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Gamma-naught stability assessment of Canadian Boreal forest using C- and L-band data

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8. Abstract	Canadian boreal forest is one of the distributed and homogenous target site, and has been used for Radarsat 1 SAR calibration activity. The temporal gamma naught analysis for this site has been done for the first time. We have conducted temporal and seasonal gamma naught stability analysis using two different frequencies (C and L band) dataset. As per the data availability, 2015, 2016 and 2017 year's data have been used in the study. Time series gamma naught values are estimated for the Canadian boreal forest by using C band and L-band data. Average Gamma naught value for C-band for 3 years is estimated as -8.16 ± 0.53 dB in co-pol and -14.18 ± 0.89 dB in cross-pol. While the gamma naught values estimated using L band data is -6.59 ± 0.23 dB in co-pol and -12.77 ± 0.46 dB in cross-pol. To understand the influence of seasonal change on gamma naught values, they are calculated for summer and winter seasons for C-band data. Average summer season gamma naught values are calculated as -7.5 ± 0.43 dB & -13.5 ± 0.22 dB for co-pol and cross-pol respectively. Estimated average gamma naught values for winter season are -8.5 ± 0.66 dB for co-pol data and -15.5 ± 0.49 dB for cross-pol data. Seasonal variation of 1.73 dB in co-pol and 2.27 dB in cross-pol was observed. Gamma naught stability analysis for the study area using available RISAT-1 data is in progress.

10. Key words	Time series Gamma Naught value, L Band and C Band data, Seasonal and Temporal analysis of Canadian Boreal forest.
11. Security classification	Unrestricted
12. Distribution statement	General

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Table of Contents

I. List of Figures

II. List of Tables

1. Introduction

Remote sensing and in particular space borne remote sensing, certainly satisfies the two points. a) The sensors carried onboard by the currently orbiting satellites provide full coverage of the globe, imaging areas of the order of several thousands of square kilometers. b) and the revisit period over an area is between a few days up to one or two months. However, at northern latitudes the amount of imagery obtained by optical sensors is severely limited for long periods of the year because of cloud cover, fog, mist, or darkness. To overcome these problems sensors active at wavelengths longer than the atmospheric elements size, such as radar, are needed. Radar is not sensitive to the fine elements that form clouds and fog, and does not depend on solar illumination; therefore, it can always provide an image, thus being suitable for observations in the boreal zone. (SANTORO 2003)

The first investigations of SAR imagery in forested areas aimed at understanding which factors govern the signal scattered back towards the radar (HENDERSON & LEWIS, 1998). Using experimental data and simulations based on behavioral models, the electromagnetic field received by the radar from a given forest was found to be dependent on frequency, polarization and incidence angle. In particular, for increasing wavelength, the penetration of the electromagnetic wave into the forest canopy increases. At high frequencies (C-band) the main interaction of the wave occurs within the canopy and the power scattered back to the radar (the “backscatter”) is primarily dependent on the properties of small branches, needles and twigs in the tree crown. At low frequencies (L band) the microwaves are returned from large branches and stems, thus carrying information about parameters of major relevance in forest inventory (i.e. the trunk diameter, the volume of the tree trunks, the aboveground biomass, etc.). (SANTORO 2003)

The Boreal forest has been used for Radarsat-1 SAR calibration activity and for other calibration activities (Satish K srivastava n.d.). There are studied conducted to determine the seasonal stability of the Boreal forest and concludes that it is seasonally stable. In recent years, there haven't been studies conducted to determine temporal stability, which gives scope for this study.

Stability of the boreal forest's is determined by calculating gamma naught values for the years 2015, 2016 and 2017 using both C and L band datasets.

The introduction of the boreal forest is described in section 1, objective is mentioned in section 2 and study area and relative backscatter terms are explained in section 3. Description of the data used for the analysis is in section 4. The methodology adopted to conduct gamma naught analysis for the forest is explained in section 5. Section 6 explain the results of seasonal and temporal analysis, quantitative comparison of gamma naught analysis is also explained with respective graphs obtained by using C and L band data. Factors effecting backscatter in freezing temperatures are also explained. To support the observations made from seasonal and temporal analysis, inferences from previous related research works are present in section 7. The following sections gives conclusion and references.

2. Objectives

Study of Seasonal and Temporal variation of Gamma Naught values for Canadian Boreal Forest using C and L band data of Sentinel-1 and PALSAR-2 respectively from the years 2015 to 2017.

3. Study Area:

Boreal forest of Canada:

Boreal forests have both a fundamental economic and environmental role. Boreal zone consists of Sweden, Finland, Russia and Canada. Boreal forests cover almost the entire land surfaces in the northern hemisphere between 70° N and 60° N, reaching 50° N in East Siberia and West Canada. (SANTORO 2003). Canada's Boreal forest comprises about one third of the circumpolar boreal forest that ringed the Northern Hemisphere, mostly north of the 50th parallel. Other countries with boreal forest, also called taiga, include Russia, which contains the majority, the United States in its northern most state of Alaska, and the Scandinavian or Northern European countries (e.g. Sweden, Finland, Norway and small regions of Scotland). The boreal region in Canada covers almost 60% of the country's land area. The area is dominated by coniferous forests, particularly spruce, with vast wetlands, mostly bogs and fens. The boreal forest zone consists of closed crown conifer forests with a conspicuous deciduous element. (Canadian Boreal forest n.d.) Canada's boreal forest is also considered to be the largest intact forest on earth, with around 3 million square kilometers still undisturbed by roads, cities and industrial development. Despite the common knowledge, the boreal region is far from being “just” a cold area. Temperatures lie above and below 0 °C. The monthly average winter temperatures decrease and the summer average increase. Precipitation is mainly in the form of snowfall but is remarkably less frequent. As a consequence, the growing season for the vegetation is longer in Sweden and Finland, although the growth rate per year is bigger in Siberia. (SANTORO 2003)

Wetland soil present in Study Region:

The information about this wetland soil is mentioned due to its effect on parameters calculated in this study. The wetland soil present in the study region is known as Gleysols, as per reference soil group. Gleysols hold wetland soils which are undrained and are saturated with groundwater for long enough periods. (ISRIC world soil information n.d.). The formation of Gleysols is conditioned by excessive wetness at depths greater than 50 cm from the soil surface. These are heavy clay surface layers that continue down to 2meters or more. This formation is present in some period of the year or throughout the year. The topsoil is typically a mixed organic and mineral H horizon. It tops a mottled clay or sandy clay subsurface horizon over permanently anaerobic subsoil. (ISRIC world soil information n.d.)

Distribution of Gleysols:

Gleysols occupy an estimated 720 million hectares worldwide. They are a zonal soils and occur in nearly all climates from per humid to arid. The largest extent of Gleysols is in sub Artic areas in Canada(Boreal forest) Alaska, Siberia (Boreal forest), Northern Russia (Boreal forest). (ISRIC world soil information n.d.)

Approximately 25% of the world’s wetlands are located in Canada, and approximately 14% of the Canadian landscape is covered by wetlands.

