American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-6, Issue-8, pp-270-274
www.ajer.org
Research Paper Open Access

A Model SAR Backscatter X-Band for Dry Snowpack

Jean Espinoza[1], Jorge Arigony-Neto[2] and Ricardo Jaña[3]
[1]*(Federal University of Rio Grande do Sul – UFRGS, Porto Alegre – RS, Brazil)*
[2]*(Federal University of Rio Grande – FURG, Rio Grande – RS, Brazil)*
[3]*(Chilean Antartic Institute – INACH, Punta Arenas, Chile)*

ABSTRACT: *This paper proposes an analytical model for the interaction between a microwave beam from Synthetic Aperture Radar in X band (SAR-X) and a snow pack in dry snow conditions with Radiative Transfer Model (RTM). For this purpose, a statistical analysis was performed with SAR-X backscattering data and reference data on snow stratigraphy obtained from snowpits implemented along the pilot study area - Union Glacier, Antarctica. This model was developed by limiting the interaction between the microwave beam and snow in areas of dry snow for simplification purposes, since the dielectric constant in areas of wet snow has a complex character. As a result, a mathematical model was generated based on the radiation transfer model, in order to represent the process of interaction and backscattering of the microwave beam with the snow. This model divided the process of interaction between the SAR-X beam and the snow in three linear effects overlap: Backscatter produced along the surface of the air-snow, Volumetric backscatter produced over the volume of snow and Backscatter produced in snow-ice interface. For the purposes of model testing, it was used to estimate the penetration of the SAR-X beam along the snow package, with a penetration of 0.9663 m ± 0.11247 m being estimated. This fact was proven from the identification of cracks in the glacier that were covered by snow and were not visible in the standard optical images. Even with limited reference data, this result indicates the robustness of the proposed approach, allowing the estimation of the spatial distribution of variations in stratigraphic parameters of snow variables in dry snow areas from SAR data in the X band.*

Keywords: *SAR-X, backscatter, inverse model, snowpack, Union Glacier*

Date of Submission: 11 -08-2017 Date of acceptance: 24-08-2017

I. INTRODUCTION

The remote sensing using radar data/ SAR for monitoring snow cover and ice in the Polar Regions is consolidated as one of the main techniques used in the field of glaciology [1][2][3]. In this context, the modeling SAR backscatter is fundamental for extracting information about the behavior of electromagnetic radiation (ER) in the microwave range over snowpack, allowing a split components such as snow particle size, density, thickness, number of layers of snow, among others [4].

The approaches used in the construction of SAR backscatter models into two categories: physical models and empirical models [5]. A physical SAR backscatter model of the physical models of scattering (Mie scattering, Rayleigh scattering, etc.) and as an empirical model of the empirical analysis of a specific set of SAR data. Most SAR backscatter description models behind the characteristic of being mathematically complex, making it difficult to understand and its use [3][5]. This complexity arises to adequately describe the electromagnetic radiation (ERs) interaction processes with the target. But this complexity leads to restricted use of these models.

The SAR backscatter on a surface of snowpack is related to three factors [6]: (1) The parameters of the sensors, which include the frequency, polarization and incidence geometry; (2) snowpack parameters including snow density, particle size and variation in size, net free water content, the characteristics of spatial distribution of particles, viscosity and stratification; and (3) the subsurface parameters, which include the characteristics of the dielectric material, surface roughness, soil on the snow and snow-ice interface. Besides these three general factors determining the SAR backscattering coefficient (or sigma nought) observed is affected by several physical parameters of snow cover [6][7][8][9]. These parameters are:

(a) depth of the snowpack;
(b) surface roughness (air interface snow and snow-ground);
(c) the size of snow crystals (grain size) and shape of the snow crystal;

(d) density profile of the accumulated snow;
(e) layer (thickness, shape of the interface between layers variation between dielectric layers, etc.).

Recent developments show a more comprehensive approach to the ERs interaction processes in the range of microwave with the masses of snow and ice, indicating new ways for modeling the backscatter in the range of microwave for snow and ice masses [10][1][4][7].

This paper proposes the construction SAR backscatter model – X Band, returned to surface snowpack, considering homogeneous snow packages and formed by dry snow. The model proposed here was developed through the solution of the general equation of an electromagnetic wave to the range microwave, described by *Mueller matrix* [6], using the method of solution of ordinary differential equations and X Band SAR data from *Cosmo-Skymed* sensor obtained for the region of Union glacier, Antarctic.

