Comparison of TRMM and NSCAT Observations of Surface Backscatter Over the Amazon Rain Forest

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Abstract–The Tropical Rain Measuring Mission (TRMM) precipitation radar (PR) is designed to measure backscatter from rain in order to map the amount and extent of rain in the tropical regions. The TRMM PR also measures the normalized radar cross section (σ^o) of the surface at a nominal resolution of approximately 4.4 km over an incidence range of 0-18°. The Ku-band NASA Scatterometer (NSCAT) made 25 km resolution measurements of the surface σ^o at incidence angles of 15.5° and higher and at 10.5°. A comparison of NSCAT and TRMM PR σ^o observations over the Amazon rainforest is presented. The relative calibration and noise levels of the two sensors are compared.

INTRODUCTION

The Tropical Rain Measuring Mission (TRMM) was successfully launched in Nov. 1997. Designed primarily to determine rain from the radar backscatter profile, the Ku-band (13.8 GHz) TRMM precipitation radar (PR) also measures the H-pol normalized radar cross section (σ^o) of the surface at a nominal resolution of approximately 4.4 km (at nadir) over an incidence range of 0-18° [1]. TRMM is in an equatorial orbit, covering 36° N to 36° S.

The NASA Scatterometer (NSCAT) flew aboard Japan's ADvanced Earth Observing Satellite (ADEOS), operating for 9 months from September 1996 through June 1997. NSCAT was designed to observe winds over the ocean from space using 25 km resolution measurements of the surface σ^o at Ku-band (14 GHz) [6]. NSCAT also collected σ^o measurements over land and ice regions. While dual-pol NSCAT wind mode σ^o measurements were made at incidence angles of 15.5° and higher in order to estimate the near-surface wind over the ocean, σ^o measurements were also made at approximately 10.5° incidence angle to assist in instrument calibration. Global maps of NSCAT σ^o values over a wide range of incidence angles have been produced [2]. NSCAT flew in a polar, sun-synchronous orbit with essentially global coverage every two days.

TRMM and NSCAT σ^o observations overlap at 10.5° and 15.5°-18° incidence angles. Taken together, the two sensors provide σ^o measurements in the tropics spanning an incidence angle range from nadir (0°) through 60°. In this paper we present a simple comparison of NSCAT and TRMM σ^o observations over the Amazon rainforest in order to cross-calibrate the two sensors. The potential for using data from the TRMM PR for vegetation classification studies is very briefly discussed.

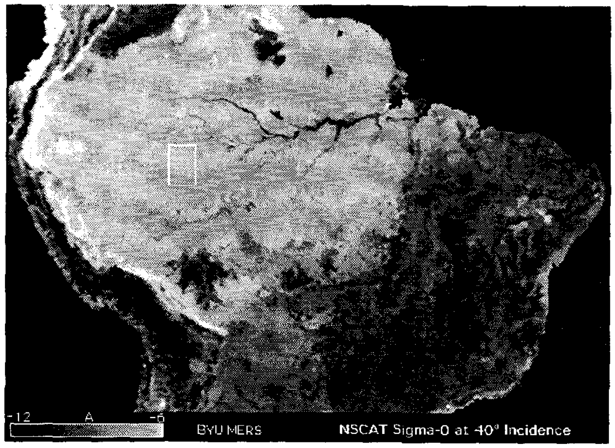

Figure 1: NSCAT SIRF $\mathcal{A}$ image (σ^o at 40° incidence angle) of the Amazon from two weeks of data in 1997. The study region is outlined.

STUDY REGION

Unfortunately, the premature end of the NSCAT mission due to the failure of the ADEOS spacecraft eliminated the possibility of simultaneous data collection from the TRMM PR and NSCAT. However, rainforests offer very stable year-to-year extended area calibration targets. Thus, a comparison is done using data from the same season but separated by one year over a spatially homogeneous region in the Amazon rainforest.

