SAR REPEAT-PASS COHERENCE IN WINTER FOR BOREAL FOREST APPLICATIONS. A FIRST COMPARISON BETWEEN ASAR AND JERS-1 SAR

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ABSTRACT

This paper presents the first comparison between repeat-pass coherence from ASAR and JERS-1 SAR. To reduce the influence of temporal decorrelation, repeat-pass pairs acquired during the winter season have been selected. ASAR 35-day coherence and JERS-1 44-day coherence from six different test areas in Siberia and northern Europe have been evaluated. The results indicate that the decorrelation is more severe for ASAR coherence than for coherence from JERS-1. Only one of the five studied ASAR pairs shows coherence levels that are high enough to contain information that can be useful for forest applications. More ASAR pairs will be acquired during the current winter season. For most of the included JERS-1 pairs, the coherence is high enough to provide useful forest information. An example of growing stock volume estimation from one of the test areas shows a potential application.

1 INTRODUCTION

Interferometric coherence from the ERS-1/2 tandem mission has in several studies proved to be a useful tool for forest monitoring. After the loss of ERS-1, the focus of InSAR studies has to some extent moved to repeat-pass solutions for current and near term satellite sensors like Envisat ASAR and ALOS PALSAR. Recently published results show that 44-day repeat-pass coherence from the SAR on JERS-1 can give information about forests if the acquisitions are made during stable winter conditions, e.g. in Siberia [1].

The goal of this study is to evaluate if L-band and/or C-band repeat-pass coherence can be used for estimation of growing stock volume. The growing stock volume is related to the living biomass in a forest. If growing stock volume can be estimated from satellite images this would be important both for regional forest inventories and for the implementation of the Kyoto protocol. C-band coherence with a 1-day repeat-cycle has shown good results for estimation of low growing stock volumes. The use of SAR images acquired during stable winter conditions should make the coherence less sensitive to temporal decorrelation and thereby allow longer repeat cycles to be used. Within the next years no orbiting system will be able to deliver coherence with a 1-day repeat cycle.

2 BACKGROUND

SAR data from Envisat have been acquired for some of the SIBERIA-II project test territories in central Siberia (Table 1). The acquisitions are from the winter season, which give the most favourable conditions for coherence estimation over 35 days. In 2002-2003, no InSAR pairs were available from the peak winter period of December to February. The first data have been acquired in March-April-May 2003 at two regions (Tura and Shestakovsky). In order to assess the interferometric ASAR repeat-pass data in winter, data acquired over Pajala (Sweden) and Ruokolahti (Finland) have also been analysed. For comparison between C and L band repeat-pass coherence, available JERS-1 pairs over 2 SIBERIA-sites (Bolshe Murtinsky and Chunsky) and two new JERS-1 pairs over Tura and Ruokolahti have been included in the study (Table 2). The centre coordinates for the included test areas are: Bolshe Murtinsky 57° N, 92° E; Chunsky 57.6° N, 96.4° E; Pajala 67° N, 23° E; Ruokolahti 61.2° N, 27.5° E; Shestakovsky 57° N, 102.7° E and Tura 65° N, 100.5° E.

All the test areas under consideration are natural forests and land cover, with low urban development. The main tree types are spruce, pine and birch for Pajala and Ruokolahti, spruce, fir, pine and birch for Bolshe Murtinsky, Chunsky and Shestakovsky, and larch, birch, and dwarf birch for Tura. Detailed forest information in GIS format is available for the test areas in Siberia. However, the current GIS data from Tura is based on old information and will be updated at a later stage in the project. For the JERS-1 pairs, meteorological data are available for Bolshe Murtinsky, Chunsky and Ruokolahti, but not for Tura. The ASAR data are from 2003 and no meteorological data have been used in the study.

