N95- 23944

FOREST INVESTIGATIONS BY POLARIMETRIC AIRSAR DATA IN THE HARZ MOUNTAINS *

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1. INTRODUCTION

The Harz Mountains in the North of Germany have been a study site for several remote sensing investigations since 1985, as the mountainous area is one of the forest regions in Germany heavily affected by forest decline, especially in the high altitudes above 800 m. In a research programme at the University of Berlin, methods are developed for improving remote sensing assessment of forest structure and forest state by additional GIS information, using several datasets for establishing a forest information system (Kenneweg, Schardt, Sagischewsky, 1992).

The Harz has been defined as a testsite for the SIR–C / X–SAR mission which is going to deliver multifrequency and multipolarizational SAR data from orbit. In a pilote project led by DLR–DFD, these data are to be investigated for forestry and ecology purposes. In a preparing flight campaign to the SIR–C / X–SAR mission, "MAC EUROPE 1991", performed by NASA/JPL, an area of about 12 km by 25 km in the Northern Harz was covered with multipolarizational AIRSAR data in the C–, L– and P–band, including the Brocken, the highest mountain of the Harz, with an altitude of 1142 m.

The multiparameter AIRSAR data are investigated for their information content on the forest state, regarding the following questions:
- information on forest stand parameters like forest types, age classes and crown density, especially for the separation of deciduous and coniferous forest,
- information on the storm damages (since 1972) and the status of regeneration,
- information on the status of forest destruction because of forest decline,
- influence of topography, local incidence angle and soil moisture on the SAR data.

Within the project various methods and tools have been developed for the investigation of multipolarimetric radar backscatter responses and for discrimination purposes, in order to use the multipolarization information of the compressed Stokes matrix delivered by JPL.

2. AVAILABLE DATA

The AIRSAR scenes were flown at July 12th, 1991. Two profiles were heading North with looking angles of 45 deg. and 55 deg., two profiles heading South, with the same looking

angles. Therefore data are available representing an illumination of the mountains from the East and from the West, each profile cut into North and South scene (Keil et al., 1993).

Parallel to the survey, 70 test areas in the upper Harz have been checked at the ground for forest type and tree composition, age class, crown density, topographic features and ground cover. A LANDSAT TM scene from July 10th 1991 (two days before the AIRSAR flight) and a digital elevation model is available for comparison. Within a cooperation with the Technical University of Berlin, infrared colour photos can be used. A large progress for investigation was reached by short when about 140 polygons from airphoto interpretation of forest state and from forest management data could be integrated within this cooperation. The data overlay is based on a geocoding of three AIRSAR scenes performed by Johanneum Research, Graz, including terrain correction.

3. TOOLS FOR INVESTIGATION OF POLARIZATION DATA

In order to study signatures of polarimetric backscatter, several extensions of the available POLTOOL software by JPL were found necessary. Thus, for the synthesis of polarimetric information of target areas, an input mask file was coupled with the SYNTHESIS software based on arbitrary closed polygons (Tares, 1993).

Besides several other tools for visualization and statistical evaluations, the following representation was found very useful: The possible discrimination of two forest stands on certain polarization states can not be checked by comparing mean backscatter amplitudes alone. Thus, a deduction of standard deviation, assuming Gaussian distribution, was performed for the marked forest reference areas and given polarization states directly from the Stokes matrix (Tares, 1993). As ellipticity seemed not to have a dominant influence for discrimination, a two dimensional representation was used mainly: For co-polarization and cross-polarization, the stand-averaged backscatter amplitude + – standard deviation can be presented in dependence of orientation angle.

By known mean values M and standard deviation Sdev for two landcover classes a and b, an expected accuracy of a Bayesian classification for one feature can be estimated using the separability index (Dobson et al., 1992):

$$S(a,b) = \mathrm{abs}(M(a)-M(b)) / (Sdev(a) + Sdev(b)).$$

For Gaussian distribution, values of $S > 1.5$ correspond to a classification accuracy better than 90%. The new developed program "discrimination" enables a separability optimization by changing both orientation angles and ellipticity angles for pairs of forest classes(Tares,1993).

The statistical evaluations were used to prepare classification investigations. In order to take into account the speckle and textural information, first classification approaches were performed using the EBIS system (an "evidenced based interpretation system") by Lohmann, 1991, developed and installed at DLR. By this system there are supported distribution functions described by multinomial statistics besides Gaussian distributions.

