CHANGES OF SCATTERING MECHANISMS IN BOREAL FORESTS UNDER FREEZING CONDITIONS BY MEANS OF SAR POLARIMETRY

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ABSTRACT

The paper aims at polarimetric analysis of PALSAR and PALSAR-2 quad-polarimetric data over Canadian boreal forests. Low air temperature in winter in the area leads to decreasing the radar cross-section, changes of scattering matrix properties, and results in confusing classification maps, which are variant in different seasons. The study demonstrates that air temperature is a simple weather parameter correlating with some polarimetric characteristics of a target. The mean daily temperature in the day before observations is found to be more suitable parameter than current temperature. The increasing interval of temperature averaging (2-7 days) does not improve the resulting correlation. Under freezing conditions the dominating scattering mechanism is a surface scattering even for dense forests. Time series of the polarimetric classification parameters alpha angle and entropy gives a possibility to distinguish real surface scattering from temporal one, that is caused by frost.

Index Terms— Synthetic aperture radar (SAR), SAR polarimetry, polarimetric target decomposition, forest classification

1. INTRODUCTION

Polarimetric target decompositions are well-known tool for land cover classification by means of quad-pol SAR data. Krogager decomposition [1] distinguishes backscattering from spherical, diplane, and helix-form objects. Freeman decomposition [2] shows the contribution of surface, volume, and double-bounce scattering mechanisms. Decomposition by Cloude and Pottier [3] based on eigenvectors and eigenvalues analysis of coherency matrix. Eight classes in the latter can provide a clear classification of natural land covers. It is effective for numbers of climatic zones from rainforest to tundra.

However, boreal forests are subject to annual weather changes with freezing/thawing periods. Under freezing conditions radar backscatter of copolarized channels drops by 3-4 dB [4], and cross-polarized channels RCS decreases even more resulting in scattering matrix distortions. Coherency matrix parameters changes alongside with it, and, as a consequence, one gets different values of alpha angle and eigenvalues entropy for winter and summer polarimetric SAR images of boreal forests, e.g. for L-band images of Siberian forest not far from Baikal Lake [5]. The similar results were reported for C-band [6] and X-band SARs [7]. The present paper focuses at time series that includes ALOS-1 and ALOS-2 SAR images of the neighbourhood of Watson Lake, Canada. Long observation period from 2007 to 2016 allows estimate the dependence of decomposition parameters on weather conditions.

2. DATA SET

As it was stated before, forests in Baikal Lake region changes dramatically their scattering mechanisms from dipole to surface-type in frosty dates [5]. Siberian data set had only two cold days with the same temperature (–11℃), so it was challenging to find some quantitative relationship between weather conditions and classification parameters. Now Canadian time series consists of 25 scenes with more than a half dates with air temperature below zero (Celsius). The most of all scenes is covered by pine forest of different density. Entropy-alpha polarimetric classification of all 25 scenes shows that the amount of vegetation class (with alpha angle near 45 degrees and entropy between 0.5 and 0.9) varies from 1% to 72% of the whole scene. For forested territories the percentage of the "vegetation" class can be informative parameter: as it was found in this study, it correlates with air temperature. Pearson correlation coefficient is equal to 0.82 for our test site. As freezing and thawing are slow processes, it is worth noting that the current air temperature measured near the moment of observation is not the perfect weather parameter: the mean temperature for previous several days can be more informative (we can draw an analogy with another weather parameters, e.g., the influence of precipitation on radar backscatter in [8]). Thus we estimated the correlation coefficient between percentage of vegetation class and mean temperature for the several days before observation (from 1 to 7). As one can see on the Figure 1, correlation is slightly better than the instant measurement (0.88 vs 0.82), but there is not improving with the increasing number of days.

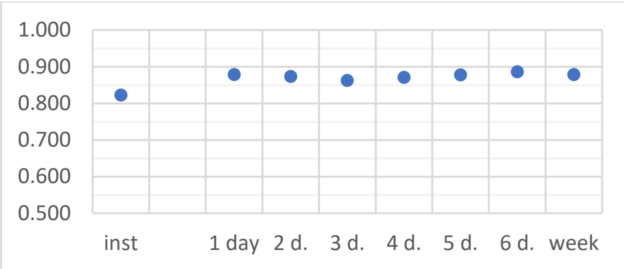

Figure 1. Pearson correlation coefficient between percentage of the vegetation class and air temperature (instant and mean for 1-7 days before observation)

3. TIME SERIES OF ALPHA AND ENTROPY VALUES

Our 25 scenes cover the neighboring areas, but some of them are not overlapping with others. Pine forests that cover the territory make them similar to each other, but the accurate measurements require the same region of interest. In order to compare alpha and entropy values of the same area we selected 2 groups of our quad-pol radar images, all images in each group have the intersected part, so it is possible to find some regions of interest within it. The first group consists of 5 images: 3 of them taken by PALSAR in 2007-2009 and 2 taken by PALSAR-2 in 2014-2015). The second group contains 8 images (5 PALSAR and 3 PALSAR-2).

