Effect of land cover types and forest characteristics on repeat-pass coherence of ASAR and JERS data

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ABSTRACT

Repeat-pass SAR scenes were studied aiming at the use of SAR data in connection with landslides and other natural hazards. The objective was to study the methods that are applicable in forested areas. The SAR data included both C-band (ENVISAT ASAR) and L-band (JERS SAR) scenes.

As SAR coherence is a key factor affecting the derivation of elevation data and elevation change data, the effect of land cover type and forest characteristics on coherence was studied in two study sites: one in central Finland and one in central Japan. The SAR scenes had been acquired in summer and winter conditions.

The Finnish study site was mainly covered by coniferous boreal forest. It was relatively flat. The Japanese study site included elevations from the sea level up to 3500 meters. The major land cover types in low-lying areas were urban and agricultural land.

The highest coherences could be observed in the urban and agricultural areas and lowest in the forest, in particular in mature coniferous forests. The coherence data in the Finnish study site shows that baseline length has a strong influence on coherence. In Japan, the highest coherence was in scene pairs acquired in winter. The reason for lower coherence in summer is the vegetation cover in agricultural areas in summer scenes.

In Japan, it was possible to derive DEM's using L-band SAR data also in a great part of the most forested regions but the elevations were smoothed out in comparison to the cartographic DEM's.

Keywords: Coherence, SAR, DEM, ASAR, JERS.

1. INTRODUCTION

A Digital Elevation Model (DEM) displays geographical features. Areas affected by land slides could be mapped by comparing DEMs before and after a land slide. If elevation data can be mapped with a high accuracy and reliability, valuable information can be obtained on the damaged area and the severity of the damage.

Today, using Synthetic Aperture Radar (SAR) data is considered to be one of the most efficient methods for DEM generation under disaster applications because SAR data can be acquired regardless of meteorological conditions and sun illumination (time of the day).

Different wavelength SAR satellites such as L-band (JERS-1, ALOS/PALSAR) and C-band (ERS-1/2, ENVISAT/ASAR) generate different DEMs from the same landform.

One factor that affects an interferometric DEM is land cover or vegetation type. In forest areas, there are many factors and their combinations that have effect on an interferometric DEM. These factors include height of trees, forest biomass or stem volume, type of trees (coniferous, deciduous or even single tree species).

2. OBJECTIVE

It is well known in the SAR interferometric literature (*e.g.* Wegmuller and Werner, 1995) that the coherence between SAR images is very low in forested areas. The coherence tends to be the lower the higher the forest biomass is. High coherence is needed for detecting surface movements using interferometric techniques.

The objectives of the study were:

1. Study the canopy effect on coherence.
2. Study the time of the year effect on coherence.
3. Study the canopy effect on SAR-derived DEM.

3. MATERIALS

Following data sets were obtained for the study:

1. Satellite Imagery
   - ASAR C-band
   - JERS L-band
2. Cartographic DEM
   - Japan
   - Finland
3. Digital Map
4. Land use data
5. Forest Inventory Data

4. METHODS

SAR Processing

Raw SAR signal data were used as the starting point of processing (Figure 1). Vexcel SAR processor (Vexcel 2002) in the computer facilities of NIED was used to produce SAR images. The SAR processor had also modules for generating SAR interferograms and coherence scenes between two SAR scenes. Ortho-rectification of the interferograms and coherence scenes was done using VTT's in-house software.

