Winter vs Summer Polarimetric Classification of Siberian Forests in X- and L-band

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Abstract

The paper presents the dependency of polarimetric classification of the natural land covers and, particularly, forests, on the freezing/thawing conditions. It is shown that X-band data are less dependent on the season than L-band. In L-band polarimetric classification the quantity of double-bounce and dipole-type scatterers vanishes almost totally in winter for all types of natural covers. X-band data demonstrate decreasing the number of pixels in double-bounce and dipole classes in the forest as well as increasing the area covered by the surface scattering class for freezing dates. In this study ALOS PALSAR 2006-2008 data were compared with TerraSAR-X 2014-2015 data.

1 Introduction

Scattering mechanism decomposition based on coherency matrix' spectral properties [1] is a powerful tool for interpretation of polarimetric SAR images of forests. In particular, it gives a possibility to highlight the regions with vegetation structure for the further analysis of its density, tree height etc. As it was noted in [2] and [3,4], winter condition in boreal forests can change dramatically the interrelation between polarization channels, and, in its turn, the result of polarimetric classification.

In this paper we compare the influence of the negative/positive air temperature during the observation date on the result of polarimetric classification in L- and X-band over forest and neighboring non-forested land cover.

2 Test Site and Data Set

Our test site is in Siberia, on the south-eastern beach of the Baikal Lake. There are coniferous (pine and fur) forest there, and also fields, meadows, pastures, and shrubby banks and islands in the delta of the Selenga River.

We use ALOS PALSAR archive data for the analysis of L-band SAR data classification and TerraSAR-X/TanDEM-X data for X-band.

ALOS PALSAR data for the area of interest were collected in 2006-2008, for different seasons of year and weather conditions. The full list of PALSAR processed data is in [3]. As ALOS-2 observation plan doesn't include the area of interest in fully polarimetric quad-pol mode, the nowaday data set consists of X-band TerraSAR-X data only.

The list of TerraSAR-X data takes from 2014/2015 winter and spring season is the **Table 1**.

Table 1: Dates and weather conditions for TerraSAR-X/TanDEM-X data takes

Date (yyyymmdd)	Air Temperature, °C	Precipitation
20141228	-1	-
20150108	-6	-
20150119	-4	light snow
20150221	-16	-
20150304	-2	-
20150417	+3	rain
20150428	+10	-

3 L-band Processing Results

Some previous results of the processing ALOS PALSAR data show that the entropy-alpha classification by S. Cloude and E. Pottier [1] for winter data takes are totally surface-like, e.g. in it the dipole vegetation scattering mechanism and double-bounce mechanism are both absent [3]. The entropy becomes lower for all types of the land cover of the scene, and the alpha angle too.

In the **Figure 1** one can see two entropy-alpha classification results for Istomino forest, where the first data take on the left was acquired on May 28 (air temperature +20°C) and the second one on the right side of the figure was taken on November 30 (air temperature was equal to –11°C). The forest border is still explicit on the right image in comparison with the neighbouring fields as a result of different entropy level, but the scattering mechanism has been changed.

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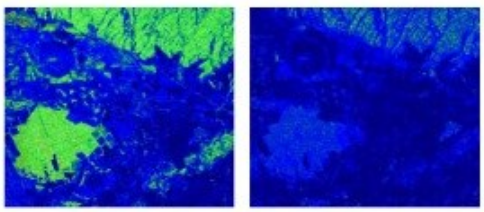


Figure 1: Entropy-alpha classification of ALOS PALSAR data on Istomino forest near Baikal Lake. Green: dipole vegetation scattering, blue: medium entropy surface scattering, dark blue: low entropy (very smooth) surface scattering. Left: 28/05/2006; right: 30/11/2006.

The freeze in the end of November (30/11/2006) results in a fall of the alpha angle below 40°, and entropy value becomes 0.63, and in the warm May (28/05/2006) these values were 48 and 0.86, correspondingly. As a result, there are only few rare green (vegetation type) pixels on the right (winter) part of the **Figure 1**.

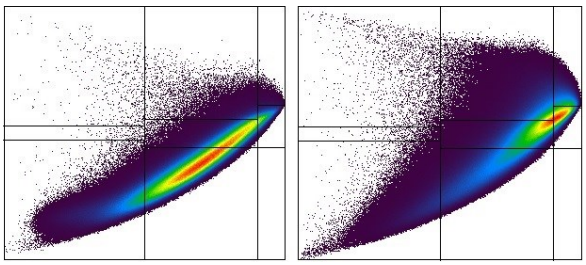
4 X-band Processing Result

As it is shown in the **Table 1**, the minimal air temperature value on the area of interest was on 21/02/2015 (-16°C) and the warmest observation date of this data set is 28/04/2015 (+10°C).

These two images were processed for entropy and alpha angle decomposition. The classification in X-band differs from L-band, mainly due to influence of the scattering surface roughness in scale of the wavelength: both classification images demonstrate higher entropy value in comparison with L-band.

Figure 2 shows alpha and entropy plane for the February (left) and the April (right) data takes. Colour scale corresponds to the number of pixels with the certain value of an {Entropy, Alpha} pair, from 0 (violet) to the maximal (red).One can see that the maximum of the histogram (the red spot in the center) moves in the April plot to the higher entropy and to the higher alpha also. And, in general, the April plot is larger and the rate of the double-bounce scattering is greater in it. Thus we can see that in L-band and X-band difference for frosty and warm weather is the same: in winter the entropy and alpha decrease. The difference is also obvious: the contribution of the double-bounce mechanism is much more than in L-band, and the whole "interior of parabola" in the **Figure 2** is shifted to the right and to the top.