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Table 1. Available ASAR pairs and their estimated baselines

First date	Second date	Track	Baseline perpendicular (m)	Test area
2003-01-03	2003-02-07	351	600	Pajala
2003-01-04	2003-02-08	365	54	Ruokolahti
2003-01-01	2003-03-12	322	418	Ruokolahti
2003-03-29	2003-05-03	68	156	Shestakovsky
2003-03-07	2003-04-11	254	409	Tura

Table 2. Available JERS-1 pairs and their estimated baselines

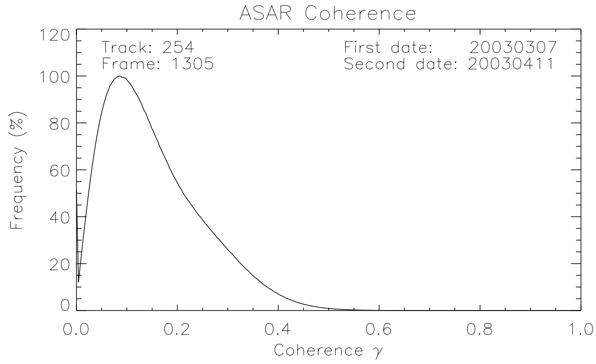
First date	Second date	GRS Path	Baseline perpendicular (m)	Test area
1994-01-06	1994-02-19	165	1752	Bolshe Murtinsky
1996-10-14	1996-11-27	165	705	Bolshe Murtinsky
1996-11-27	1997-01-10	165	844	Bolshe Murtinsky
1997-01-10	1997-02-23	165	1875	Bolshe Murtinsky
1997-02-21	1997-04-06	163	2091	Bolshe Murtinsky
1997-02-23	1997-04-08	165	1212	Bolshe Murtinsky
1997-04-06	1997-05-20	163	374	Bolshe Murtinsky
1997-05-20	1997-07-03	163	>7000	Bolshe Murtinsky
1997-07-03	1997-08-16	163	970	Bolshe Murtinsky
1998-06-22	1998-08-05	165	208	Bolshe Murtinsky
1993-12-29	1994-02-11	157	550	Chunsky
1995-10-20	1995-12-03	157	1947	Chunsky
1995-12-03	1996-01-16	157	3	Chunsky
1995-12-04	1996-01-17	158	106	Chunsky
1996-01-16	1996-02-29	157	319	Chunsky
1996-01-17	1996-03-01	158	509	Chunsky
1997-04-01	1997-05-15	158	27	Chunsky
1998-06-14	1998-07-28	157	1108	Chunsky
1995-12-01	1996-01-14	289	108	Ruokolahti
1993-12-29	1994-02-11	157	580	Tura

3 DATA ANALYSIS

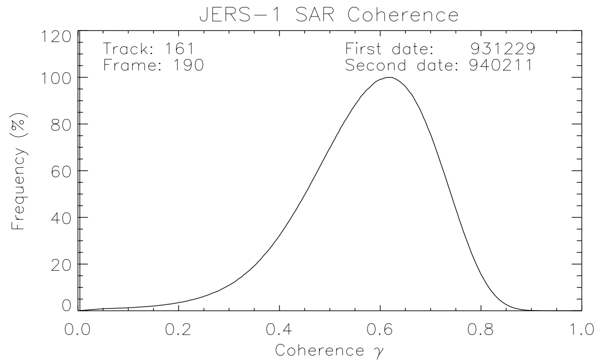
3.1 Initial quality analysis

One way to get a quick estimation of the information content in a coherence image is to look at the histogram. In general open water and dense forests have low coherence levels and smooth open surfaces and urban areas have high coherence. For forests, decreasing growing stock volumes normally give increased coherence. A histogram that shows high coherence levels is a good indication that the image can be used also for forestry applications. However, more important than a high maximum coherence is that the range between the lowest and highest coherence values is large. This range will hereafter be called the dynamic range. If the dynamic range is large there is a higher probability that forest with high growing stock volumes can be separated from forests with low growing stock volumes and that low density forest can be separated from open fields.