3.1. Group 1: forests vs bare soils

Entropy and alpha angle mean values were estimated for four region of interests (ROI) of the first data subset (Group 1). Two ROIs are in the forest, and two are almost without trees. Fig. 2 illustrates difference between forests (ROI 1 and ROI 4) and non-forest (ROI 2 and ROI 3), as well as decreasing of alpha angle in the frosty date 20091210 with daily average temperature –21°C. Let us note that only in June (20070604) and May (20150505) alpha angle for both forests is above 40-42 degrees (that is a threshold between surface and dipole scattering mechanisms). Entropy values (not presented in the figures) allow easily separate forest from non-forest as well, and all of them are between 0.5 and 0.9 (medium entropy zone), except for the same cold day 20091210: bare soil shows the lowest entropy of 0.4 on it. Entropy values for two forest sites are very close to each other with maximal difference between ROI 1 and ROI 4 that equal to 0.02, so alpha angle can be more suitable parameter for distinguishing forest types by means of temporal dynamics of their scattering properties.

3.2. Group 2: different forests and deforestation

The second data subset (Group 2) has only one field ROI, and 4 ROIs of different forests. Alpha values for non-forest region is between 20 and 30 degrees with increasing and decreasing that correspond to the temperature changes in general (see Fig.4, data available at Canadian web-archive [9]). Forest ROIs gives alpha values above 40 degrees for all dates except for two frosty ones: 20070402 and 20160117, when the air temperature was –11°C and –13°C, respectively (they are the first and the last dates on the Fig. 3 and Fig. 4). In three warm dates (20070518, 20090609, 20150421) differences between alpha values are minimal for ROI1, ROI2, and ROI3. Our ROI4 (with diamond marks on the Fig 3) is remarkable: since 2014 it becomes closer to the surface-type scattering. This ROI is located on a swamp between small lakes, and the amount of trees on it decreased since 2014, so alpha decrease indicates deforestation here.

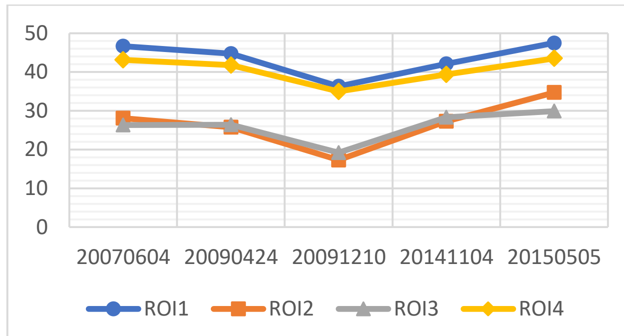

Figure 2. Alpha angle values (degrees) for Group 1 (observation dates are given in the format yyymmdd).

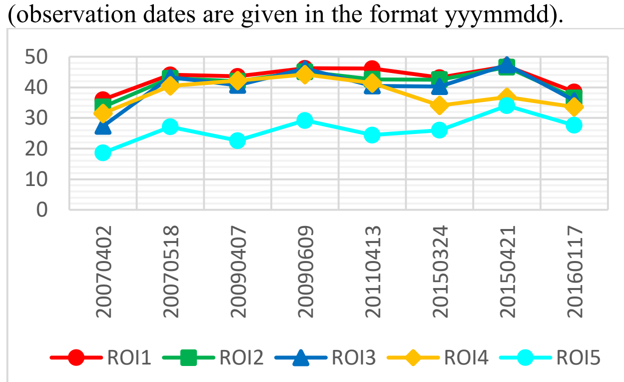

Figure 3. Alpha angle values (degrees) for Group 2 (observation dates are given in the format yyymmdd).

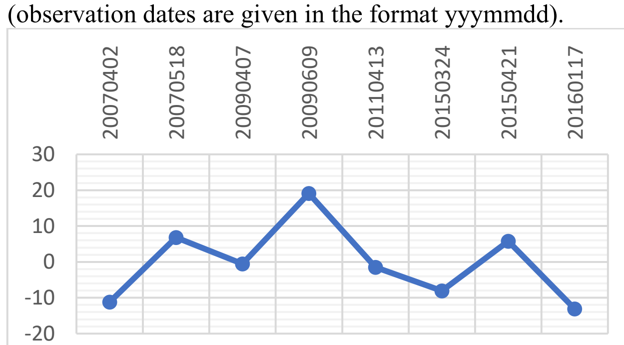

Figure 4. Daily air temperature (Celsius degrees) for the Group 2 (observation dates are given in the format yyymmdd).

