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Forest Canopy Modelling from TanDEM-X Interferometry and Lidar DEM

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Introduction

There is an on-going laser scanning campaign run by the Swedish Land Survey aiming to acquire a high-resolution digital elevation model (DEM) of Sweden. By the year 2015, a 2 m x 2 m DEM with a mean height error of 0.5 m is to be available for the whole country.

TanDEM-X (TDM) is a new twin satellite system designed to create the first homogeneous, high-resolution, global DEM using X-band (9.6 GHz) synthetic aperture radar (SAR) interferometry. In forested areas, TDM provides height profile for the upper part of forest canopy.

Therefore, if TDM data are used together with the new national DEM, digital canopy models (DCMs) can be obtained. It is here shown that this approach has the potential to become a future tool for accurate, frequent, nationwide forest canopy mapping, as the topography in Sweden is temporally stable and the DEM does not change significantly.

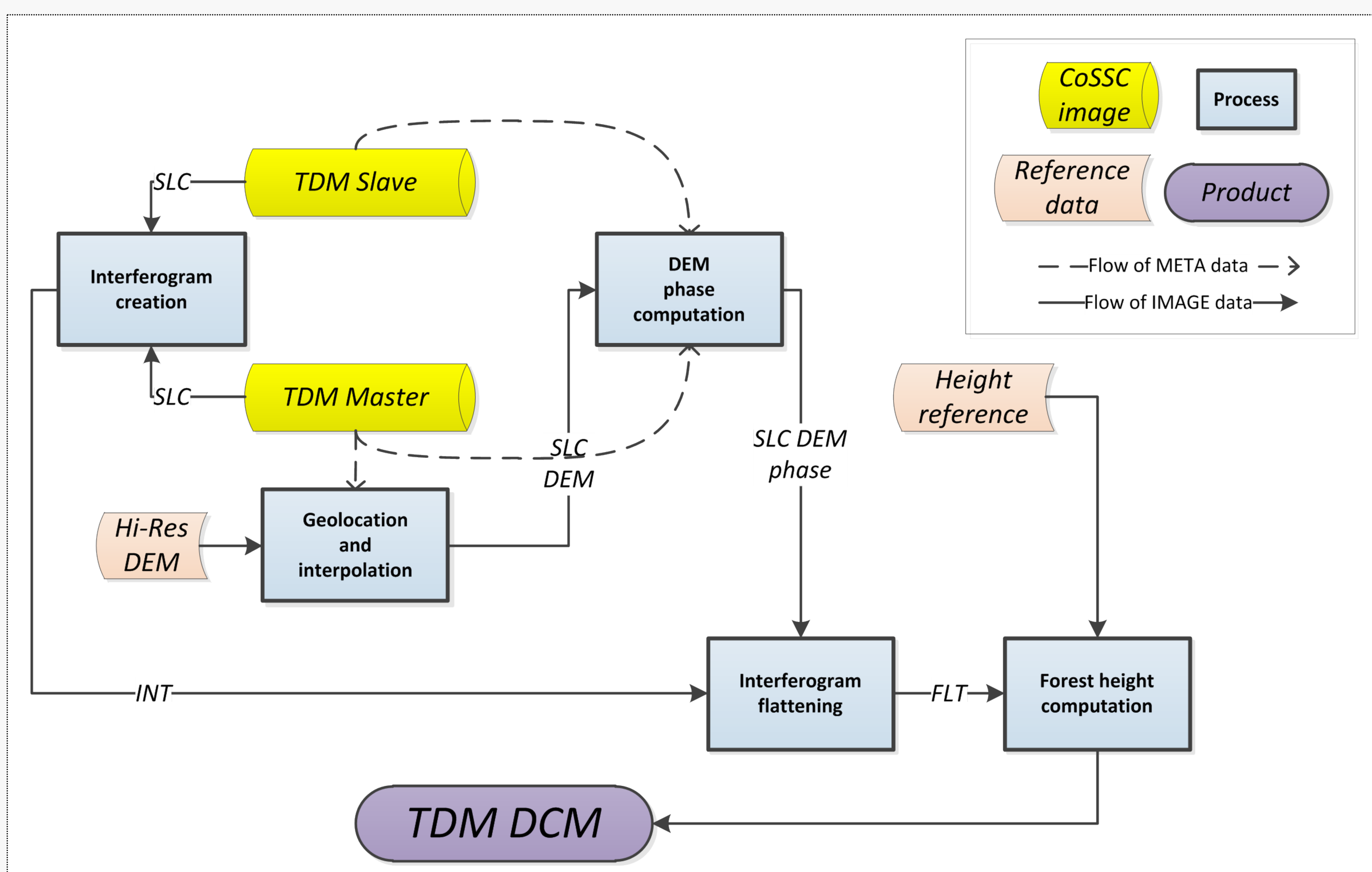

Figure 1: Flow chart for processing of interferometric TDM pairs (shown above as yellow cylinders) to obtain DCM.

