EC ENVIRONMENT AND CLIMATE PROGRAMM

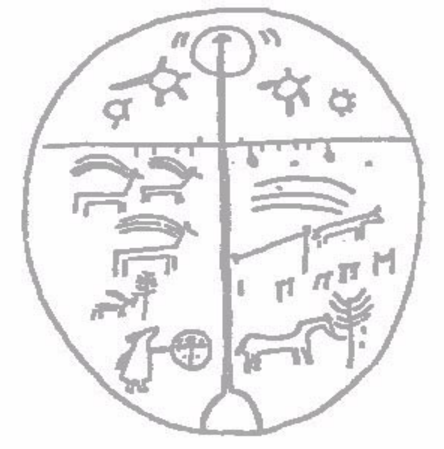
THEME 3: SPACE TECHNIQUES APPLIED TO ENVIRONMENTAL MONITORING

AREA 3.3: CENTER FOR EARTH OBSERVATION

3rd Progress Report

SIBERIA

SAR IMAGING FOR BOREAL ECOLOGY AND RADAR INTERFEROMETRY APPLICATIONS



February 2000

List of Partners:

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Teams	2	1	3	1	1	1	3	1

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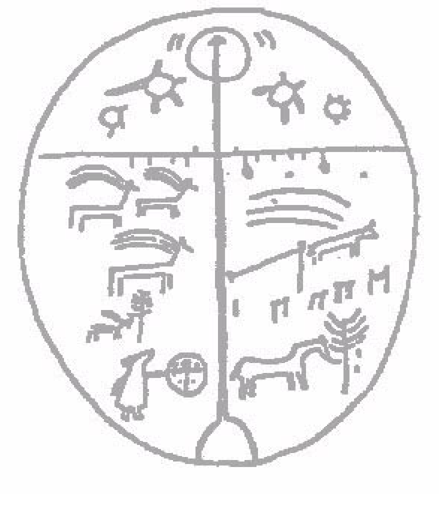

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This report describes the work done during the third six month period of the SIBERIA project (August 1999 to January 2000). Due to the 3-month extension of the project, February 2000 is also included. SIBERIA is financed through the 4th Framework Programme of the European Commission, Environment and Climate, Area 3.3: Centre for Earth Observations.

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Project Co-ordination: Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)

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Abbreviations

AVHRR	Advanced Very High Resolution Radiometer
CA	Coefficient of Agreement
CEO	Centre for Earth Observation
CESBIO	Centre d´Etudes Spatiales de la Biosphere
DEM	Digital Elevation Model
DLR-DFD	Deutsches Zentrum für Luft- und Raunfahrt, Deutsches Fernerkundungsdaten-zentrum
DLR-HF	Deutsches Zentrum für Luft- und Raunfahrt, Institut für Hochfrequenztechnik
EC	European Commission
ERS	European Remote Sensing Satellite
GAMMA	Gamma Remote Sensing Research and Consulting AG
GEC	Geocoded Ellipsoid Corrected Image
GIM	Geocoded Incidence Angle Mask
GIS	Geographical Information Systems
GTC	Geocoded Terrain Corrected Image
ICP	Iterated Contextual Probability classifier
IIASA	International Institute for Applied System Analysis
InSAR	Interferometric SAR
JERS	Japanese Earth Resources Satellite
MLC	Maximum Likelihood Classifier
NASDA	National Space Development Agency of Japan
NERC	Natural Environment Research Council
NESDIS	NOAA's National Environmental Satellite, Data, and Information Service
NOAA	National Oceanic and Atmospheric Administration
OSEI	Operational Significant Event Imagery support team
PRI	SAR Precision Image
SAR	Synthetic Aperture Radar
SCEOS	Sheffied Center for Earth Observation Science
SFA	State Forest Account (Russian forest inventory system)
SIBERIA	CEO Project “SAR Imaging for Boreal Ecology and Radar Interferometry Applications”
SLCI	SAR Single Look Complex Image
UWS	University of Wales, Swansea
VTT	VTT Technical Research Centre
WP	Work package

EXECUTIVE SUMMARY

This report describes the work done during the third six month period of the SIBERIA project (August 1999 to February 2000). SIBERIA is financed through the 4th Framework Programme of the European Commission, Environment and Climate, Area 3.3: Centre for Earth Observations. The aim of SIBERIA is to generate information about the state of Siberian forests for dedicated Russian customers based on state-of-the-art satellite data and remote sensing techniques. More specifically, the objectives are 1) to demonstrate the capabilities of microwave remote sensing for monitoring criteria and indicators for sustainable development, and 2) to retrieve information needed for reliable estimations of economic, ecological and social roles of Russian forests under transition conditions.

Direct interaction with potential customers of such information is given through the participation of IIASA and institutions from the Russian forestry sector in the project. Within the project, the tasks of IIASA and its Russian partners are the definition of the structure and content of the foreseen forest data base, and the establishment of a reference in-situ data base. The collection and compilation of the forest data base is complete. Reference data from totally 38 ground truth areas and 11 test territories are available to the project.

SIBERIA uses the advantages of dual-frequency, interferometric, and multi-temporal ERS-1/-2 and JERS-1 SAR products. Data processing has made excellent progress within the reporting period. The satellite data can be viewed on the project webpage http://pipeline.swan.ac.uk/siberia/.In total 85 of 113 planned ERS products were delivered until now. 33 DEMs could be derived, enabling terrain correction. Due to low coherence, 52 interferometric data sets could only be registered and geocoded using a coarse DEM (GLOBE-product). Up to date 29 tracks, each with 15 JERS-1 scenes (total of 435 scenes!) have been processed. Most of the tracks have interferometric coverage so that not only the backscattering and texture images were computed but also the coherence images. Two NOAA AVHRR mosaics complete the satellite database.

The tests of the methods for co-registration led to the decision to use co-registration software developed by GAMMA Remote Sensing. The tool works very quickly and gives good results for fairly mountainous areas. A new method for masking mountainous regions based on the globally available GTOPO30 DEM has been developed. The information content of the ERS intensity, ERS coherence and JERS intensity images as a function of the forest volume and land cover classes was investigated. A data base containing selected field and radar data from all available testsites was generated to derive classification rules that are generally applicable to the entire SIBERIA region. Based on the common database the use of the ERS coherence for determining forest classes with different levels of growing stock volume was investigated. The classification scheme includes i) flagging of radar data affected by weather conditions through the use of ERS intensity information; ii) the use of JERS summer intensity images to identify non-forest categories such as water, agricultural fields, bogs and urban areas; and iii) the use of ERS coherence information to identify low and high volume forest cover.

Rule-based classification is, in principle, preferred for its transparent connection to forest backscatter properties and easily-identified error sources. The following classifiers were considered and investigated: Maximum likelihood classification (MLC), Fuzzy c-means clustering, and ISODATA clustering – the latter one being chosen. Geometric, classification and spatial accuracy have been investigated.

Two critical issues of the project, data availability and establishment of data processing flows, had been solved at the time of the 2nd Progress Report. The satellite and ground truth data bases for the test sites are almost complete. The methodological development is making the expected good progress leading to a unified classification algorithm to be synergized this month, March 2000. The data base is sufficient for the start of the operational classification at Satellus and all hand-over procedures concerning the pre-processing of the satellite data have been tested. The spring period of the year 2000 will show by processing a large amount of satellite frames at Satellus, how SIBERIA's Meth-Team has accomplished the task of developing a unified, operational strategy for large-scale forest mapping.

SUMMARY REPORT

1. Introduction

This report describes the work done in the framework of the SIBERIA project (SAR Imaging for Boreal Ecology and Radar Interferometry Applications). The aim of SIBERIA is to generate valuable information about the state of Siberian forests for dedicated Russian customers based on state-of-the-art satellite data and remote sensing techniques. This report focuses on the progress made in the third six month period of the project (August 1999 to January 2000), but also includes results from February 2000, since the project has been extended by three months. The extension became necessary due to a delay in connection with the JERS-1 processing chain causing delays in the methodological development. With respect to this problem the great support and cooperation between NASDA's processing department and the DLR-DFD's ground segment team is highly acknowledged.

SIBERIA's approach is to identify the customer's key problems and policy issues and then to develop a remote sensing technology based on their demands in order to achieve a realistic implementation and service to the policy settings. The aim of SIBERIA is to demonstrate the usefulness of forest information derived from multi-frequency, interferometric, and multi-temporal SAR products for Russian forestry. SAR data from the ERS and JERS satellites from the years 1997 and 1998 became available thanks to a recent international effort initiated by DLR and ESA, that ensured the systematic acquisition of these data over Siberia. The constraints of current operational satellite systems have to be clearly identified and addressed.

A major forest management task for Siberian foresters is to protect their forests against natural and human-induced disturbances. To fight these disturbances with the limited financial and human resources as effectively as possible, accurate and up-to-date information on the state of the forests is needed for operational forest inventories. The one major source of information concerning all Russian forests is the State Forest Account (SFA), which is an accounting inventory based on field observations, aerotaxation, and satellite remote sensing. Even if the Russian inventory system is better than in many other countries, there are a number of concerns:

- Given the current economic situation and the size of the country, Russia may not be able to afford to continue with the conventional forest inventories.
- Inventories for individual regions are carried out at wide and irregular intervals, sometimes dating back as long as 25 years.
- A comprehensive inventory of disturbances due to fire, pests, diseases and other biotic factors does not exist. About 40 % of the forested areas are not monitored.
- Wood harvest is believed to be higher than official data due to shadow economy, intentional underestimates, and "losses" resulting from statistical agencies.

Remote sensing may help to alleviate some of the problems connected with the Russian forest inventory system.

2. Customer Needs

Transition of the world's forest management to sustainable development requires significant improvement of information currently available describing the forest resources. The creation of an Integrated Information System for Russia to meet these needs is proposed. This system would provide information that is highly accurate, operational, comprehensive, inexpensive and suitable for sustainable forest management. The information utilised by this system would include field-based measurements, existing inventory data, aerial photos and data from passive and active satellite sensors.

Remote sensing methods used in an Integrated Information System, designed in a holistic way, can be decisive in achieving sustainable development of the Russian Forest Sector. Remote sensing can be applied to forest inventory and monitoring, planning and control of management and assessing the state and dynamics of forest resources, ecosystems and natural landscapes.

The Russian forestry needs the following information about the forest measured:

- Forest composition
- Tree species and non-forest communities' structure
- Disturbances, forest age, etc.
- Biomass
- Productivity (primary)

The Russian forestry and IIASA have two main expectations from the SIBERIA project: methods of how to use SAR data to provide the needed information and knowledge of the capabilities of SAR gained from general results in the test areas.

3. Administrative Issues and Project Co-ordination (WP 1000)

3.1. Personnel

With respect to personnel, no changes have taken place in the reporting period.

