalues from the polarimetric coherence matrix represent (i.e. the contribution of a type of scattering). For example, the knowledge that the anisotropy is a measure for the difference of the secondary scattering mechanisms will facilitate the explanation why *A* is such a noisy parameter. In case vegetation is present, the anisotropy decreases, leading to overestimation of surface roughness, so in this case the real part of the coherency seems to be the only appropriate estimator, theoretically not influenced by vegetation, especially for $ks \leq 0.5$ cm (Schuler, 2002). For $ks > 1$, *A* becomes insensitive to an increase in roughness. It could also be very interesting to discuss the sensitivity of the different estimators to sensor frequency, incidence angle and surface correlation length.

I think it would be more logic if you change places between section '2.2 Radar acquisitions and processing', and section '2.3 In situ measurements'. As such, the discussion of the in situ measurements comes directly after the introduction of the study site and the sample points where these measurements are performed. In this way, you also introduce the parameter RMS height before you explain the methodology you use to

HESSD

5, S2316–S2326, 2009

derive it. Moreover, in the results, you start with the discussion of the *in situ* measurements and end with the SAR-derived roughness.

Section 3.2
Please extend the discussion and presentation of the roughness retrieval results from PolSAR versus photogrammetry. It could be interesting to really show the scatter plots of estimators or modeled RMS height versus measured RMS heights, and particularly, to show the eventual relationship that has been used to derive further roughness maps, with reflection to perhaps similar relationships found in literature. With respect to the scatter plot presented in Figure 8, you should give more information on what is presented: which dates (only April 19?), which sample points, are these average field values? It would be more informative to give a different style to points that correspond to vegetated (overestimations) and bare fields. Also, Figure 8 does not show any points for $ks < 0.27$, so it is not demonstrating the overestimation in this region as you mention.

Section 3.3
Please define in more detail how exactly you have produced the multi-temporal roughness maps. For example, did you use different relationships for bare and vegetated areas? It would be very interesting to show the roughness retrieval results for the bare soil surfaces in a different color or style than the ones for vegetated fields within the multi-temporal roughness plots, since one of the conclusions of your paper is that roughness retrieval for bare soil surfaces is feasible using PolSAR, but you never show this clearly.
Could it be possible that the roughness overestimation on field 101 (winter rape) of 0.8 cm, and the underestimation on field 222 of 0.2 cm may partially be due to slope effects, or is this already taken into account? In their paper of 2002, Schuler et al. suggest a correction of the real part of the coherence for large scale azimuth terrain slopes, as an extension to Eq. 5. Did you try this?
In my opinion, there are really clear similarities between at one side roughness under

HESSD

5, S2316–S2326, 2009

maize and winter rape, and on the other side roughness under winter wheat, barley and sugar beet. Were there any remarkable changes in the appearances of barley and winter wheat from May 17 to August? Can you specify the multiple regressions that were performed between the real part of the coherence, surface roughness and vegetation parameters, e.g which vegetation parameters were used?
It would be interesting to add a graph showing the multi-temporal RMS height results of photogrammetry for the different fields, and to compare this with Figs. 9 and 10. Maybe such graph already fits in Section 2.3.1 and could eventually replace Table 1, which is not very informative.

Section 4.1
In my opinion, it may be better to remove this part, as it cannot be validated. Moreover, the research performed with respect to the retrieval of roughness and bulk density already allows without any problem for assembling a very interesting full research paper. If removed, the title of the work may be revised.
Something contradicting about your approach for the retrieval of micro-depression storage capacity (MDS) is the fact that its calculation is based on s only (I assume you only used the approach of Kamphorst, or did you compare Eqs. (7) and (8) for MDS retrieval?) In the discussion of your results, however, you specify that the main parameter of importance in the derivation of MDS is slope. How can you see this if it is not incorporated in the calculations? Furthermore, different surfaces with equal RMS heights may have completely different MDS values due to differences in spatial aspects of the roughness. I think this is important information and should be mentioned.

