MAPPING OF WIND-THROWN FORESTS USING SATELLITE SAR IMAGES

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ABSTRACT

The study includes investigation and evaluation of mapping of wind-thrown forest using satellite radar remote sensing. For this purpose, remotely sensed data from three satellite synthetic aperture radar (SAR) sensors are used together with field observations. The study involves analysis of a well characterized test site located in the south of Sweden. The satellite data consist of time series of SAR images acquired by the Advanced Land Observing Satellite Phased Array type L-band Synthetic Aperture Radar (ALOS PALSAR), TerraSAR-X and Radarsat-2. In addition, digital aerial photographs captured by a small Unmanned Aerial Vehicle (UAV) are used as a visual reference. The major benefits of using satellite SAR are the all weather day and night capability and the short revisit time, feasible to provide timely maps. The ultimate goal of the present study is to develop a new application for mapping of wind-thrown forest using high-resolution SAR data, where previous satellite sensors have been unable to deliver the information required in a timely fashion. The set up of the study will also allow a comparison of images acquired by the three SAR sensors and the possibility to investigate synergies among those.

Mapping of wind-thrown forest using satellite data is an area of research important to explore further. This was demonstrated in 2005 and 2007, when devastating storms hit Sweden (among other countries) causing large damages to forested areas. In these two storms, it was estimated that about 70 million cubic meters (2005) and about 12 million cubic meters (2007) of timber fell down to a value of billions Euro. At these occasions, a rapid mapping of wind-thrown forests is crucial in order to salvage timber values and prevent insect outbursts that could kill the remaining standing trees. After a severe storm it is also of high importance to get a fast overview to assess the roads that should be cleared from wind-thrown trees as well as detect power lines that are broken. It is likely that storm events causing damages to forests will occur more often in the future due to global climate change; one reason being the warmer temperature during winter time.

After the devastating storm in 2005, research activities for detecting wind-thrown forests were initiated and conducted. Satellite images were provided from the International Charter for Space and Major Disasters that is an instrument for rapid provision of images in catastrophic events. A large number of different spaceborne remote sensing techniques were investigated including optical remote sensing. The success of the optical satellites was limited by the prevailing winter conditions (low sun-angle, extensive cloud cover and variable snow cover). The radar analysis showed that with a limited number of backscatter intensity images from C-band SAR onboard Envisat and Radarsat-1 it was not possible to detect wind-thrown forests due to too high frequency and coarse resolution [1-2]. However, a sign of storm damage was seen in the highest resolution Radarsat-1 images as changes in texture, primarily related to changes in shadowing from standing/fallen trees.

The lack of sensitivity in backscatter measurements with coarse resolution at shorter wavelengths is possible to explain theoretically as the felling of trees does not change significantly the total backscatter, since the needles and small branches are still present as a randomly oriented scattering volume. At coarse resolution, the speckle noise is also more extended compared with higher resolution SAR images, limiting the possibilities to detect wind-thrown forests. Another issue that should be accounted for is the effect of soil moisture on backscatter measurements. On the other hand, longer wavelengths are sensitive to larger structures like stems and large branches that would improve the possibilities to detect wind-thrown forest. In particular, the significantly improved resolution of satellite SAR images is expected to improve the possibilities to detect wind-thrown forest. Thus, to further explore the use of radar remote sensing to detect wind-thrown forest it is of interest to analyze images from the new satellite SAR systems ALOS PALSAR (L-band) because of the longer wavelength, and TerraSAR-X and Radarsat-2 because of the high resolution (on the order of meters).

A preliminary investigation on the feasibility of mapping wind-thrown forest using ALOS PALSAR data was carried out as a controlled experiment, where trees were manual felled to simulated wind-thrown forest. The experiment took place in 2006 at the test site Remningstorp located in the south of Sweden [3]. The results showed that the backscatter intensity decreased about 1.6 dB for the PALSAR Fine Beam Single 34.3° (look angle) HH polarized images, when comparing the reference with the wind-thrown stands. This drop in backscatter is not considered enough in order to detect wind-thrown forests. Hence, further research should also focus on image texture analysis to evaluate whether PALSAR data can be used for detection of wind-thrown forests.

With the launch of TerraSAR-X and Radarsat-2 in 2007, high-resolution spaceborne SAR data became available and the idea of further evaluating the possibilities to detect wind-thrown forest was restored. A second controlled experiment was carried out in September of 2009 at the Remningstorp test site. The simulation of wind-thrown forest was done, once again, by manual felling of trees and instead of stripping and removing the trees (as is done in clear-felling), the trees were left for a few orbit repeat cycles to ensure image acquisitions after the "storm". In total, four coniferous stands with a size of about 1.2 ha were used to simulate wind-thrown forest. The trees were felled in two directions to simulate two possible main wind directions during a storm. For two of the stands, the trees were felled in 35° and for the other in 80° with the heading measured clockwise from north (0°). In Fig. 1, a mosaic of digital aerial photographs captured by a UAV shows three of the investigated stands after tree felling together with a photograph taken from the ground. For the entire duration of the experiment, TerraSAR-X and Radarsat-2 were programmed to acquire data at different look angles and in both descending and ascending passes in order to study differences in the shadowing effects.

