N95- 23960

SOIL MOISTURE RETRIEVAL IN THE OBERPFAFFENHOFEN TESTSITE USING MAC EUROPE AIRSAR DATA

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1. INTRODUCTION

Soil moisture content is an important parameter in many disciplines of science like hydrology, meteorology, agriculture and others. Microwave remote sensing technique has a high potential in measuring the dielectric constant of soils, which is strongly governed by the soil moisture (Ulaby et al. 1982). Much excellent work has been done on investigating the relationship between backscattering coefficient and soil moisture (Schmugge et al. 1980, Ulaby et al. 1986, Dobson et al. 1985, Rao et al. 1992, Shi et al. 1992). Most of these studies are measured in a laboratory or are carried out with a multitemporal data set. This means, that the variation in the backscattering coefficient is only related to the soil moisture because all other parameters influencing the backscattering like surface roughness, vegetation cover, plant geometry, phenology of plants and row direction are kept constant. In this study the sensitivity of the backscattering coefficient to soil moisture of corn fields is investigated. In the framework of the MAC-Europe Campaign in June 1991, the NASA/JPL three-frequency polarimetric AIRSAR system collected data over the test site Oberpfaffenhofen (Germany). The AIRSAR campaign in Oberpfaffenhofen was complemented with intensive ground truth measurements. The sampled corn fields are nearly in the range of the same incidence angle ($\approx 20°$) and belong to different soil types. The evaluation was carried out at a single data set. The results show, that the backscattering, measured at P-band can be described with only two parameters very well. The main parameter, influencing the backscattering is the soil moisture content, the second subordinated parameter is the row direction.

2. ANALYSES AND RESULTS

For the assessment of the AIRSAR data for soil moisture retrieval all frequencies (C-, L- and P-band) were investigated. Also different polarizations and processing steps were used. Multiparameter least square regression analysis was carried out to fit the values of soil moisture (grav. % and vol. %) with these ($\sigma°$) of the AIRSAR system. The objective was to identify the best frequency and polarization respectively the best processing steps for soil moisture retrieval over corn fields. 17 corn fields with different SMC and different row directions relative to the look direction have been sampled. All fields are placed within a range with a similar incidence angle near 20 degrees to avoid effects referring to the incidence angle. To get different SMC's, the cross section of sampled fields covers three different types of soils: a loess soil, a waste gravel soil upon glacial gravel terraces and a drained ground-water soil. One problem is the spatial registration of the SMC on the ground. Due to the fact, that only point measurements of SMC are possible, the accuracy of the ground acquisition of SMC depends on the quantity of measurements.

The backscattering coefficient at C-band is mainly influenced by the interaction between the incident wave and the vegetation cover, which is expressed by the good perceptibility of the land use. The row direction takes no measurable effects and the differences in the soil moisture are masked from the vegetation cover.
The same investigations were done for the L-band at all polarization combinations. Also at this frequency the backscattering coefficient is mainly influenced by the differences in the vegetation cover. However the canopy loss is smaller, which is expressed by the week perceptibility of soil boundaries representing differences in soil moisture content. The same is valid for the row direction tracing weekly on fields with the same vegetation cover, in this case corn.

Summarized it can be said that at L- and especially at C-band and an incidence angle of approximate 20° the attenuation coefficient of vegetation canopies is to high for monitoring soil moisture without modelling.
Our measurements with P-band look very promising. The attenuation coefficient of vegetation canopy is relative small, because now the soil moisture is the dominant part influencing the backscattering (fig. 2). The second subordinated parameter is the row direction (tab. 1). A multiparameter least square regression analysis with the parameters row direction, soil moisture content and the backscattering coefficient was carried out. Figure 1 shows, that 92% of the backscattering can be described with the parameter row direction and gravimetric SMC at HH-HV polarization and with HH polarization 90% of the backscattering. Table 1 illustrates the composition of the total backscattering referring to the difference of HH-HV polarization. It can be seen, that the main part of the signal can be counted back to the SMC. To get the single least square fit for gravimetric SMC the fields have to be calibrated to one fixed row direction (in this case 45°). Figure 4 shows the linear least square fit between gravimetric SMC and σ° at HH-HV polarization. The correlation coefficient of the relative to the row direction corrected data amounts to 0.83 at HH- respectively 0.85 at HH-HV polarization. Figure 3 demonstrates the linear dependence of row direction and the backscattering coefficient.
A comparison of the correlation coefficients illustrates the improvement taking a nonlinear fit. The decreasing slope in the region of lower SMC concerning the nonlinear fit might be derived from the effects of bound water (fig. 5, tab. 2).

