Detecting Forest Structure Changes with SAR Tomography

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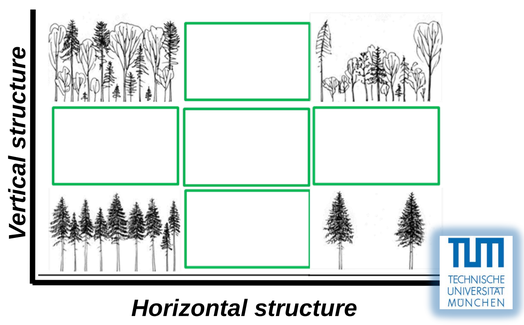
Motivation

Synthetic Aperture Radar Tomography (TomoSAR) allows the reconstruction of the 3D (radar) reflectivity opening the door for the estimation of 3D forest structure parameters. Future SAR missions will be able to provide global tomographic coverage in relative small revisit times, enabling the monitoring of 3D forest structure dynamics. In this poster, the temporal variations of forest structure based on TomoSAR estimation are analyzed using an airborne dataset covering a period of five years over the Traunstein forest, in the south of Germany.

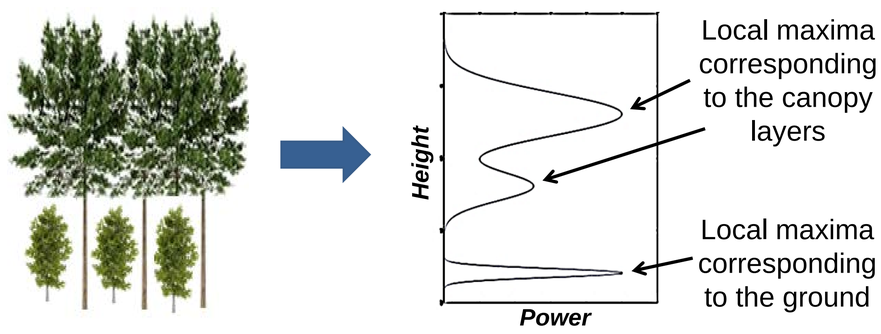
Forest Structure

In forestry, forest structure is characterized by the height, the vertical extend and the spatial distribution of the individual trees within a stand. Accordingly, it is possible to characterize forest stands in terms of their horizontal and vertical structure complexity derived using single tree information.

Due to the inability of TomoSAR to distinguish single trees, an indirect correspondence to trees distribution has to be established. In order to get such a correspondence, one basic assumption is the physical significance of local maxima (peaks) in the vertical radar reflectivity.



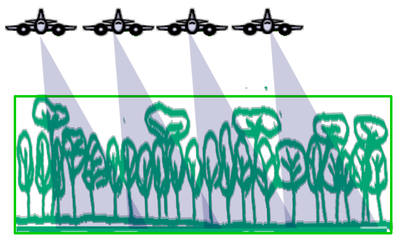
Forest structure classification based on single tree measurements



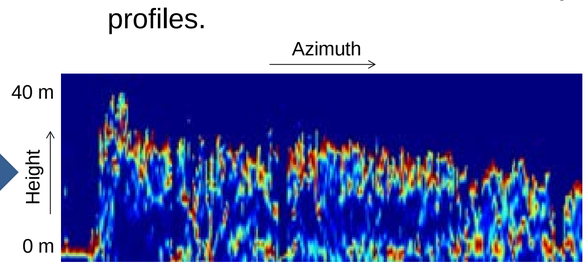
Correspondence between canopy layers and 3D reflectivity from TomoSAR measurements

Methodology for Forest Structure from TomoSAR

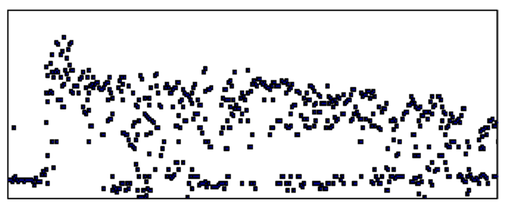
1 Several acquisitions over the same area to get a tomographic SAR data set



