DUAL POL-INSAR FOREST HEIGHT ESTIMATION BY MEANS OF TANDEM-X DATA

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1. INTRODUCTION

The TanDEM-X mission [1] provides for the first time single pass (single- and dual-) polarimetric interferometric data from space. This allows the acquisition and analysis of Pol-InSAR data without the disturbing effect of temporal decorrelation on a global scale. Polarimetric interferometric X-band data are now available for different forest ecosystems (from boreal to tropics) in different seasons. The penetration capability of X-band in vegetation is limited and depends strongly on the corresponding forest conditions. However, first data analysis showed sufficient penetration to apply Pol-InSAR height estimation at least for a boreal forest scenario [2]. The limitations of X-band for forest parameter estimation can be identified by analyzing data sets from different forest types. Additionally seasonal effects like leaf fall or freezing conditions may change the backscattering behavior or penetration capability of X-band for forests. It was already shown that the ability to penetration depends on the seasonal stage of a forest. Figure 1 on the left shows the penetration depth of X-band by means of boreal forest (Krycklan forest northern Sweden) for a summer (Figure 1 left side) and a winter (Figure 1 middle) acquisition. Penetration depth of the winter acquisition is with a mean of 11.8m significantly larger than for the summer acquisition with a mean of 9.45m. This is probably due the lower dielectricity of the tree compartments in frozen conditions.

1. POL-INSAR DATA EVALUATION

An indicator for the applicability of Pol-InSAR is the maximum phase difference $\Delta\varphi$ between the polarizations with the lowest $\tilde{\gamma}_{Vol}(\vec{w}_{\min})$ and the highest ground contribution $\tilde{\gamma}_{Vol}(\vec{w}_{\max})$. In this paper the phase difference was maximized by applying Schur's decomposition to dual Pol (HH/VV) Pol-InSAR data. Figure 2 left side shows a plot of $\Delta\varphi$ (converted to a height difference in [m]) as a function of forest height. $\Delta\varphi$ increases with increasing forest height (up to 7m), but with increasing forest height also the variance of $\Delta\varphi$ increases. This reflects the heterogeneity of the different forest stands but

also indicates sufficient penetration capability that enables Pol-InSAR forest height inversion [5][6][7][8] with TanDEM-X data.

BOREAL FOREST

First inversion results were obtained for the Krycklan-test site. A validation plot for forest heights obtained applying Pol-InSAR with TanDEM-X data is shown in Figure 1 on the right. Data for this were acquired during the pursuit monostatic phase of the mission i.e. in a repeat pass mode with 3 seconds of temporal baseline. In [4] was lined out that 3 seconds of temporal decorrelation are sufficient making a meaningful Pol-InSAR inversion impossible. Therefore temporal effects can not be completely excluded for the result shown in Figure 1 on the right. TanDEM-X data acquired in the bistatic mode could probably improve the results for this test site.

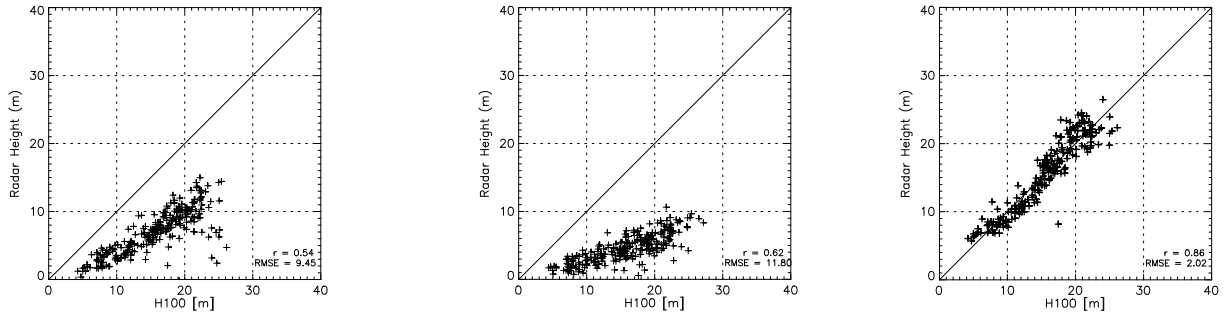

Figure 1: Test site Krycklan forest (boreal forest in northern Sweden) [2]; left: Penetration depth HH polarization 17th Juli 2010 (r^2=0.54, RMSE = 9.45m); middle: Penetration depth HH polarization 17th December 2010 (r^2=0.62, RMSE = 11.80m); right: Validation Plot Pol-InSAR Height estimates vs LIDAR H100 (r^2=0.86, RMSE = 2.02m)