II. CONCEPTUAL MODEL PROPOSED

The construction of the backscattering data model for X-band SAR data (ie, Cosmo-SkyMed) proposed in this work was based on the physical interaction between the microwave bundle and the snowpack. As a premise, four initial considerations were adopted:
(1) The beam of microwaves from the SAR sensor is consistent and collected in phase;
(2) snow grains are regarded as homogeneous spherical scatterers (ie, in a given volume of snow, all grains are considered to a typical average size behave like spherical scatterers);
(3) The characteristics of a dielectric layer of snow are constants; and,
(4) to the region of interest, the snowpack has no presence of liquid water or ice (ie, snowpack and comprises a homogeneous dry ice).

The backscatter SAR obtained from the integration of the different scattering processes beam microwave occurring over the modeled area, being restricted to the scattering surface along the snow-air interface, volumetric scattering of snowpack and scattering of bottom, occurred with ice-snow interface or the total attenuation of the beam along the snow profile (Fig. 1).

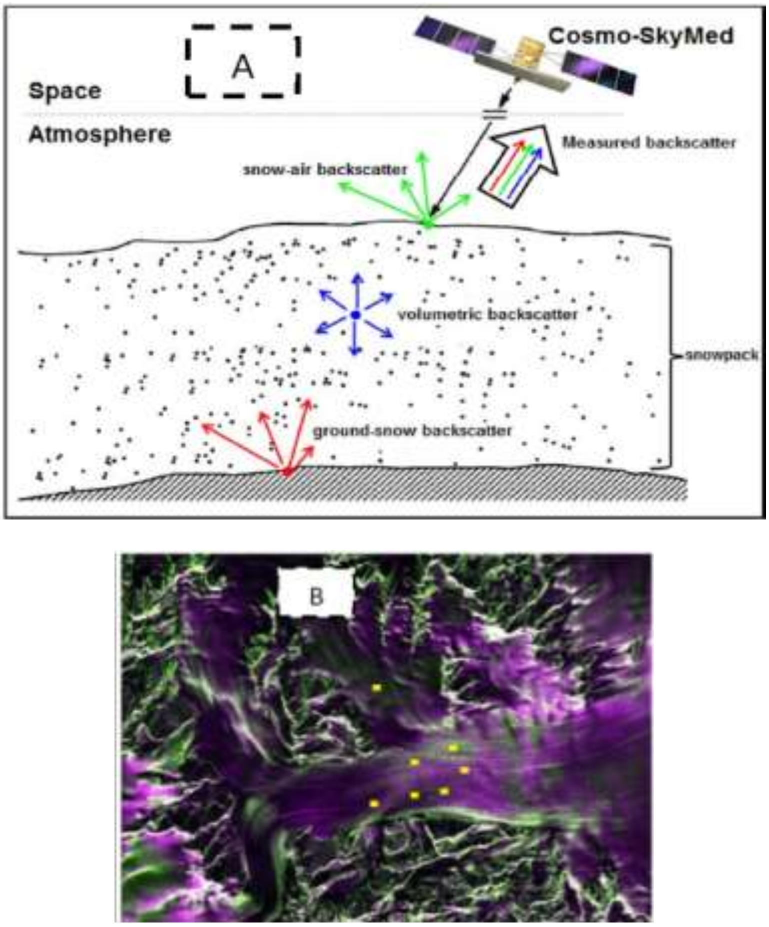

Figure 1: (A) Representation of backscatter processes in a snowpack. (B) Cosmo-SkyMed color composition acquired in the cross-polarization imaging mode (R=VV, G=VH, B=VV-VH) - Yellow points indicates the marked collection sites for field data snowpits

With these considerations, the backscatter of a mass of snow, for a given unit imaged on the ground is represented by equation 1:

$$\sigma^0_{Total} = \sigma^0_{air-snow} + \sigma^0_{vol.snowpack} + \sigma^0_{ground-snow} \quad (1)$$

Where,

- σ^0_{Total} : Total backscatter obtained for a pictorial unit;
- $\sigma^0_{air-snow}$: Backscatter produced along the surface of the air-snow;
- $\sigma^0_{Vol.snowpack}$: Volumetric backscatter produced over the volume of snow;
- $\sigma^0_{ground-snow}$: Backscatter produced in snow-ice interface, and / or total attenuation (i.e., σ0_final interface→ 0).