3.2. Meetings

The 3rd Progress Meeting took place as scheduled at the location of Satellus in Kiruna, Sweden. The planned hand-over period of the forest classification algorithm from the Methodology Team to the map producing company Satellus, however, had to be postponed due to the severe delays of the JERS-1 products. The meeting still took place to discuss the several pre-processing steps (calibration, co-registration, filtering) and details of the final map lay-out. The following decisions and conclusions were made:

- **Map Product Session**

1. Map Projection? UTM Projection.
2. Which UTM zone to use where? Zone corresponding to center coordinate for ERS, JERS-data is being processed in two respective zones where necessary
3. What do the users prefer? UTM Projection
4. Map production to be done by Satellus for all frames? UWS sends CD with processed data for <u>all</u> ERS scenes to Satellus

- **SAR Geometry**

1. Masking Procedure based on relative GTOPO30 pixel displacement. Most of the high-reliefed terrain is covered by GECs – masking procedure may be used to decide which GECs further to be used.

- **Information Content**

1. Presentation of coherence variations. Histogram of coherence values changes from frame to frame along track. Coherence values may look very bad, but image still visually with a lot of contrast.
2. Presentation of Coherence Model: 2 classes, < and > 70 qm/ha, also includes quality estimation of information content of image. Advantage: independent from meteorological or baseline aspects.
3. Analysis on JERS data. No information in coherence seen.
4. Analysis of Relative Stocking parameter in connection with Volume Classes. No impact/ no new dependencies.

- **Filtering and Classification**

1. Multi-channel filtering algorithm available for team.

2. Classification algorithm comparison: Isocluster vs. Neural net (C-means) approach. Neural Net too time expensive.
3. Example of Segmentation Results. Good.
4. Demonstration of ICP Classifier Results. Promising.

- **Accuracy Assessment**

1. Kappa (a posteriori accuracy) accepted as assessment parameter.
2. Level I and II classification product with different Kappas.

- **Synergy SAR + Optic**

1. Only NOAA-14 checked (to avoid radiometric problems).
2. 2 Landsat scenes purchased – funding problem for more scenes.
3. Coordination with IIASA necessary for further purchase of optical data (because of re-assignement of INCO funds).

During the Kiruna meeting, the Methodological Team inaugurated the new project mascot:

the Moose.

Due to the 3-month delay of the methodological development an additional Meth-Team meeting has been scheduled for March 10 and 11 at the site of Partner 7, NERC, Monkswood/UK. Major methodological achievements have been accomplished at the writing of this report and will be concluded during the NERC-meeting.

3.3. Communication and Web Sites

Communication within the team and with the customers, IIASA and its Russian partners, is excellent. Progress monitoring, sharing of methodological tools, and data transfer is secured by following means:

1. Regular e-mail contact between all partners. E-mail distribution lists for the entire SIBERIA team and the methodological development group exist.
2. Monthly progress reports of the methodological team. The individual monthly partner reports are collected by SCEOS who write and distribute a summary monthly report.
3. The web pages established by IIASA and UWS have proven to be very useful for the project. The initially planned web page at DLR was not implemented - instead contributions from DLR-HF were integrate at the UWS web page. Continued development and improvement of the SIBERIA WWW-site at UWS has been achieved. The site now serves to inform the public and promote the research being undertaken on the project. Encouraging feedback, on how informative the site is, has been received from colleagues in institutions not linked to SIBERIA. The web site serves also, as a catalogue of image data, for the distribution of documents and meta-data and for charting the progress of all aspects of the project. Within the project itself, the feeling seems to be that this is a valuable tool for the SIBERIA consortium and should continue to be developed as a Computational Issues Work Package (WP5050). The web site at http://pipeline.swan.ac.uk/siberia/ now contains the following information:

- *Home Page* - lists funding, general objectives, geographical location (a map) and partner institution information.
- *What's New* - lists all the new and important project developments and recently acquired images.
- *E-mail Listing* – lists full SIBERIA group and methodology sub-group e-mail addresses
- *ERS/JERS Coverage* – lists all ERS and JERS images that have been processed. From here thumbnail and low-resolution images can be viewed. Provision is made for searching the SIBERIA project region by geographical location via point and click images.
- *Field Data* – lists important field data information and links to the IIASA web site.
- *Working Notes* – lists SIBERIA technical notes, results, EU reports and conference papers. The notes can be downloaded in either html or pdf format.
- *ERS/JERS Status* – lists the ERS and JERS satellite orbit information over the SIBERIA area.

- *Weather Data* – lists weather data for climate stations in the region.
- *Database Plots* – lists the plots of image information against forest parameters.

4. A number of working notes on specific topics were distributed via e-mail and integrated at the UWS web page. A list of the working notes is given in the next paragraph.
5. FTP Servers at UWS, DLR-DFD, and IIASA.
6. *New Item*: Teleconferences have been established between all seven Methodology Team partners. Telecons take place Wednesdays at 13:00 (GMT) in a 1 to 3 week interval, depending on issues.
7. Regular phone calls.

3.4. Working Note Publications

The following working notes were produced in the reporting period (full text is available on the SIBERIA webpage):

- Methods of Accuracy Assessment in the Siberia Project (Heiko Balzter - ITE - 21st June 1999)
- Treatment of extreme topography in GEC and GEC_GLOBE images (Heiko Balzter - ITE - 9th September 1999)
- Analysis and interpretation of ‘strange’ outliers at the northern Irbeiskii test site (Kevin Tansey - UWS - 20th September 1999)
- Comparison of slope estimates from the InSAR DEM and GTOPO’30 (Kevin Tansey - UWS - 20th September 1999)
- Classification of boreal forest (Ust-Illimsk) with maximum likelihood classification (David Gaveau - ITE - 6th October 1999) PDF format (2.4 Mb)
- Coherence analysis of all processed test sites (Thuy le Toan & Malcolm Davidson - CESBIO - 19th October 1999)
- Analysis of the information content of three texture measures of ERS amplitude and coherence (Heiko Balzter et al. - ITE - 26th October 1999) PDF format
- Investigation of image properties in the SIBERIA project (J.J. Yu and S. Quegan - ITE - 26th October 1999) PDF format (2.0 Mb)
- First results of database analysis for Bolshemurtinskii (W. Wagner, J. Vietmeier, C. Schmullius & A. Holz - DLR - 4th November 1999) PDF format
- Use of the ERS coherence for forest classification (W. Wagner - DLR - 9th December 1999) PDF format
- Boxplots of texture statistics against land use class (H. Balzter, D. Gaveau & S. Plummer - ITE - 21st December 1999) PDF format
- The Iterated Contextual Probability (ICP) classifier (H. Balzter & J. Baker (RSAC) - ITE - 11th January 2000) PDF format
- Ground offsets during coregistration of JERS-1 and ERS images (H. Balzter & K. Tansey - ITE/UWS - 14th January 2000) PDF format
- Results of the application of the topography mask to the resampled GTOPO’30 DEM for 2 ERS frames (K. Tansey & A. Luckman - UWS - 14th January 2000)
- Working note of histogram generation (M. Davidson - CESBIO - 18th January 2000) PDF format
- Pixel histograms for selected test sites (no supporting text) (D. Gaveau - ITE - 18th January 2000) PDF format
- Comments and summary: Ground offsets during coregistration of JERS-1 and ERS images (J. Vietmeier & W. Wagner - DLR - 20th January 2000) PDF format
- Report on coregistration using GAMMA software (K. Tansey - UWS - 31st January 2000) PDF format
- Boreal Forest INSAR Classification Properties (D. Gaveau - ITE - 1st February 2000) PDF format
- Extended Accuracy Assessment of Coherence Model(W. Wagner & J. Vietmeier - DLR - 16th February 2000) PDF format
- Use of ERS Backscattering Coefficient for Forest Classification (W. Wagner & J. Vietmeier -

DLR - 18th February 2000) PDF format

4. Work Packages and Deliverables

Three types of progress monitoring tools for the Work Packages have been defined for SIBERIA:

1. external reports and comments to the EC;
2. internal deliverables (intermediate reports, data products, methodological tools) and internal milestones (conclusion of a work package, which is essential for the project's progress);
3. external deliverables for third parties.

The following deliverables and milestones in Tables 4-1 to 4-3 were due in the reporting period from August 1999 to January 1999. List of responsible partners and deliverables: Gamma, DLR-DFD – D27, IIASA/NERC – D28, *delayed*: D29, D30. The detailed Work Package results are described in the Individual Partner Reports section and are summarised in the following chapters. Further material is contained in the hand-out proceedings of the 3rd Progress Meeting at Satellus, Kiruna from December 11-14, 1999.

In addition to the Project Deliverables, monthly progress reports have been sent to the Methodology Coordinator at SCEOS from each Methodology Team member. The status of methodological development is summarised in Chapter 7.

The delayed Milestones 2 and 3 of the last reporting period have meanwhile been accomplished. Milestones 4 and 6 are concluded as planned. Milestone 5, 7 and 8 are affected by the 3-month delay of the methodological development and are thus still in the process of being accomplished. SIBERIA's major milestone (MM1) "Methodology Synthesis" will be reached during the upcoming additional Meth-Team meeting at NERC during March 10-11, 2000.

As a reminder, the 3-month delay is due to former tremendous logistical problems in establishing a processing procedure at NASDA for the special recording format of the repeat-pass JERS-1 data acquisitions at the DLR Mobile Receiving Station Ulaanbaatar during summer 1998. Due to the outstanding support of Dr. Klaus Reiniger/DLR-DFD and Dr. Masanobu Shimada/NASDA this only complete repeat-pass JERS-1 coverage of Siberia was during the reporting period synchronised at DFD and processed at Dr. Shimada's new processor at NASDA. The last JERS-1 Level 0 products have been sent to Gamma at the writing of this report in Week 9, 2000.

4.1. External Deliverables for EC

Item	#	Title	Work Packages Involved	Due Date
Reports	3	3rd Progress Report	1100, 1150, 2200-2300, 3300-3400, 5000, 5030, 5040, 5130, 5140, 5160, 5170, 5230, 5240, 5260, 5270, 5330, 5340, 5360, 5370, 5400, 5510, 6050, 6100, 6300	T0 + 18

Table 4-1: Reports to EC.

4.2. Internal Deliverables and Milestones

Item #	Title	Work Packages	Due Date
	Deliverables		
27	Processing Status III	2300, 3300, 3400	T17/18
28	Accuracy Assessment III	4500, 5040, 5140, 5240, 5340	T17/18
29	Map Status	6100	***Delay***
30	Sampling Scheme for Map Assessment	6300	***Delay***

	Milestones		
2	Co-Registration Strategy	5010	T19√
3	Quantification of Image Information Defined	5020	T19√
4	Interferometric Processing Concluded	2100, 3100, 3200	T14
5	Reference Data Manual	4300	T14
6	DEM Generation Concluded	2200, 3300	T17/18
7	Classification Methodology Revised	4400, 5000	***Delay***
8	Synergy SAR + Landsat	5510	***Delay***
	Major Milestones		
1	Methodology Synthesis	5000, 5130, 5230, 5330, 5400	***T20***

Table 4-2: Internal deliverables and milestones.

4.3. External Deliverables for Third Parties

No external deliverables were due in the reporting period. However, since the mid-term, 2nd project report was considered as a summary of major developments in the field of forest radar remote sensing, the report was send out to 34 interested parties around the world, resulting in intensified contacts and feedback.