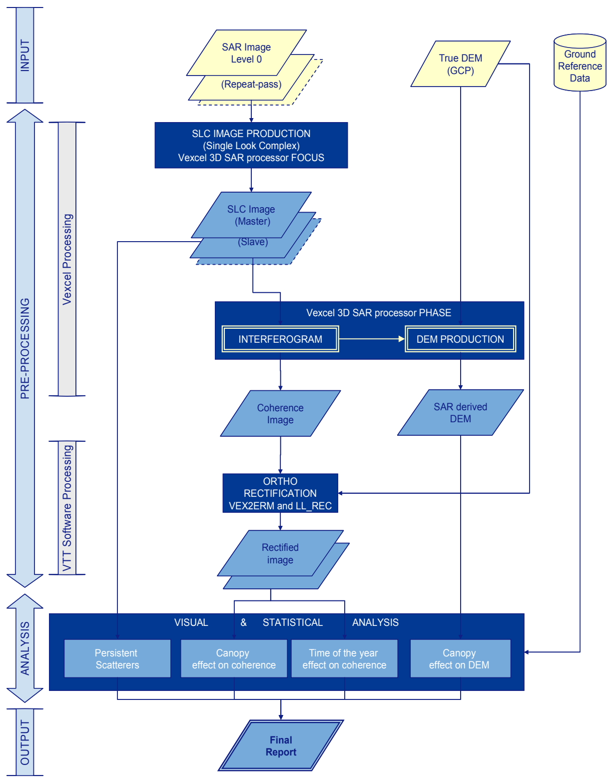

Figure 1. Overview of data processing and analysis flow.

Coherence

The canopy effect on coherence was studied by computing the average coherences and their standard deviations for each image and for each land use class. A digital land cover mask was used in the average computation.

The time of the year effect on coherence was studied visually by plotting the coherence data in ascending time order.

DEM

The canopy effect on DEM was studied by computing the difference between the SAR-derived DEM and the cartographic DEM.

5. RESULTS

DEM and Coherence computation

Table 1 shows the coherence level, base line and DEM resolution for the scene pairs in the Finnish study site. The reason for the failure of DEM generation was too low coherence in all cases of Table 1. Table 2 shows the corresponding table for the Japanese study site. In the third JERS SAR pair, the coherence was high, but the baseline was too short for DEM generation.

Table 1.Coherence in scene pairs in the Finnish study site.

Sensor	Master (reference)	Slave	Baseline (meter)	Coh	DEM
JERS SAR	19950314	19950427	744	Low	20m
JERS SAR	19951203	19960116	36	High	20m
JERS SAR	19960527	19960823	1549	Low	No DEM
JERS SAR	19970331	19970514	275	Mid	20m
JERS SAR	19951203	19960527	1203	Low	No DEM
JERS SAR	19960116	19960527	1199	Low	No DEM
ASAR	20030307	20030620	457	Low	No DEM
ASAR	20030620	20030725	149	Mid	20m
ASAR	20030725	20031107	129	Low	No DEM
ASAR	20031107	20031212	726	Low	No DEM
ASAR	20031212	20040326	188	Low	20m

Table 2. Coherence in scene pairs in the Japanese study site.

Sensor	Master (reference)	Slave	Baseline (meter)	Coh	DEM
JERS SAR	19951203	19960116	606	High	50m
JERS SAR	19951203	19960229	553	High	50m
JERS SAR	19960116	19960229	83	High	No DEM
JERS SAR	19970627	19970810	377	Mid-High	50m
JERS SAR	19970627	19970923	822	Mid	50m
JERS SAR	19970810	19970923	1050	Mid	50m
ASAR	20030621	20030726	190	High	50m
ASAR	20030726	20030830	481	Low	No DEM
ASAR	20030830	20031004	220	High	50m
ASAR	20031004	20031108	973	Low	No DEM
ASAR	20031108	20031213	243	High	50m
ASAR	20031213	20040117	629	Low	50m

SAR image ortho-rectification

SAR images were orthorectified using VTT in-house software. Geometric accuracy of original VEXCEL processed data was between 200 and 1300 meters. An interactive method was used to derive a constant translation for each scene. The translation was then applied in the ortho-rectification (re-sampling) phase.

Canopy Effect on Coherence

Figure 2 shows the average coherence for 4 land cover types in the Finnish study site. The highest coherence is in the winter-time JERS pair. This is the scene pair with the shortest baseline.

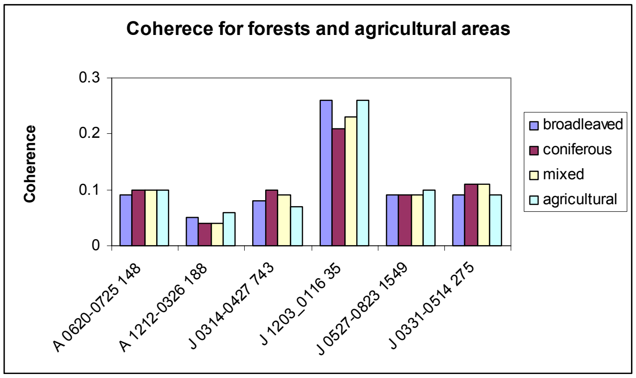

Figure 2. Average coherence in the Finnish study site.

