SAR-based forest mapping and evaluation of TanDEM-X InSAR height in forest stands

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ABSTRACT

In 2016, DLR launched the final digital elevation model (DEM) product of the TanDEM-X mission and made it available to the scientific community. The TanDEM-X DEM is considered to represent the earth surface including all objects (digital surface model, DSM), however, for many applications in hydrology and ecology, the surface height needs to be reduced to the ground height. One challenge in the correction of the DSM to ground height is the fact that the TanDEM-X DSM does not represent the height of the vegetation, since the radar signal penetrates the canopy to varying extent. Thus, it models a deviating surface that is described by the difference between object height and penetration depth of the SAR signal (InSAR height).

26.8 % of the land area is covered by forests. In this area of about 40,000,000 km², the TanDEM-X DEM does not reflect the ground height. In the present study, we evaluated the TanDEM-X DEM with regard to forest areas and the surrounding landscape, indicating and analysing the parameters that contribute to the varying penetration depth and thus InSAR height of forest stands. The overall aim of the underlying project was to understand and characterize the factors that influence the penetration of the X-band in different forest stands and to propose a workflow for the adjustment of the TanDEM-X height to the ground height. Here, the delineation of forest stand parameters that have an impact on InSAR height is solely based on X- and C-band data from the present EO satellite missions of ESA, DLR and CSA.

The proposed contribution will outline the overall concept of the project “BoDEM”, Processing of digital terrain models from X- and C-band SAR data for the derivation of high resolution surface layers for soil and ecosystem mapping. It is part of the CSA-DLR collaborative agreement for the joint evaluation of C & X band EO satellite missions. Furthermore, we will present preliminary results of the first milestones of the project:

Forest cover mapping: A workflow for forest/non-forest detection is proposed based on multitemporal Sentinel-1 SLC C-band backscatter and TanDEM-X CoSSC X-band imagery. Different combinations of input layers were tested systematically for unsupervised random forest classification with regard to SAR frequency, polarization, texture and time of season. Results were compared against existing global forest maps and validated against field survey data for different test sites in Germany and Canada.

Results show that the maps based on multitemporal Sentinel-1 backscatter data covering the whole growing season, together with textural features and TanDEM-X coherence provide the highest overall accuracies (89.55 % and 93.62 %). This is in the range of the existing global forest map products based on optical satellite data and on L-band ALOS-PALSAR for the test sites. Satisfactory results were also achieved with Sentinel-1 data only from the onset of the growing season.

TanDEM-X forest InSAR height evaluation: The forest maps were used as a mask to evaluate the penetration depth of the TanDEM-X X-band. First tests confirmed the dependencies of the penetration depth in open land with isolated small tree areas mainly by vegetation characteristics whereas in closed forest stands the orientation of the covered surfaces in relation to the scan direction of the TanDEM-X play a more important role. Analysis of stock density revealed that the smaller (by area) the tree group is and the narrower the tree rows are the greater is the penetration depth of the radar signal into the canopy. At the edge of forests, similar effects could be observed.

In closed stands, however, the influence of the direction and angle of the forested areas in relation to the direction and angle of the TanDEM-X signal prevails. This impact is higher in regions with more terrain energy. In extreme cases, for instance, if the aspect of a steeply inclined slope is in direct opposite direction of the TanDEM-X signal, the signal can penetrate to the earth’s surface.