Data

VV-polarised, scientific TDM data acquired over the boreal test site of Remningstorp, situated in southern Sweden, are used. The data delivered by DLR consist of two co-registered single-look complex (SLC) images together with auxiliary information, which includes orbit vectors (satellite positions and velocities). Ground range and azimuth resolutions of TDM images are of the order of 2-3 m and 3-7 m, respectively, depending on the acquisition scenario and geometry.

Processing

Geocoding and interferometric processing of TDM data to DCM is done with a MATLAB-based algorithm, see Figure 1. The processing is done in radar geometry, after the DEM has been transformed to range-azimuth coordinates. Interferometric phase caused by ground topography and Earth curvature is first computed from the DEM and orbit vectors, and then removed from the interferogram by means of complex multiplication. The resulting flattened interferogram is averaged using a 5x5 window, and its phase ϕ_{flt} is converted to DCM using:

$$DCM = HOA \cdot \frac{\phi_{flt}}{2\pi} - H_0,$$

where $HOA = \lambda R \sin\theta\, B_\perp^{-1}$ is the height of ambiguity (vertical height difference equivalent to a 2π interferometric phase shift, for wavelength λ, range R, incidence angle θ, and perpendicular baseline $B_\perp$), and H_0 is a height offset (here estimated from lidar data in non-forested areas).