5. Data Acquisition and Processing Status

5.1. ERS Synthetic Aperture Radar

The establishment of the ERS SAR data base has been co-ordinated by DLR-HF and the interferometric processing has been done at DLR-DFD. At DLR-HF the specific tasks with respect to the ERS SAR image data base have been to select the images, order the data from ESA, and to determine the processing sequence at DLR-DFD in accordance with the available ground data and the status of methodological development.

The SAR data used in the SIBERIA project were acquired in two campaigns in 1997 and 1998 with a mobile receiving station of DLR-DFD in Ulaanbaatar, Mongolia. The goal of the ERS SAR selection and ordering has been to obtain a rather complete coverage for an area from about 51-62°N and 88-112°E with one ERS-1/ERS-2 tandem pair from 1997 and one summer image from 1998. A problem is that particularly in the eastern part of the study area many of the SAR data takes are of low quality (high biterror, missing lines). Therefore a complete coverage with ERS tandem data could not be achieved.

At DLR-DFD the ERS tandem data are processed interferometrically. Where interferometric coherence allows, DLR-DFD produces geocoded terrain corrected (GTC) co-registered imagery: amplitude images of the two autumn 1997 and summer 1998 images, one coherence image, the digital elevation model (DEM), and a geocoded incidence angle mask (GIM). If low coherence does not allow the generation of a DEM then the data sets were processed to geocoded ellipsoid corrected products (GECs). Because of the considerable geometric distortions of the GECs it was decided at the interim meeting in Swansea that DLR-DFD should use a global DEM with a raster width of 30 arc seconds (GTOPO30) to make a crude geometric correction of the images. However, no radiometric correction is applied. This procedure has been established at DLR-DFD.

As agreed between the project partners the product quality has priority against quantity. This has two consequences:

- a terrain correction is envisaged wherever the estimated success rate is higher then 50 %;

- The DEM quality is additionally improved by interactive steps like correcting phase unwrapping errors and the masking of water bodies.

Unfortunately the conditions for an interferometric generation of a DEM are not optimal (vegetation and relief). Therefore interactive corrections have to be applied to approximately 75 % of the GTCs, slowing down the production throughput accordingly. Figure 5-1 gives an overview of the processing status at DLR-DFD. So far 37 GTC and 56 GEC have been produced.

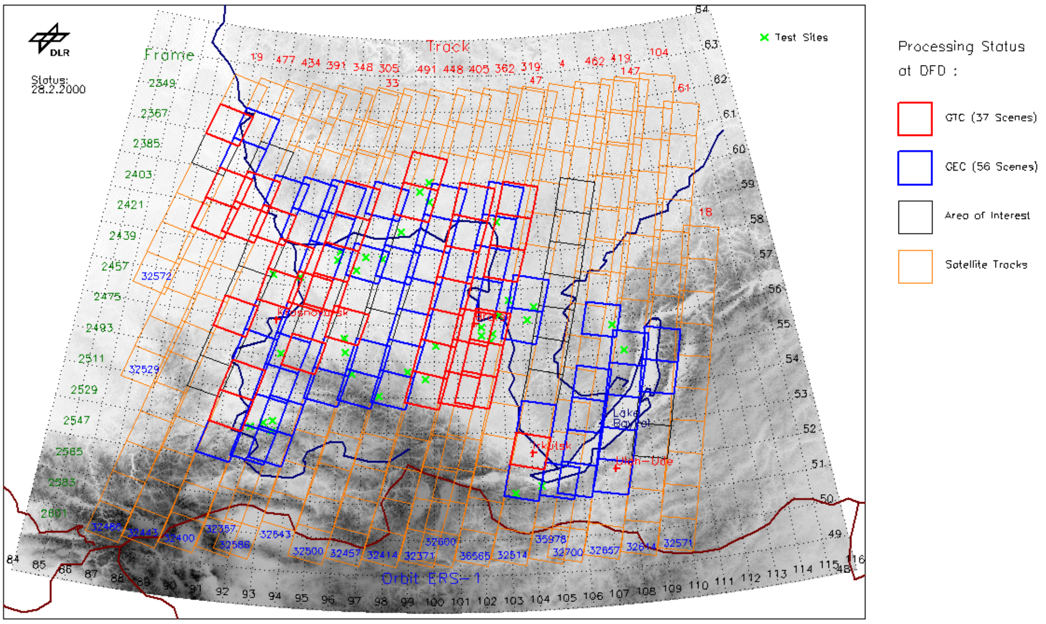

Figure 5-1: Processing status at DLR-DFD.

5.2. JERS Synthetic Aperture Radar

The selection and processing prioritisation of the JERS data was carried out by DLR-HF in collaboration with Gamma. Since DLR-DFD, NASDA, and Gamma are capable of processing complete JERS tracks that span the south-north extension of the study area (50-62°N) only the RSP number and the acquisition date had to be determined. Up to date 29 tracks of about 15 scenes (total of 435 scenes !) have been processed at Gamma (Partner X). Most of the tracks have interferometric coverage so that not only the backscattering and texture images were computed but also the coherence images. Figure 5-2 shows the location of the JERS tracks with even RSP numbers. For further information and quicklooks of JERS-1 amplitude and coherence images (where repeat-pass tracks were available), please refer to SIBERIA’s webpage.

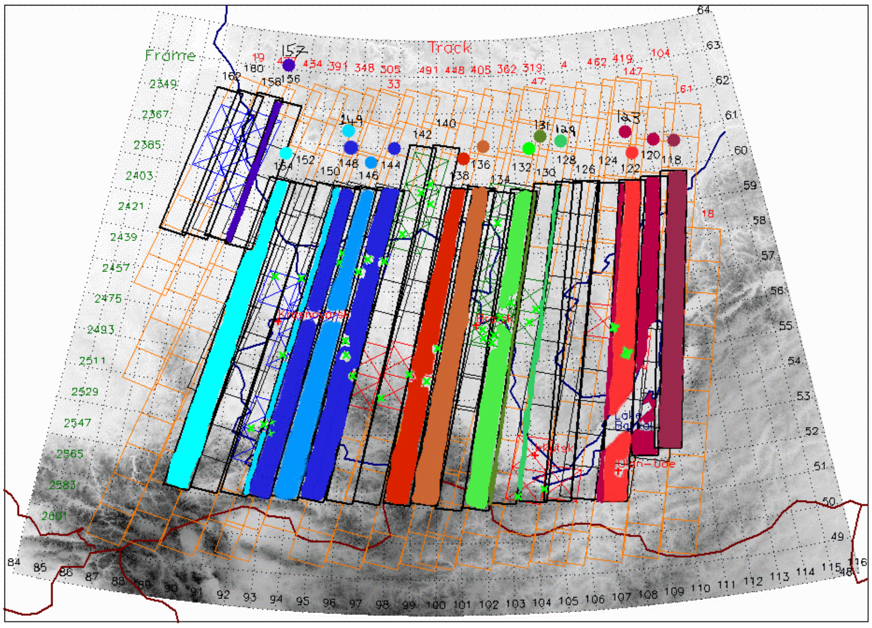

Figure 5-2: Overplot of JERS tracks over the ERS scenes. Shown are only JERS tracks with even RSP numbers which can be seen above the respective tracks.

5.3. Optical Imagery

VTT (Partner VIII) has investigated first classification results using a Landsat ETM image. Clouds and shadows of clouds have caused problems. Two NOAA AVHRR mosaics have also been produced and major landscape units identified (compare Figure 5-3). For further information, see Individual Partner Report VIII.

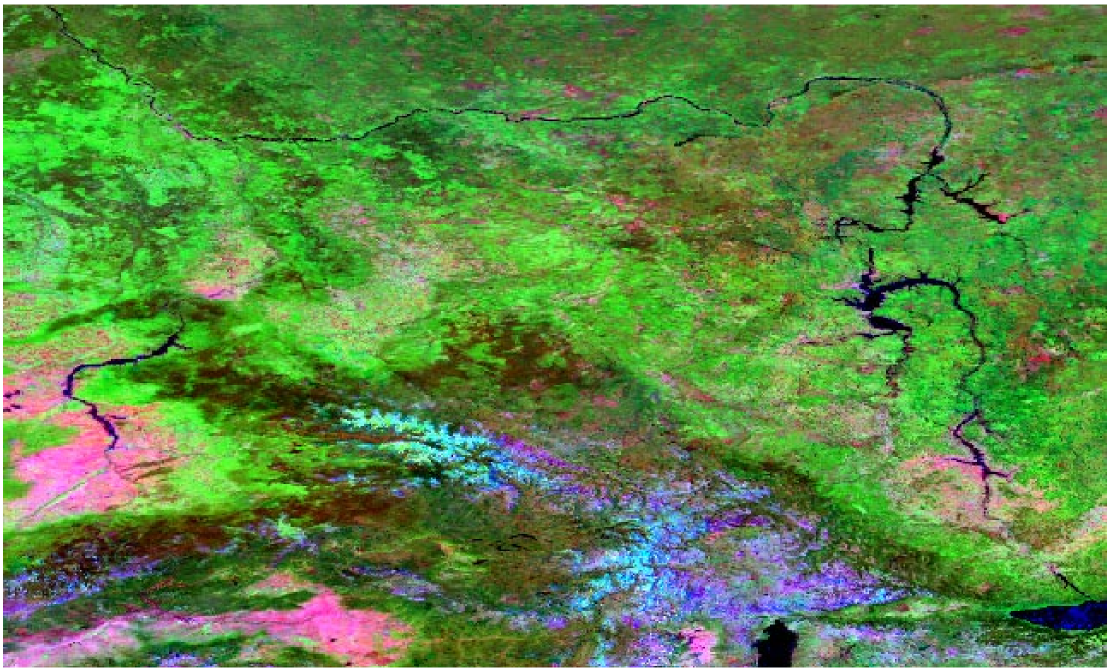

Figure 5-3: NOAA AVHRR mosaic. Blue = visible, green = near infrared, and blue = mid infrared.

5.4. Meteorological Data Base

To aid the interpretation and analysis of the radar images, meteorological data from 113 stations spread over an area from about 49 to 62°N and 84 to 115°E were acquired from the "Deutscher Wetterdienst". To allow easy checking of the meteorological conditions at the dates of satellite acquisition, plots of temperature and precipitation series were prepared and put on the Swansea web page. If an ERS scene was within 50 km of the geographic location of the meteorological station then the acquisition dates of the three ERS images were indicated by vertical lines in the plots (for JERS-1 images in preparations).

6. Classification Requirements and Ground Truth

Based on a review of criteria for indicators for Sustainable Forest Management by the Federal Forest Service of Russia, current forest inventory manuals, and accuracy assessment criteria, IIASA has defined the structure and content of the up-to-date forest data base to be created. It is suggested to use the land cover / land use categories currently in use in the Russian forest inventory as targets for forest variables to be measured (compare 2nd Progress Report).

So far, reference data for 38 ground truth areas for six test territories have been produced in ArcInfo format. The data are available on request to the Project partners and on the Internet site http://www.iiasa.ac.at/Research/FOR/siberia. Additional 11 test areas are reserved for accuracy assessment.

7. Methodological Development

The development of methodological tools for forest classification and extraction of relevant information for the Russian State Forest Account is the critical technical issue in this project. Methodological development is carried out by the “methodology team” DLR-HF, CESBIO, SCEOS, UWS, NERC, and VTT. The work of the methodology team is co-ordinated by SCEOS who review the progress on a monthly basis.