Each of these terms presents in the mathematical representation of the general equation for the SAR backscatter is given by a differential equation, given by RTM (Radiative Transfer Model) [6]. With the numerical solution of the differential equation proposed by finite element method [11] is obtained an analytic equation that approximates to behavior of analysed microwave beam. As the study site to validate the implementation of the backscatter model SAR proposed, an area was selected along the glacier Union, Antarctica (Coordinates: Lat/Long 79°45′S/082°30′W). The choice of this area was given by comprising an area with dry snow and the availability of field data about the stratigraphy of the snowpack and data *SAR CosmoSkymed* (Stripmap/HIMAGE). As a way equating and solving this process of interaction between the microwave radiation and the snow for this case of interest, is adopted the matrix of representation descriptor, for the RTM differential equation, from the Stokes vector notation, which representing polarization of an electromagnetic wave [6].

For specific conditions of interaction between the beam and the target, whereas a SAR system operates in a coherent and polarized form, the Stokes vector to represent the scattering produced by a means (scattered g) is related to the Stokes vector representing the incident beam (incident g) by a Mueller matrix (M), so that "scatter g = M incident g" .. To represent the RTM a beam of microwaves from a SAR sensor with a vertical-vertical polarization (VV) (eg, Cosmo-SkyMed this work), only the first term of the Mueller matrix is non zero [6][7][4]. Thus, the equation for the backscattering occurred in the process of interaction between a microwave beam and a mass of snow from the Mueller matrix, represented in a given polarization is written as (Eq.2):

$$\mathbf{M}_{\mathbf{snow}} = \mathbf{M}_{\mathbf{air\text{-}snow}} + \mathbf{M}_{\mathbf{vol}} + \mathbf{M}_{\mathbf{ground\text{-}snow}} \quad (2)$$

In thick snowpacks (ie, depths greater than 1.5 m), the Mg share will tend to zero, exposing the fact that the radiant beam wane completely over volume without finding a subsurface barrier of reflection. Thus, there will be a background of target (ie, below the snow layer), causing a reflection of the radiant interaction with a microwave beam, which simplifies the process of interaction.

III. EXPERIMENT AND ANALYSIS

In this paper, we consider a set of field data collected in summer 2011-2012 formed by stratigraphic data from the snow pack (i.e., snow temperature, limits between layers, average size and form of snow grains and average density of snow pack). These data were obtained through the excavation of snowpits over an area covered by a Cosmo-Skymed Sensor/Orbit CSKS2/Scion21378 (X-band) scene acquired approximately at Dec/2011. Fig 2 depicts the scene used here.

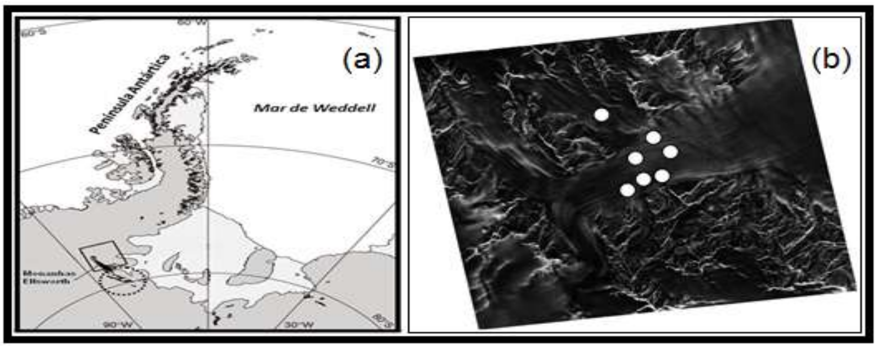

Figure 2: Study area (a) - Adapted from Gudmundsson e Jenkins [6], with the dots indicating the region of Union Glacier; *Cosmo-Skymed* Image used in this study (b). White dots depict the *snowpits.*

In the case of a superficial snowpack formed exclusively of dry snow, there will be a good penetration of the microwave beam along the X band, being relevant consider the volume scattering of the microwave beam occurred internally to the snowpack. In the specific case of the X band, the developed modeling in this study estimated a mean penetration of 0.9663m ± 0.1247m (threshold maximum penetration of 1.091m), represented by Figures 3 and 4:

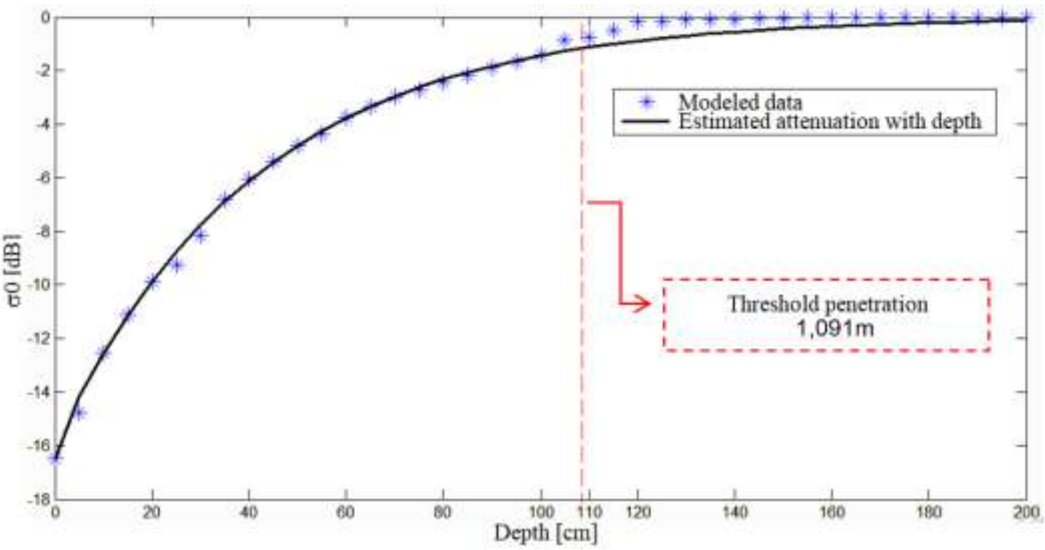

Figure 3: (A) Penetration threshold - maximum estimated penetration SAR-X in the snowpack.

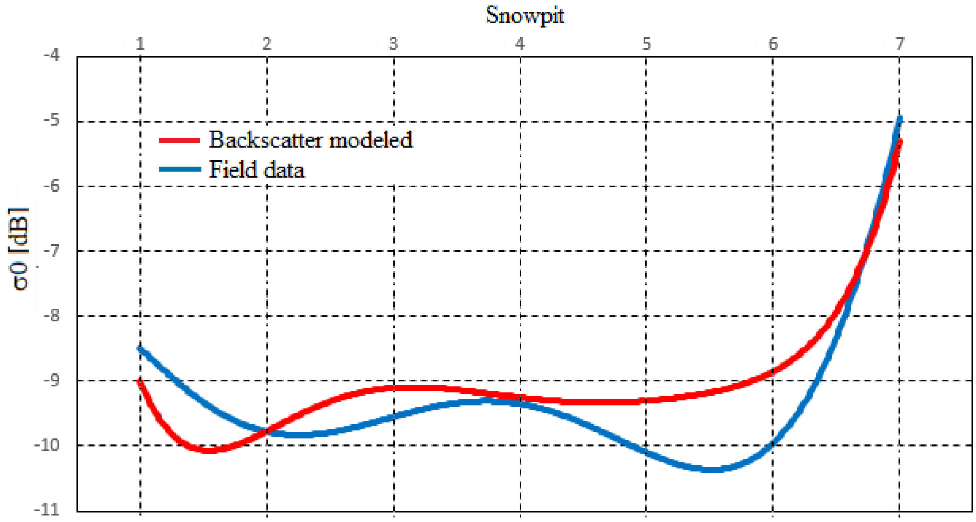

Figure 4: Estimated SAR X backscatter: Model and *Cosmo-SkyMed* data (data obtained for location of *snowpits*).

For the study area along the Union Glacier, due to local climatic conditions, characteristics of high latitudes (ie, study area surrounding the latitude 79s), there is no presence of wet snow, because the local annual maximum temperature does not exceed snow fusion point (ie, maximum local temperature always lower than 0°C). This makes the entire surface of the snowpack along the studied area can be considered as formed by dry snow, reaches the penetration of microwaves along the X-band range from 0,9663m ± 0,1247m.

