X-BAND SAR INTERFEROMETRY FOR FOREST DYNAMICS DETECTION

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ABSTRACT

The study aims at the interferometric phase measurements in order to estimate the effective phase center shift for the forested area during short time intervals (11–22 days) in X-band. Regular repeated-pass TerraSAR-X/TanDEM-X observations in winter, spring and summer allow interferometric measurements under different weather conditions. Low values of phase difference variations are typical for dry weather. Larger values were observed under the wet conditions and probably during the active vegetation period.

***Index Terms*—** SAR Interferometry, TerraSAR-X, TanDEM-X, forest dynamics, phase centers.

1. INTRODUCTION

Interferometric estimation of the surface displacement from space is a well-known tool since the end of 1980s [1]. Repeat-pass SAR interferometry can be implemented for different applications in forestry and vegetation [2,3,4]. In addition, polarimetric SAR interferometry [5] demonstrates its potential for evaluation of vegetation parameters, including forest height and signal extinction coefficient.

Forest state season dynamics in L-band was scrutinized in [6], and this paper aims at change detection of the same Siberian forest in X-band. New TerraSAR-X data from 2014-2015 were used in the study.

2. REGION OF INTEREST

The area of interest includes a coniferous forest on the right bank of the River Selenga not far from its estuary on the south-eastern side of the Baikal Lake, Siberia.

The forest is surrounded by agricultural fields, meadows, pastures, marshlands and bushlands between the branches of the river. Pine is the principal species of trees in the forest, but there are inclusions of larch and fir. For the detailed examination we took a fragment from the western side of the forest with sizes approximately 1 km × 0.5 km and a neighboring field.

3. DATA SET

Data set includes 13 TerraSAR-X scenes over the area of interest from the end of 2014 till the middle of 2015. The dates of datatakes and the air temperature (from the online-meteoarchive www.rp5.ru) one can find in the Table 1.

Table 1. Dates and meteorological conditions.

Date (yyyymmdd)	Air temperature, °C	Precipitation
20141228	–2	-
20150108	–6	-
20150119	–4	light snow
20150221	–20	light snow
20150304	–4	-
20150417	+4	light rain
20150428	+13	-
20150509	+6	-
20150520	+20	-
20150531	+15	-
20150622	+13	rain 4mm
20150703	+16	-
20150827	+16	-

Five of our data takes were acquired in the cold season (air temperature was below zero Celsius), weather in observation dates of rest eight images was warmer.

4. DATA PROCESSING AND DISCUSSION

The study aims at examining phase center vertical location dynamics on the short time intervals in order to detect the possible permafrost heave in winter and vegetation growing effect in summer.

Interferometric pairs under review, time intervals and normal baselines are in the Table 2.

As the temporal decorrelation is a serious inhibiting factor for X-band repeat-pass interferometry, only 6 interferometric pairs are found to be suitable for processing.

We used in our work the SRTM Digital Elevation Model, thus the forest height needed some revision because of changes in the forest since SRTM observation and because of a relatively low spatial resolution of the SRTM

DEM. In order to improve the forest height, we use a tandem TSX-1/TDX-1 observation on 20141228 (the first line in the Table 2). The height of the forest in the region of interest was calculated using a mean interferometric phase difference between forest fragment and neighboring field fragment (Fig. 1). The correcting forest height value is 10.1 m.

Table 2. Interferometric parameters and measurement result

Date1-Date2	Normal baseline, m	Time interval, days	Displace-ment rate, mm
20141228-20141228	382	0	-
20141228-20150119	270	22	2.5
20150108-20150119	117	11	1.6
20150509-20150531	71	22	0.8
20150520-20150531	105	11	-7.6
20150531-20150622	57	22	-1.6
20150531-20150703	25	33	0.8

After the forest height correction procedure we calculated the phase difference on the interferogram between the forest and the neighboring field (see Fig. 1). These phase differences can indicate some frost processes in the soil in winter, and the changes of the forest height in summer.

4.1. Winter interferometric pairs

Two winter interferometric pairs with 11- and 22-days interval (20141228-20150119 and 20150108-20150119) have the same second image observed on 20150119, and they show both very low phase differences of 1.6 and 2.5 mm (see Table 2). This observation confirms that the digital elevation model correction was rather accurate, but at the same time we can see that interferometric method does not give a sign of any surface displacement during the observation period.

In addition, we can estimate interferometric coherence for winter pairs. As it is stated in the Table 3, field and forest sites are both stable (coherence value is above 0.35 for the forest patch and above 0.5 for the field). Temporal baseline influence is very little for forest. On the contrary, coherence value increases by 20% for the pair with twice shorter time interval.

Table 3. Interferometric coherence, winter

Date1-Date2	Interferometric coherence	
	Field	Forest
20141228-20150119	0.51	0.35
20150108-20150119	0.62	0.37

There are two possible ways for searching winter displacement effects in the area: one can use longer time intervals between the observations in order to discover slow processes' marks, or, in addition, process data takes from early winter during the beginning of frozen period.

4.2. Spring and summer interferometric pairs

Spring and summer interferograms were more promising, since the beginning of the warm season is a period of the intensive vegetation growth that can affect the location of the effective phase centers in the forest, and thereby phase values on the resulting interferogram.