- SAR Geometry, DLR-HF (WP 5010)
- Information Content, CESBIO (WP 5020)
- Pre-processing and Classification, SCEOS (WP 5030)
- Accuracy Assessment, NERC (WP 5040)
- Computational Issues, UWS (WP 5050)

7.1. SAR Geometry (WP 5010)

The Working Package WP 5010 is completed.

Geocoded Incidence Angle Mask, Radiometric Calibration and Strategy for Layover and Shadow Areas **-** A procedure for the generation of geocoded incidence angle masks (GIMs) has been developed and tested. It involves the application of a 5 x 5 median filter to reduce the noise of the InSAR DEM prior to the incidence angle mask calculation. A c-program called "medi5x5_sib" was written for operational filtering. For GEC products it is not possible to consider the influence of the topography due to the lack of an InSAR DEM. Therefore mountainous areas would lead to errors in the classification and should be masked out. The masking is discussed further below.

Co-registration of ERS and JERS Images **-** The topography induced geometric distortions of the SAR images are representing the main problem for the co-registration of JERS and ERS products. We are confronted with two different dataset combinations for co-registration (see working notes “Ground offsets during coregistration of JERS-1 and ERS images” by Heiko Balzter and Kevin Tansey and

"Comments and Summary: Ground offsets during coregistration of JERS-1 and ERS images" by Jan Vietmeier and Wolfgang Wagner):

1. *InSAR/GTOPO30:* The ERS products are geocoded using the InSAR DEM and the JERS products are geocoded using the GTOPO30 DEM. This is the case for ERS-GTC products.
2. *GTOPO30/GTOPO30:* Both the ERS and JERS products are geocoded using the GTOPO30 DEM.

The tests of the methods for co-registration led to the decision to use co-registration software developed by GAMMA Remote Sensing. The tool works very quickly and give good results for fairly mountainous areas. The Working Note 'Report on coregistration using GAMMA software' (January 2000) describes the procedure, an estimate of the processing load and results from the fully automated coregistration procedure available from GAMMA. In Figure 7-1, a false colour composite image shows a coregistered ERS coherence, ERS intensity and JERS intensity image, an output from this processing stage.

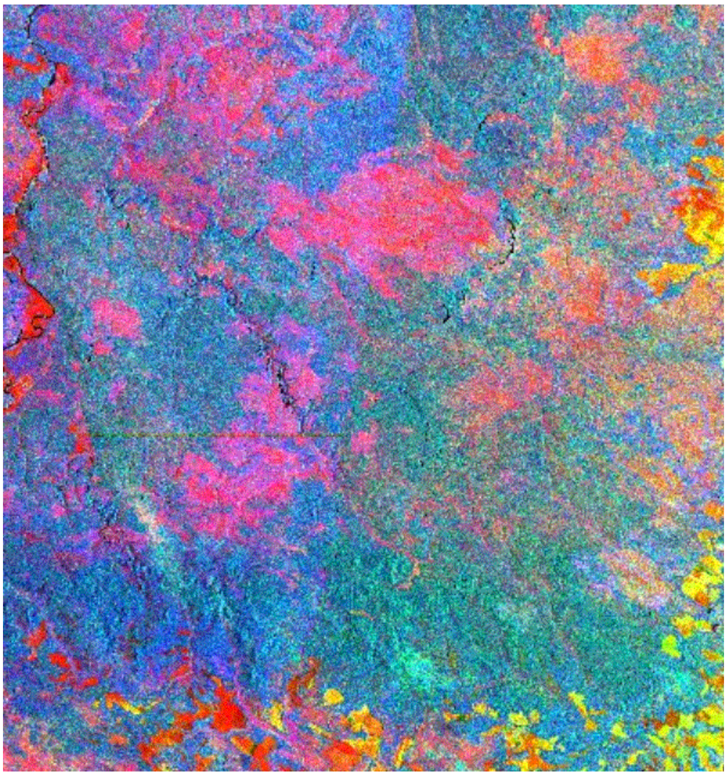

Figure 7-1: False colour composite comprising RED = ERS tandem coherence, GREEN = ERS intensity, BLUE = JERS intensity. In this example, 4 JERS image products have been coregistered to the ERS image, using software developed by GAMMA. The JERS data were acquired in summer 1998 and were coregistered initially to an ERS intensity image acquired during the same season.

Masking Procedure for Strong Topography - A new method for masking mountainous regions based on the globally available GTOPO30 DEM has been developed. The procedure is the following:

1. Resample the GTOPO30 DEM to 50 x 50 m pixel spacing and generate a subset according to the area of the respective ERS frame.
2. Calculate the geocoded incidence angle mask (GIM) based on the GTOPO30 DEM and the specific ERS acquisition geometry.
3. Calculate the standard deviation for subsets of the GIM of a specific size, e.g. 10 x 10 pixel.

Apply a threshold of the standard deviation to mask out hilly terrain. A threshold of 1.4° and a window size of 20 x 20 pixels lead to the best results for masking (see Figure I-1 in Individual Partner Reports).

7.2. Information Content (WP 5020)

Considerable time was spent on interpreting the information content of the ERS intensity, ERS coherence and JERS intensity images as a function of the forest volume and land cover class.

- Very low volume forest (<50 m3/ha) can on average be distinguished from well-developed forests having volume levels greater than 150 m3/ha.
- Intermediate volume forests exhibit coherence lying in-between these two ranges but generally overlap with either low-volume or high-volume classes.
- Overall there is a relatively high variability in average coherence for a given class. This is due to a number of factors including polygon misregistration (especially in areas of high relief), accuracy of volume estimate, regrowth of forest since inventory as well as environmental factors.

Common Data Base Plots - Besides the more detailed analysis at the individual sites it was decided to establish a data base that contains selected field and radar data from all available testsites to derive classification rules that are generally applicable to the entire SIBERIA region. The format of the data base and the corresponding metadata base was defined by DLR-HF in collaboration with all partners from the methodological team (Table 7-1).

Position	Variable
1	Unique number
2	GIR: forest district
3	KV: kvartal
4	SKNR: stand
5	Area in ha
6	ZK: land category
7	TUR1H: growing stock volume in m^3/ha
8	Number of pixels (only ≥ 20)
9	local incidence angle (degree) (in case of a GEC -9999)
10	ERS Int1 mean: Mean of ERS-1 tandem pair image in m^2m^{-2}
11	ERS Int1 stdev
12	ERS Int2 mean: Mean of ERS-2 tandem pair image in m^2m^{-2}
13	ERS Int2 stdev
14	ERS Int3 mean: mean of third image in m^2m^{-2}
15	ERS Int3 stdev
16	ERS Coherence 20 pixels mean
17	ERS Coherence 20 pixels stdev
18	ERS Coherence 80 pixels mean
19	ERS Coherence 80 pixels stdev
20	JERS Int1 mean: Mean of first JERS image in m^2m^{-2}
21	JERS Int1 stdev
22	JERS Int2 mean: Mean of first JERS image in m^2m^{-2} (If applicable, otherwise –9999)
23	JERS Int2 stdev (If applicable, otherwise –9999)
24	JERS Coherence mean (If applicable, otherwise –9999)
25	JERS Coherence stdev (If applicable, otherwise –9999)
26	Strange Flag: 0 = nothing strange, 1 = something is strange

Table 7-1: Field and radar parameters in the common data base.

Use of ERS Coherence for Forest Classification - Based on the common data base the use of the ERS coherence for determining forest classes with different levels of growing stock volume was investigated. The analysis of the scatter plots of ERS coherence γ versus growing stock volume v showed that the functional relationship can be reasonable modelled with an exponential function of the form (Figure 7-2):

$$\gamma(v) = \gamma_\infty + (\gamma_0 - \gamma_\infty)e^{-\frac{v}{100}} \qquad (1)$$

where γ_0 is the coherence at v = 0 m^3/ha and γ_∞ is the coherence towards infinity. The physical interpretation is that γ_0 is the representative value for bare ground surfaces respectively surfaces with low vegetation cover, and γ_∞ represents dense forest. The factor 100 in the exponential function means that the coherence saturates in general at values between about 200 - 300 m^3/ha.

To summarise the findings:

- ERS coherence images are in general useful for separating two forest classes (growing stock volumes smaller and greater than 70 m^3/ha);
- The use of three forest classes cannot be recommended;
- The classification accuracy is affected by image quality and to some extent by topography;
- These findings apply both to GTC and GEC products.

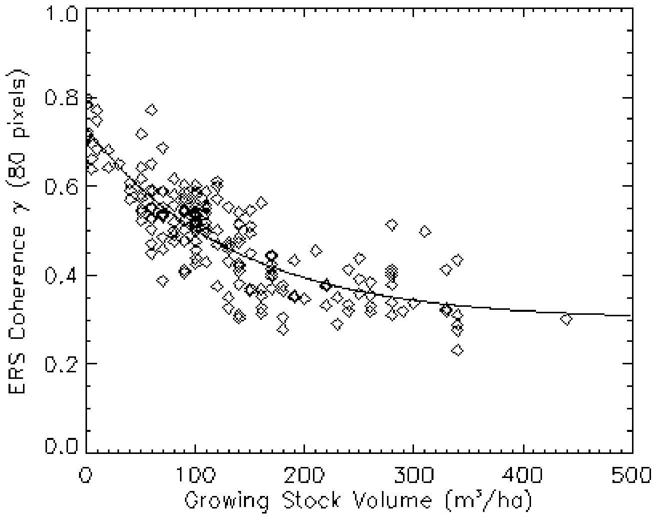

Figure 7-2: Observed and modelled relationship between ERS coherence γ and growing stock volume v in m^3/ha for Primorskii, subsite 3.

Use of ERS Backscattering Coefficient for Forest Classification - Like for the ERS coherence a common data base analysis was carried out to get a better understanding about the usefulness and limitations of the ERS backscatter images for forest classification. In the majority of testsites a simple threshold method did not allow to distinguish forests from non-forested areas (without knowing the spatial context). Besides topography, soil moisture influences the information content of ERS σ^0 images. If it is dry or frozen, non-forested areas have a lower backscatter than dense forest areas which allows a certain degree of separability. However, if it is wet σ^0 of forest and non-forest areas are similar. One suggestion to determine if it is dry/frozen or wet is to identify non-forest areas using the ERS coherence and extract the level of backscatter. If σ^0 is lower than about -9/-10 dB then the ERS σ^0 image could possibly be used to improve the classification.

Classification - The classification scheme includes

- The flagging of radar data affected by weather conditions through the use of ERS intensity information
- The use of JERS summer intensity images to identify non-forest categories such as water, agricultural fields, bogs and urban areas
- The use of ERS coherence information to identify low and high volume forest cover

The approach itself is illustrated in Figure 7-3. The different decision rules to be adopted in the classification could use thresholding or statistical models, both based on the analysis of the radar database as a function of surface type or parameter.

