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# COMPARISON OF MODELED BACKSCATTER WITH SAR DATA AT P-BAND

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## 1. Introduction

In recent years several analytical models have been developed to predict microwave scattering by trees and forest canopies [1-6]. These models contribute to the understanding of radar backscatter over forested regions to the extent that they capture the basic interactions between microwave radiation and tree canopies, understories, and ground layers as functions of incidence angle, wavelength, and polarization. The Santa Barbara microwave model backscatter model for woodland (i.e. with discontinuous tree canopies) combines a single-tree backscatter model and a gap probability model [5-6]. Comparison of model predictions with synthetic aperture radar (SAR) data at L-band ($\lambda$ = 0.235 m) is promising [7], but much work is still needed to test the validity of model predictions at other wavelengths. Here we test the validity of the model predictions at P-band ($\lambda$ = 0.68 m) for woodland stands at our Mt. Shasta test site.

## 2. Study area

Extensive ground data have been collected to support our SIR-B (Shuttle Imaging Radar) and SIR-C/X-SAR studies. The site is located to the southeast of Mt. Shasta, California (41°18' N, 122°05' W), and spans elevations from 1160 to 1220 m. The forest stands under investigation are natural, are on level ground, and are dominated by ponderosa pine *(Pinus ponderosa)* or pine mixed with white fir *(Abies concolor)*. Under story vegetation is sparse and consists primarily of perennial grasses and forbes. The litter layer can reach a depth of about 0.1 m. Three ponderosa pine stands ("Sp2", "St2", and "St11") in the site were chosen for this study because adequate ground data for these stands are available to provide inputs to the model. The three stands have different stand densities and trunk diameters at breast height (dbh). "Sp2" has trees of 25.0 m $\underline{h}$ and 0.77 m $\underline{dbh}$, with stand density of 23 trees per hectare. "St11" has trees of 27.0 m $\underline{h}$ and 0.46 m $\underline{dbh}$, with stand density of 228 trees per hectare. "St2" has trees of 25 m h and 0.42 m $\overline{dbh}$, with stand density of 303 trees per hectare. The soil of the stands is derived from recent alluvial deposits of volcanic ash, and the ground surface is smooth at P-band. Other ground data used as model inputs can be found in [8].

## 3. SAR data

SAR data were acquired by the Jet Propulsion Laboratory (JPL) airborne SAR overflights on 6 September 1989 after a dry summer. The SAR data were processed and calibrated by JPL. The estimated calibration uncertainty of the backscatter is ±1.0 dB [3]. The estimated calibration uncertainty of VV-HH phase difference is ±10°, and the estimated calibration uncertainty of HH and VV correlation coefficient is ± 0.1 (personal communication, Freeman 1992). We received the standard 4-look compressed data with pixel spacing of 12.1 m (azimuth) and 6.7 m (slant range). For the three stands, the means of the backscatter (HH, HV, and VV polarizations), the VV-HH phase difference, and the HH and VV correlation coefficient were extracted from the SAR data.

## 4. Comparison of model results with SAR data at P-band

Model simulations for stands "St2", "St11", and "Sp2" were carried out at the same incidence angle ($\theta_o$) as the SAR data. We have 8 SAR data takes covering stand "St2" ($\theta_o$ ranges from 22° to 54°), 5 data takes covering stand "St11" ($\theta_o$ from 25° to 45°), and 5 data takes covering stand "Sp2" ($\theta_o$ from 27° to 47°). The HH, HV, and VV backscatter, and the HH and VV correlation coefficient are shown in Figure 1. The model makes good predictions of the HH backscatter for stands "St2" and "St11" (Figure 1a), the VV backscatter for all three stands (Figure 1b), and the HV backscatter for stand "St11" (Figure 1c). The model overestimates the HH backscatter for stand "Sp2" (Figure 1a). The model underestimates the HV backscatter for stand "Sp2" and stand "St2" (Figure 1c). We attribute the underestimate to the surface model, in which we model only the co-polarized surface backscatter. Since the soil is dry and the radar wavelength is long, deep penetration into the soil is expected. Because "Sp2" has the low stand density and "St2" has small trees, more soil surface is exposed in these stands. Thus, the backscatter from the sub-surface may be a major contributor.

The model predicts well for the HH and VV correlation coefficients of stands "St2" and "St11", but overestimates the coefficient of stand "Sp2" (Figure 1d). The overestimate can be attributed to inadequate modeling of surface backscatter. The surface model used gives completely correlated backscatter for HH and VV because identical surface parameters are used for all the simulated pixels in a stand, and because the surface model predicts zero cross-polarized backscatter. For the sparse stand "Sp2", the surface backscatter is the major scattering source. Thus, strong and completely correlated surface backscatter is predicted by the model.