Study Region:

Region Name: Ontario province situated in Canada Boreal Forest

Geo-coordinates of the study area:

49^{0}58’34’’ N, 84^{0}00’00’’ W
50^{0}59’54’’ N, 84^{0}59’57’’ W

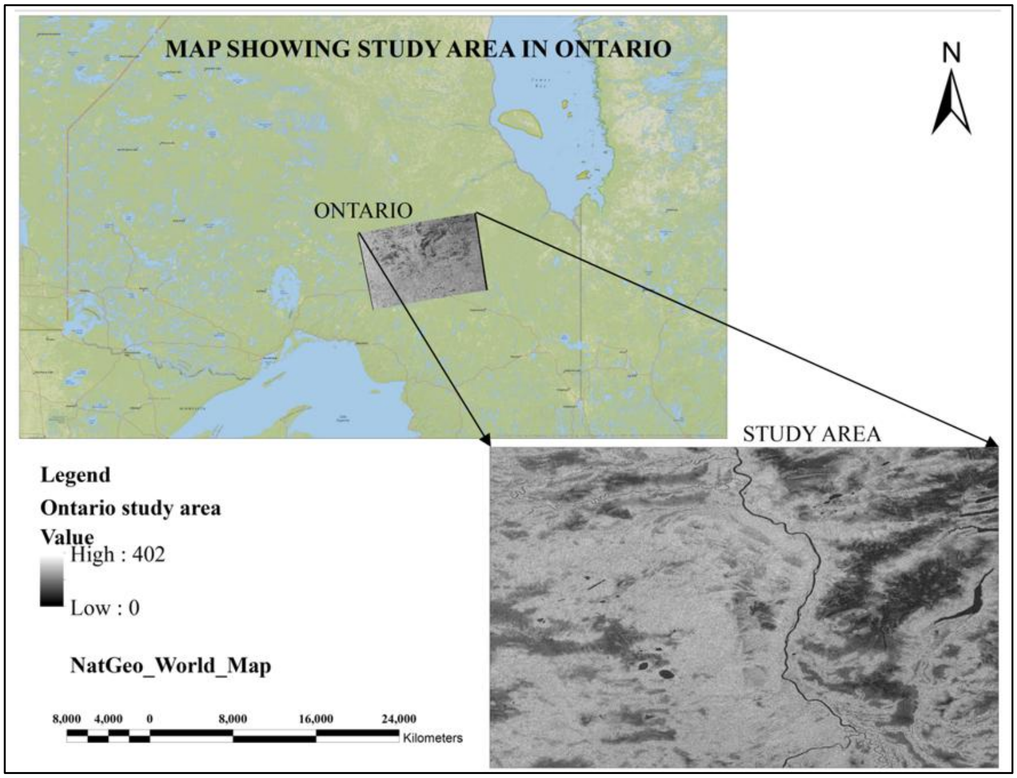


Figure 1. Study area in Ontario, Canada

3.1 Radar Back Scatter Terms

With the development of radar systems different terrain reflectivity terms for distributed targets have been formulated. Intrinsic reflectivity of a material (sigma naught) which can be expressed as the reflectivity per unit surface area of a material. The intrinsic mean reflectivity can be considered as the theoretical predicted backscattering of a target, which will exhibit when illuminated by a radar signal. In radar processing field, a radar reflectivity estimate (sigma naught) is usually measured, as it is the closest expression of the true reflectivity that can be observed from radar scenes. The reflectivity corrections can be obtained from radar brightness only if there is a calibration of radar system and if radiometric corrections are applied to account for terrain slope.

Reflectivity estimates are expressed in terms of gamma and/ or sigma and they differ basically in the way they normalized. (Lopez 2008)

Table 1. Radar backscattering terms

Reflectivity estimate	Sigma	$\sigma°=10\log_{10}(I) \quad I = A^2$
	Gamma	$\gamma_0=\sigma°-10\log_{10}(\cos\varphi)$

In summary, the strength of the signal returns measured by radar systems can be expressed in intensity or amplitude. Sigma and Gamma are trigonometric transformations of radar brightness in logarithmic scale. The term backscattering or backscatter is more general and does not restrain to specific measurement units.

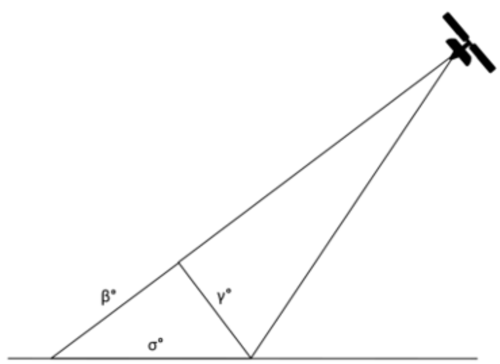


Figure 2 Brightness expressions for radar backscattering © *(Lopez 2008)*

The above fig. illustrates the three components related to radar backscattering. Following are the most common backscattering terms:

i. **Sigma Naught:** which measures the mean reflectivity of a patch of distributed scatters per unit area of a horizontal surfaces, measured along ground range.

ii. **Gamma Naught:** the reflectivity of distributed scatterer per unit area of incident wave front.

iii. **Beta Naught:** where backscatter in slant range domain and a simple normalization by the cosine of the incident angle is applied. *(Lopez 2008)*

4. Data Used

4.1 Sentinel -1:

Sentinel-1 is equipped with a SAR sensor operating at C-band (5.405 GHz). The data acquired is level -1 GRD (Ground Range Detected). This product consists of focused SAR data that has been detected, multi-looked and projected to ground range using an Earth ellipsoid model. Ground range coordinates are the slant range coordinates projected onto ellipsoid of the Earth. Pixel values represent detected magnitude. Phase information is lost. (Hub n.d.)

GRD products available in three resolutions, characterized by the acquisition mode and the level of multi looking applied.

- Full Resolution, High Resolution, Medium Resolution.
- Product resolutions by mode: Strip Map GRD, Interferometric Wide Swath GRD, Extra Wide Swath GRD.

Table 2. Details of Sentinel -1 data

Satellite:	**Sentinel-1**
Product Type:	Ground Resolution Data
Sensor mode:	Interferometric Wide swath
Acquisition mode:	Dual Polarization
Radar Center Frequency (GHz):	5.404999
Study Year:	2015, 2016, 2017
Spatial Resolution	10 m * 10 m

4.2 ALOS PALSAR 2:

PALSAR 2 (Phased Array Type L Band Synthetic Aperture Radar) is equipped with a SAR sensor operating at L-band (1.2 GHz) with a Dual Polari-metric mode. These data are obtained from Advanced Land Observing Satellite 2 (ALOS 2). PALSAR 2 mosaic is a seamless global SAR image created by mosaicking the SAR images in backscattering coefficients. The strip data with

10*10 degree in latitude and longitude are path processed and mosaicked for processing efficiency. PALSAR-2 Forest & Non-Forest mosaic product is generated by classifying the backscattering intensity values, so that strong and low backscatter in HV polarization are called 'forest' (colored in green) and 'non-forest' (colored in yellow) respectively. The classification accuracy is more than 84% when compared with in-situ photos and high resolution optical images. (shimda 2007) The mosaic product has spatial resolution of 25 m and global mosaic data with temporal interval of one year.

Table 3. Details of PALSAR 2 data

Satellite:	**ALOS 2**
Product Type:	HDR
Sensor mode:	PALSAR 2
Acquisition mode:	Dual Polarization
Radar Center Frequency (GHz):	1.2
Study Year:	2015, 2016, 2017
Spatial Resolution	25m * 25m

5. Methodology

Stability evaluation of the gamma naught values for Canadian Boreal Forest: -Boreal forest is a uniform, distributed and reference target for relative (range and azimuth antenna pattern determination) and absolute calibration target. Reflectivity estimates (sigma or gamma naught) are calculated to understand the stability of the Canadian boreal forest. To calculate gamma naught, following formula is applied to the dataset.

$$\sigma^\circ = 10 \log_{10}\langle DN^2 \rangle + CF$$

$$\gamma^\circ = \sigma^\circ / \cos \varphi$$

DN = digital number of the intensity image.