Fig. 1. A mosaic of digital aerial photographs captured by a UAV covering three of the simulated wind-thrown forest stands, each with a size of about 110 × 110 m^2 (left) and a photograph taken from the ground over one of the stands (right).

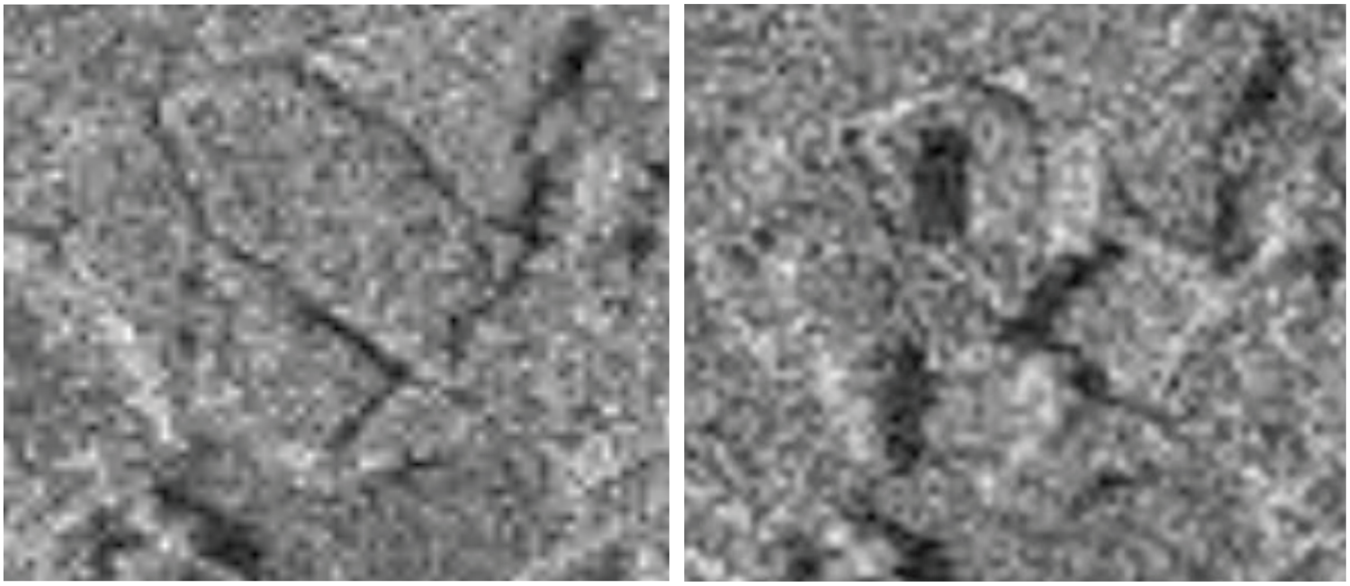

Fig. 2. Radarsat-2 UltraFine HH polarized images with a look angle around 41° acquired on 2009-08-23 before the simulated wind-throw (left) and on 2009-10-10 after the simulated wind-throw (right). Note the shadowing and layover effect in the border line between standing/fallen trees.

The analysis will be focused on change detection techniques, in particular image texture analysis in order to develop an algorithm able to detect wind-thrown forests; one part being to trace the expected shadowing effect in the border line between standing/fallen trees. As an example, Radarsat-2 UltraFine HH polarized images acquired before and after tree felling are shown in Fig. 2 (over the same area as in Fig.1 (left)). Here, the shadowing effect from standing/fallen trees is clearly visible as three dark patches in the central part of Fig. 2 (right).

The result from the visual interpretation of SAR images acquired by Radarsat-2 implies that it may be possible to develop a new application for mapping of wind-thrown forests.

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REFERENCES

[1] L.M.H. Ulander, G. Smith, L. Eriksson, K. Folkesson, J.E.S. Fransson, A. Gustavsson, B. Hallberg, S. Joyce, M. Magnusson, H. Olsson, A. Persson, and F. Walter, "Mapping of wind-thrown forests in southern Sweden using space- and airborne SAR," in Proc. IGARSS 2005, Seoul, Korea, 25-29 July, 2005, pp. 3619–3622.

[2] L.M.H. Ulander, G. Smith, L. Eriksson, K. Folkesson, J.E.S. Fransson, A. Gustavsson, B. Hallberg, S. Joyce, M. Magnusson, H. Olsson, A. Persson, and F. Walter, "Evaluation of using space- and airborne radar for mapping of wind-thrown forests after the January 2005 hurricane in southern Sweden," in Proc. ForestSat 2005, Borås, Sweden, 31 May-3 June, 2005, 6 pages.

[3] J.E.S. Fransson, M. Magnusson, H. Olsson, L.E.B. Eriksson, G. Sandberg, G. Smith-Jonforsen, and L.M.H. Ulander, "Detection of forest changes using ALOS PALSAR satellite images," in Proc. IGARSS 2007, Barcelona, Spain, 23–27 July, 2007, pp. 2330-2333.