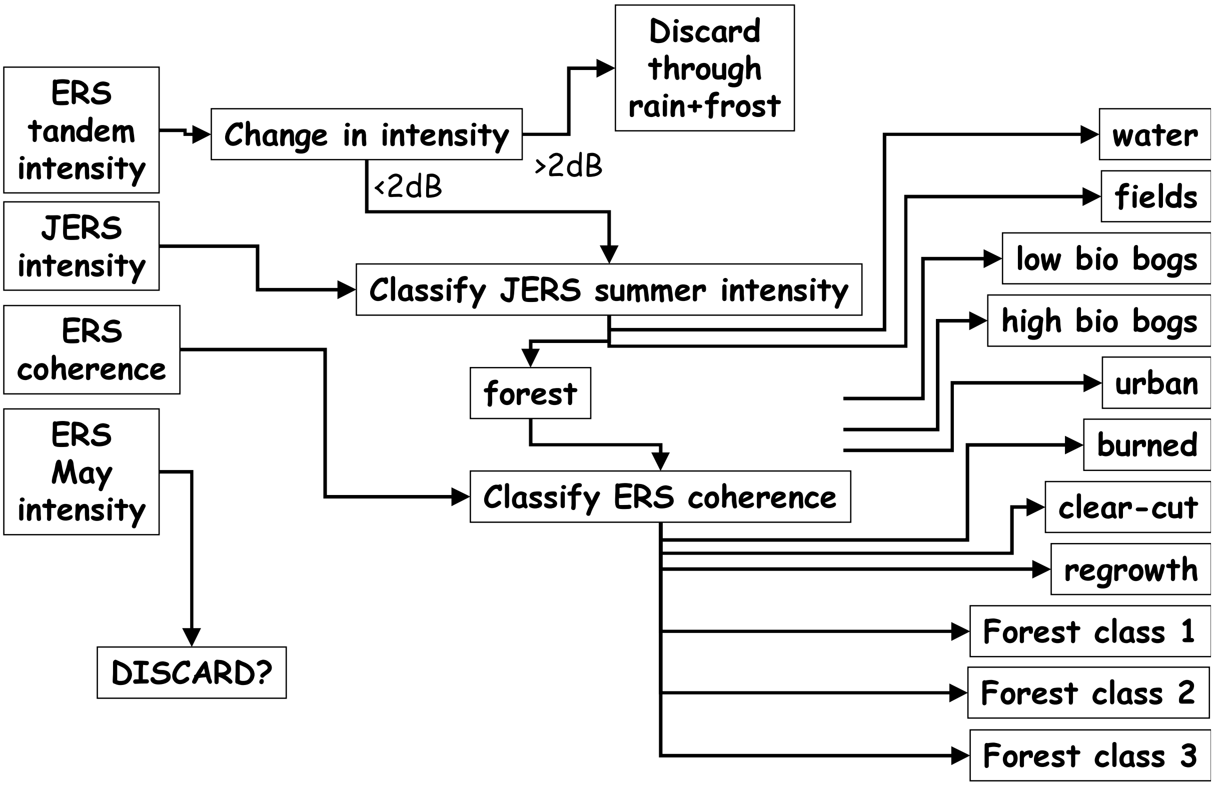

Figure 7-3: A suggested supervised classification approach based on interpretation and statistical analysis of the database.

The objective is to interpret the clusters obtained by unsupervised methods in terms of the land use and forest classes, based on the knowledge of distributions (histograms) of those classes in the radar database.

7.3. Pre-processing and Classification (WP 5030)

Rule-based classification is, in principle, preferred for its transparent connection to forest backscatter properties and easily-identified error sources. After the common database was set up and data from all sites were compared, it appears that a simple rule-based method independent of data frames and test sites is unlikely to be applicable to all test sites in Siberia. Therefore, it became clear that we need to link data-based classifiers to physical insight. The following classifiers were considered and investigated:

- Maximum likelihood classification (MLC)
- Fuzzy c-means clustering
- ISODATA clustering

MLC is one of the most well-known supervised methods, available in most commercial software, but relies on overall stability or the need to retrain on different frames. For many frames, in the whole Siberian coverage, there is no ground data to drive MLC. The test images run by Chalmers University indicated that Fuzzy c-means is capable of producing well classified images. However, this software is not widely available. Instead of simply measuring the distance to cluster means, as is done in IMAGINE, a modified ISODATA algorithm was developed at SCEOS which calculates the likelihood that a data point belongs to various classes assuming a multi-variant Gaussian distribution. Examples of 4-cluster and 5-cluster classifications obtained after 20 iterations are shown as Figures 7-4a and 7-4b, using as input data multi-channel filtered ERS Tandem pair, one ERS-2 and two JERS intensity dB images, as well as an 80-pixel coherence image of the Bratsk test area.

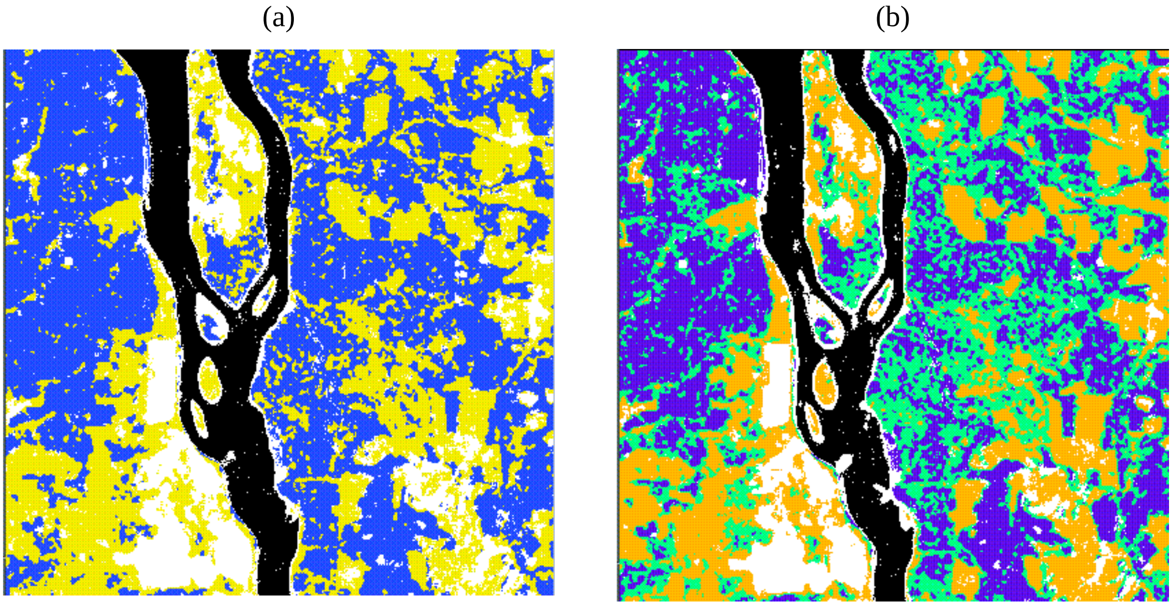

Figure 7-4: Improved ISODATA classifications from Bratsk obtained after 20 iterations: (a) 4-cluster and (b) 5-cluster, based on multi-channel filtered ERS Tandem pair, one ERS-2 and two JERS intensity images (in dB), as well as an 80-pixel coherence image (filtered using a 3x3 window).

Image properties can have a big impact on the data handling, error analysis and image operations such as filtering. Three important aspects of image properties, namely spatial correlation, equivalent number of looks (ENL) and texture were investigated using the Bratsk data set, including the coherence (80-pixel and 20-pixel), ERS and JERS intensity images. The main results are as the following.

1. The ERS and JERS intensity data are GAMMA distributed, with ENLs greater than 12 (probably around 14 - 15) for the ERS data and 6 for the JERS data;
2. The pixels in the JERS data are almost uncorrelated; ERS data has high correlation at lag 1 and lag 2. The correlation at lags > 1 in the 80-pixel and 20-pixel coherence images is insignificant. Correlation is only significant at lag = 1 in 80-pixel coherence;

The assessment of ERS texture statistics was undertaken. Two measures, namely the coefficient of variation and the normalised log, have been used for examining the texture information in both ERS and JERS data. Both measurements show no evidence that texture can be used for separating forest classes. Further the usefulness of texture was assessed by means of a Principal Component Analyses (PCA). The most important principal component (i.e. component 1) is determined mainly by different texture statistics from ERS amplitude (1) and ERS coherence. In all cases, the most important PC explaining more than 40% of the variation in the data was determined mainly by the texture statistics, and only secondarily by the amplitude and coherence. From visual judgement, there is a high potential of texture for classification. The high contributions of the texture statistics to all most important principal components for PCA1 to PCA4 is evidence for the importance of including at least one texture measure for the amplitudes and one for the coherence in the development of the classification methodology. Conclusions from this texture analysis at one test site are:

- Bogs (ZK=2507) can easily be separated from any other land use class at test site Lake Baikal South using image texture.
- The observed discrimination is valid for any of the texture statistics: standard deviation, entropy and contrast within a 7x7 window, as well as the coefficient of variation within a polygon.
- The same relationship holds whether the texture is based on amplitude 1, amplitude 3, intensity 1, intensity 3 or coherence.

- There is no relationship between texture and total growing stock at this test site.
- Image texture can easily be calculated and should be considered to classify bogs in the final classification methodology.

7.4. Accuracy Assessment (WP 5040)

Geometric Accuracy - The co-registration of JERS-1 and ERS-1 GTC products results in pixel displacements caused by the different DEMs. The expected pixel displacements of 95% of the image will vary between 0 and 3 pixels, and will be 1 or 2 pixels on average. A polygon erosion of 2 pixels will be able to reduce the problem significantly. Intelligent contextual classification methods need to be applied to correct the classified map for the ground offsets between JERS-1 and ERS-1.

Classification Accuracy - Because of the varying information content of the image frames, a data-driven algorithm like ISODATA looks more promising than a generalised maximum likelihood approach. The contextual information of neighbouring pixels can be included by a few iterations with ICP. A combination of both is likely to give the highest accuracy.

Spatial Accuracy - The problem of land cover changes between the last forest inventory and the SAR data acquisition has been identified in the First and Second Progress Report. A method of spatial accuracy assessment is proposed to avoid the Kappa coefficient mixing up land use change, co-registration error and map accuracy.

7.5. Computational Issues (WP 5050)

Since the 2nd Progress Report the following specific computational issues have been addressed:

- Collation of the most current and fully tested programs that are required for the pre-processing stages of the ERS products. These include calibration, topography masking and filtering.
- Addition of the front-ends and copyright information to the executable processing scripts.
- Publication of the ‘SIBERIA Operational Manual, Version 1’.
- Delivery of 32 ERS GTC products, a list of working notes, source code, compiled binaries and full documentation (including the SIBERIA operational manual) to Satellus.
- Resampling and filtering of the GTOPO’30 DEM to enable operational implementation of the topography masking program. The products were sent to Satellus.
- Investigation of the co-registration between ERS and JERS data using the GAMMA software. The successful conclusion of this work was the agreement by Satellus to lease the software from GAMMA.
- Currently, UWS is assisting with the operational implementation of a pre-classification procedure called ISODATA.