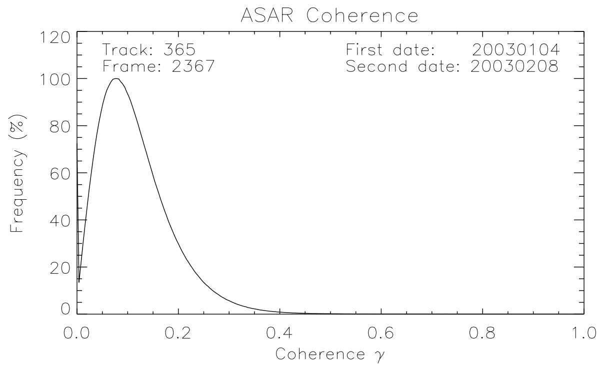
a) Tura



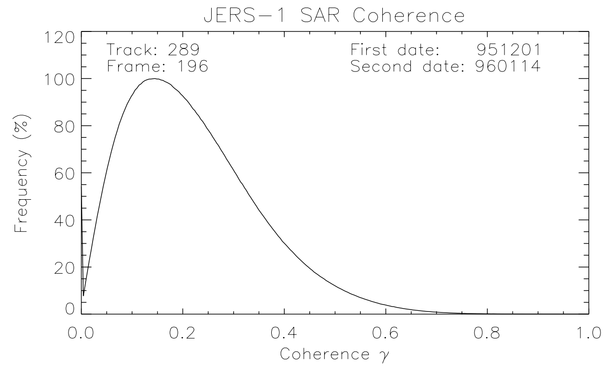
b) Tura



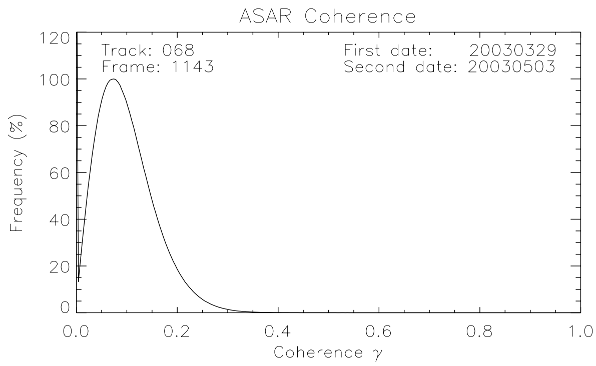
c) Ruokolahti



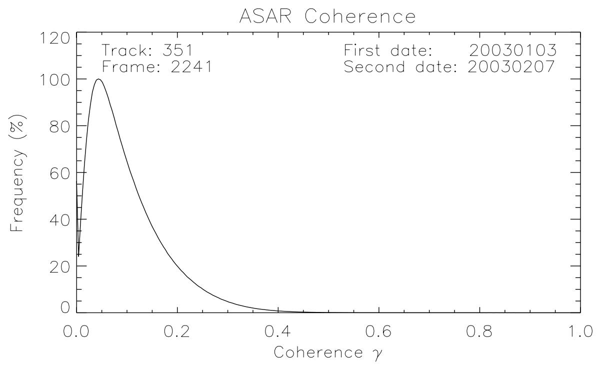
d) Ruokolahti



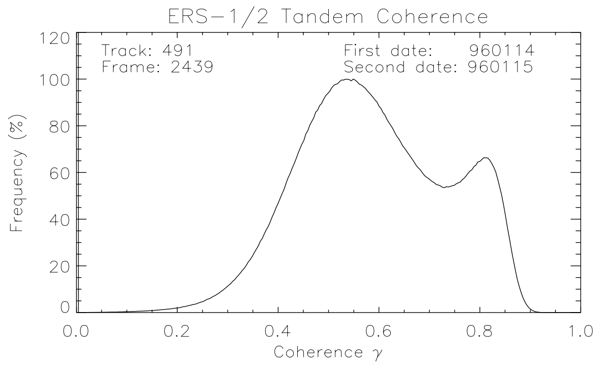
e) Shestakovsky



f) Pajala



g) Chunsky



h) Chunsky

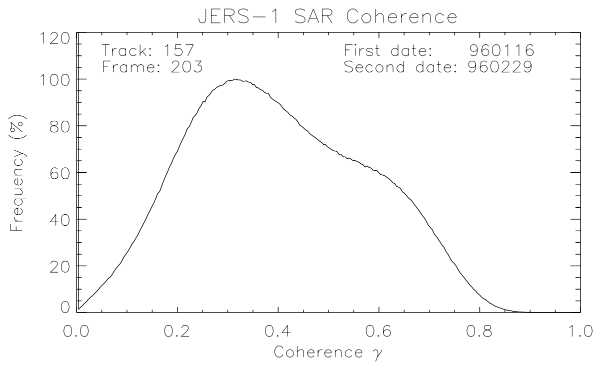


Fig. 1. Examples of coherence histograms for ASAR, JERS-1 SAR and ERS-1/2 SAR All histograms have been scaled individually so that 100% corresponds to the maximum frequency in that image.

