OPTIMIZATION OF COHERENCE ESTIMATION WINDOW SIZE AIMING AT GROWING STOCK VOLUME RETRIEVAL IN SIBERIAN FOREST

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ABSTRACT

This research was conducted to find the optimal coherence estimation window size aiming at growing stock volume (GSV) retrieval in Siberian Forest. Additionally, the properties of ALOS PALSAR L-band interferometric coherence of Siberian boreal forest have been presented. It was confirmed that the data acquired during frozen conditions are better suited for the growing stock volume retrieval, showing high coherence for sparse forest and low coherence for dense forest. It was concluded that at least ~ 60 equivalent number of looks (ENL) are necessary to achieve a compromise between a good spatial resolution and reliable estimation of coherence using ALOS PALSAR FBS images for Siberian forest.

1. INTRODUCTION

The basis for the Interferometric Synthetic Aperture Radar (InSAR) system is observation of a target by the radar antenna from two slightly different positions and or at different times [1]. The main output of the InSAR processing is the interferogram. It consists of magnitude (correlation between images - coherence) and phase (interferometric phase). The complex coherence γ is formed by multiplication of one SAR image with the complex conjugate of a second image. In practice the coherence is obtained using estimators by spatial averaging within a two-dimensional window (Eq. 1) [2]:

$$\gamma = \frac{\left|\sum_{i=1}^{N} g_{1,i} g_{2,i}^{*}\right|}{\sqrt{\sum_{i=1}^{N} \left|g_{1,i}\right|^2 \sum_{i=1}^{N} \left|g_{2,i}\right|^2}} \qquad (1)$$

where γ represents sample coherence, N is number of pixels within averaging window. Unfortunately, the estimation is biased and tends to overestimate low coherence [1, 3, 4, 5, 6, 7], which typically represents forest. The larger the estimation window size is used the lower the estimation bias and the true coherence value is approached. However, the complete bias cancelation is only achieved when an infinite number of samples is used. This is not possible in case of real SAR data due to the heterogeneity of large areas. Additionally, with larger window size the resolution gets coarser. Hence, the optimization of coherence estimation window size is a compromise between a good spatial resolution and a reliable estimation of coherence.

2. TEST SITES AND IN-SITU DATA

For the investigation of the coherence estimation window size two forest territories in Central Siberia were used: Primorsky and Chunsky East (E). These areas belong to the southern taiga sub-zone of the boreal forest and two Russian Siberian Federal districts: Krasnoyarsk Kray and Irkutsk Oblast (Fig. 1).

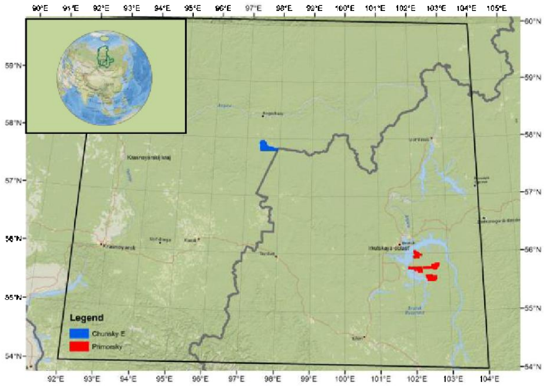

Figure 1. Location of study area

The areas are characterized by continental climate with long, severe winters and short, warm and wet summers. The mean temperature in winter is below -16°C to -30°C, in summer is 15°C to 25°C. The annual precipitation is below 450 millimetres [8] (Thiel et al. 2009a). The areas are rather flat - more than 60% of terrain is characterized by a slope less than 5%.

To study the coherence estimation on the growing stock volume retrieval the forest inventory data were used. The database was available at the Department of Earth Observation, University of Jena and was acquired within the SIBERIA-II project [9]. The database consists of detailed measurements of several forest biophysical parameters, including growing stock volume, i.e. the volume of the tree stem per unit area. To avoid the discrepancies result from the time difference between the inventory dataset and the SAR data the inventory database was updated. First the optical data were used to exclude changed stands and afterwards the models of growth were applied [10]. The

Proc. 'ESA Living Planet Symposium 2013', Edinburgh, UK
9–13 September 2013 (ESA SP-722, December 2013)

main statistics of updated forest territories are given in Tab. 1.