CF = calibration factor, -83.0 dB

The following procedure is used to calculate gamma naught values for both C and L band data:

Common area shared by both C and L band data was selected. The coordinates for the study area are **$49^0$58'34'' N, $84^0$00'00'' W;$50^0$59'54'' N, $84^0$59'57'' W**. Preprocessing of data is required to apply gamma naught formula in which calibration is important step. Calibration provides the pixel values that are directly related to the radar backscatter of the scene. Though un-calibrated SAR imagery is sufficient for qualitative use, calibrated SAR images are essential for quantitative use of SAR data.

For performing the calibration step, following equation is used:

$$\text{Value (i)} = \frac{DN^2}{Ai^2}$$

Where, value (i) = original DN

Ai = dn(i), one of Sigma Naught, Gamma Naught

The steps used in the analysis are shown in Figure 3.

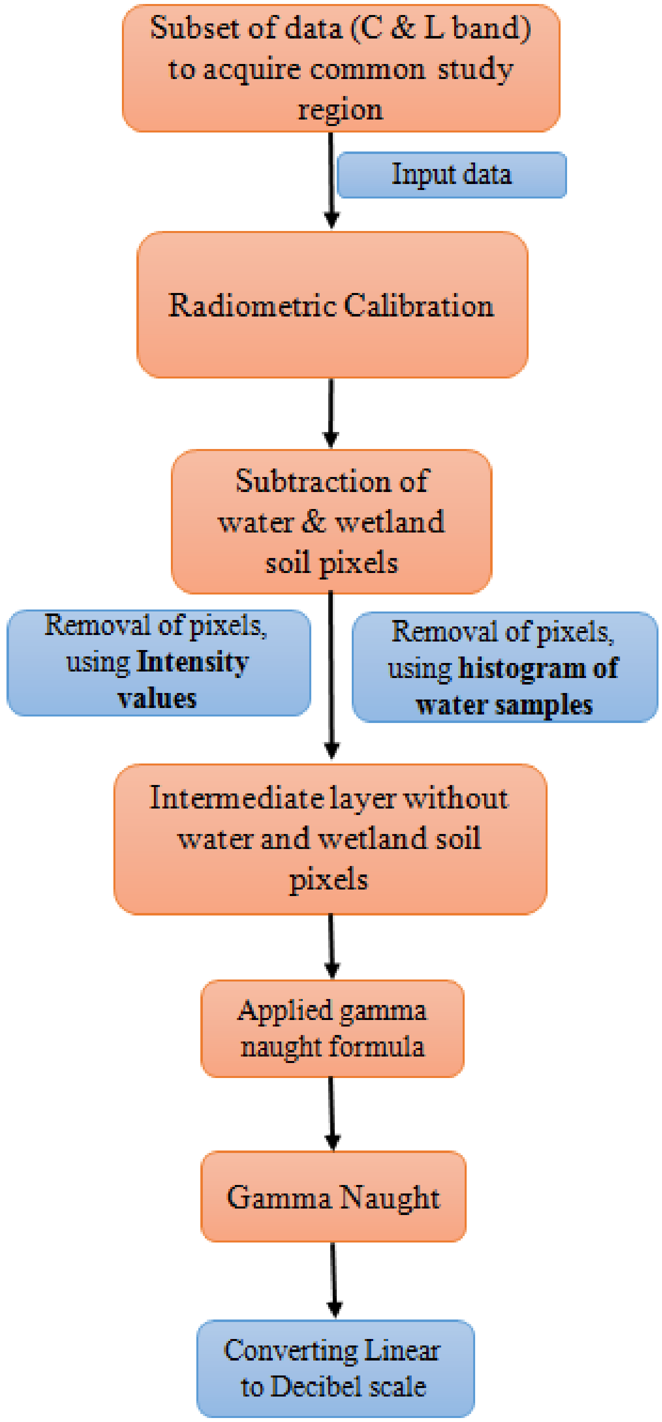


Figure 3. Flow-chart showing methodology

For masking out the water pixels, two methods can be utilized which are shown below:

- Based on the intensity values: In this, histogram is generated for the intensity image and from the histogram, minimum value was used to select water pixels. Either sigma naught or gamma naught may be used to select water pixel. The condition applied is "*IF Sigma_VV<3.74E-2 then 1 else 0*". This condition selects the water pixels and wetland pixels.

- Based on sample water pixels' histogram: In this, samples of water pixels are selected and histogram is generated. The threshold values observed were Pixels, which lie between -12 dB to -27 dB, selects all the water pixels. These values are used to remove the water pixels from the image.

In this study, water pixels were masked out by using histogram method.

The intermediate layer contains only forest pixels i.e., without water and wetlands, which is used for gamma naught calculation. The calculated gamma naught values are in linear scale which is converted to decibel scale for further observations.