In most cases, if the image contains a large amount of pixels with high coherence the dynamic range is also large, but as will be shown later, under certain very stable frozen winter conditions it is possible to get image pairs where not only the upper coherence limit is high but also the lowest coherence values are comparatively high. In these cases we have a reduced dynamic range even though the overall coherence level is very high. This can be difficult to see by a first visual look at the coherence image, but is clearly revealed by the histogram. That these variations in the dynamic range can give problems even for classification algorithms that adapt to the overall coherence level of the image has been shown in [2] for coherence from the ERS-1/2 tandem mission. For a coherence image with a large dynamic range the histogram can also give an initial rough estimation of the relative occurrence of forest and open surfaces.

Some of the coherence histograms for the image pairs in Table 1 and Table 2 are shown in Fig. 1. It is already here possible to see that several of the available ASAR pairs will not contribute with any useful information about forest parameters. The coherence levels for the pairs from Ruokolahti (c), Shestakovsky (e) and Pajala (f) are so low that the only features that can be expected to be above the noise level are urban areas. For Shestakovsky this is an expected result since the acquisitions were done during the springtime when large changes in the scattering conditions occur due to thawing. The ASAR acquisitions for Ruokolahti and Pajala on the other hand are done during the coldest period of the year. For Pajala the 600 m baseline can be expected to introduce large spatial decorrelation [3]. The histogram from Ruokolahti is from the 35-day pair with 54 m baseline. Here it can only be assumed that the comparatively mild winters in northern Europe not always are stable enough for C-band over a 35-day period. The ASAR histogram for Tura (a) looks slightly better. Even though the acquisitions were done in March and April, the location of the test site at high latitude in central Siberia gives it winter conditions also at this time of the year. The coherence levels are still low, but large parts of the histogram are above the noise level and should contain some information.

The three coherence histograms from the JERS-1 SAR pairs show considerably higher coherence, and thereby also larger dynamic ranges, than the ASAR pairs do. The coherence for Tura (b) is extremely high, with the peak of the histogram at a coherence level above 0.6. This can only be explained by a combination of the relatively sparse vegetation, the long wavelength and minimal changes on the ground and in the vegetation between the acquisitions. The coherence levels for Ruokolahti (d) are only moderate, but high enough to show that it under favourable conditions is possible to get useful coherence levels from a L-band SAR with 44-days repeat cycle also in northern Europe. Fig. 1 h show an example of a coherence histogram from one of the many JERS-1 SAR pairs that are available for the test sites Bolshe Murtinsky and Chunsky. The large dynamic range indicate that this coherence image can be suitable for forest studies like change detection and growing stock volume estimation. Histogram g has been included as an example of coherence levels that can be achieved with a C-band system with a one-day repeat-cycle, in this case the ERS-1/2 tandem mission. The image is from the same test site as histogram h and was acquired during the same period. It is logical that the shorter repeat cycle give less temporal decorrelation, but here we also see the previously mentioned problem that the useful dynamic range get reduced by the fact that there are so few pixels with low coherence. So far histogram b is the only available example of a similar situation for JERS-1.

3.2 Visual interpretation

During the initial phase of the study no ground data were available from the Tura test site. To evaluate if the coherence from ASAR can give any information about forest a comparison with Landsat ETM data was done. Fig. 2 shows the images that were used. The left side of the image shows a composite image, where red is the coherence, green is the average backscattering coefficient and blue corresponds to the ratio of the backscatter.

The image shows interesting features, many of them related to relief and rivers. The main river is Kochechum, which flows NS at the bottom of the image, towards the town of Tura that is situated outside the image. Three sections of the image were selected based on interpretation of Landsat ETM quicklook images of the region, acquired in June 2002. Section 1 contains an area identified as a recently burnt area, section 2 a forested area, and section 3 an area with low vegetation, assumed to be grassland on an exposed site.

