SEASONALITY OF ALOS PALSAR INTERFEROMETRIC COHERENCE AND INTERFEROMETRIC PHASE IN CENTRAL SIBERIA AND ITS IMPLICATION ON FOREST PARAMETER RETRIEVAL

Christian Thiel, Christiane Schmullius

Department of Earth Observation, Friedrich-Schiller University, Grietgasse 6, D-07743 Jena, Germany

1. INTRODUCTION

The boreal zone is characterised by unique environmental conditions, which need to be considered throughout the SAR data exploration. During winter the trees are frozen and thus almost transparent for the incoming radar wave. The backscatter from the trees is significantly reduced, as is the contrast between forest and non-forest areas. However, the environmental conditions are very stable. Due to the very low temperatures the very dry snow hardly impacts the scattering. As the soil is also frozen, changes in soil moisture do not appear. With regards to coherence these circumstances lead to very low temporal decorrelation. Even temporal baselines of 44/46 days (JERS-1/ALOS PALSAR) do not necessarily lead to problems caused by temporal decorrelation. From a number of studies it became evident that in particular coherence images acquired during winter do have great potential for forest biomass estimation. Furthermore it was recognised, that the thawing season is the most unsuitable time. At midsummer the major sources of temporal decorrelation are changing soil moisture, movement of the trees due to wind, and precipitation (interception water). Thus, the repeat pass coherence for forest is assumed being in general much smaller compared to mid-winter. However, not much is known about mid-summer coherence in the boreal zone. Though, first investigations surprisingly reveal an overall high coherence in summer, even for dense forest. This fact implies the feasibility of POLINSAR methods for forest height estimation.

This paper investigates multi-seasonal ALOS PALSAR interferometric coherence images for forestry applications in the boreal zone. Coherence is estimated using PALSAR FBS and FBD data. The test sites are located in Russia (Central Siberia). First results substantiate the great potential of midwinter coherence. With regards to midsummer coherence almost no correlation with regards to stem volume was evident. However, the interferometric phase proved being sensitive to tree height.

2. STUDY AREA

The study area is located in Central Siberia, Russia (see Fig. 1) and features the administrative compartments Irkutsk Oblast and Krasnoyarsk Kray. The Middle Siberian Plateau in the southern part of the territory is characterised by hills up to 1,700 m. The northern part is flat with heights up to 500 m. Taiga forests (spruce, birch, larch, pine, aspen etc.) dominate and cover ca. 80% of the region. The site exhibits continental climatic conditions. The yearly amount of precipitation is generally below 450 mm; the winters are very cold and dry, the summers are warm; most of the precipitation occurs in summer. The whole territory is characterised by extreme land cover changes mainly caused by forest fires and logging.

Figure 1. Study area (light green) in Central Siberia and forest inventory data (right image, red patches); Area covered by right image ca. 2,000 km × 2,000 km

3. DATABASE

3.1. Forest Inventory Data

Forest Inventory Data was available for the sites Bolshe Murtinsky NE and SE, Chunsky N and E, and Primorsky N, E, S, and W. Thus eight different sites were considered. Although the forestry data contains lots of parameters, so far only stem volume, stand id, and relative stocking have been considered. The data was provided digitally (polygons). Fig.2 provides an example for stem volume. The minimum number of forest stands was 394 (at Primorsky S).

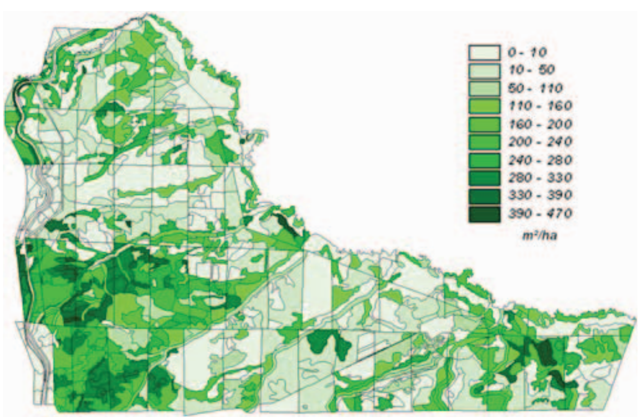

Figure 2. Example for forest inventory data (Chunsky E)

Some specific characteristics of the forestry data base had to be considered: i) Only trees with economic relevance are included (stem diameter > 8 cm etc.), ii) In places high heterogeneity within forest stands was detected (e.g. only partly logged), iii) Polygons are inaccurate – the misregistration is partially more than 100 m,

iv) The forest information is outdated (GIS layer 10 years old, information contained in GIS even older, thus potentially new clear-cuts, growth and regrowth of forest). To overcome some of these issues the following strategies have been applied: i) Buffering polygon information, ii) Excluding forest stands which have been logged or burned during last 10 years (detection by means of HR EO data, creation of list with obsolete stands), iii) Exclusion of stands with very high variance of coherence, iv) Excluding stands smaller than 2 ha, v) Excluding outliers (see paragraph 4), the threshold was set to 2 standard deviations.