8. Encountered Problems

The main problem that have been encountered in the third phase of the SIBERIA project are:

- The central database is still incomplete as not all JERS data have arrived or been processed. However, analysis based on existing data suggests that rule-based classification using single threshold schemes will not be able to correctly classify all test sites in this project. Instead, a data-based unsupervised approach, ISODATA, which will be linked to physical class interpretation appears a more productive and pragmatic approach.

- The unsupervised improved ISODATA algorithm seems capable of generating very sensible results at the Bratsk test site. The immediate task to be carried out is to test this algorithm on various test sites. If the results can be explained using physical interpretations, a final classification approach (i.e. the *alpha-classifier*) for the Siberia project can be considered to be established.

The problems have created a delay of three months which is influencing the start of the hand-over period for the operational classification methodology to Satellus. This delay causes no threat to the overall project objectives.

9. Feedback from Customer

SIBERIA had been laid out according to the customer- and product-driven philosophy of CEO. Since the times of writing of the proposal, SIBERIA has followed two guidelines: customer requests and radar capabilities. During the first year, numerous discussions and email conversations took place between our customer IIASA (representing the Russian Federal Forest Service) and SIBERIA's methodology team. On top of the questions was the general concern about the usefulness of SIBERIA's final products for the Russian Federal Forest Service to support sustainable development. The forest classes that can be discriminated in the SIBERIA project are not sufficient to contribute on an enterprise level. IIASA (or -eventually- the remote sensing community) needs a product that attracts the users to keep them as customers. IIASA suggested to move from the enterprise level to a regional scale (i.e. scale 1:200,00 to 1:1,000,000), because on the regional scale SIBERIA's map products could indeed be implemented in the decision making process of the Forest Service.

10. Outlook

Two critical issues of the project, data availability and establishment of data processing flows, had been solved at the time of the 2nd Progress Report. The satellite and ground truth data bases for the test sites are almost complete. The methodological development is making the expected good progress leading to a unified classification algorithm to be synergized this month, March 2000. The data base is sufficient for the start of the operational classification at Satellus and all hand-over procedures concerning the pre-processing of the satellite data have been tested. The spring period of the year 2000 will show by processing a large amount of satellite frames at Satellus, how SIBERIA's Meth-Team has accomplished the task of developing a unified, operational strategy for large-scale forest mapping.

INDIVIDUAL PARTNER REPORTS

I. Institut für Hochfrequenztechnik (DLR-HF)

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I.1. Administrative Issues

Due to an internal reorganisation of the German Aerospace Agency (DLR) the personnel involved in the technical work of SIBERIA (the Geomatics group of DLR-HF) were integrated in a new institute, the German Remote Sensing Data Center (DFD) in January 2000.

Meetings:

- Dr. Christiane Schmullius, Mr. Jan Vietmeier, and Dr. Wolfgang Wagner participated in the interim meeting in Kiruna.

Project Documents and Technical Notes:

- J. Vietmeier, Clue to Problems using GTC Amplitude Images, September 24, 1999.
- W. Wagner, J. Vietmeier, C. Schmullius, A. Holz, First Results of Data Base Analysis for Bolshemurtinskii, November 4, 1999.
- W. Wagner, Short Description of IDL Software, November 11, 1999.
- W. Wagner, Format of Common Data Base, November 19, 1999.
- W. Wagner, Use of ERS Coherence for Forest Classification, December 9, 1999.
- K. Tansey, J. Vietmeier, S. Quegan, A. Luckman, Siberia Operational Processing Manual for ERS GTC Products, January 18, 2000.
- J. Vietmeier, W. Wagner, Comments and summary: Ground offsets during coregistration of JERS and ERS images, January 20, 2000.
- W. Wagner, J. Vietmeier, H. Balzter, Extended Accuracy Assessment of Coherence Model, February 16, 2000.
- W. Wagner, J. Vietmeier, Use of ERS Backscattering Coefficient for Forest Classification, February 18, 2000.

Presentations:

- C. Schmullius, Radarverfahren für die Waldkartierung - SIBERIA, Deutsche Gesellschaft für Photogrammetrie und Fernerkundung, Essen, 13-14 November, 1999.
- C. Schmullius, SIBERIA Project Presentation, DOSTAC Invitation, ESTEC, Noordwijk, Netherlands, 27 November, 1999.
- C. Schmullius, Operational Application of Interferometry in the SIBERIA Project FRINGE Workshop, Liege, Belgium, 10-12 November, 1999.
- C. Schmullius, SIBERIA Project Presentation, EURISY-RKA Colloquium „Space-base information for environmental security“, Moscow, 7-8 December 1999.
- C. Schmullius, SIBERIA Project Presentation, Harnessing Remote Sensing to Accomplish Full Carbon Accounting, Laxenburg, Austria, December 9-11, 1999.
- W. Wagner, Potential der Mirkowellen-Fernerkundung, Universitätslehrgang Geo-Basisdaten-Erfassung, Technische Universität Wien, September 29, 1999.

- W. Wagner, Waldkartierung mit SAR Interferometrie, Beitrag zum Blockseminar "Biosphäre", Universität Bremen, November 22, 1999.

Abstracts submitted to IGARSS'2000:

- W. Wagner, J. Vietmeier, C. Schmullius, A. Holz, Information Content of ERS and JERS SAR Images for Forest Classification in SIBERIA: A Case Study over the Bolshemurtinskii Forest Enterprise.
- W. Wagner, J. Vietmeier, C. Schmullius, T. Le Toan, M. Davidson, S. Quegan, J.J. Yu, A. Luckman, K. Tansey, H. Balzter, D. Gaveau, The Use of Coherence Information Derived from ERS Tandem Pairs for Determining Forest Stock Volume in SIBERIA.
- Schmullius, C., S. Nilsson, A. Shvidenko, E. Vaganov, Russian Forest Inventory Requirements and Remote Sensing Parameters-Operational Aspects.
- Shvidenko, A., S. Nilsson, M. Gluck, C. Schmullius, V. Skudin, et al., Generating a Universal Forest Ground-Truth Catalogue for Remote Sensing Applications to Forest Inventory.
- Etzrodt, N., R. Zimmermann, K. McDonald, C. Schmullius, J. Vietmeier, et al, Upscaling of Xylem Flux Rates of Central Siberian Pine Forests by an ERS-1/2 InSAR Image Classification.
- Zakharov, A.I., C. Schmullius, D.D. Darizhapov, On the Use of ERS INSAR Data in the Ecological Monitoring of the Baikal Region.
- T. Le Toan, H. Balzter, M. Davidson, D. Gaveau, A. Luckman, S. Quegan,C. Schmullius, K. Tansey, W. Wagner, J.J. Yu, Assessing SAR information content for large-scale forest mapping in Siberia

I.2. Responsibilities

The tasks of DLR-HF are:

- Project Co-ordination, Data Acquisition Updates and Prioritisation, CEO and Customer Support (WP 1000);
- SAR Geometry: Evaluate topographic correction mechanisms for calibration and classification and suggest ERS and JERS co-registration approach (WP 5010);
- Analysis and Validation at IGBP Transect (WP 5100);
- WWW-Documentation and satellite image database (WP 7300).

Work on these tasks has been continuously performed and is reported below.

I.3. Project Coordination (WP 1000)

The following coordinating activities were carried out:

- Setting up of teleconferences with methodological team (DLR-HF, CESBIO, SCEOS, UWS, NERC, IIASA, Sattelus) in weekly to three-weekly intervals to discuss project progress and technical problems.
- Regular contact with partners by phone and via e-mail.
- Most of the problems related to the late-availability of the JERS data had been solved in summer 1999. However, still some effort was necessary to coordinate data exchange between DLR-DFD, NASDA, and Gamma.
- Data acquisition and processing prioritisation.
- Representation of the SIBERIA project to the outside.

I.4. Work Progress

- Tasks related to data ordering, acquisition, and processing prioritisation of ERS and JERS data (WP 1150) have been successfully completed.

- Questions related to SAR geometry (WP 5010) have been resolved and routines for calibration, co-registration and masking have been developed.
- The data analysis at the IGBP Transect has made good progress, albeit it has still been hampered by the late availability of JERS imagery.
- In support of CESBIO's WP 5020 (Quantification of ERS/JERS SAR Information Content) DLR-HF has integrated data sets from the other methodological teams into one common data base to derive generally applicable classification rules.
- Software for the automatic generation of data base plots were developed and the resulting imagery was put on the SIBERIA Web page maintained by UWS.

I.5. SAR Geometry (WP 5010)

The working package is practically completed. Only task WP 5016 to determine a procedure on how to interpolate on GEC/GTC borders is still open because the properties of the classified end product are not yet defined exactly. If the output format will be based on the ERS images instead of a mosaic it would not be necessary to carry out interpolation on GEC/GTC borders. For all other subtasks strategies have been defined and necessary IDL or c-programs developed.

I.5.1. Geocoded Incidence Angle Mask, Radiometric Calibration and Strategy for Layover and Shadow Areas

A procedure for the generation of geocoded incidence angle masks (GIMs) has been developed and tested. It involves the application of a 5 x 5 median filter to reduce the noise of the InSAR DEM prior to the incidence angle mask calculation. A c-program called "medi5x5_sib" was written for operational filtering.

The program performing the GIM generation is able to apply a threshold to the incidence angle to mark layover areas. A threshold of 12 degrees was chosen. Below this threshold the InSAR DEM is not reliable due to geometric and image processing reasons. For example, close to 12° the interferometric phase becomes ambiguous and can not be resolved by phase unwrapping procedures. The marked areas will be masked out by the program carrying out the calibration (calit). Due to the look angle of ERS the occurrence of shadow is very seldom. Therefore the application of a threshold for shadow areas is not necessary.

For GEC products it is not possible to consider the influence of the topography due to the lack of an InSAR DEM. Therefore mountainous areas would lead to errors in the classification and should be masked out. The masking is discussed further below.

I.5.2. Co-registration of ERS and JERS Images

The topography induced geometric distortions of the SAR images are representing the main problem for the co-registration of JERS and ERS products. We are confronted with two different dataset combinations for co-registration (see working notes "Ground offsets during coregistration of JERS-1 and ERS images" by Heiko Balzter and Kevin Tansey and "Comments and Summary: Ground offsets during coregistration of JERS-1 and ERS images" by Jan Vietmeier and Wolfgang Wagner):

1. *InSAR/GTOPO30:* The ERS products are geocoded using the InSAR DEM and the JERS products are geocoded using the GTOPO30 DEM. This is the case for ERS-GTC products.
2. *GTOPO30/GTOPO30:* Both the ERS and JERS products are geocoded using the GTOPO30 DEM.

The ground offset for SAR images Δg can be estimated by (Schreier 1993):

$$\Delta g = \frac{h}{\tan\theta} \tag{I-1}$$

where h is the elevation and θ is the look angle of the sensor. Using this equation it is possible to estimate the theoretic possible offset between the image products. Assuming an incidence angle of 23° for ERS and 35° for JERS the offset for the InSAR/GTOPO30 case is:

$$\Delta g_{InSAR/GTOPO} = 2.35(h_{InSAR} - h_{true}) - 1.4(h_{GTOPO} - h_{true}) \quad \text{(I-2)}$$

where h_{true} is the real elevation. As can be seen from the equation that the offset between both images is smaller if the direction of the error of both DEMs has the same size. Due to the smaller look angle of ERS the image offset is more sensitive on the error of the InSAR DEM.