The Amazon rainforest has been widely used for the calibration of scatterometers (e.g., [3]), most recently NSCAT. The rainforest represents a large, spatially homogeneous region of high backscatter dominated by volume scattering from the dense leaf canopy. To minimize residual inhomogeneity, a small subregion within the rainforest is selected with the aid of NSCAT scatterometer data. Figure 1 shows an enhanced resolution image of $\mathcal{A}$, the incidence angle normalized cross section computed from NSCAT data. The Scatterometer Image Reconstruction with Filtering (SIRF) algorithm [5] was used with two weeks of NSCAT data to create this image. The large bright area is the Amazon rain forest which has an average $\mathcal{A}$ (σ^o

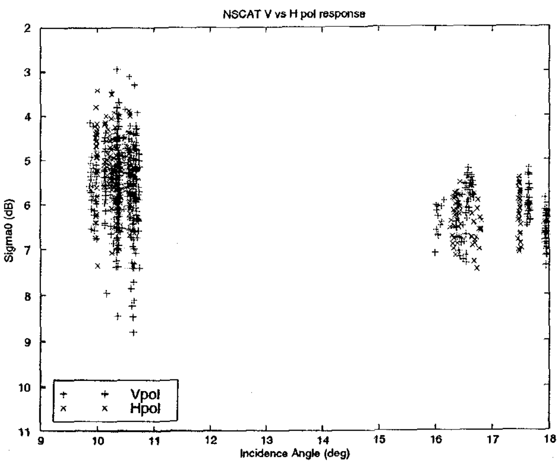

Figure 2: NSCAT dual-polarization σ^o measurements for incidence angles less than 18° over the study region from JD 25-55, 1997.

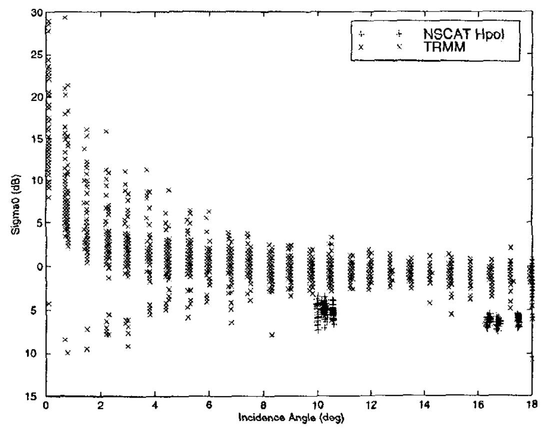

Figure 3: Comparison of TRMM and NSCAT H-pol σ^o measurements over the study region. TRMM data is from days Feb. 24-25,1998 while NSCAT data is from JD 25-55, 1997.

at 40° incidence angle) of approximately -7.5 dB. The study region, arbitrarily selected in a homogeneous area within the rainforest, is indicated. The study region is bounded by 68° W, 66° W,7° S, and 4° S. In this area, the spatial variation of $\mathcal{A}$ is less than 0.1 dB as observed by NSCAT.

NSCAT OBSERVATIONS

Unlike the TRMM PR, which operates at only H-pol, NSCAT made dual-polarization σ^o measurements. NSCAT used 6 fanbeam antennas, three on each side. Each antenna was at a different azimuth angle to provide the azimuth angle diversity required to infer the near-surface wind from the σ^o measurements [6]. The forward and aft antennas on each side were V-pol while the center antenna was dual-pol. As a result, there are 1/3 as many H-pol measurements as V-pol measurements. Since radar scattering over the rainforest is dominated by volume scattering from the dense vegetation canopy, little polarization difference is expected. This is confirmed in Figure 2 which plots NSCAT H- and V-pol σ^o measurements versus incidence angle. All of the NSCAT measurements collected during a 30 day period in Feb. 1996 in the study region that have incidence angles less than 18° are shown. While NSCAT made σ^o measurements at approximately 10.5° incidence, these measurements were included to verify instrument calibration over the ocean since the ocean exhibits only a limited wind speed and direction dependence at this incidence angle. The mean V- and H-pol σ^o measurements at 10.5° differ by 0.5 dB. Note that no rain flag was available for NSCAT measurements. Thus, at least some of the NSCAT measurements of the surface σ^o can be expected to be rain contaminated. Depending on the incidence angle and the rain rate and spatial extent within the NSCAT footprint, rain can increase σ^o due to backscattering from the raindrops or increased scattering from wet leaves, or σ^o can be reduced due to signal attenuation by the rain.