The model predicts a phase difference of $\approx$ 210.0° for the dense stands "St2" and "St11". Since the model phase difference and the SAR observed phase differences are close to 180° for stands "St2" and "St11", there is some indication that the VV-HH phase difference from double-bounce trunk-ground interactions (180°) contributes to the total phase difference.

To investigate the model prediction quantitatively, we test the null hypothesis of $H_o$: $\mu_{model} = \mu_{sar}$, where $\mu_{model}$ is the modeled mean and $\mu_{sar}$ is the mean of the SAR data. At the 5% significance level, the $H_o$ tests of the HH, HV, and VV backscatter, the correlation coefficient of HH and VV polarizations, and the VV-HH phase difference are accepted.

## 5. Conclusions

For P-band, the model predicts well compared with SAR data for HH, HV, and VV backscatter, VV-HH phase difference, and HH and VV correlation coefficient for stands with medium-to-high density (228 -- 303 trees per hectare). When stand density is low (23 trees per hectare), model performance becomes unacceptable: the model overestimates HH and VV backscatter, underestimates HV backscatter, and overestimates HH and VV correlation coefficient.

## 6. References:


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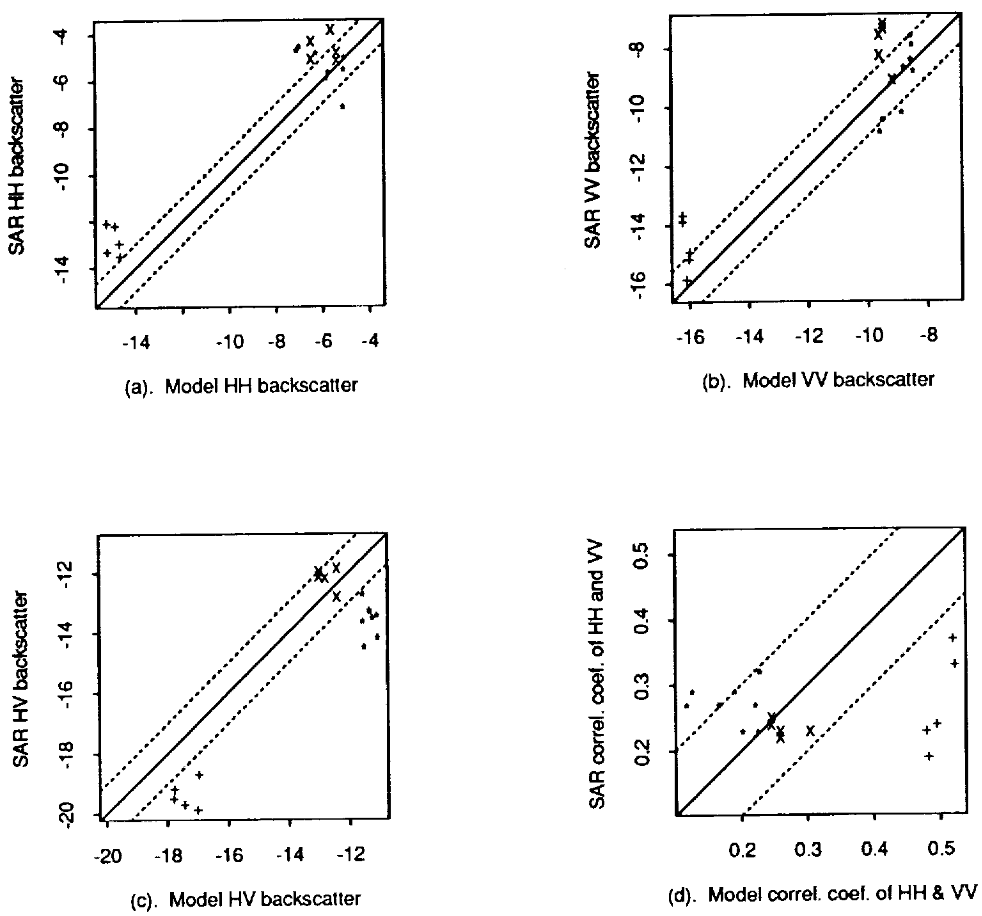
Figure 1. Model results vs SAR data at P-band




Solid lines indicate the equality of modeled means to those of SAR data. Dotted lines show ± 1.0 dB calibration uncertainty for the HH, HV, and VV backscatter (Figure 1a-c) and ±0.1 for the HH and VV correlation coefficient (Figure 1d). "+", "*", and "x" represent data points of stands "Sp2", "St2", and "St11", respectively.