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COMPARISON OF INVERSION MODELS USING AIRSAR DATA FOR DEATH VALLEY, CALIFORNIA

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1. INTRODUCTION

Polarimetric Airborne Synthetic Aperture Radar (AIRSAR) data were collected for the Geologic Remote Sensing Field Experiment (GRSFE) over Death Valley, California, USA, in September 1989 (Evans and Arvidson, 1990; Arvidson et al, 1991). AIRSAR is a four-look, quad-polarization, three frequency instrument. It collects measurements at C-band (5.66 cm), L-band (23.98 cm), and P-band (68.13 cm), and has a GIFOV of 10 meters and a swath width of 12 kilometers. Because the radar measures at three wavelengths, different scales of surface roughness are measured. Also, dielectric constants can be calculated from the data (Zebker et al, 1987).

The scene used in this study is in Death Valley, California and is located over Trail Canyon alluvial fan, the valley floor, and Artists Drive alluvial fan. The fans are very different in mineralogic makeup, size, and surface roughness. Trail Canyon fan is located on the west side of the valley at the base of the Panamint Range and is a large fan with older areas of desert pavement and younger active channels. The source for the material on southern part of the fan is mostly quartzites and there is an area of carbonate source on the northern part of the fan. Artists Drive fan is located at the base of the Black Mountains on the east side of the valley and is a smaller, young fan with its source mostly from volcanic rocks. The valley floor contains playa and salt deposits that range from smooth to Devil's Golf Course type salt pinnacles (Hunt and Mabey, 1966).

2. CALIBRATION

The AIRSAR data were calibrated to allow extraction of accurate values of rms surface roughness, dielectric constants, sigma-zero backscatter, and polarization information. The data were calibrated in two ways, assuming a flat surface, and using a digital elevation model to remove topographic effects. Both calibrations used in-scene trihedral corner reflectors to remove cross-talk, and to calibrate the phase, amplitude, and co-channel gain imbalance (van Zyl, 1990). The altitude of the aircraft was measured incorrectly because the plane was flying over the Panamint mountains and imaging the valley floor. This was corrected in the calibration in both cases. A digital elevation model (DEM) was generated by digitizing four USGS topographic quads using Arc/Info. This DEM was registered to the radar scene and used in the calibration to remove the effects of topography (van Zyl et al, 1992). The near-range part of the image contains Trail Canyon fan which slopes away from the radar look direction and has the largest topographic effect. Artists Drive fan, in the far range, has a gentle slope which did not effect the calibration greatly. The corner reflectors used in the calibration were located on Trail Canyon fan. In the calibration without the DEM correction, the calibrated polarization signatures for the corner reflectors were not ideal. However, once the DEM was used, the calibrated signatures were much better. Figure 1 shows before and after DEM calibration polarization signatures for a corner reflector in C-band. Also, the sigma-zero values changed slightly with the DEM correction. Areas that face away from the radar look direction due to topography have DEM corrected sigma-zero values that are greater than (less negative) those that are DEM uncorrected. Areas that face toward the radar look direction have DEM corrected sigma-zero values that are less than (more negative) those that are DEM uncorrected. Areas that are flat, without topography, have sigma-zero values that are the same in both calibrations.

3. INVERSION AND ANALYSIS

The first-order small perturbation model (Evans et al, 1992; van Zyl et al ,1991; Barrick and Peake, 1967) was used to estimate the surface power spectral density and the dielectric constant at every pixel by performing an inversion using the AIRSAR data. This model is valid only for very smooth surfaces. Results from the small perturbation model inversion are three values, one for each of the radar frequencies, that describe the power spectral density of the surface and a value for the dielectric constant at each frequency. The power spectrum of a geologic surface is approximately linear in log-log space. Fitting the three points from the inversion with a line using a least-squares method produces slope and intercept values that allow calculation of the fractal dimension of the surface and a rms surface roughness value. The slope of the power spectrum is related to the two-dimensional fractal dimension of the surface. The fractal dimension of a surface describes the scaling properties of the topography (Mandelbrot, 1982). A surface may have a fractal dimension between 2 and 3 and as the fractal dimension increases, heights of nearby points become more independent (Brown and Scholz, 1985). The intercept of the power spectrum can be directly related to a rms surface roughness using forward modelling. Using the fractal dimension and rms surface roughness calculated from the radar inversion power spectrum, a synthetic three dimensional plot can be made that represents the surface (Huang and Turcotte, 1989; Kierein-Young and Kruse, 1992).

A modified small perturbation model (van Zyl, personal communication; Zebker et al, 1991) was also used to estimate the rms surface height and dielectric constant at every pixel by performing an inversion using the AIRSAR data. This model modifies the small perturbation model to extend the validity range to all surfaces by including an empirically derived function that approximates the change in roughness with backscatter. Two versions of the modified small perturbation model inversion were used. The first assumes a constant value for the slope of the power spectrum. The second method uses, at every pixel, the power spectrum slope obtained from the small perturbation model inversion. Results from both the modified small perturbation models are values for the rms surface roughness and dielectric constant for each frequency.