As one can see on Fig. 3-4, the temperature drop corresponds to significant alpha decrease in the forest ROIs only in the case of zero crossing: 18°C difference between 20070402 and 20070518 results in alpha increasing from 27 to 43 degrees, whereas 20°C difference between 20090407 and 20090609 corresponds to alpha increasing from 41 to 46 degrees. The ROI 1 (circle markers on the Fig. 3) gives the minimal temporal variations: it is the most homogenous and rather dense forest site. The ROI 3 (triangle markers on the Fig. 3) is a forest with the lowest tree density, and, consequently, the highest impact of surface scattering with the highest temporal variations of alpha angle.

3.3. Group 2: differences between PALSAR-1 and PALSAR-2 data

Along with temperature dependence stated above there is difference between PALSAR-1 and PALSAR-2 polarimetric decomposition results. Notwithstanding the fact that for sub-groups containing PALSAR-1 images only or PALSAR-2 ones only show explicit dependence of the polarimetric classification results on temperature, this dependence is broken if we take into account the whole group. Using the group 2, we compared dates with similar season and temperatures that are close to each other (e.g., 20070402 with –11.3°C and 20150324 with –10.3°C; another pair: 20070518 with +3.4°C and 20150421 with +0.8°C, see Fig. 5).

Classification results in the Fig. 5 demonstrate that for PALSAR-2 we have an increasing amount of vegetation (dipole scattering mechanism) for both negative and positive air temperature. As one of differences in PALSAR-1/2 technical parameters is noise floor, we simulated thermal noise at 25 dB level for PALSAR 20070402 image and PALSAR-2 20150324 image, adding white Gaussian noise. Comparing classification maps for initial images and images with 25 dB noise, we got the following results: the amount of pixels with Bragg surface scattering (low entropy) slightly reduced after introducing noise from 6% to 3% in PALSAR-1 image and from 3% to 2% for PALSAR-2, the amount of pixels with dipole type of scattering (vegetation class) increased from 2% to 6% and from 39% to 43%, respectively. As for the main class, surface scattering with medium entropy, it remained the same (91%) in PALSAR-1 image and changed from 53% to 54% in PALSAR-2 images.

Thus we can see that known differences in noise level of PALSAR-1 and PALSAR-2 does not explain the differences in classification maps. Another suggestion lies in the geometrical field: our images were taken with different incidence angles: 21.5º for PALSAR-1 observations and 30.4º for PALSAR-2 scenes. The steeper angle allows penetrating the vegetation layer and get more backscatter from the ground level, and, as a result, we can see that PALSAR-1 image classification indicates the surface scattering in the area where PALSAR-2 classification shows dipole scattering type.

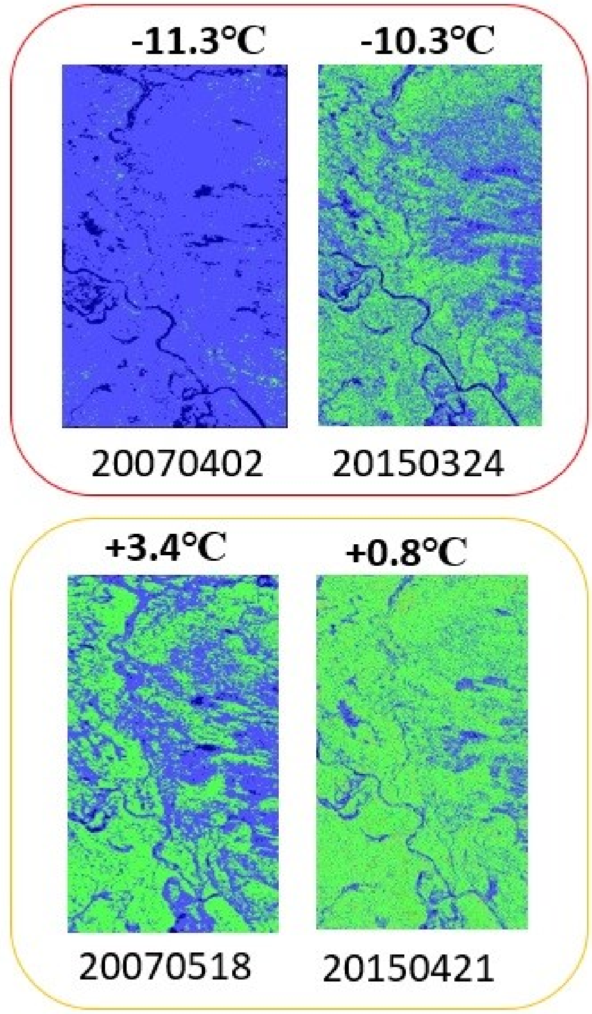

Figure 5. Differences between PALSAR-1 and PALSAR-2 classification maps. Green: dipole scattering; blue: surface scattering with medium entropy; dark blue: surface scattering with low entropy.

4. CONCLUSIONS

Boreal forests scattering properties are subject to weather influence, and, in particular, temperature variations. Entropy -alpha polarimetric classification can be implemented in such areas in the form of temporal analysis with additional air temperature data. The dynamics of the polarimetric parameters (in particular, alpha angle and entropy) is more reliable classification base than a single measurement.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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