The ground offset for the GTOPO30/GTOPO30 case is:

$$\Delta g_{GTOPO/GTOPO} = 0.9(h_{GTOPO} - h_{true}) \quad \text{(I-3)}$$

That means that the offset between the ERS GECs and the JERS images is more or less equal to the height error of the GTOPO30 DEM.

Based on these equations it is possible to estimate the standard deviations (StDev) of the ground offsets for each case dependent on the standard deviation of the height errors of the used DEMs. For an estimated StDev of 25 m for the InSAR DEM and 75 m for the GTOPO30 DEM the StDev of the ground offset are 120 m or 71 m. That means that 95% of the offset values are lying in the intervals ±240 m (or ±5 Pixels) and ±142 m (or ±3 Pixels) respectively. In general we can expect higher offsets for rugged terrain than for gently undulating areas. Therefore mountainous regions should be masked out independent on the method for co-registration.

The tests of the methods for co-registration led to the decision to use co-registration software developed by GAMMA Remote Sensing. The tool works very quickly and give good results for fairly mountainous areas. The partner which perform the forest map production (Satellus: WP6100-WP6200) leased the software and therefore will be able to carry out the co-registration almost automatically.

I.5.3. Masking Procedure for Strong Topography

As mentioned above, masking of highly reliefed areas is necessary for two reasons. Firstly, the ERS-GEC and the JERS images are not radiometric terrain corrected. Secondly, the terrain induced distortions of the SAR images can make the co-registration of JERS to ERS images impossible over mountainous regions. A new method for masking mountainous regions based on the globally available GTOPO30 DEM has been developed. The procedure is the following:

1. Resample the GTOPO30 DEM to 50 x 50 m pixel spacing and generate a subset according to the area of the respective ERS frame.
2. Calculate the geocoded incidence angle mask (GIM) based on the GTOPO30 DEM and the specific ERS acquisition geometry.
3. Calculate the standard deviation for subsets of the GIM of a specific size, e.g. 10 x 10 pixel.
4. Apply a threshold of the standard deviation to mask out hilly terrain.

(a) (b)

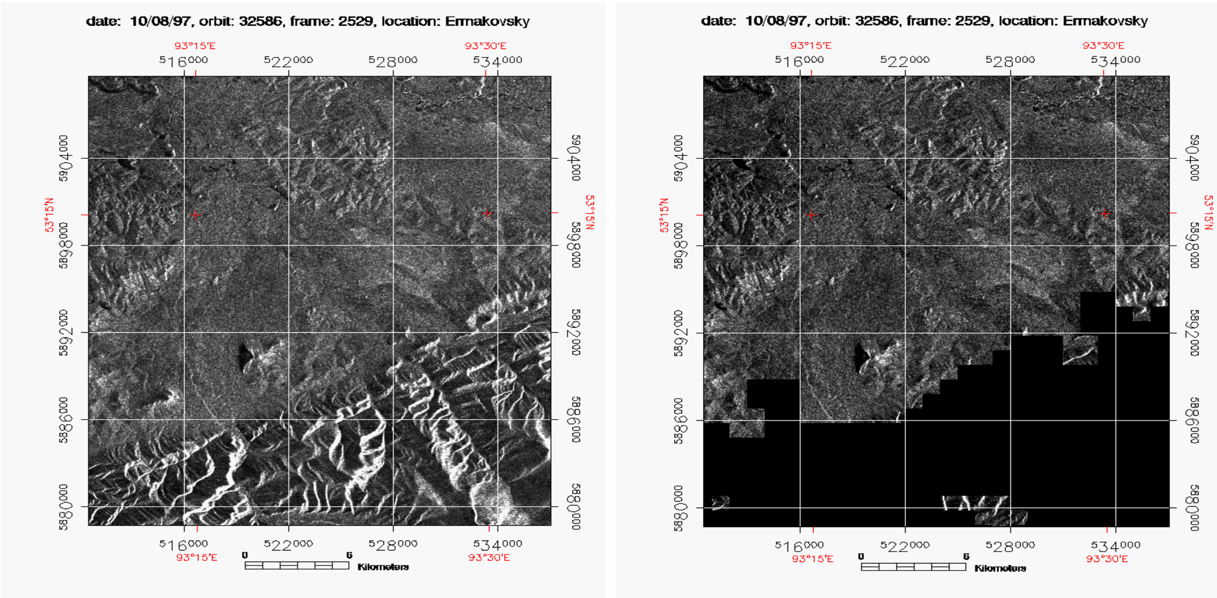

Figure I-1: Subset of an ERS backscatter image located in the Ermakovsky region in the south of the IGBP-Transect. a) Backscatter intensity image. b) Masked image. Acquisition date: 5.10.97.

A threshold of 1.4° and a window size of 20 x 20 pixels lead to the best results for masking (see Figure I-1).

Despite the coarse method is (due to the low resolution GTOPO30 DEM), it produces the most reliable and stable results of the three proposed methods that have been considered initially (see 2nd Progress Report). Using this masking method a correspondence between the masked area and the quality of the ground truth site for the common database could be ascertained.

I.6. Analysis and Validation at IGBP Transect (WP 5100)

Pre-processing steps for the preparation of the ERS as well as for the JERS products were automated. The developed procedures include the extraction of the images from the image datasets provided by DLR-DFD and GAMMA Remote Sensing, byte-swapping of the image data, calculation of the incidence angle mask for ERS-GTCs and the calibration of the ERS data. Additionally a routine was written to read the map information of each image product and to generate a header file in the an appropriate format for the used image processing software.

To compare the ground truth data with the ERS/JERS products, a polygon based database has been constructed. The number of image pixels, the mean value and the standard deviation for each ground polygon and every satellite image underlying a polygon was calculated and stored in the database. For this task twelve ground truth sites were rasterised from ArcView shape files. These raster data were then co-registered to twelve satellite datasets to enable the comparison of the information content of the satellite products with ground truth attributes, e.g. landuse, growing stock volume of the forest. The co-registration was carried out on subsets of the satellite products that cover the ground truth sites to increase geometric accuracy.

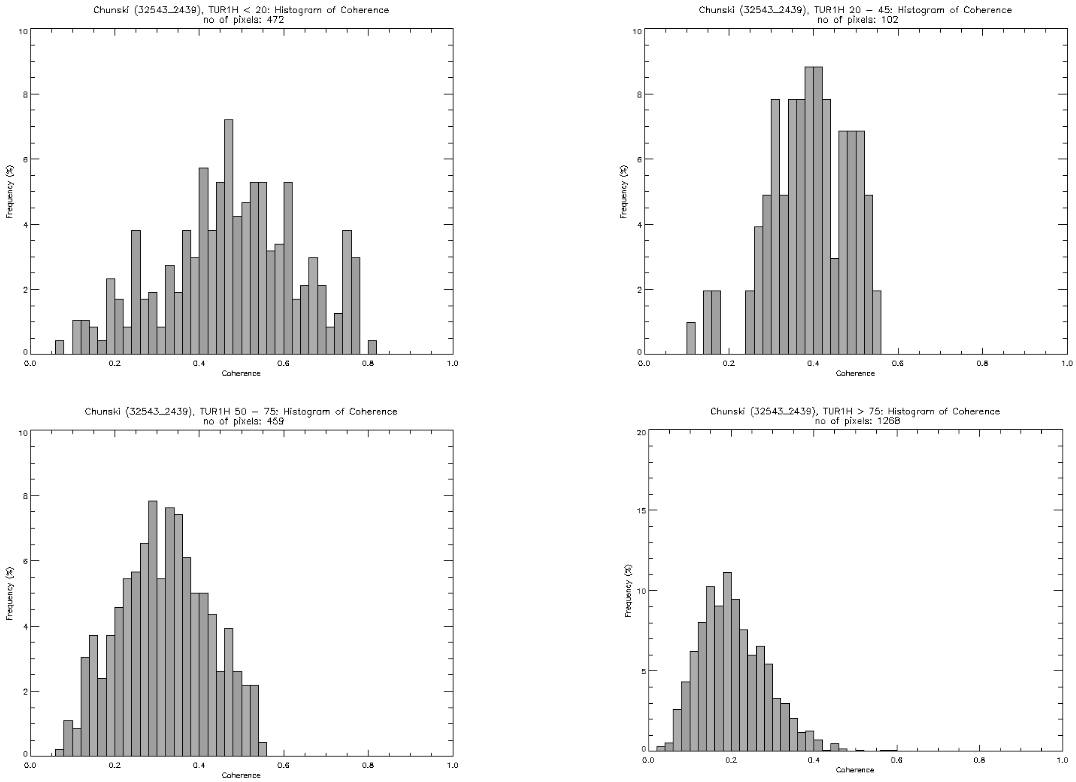

Figure I-2: Histograms of the stock volume classes < 20 m3/ha, 20 – 45 m3/ha, 50 – 75 m3/ha and > 75 m3/ha for the ERS coherence of selected polygons of the Chunski testsite (58°N, 97° E). The ERS coherence is derived from the tandem pair 5/6.10.98.

Additionally, histograms and scatterplots of ERS coherence (tandem pair 5/6.10.97) and JERS intensity (acquisition date: 16.6.98) were produced for some selected polygons of the Chunskii testsite. The histograms are generated for the stock volume classes < 20 m^3/ha, 20 – 45 m^3/ha, 50 – 75 m^3/ha and > 75 m^3/ha. A general trend of the histogram is visible. For example, the coherence decreases for increasing growing stock volumes (Figure I-2). The histograms were sent to CESBIO for their analysis of the information content of the radar data base.

For the testsites located in the Bolshemurtinskii forest enterprise the relationship of the radar parameters on various ground parameters was studied in more detail. As JERS data were initially not available, only ERS parameters were considered: ERS coherence, ERS backscattering coefficient and backscatter intensity change. The dependencies of these observables on:

- land cover category,
- stock volume,
- dominant tree species, and
- average tree height,

were investigated. For this purpose IDL software with an interactive User Interface was written. For example, Figure I-3 shows the User Interface to display various radar parameters versus growing stock volume. The user interface allows for example to chose the test sites, the radar parameters (e.g. σ^0 in natural or logarithmic units) and the minimum number of pixels of the ground truth polygons. Other routines to display radar parameters versus land cover category, dominant tree species, and average tree height were also developed.

