VARIOUS TRENDS IN BACKSCATTER OF NATURAL TARGETS ON LAND OBSERVED IN QUICKSCAT DATA AT KU-BAND

D.Arun Kumar, M.BalaKrishna, P.V.Murali Krishna

ECE Department, GMR Institute of Technology, A.P.,INDIA

ABSTRACT

Now a days there are few areas on the surface of earth having a relatively constant BSC and can serving as radar calibration targets. Few Examples include the Amazon rain forest, the Greenland ice sheet etc. In this paper we analyse a consistent set of Ku-band radar measurements from the QuickSCAT data mission for about ten years. To study the long-term variation of observed BSC, a set of data is required from Earth's surface this band. A global survey of potential constant land targets is performed. To identify the locations of the best natural calibration targets Quantitative measurements of temporal and spatial variabilities (homogeneity) and isotropy are used. By concentrating on low variation areas, useful calibration targets for future radar missions and for inter calibration between existing radars can be identified. By focusing on regions with little spatial heterogeneity, the temporal variations on diurnal, seasonal, and also decadal scales in homogenous natural terrain types including rain forest, dry brushy areas, and ice sheets can be analysed. The Greenland ice sheet shows a significant trend in backscatter in recent years, and therefore, may not be a suitable calibration site anymore. Another location for a good stable target is a dry brushy area in the Sahara, which shows comparable stability and isotropy with those of the Amazon, Congo, and Antarctica.

KEYWORDS

back scattering coefficient (BSC), target, heterogeneity, terrain, and isotropy

1. INTRODUCTION

Natural land targets have often been used for radar calibration. An ideal calibration target should be constant in time, i.e., it should have little diurnal or seasonal variations and no long-term trend. It should also be isotropic, i.e., it should be invariant to changes in the observation azimuth angle (Invariance with respect to incidence angle would also be useful, but such invariance does not commonly occur for natural targets). A few places on the Earth's surface have been suggested as sufficiently invariant, including portions of the Amazon rain forest and parts of the permanent Greenland and Antarctic ice sheets. However, there are little quantitative measures of the variability of these targets, particularly with regard to long term[1].

The Amazon rain forest has been most often referred to in calibrating radar backscatter. It has been shown to have a calibration limit of 0.15 dB in normalized radar cross section (NRCS), the geophysical quantity obtained in radar backscattering measurements. However, the Amazon rain forest also has some drawbacks. It is subjected to diurnal variation due to the moisture content of vegetation. Also, recent deforestation can have an effect on NRCS. Therefore, other potential natural targets should also be considered, such as Greenland, Antarctica, and the Sahara desert, to name a few. Several of these targets can be shown to have complementary invariance. For

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example, the Amazon rain forest has small long-term trends with moderately large diurnal variation, while the Greenland ice sheets have seasonal trends but little diurnal variation. A long-term calibration scheme can make use of this complementarity to eliminate different kinds of calibration errors.

Here, a consistent long-term Quik SCAT scatter meter data set at Ku-band is employed to evaluate the consistency of the observed NRCS on natural land targets. The Sea Winds instrument onboard Quik SCAT is a spinning pencil beam scatter meter operating at a frequency of 13.4 GHz with fixed incidence angles of 4◦ for the H-polarization beam and 55◦ for the V-polarization beam. It has been in nominal operation since 1999 until it stopped spinning in November 2009. Because of their duration and consistent geometry of observation, QuikSCAT data are very valuable for quantifying the long-term variability of these potential targets including the azimuth diversity of observations [5].