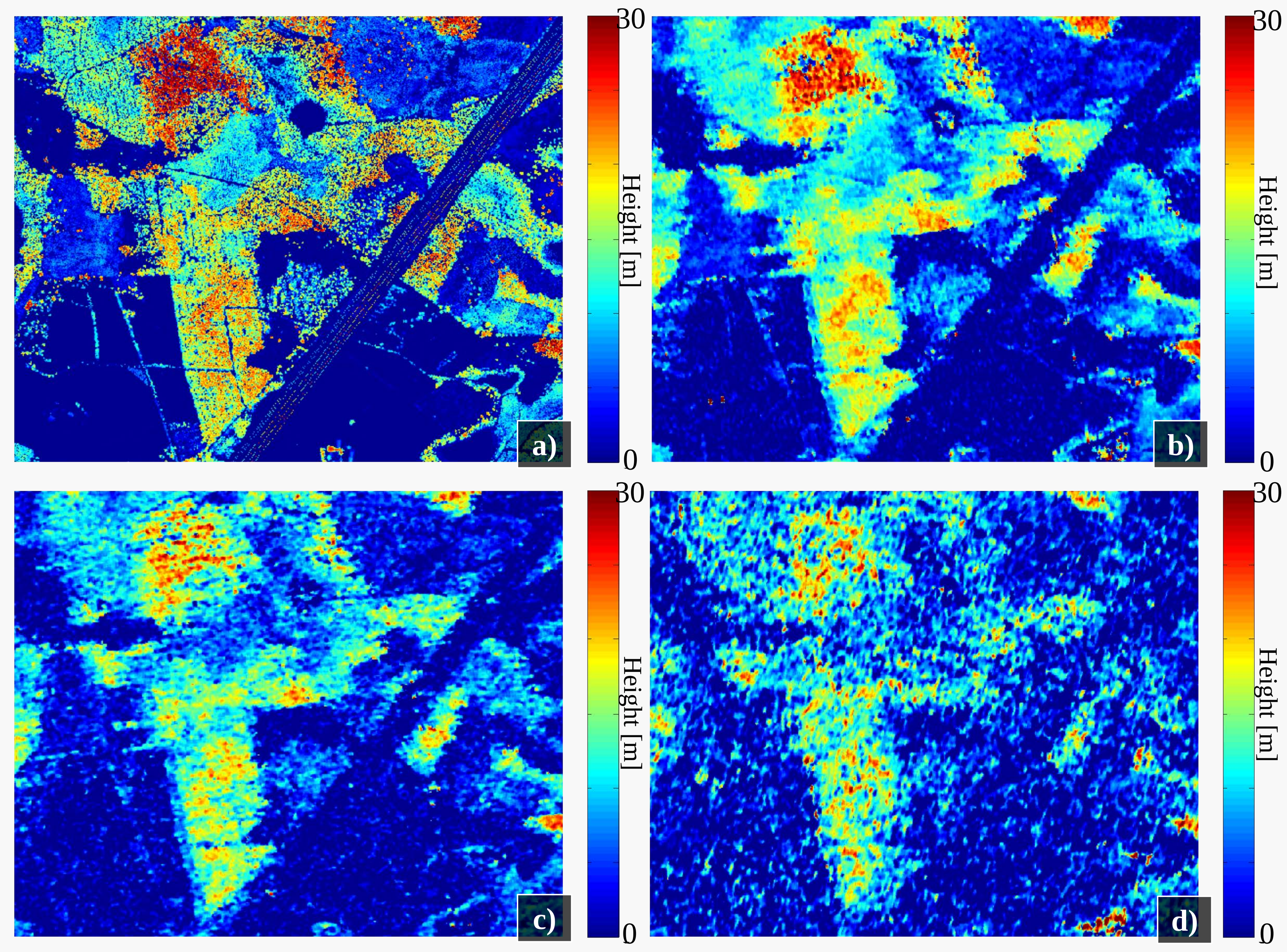

Figure 2: HOA influence on DCM quality. a) Lidar DCM, 29/08/2010 b) TDM DCM, 04/06/2011, HOA=49 m c) TDM DCM, 01/02/2012, HOA=78 m d) TDM DCM, 26/12/2011, HOA=181 m

Results

In Figure 2, four DCMs of the same region in Remningstorp are shown. In Figure 2a), lidar DCM acquired on August 29th, 2010 is shown (pulse density: at least 10 m^{-2}, here resampled to 2 m x 2 m pixels to match the DEM and TDM DCMs). In Figures 2b)-d), TDM DCMs are shown for three different HOA values: 49 m, 78 m, and 181 m. As it can be observed, DCM quality decreases with HOA. As HOA is inversely proportional to the perpendicular baseline, large HOA values correspond to short baselines, resulting in low height sensitivity. On the other hand, large baselines will cause loss of coherence due to baseline decorrelation. Therefore, HOA need be large enough to provide high coherence, but small enough to keep the sensitivity high.

In Figure 3, three DCMs for a different region in Remningstorp are shown. They are ordered chronologically: first, the lidar DCM from August 29th, 2010 is shown, followed by two TDM DCMs, one from June 4th, 2011 (HOA=49 m) and one from August 28th, 2012 (HOA=36 m). As it can be observed, several clear-cuts have been done between the acquisitions, resulting in reduction of forest height in the DCMs.

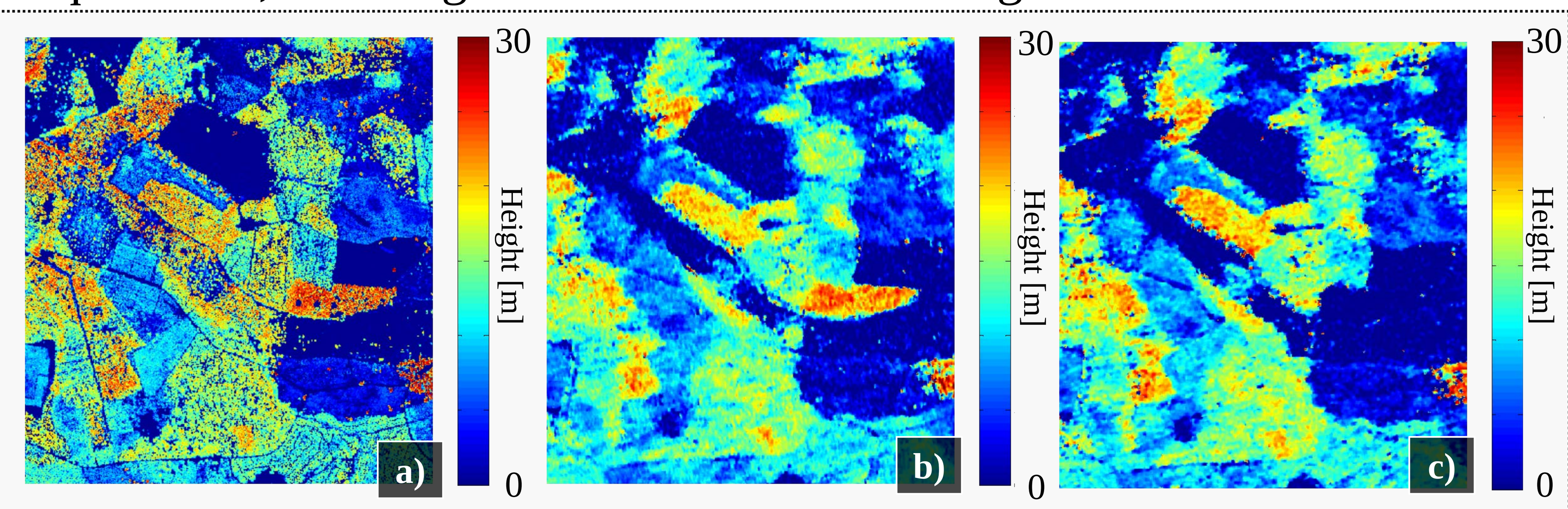

Figure 3: Detection of temporal forest change. a) Lidar DCM, August 2010 b) TDM DCM, June 2011 c) TDM DCM, August 2012

Conclusions

TDM DCMs show good agreement with lidar DCM, provided that the choice of HOA is made correctly. Forest changes such as clear-cuts can easily be detected.

Acknowledgements

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