N94-16754

PROCESSING OF POLARIMETRIC SAR DATA FOR SOIL MOISTURE ESTIMATION OVER MAHANTANGO WATERSHED AREA

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1. INTRODUCTION

Microwave remote sensing technique has a high potential for measuring soil moisture due to the large contrast in dielectric constant of dry and wet soils (Ulaby et al. 1982). Recent work by Pults et al. (1990) demonstrated the use of X/C-band data for quantitative surface soil moisture extraction from airborne SAR system. Similar technique was adopted in this study using polarimetric SAR data acquired with the JPL-AIRSAR system over the Mahantango watershed area in central Pennsylvania during July 1990. The data sets reported here include C-, L- and P-bands of July 10, 13, 15 and 17, 1990.

2. RESULTS AND DISCUSSION

SAR data was calibrated and registered with digital elevation data using a second degree polynomial to study the possible effects of local topography on σ° averaged over a corn field (Rao et al. 1992). The results did not show any significant effect of local topography on σ° within a single scene for the type of terrain in the study area. Multiparameter least square regression analysis was used to fit the soil moisture data with multifrequency, multipolarization σ° data to identify the best frequency - polarization combinations for the accurate estimation of soil moisture. There were 4 corn fields in the study area for which surface soil moisture data (0-5 cm) were available for July 10, 13, 15 and 17. The plant water content of these fields varied from 1.9 to 2.2 kg/sq.m. Neglecting the differences in the vegetation parameters, σ° of the 4 corn fields was plotted as a function of soil moisture. It was observed that σ° was linearly related to soil moisture in accordance with Ulaby et al. (1981). However, the degree of nonlinearity is more for L-band than for C-band.

Table 1 gives the correlation coefficient (r), standard error of estimation of soil moisture (s) and slope for C-, L- and P-bands; HH, VV and HV polarizations; both for linear and nonlinear fittings. It can be seen from Table 1 that C-band showed higher r compared to L-band, and P-band showed the least. The trends were similar for s values. L-band showed higher slope values compared with C-band, indicating the higher sensitivity of L-band to soil moisture. The lesser sensitivity of C-band can be understood due to its less penetration ability through vegetation. Nonlinear fitting considering a square term showed a marginal improvement in the results.

Multifrequency linear least square fit was attempted considering several combinations of frequencies and polarizations and the results are shown in Table 2. It can be seen from Table 2 that the combination which includes all polarizations and frequencies gave the best correlation coefficient ($r = 0.9$) and standard error of estimation ($s = 2.83$). However, other combinations are also reasonably good. For further investigations, the combination of L-, C-bands with HH, VV and HV polarizations was considered which showed $r = 0.89$ and $s = 2.94$.

It should be noted that, in all the above calculations, the same data were used for computing the coefficients as well as for estimating r and s. To check if the coefficients are useful for other data sets, we estimated the coefficients using the data sets of July 10, 13 and 15. These coefficients were then used with σ° of July 17 to estimate the soil moisture. Comparison with field measured soil moisture showed good agreement between estimated and measured soil moisture for July 17. To assess how best these coefficients can be used for other corn fields in the study area, we estimated soil moisture values for some other corn fields and observed that they were on the same order of magnitude as that of the field measured soil moisture for all 4 dates. There were no ground truth data available for these fields to directly verify the results. However, the meteorological station within the study area recorded 1.3, 5.0, 18.1, 18.5, 19.8 and 0.0 mm for the dates July 10, 11, 12, 13, 16 and 17. The estimated soil moisture was in accordance with the precipitation rates.

3. CONCLUSION

In spite of the presence of corn fields in the study area, SAR data showed good correlation with soil moisture for L- and C-bands. A simple linear regression of multipolarization, multifrequency approach gave correlation coefficient of 0.9 and standard error of estimation of 2.83. The regression coefficients derived from the 4 corn fields with ground data were useful for estimating soil moisture levels of other corn fields in the study area for the same date as well as for other dates. One limitation of the current approach is that the regression analysis considered each frequency meassurement as independent. Therefore, there is a need to develop a model which makes use of the inter-relationships among frequencies (in terms of penetration capability) and polarizations (in terms of geometry of vegetation) in such a way that the effects of vegetation can be accounted for automatically. Our ongoing research addresses this problem.

4. ACKNOWLEDGEMENTS

The authors are thankful to E.T. Engman, Head of Hydrological Sciences branch, GSFC for providing the AIRSAR and ground truth data. They also gratefully acknowledge N. Chauhan for his useful discussions. K.S. Rao is thankful to the National Research Council for providing a senior research associateship during the course of the work.

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TABLE 1. RESULTS OF THE LINEAR AND NONLINEAR REGRESSION ANALYAIS

DATA σ°	LINEAR REGRESSION r	s	SLOPE	NONLINEAR REGRESSION r	s
C-HH	0.75	4.23	0.17	0.77	4.10
C-VV	0.83	3.57	0.19	0.83	3.56
C-HV	0.79	3.96	0.13	0.79	3.95
L-HH	0.77	4.06	0.32	0.81	3.73
L-VV	0.61	5.09	0.40	0.76	4.16
L-HH	0.79	4.00	0.29	0.79	3.94
P-HH	0.19	6.30	0.16		
P-VV	0.20	6.29	0.15		
P-HV	0.09	6.69	-0.05		

TABLE 2. RESULTS OF LINEAR LEAST SQUARE FITTING FOR SEVERAL COMBINATIONS OF FREQUENCY AND POLARIZATION

S.NO	BAND	POLARIZATION	r	s
1	C	HH,VV,HV	0.84	3.51
2	L	"	0.85	3.33
3	P	"	0.31	6.11
4	C,L,P	HH	0.80	3.83
5	"	VV	0.84	3.44
6	"	HV	0.84	3.52
7	C,L	HH,VV,HV	0.89	2.94
8	C,P	"	0.86	3.27
9	L,P	"	0.87	3.16
10	C,L,P	"	0.90	2.83
11	C,L	HH,HV	0.86	3.22
12	C,P	"	0.82	3.68
13	L,P	"	0.86	3.26
14	C,L	HH,VV	0.85	3.33
15	C,P	"	0.86	3.30
16	L,P	"	0.84	3.48
17	C,L,P	HH,VV	0.87	3.15
18	"	HH,HV	0.87	3.17