Table 1 Main statistics of investigated forest territories

	Primorsky	Chunsky E
Area [km^2]	318	130
Number of stands	1508	363
Mean stand size [ha]	21	35
Stem volume (GSV) [m^3/ha] (min/max/mean/std)	0/500/145/109	0/440/120/110
Mean stem volume for sparse forest (GSV < 50) [m^3/ha]	40	36
Mean stem volume for dense forest (GSV > 250) [m^3/ha]	300	323
Age of stands (min/max/mean/std)	0/300/112/71	0/310/120/73
Relative stocking [%] (min/max/mean/std)	0/100/69/18	0/100/60/19

3. SAR DATASETS AND PROCESSING

Phased Array type L-band Synthetic Aperture Radar (PALSAR) data from the Advanced Land Observing Satellite (ALOS) were used to investigate the coherence estimation. The PALSAR datasets were in 1.1 processing level, which is a Single Look Complex (SLC) product. The data were provided as complex data including phase history in slant range geometry. Both Fine Beam Double (FBD) and Fine Beam Single (FBS) Polarisation modes were investigated. In Tab. 2 the summary of the SAR data is presented.

Table 1 PALSAR data acquisition summary

	Primorsky		Chunsky E
	FBD*	FBS	FBS
Track/Frame	466/1110	466/1110	473/1150
Acquisition dates	29.07.2010 13.09.2010	26.01.2010 13.03.2010	07.01.2010 22.02.2010
Weather conditions	T_1≈13°C, T_2≈4°C, WS_1≈4 m/s, WS_2≈3 m/s, P_1≈7 mm, P_2≈0.5 mm	T_1≈-30°C, T_2≈-11°C, WS_1≈5 m/s, WS_2≈2.5 m/s, SD≈50 cm	T_1≈-32°C, T_2≈-22°C, WS_1≈0.1 m/s, WS_2≈3.5 m/s, SD≈40 cm
Perpendicular baseline (B_n) [m]	249	703	789

*Abbreviations used: FBS – Fine Beam Single Polarisation, FBD – Fine Beam Double Polarisation, T, WS, SD and P stand respectively for temperature, wind speed, snow depth and precipitation.

The coherence was calculated based on interferometric pairs with 46-days repeat-pass interval. The SAR processing consisted of SLC co-registration at sub-pixel level, less than 0.1 pixel [4], common-band filtering in range and azimuth and generation of a differential interferogram. In order to obtain squarish pixel size the interferogram was calculated using 1number of look in range and 3 in azimuth for FBS data and 1in range and 5 in azimuth for FBD data. Afterwards the coherence was calculated over sufficiently large homogenous areas. To ensure that the areas with low and high coherence would not mix with growing window size the buffering was implemented. The same procedure was repeated for different window sizes from 3 by 3 to 85 by 85 and different coherence areas and test areas. Afterwards the data were geocoded. The example coherence maps are shown in Fig. 2. To compare the coherence estimation between investigated test sites data with similar perpendicular baseline were selected (Bn =~700m). InSAR processing and geocoding was done using the GAMMA ISP, DIFF&GEO and LAT modules [11].