2 From the TomoSAR acquisitions a compressive sensing approach is used to estimated the reflectivity profiles.

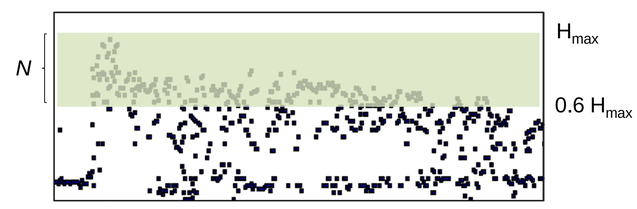


3 From the TomoSAR reflectivity, the local maxima (or *peaks*) are extracted.



4 From the distribution of local maxima, two forest structure indicators, both in vertical and horizontal directions, are estimated.

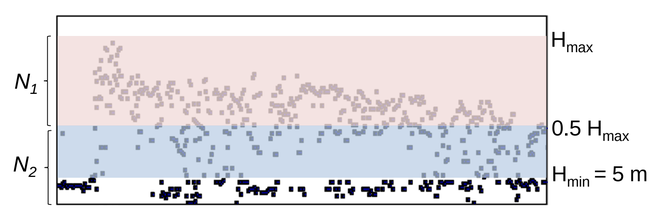
Horizontal structure



$$N_{i,j} = \sum_{i,j}^{25\,m} \sum_{h=0.6Hmax}^{Hmax} P_{i,j} \qquad H_{i,j} = \frac{N_{i,j}}{area} H_{max}$$

Where $P_{i,j}$ is a binary matrix with non-zero elements at the position of every *peak* and $\sum_{i,j}^{25\,m}$ denotes the window of 25 by 25 meters around the pixel i,j.

Vertical structure



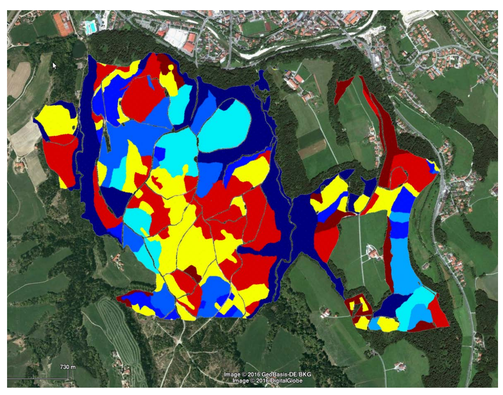
$$V_{i,j} = -\frac{C_{N1} log_{10}(C_{N1}) + C_{N2} log_{10}(C_{N2})}{log_{10} 2}$$

$$C_{N1} = \frac{N1}{N1+N2} \qquad C_{N2} = \frac{N2}{N1+N2}$$

$$N_{1i,j} = \sum_{i,j}^{25\,m} \sum_{h=0,5Hmax}^{Hmax} P_{i,j} N_{2i,j} = \sum_{i,j}^{25\,m} \sum_{h=Hmin}^{Hmin} P_{i,j}$$