Showing water pixels   Showing water and wetland pixels

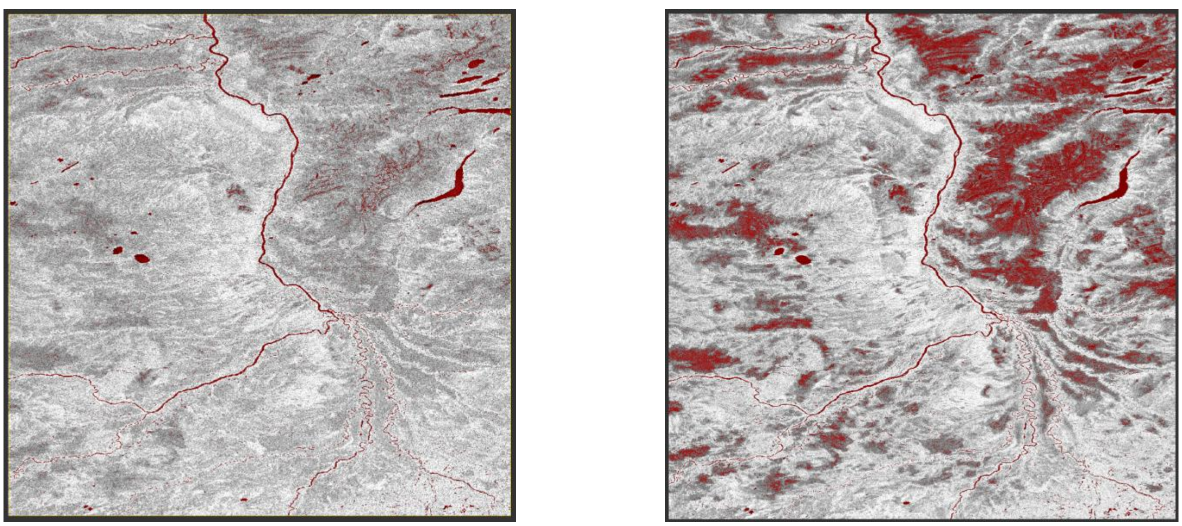


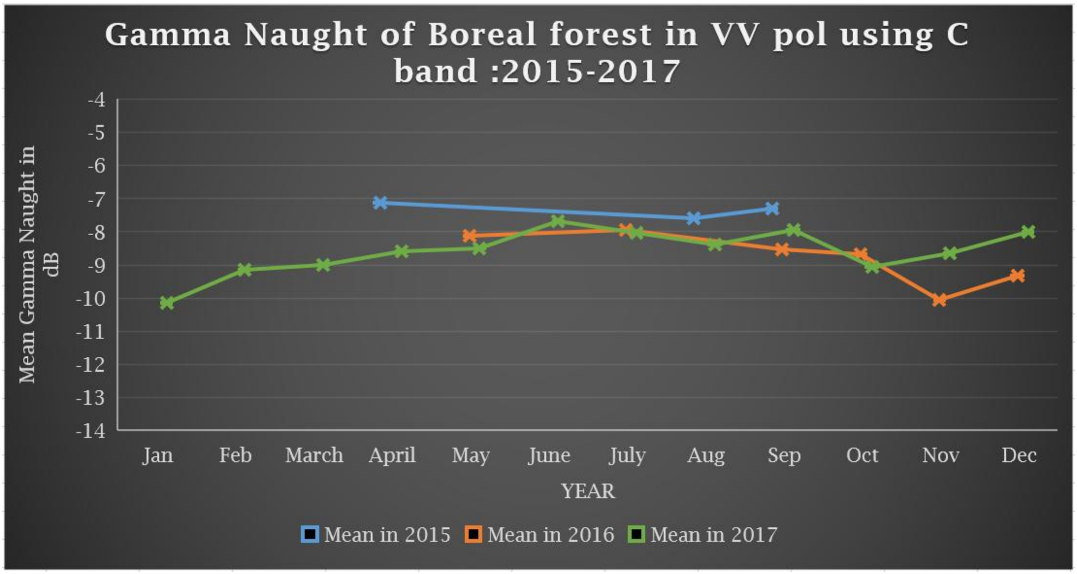
Figure 4 Left image show the selection of water pixels based on water threshold and right image show the selection of wet land soil and water pixels based on intensity values.

6. Results and Discussions

After Gamma Naught calculations for common region over Canadian Boreal forest, the following observations are noted.

6.1 Variation of gamma naught – throughout the year: Using C band

Below Graph is average Mean Gamma Naught of Canadian Boreal Forest in dual pol (VV, VH) from the year 2015-2017



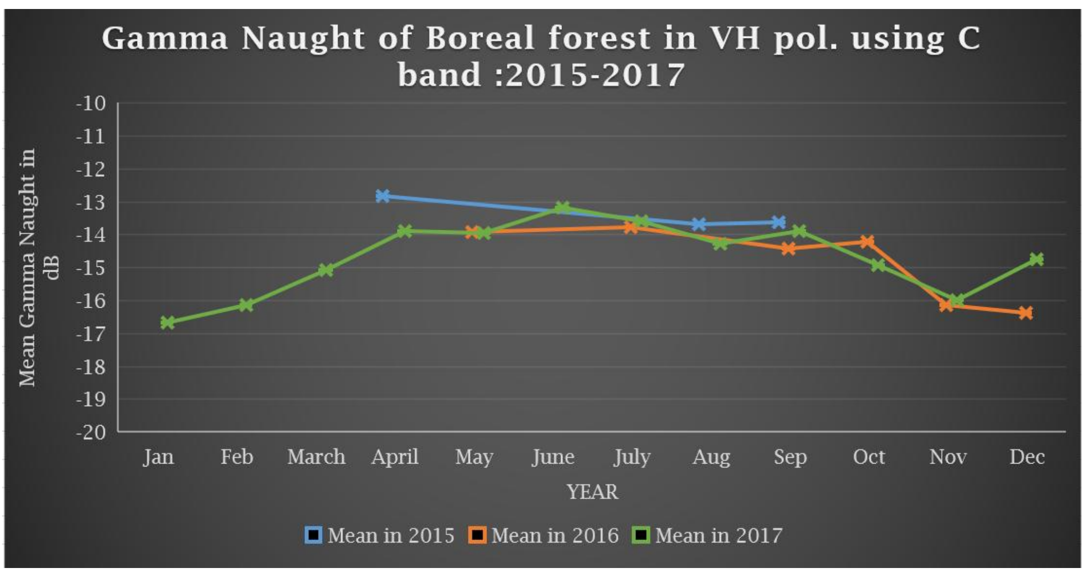


Figure 5 Graph displaying monthly variation of average gamma naught in VV & VH pol.using C band

The above year wise temporal graph of Canadian Boreal rainforest displays the gamma naught values calculated for the years 2015, 2016 & 2017 respectively using C band data from Sentinel-1 satellite. The time series graph helps to understand the changes in gamma naught values, which occurred in the observation period and to observe the stability of the boreal forest in different polarization of the data. Boral forest has summer and winter seasons, it starts from December to February and summer season is from June to August. In winter season temperature ranges from -54°C to-1°C and in summer temperature ranges from -7°C to 21°C.Due to freezing temperature in winter, helps in formation of ice on canopy and tree. In summer, temperature is above freezing point leads to melting of ice and change in the gamma naught values.

From the above graph- 2015-year data-line, shows that the gamma naught value in VV pol. vary from -7.14 to -7.31 dB. The data available in this year falls in summer season, due to temperature above zero degree helps in melting of accumulated ice providing variation in gamma naught value. Throughout the year, the gamma naught value is -7.34 ± 0.23 dB respectively. While in VH, the gamma value varies from -12.84 dB to -13.64 dB, the gamma naught value is -13.37 ± 0.48 dB

From the above graph- 2016-year data-line, the gamma naught values observed to be mostly consistent, with minor disturbance in November. The disturbance may be due to formation of ice on the target which affects gamma naught value. Throughout the year, the calculated gamma naught values in VV vary from -8.14 to -9.33 dB and the value is -8.71 ± 0.70 dB The gamma value in VH, observed to be varying from -13.93 to 16.38 dB and the value is -14.68 ± 1.03 dB

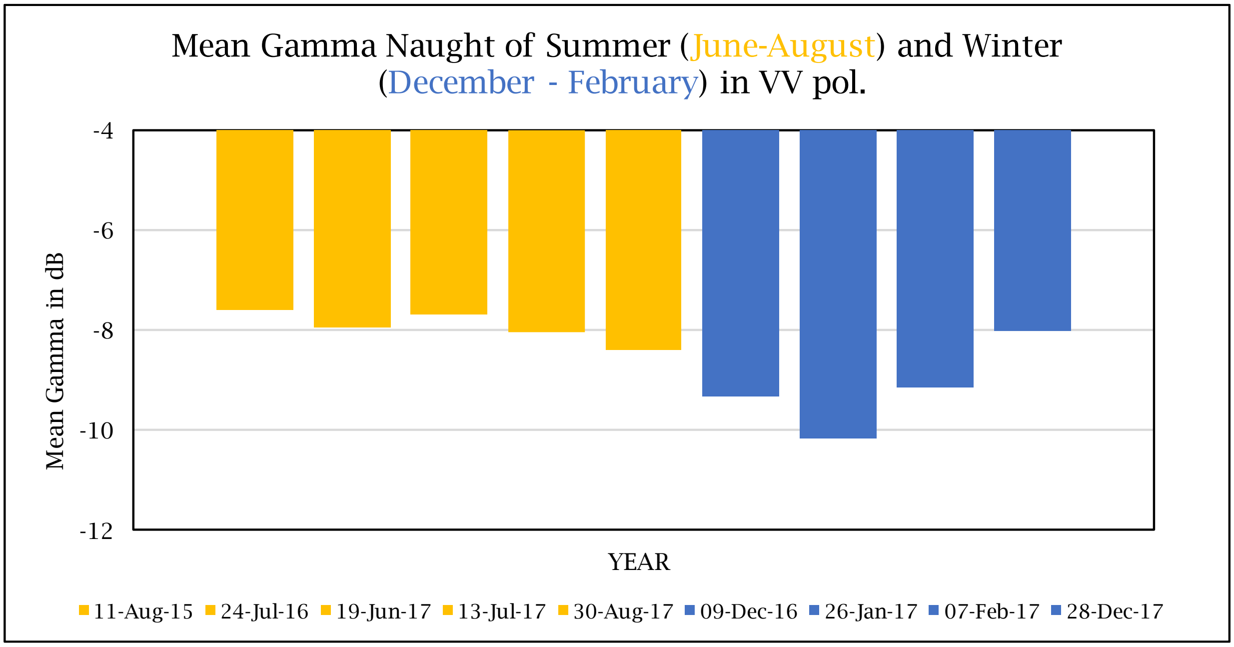
From the above graph- 2017-year data-line, the calculated gamma naught values observed are increasing and consistent, without any noticeable variation in calculated gamma values. Throughout the year, the calculated gamma naught values in VV vary from -10.16 to -8.02 dB and the value is -8.57 ± 0.65 dB The gamma value in VH, observed to be varying from -16.7 to -14.76 dB the value is -14.60 ± 1.18 dB

Even with presence of sudden rise and fall of the gamma naught values of the years 2015 to 2017, it is observed that the graphs patterns are similar and proximately overlapping each other.