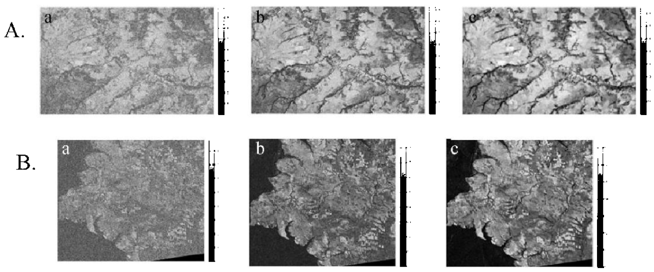

Figure 2. Coherence maps, a. 3x3 window, b. 7x7 window, 31x31 window size used, A. Chunsky E, B. Primorsky

In order to investigate the influence of the implemented coherence estimation window size on GSV retrieval an exponential regression equation was used (Eq. 2) [12].

$$\Gamma(V) = a_1 e^{-a_2 V} + a_3(1 - e^{-a_2 V}) \qquad (2)$$

Γ(*V*) is coherence in function of volume (V), which refers to GSV, and a_1, a_2, a_3 are empirical coefficients.

4. RESULTS

The results of optimization of coherence estimation window size aiming at growing stock volume retrieval in Siberian forest are presented in Fig. 3.

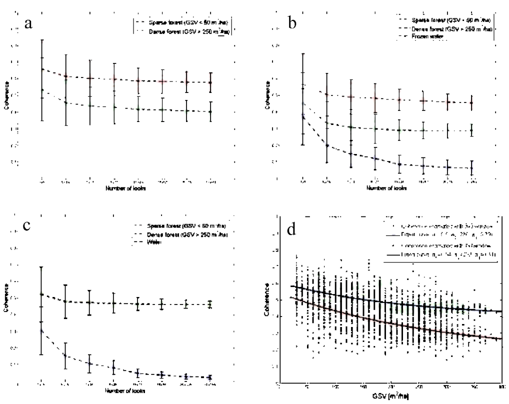

Figure 3. Mean and standard deviation of interferometric coherence as a function of number of looks, a. Chunsky test site (FBS data), b. Primorsky test site (FBS data), c. Primorsky test site (FBD data), d. coherence versus GSV, Primorsky test site.

Firstly, comparing the results between FBD and FBS coherence it can be clearly seen that during the unfrozen conditions it is not possible to separate the sparse and dense forest (Fig. 3c). This is due to the temporal decorrelation caused by the time difference between the data acquisitions. Hence, the data acquired under stable, frozen conditions are better suited for GSV retrieval. This is with an agreement to the previous studies [e.g. 13, 14, 15]. Secondly, it can be noted that for areas with high and medium interferometric correlations small averaging windows resulted in reliable coherence estimates. Based on the FBS data it can be observed that already the second implemented window size (75 pixels, ~60 equivalent number of looks - ENL) can give reliable coherence estimate. On the other hand bigger estimation window size is required for low coherence, example of frozen water (Fig. 3b). In this case 675 pixels are needed to provide reliable coherence estimate. For this class slightly bigger standard deviation was also observed, indicating biased, overestimated coherence. Thirdly, using the simple exponential regression equation it was shown (Fig. 3d) that applied window size can affect the saturation level.

5. CONCLUSIONS AND OUTLOOK

The research was conducted to optimize the coherence estimation aiming at growing stock volume retrieval over Siberian forests using ALOS PALSAR data. It can be concluded that at least ~ 60 equivalent number of looks (ENL) are necessary to achieve a compromise between a good spatial resolution and reliable estimation of coherence in ALOS PALSAR FBS images over Siberian forest. It can be seen as a big number. This means that in case of the future ALOS-2 PALSAR-2 mission with 3 m resolution within the Ultra Fine mode not only a reliable coherence estimation can be achieved but also a very good spatial resolution.

6. ACKNOWLEDGMENTS

This work has been performed within the GIONET project, funded by the European Commission, Marie Curie Programme, Initial Training Networks, Grant Agreement number PITN-GA-2010-264509.
The authors would like to thank the GAMMA Remote Sensing's team for a great support and provided materials.
The ALOS PALSAR data were provided by Japan Aerospace Exploration Agency (JAXA) within the Kyoto & Carbon Initiative.
The optical data were provided by the European Space Agency (project id: 13300).
The GIS forest inventory data were collected within the FP5 EC-funded SIBERIA II project.

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