Characterization of the Amazon Rainforest Backscatter for X-Band SAR Calibration Using TanDEM-X Data

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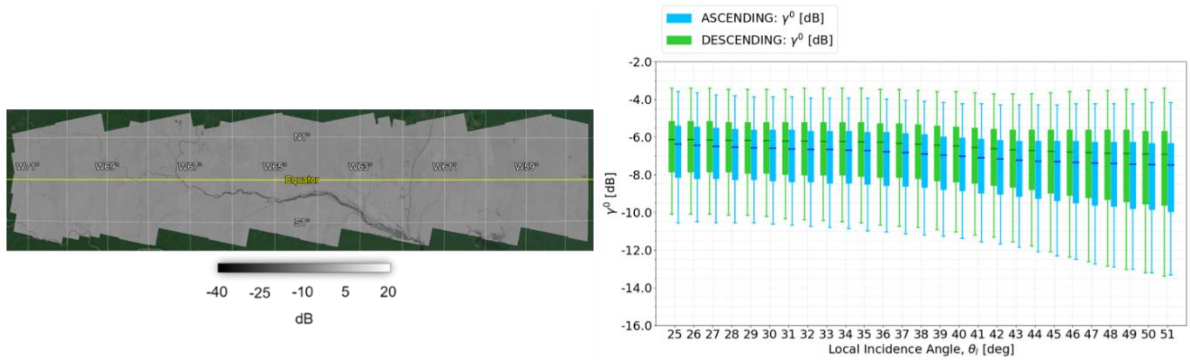
The radiometric calibration of spaceborne SAR products plays a key role for ensuring a good performance of the whole end-to-end system and requires a precise knowledge of both the radar system and the illuminated target [1]. The shape of the antenna pattern in elevation can be directly estimated by analyzing SAR detected images in presence of a flat backscatter profile in the slant range dimension. This is typically accomplished by acquiring SAR data over homogeneous distributed targets, under the assumption of isotropic scattering. This is the case of tropical rainforests, such as the Amazon and Congo forests, which have been established by the SAR community as well-known test sites for SAR calibration [2-4], thanks to their homogeneous and almost isotropic signature. Nevertheless, several studies using X- and C-band sensors have shown a slight dependency of the rainforest backscatter on the incidence angle, as well as on ground target properties and meteorological conditions [5-8]. The aim of this work is to present a statistical characterization of radar backscatter at X-band over the Amazon rainforest using TanDEM-X data, and to provide insights on how to best utilize radar backscatter data in this region for SAR calibration and modeling purposes.

Typically, the quantity used for measuring and analyzing backscatter levels in SAR data over rainforests is the backscattering coefficient gamma nought $\gamma^0(\theta_l)$. In particular, $\gamma^0(\theta_l)$ describes the radar reflectivity per unit area perpendicular to the antenna and remains relatively constant over a wide range of incidence angles for very dense volumetric targets [9].

The main focus of the present work is on the equatorial Amazon rainforest, which comprises images acquired using all TanDEM-X ascending/descending geometries. Here, we concentrate on the γ^0 backscatter dependency on orbit direction, whereby descending and ascending orbit acquisitions are generally acquired in the morning and in the evening, respectively. The area is depicted in Fig. 1(a) and it is composed by the complete TanDEM-X data set of StripMap, single-polarization (HH) data, acquired from December 2010 to September 2014. In particular, for the current investigation we processed 1998 SAR images at almost-full resolution, i.e. 6 m x 6 m: after absolute calibration of each image to retrieve β^0, we computed γ^0 and we generated the corresponding local incidence angle map θ_l.