The temporal change does not bring much information to the discrimination of the three types of surface. The backscattering coefficient is about –10 dB for the forest and about –14 dB for low vegetation, including the burnt area. The general dynamic range is about 3 to 4 dB if topographic effects are excluded. The coherence is high for areas that appear to have low biomass vegetation on the Landsat image, including areas interpreted to have recent fires. Reversely, the low vegetation on exposed sites shown in the Landsat image has low coherence. It is possible that the areas are exposed to melting or refreezing effects between March and April. In this case, the coherence decreases but the backscatter will have no significant change. The visual interpretation shows that even though the ASAR coherence only has a small dynamic range and a relatively low overall coherence level it contains information that, when combined with the backscatter, can be useful for forestry applications.

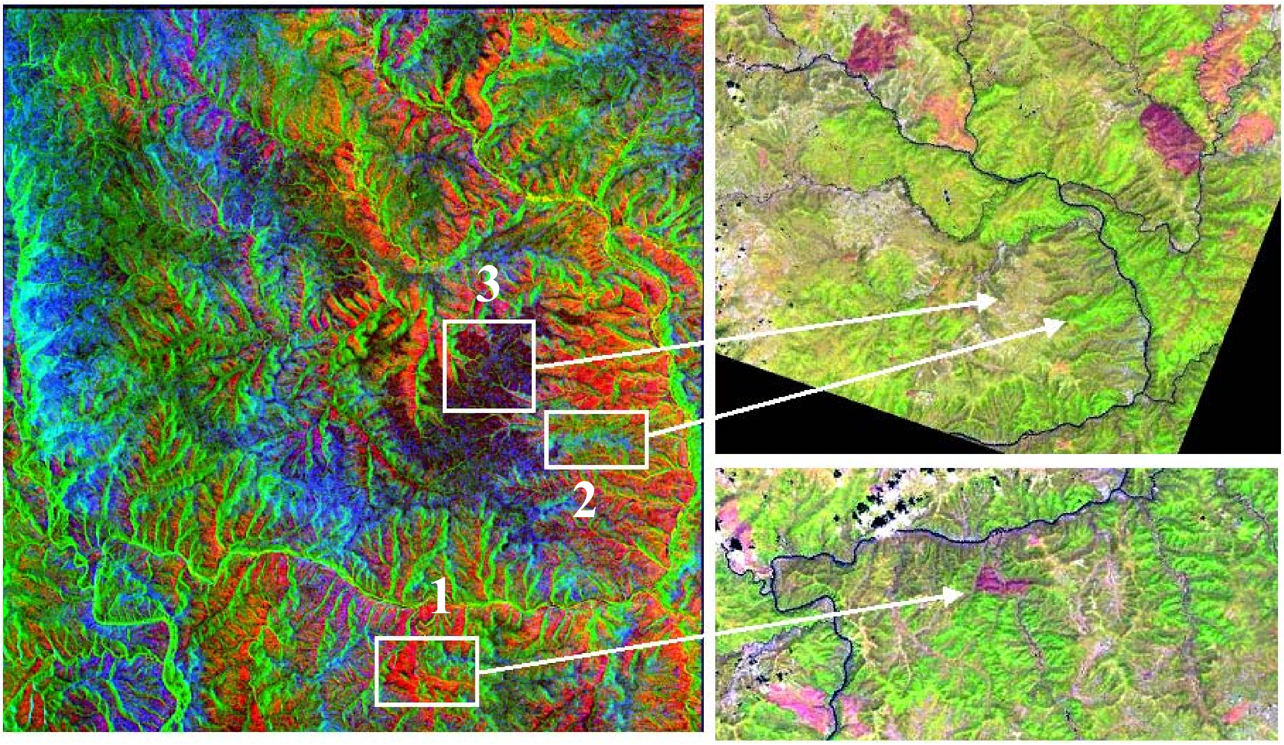
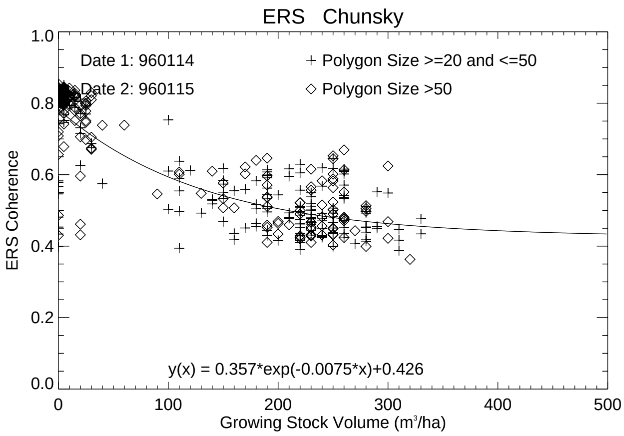