Unfortunately, all the measured displacements were under 1 cm, and the only one over 0.5 cm was got for the 11-days May pair 20150520-20150531 (May 20 – May 31, 2015). It is worth noting that an interferogram with twice longer temporal baseline that covers the preceding one (May 09 – May 31) gives the smaller displacement in comparison with May 20 – May 31 interferogram, and they have different signs. In general, two interferograms (20150520-20150531 and 20150531-20150622) show the relative uplifting of the field with respect to the forest, and two others demonstrate the relative uplifting of the forest massive. Possible reason for this situation can be, for example, the periods of intensive grass growth in the area during the second half of May and the beginning of June.

On the Fig. 2 there are coherence, phase and amplitude image fragments for 4 our summer interferometric pairs. Dark tones on the phase image indicate the relative uplifting of the effective scattering height with respect to the lighter areas. We can see that May 20 – May 31 and May 31 – June 22 are the periods of the forest uplifting (forest is darker than field, the rate is 7.6 mm and 1.6 mm, respectively). In total, the difference between forest and field between May 20 and June 22 constitutes 9.2 mm in the line of sight direction. June is known as a month of the fastest tree growth, and we can see that even X-band with its scattering from the tree tops is sensitive to this effect. In addition, the rainfall on June 22 (see Table 1) could result in soil swelling afterwards, and field uplifting effect in the interferogram.

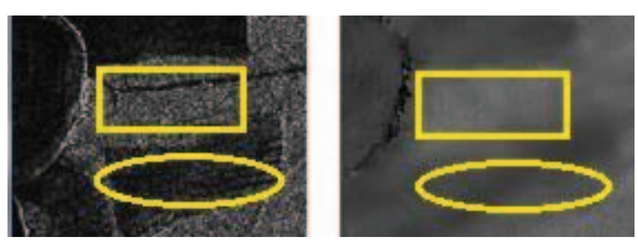
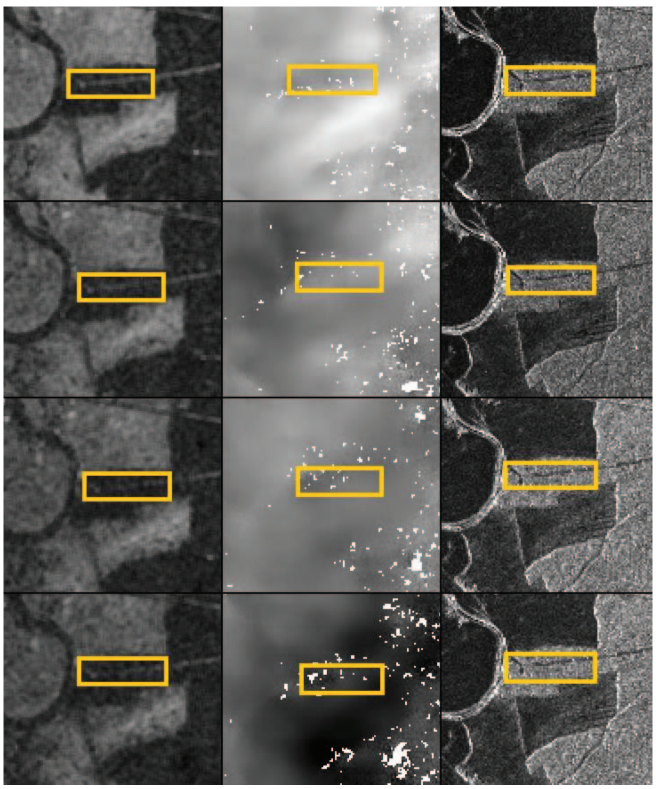


Fig. 1. Fragments of the amplitude image (left) and the winter interferogram (right). The rectangle on each image marks the forest fragment location, and the ellipse below it marks the field.

Analysis of complex coherence values for spring and early summer interferometric pairs indicates its decrease in comparison with winter pairs (see Table 4). Field remains more stable with respect to forest, but now its coherence is below 0.5. As for forest patch coherence, it is very low (between 0.15 and 0.18), and the phase image is a little bit noisier than in winter.

Table 4. Interferometric coherence, spring and summer

Date1-Date2	Coherence	
	Field	Forest
20150509-20150531	0.44	0.17
20150520-20150531	0.50	0.18
20150531-20150622	0.38	0.15
20150531-20150703	0.34	0.16



Coherence Phase Amplitude

Fig. 2. Coherence images, phase difference, and amplitude for summer interferometric pairs (from top to bottom):
20150520-20150531,
20150509-20150531,
20150531-20150622,
20150531-20150703.
Rectangles mark the location of the forest region of interest; field is below the rectangle (see the ellipse on the Fig. 1).

5. CONCLUSION

Preliminary result of our study is the following: although there are no prominent displacements of the scattering phase centers in the forest on X-band interferograms obtained in repeat pass observation mode (11–33 days interval), there is a subtle indication of the forest phase center shift in the SAR session conducted in the beginning of the vegetation period gave us the maximal displacement value of 9.2 mm per month. The soil (field) uplifting effect can be related to the rainy weather in the time interval between observations.

The study will be continued in order to compare the results obtained with new interferometric observation in other seasons of year and involvement of single-pass interferometric and polarimetric techniques for better evaluation of the forest height.

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