# CHARACTERIZATION OF FOREST STRUCTURE CHANGES EXPLOITING TANDEM-X AND GEDI SYNERGIES

*Lea Albrecht, Nikita Basargin, Islam Mansour, Roman Guliaev, Noelia Romero-Puig, Matteo Pardini, and Konstantinos Papathanassiou*

German Aerospace Center (DLR) – Microwave and Radar Institute, Wessling (Germany)

## ABSTRACT

The objective of this paper is to discuss experimentally potentials and perspectives of the synergetic combination of spatially continuous TanDEM-X interferometric measurements at X-band and sampled GEDI lidar waveforms to map forest height and structure changes at high resolution and large scale. For this, the two TanDEM-X forest coverages in the time periods 2011-2013 and 2018-2020 will be considered over relevant sites.

***Index Terms—*** Forest height, forest structure, synthetic aperture radar, lidar, interferometry, TanDEM-X, GEDI.

## 1. INTRODUCTION AND FRAMEWORK

The synergy of TanDEM-X interferometric data with GEDI lidar full waveform measurements for large-scale forest mapping has been addressed in a number of studies in the last years [1-9]. Spatially continuous TanDEM-X and discrete GEDI measurements have a significant synergetic potentials towards mapping forest structure because both measurements (i) are at the same time similar enough due to the high sensitivity to the geometrical architecture of the canopy and the high spatial resolution common to both configurations, facilitating a common interpretation, and (ii) are different enough because of the different acquisition geometries and measurement approaches to carry independent information.

In [10], [11], the GEDI lidar full waveforms have been used to approximate the TanDEM-X X-band radar vertical reflectivity function (e.g. the vertical distribution of scatterersr) in order to enable the inversion of single-pol single-baseline TanDEM-X datasets. This allows the generation of continuous high-resolution forest height maps at large and global scales without the need / use of external information as of about the underlying topography. All the results in different test sites and ecosystems show that this combination of GEDI and TanDEM-X data cannot avoid significant absolute height errors, especially at the local scales arising from fundamental limitations. One of them, and maybe the most important one, is the limited penetration at X-band. In this case, the interferometric volume coherence no longer represents the full vertical extent of the forest. Regardless of the assumed vertical reflectivity profile, this leads to an underestimation of forest height. As a consequence, underestimation of high and/or dense stands because of insufficient X-band penetration cannot be avoided and, more importantly, it is very difficult if not impossible to be detected without additional information. As such, it has to be accepted and impacts on the inversion performance. Despite this, the achieved performance indicates the potential of combining the inherent sensitivity to forest structure from lidar measurements and interferometric SAR measurements for large scale forest height mapping. Fig. 1 shows the forest height map derived from the combination of TanDEM-X and GEDI data over the whole Brazilian Amazon (including more than 12,000 TanDEM-X scenes and 250 millions GEDI lidar measurements). Even a simple visual comparison to the distribution of the GEDI samples shows the significance of the obtained continuous TanDEM-X heights in following spatial patterns at high resolution.

On the other hand, the high attenuation rates at X-band and the resulting limited penetration into the forest volume (which limits the height estimation performance and makes the characterisation of the vertical forest structure at reasonable scales almost impossible) maximize the interferometric sensitivity to the spatial variability of the top canopy layer and make it especially appropriate for the characterization of the horizontal forest structure. At the same time the high spatial resolution of the TanDEM-X interferograms and its continuous measurement nature allows the estimation of forest structure variations at spatial scales relevant for the characterization of the horizontal forest structure. Accordingly, from the spatial variability of the interferometric phase center it is possible to determine the horizontal canopy heterogeneity and/or density e.g. at a 1 hectare scale. A large variability resulting from a large canopy height variation is associated with a large canopy roughness and interpreted as “sparse forest”. On the other hand, a low variability resulting from low canopy height variation is associated with low canopy roughness and is interpreted as a close canopy, e.g. a “denser forest”. The canopy heterogeneity map, for the Brazilian Amazon is