Fairly extensive studies demonstrate that the volumetric SMC represents the dielectric properties of different soils better than the gravimetric SMC (e.g. Scott & Smith 1992). This study apparently do not confirm this thesis, but this effect might be derived from the little number of sampled fields referring to a statistical approach and the greater inaccuracy in measurement of the volumetric SMC on the ground due to the small sample volume (100 cm^3) we have used (fig. 6).
The dotted lines in the figures are representing the average standard deviation of the ground measurements.

A approach was carried out to detect the row direction automatically. With the correlation coefficient between the HH and VV polarization there is a parameter for the assessment of the row direction. For corn fields the influence of the row direction is one order higher at VV polarization as for other polarizations. This is caused by the strong interaction between the incidence wave and the vertical corn stalks. These interactions depend on the row direction, because the spacing between corn plants within a row is much smaller than the spacing between the rows of corn. At HH polarization the influence of row direction is smaller and shows a more linear dependance. These results are corresponding with a similar study of Brunfeldt & Ulaby (1984). The regression between the correlation coeffizients of HH- and VV polarization and the row direction for each field was calculated. The correlation coefficient of this regression amounts to 0.67. Using this regression line the angle between the row direction and the look direction can be assessed. A multiparameter least square regression analysis was carried out taking the parameters calculated row direction, grav. SMC and the backscattering coefficient of HH-HV polarization. The correlation coefficient amounts to 0.79 which means that about 80% of the backscattering can be described without complex modelling of the vegetation cover only by the data itself. Taking into account a relative great insecurity represented by the measurements of the SMC on the ground these results suggest that for soil moisture retrieval from SAR imagery P-band is very suitable using HH- or HH-HV polarization. With the two parameters soil moisture and known row direction about 90% respectively 80% of the total backscattering can be described depending on the use of gravimetric- or volumetric SMC. Further investigations have to be done to confirm these results with other plant canopies. Supposing that the influence of row direction is very high at corn due to the marked differences in spacing between corn plants within a row and the spacing between the rows of corn, soil moisture retrieval with P-band is promising even better results about other land use canopies, especially at smaller incidence angles because the influence of row direction becomes smaller.

3. REFERENCES

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field	row direction (degrees)	soil moisture (grav. %)	influence of soil moisture (dB)	influence of row direction (dB)	residue (dB)
1	35	17,34	7,70	2,05	0,81
2	23	14,91	6,62	1,35	0,83
3	23	13,61	6,04	1,35	0,65
4	15	15,83	7,03	0,88	0,61
5	45	15,66	6,96	2,64	1,20
6	66	16,39	7,28	3,87	0,45
7	75	20,54	9,12	4,40	1,57
8	75	20,27	9,00	4,40	0,26
9	75	20,54	9,12	4,40	0,08
10	4	20,57	9,14	0,23	0,80
11	80	21,09	9,37	4,69	1,38
12	32	15,93	7,08	1,88	2,39
13	40	22,3	9,90	2,35	0,01
14	5	26,78	11,89	0,29	1,59
15	28	21,81	9,69	1,64	1,03
16	73	27,58	12,25	4,28	0,19
17	27	23,11	10,26	1,58	1,36

Table 1. Composition of the total backscattering at HH-HV polarization.

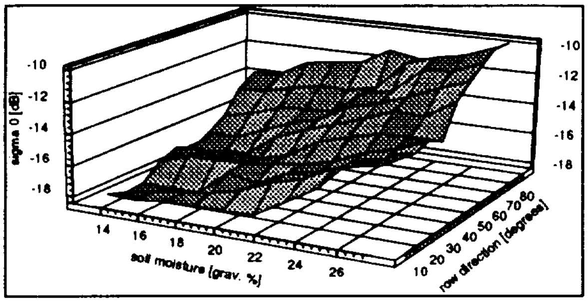

Fig. 1. Multiple linear regression for HH-HV polarization.