TRMM PR OBSERVATIONS

In order to cross-calibrate NSCAT and the TRMM PR, σ^o measurements from both sensors are plotted together in Figure 3. It is clear that, relative to NSCAT, TRMM PR measurements are biased several dB high (4.7 dB at 10.5°). However, both sensors exhibit similar σ^o versus incidence angle behavior with an almost linear (in dB) variation in σ^o versus incidence angle for incidence angles greater than about 5°. Further, the scatter in the observations is remarkably similar with NSCAT appearing to have somewhat less scatter. The TRMM PR σ^o measurements at 10.5° incidence angle exhibit a standard deviation of 0.92 dB while NSCAT measurements at 10.5° have a standard deviation of 0.70 dB.

TRMM provides the opportunity for studying the effects of rain on the surface σ^o of the rainforest. Such information can help evaluate the effects of rain on NSCAT measurements for which no rain flag was available. Figure 4 shows the locations of the TRMM measurements over the study region for the two passes during the Feb. 24-25, 1998 study period. During the first pass (upper-left to lower-right diagonal swath), only small, isolated rain patches are observed. The second pass (lower-right corner) exhibits rain over a large areal extent. The area in the lower right corner is observed both with and without rain.

As a first step toward quantifying the effects of rain on the surface σ^o observations, Fig. 5 plots just TRMM PR σ^o measurements with the rain flag indicated by different symbols. While the rain flag incorporates everything from light to heavy rain, it is apparent that over this region the surface σ^o is relatively insensitive to rain, with rain causing only a small ($\sim$ 0.5

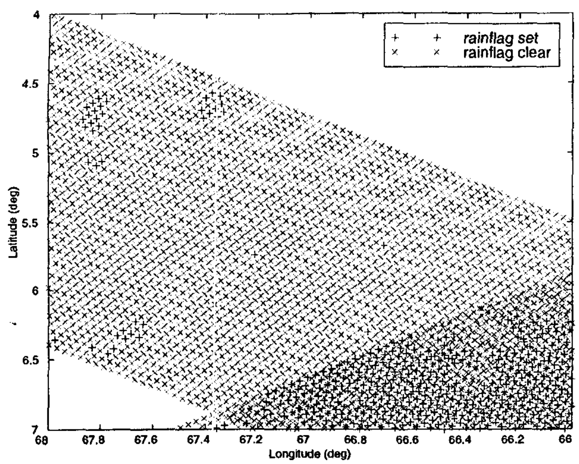

Figure 4: Locations of TRMM observations during Feb. 24-25, 1998 over the study region.

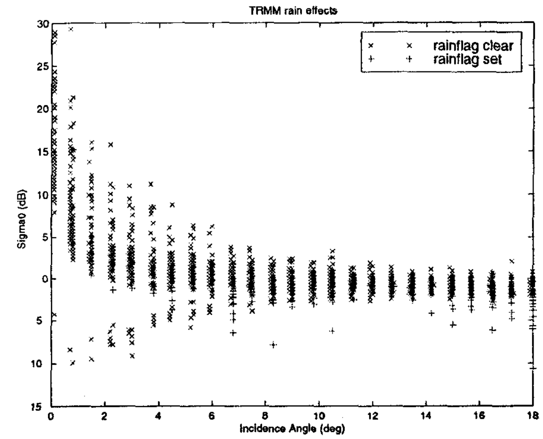

Figure 5: Comparison of rain flagged TRMM surface σ^o measurements over the study region during Feb. 24-25, 1998.

dB) average reduction in σ^o at this incidence angle range. This suggests that NSCAT observations of the rainforest (at least at low incidence angles) have relatively little contamination from rain effects.

DISCUSSION

In order to cross-calibrate the two sensors, a comparison of NSCAT and TRMM PR Ku-band σ^o observations over the Amazon rainforest has been presented. Using the mean response over a large, spatially homogeneous region in the Amazon rainforest, it is suggested that the TRMM PR is biased approximately 4.7 dB higher than NSCAT at 10.5° incidence angle, but that both sensors follow a similar trend in incidence angle. Ku-band measurements from the Seasat scatterometer (SASS), have proven remarkably useful in tropical vegetation classification [4]. Given the proven success of mid-incidence angle SASS observations in vegetation classification, it is postulated that TRMM measurements will also have utility in vegetation classification. Methods for inferring rain using NSCAT data are being developed by comparing the σ^o signature observed in TRMM data when rain is detected by TRMM. Such an algorithm will be useful for future Ku-band scatterometers such as QuikScat and Seawinds.

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