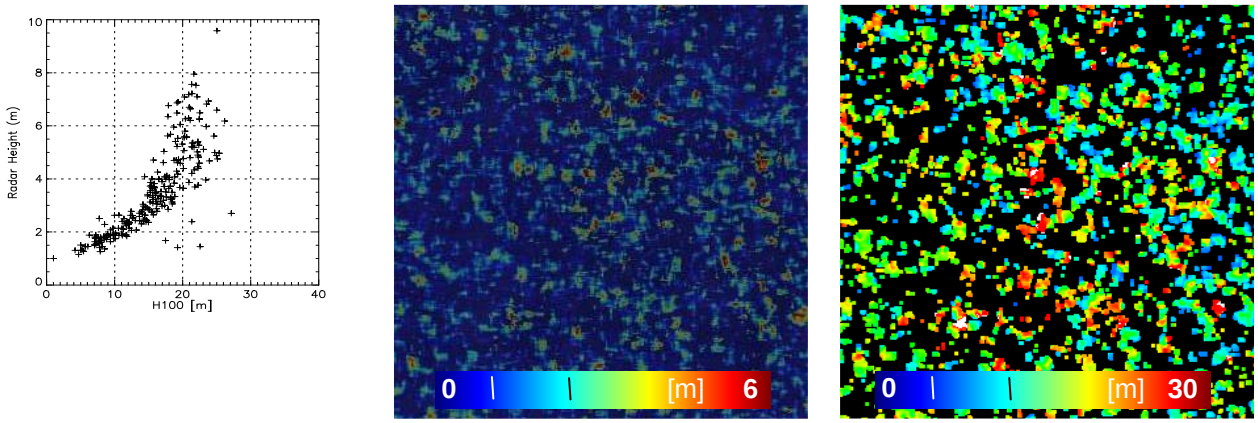

Figure 2: left: Maximized polarimetric phase difference (minimum ground contribution, maximum ground contribution) vs LIDAR H100 for Krycklan forest in northern Sweden; middle: image section of maximized polarimetric phase difference (minimum ground contribution, maximum ground contribution) for a Savannah forest in Krüger Park South Africa; right: image section of forest heights obtained from Pol-InSAR forest height inversion

2. SAVANNAH FOREST

In the previous section the potential of TanDEM-X data for Pol-InSAR forest applications was demonstrated for a boreal forest test site. Analysis and evaluation of the potential of TanDEM-X for other forest ecosystems is still missing.

Figure 2 middle shows the maximum phase difference $\Delta\varphi$ (in [m]) for a savannah forest in Krüger Park South Africa. This forest type is characterized by single trees or tree groups interrupted by grassland or bare soil. For this forest type a maximum $\Delta\varphi$ of 6m could be observed. The $\Delta\varphi$ map shows already the for this forest type characteristic forest (high $\Delta\varphi$) - open land (low $\Delta\varphi$) patterns. The corresponding forest height map is displayed in Figure 2 right side. Forest height reaches a maximum of 30m. A validation of this result is still missing and should be part of the work for this paper.

2. OUTLOOK

Results obtained for the Savannah forest indicate already the transferability of the results obtained for boreal forest to other forest ecosystems. But boreal forests and savannah forests are less dense ecosystems and therefore easy to penetrate even for frequencies like X-band. In dense vegetation as for example found in the tropical belt it is expected that X-band saturates. A penetration of X-band down to the ground –which is required for a successful Pol-InSAR implementation [3][8] is probably not anymore given.

Another open point is the seasonality of forest backscattering. The penetration capability of X-band depends strongly on the density and the dielectric properties of the vegetation. Dielectricity decreases at freezing conditions or during dry seasons which again increases the penetration capabilities of X-band. Differences in penetration depth due to freezing - non freezing conditions were already shown in [2] (see also Figure 1 left side and Figure 1 middle) but their consequences for a successful height inversion are not yet described. An analysis of the effects of leaf on - leaf off forest stages or the differences in backscattering of a forest between dry season and wet season is missing too.

Acquisitions planned according to the forest stage (dry, wet, leaf on, leaf off, frozen or non frozen) with the best performance could probably increase the number of forest types where X-band could provide reliable height estimates.

This paper should close at least some of the mentioned gaps, whereas the focus of data evaluation will be on tropical forest systems.

A successful analysis of Pol-InSAR data depends also on the availability of up to date ground reference data. For this paper LIDAR reference measurements are available for two tropical ecosystems (lowland dipterocarp forest and tropical peat swamp forest) on the island of Borneo and for a temperate forest system located in southern Germany. For all three test sites TanDEM-X data were acquired too.

11. REFERENCES

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