SAR BACKSCATTER FROM CONIFEROUS FOREST GAPS

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Introduction

A study is in progress comparing AIRSAR backscatter from coniferous forest plots containing gaps to backscatter from adjacent gap-free plots. We are asking "How do gaps in the range of 400 to 1600 m^2 (approximately 4-14 pixels at intermediate incidence angles) affect forest backscatter statistics?" and "What incidence angles, wavelengths, and polarizations are most sensitive to forest gaps?" In order to visualize the slant-range imaging of forest and gaps we make use of a simple conceptual model. This strictly qualitative model has led us to hypothesize that forest radar returns at short wavelengths (eg., C-band) and large incidence angles (eg., 50°) should be most affected by the presence of gaps, whereas returns at long wavelengths and small angles should be least affected. Preliminary analysis of 1989 AIRSAR data from forest near Mt. Shasta supports the hypothesis.

Current forest backscatter models such as MIMICS (Ulaby *et al.* 1990) and Santa Barbara Discontinuous Canopy Backscatter Model (Sun *et al.* 1991) have in several cases correctly predicted backscatter from forest stands based on inputs of measured or estimated forest parameters (McDonald *et al.* 1990, Wang and Paris 1992). These models do not, however, predict within-stand SAR scene texture, or "intrinsic scene variability" as Ulaby *et al.* (1986) has referred to it. For instance, the Santa Barbara model, which may be the most spatially coupled of the existing models, is not truly spatial. Tree locations within a simulated pixel are distributed according to a Poisson process, as they are in many natural forests, but tree size is unrelated to location, which is not the case in nature. Furthermore, since pixels of a simulated stand are generated independently in the Santa Barbara model, spatial processes larger than one pixel are not modeled. Using a different approach, Oliver (1991) modeled scene texture based on an hypothetical forest geometry. His simulated scenes do not agree well with SAR data, perhaps due to the simple geometric model used.

Insofar as texture is the expression of biological forest processes, such as succession and disease, and physical ones, such as fire and wind-throw, it contains useful information about the forest, and has value in image interpretation and classification. Forest gaps are undoubtedly important contributors to scene variance. By studying the localized effects of gaps on forest backscatter, guided by our qualitative model, we hope to understand more clearly the manner in which spatial heterogeneities in forests produce variations in backscatter, which collectively give rise to scene texture.

Shasta Forest Gaps: a Conceptual Model

The forest at the Mt. Shasta study site spans a range of tree sizes and stand densities, but for the purpose of a conceptual model, we assume crowns are interlocked and tree heights are 20-25 m. Forest gaps ranging from 400 to 1600 m^2 are assumed circular. Slant range pixel spacing is 6.7 m.

The imaging geometry is illustrated in Figure 1 for θ_o=45°. One slant range-pixel is shown shaded. If canopy penetration is deep, as at P-band, the entire pixel

volume can contribute to backscatter. In this case, *effective range resolution* becomes a function not only of θ_o and slant-range resolution, but also of tree height, canopy depth, and extinction coefficient. *Effective range resolution* for long wavelengths and small incidence angles could be much coarser than ground range resolution. Conversely, at large incidence angles the pixel is oriented more vertically, which reduces the pixel volume intersecting the canopy. At short wavelengths, canopy extinction limits backscatter to the upper canopy, further reducing pixel volume. It follows that short wavelengths combined with large incidence angles should lead to the maximum *effective range resolution* of laterally oriented forest features (such as gaps), and to the greatest effects on local backscatter.

