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Hydrology and Earth System Sciences Discussions

Interactive comment on "Relating surface backscatter response from TRMM Precipitation Radar to soil moisture: results over a semi-arid region" *by* H. Stephen et al.

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We agree with the reviewer comment and would like to note that ground measurements of soil moisture are only available at 5 cm depth in the Walnut Gulch Experimental Watershed in the Lower Colorado River basin. This scarcity of soil moisture measurements resulted in using simulated soil moisture data from a hydrological (VIC) model. Nevertheless, we would like to note that the surface soil moisture is a surrogate of its values at near surface depths (5-10cm). Moreover, a 14 day averaging window is used which is long enough time period to smooth out rain event based differences

in the soil skin and near surface soil moisture. In order to make this point clear in the manuscript, following paragraph has been added (2nd last paragraph of Results and Discussion section). **We note that the penetration depth of Ku-band microwaves is shallow and thus only top few millimeters (depends on the moisture) of soil layer soil moisture affects the backscatter measurements. Nevertheless, the surface moisture is linked to the soil moisture at near surface layers (5 - 10 cm). This is evident from the high correlation of derived soil moisture to VIC and gage soil moisture data.**

Relating Ku-band for soil moisture has not gained much attention. Very little literature is available that is mostly using high resolution radars (SAR). We have added a few references and following text is added in the introduction section of the paper. **Nevertheless, the potential of Ku-band microwave to measure soil moisture has been demonstrated in several studies (Ringelmann et al., 2004). European Remote Sensing SAR data over agriculture fields have been shown to retrieve leaf area index and soil moisture under lower vegetation conditions (Moran et al., 1998). A similar study compared soil moisture retrieval from agricultural fields using C- and multiangle Ku-band SAR data for different surface roughness conditions (Sano et al., 1998). In recent studies, Ku-band backscatter data measured by Seawinds scatterometer has been shown to be temporally consistent with the changes in measured soil moisture (Mladenova et al., 2008, Mladenova et al., 2009).**

In general, the vegetation density in Lower Colorado basin is low except in Coconino forest. As indicated by the reviewer, we have added leaf area index (LAI) ranges corresponding to the three vegetation covers. Following text has been added. **The leaf area index (LAI) value ranges for the selected sites with vegetation covers LV, MV, and DV are 0.08–0.53, 0.22–1.38, and 0.55–2.20, respectively. The range of values represent the seasonal variations of the vegetation cover reflected in LAI. In general, LCRB presents an area with relatively low leaf area index.**

Similar to Fig. 2, we have added Fig. 3 that shows the variation of backscatter incidence angle response as a function of soil moisture. Three plots are shown for three vegetation covers. This figure better demonstrates the sensitivity of the signal to soil moisture. Following text is also added. **In order to further clarify the role of soil moisture in the σ° θ-response, Fig. 3 shows the σ° vs. θ plots and line fits for three soil moisture values over the three vegetation cover types. It is evident that the increase in soil moisture increases the backscatter and slope of the incidence angle response. This effect is more pronounced in the areas with low vegetation.**

We have added several details about equation 1. In order to elaborate the sensitivity to soil moisture, Fig. 3 and corresponding text has been added. Moreover, we have reported the RMS error of the model fit in Table 1. More description on the parameter calculation and stability is also added. We agree with the reviewer, that if μ_s and μ_{ndvi} are not included in the model, their values will be compensated in the fitting parameters. We chose to incorporate the mean values to show the relationship in terms of the variation about the mean value which the authors find more convenient and intuitive.

The VIC model has been validated in another publication by the coauthors of this paper. The corresponding paper has been added in the references and cited in the text, i.e., Tang and Piechota 2009. The model fitting is performed at the resolution of the most coarse input data which in this case is gridded VIC soil moisture data (12 km x 12 km). Thus, although σ° is available at 4.4 km resolution the parameter maps and the derived soil moisture maps are made at 12 km spatial resolution.

The model is a point based model and thus model calibration has to be done separately for each model. The aim of this paper is to show that Ku-band backscatter has the potential of mapping soil moisture over the arid regions using the proposed model. The model calibration depends on the availability of the soil moisture data and authors show the potential by using the simulated VIC data. We have added the following text to clarify this point. **The proposed model is point-specific and thus needs**

soil moisture measurements for calibration. In order to extend the model to the whole area and prepare soil moisture maps, simulated VIC soil moisture is used, As shown in Fig. 4 the model parameters are spatially coherent with the surface spatial characteristics.

Minor Comments:

(6428,6) Three more references suggested by the reviewer are added to the paper, i.e., Ferrazzoli et al., 1991, Ferrazzoli et al., 1997, and Kurum et al., 2009.

(6429,3) We do not have a reference but we have restated the sentence as our conjecture.

(6430, 18-19) This sentence has been rephrased to **The relationship between σ° and θ is non-linear over the whole range of incidence angles but is approximately linear within 3°–15°. This angle range is used for the normalization to 10°.** to clarify this further.

(6432,3) The sentence has been rephrased to clearly state what cleaning of the data has been done. The sentence now reads, **TRMMPR σ° is cleaned by removing the rain contaminated and near-nadir high noise measurements.**

(6434, 2-5) The suggested reference has been added.

(6434, 18-20) Reference (Long and Hardin, 1994) has been added for this comment.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 6, 6425, 2009.

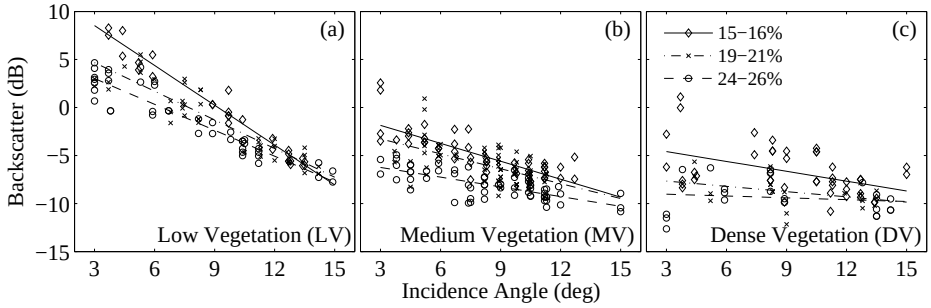

Fig. 1. Backscatter incidence angle dependence for three soil moisture ranges (15-16%, 19-21%, and 24-26%) and vegetation covers, i.e., (a) LV, (b) MV, and (c) DV.