See, e.g., the **Figure 3** for comparison. There is almost empty top left rectangle, and poorly dotted the rest top rectangles. The most part of the image corresponds to the surface and dipole scattering, and one can see that there are two maximum of the histogram: for surface and for dipole-type scattering natural targets.



21/02/2015 28/04/2015

Figure 2: Entropy and alpha angle planes for TerraSAR-X data. Vertical axis: alpha from 0 to 90 degrees. Horizontal axis: entropy from 0 to 1.

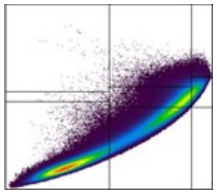
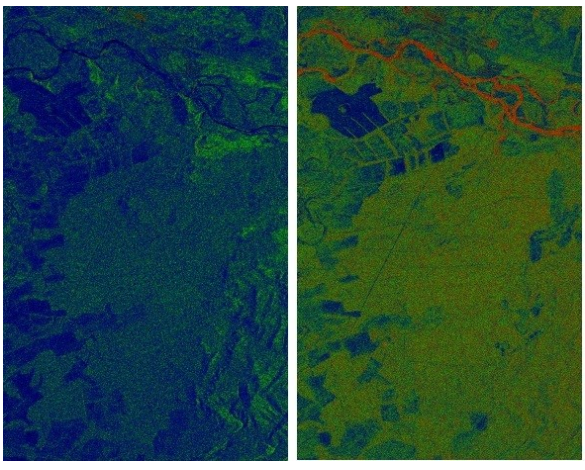


Figure 3: Entropy and alpha angle plane for PALSAR data, warm date (28/05/2006).

On the classification images (**Figure 4**) we can see that green dipole classes present on all images in the forest even for frosty dates, in the opposite to the L-band classification (**Figure 1**).



21/02/2015 28/04/2015

Figure 4: Fragments of entropy-alpha classification images for TerraSAR-X data. Blue: surface scattering mechanism, green: dipole (vegetation branches/needles) scattering mechanism, red: double-bounce scattering mechanism.

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Light green dipole-scattering pixels with high entropy on the left February image, especially in its upper and right part, are the mountain slopes effect. The dark green pixels on the February image correspond to the forest and to the area over the river delta covered by bushes. The boundary of the forested areas are more explicit in the frosty image (**Figure 4**, left), in spite of presence of numerous point-like inclusions of the blue surface scattering class all over the forest. In the April classification one can see the appearance of the red double-bounce class in the forest, they are also point-like. In addition, in the upper part of the April classification image there are arms of the river Selenga, they are red too. It is a manifestation of river ice thawing, that results in a very low backscattering level of all polarization channels. In such a case a small bias (direct current) in signal data can lead to incorrect polarization phase difference estimation, e.g., high alpha angle level.

The main differences in L- and X-band classification results are collected in the **Table 2** as well as the effect of the low air temperature on a polarimetric entropy-alpha classification. For example, we can see that decreasing of entropy and alpha values in frosty days leads to change of scattering mechanism for forest area in L-band, and to decreasing of the rate of dipole scattering pixels for the same forest in X-band with appearing pointwise surface class in the forest. Similarly, the non-forested areas change the medium entropy class to the low entropy class in L-band, and in the X-band the same territory is a mix of surface and dipole pixels on warm date, and mainly surface class in the case of frost.

5 Conclusion

The study revealed that the freezing conditions decrease the rate of high alpha and entropy pixels in the images for both X- and L-band data.

At the same time, the main scattering mechanisms of the land covers are different for these two wavelength, and the distribution of the {entropy, alpha} pairs on the plane are quite different.

6 Acknowledgements

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References

[1] S.R. Cloude and E. Pottier, *An Entropy Based Classification Scheme for Land Applications of Polarimetric SAR,* IEEE Transactions on Geoscience and Remote Sensing. 1997. Vol. 35, no. 1, pp. 68–78, January 1997

[2] Kwok, R., Rignot, E.J.M., JoBea Way, J.B., Freeman, A., and Holt, J. *Polarization Signatures of Frozen and Thawed Forests of Varying Environmental State,* IEEE Transactions on Geoscience and Remote Sensing, vol. 32. No. 2. March 1994.

[3] L.N. Zakharova. *Seasonal variations of land cover polarimetric properties on ALOS PALSAR images,* 8th European Conference on Synthetic Aperture Radar (EUSAR-2010), 7-10 June 2010, Eurogress, Aachen, Germany.

[4] Zakharova, L.N., *Some peculiarities of polarimetric classification for winter data takes,* Proc. of 2011 IEEE International Geoscience and Remote Sensing Symposium (IGARSS-2011), Vancouver, Canada, 24-29 July 2011. P. 389–392.

Table 2. Effect of freezing weather on the polarimetric classification of two land covers in two frequency bands.

	L-band	X-band
Forest	dipole → surface	double-bounce+dipole → dipole+surface
Non-forested	surface medium entropy → low entropy	dipole+surface → surface