Figure 3 displays the correlation coefficient between the coherence data and total stem volume in the Finnish study site. The data was averaged in a 100 m by 100 m window before analysis. Data labelling follows the syntax: Sensor (A = ASAR, J = JERS) master date, slave date, baseline length in meters. The same pair (winter-time JERS SAR pair) that had the highest coherence level has also the highest (absolute) value of correlation between SAR coherence and stem volume.

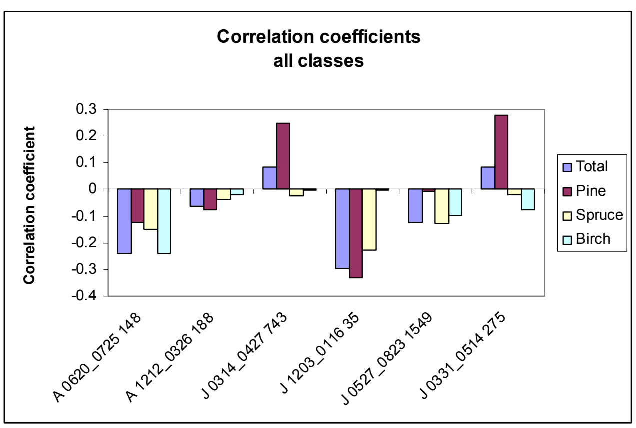

Figure 3. Correlation coefficient between coherence images and tree stem volume. This figure shows correlation coefficients for two ASAR and four JERS images against the total stem volume and the pine, spruce and birch volume. All classes are included. The number of observations (pixels) was 7107.

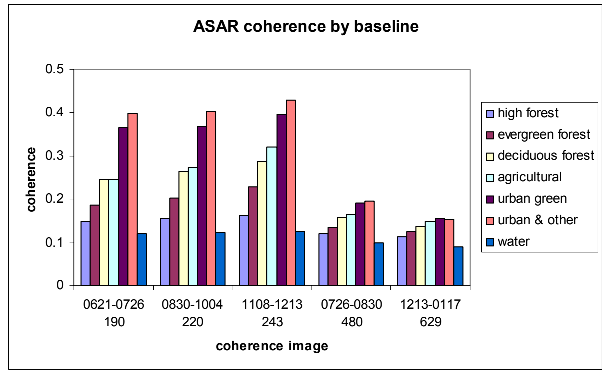

Figure 4. Average ASAR coherence for each image and for each land use class in the Japanese study site.

Figure 4 shows the average ASAR coherence for each image and for each land use class. Coherence images are in the order of ascending baseline length. As can be seen in Figure 4, the coherence drops notably when the baseline increases from 243 to 480 metres.

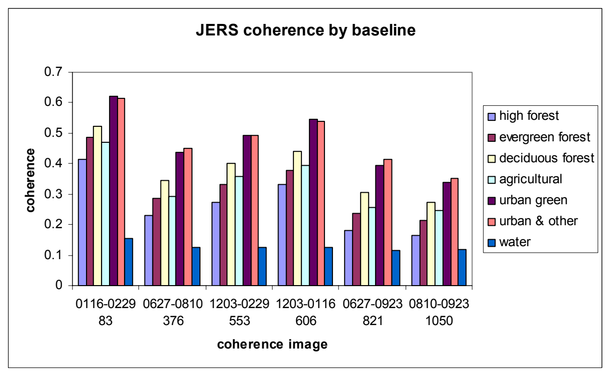

Figure 5. Average JERS coherence for each image and for each land use class in the Japanese study site.

Figure 5 shows the average JERS coherence for each image and for each land use class for the Japanese study site. As with ASAR (Figure 4), the coherence decreases with increasing baseline, but he decrease is slower in the L-band JERS SAR data.