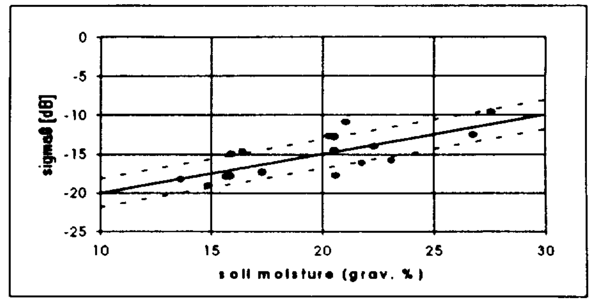

Fig. 2. Linear regression for HH-HV polarization.

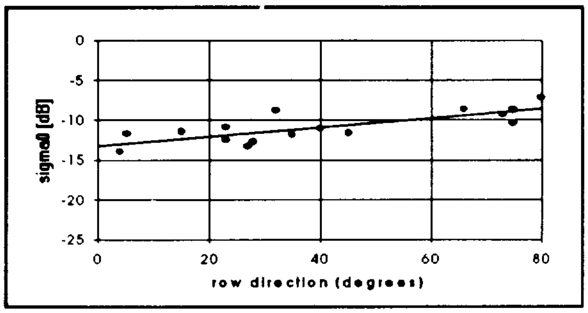

Fig. 3. Linear regression of row direction relative to the look direction versus σ° at HH-HV polarization after calibration to one fixed SMC.

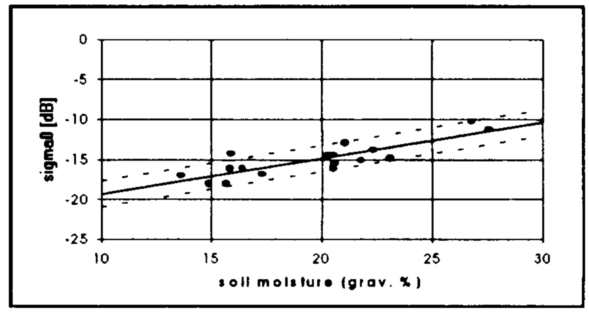

Fig. 4. Linear regression of grav. SMC versus σ° at HH-HV polarization after calibration to one fixed row direction (45°).

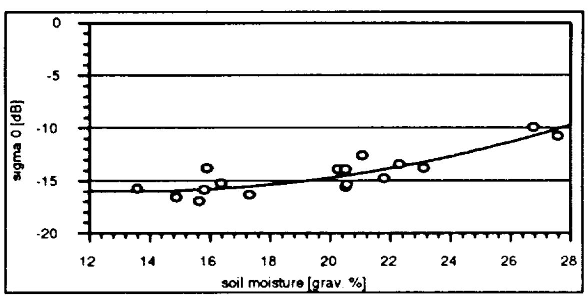

Fig. 5. Nonlinear regres. of grav. SMC versus σ° at HH polarization after calibration to one fixed row direction (45°).

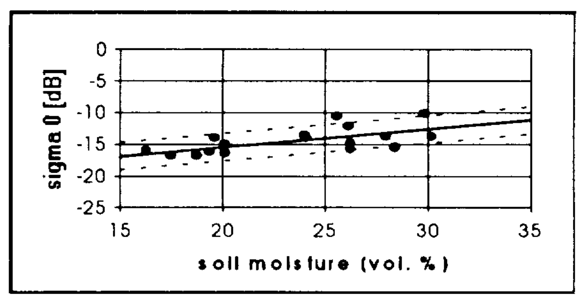

Fig. 6. Linear regres. of vol. SMC versus σ° at HH-HV polarization after calibration to one fixed row direction (45°).

data (P-band)	linear regression			nonlinear regression	multible linear regression		
	grav. %	vol. %	row direction	grav. %	grav.% / row d.	vol.% / row d.	grav.% / calc. row d.
HH	0.73	0.65	0.64	x	0.90	0.79	0.80
HH-HV	0.73	0.68	0.66	x	0.92	0.82	0.79
HH (calibrated)	0.83	0.64	0.77	0.89	x	x	x
HH-HV (calibrated)	0.85	0.69	0.80	0.87	x	x	x

Table 2. Correlation coefficients of the linear and nonlinear regression analyses.