Several satellite instruments have proven the utility of scatter meters in monitoring the Arctic and Antarctic regions. The first was the Sea sat-A Scattero meter (SASS). Though the SASS mission was short, SASS data illustrated that Ku-band measurements are sensitive to the presence of sea ice and show valuable variations within the ice pack that relate to surface features. Later, the Active Microwave Instrumentation (AMI) scatter meters aboard the European Remote Sensing 1 and 2 (ERS-1 and ERS-2) satellites demonstrated the value of C-band active scatter meter data in monitoring sea and glacial ice regions. The National Aeronautics and Space Administration (NASA) Scattero meter (NSCAT) flew aboard the Advanced Earth Observation Satellite (ADEOS) platform from approximately August 1996 through June 1997. Ku-band NSCAT data have been used in a number of cryosphere studies. When the NSCAT mission was prematurely terminated due to a solar panel failure, the NASA-built Sea Winds instrument aboard QuikSCAT filled the gap of active Ku-band data in mid-1999. Sea Winds data is used to monitor sea ice extent[6].

A Ku-band precipitation radar on the Tropical Rainfall Measuring Mission satellite provides backscattering coefficients σ^o of earth surfaces. The data are used to investigate σ^o characteristics of rain forest, and they show unique dependence on incidence angles and little dependence on seasons. A diurnal cycle is found in σ^o of the Amazon rain forest, showing the maximum in the morning and the minimum in the evening. It is inferred that the diurnal cycle is caused by dew drops on the leaves in the forests, and discussion on the dew effects with a simple model follows. Tropical rainforests have traditionally been used to calibrate scatter meters. The Amazon rainforest covers a large spatially homogeneous area and exhibits little seasonal or azimuthal variation. It can effectively be used for scatter meter calibration to within a limit of ±0.15dB for a relative calibration method designed to ensure intra-sensor antenna consistency. However, some concern has been noted over possible time-of-day effects relating to the diurnal cycle. As a result, ocean-based techniques were used to individually calibrate QuikSCAT and SeaWinds, with only a limited land-based study for QuikSCAT calibration[4].

2.METHOD

A.QUANTIFICATION OF TOTAL VARIATION:

QuikSCAT slice data are binned globally according to the centroid of each measurement into 0.1° latitude × 0.1° longitude boxes (approximately 10 km at the equator). All the valid data that fall into the 0.1° × 0.1° box are separated by "flavors" (ascending/descending pass and forward/aft looks). The data of each flavor are then averaged over one-month periods to reduce the measurement noise. Then, the monthly averaged data σ^o_Mavg is used to calculate the variability denoted by Kp.

where **“$Kp = std(\sigma^o\_Mavg)/mean(\sigma^o\_Mavg)$”**

where std denotes standard deviation. This is a measure to quantify the total variation, which includes diurnal (ascending/descending pass), seasonal, long-term, and azimuthal variations. A more detailed analysis is performed on several regions of interest, including the Amazon rain forest, Greenland, Antarctica, the Congo rain forest, the Indonesian rain forest, the Australian outback, and a region on the outskirts of the Sahara desert. In these regions, a 1° × 1° box that has the least variability (smallest Kp) is identified. Then, the long- term behavior, isotropy, diurnal and seasonal variation, and spatial homogeneity of the NRCS of these 1° box targets are investigated[2].

B.ISOTROPY OF TARGET

To evaluate the isotropy of the target, we binned the data at these 1° box targets as a function of azimuthal observation angles of 10° resolution. The monthly average NRCS within a 10° azimuth σ^o_azmavg is calculated. Using average data in each bin, the variation is quantified among the bins by calculating

“$Kp\_azm = std(\sigma^o\_azmavg)/mean(\sigma^o\_azmavg)$”.

A lower value of Kp_azm indicates an isotropic region with little azimuthal variation[8].

C.Spatial Variation

To evaluate the spatial variation within each 1° box, the monthly average NRCS is calculated at a resolution of 0.1°. Thus, within each 1° box, 100 data points of monthly average NRCS are obtained, denoted as $\sigma^o\_0.1^\circ$ avg. Then, the spatial variation is calculated within that 1° box by computing

$$\text{“}Kp\_spa = std(\sigma^o\_0.1^\circ\ avg)/mean(\sigma^o\_0.1^\circ\ avg)\text{”}$$

This gives the spatial variation within each 1° box[3].