From the above temporal graphs and discussions, the calculated average gamma naught value is -8.16 ± 0.53 dB in VV and -14.1 ± 0.89 dB in VH. Consistent stability is observed over the study area of the boreal forest.

Meanwhile, understanding the aftermath on gamma values due to season change is also the key factor in deciding the stability of the boreal forest.

6.2 Variation of gamma naught in Summer and Winter season: Using C band



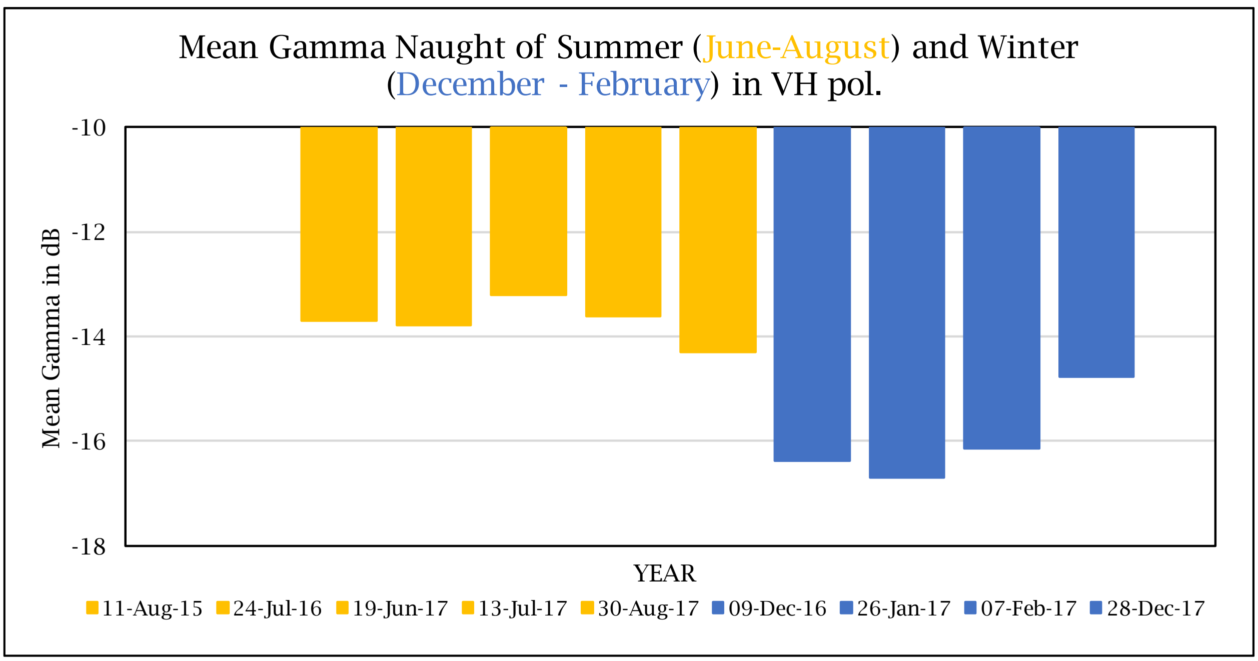


Figure 6 Seasonal variation graph for summer and winter in VV & VH pol. using C band

As season changes, backscatter from the target varies which cause changes in gamma naught calculations. Understanding these variations in gamma naught values due to change in seasons of the boreal forest is important in deciding the stability of the distributed target site. Winter season in Boreal forest area starts from December to February and summer season is from June to August. Accordingly, data is separated and plotted for winter and summer seasons, which is distinguished by yellow and blue colors respectively.

The backscatter in forests was indeed determined by the dielectric properties of the forest floor (snow cover and soil moisture). Since almost all images were acquired when the ground was either wet or covered with wet snow, it has not been possible to compare with typical backscatter values of dry-unfrozen conditions i.e., comparison with -6.5 dB threshold.

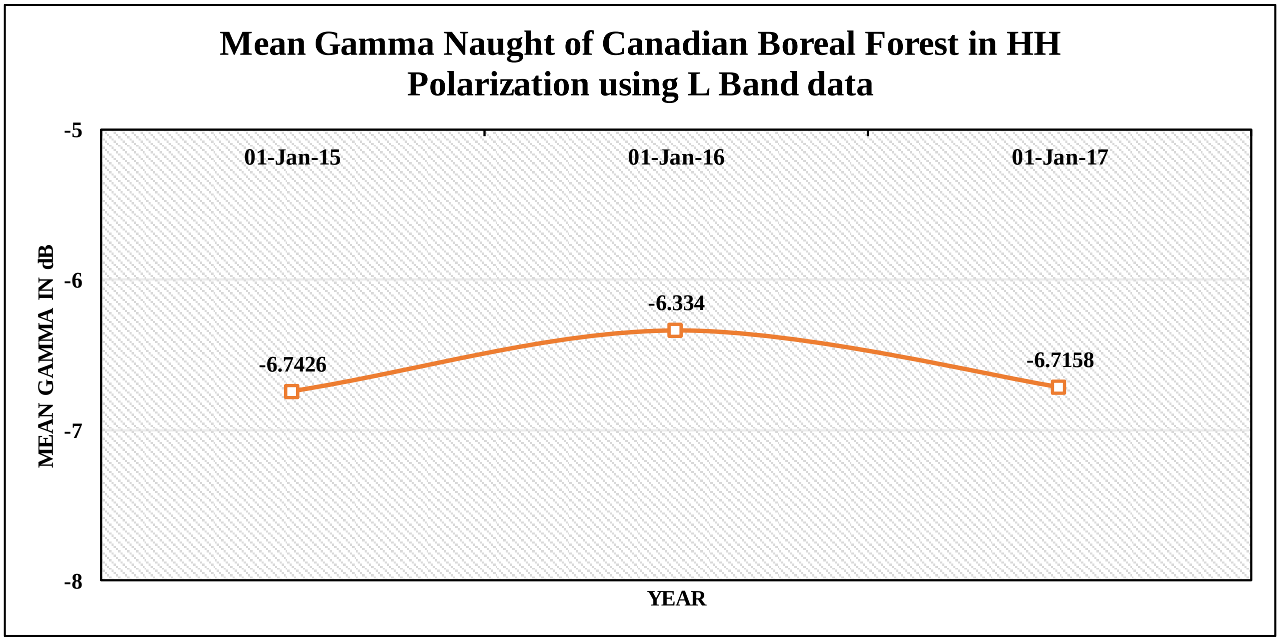
In winter season, temperature is below the freezing point - formation of dry snow occurs, which results in change in the in Gamma naught values. Temperature above 0 °C, leads to melting of snow into water, affecting the backscatter values of the forest, which is observed in summer.

In boreal forest the gamma naught value in VV pol is -7.60 dB to -8.39 dB in summer and -9.32 dB to -8.01 dB in winter season. We observed that there is constant value of -7.5 dB in both the summer and winter seasons respectively. The gamma naught value is -7.5 ± 0.43 dB in summer season and-8.5 ± 0.66dB in winter.