Section 4.2
Please extend the discussion of the results. Can you validate the obtained bulk density values with the ground measurements? For example, using the established relationship, how large are the errors on the retrieved bulk density parameters in g/cm^3? Were similar linear relations found by Sun et al. or did they use a complete different *in situ* roughness characterization technique? You should also show the range of bulk density

HESSD

5, S2316–S2326, 2009

parameters that has been covered by the ground measurements to evaluate whether this correlation can be representative. Finally, what is the correlation between remotely sensed roughness parameters and field measurements?

Specific comments

In general, I advice the authors to re-read the manuscript carefully or ask a native English speaking person to correct for grammatical errors. Please check the use of a hyphen (e.g. multi-parametric, in field, three-dimensional,...) and be consistent, e.g. test-site, test site and testsite, modelling and modeling, hydrological and hydrologic, and DSM and DEM are used together.

Page 3384, line 4-5: rephrase, suggestion: 'The present study utilizes microwave backscattering from the **full-polarimetric** L-band E-SAR system, collected over the DEMMIN **test site** in **North East** Germany during the AgriSAR 2006 campaign.' (Use capitals if referring to a place, no capitals if referring to a direction, e.g. 150 km north of Berlin)

Page 3384, line 9: 'indices'; only one index (RMS height) is used

Page 3384, line 11: the obtained maps (not maps in general)

Page 3384, line 15: micro-depression storage capacity

Page 3384, line 16-19: Please rephrase

Page 3384, line 24-25: '...that roughness influences runoff generation...'

Page 3385, line 3: '...soil surface roughness and roughness dependent parameters such as...'

Page 3385, line 9: a smoothing of the soil surface

Page 3385, line 13: ...on the applied tillage operation or...

Page 3385, line 21: ...Bertuzzi...

Page 3385, line 22: rephrase, 'dissolve' is rather used for particles in fluids.

Page 3385, line 23-25: Please rephrase: the message you want to put in this sentence is ok, but as I read it, 'considerable data uncertainty in the description of roughness conditions' feels rather strange.

HESSD

5, S2316–S2326, 2009

Interactive Comment

Page 3385, line 26: *in situ* in cursif
Page 3385-3386, line 29-5: Please rephrase.
Page 3386, lines 12-15, Please rephrase, suggestion: 'Therefore, weekly E-SAR flights...'
Page 3386, line 21: '...in the southern part, near the Peene river.' (There is only one minimum and one southern part)
Page 3386, line 25: Rephrase
Page 3387, line 2: Rephrase. Now it sounds like you have used the 18 sample points only to characterize the main crops in the area.
Page 3387, line 3: locations
Page 3387, line 8: L-band.
Page 3387, line 8: Please provide the incidence angle
Page 3387, line 14: provide reference for enhanced Lee-filter: Lee et al., 1997
Page 3387, Eq. (1): positioning of the equation would be better just after the reference to Cloude and Pottier, 1996. As such, the two linear equations (2) and (3) directly follow upon the sentence '...using two different linear approaches...'
Page 3387, line 25: First introduce the RMS height *s* and mention the wave number *k* if you use them in a formula.
Page 3387 and 3388: are there conditions with respect to *ks* for use of Cloude and Lewis (2000) or Cloude (1999)? Which one of the two is used in further calculations or showed best results?
Page 3388, line 3: As shown by Mattia et al. (1997) using PolSAR data over the Matera...
Page 3388, line 5: '...sensitive to roughness and insensitive to...'
Page 3388, line 7: add reference before the formula
Page 3388, line 9: S_{RR} reflects to scattering coefficients for right-right rotating electric field vector and not to the rotation itself.
Page 3388, line 19: replace 'such as vegetation' by 'e.g. caused by vegetation'
Page 3389, line 1: '...soil surface roughness, the Anisotropy...'