3.RESULTS

A.VARIATION OF OBSERVED BACKSCATTERING COEFFICIENT:

First, the variability of backscatter in time for all the data from 1999 to 2009 is evaluated. Fig. 3.1 shows the average and Kp for the QuikSCAT normalized backscattering cross section from July 1999 to November 2009. Here, Kp is shown in log scale. These plots illustrate that the regions of least variation are located in the rain forest areas of the Amazon, Congo, and Indonesia and in Greenland and Antarctica. These regions also exhibit strong backscatter cross sections. All are good calibration targets.

Seven potential land target regions are focused: Antarctica, the Amazon, Australia, Congo, Greenland, Indonesia, and the Sahara. In each region, a 1º × 1º box is identified that shows the least variation. Table I summarizes the location and backscatter properties of these 1º × 1º boxes. The location in Table I is the center of the 1◦ box. The Antarctica location is close to Dome C where it is very dry with little precipitation. On the other hand, the Greenland location locates in dry snow zone near Summit. The location in Sahara is dry bushy area in Libya. All rain forest locations are covered by dense forest. Results from the table suggest that Antarctica may be the best target in terms of temporal variability throughout the QuikSCAT mission. One particular 1º box in the Sahara also shows a very stable backscatter.

Table I Seven Potential Land Targets And Their Properties

		Amazon	Antarctica	Australia	Congo	Indonesia	Greenland	Sahara
Location		N 5.3 W 59.2	S 75.1 E 123.1	S 23.5 E 142.7	S 0.2 E 11.2	S 6.0 E 139.5	N 73.5 W 37.5	N 27.2 E 17.8
Average σo (dB)	H-pol asc	-6.891	-6.610	-11.380	-7.373	-7.106	-8.466	-10.346
	H-pol des	-7.123	-6.631	-11.218	-7.553	-7.396	-8.457	-10.344
	V-pol asc	-8.114	-7.441	-13.133	-8.607	-8.564	-8.297	-11.977
	V-pol des	-8.428	-7.459	-12.912	-8.988	-8.847	-8.303	-11.973
Variation (Kp)	H-pol asc	0.0255	0.0275	0.0444	0.0181	0.0299	0.0485	0.0276
	H-pol des	0.0194	0.0282	0.0436	0.0193	0.0192	0.0481	0.0233
	V-pol asc	0.0256	0.0243	0.0443	0.0200	0.0330	0.0414	0.0288
	V-pol des	0.0165	0.0239	0.0447	0.0189	0.0169	0.0405	0.0213

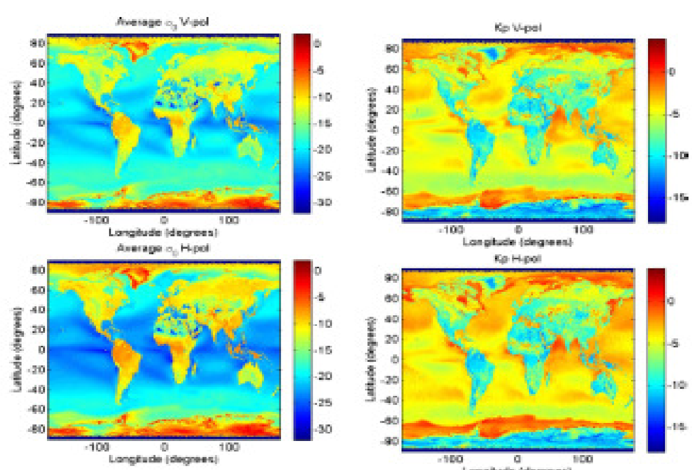

Fig. 3.1. Global average BSC and its variation.[ref.1]