Canopy effect on DEM

In the Finnish study site, the coherence in almost all JERS scene pairs was so low that DEM production was impossible. In cases where DEM production was possible, the DEM covered only a small area. The situation was similar with ASAR data in the Finnish study site.

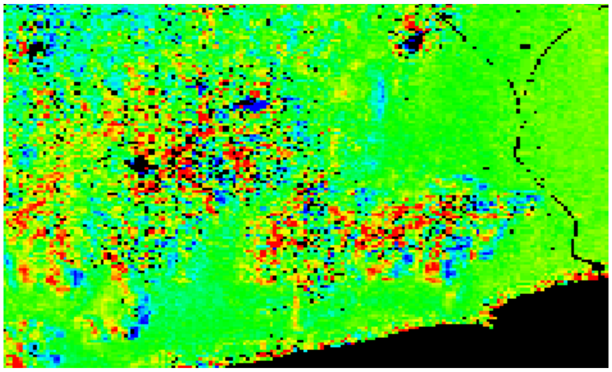

Figure 6. DEM error from JERS-1 SAR summer pair 27Jun1997 - 10Aug1997 in the Japanese study site. Baseline is 377 meters.

Figure 6 shows the DEM error (SAR derived elevation minus cartographic DEM) from the JERS-1 pair 27Jun1997 - 10Aug1997. Baseline is 377 meters.

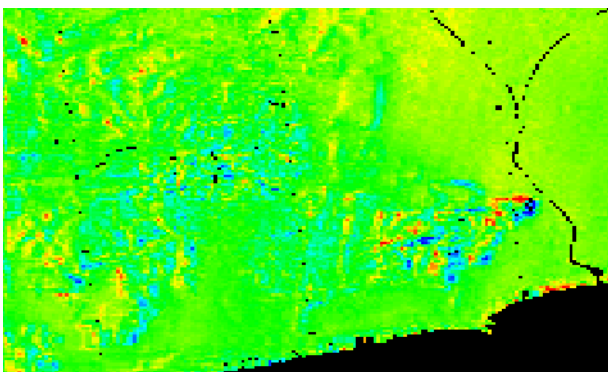

Figure 7. DEM error from JERS-1 SAR winter pair 03Dec1995 -16Jan1996. Baseline is 606 meters.

Figure 7 shows the DEM error for the JERS-1 winter pair 03Dec1995 -16Jan1996. Baseline is 606 meters.

In summer, when the coherence is low in agricultural areas, large areas of both forest and agricultural land remain without ASAR-derived DEM data. JERS-derived DEM includes most of the area. High forest areas have a noisy look and occasionally high differences compared to true DEM. This is most likely due to low coherence in high forest. In wintertime, the agricultural areas have higher coherence. Also the JERS-derived DEM has less noise and smaller difference compared to the true DEM (see Figure 6 and Figure 7).

6. CONCLUSIONS

The results of the study show that the canopy and the time of the year have clear influence on SAR coherence. Accurate and reliable DEMs are hard to compute over heavily forested areas using (repeat-pass) SAR interferometry.

Analyses show that JERS L-band produces higher coherence than ASAR C-band. A weak negative correlation exists between the stem volume and coherence in boreal forests.

Both ASAR and JERS coherence data were analyzed using land use data. ASAR coherence dropped significantly when the baseline was around 500 meters or more. In the Finnish study site, the coherence was quite similar within areas of different forest types. Over the Japanese study site, urban targets produced highest coherence on both bands. Deciduous forests and agricultural lands showed high coherence whereas high forests showed low coherence. The reason for this is that high forests are not stable as they move easily with wind. Coherence is sensitive to different land use classes in less forested areas. Over heavily forested areas – like the Finnish study site – coherence is not very sensitive to different forest types.

High quality DEMs can not be computed over areas with high forests. Over urban areas and agricultural lands, the computed DEMs fit quite well with the true DEM. JERS derived DEMs are usually more accurate than the ones derived from ASAR data. The best DEM was computed from JERS winter time data.

5. ACKNOWLEDGEMENTS

This project was funded by National Research Institute for Earth Science and Disaster Prevention (NIED).

6. REFERENCES

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