HESSD

5, S2316–S2326, 2009

Interactive Comment

Page 3389, line 6 chosen because of its efficiency
Page 3389, line 6-7: In my opinion this is a rather strange sentence. Moreover, can you explain what you mean with efficiency regarding a decoupled acquisition and analysis? Also, is this the main reason why photogrammetry is chosen, hence not for its 3-dimensional output with good accuracy? Other measurement techniques have decoupled acquisition and analysis possibilities as well.
Page 3389, line 8: you only collect one roughness characteristic, namely RMS height. Please also reformulate this sentence.
Page 3389, line 10: Please rephrase: Crusted surfaces and ploughed or harrowed fields are no roughness characteristics but rather states of a surface
Page 3389, line 11: Please rephrase, suggestion: To measure surface roughness on vegetated fields, plants were carefully cut off at the surface and completely removed from the areas covered by photogrammetric image acquisitions, without disturbing the soil surface.
Page 3389, line 23-24: Please rephrase
Page 3389, line 26: highly or very
Page 3390, line 7: Can you provide the window size used to calculate the correlation between respective images for DSM generation, or is this variable? Please mention clearly, because the window size or the threshold on the correlation coefficient may have an important influence on smoothing of the DSM.
Page 3390, line 15: 'Due to the tripod geometrics,...': please explain. Is this because of the small size of the sampled area? Also, if you look at the correlation plot in Fig. 5 for sample ESU 222-2, it seems there is a low-frequency roughness pattern due to rows, which may lead to large RMS heights. This may largely influence the comparison with SAR-based roughness values. Moreover, with respect to Fig. 5, the dark black patterns do not show up in the legend.
Page 3390: Also add and refer to literature that the short sampling area of the photogrammetric setup may have an effect on the finally obtained RMS heights. I think it is very important to mention that small areas for roughness characterization may lead

HESSD

5, S2316–S2326, 2009

to underestimation of roughness parameters.
Page 3390, line 19: 'Z is the height value' or 'Z are the height values'
Page 3390, line 24-25: '...and is therefore applied in this study.'
Page 3391, lines 2-4: Rephrase. Were these additional campaigns only organized for vegetation and soil moisture measurements, or also for the roughness measurements? The fact that you only mention this now is quite confusing. It may be better to discuss more completely the number of campaigns and measurements during each campaign (maybe add an overview in a table) as an introduction to 'in situ measurements'.
Page 3391, lines 8-10: Rephrase, suggestion: 'Soil moisture content was measured gravimetrically (oven drying at 105°C) using 100 cm^3 Kopecky rings, at depths of 0-5 cm and 5-10 cm, with three repetitions each. From the known volume of the Kopecky rings, bulk density (g/cm^3) was derived and subsequently used to convert gravimetric soil moisture content into volumetric soil moisture content (vol%).'

Page 3391, lines 14-16: No correct sentence.
Page 3391, line 20: it is possible to distinguish between different soil clods and even small aggregates, can you explain this?
Page 3391, line 22: precision $z = 0.8$ mm
Page 3391, line 32: 'related to...' means 'according to the errors found for the manually measured reference points'?
Page 3391, line 25: Please define 'matching rate'
Page 3392, line 1: mismatches 'preferably' should be 'mostly', as preferably they do not occur.
Page 3392, line 2: soil clod obstruction... and strong height differences
Page 3392, line 5: the aim of the present study
Page 3392, line 8: highly or very
Page 3392, line 12: From the obtained micro-DSMs,...
Page 3392, line 13: Table 1 showing the statistical characteristics of all roughness samples together is not very informative. RMS height generally shows a very high variability, within one single field, and certainly between different fields that were subject to