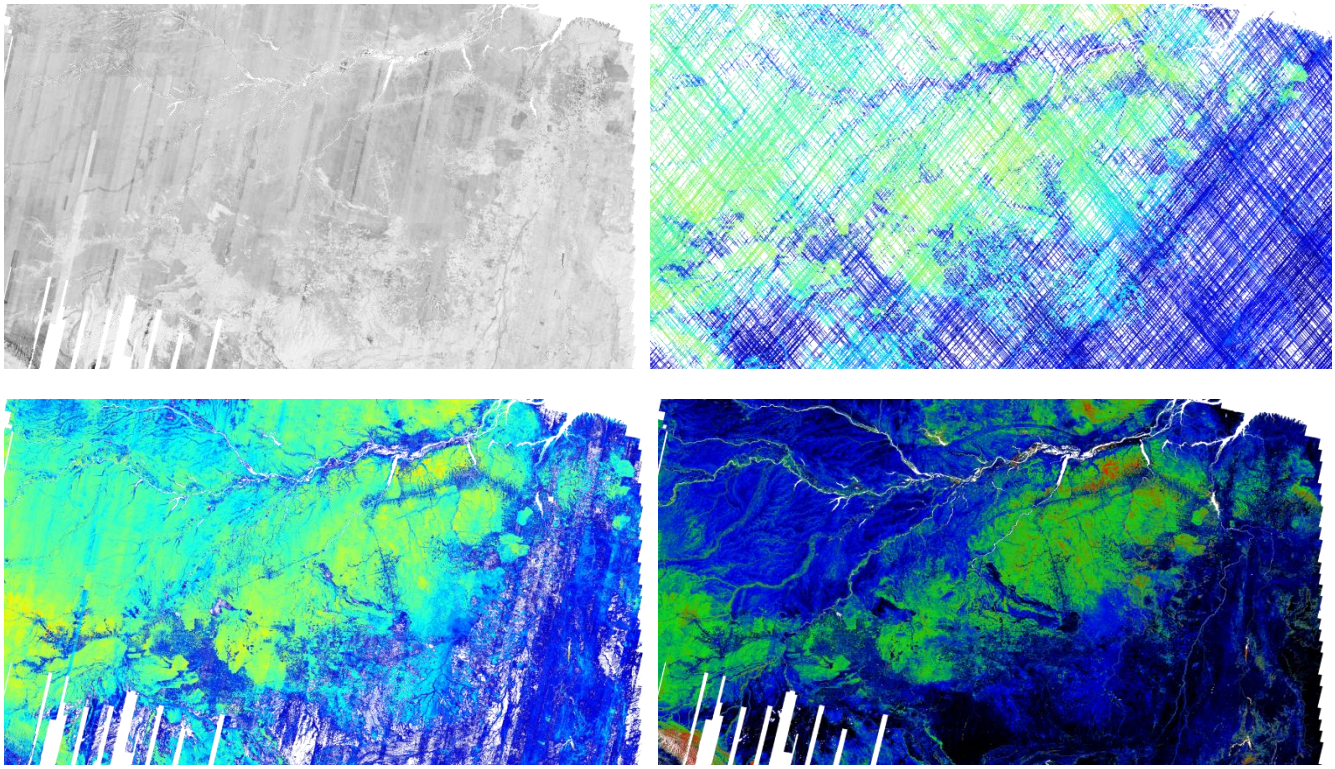

Fig. 1 Brazilian Amazon. Top left: TanDEM-X InSAR Coherence; Top right: GEDI RH98 Height measurements; Bottom left: forest height map derived from the combination of TanDEM-X and GEDI data; Bottom right: Canopy heterogeneity map (red: high heterogeneity – blue: low heterogeneity). (12,000 TanDEM-X scenes and 250 millions GEDI lidar measurements).

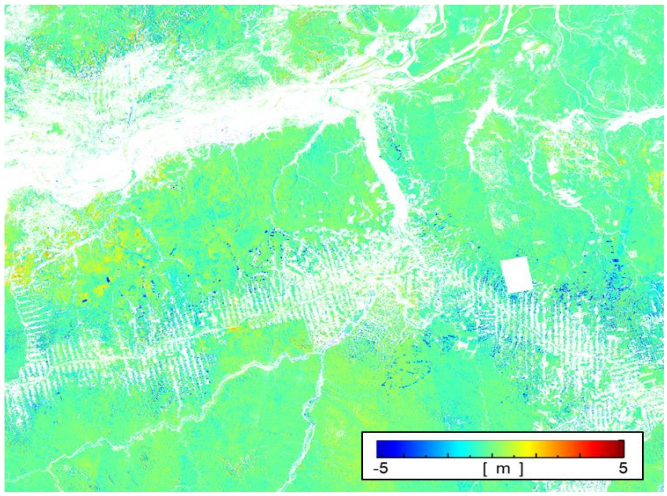


Fig. 2 Canopy heterogeneity change map at 1 hectare for the time between 2011/2013 and 2018/2020.

shown on the left of Fig. 1 and denotes a complementarity with respect to the height map.

## 2. OUTLOOK

TanDEM-X performed complete forest coverage in 2011-2013 and 2018-2020. There is thus the ability to measure changes in height and structure in a 10-year period. In this paper we discuss the potential of estimating forest height and structure change using TanDEM-X data combined with GEDI meassurements. The canopy heterogeneity can be used directly to detect structural changes in the canopy and to differentiate between different change and disturbance processes. An example of such a structure change map is shown in Fig. 2. It shows the change of standard deviation of the interferometric phase center estimated at 25 m spatial resolution within a 1 Hectare window in the time between 2011/2013 and 2018/2020. The area corresponds to a smaller area within the map of Fig. 1. An increase of standard deviation indicates an increase in canopy heterogeneity

caused by processes as stand thinning or selective logging while an degrease of the standard deviation indicates an degrease in canopy heterogeneity that can be caused by regrowth.

## 3. REFERENCES


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