4. PRESENT RESULTS

From visual interpretation and statistical evaluations, several characteristics could be deduced for the AIRSAR data of the Harz study site.

L-band data seem to deliver the best single band information for separation of deciduous and coniferous stands, when two or three characteristic polarization states can be used. This is due to the fact, that polarization response vary much more for spruce stands than for deciduous stands with changing orientation angle (showing a maximum near HH and a minimum near VV for co-polarization of spruce). Age classes are difficult to delineate in L-band alone, cultures and clearings can be detected well (Raupenstrauch, 1993). The high-level spruce stands with lower crown density can be distinguished against the denser stands in the North, for which the different texture gives also important information.

The three polarizations at P-band show the highest differenciation within the forest areas. Two influences besides crown and stem parameters seem to overlay forest information: P-band shows the strongest relations to the topography. P-HH and P-VV, not P-HV, reflect information not correlated with forest stand parameters; investigations are planned to check how far soil types, soil moisture and ground cover are responsible for that.

Weakest influences by topography are shown in the C-band. The polarization information is smaller than in L- and P-band, leading to a low differentiation between deciduous and coniferous trees. There is a higher potential for the differentiation of regeneration states (clearings / cultures) and additional information for age class separation (thickets / timber).

An example of polarimetric signatures for three different stand types is shown in Fig. 1. The spruce and the deciduous stand can be distinguished in L- and P-band, not in C-band, the orientations VV and HV seem best for that separation. VV-polarization has proved the most informative orientation for C-band, e.g. for the separation of cultures from spruce, pole and old timber (Keil et al., 1993).

For the present classifications by EBIS, datasets of L-HH, L-VV and L-HV as well as C-VV and P-HV proved a suitable base. Important for classification was the use of local incidence information which is available now in the co-registrated incidence angle mask.

5. REFERENCES

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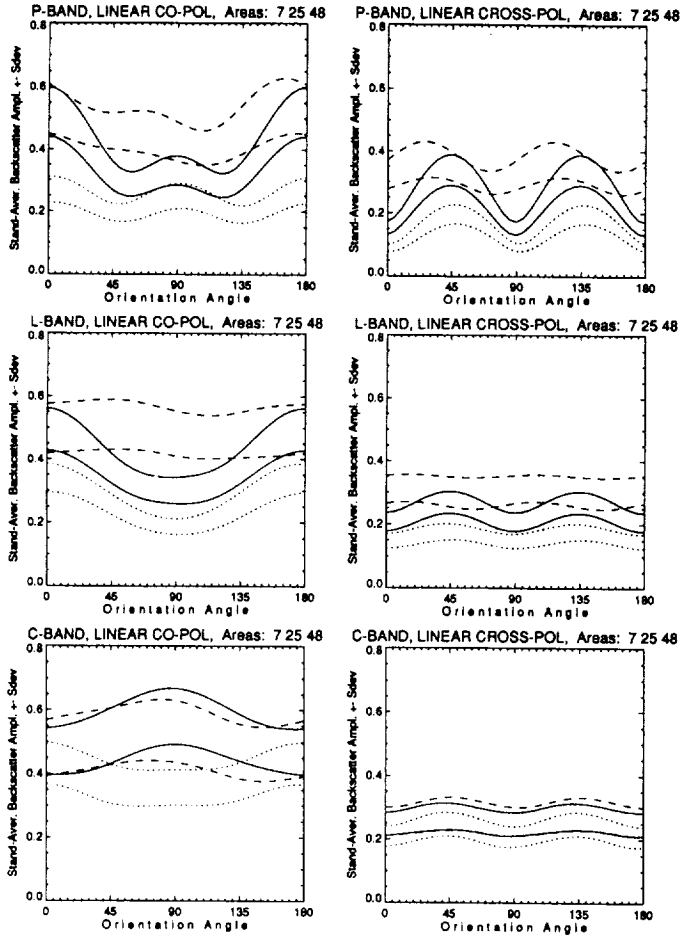

Fig. 1. Polarization signatures for three stands: ——— spruce, pole and old timber, mainly closed, slope E 5 deg. – – – deciduous stand, old timber, slope SW, 20–30 deg. . . . . culture (spruce), open, 0 deg.

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