The gamma naught value in VH pol is -13.69 dB to -14.29 dB in summer and -16.38 dB to -14.76 dB in winter season. We observed that there is constant value of -13.5 dB in both the summer and winter seasons respectively. The gamma naught value is -13.5 ± 0.22 dB in summer season and -15.5 ± 0.49 dB in winter.

Between rainy and dry season, seasonal variation observed was 1.73 dB in and 2.27 dB in VH. The variation in gamma naught is of noticeable difference and proves that seasonal change effect the gamma naught value.

6.3Mean Gamma Naught of ALOS PALSAR 2 - L Band mosaic data.



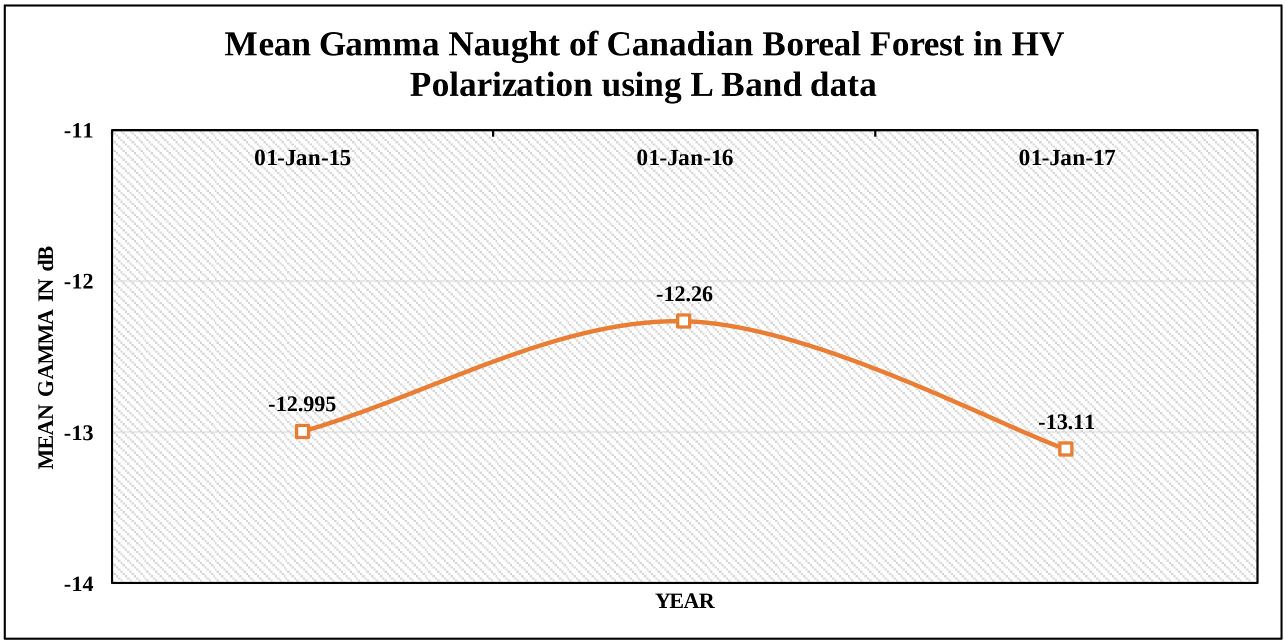


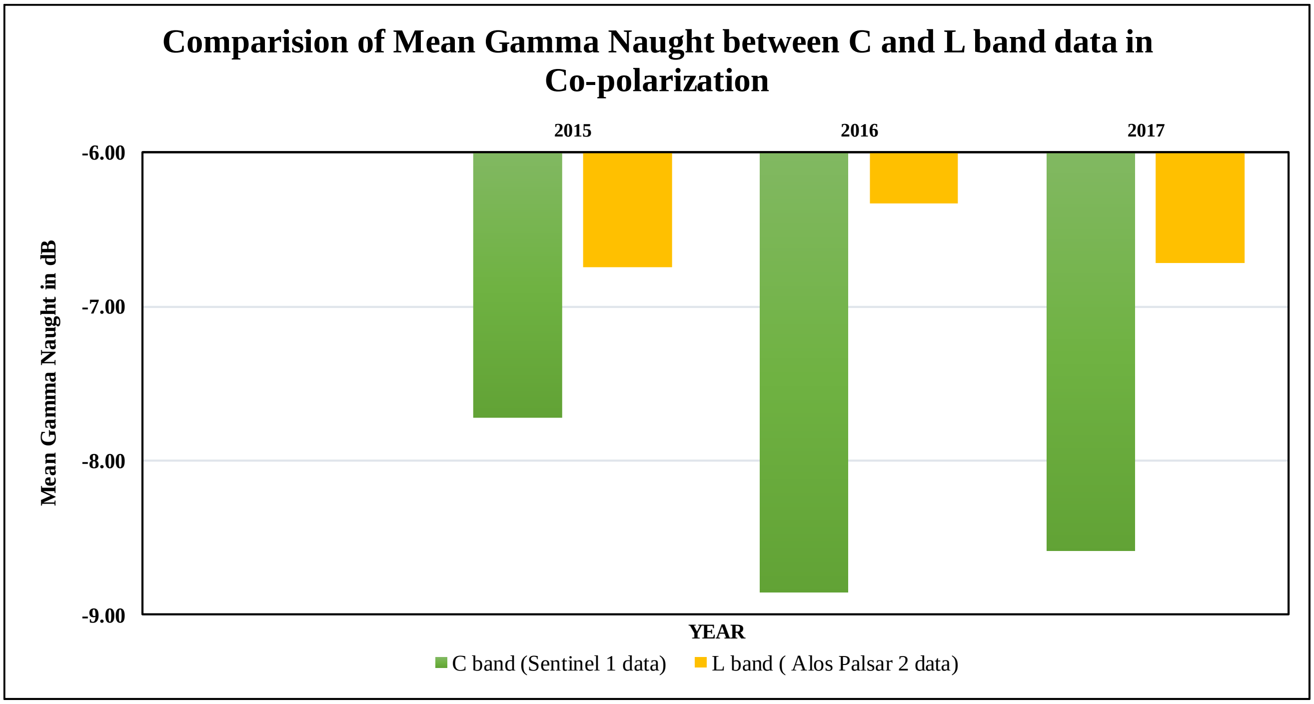
Figure 7 Mean Gamma Naught in HH & HV pol using L band

To generate the above graph, data used was of the frequency- L (1.2 GHz) which is mosaic product. Gamma naught values of boreal forest are calculated for the years 2015, 2016 and 2017. The graph helps in observing that; the gamma naught values are-6.74 dB, -6.33 dB and -6.71 dB in HH pol.

and -12.99 dB, -12.26 dB and -13.11 dB in HV pol. The mean gamma values -6.59 ± 0.23 dB in co-pol and -12.77 ± 0.46 dB in cross-pol. The calculated gamma naught values are identical and proves that stability is observed in boreal forest.

All the section above helps in understanding the stability pattern of boreal forest, while the section 6.4, helps in quantitative comparison of the L and C band calculated gamma naught values.

6.4Comparison of the Mean Gamma Naught values obtained from the data of Sentinel-1 and ALOS PALSAR 2.