Fig. 2 A composite of ASAR repeat pass interferometric images (left) is compared with Landsat ETM images (right). In the ASAR composite red is coherence, green is the average backscattering coefficient and blue correspond to the ratio of the backscatter. Three regions of interest are indicated. Region 1is a recent burnt area, region 2 is forest, and region 3 is exposed low vegetation.

3.3 Retrieval of forest information

As discussed in previous sections, Tura is the only test area with useful coherence from both ASAR and JERS-1 SAR, but as long as no reliable ground data are available from this site, a good quantitative analysis is not possible. For the test sites Bolshe Murtinsky and Chunsky, studies have been conducted about the correlation between the interferometric coherence and the growing stock volume both for ERS-1/2 tandem data and for JERS-1 repeat-pass data. Fig. 3 shows two examples of the results. These plots correspond to histogram g and h in Fig. 1. Apart from the fact that the ERS curve is shifted towards higher coherence values, the two curves show large similarities. The three diamonds that show low coherence even though they have low growing stock volumes are most likely clear cuts that occurred between the acquisition of the satellite data in 1996 and the updating of the forest inventory in 1998. A more comprehensive interpretation of the results from Bolshe Murtinsky and Chunsky is given in [1] for the JERS-1 44-day coherence and in [4] and [5] for the ERS-1/2 1-day coherence.



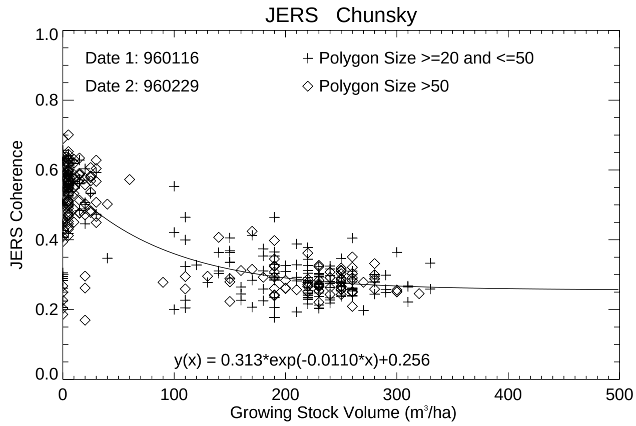


Fig. 3 Coherence from ERS-1/2 and from JERS-1 plotted against the growing stock volume in the test site Chunsky.

4 DISCUSSION AND CONCLUSIONS

The results from the Siberian test sites indicate that under frozen winter conditions L-band repeat-pass coherence can be a useful tool for estimating low growing stock volumes in Boreal forests. Initial results indicate lower repeat-pass coherence for C-band than for L-band. The reason for this can be that C-band coherence is more sensitive to tree scatterers and ground cover which are not stable enough over a 35 day repeat-cycle, whereas L-band coherence is sensitive to more stable elements, like branches and soil surface. However, the number of ASAR pairs has so far been limited and during the winter 2003/2004 the investigation will be extended to include more ASAR pairs from current and new test sites. This will clarify the usefulness of coherence from C-band data with 35-day repeat-cycle. Long repeat-cycles make the coherence very sensitive to temporal decorrelation caused by, e.g., freeze, thaw, or soil moisture differences. This results in a strong seasonal variability that makes it important to have data acquisitions dates associated to minimum change in surface conditions. In Siberia this occurs during the December-February period.

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