Once the using of this inverse model approach of SAR signals allows estimating stratigraphic parameters for extended areas imaged by SAR sensors, and also considering the difficulties to rely on field data for stratigraphic snow, the proposed methodology is a valuable tool. The use of inverse backscattering models showed promising for estimating the stratigraphy of the snow pack of large areas. These estimates are very important for evaluating mass balance and thermodynamic equilibrium of areas marked by snow and ice.

IV. CONCLUSION

The experimental results indicate the robustness of the backscatter SAR models in the X band aimed at simulating the interaction between a radar microwave beam and a dry snow package. In addition, the fact that the model is based on three independent and linear effects overlapping: 1- radar backscattering produced along the air-snow surface; 2- the volumetric backscatter produced along the snow volume; and 3- the radar backscatter produced in the Ice-to-snow interface to the bottom of the package. This allowed to measure the individual contributions of each of these processes in the radar signal collected by the sensor. The method presented here allows us to estimate the parameters of the snow stratigraphy in snow package from SAR-X radar data, which allows us to measure dry snow stratigraphic parameters. However, experiences with other images and in different areas are needed to establish more consistent conclusions.

REFERENCES

[1] YURCHAK, B.S.: Some features of the volume component of radar backscatter from thick and dry snow cover. In Advances in Geoscience and Remote Sensing. (93-140). Chapter 6: Vukovar, Croatia. 978-953-307-005-6 (2009).

[2] ROTT, H., NAGLER, T. HEIDINGER, M. MULLER, F. e MACELLONI, G.: CoReH2O – A Ku- and X-Band SAR Mission for Snow and Ice Monitoring. Final Report. ESA ESTEC Contract No. 22830/09/NL/JC (2008)

[3] ROTT, H., NAGLER, T., VOGLMEIER, K., KERN, M., MACELLONI, G., GAI, M., CORTESI, U., SCHEIBER, R., HAJNSEK, I., PULLIAINEN, J. e FLACH, D.: Algorithm for retrieval of snow mass from KU and X band radar backscatter measurements. Geoscience and Remote Sensing Symposium, IGARSS, IEEE, - Munchen, Germany. (2012).

[4] JINYANG, D., SHI, J. e ROTT, H.: Comparison between a multi-scattering and multi-layer snow scattering model and its parameterized snow backscattering model Remote Sensing of Environment 114 1089 –1098 (2010).

[5] SIQUEIRA. P. R. SARABANDI, K. e ULABY, F. T.: Semi-empirical model for radar backscatter from snow at 35 and 94 GHz. IEEE Transactions on Geoscience and Remote Sensing, 1995, pp. 1498-1501. (1995).

[6] ULABY, F., MOORE, R. e FUNG, A.: Microwave remote sensing, active and passive, Volume III. Reading, Addison Wesley (1986).

[7] FUNG, A. K.: Microwave Scattering and Emission Models and Their Applications. Artech House Norwood, MA, (1994).

[8] PULLIAINEN, J. HEISKA, K. HYYPPA J. e HALLIKAINEN, M.: Backscattering Properties of Boreal Forests at C- and X-Band, IEEE Trans. Geoscience and Remote Sensing, Vol. 32, No. 5, pp. 1041-1050, (1994).

[9] KOSKINEN, J., METSMKI, S. GRANDELL, J. JNNE, S. MATIKAINEN, L. e HALLIKAINEN, M.: Snow monitoring using radar and optical satellite data, Remote Sensing of Environment, Vol. 69, 16–29, (1999).

[10] STORVOLD, R., MALNES, E. e LAUKNE, S. I: Using ENVISAT ASAR wideswath data to retrieve snow covered area in mountainous regions. EARSeL eProceedings, 4(2), 150-156 (2006).

[11] S. Brenner & R. Scott, The Mathematical Theory of Finite Element Methods. Springer-Verlag, 1994. Corr. 2nd printing. [Chapters 0,1,2,3; Chapter 4: Secs. 4.1{4.4}, Chapter 5: Secs.] 5.1(1996)

Jean Espinoza " A Model SAR Backscatter X-Band for Dry Snowpack" American Journal of Engineering Research (AJER) 6.8 (2017): 270-274