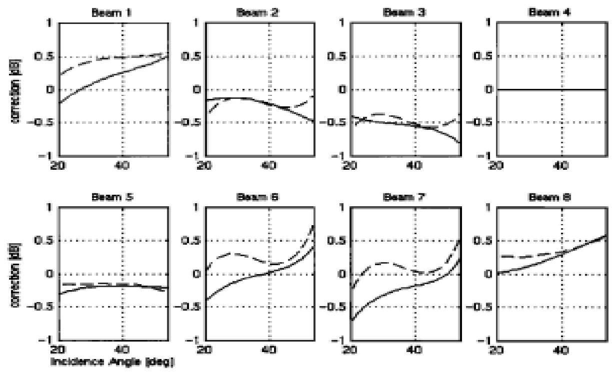

Fig 3.2 Comparison of NSCAT baseline, ocean-derived and land-derived beam corrections for descending passes. [ref.2]

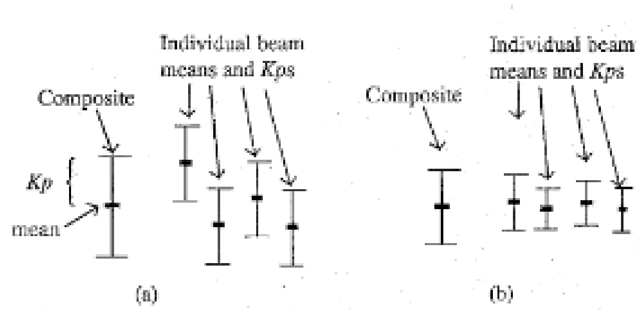

Fig 3.3 Illustration of the individual and composite data means and standard deviations for each antenna (a) prior to and (b) after the calibration correction. The vertical axis is the σ° error. Horizontal placement is shown for clarity.[ref.3]

4.CONCLUSIONS

In this paper, the quantitative assessment of possible natural constant targets at Ku-band for use as radar calibration sites is discussed. This evaluation of land target is necessary for continuing efforts to calibrating Ku-band sensor among past, current, and future missions, including NASA QuikSCAT, the Indian Oceansat -2, and planned Oceansat -3. Long- term QuikSCAT data is employed to perform an assessment that includes time variation, isotropy, and spatial variation. It is able to identify locations of natural targets that have very small overall variation. These targets are investigated in detail for isotropy, change over time, and spatial variation. Several interesting properties of these target sites are observed[7].

The NRCS in rain forests exhibits diurnal variation but is isotropic and shows little seasonal or long-term trends. The observed diurnal variation is likely due to differences in the amount of moisture in the canopy at the 6:00 A.M. and 6:00 P.M. observation times.

In Greenland and Antarctica, the main contribution of the variation comes from the seasonal variation. The maximum and minimum of the monthly average backscatter cross section are out of phase when comparing between Greenland and Antarctica, showing changes in the scattering behavior from the winter to summer months of each region. The variation of Greenland throughout the ten years is greater than that of Antarctica. This is due to an obvious trend of increasing backscatter as a function of time, which is more pronounced in Greenland data after June of 2004.

The observed seasonal variation in the chosen location is not large enough to be attributed to large-scale melting and freezing of ice. Indeed much large variation is observed near the edge of the ice sheets where freeze/thaw events occur. Instead, the seasonal changes and trends are likely due to changes in the composition and structure of the ice sheets or due to changes in snow cover. An interesting location of relatively constant NRCS exists in the Sahara region. This particular location is not in the desert, where extremely low NRCS values with relatively large instrument noise predominate but rather in an outlying brushy area. The region shows remarkably little variation in the ten- year span. There are relatively small diurnal and seasonal variations, and it is somewhat isotropic. However, the average backscatter value is smaller than those of rain forest regions and ice sheets. This region is an ideal target for calibrating the radar data for lower NRCS values. When using rain forest calibrations in conjunction with ice sheet calibrations for high NRCS values, one can estimate trends (log scale) in calibration error with NRCS in addition to a constant (log scale) bias.

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