HESSD

5, S2316–S2326, 2009

Interactive Comment

different tillage operations. It would be more informative to show a table or figure that illustrates this variability of RMS height for every field or tillage operation separately. This will also give an idea of the range of roughness parameters that is covered for validation purposes of the polarimetric roughness estimators.
Page 3392, line 17: should be Eqs. (1), (4) and (5), and 'for April 19, 2006' or 'for the 19^{th} of April, 2006'; Please correct this throughout the paper
Page 3392, line 19: (see Eq. (1))
Page 3392, line 21: Schuler could start in a new paragraph, as there is no connection with the discussion above
Page 3392, line 24 large enough backscatter intensities
Page 3392, line 25: images of Re[] appear different:...
Page 3392, line 26: the value of Re[] increases with an increase of surface roughness
Page 3392, line 28: on a field scale
Page 3392, line 28: 'for derivation' is not correct, actually it is more for comparison of different estimators that you calculate correlation coefficients.
Page 3393, line 2: You could maybe add a classification of bare soil fields and areas with dominant surface scatter?
Page 3393, line 5: Suggestion: As was also applied by Thiel (2003), values of $s < 1$ cm were excluded from the comparison, since these are strongly affected by noise.
Page 3393, line 14: especially for those fields covered by winter rape.
Page 3393, line 19: delete multi-temporal
Page 3393, line 21: are displayed
Page 3393, line 28: leads to the assumption
Page 3394, line 1-4: To prove this assumption...: Please can you rephrase this sentence and explain more clearly what you did and how you come to the conclusion of overestimated s with 0.8 cm? Do you have any idea what happens with the winter resistant vegetation that causes a decrease and successive increase in roughness?
Page 3394, line 5: 'The change of roughness in time under summer vegetation...'
Page 3394, line 8: So here roughness under vegetation is underestimated with Pol-

HESSD

5, S2316–S2326, 2009

SAR? Please also rephrase this sentence as this result cannot be derived from the former sentence.
Page 3394, line 16: ...only a strong relationship for field 460...

Page 3394, line 21: feasibility study on the use of...
Page 3395, line 5 and 7 and 18: Onstad
Page 3395, line 13: pixel
Page 3395, line 22: add ':' before equation
Page 3395, line 24: examples of...
Page 3396, line 2-4: Rephrase
Page 3396, line 13: transfer-functions
Page 3396, line 18: mostly measured
Page 3397, line 1: First, destructive measurements using Kopecky rings or the air pycnometer do not allow for a...
Page 3397, line 8: silty loam soil
Page 3397, line 9: tillage practice
Page 3397, line: 12-13: 'correlations coefficients are determined', or 'correlation is determined'
Page 3397, line 16-17: Rephrase

Page 3398, line 2: s in cursif
Page 3398, line 4: However, the overestimation... Thiel (2003)**.**
Page 3398, line 9: leave out 'an incorporation of'
Page 3398, line 17: This should already be mentioned in the results under section 4.2
Page 3398, line 21: better roughness retrieval needs to...
Page 3398, line 25-27: Rephrase.
Page 3399, line 1: To solve the problem
Page 3399, line 5: as well as the deployment of...

References:
Page 3399, line 14: Soil Till**.** Res.

HESSD

5, S2316–S2326, 2009

Interactive Comment

Page 3400, line 16: D'Urso G.
Page 3400, line 30: Guérif
Page 3401, line 20: multi-frequency
Page 3401, line 7: ',' to previous line?

Tables:
Table 1: Title: Rephrase, suggestion: Statistical characterization of RMS height measurements. Replace the table by a more informative representation of the measured RMS heights in function of time and field or tillage type
Table 2: Title: rephrase, you are not showing polSAR parameters but parameters obtained using polSAR

Figures:
Fig. 4: Scheme of the roughness retrieval approach
Fig. 6: The legends are not legible
Fig. 9: winter barley
Fig. 12: Void ratio

References:
J.S. Lee, M.R. Grunes, G. De Grandi, Polarimetric SAR speckle filtering and its impact on classification, IEEE Trans. Geosci. Remote Sens., vol 37, pp. 2363-2373, 1997.
D.L. Schuler, J.S. Lee, D. Kasilingam, G. Nesti, Surface roughness and slope measurements using polarimetric SAR data, IEEE Trans. Geosci. Remote Sens., vol 40(3), pp. 687-698, 2002.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 5, 3383, 2008.