Figure 1

Figure 1
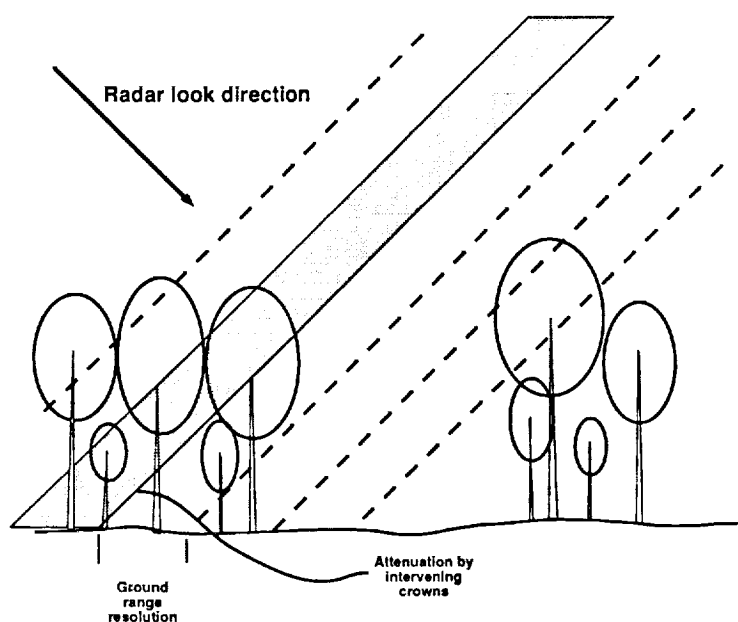
Methodology and Preliminary Results

To test this hypothesis, 238 forest gaps were located on orthophotoquads of the region. Gap coordinates in three SAR images ($\theta_o \approx 23°$, $40°$, *and* $50°$) were determined by co-registering a digitized map of the forest gaps to the SAR images. We are currently comparing backscatter from plots containing gaps in several size classes to adjacent areas without gaps. The mean and median of the backscatter distributions from 5x7 pixel windows have proven insensitive to the presence of gaps in the 500-900 m^2 size range. A more effective test statistic is the difference in backscatter at the lower quartiles of the gap and non-gap backscatter distributions. Tests on a subset of the data (n=12 pairs) indicate that the lower quartile backscatter at C-band, HH polarization, for $\theta_o \approx 50°$ is significantly lower (at the 95% confidence level) for gap-containing plots than for gap-free plots (Table 1). Lower quartile differences for other bands and angles are not significant. Following analysis of the full data set, we plan to test other parameters, such as the difference in the coefficient of variation of gap and non-gap windows, so as to build a clearer empirical understanding of the effects of forest spatial heterogeneities on backscatter.

Table 1. Difference between backscatter from gap-containing and gap-free forest plots

	C-band			L-band			P-band		
	HH	HV	VV	HH	HV	VV	HH	HV	VV
25°	0.56	0.65	0.41	-0.34	-0.01	0.22	0.27	0.06	-0.22
40°	-0.39	-0.09	-0.38	-0.18	-0.31	-0.08	-0.45	-0.01	-0.76
50°	*-1.42	-0.85	-0.40	-0.02	-0.66	-0.52	-0.36	0.29	-0.86

Values shown are the mean differences in backscatter (dB) between the lower quartiles of gap-containing plots and the lower quartiles of gap-free plots. * indicates significance at the 95% confidence level for the 12 pairs of plots tested.

References

McDonald, K. C., M. C. Dobson, and F.T. Ulaby, 1990,
Using MIMICS to model L-band multiangle and multitemporal backscatter from a walnut orchard. *IEEE Transactions on Geoscience and Remote Sensing*, vol. GE-28, no. 4, pp. 477-491

Oliver, C. J., 1991,
Natural clutter in coherent imaging, *International Journal of Remote Sensing*, vol. 12, no. 2, pp. 329-338,

Sun, G., D. S. Simonett, and A. H. Strahler, 1991,
A radar backscattering model for discontinuous coniferous forests, *IEEE Transactions on Geoscience and Remote Sensing*, vol. 29, no. 4, pp. 639-650.

Ulaby, F. T., F. Kouyate, B. Brisco, and T. H. Lee Williams, 1986, Textural information in SAR images, *IEEE Transactions on Geoscience and Remote Sensing*, vol. GE-24, no. 2, pp. 235-245,

Ulaby, F. T., K. Sarabandi, K. C. McDonald, M. Whitt, and M. C. Dobson, 1990a,
Michigan Microwave Canopy Scattering Model (MIMICS), *International Journal of Remote Sensing*, vol. 11, no. 7, pp. 1223-1253.

Wang, Y., and J. F. Paris, 1992,
Inclusion of a simple multiple scattering model into the Santa Barbara microwave backscatter canopy model for woodland, submitted to *IEEE Transactions on Geoscience and Remote Sensing*