4. RESULTS AND CONCLUSIONS

The results from the three inversion models are shown in Table 1 compared with field data for five sites. These five sites consist of three alluvial fan units, a playa, and Devil's Golf Course type salt pinnacles. The active fan site is from the most active channel on Trail Canyon fan, the desert pavement site is also from Trail Canyon fan, and the third site is from Artists Drive fan. Field surface roughness data were obtained from digitized helicopter stereo pairs (Farr, personal communication) of each site and from an USGS Open File Report (Schaber and Berlin, 1993). Field dielectric measurements were made with a C-Band dielectric probe. In general, the results from the small perturbation model underestimates the value of surface roughness. In both of the modified small perturbation models, the surface roughness values generally increase with frequency. The roughness values in the model with a constant power spectrum slope value (y) are larger than those from the model using the power spectrum slope from the small perturbation model. The P-Band data seem to match the field data more closely than the other bands. However, this may be because of the dielectric values. The dielectric values are most reasonable in the small perturbation model. The dielectric values in the modified models are too high except in P-Band. The modified small perturbation model was tried assuming a dielectric constant equal to 3.0 for every pixel. This inversion produced surface roughness values that were too large in most cases.

Using inversion models to obtain surface roughness and dielectric constants from AIRSAR data produces quantitative results that are reasonably accurate. The small perturbation model tends to give the overall best results for dielectric constants. C-band and L-band data in the modified small perturbation model tend to produce dielectric constants that are too high. P-band data in the modified model produces the best overall results for both surface roughness and dielectric constant. The results from the modified model with a constant power spectrum slope are similar to those of the model with variable power spectrum slopes. Since surfaces do show differences in their power spectrum slopes, it is more accurate to include this variation in the inversion model. The results of these inversion models can be used to help in determining the active surficial processes and the age of alluvial fan surfaces. Combining the inversion results with data from other sensors can help to determine why roughness characteristics are spatially variant (Kierein-Young and Kruse, 1991). For example, the north part of Trail Canyon fan has a lower surface roughness than the rest of the fan. This difference is due to a different, more easily eroded source material.

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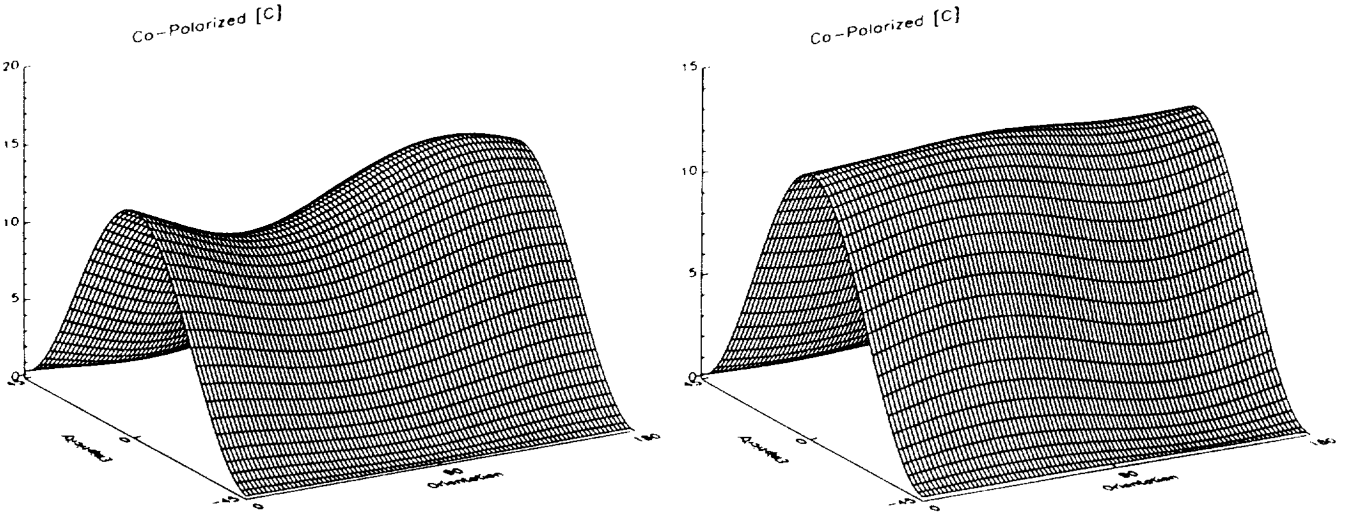

Figure 1. Co-polarized C-band corner reflector polarization signatures without DEM correction (left) and with DEM correction (right).

Table 1. AIRSAR inversion model results.

			SPM		MSPM y=2.55		MSPM y=SPM		Field	
Surface		RMS	fd	e	RMS	e	RMS	e	RMS	e
Active Fan	C	6.5	2.13	4.0	2.7	66.8	2.1	68.4	17.4	3.1
	L			3.6	6.7	27.3	5.0	27.3		
	P			3.0	10.9	4.2	10.3	3.6		
Desert Pvt Fan	C	2.0	2.18	10.3	1.4	26.9	1.2	25.7	9.8	3.0
	L			8.8	2.7	12.3	2.6	10.8		
	P			3.0	10.7	1.5	6.9	1.4		
Artists Dr. Fan	C	1.0	2.405	2.4	2.6	46.1	2.6	28.7	11.5	2.8
	L			2.3	2.5	10.0	3.4	13.6		
	P			2.7	9.4	2.1	11.8	4.3		
Playa	C	2.3	2.105	4.8	1.5	28.3	1.0	28.3	7.6	5.3
	L			10.9	0.9	26.1	0.5	20.8		
	P			2.5	6.2	3.9	9.9	3.3		
Devil's Golf Cs.	C	19.0	2.03	3.0	NGP	NGP	NGP	NGP	12.0	2.4
	L			2.5	12.1	50.7	5.7	27.5		
	P			3.0	30.3	17.7	28.2	39.4		

RMS = root mean square surface roughness in cm
fd = fractal dimension
e = dielectric constant
NGP = no good points