DECOMPOSITION METHODS FOR THE ESTIMATION OF BARE SOIL MOISTURE USING FULLY POLARIMETRIC SAR DATA*

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ABSTRACT

Soil moisture plays a critical role in the surface energy balance at the soil-atmosphere interface [4]. Using radar backscattering to retrieve soil moisture is a method of major concern due to its sensitivity to soil moisture [14] [15].In the past decades, many empirical, semi-empirical and physical models that relate the measured σ^0 to volumetric soil moisture mv have been carried out[14][15]. Integral Equation Model (IEM) [2] as an electromagnetic wave scattering and emission model is widely used to predict target's backscattering coefficients due to its larger applicable region than Kirchhoff model [3] and SPM [3]. The recently proposed Advanced Integral Equation Model (AIEM) [6] [7] is used in this paper because of its several major modifications and higher accuracy. With the increasing exploration on fully polarimetric SAR data, target polarimetric decomposition of fully polarimetric SAR data has gained much attention in respect that it can generate an average or dominant scattering mechanism for the purpose of either classification or inversion [10]. Shi, et al. [9] only certified that employing Cloude decomposition has an improvement for estimating bare surface soil moisture. However, few studies have compared the effectiveness of applying different decomposition methods to moisture retrieval. In this paper we apply two different target polarimetric decomposition methods based on filtered fully polarimetric SAR data. According to the comparison of AIEM simulation results, we have validated the effectiveness of applying target polarimetric decomposition compensation to fully polarimetric SAR data for soil moisture estimation in bare soil case. Finally we conclude that the result of Cloude decomposition matches the theoretical results better.

In the first step, we simulate the radar backscattering coefficients by inputting synchronous in-situ ground parameters to AIEM. When isotropic surface is assumed, it can be reduced to general form: $\sigma_{qp}^0 = AIEM\left(\varepsilon_r, h_{RMS}, L_C\right)$, where h_{RMS} and L_C denote the root mean square(RMS) of surface height and the

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correlation length respectively; ε_r represents dielectric constant of bare soil which is calculated by $\varepsilon_r = f(mv, sc, T, freq)$, Where mv, sc, T and $freq$ stand for soil moisture, characteristic and temperature and microwave frequency separately. In the second step, to reduce/restrain the speckle noise, we need to filter SAR data before any manipulation. J. S. Lee polarimetric Refined Filter [5] with 7×7 window is applied on T_3 to reduce the speckle noise and then the filtered T_3 is converted to C_3 according [5]. In the next step, Cloude decomposition [8] is performed on the filtered T_3 matrix to extract the first component that represents the dominant surface scattering. Then the decomposed T_3 is converted to C_3 to retrieve backscattering coefficients. For the Freeman decomposition [1], it is applied on filtered C_3 matrix to get the surface scattering coefficients. Finally after geometric correction, the comparison between AIEM predictions versus filtered polarimetric data, Cloude decomposed and Freeman decomposed results can be conducted respectively. For the experimental sites in this paper [11], (Fig. 1), the RMSE of σ_{hh}^0 and σ_{vv}^0 are 1.96 and 1.25 dB after filtering (Fig. 2(a)). After Freeman decomposition (Fig. 2(b)), the RMSE of σ_{hh}^0 is reduced to 1.64 dB however the RMSE of σ_{vv}^0 slightly increases to 1.35dB. On the other hand, the results of Cloude decomposition (fig. 2(c)) are significantly improved at both polarizations with the RMSE of σ_{hh}^0 and σ_{vv}^0 are 1.45 and 1.14 dB respectively.

In summary both Freeman and Cloude decomposition methods are performed on AIRSAR L-band fully polarimetric data. The results of Freeman decomposition has an improved accuracy of σ_{hh}^0 yet slightly degrades on σ_{vv}^0, but lowers overall error. The accuracy of backscattering coefficients is significantly improved by Cloude decomposition, which can link a target distributed pixel to its equivalent "pure target" that matches the single scattering of AIEM. Freeman decomposition assumes that cross-polarized returns $\langle S_{HV} S_{HV}^* \rangle$ are contributed only by volume scattering f_V, actually double-bounce f_D and surface scatter f_S components also have slight contribution. Furthermore, if $\mathrm{Re}\left(\langle S_{HH} S_{VV}^* \rangle\right) \geq 0$, the surface scatter is considered as dominant and the parameter α is fixed with $\alpha = -1$ [5], which may lead to imprecise results in the quantitative analysis. Through comparison with AIEM predictions, Cloude decomposition demonstrates much more accuracy for quantitatively retrieving soil moisture.

KEY WORDS: soil moisture, Synthetic Aperture Radar (SAR), Advanced Integral Equation Model (AIEM), polarimetric decomposition

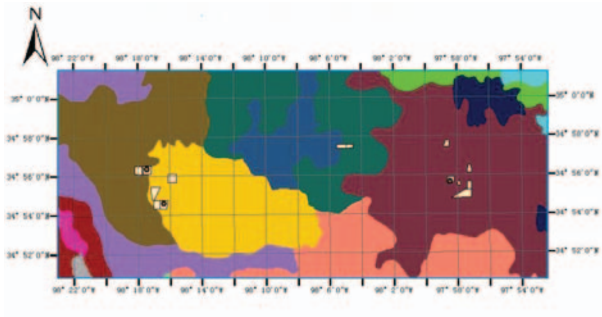
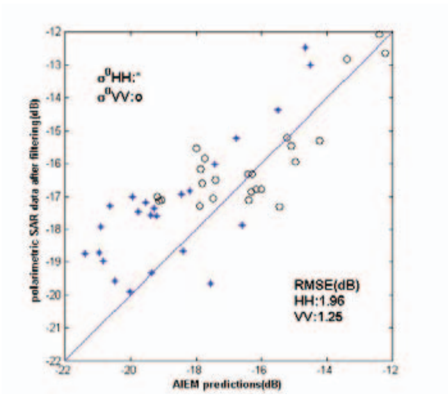
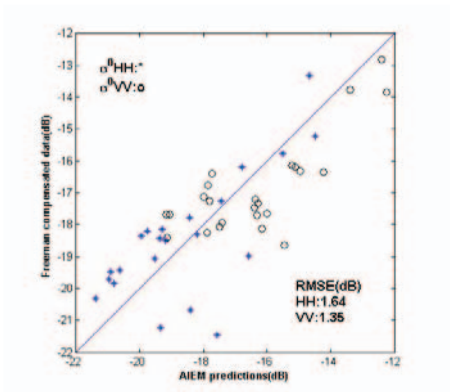


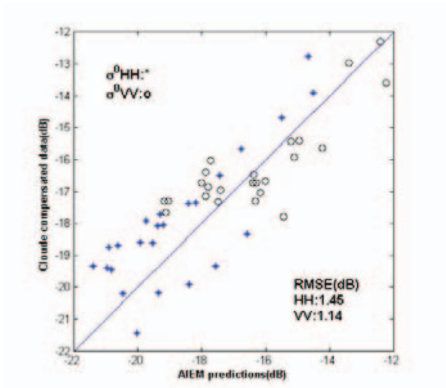
Fig. 1 Experimental Sites in southern Oklahoma. AIRSAR L-band POLSAR Multi-Look Complex (MLC) data are used in this study. Bare soil fields were indicated by a dot inside [11].



(a)



(b)



(c)

Fig. 2 RMSE of original filtered (a) Cloude decomposed (b) and Freeman decomposed(c) SAR data versus theoretical predictions.

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