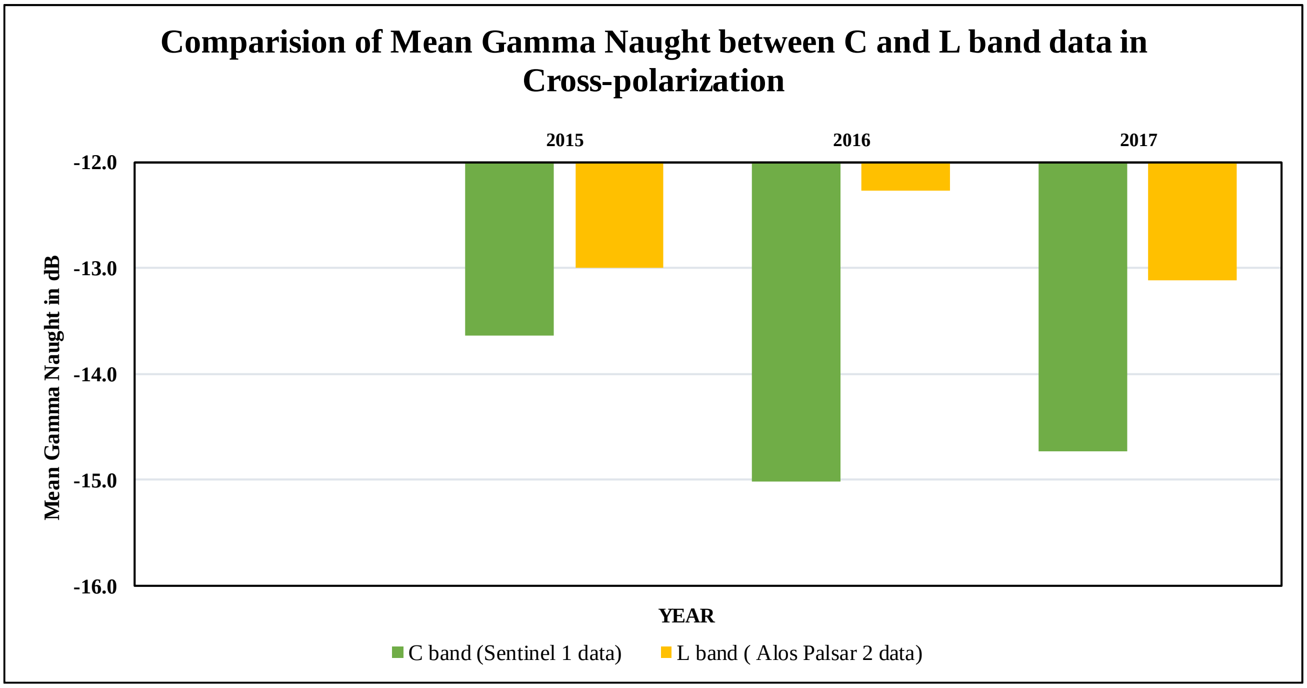


Figure 8Comparison of C and L band, Annual Gamma Naught in Co & Cross-pol

This Section shows the quantitative difference between C and L band calculated gamma naught values, which helps in determining suitable frequency data to conduct this kind of stability studies for distributed targets. Average mean gamma naught values of L and C band are used to construct the above graph.

The gamma naught values of C band in co-pol are -7.72 dB in year 2015, -8.85 dB in year 2016, -8.58 dB in year 2017 respectively. While gamma naught values in L band are -6.74 dB, -6.33 dB, -6.72 dB for 2015, 2016 and 2017 respectively.

The gamma naught values of C band in cross-pol are -13.64 dB in year 2015, -15.01 dB in year 2016, -14.73 dB in year 2017 respectively. While gamma naught values in L band are -13.00 dB, -12.26 dB, -13.11 dB for 2015, 2016 and 2017 respectively.

From the above values, the average gamma naught value of co-pol and cross-pol can be rewritten as -7.5 ± 0.24 dB and -13.5 ± 1 dB of C band and -6.5 ± 0.1 dB & -12.5 ± 0.29 dB of L band respectively.

The gamma naught values of L band are mostly identical without any disturbances. To check the validity of the gamma values obtained from L band, data of same area is downloaded from “Alaska data facility” and “ALOS 2 Jaxa” sites. The following results are obtained:

L BAND DATA			
Data from Alaska Data facility 25m		**Data from ALOS 2 data site 100m FNF**	
Date	Co-pol	Date	Co-pol
22-Feb-07	-10.9356	2007	-6.823
25-Nov-07	-8.4434	2008	-6.9982
10-Jan-08	-9.4605	2009	-7.1147
12-Jan-09	-9.2805	2010	-6.977
14-Apr-09	-6.9395		
18-Jan-11	-8.9642		
02-Aug-12	-8.9814		

From the above table it is observed that gamma naught values of L band data are same as gamma values of C band data derived from Sentinel 1. While gamma naught values of ALOS 2 data are ideal to -6.5 dB. It can be concluded that C band calculated gamma values and calculated gamma values from L-band data are true because the same values are also observed in previous works.

Comparison with the results reported in the literature

1) Estimation of Biophysical Parameters in Boreal Forests from ERS and JERS SAR Interferometry by MAURIZIO SANTORO (SANTORO 2003)