The whole range of nominal local incidence angles θ_l, which extends from about 25° to about 51°, has been sampled with angular intervals of 1°. γ^0 samples which belong to each single interval are then grouped together, allowing for the derivation of statistical parameters. Moreover, we applied the TanDEM-X Forest/Non-Forest (FNF) map [10] in order to select the forest pixels only. The obtained results are presented in Fig. 1(b) for both data acquired in the morning, i.e. descending orbit acquisitions, and in the evening, i.e. ascending orbit ones. The boxes extend from the 25^{th} to 75^{th} percentiles, with whiskers reaching the 5^{th} and 95^{th} percentiles. The solid lines within each box identify the distributions mean values. Despite the Amazon rainforest appears to be a quite stable and isotropic target, the figure demonstrates its non-fully-isotropic nature, as backscatter profiles slightly decrease with respect to local incidence angles. Moreover, γ^0 properties are influenced by the day-time of acquisition, where images acquired in the evening, i.e. in ascending orbit direction, present lower backscatter values, with a bias of about 0.5 dB, when compared to the ones acquired in the morning, i.e. in a descending orbit geometry.

In the final work, we will present more exhaustive results on a larger set of different test cases. The work provides useful insights on the properties of SAR distributed scattering mechanisms in the Amazonas, showing different behaviours depending on the day-time of acquisition. This information can guide users in a proper exploitation of the area for, e.g., SAR calibration purposes or for the



(a) (b)

Fig. 1: (a) γ^0 mosaic over the equatorial Amazon rainforest, visualized on GoogleEarth. (b) γ^0 backscatter dependency on the local incidence angle θ_l and on orbit direction, i.e. day-time of acquisition.

monitoring of the radar antenna pattern. An investigation on γ^0 seasonal dependency has been performed as well and will be presented at the conference, together with a series of X-band backscatter parametric models which could be used for a variety of applications, ranging from SAR system design to physical modeling.

References

[1] M. Schwerdt, B. Brautigam, M. Bachmann, B. Döring, D. Schrank, and J. Hueso Gonzalez, "Final TerraSAR-X calibration results based on novel efficient methods," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 48, no. 2, pp. 677– 689, 2009.

[2] M. Shimada and A. Freeman, "A technique for measurement of spaceborne SAR antenna patterns using distributed targets," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 33, no. 1, pp. 100–114, 1995.

[3] J.L. Alvarez-Perez, M. Schwerdt, and M. Bachmann, "TerraSAR-X antenna pattern estimation by a complex treatment of rain forest measurements," in *2006 IEEE International Symposium on Geoscience and Remote Sensing*. IEEE, 2006, pp. 3857–3860.

[4] M. Bachmann, M. Schwerdt, and B. Brautigam, "TerraSAR-X antenna calibration and monitoring based on a precise antenna model," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 48, no. 2, pp. 690–701, 2010.

[5] Z. Bartalis, W. Wagner, V. Naeimi, D. Sabel, and C. Pathe, "SAR calibration requirements for soil moisture estimation," in *CEOS SAR Calibration and Validation Workshop*, November 2009, Pasadena, California, USA.

[6] S. Cote, S. Srivastava, S. Muir, and T. Lukowsk, "Assessment of distributed target sites within the RADARSAT program," in *CEOS SAR Calibration and Validation Workshop*, November 2011, Fairbanks, Alaska (USA).

[7] P. Rizzoli, B. Brautigam, and M. Zink, "TanDEM-X large-scale study of tropical rainforests for spaceborne SAR calibration in X-band," in *EUSAR 2014; 10th European Conference on Synthetic Aperture Radar*. VDE, 2014, pp. 1–4.

[8] H. Woodhouse, J. van der Sanden, and D. Hoekman, "Scatterometer observations of seasonal backscatter variation over tropical rain forest," *IEEE transactions on geoscience and remote sensing*, vol. 37, no. 2, pp. 859–861, 1999.

[9] R. K. Raney, A. Freeman, R. W. Hawkins, and R. Bamler, "A plea for radar brightness," *Proceedings of the International Geoscience and Remote Sensing Symposium*, vol. 2, pp. 1090–1090, 1994.

[10] M. Martone, P. Rizzoli, C. Wecklich, C. Gonzalez, J. L. Bueso-Bello, P. Valdo, D. Schulze, M. Zink, G. Krieger, and A. Moreira, "The global forest/non-forest map from TanDEM-X interferometric SAR data," *Remote sensing of environment*, vol. 205, pp. 352–373, 2018.