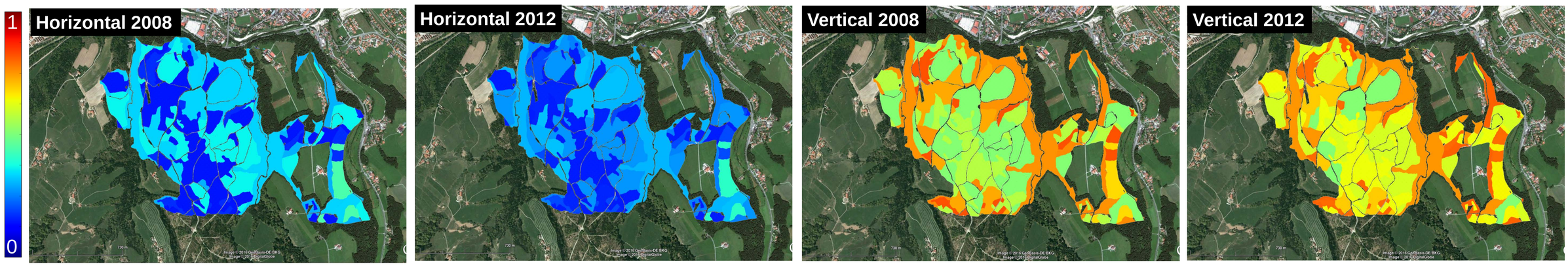
Test site: Traunstein forest

The approach proposed is applied to a TomoSAR data set acquired at L-band using the E-/ F-SAR airborne system of the Microwaves and Radar Institute of DLR. The forest under study is located in Traunstein, in the South-East of Germany. The area is constituted by a highly heterogeneous managed forest, with coniferous, deciduous and mixed stands at different growth stages. The data are fully polarimetric (L-band) and have been acquired in 2008 and 2012, under different seasons and weather conditions. The resolutions of the SLC data are from 1.28 m to 2.12 m in range and from 1.2 to 0.6 m in azimuth. For the vertical and horizontal structures, a window of 25 m by 25 m is used.



Growth stages

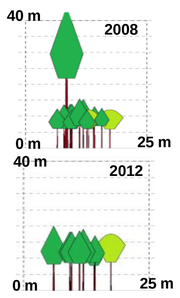
Horizontal and vertical structure maps



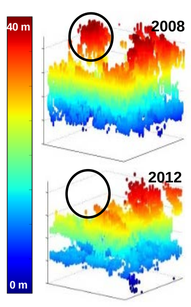
Local changes

Height, position, and species of trees are collected in an area of 500 m. In the figures below, a zoom over the area of the ground measurements are show.

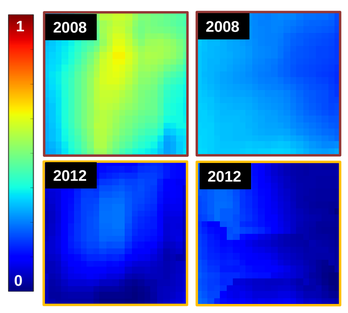
The logging of a layer of high trees is detected in the reflectivity. A greater change in the vertical descriptor is observed due to the reduction of variability in the vertical direction.

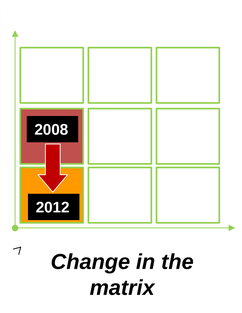


Ground measurements



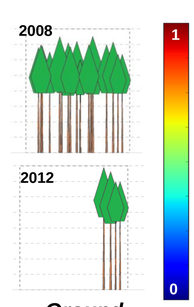
TomoSAR reflectivity



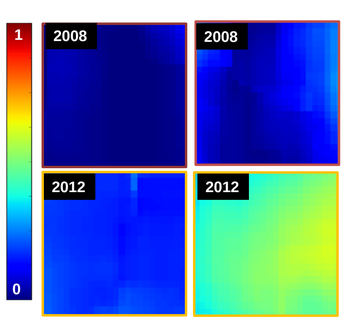


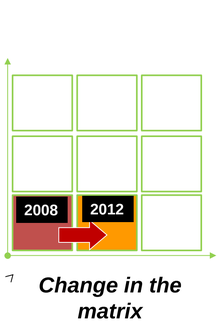
Change in the matrix

After a strong logging in a one layered stand, the density of trees decreases and, as a consequence, the horizontal descriptor is higher (low density) while the vertical remains stable because the variability in the vertical direction is not changing.



Ground measurements





Change in the matrix

Conclusions

Remote sensing systems based on TomoSAR techniques allow us to characterize forest structure in 3D by defining two complementary indicators, for both horizontal and vertical directions. The indicators are consistent with growth stage classifications and they can be used to monitor structure changes in the forest. Extended loggings as well as local changes reported in ground measurements between a period of 5 years have been detected.