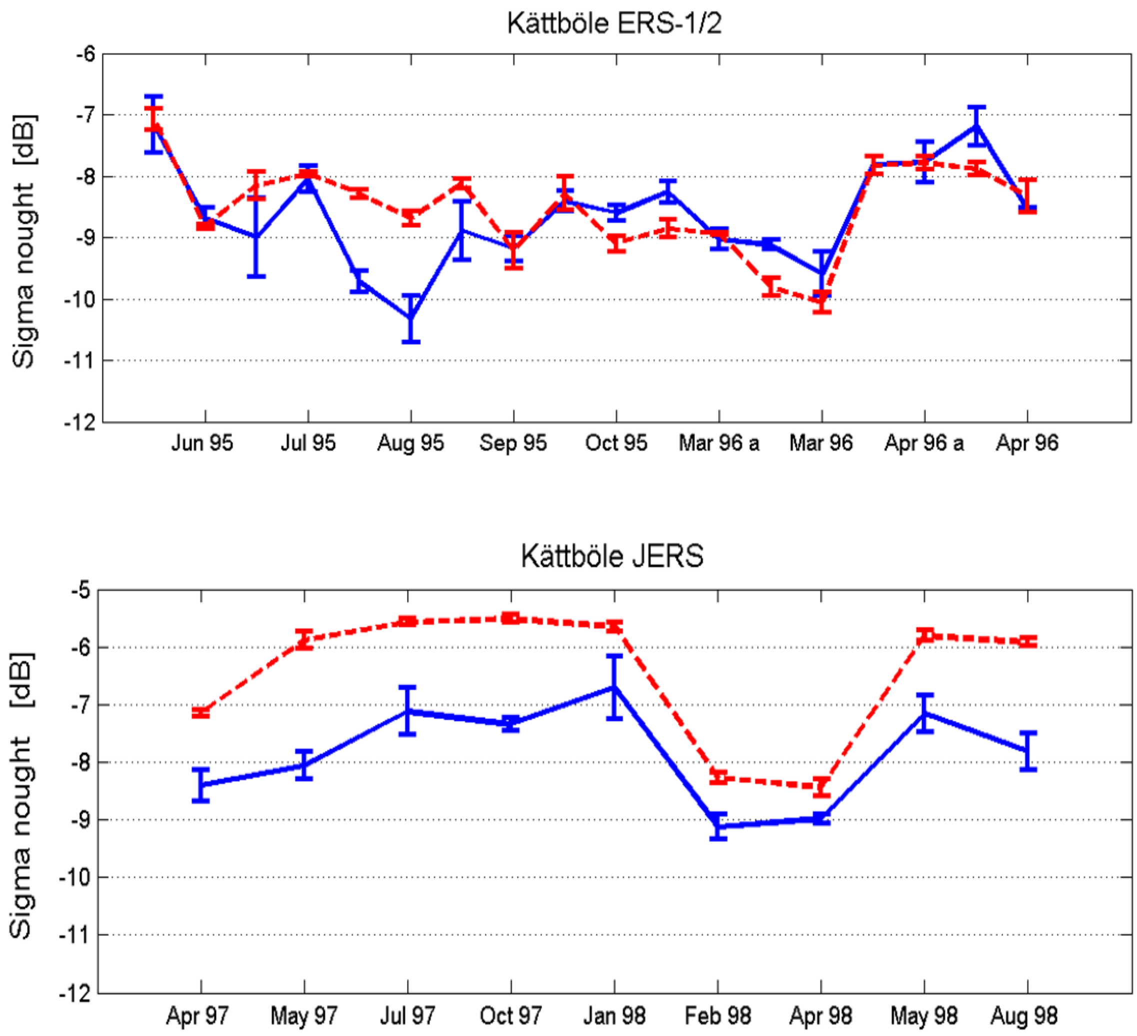


Figure 9 Run of ERS& JERS backscatter in sparse (solid line) and dense forest (dashed line)© *(SANTORO 2003)*

Study region: Kattabole, Sweden (part of Boreal Forest).

Observations with ERS (C band) data: In dense forest the backscatter was around

-8dB and decreased when temperature was below freezing point. In sparse forest, the backscatter shows larger variability and dependent of season. In case of snow fall, it is transparent to radar wave, giving rise to low backscatter.

Observations with JERS (L band) data: influence of wetlands was stronger on the ERS than on the JERS backscatter. The backscatter of dense and sparse forest was around -6 and -8dB.For dry-unfrozen conditions both in sparse and dense forests the backscatter was found to be higher than for winter-frozen conditions. A frozen canopy and a frozen ground give scatter with less power because the dielectric constant is much smaller. Moreover, an incoming wave penetrates the canopy deeper and the percentage of ground seen by the radar increases. Dry-unfrozen conditions occurred in Kättböle, between May and October 1997 and then again starting in May 1998.

2) RADARSAT -1 Image Quality and Calibration Performance Maintained Beyond 12 Years of Operation by Satish k Srivastava (Satish K srivastava n.d.)

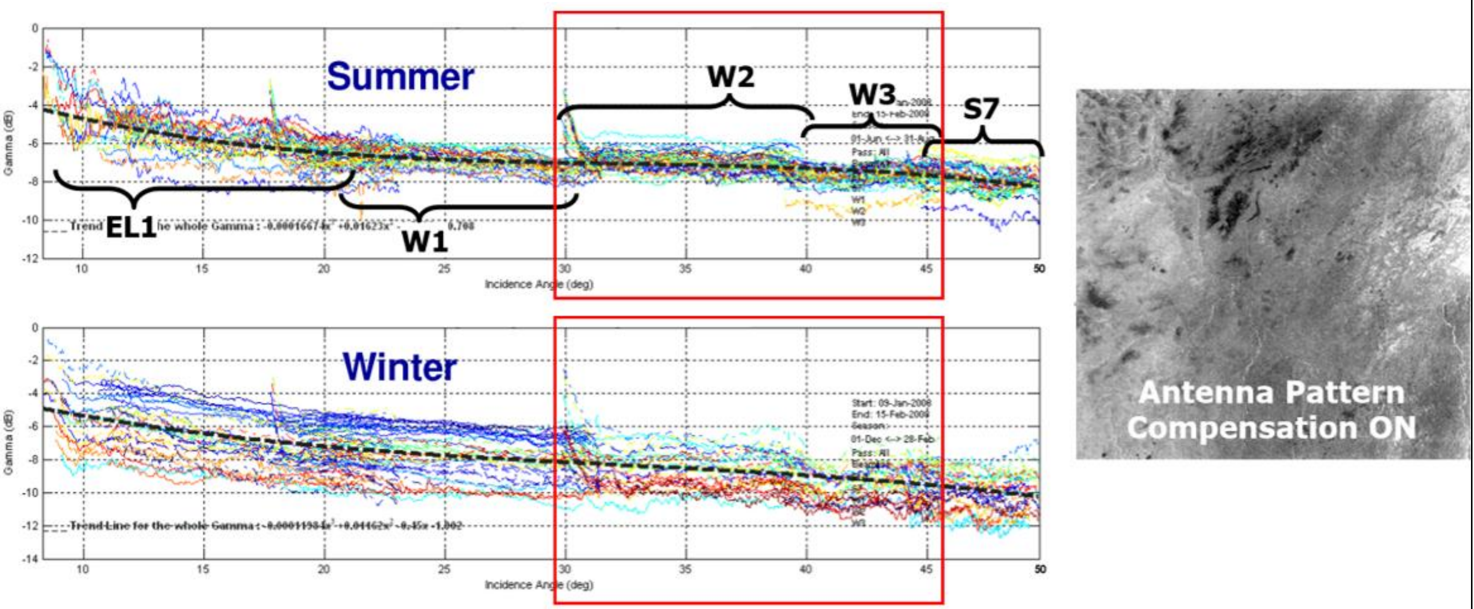


Figure 10 Boreal forest seasonal reflectivity © *(Satish K srivastava n.d.)*

The above figure shows gamma naught values obtained for Ontario, boreal forest using RADARSAT-1 image. Assuming that beams remain calibrated, gamma naught values are extracted with respect to incidence angle. Sentinel-1 C band has incidence angle from 30^0 to 45^0, which is used for studying stability of boreal forest. With respect to 30^0 to 45^0 incidence angle, during summer the gamma naught values are -7.5dB to -8.5dB and in winter the gamma naught values are

-8.5 dB to -10 dB, which are observed from the figure above.

The above observed gamma naught values happen to be same as gamma naught values calculated using C band frequency data, mentioned in above section.

The inference jotted down in this section helps in proving that calculated gamma naught values are true and are verified with the results obtained from 12 years' study of image quality and calibration performance.

7. Summary and Conclusions

This study is carried out to analyze the gamma naught stability of the Canadian Boreal forest and evaluation of its potential to be used as a distributed target site. The seasonal and temporal variation in gamma naught values over the boreal forest for C- and L-band SAR data were analyzed and reported here.

Using C band, average gamma naught value of the years is found to be -8.16 ± 0.53 dB in co-pol &-14.18 ± 0.89 dB in cross-pol. Average summer season gamma naught values are calculated as -7.5 ± 0.43 dB & -13.5 ± 0.22 dB for co-pol and cross-pol respectively. Estimated average gamma naught values for winter season are -8.5 ± 0.66 dB for co-pol data and -15.5 ± 0.49 dB for cross-pol data. Seasonal variation of 1.73 dB in co-pol and 2.27 dB in cross-pol was observed.

Using L band mosaic product, calculated gamma naught values are -6.59 ± 0.23 dB in co-pol and

-12.77 ± 0.46 dB in cross-pol. Due to non-availability of day wise data, Seasonal analysis were not performed. From the above analysis, we concluded that boreal forest is stable since 2015 - 2017

The second objective of the study is the quantitative comparison of the C and L band results. The mean gamma values of C and L band results are -8.16 ± 0.53 dB & -14.18 ± 0.89 dB and -6.59 ± 0.23 dB & -12.77 ± 0.46 dB respectively which shows higher value for C-band than L-band.

From the above analysis, it can be concluded that gamma naught for Canadian boreal forest has the seasonal dependence and the variation was found to be more for cross-polarization (2.27 dB) than for co-polarization (1.73 dB) for C-band. Gamma naught stability analysis for the study area using available RISAT-1 data is in progress.

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