3.2. SAR Data and Coherence Estimation

Only four frames were selected as some of the frames cover more than one test site. In general, FBS was acquired in winter and FBD in summer. The whole dataset covers about two years and consists of 38 scenes. For each ALOS PALSAR frame almost every combination of image pairs was considered for coherence estimation. For the coherence estimation standard level 1.1 FBS/FBD scenes were applied. Interferometric processing consisted of SLC data co-registration at sub-pixel level, slope adaptive common-band filtering in range [1], and common-band filtering in azimuth. Image texture (stdev/mean, 15×15 window) was used for the coherence computation procedure which employs an adaptive estimation approach [2]. This approach considers variable coherence estimation window sizes, whereas small windows (3×3) are used at heterogeneous areas and larger (5×5) windows at homogeneous patches. Thus, smoothing of coherence is only applied at homogeneous areas. The coherence images were orthorectified using SRTM elevation data. Final pixel spacing is 12.5 m × 12.5 m for FBS-FBS coherence and 25 m × 25 m for FBS-FBD and FBD-FBD coherence.

4. FIRST RESULTS AND DISCUSSION

Besides the beneficial effect to learn more about L-band repeat pass coherence in the boreal zone and its suitability for stem volume retrieval, this study brought up an interesting and to some part unexpected aspect of the seasonal behaviour. For consecutive cycle coherence in summer obviously the overall temporal decorrelation is not larger than in winter. This surprisingly seems also to apply to high stem volume classes (Fig. 3). So far, the decorrelation of high stem volume areas is interpreted as effect of volumetric decorrelation. Temporal decorrelation is assumed to have minor effects (so far only winter coherence data have been applied to model the relationship between stem volume and L-band coherence; in winter we find extremely stable environmental conditions in Central Siberia).

The decrease of penetration depth into the canopy of the in-coming SAR wave in summer could result in reduced volumetric decorrelation (raised and narrower scattering centre). Evidence of this assumption could be seen in the remarkable examples, where increasing coherence with increasing stem volume was detected, because potential changes in soil moisture in particular impacts areas with low stem volume. During the week before the

October acquisition, temperatures below 0°C have been measured at Bratsk. During that time precipitation was registered at Tulun. Hence, there is even the chance for a small snow layer (rather wet snow) on 21st October 2007, which obviously can cause decorrelation.

The larger spread of summer coherence could be caused by various tree geometries, which are related to the diverse tree types. In winter, the trees are more or less transparent; at least twigs and branches can be expected to hardly impact the backscatter. Thus, all tree types are more or less equal targets, as the stem is the only part being able to interact with the radar wave. However, more work has to be done to completely understand the seasonality of coherence and backscatter in the boreal zone.

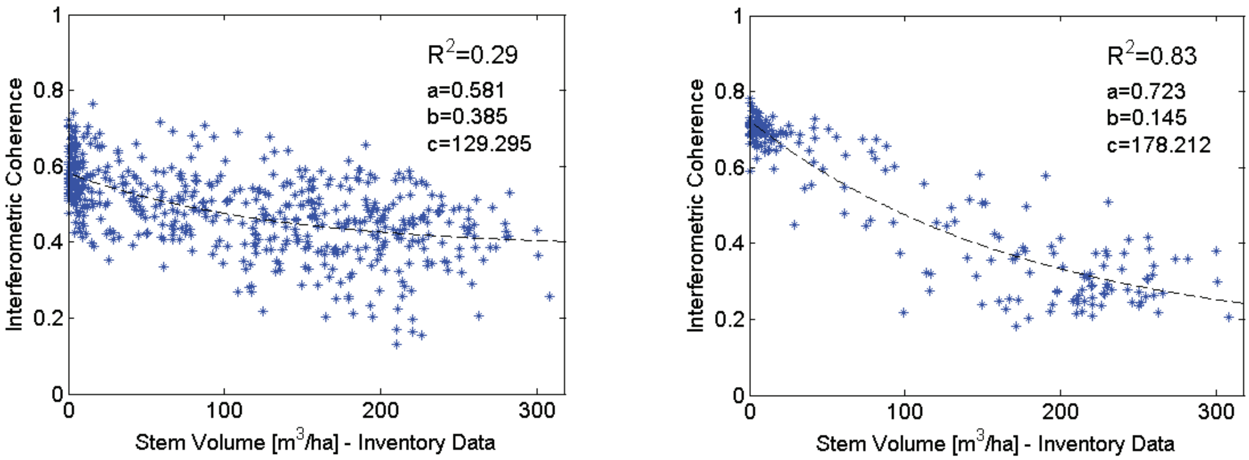

Figure 3. Scatterplots for Chunsky N 05aug07_20sep07 (left) and 21dec07_05feb08 (right)

5. CONCLUSIONS

ALOS PALSAR data proved having great potential for forest stem volume estimation in Siberia. Winter FBS coherence is the most powerful measure. Summer FBD coherence can provide additional information (e.g. for forest cover mapping), but the temporal baseline must be enlarged to increase temporal decorrelation of forest. However, this approach is very susceptible to variable environmental conditions. The computation of coherence based on FBS (winter) and FBD (summer) images is technically feasible but not very useful; it might - if at all - be used to support forest cover mapping.

6. REFERENCES

[1] M. Santoro, C. Werner, U. Wegmüller & O. Cartus, “Improvement of interferometric SAR coherence estimates by slope-adaptive range common band filtering”, Proc. IGARSS, Barcelona, Spain, 2007.

[2] U. Wegmüller, C. Werner & T. Strozzi, “SAR interferometric and differential interferometric processing”, Proc. IGARSS, Seattle, USA, IEEE Publications: 1106-1108, 1998.