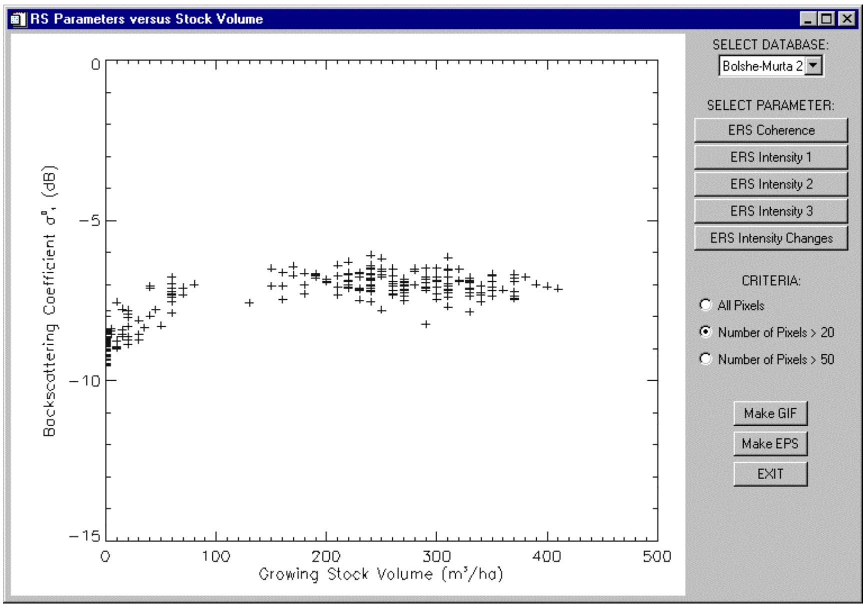

Figure I-3: User Interface for displaying various radar parameters versus growing stock volume.

In summary, the findings for the Bolshemurtinskii forest enterprise are:

- For this particular forest enterprise, both the ground truth and ERS data are of exceptional high quality: The last field inventory was made in 1998 and for the ERS data high-quality GTC products could be produced.
- *Growing stock volume:* Both the ERS coherence and the ERS intensity showed an exponential relationship to growing stock volume. The saturation of the radar parameters is observed at growing stock volumes around 200 m^3/ha. ERS intensity change did not show any relationship to forest biomass.
- *Land cover category:* In the Bolshemurtinskii forestry enterprise only six land cover categories occur: natural stand, unclosed natural forest, forest plantation, unclosed forest plantation, burned forest (only one polygon), and clear cut area. The coherence showed the expected dependencies on the various land cover types, while the behaviour of the ERS intensity and ERS intensity changes was less clear.
- *Dominant tree species:* The "dominant tree species" of one polygon was defined as the tree species for which the KF number (composition) is greater than 5. If in a stand no species has a KF greater than 5 then no dominant tree species is given. Figure I-4 shows a scatter plot of the ERS coherence versus tree species. It can be observed that the coherence is basically independent of tree species. There is also no difference between evergreen and deciduous trees. The same applies to ERS intensity and intensity change.

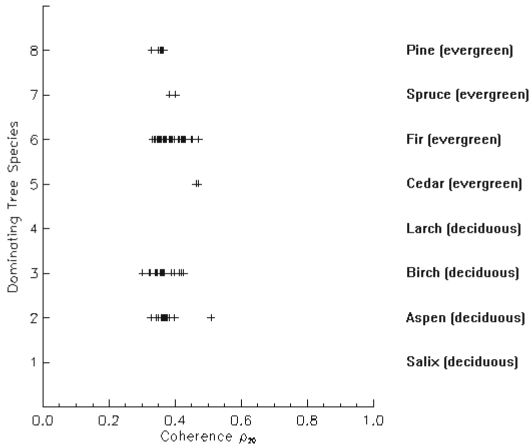

Figure I-4: Coherence from 20 pixels window versus dominant tree species for polygons greater in size than 50 pixels and for growing stock volume greater than 100 m^3/ha.

- *Average tree height:* The average tree height was defined as the tree height of the different species within one polygon weighted by the KF number. Figure I-5 shows a good relationship between ERS coherence and intensity on tree height. There is no apparent saturation effect with increasing forest height. Compared to growing stock volume, the correlation of the radar parameters with tree height is better (R^2 is 0.75 for coherence and 0.49 for σ^0).

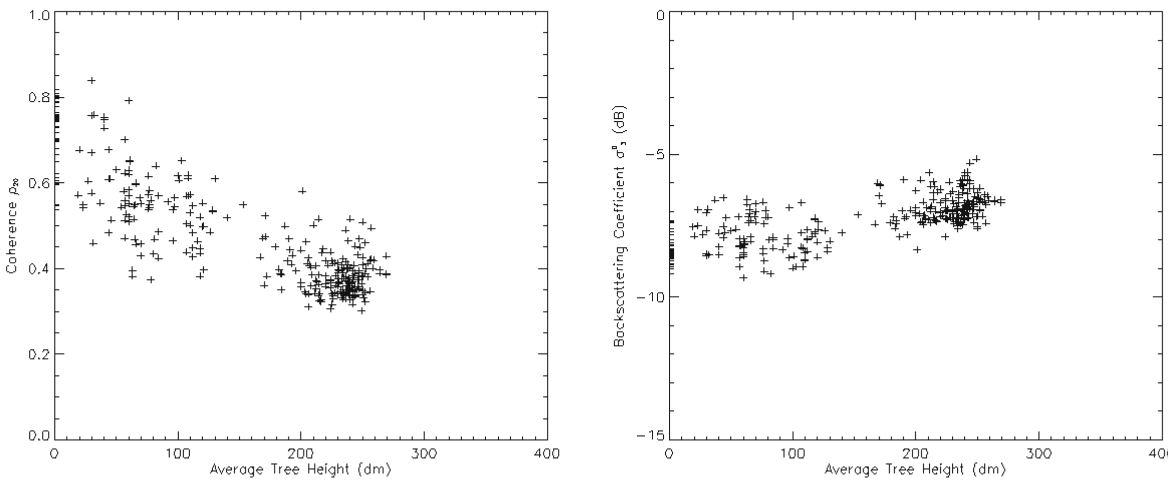

Figure I-5: Coherence from 20 pixels window versus average tree height for polygons greater in size than 50 pixels.

I.7. Common Data Base Analysis (Support to WP 5020)

I.7.1. Common Data Base Plots

Besides the more detailed analysis at the individual sites it was decided to establish a data base that contains selected field and radar data from all available testsites to derive classification rules that are generally applicable to the entire SIBERIA region. The format of the data base and the corresponding metadata base was defined by DLR-HF in collaboration with all partners from the methodological team (Table I-1).

Position	Variable
1	Unique number
2	GIR: forest district
3	KV: kvartal
4	SKNR: stand
5	Area in ha
6	ZK: land category
7	TUR1H: growing stock volume in m^3/ha
8	Number of pixels (only ≥ 20)
9	local incidence angle (degree) (in case of a GEC -9999)
10	ERS Int1 mean: Mean of ERS-1 tandem pair image in m^2m^{-2}
11	ERS Int1 stdev
12	ERS Int2 mean: Mean of ERS-2 tandem pair image in m^2m^{-2}
13	ERS Int2 stdev
14	ERS Int3 mean: mean of third image in m^2m^{-2}
15	ERS Int3 stdev
16	ERS Coherence 20 pixels mean
17	ERS Coherence 20 pixels stdev
18	ERS Coherence 80 pixels mean
19	ERS Coherence 80 pixels stdev
20	JERS Int1 mean: Mean of first JERS image in m^2m^{-2}
21	JERS Int1 stdev
22	JERS Int2 mean: Mean of first JERS image in m^2m^{-2} (If applicable, otherwise –9999)
23	JERS Int2 stdev (If applicable, otherwise –9999)
24	JERS Coherence mean (If applicable, otherwise –9999)
25	JERS Coherence stdev (If applicable, otherwise –9999)
26	Strange Flag: 0 = nothing strange, 1 = something is strange

Table I-1: Field and radar parameters in the common data base.

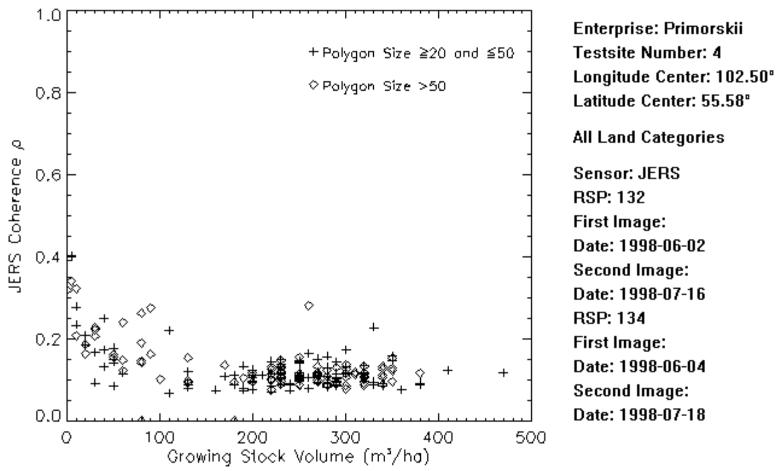

Figure I-6: One example of in total 588 common data base plots displayed at Swansea's SIBERIA Web Page.

DLR-HF collected the data from the partners and wrote IDL routines for the automatic generation of data base plots (as GIF images) and HTML scripts for web display. The data base plots were then integrated by UWS in Swansea's SIBERIA Web Site: http://pipeline.swan.ac.uk/ siberia/. The plots are routinely updated when new satellite data become available (many of the JERS data are still missing). Figure I-6 shows just one example of the in total 588 different common data base plots. Fourteen different plots are currently produced for each testsite.

I.7.2. Use of ERS Coherence for Forest Classification

Based on the common data base the use of the ERS coherence for determining forest classes with different levels of growing stock volume was investigated. The analysis of the scatter plots of ERS coherence γ versus growing stock volume v showed that the functional relationship can be reasonable modelled with an exponential function of the form (Figure I-7):

$$\gamma(v) = \gamma_\infty + (\gamma_0 - \gamma_\infty)e^{-\frac{v}{100}} \qquad \text{(I-4)}$$

where γ_0 is the coherence at V = 0 m^3/ha and γ_∞ is the coherence towards infinity. The physical interpretation is that γ_0 is the representative value for bare ground surfaces respectively surfaces with low vegetation cover, and γ_∞ represents dense forest. The factor 100 in the exponential function means that the coherence saturates in general at values between about 200 - 300 m^3/ha.

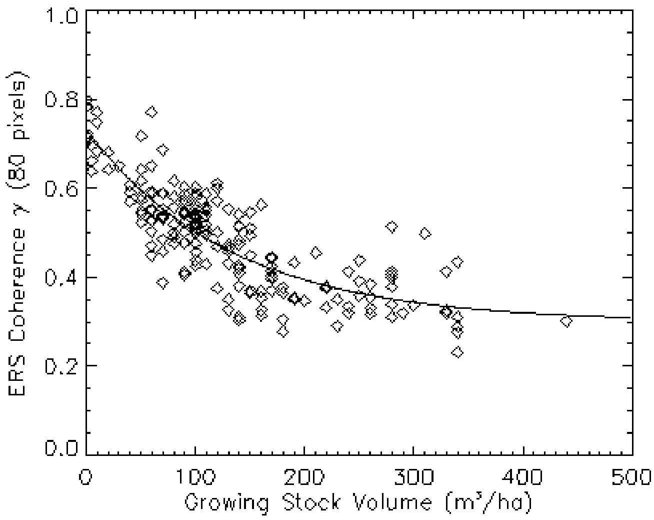

Figure I-7: Observed and modelled relationship between ERS coherence γ and growing stock volume v in m^3/ha for Primorskii, subsite 3.

In principle, if estimates of γ_0 and γ_∞ would be know for each ERS coherence image then equation (I-4) could be used to estimate growing stock volume from the coherence. Due to the generally large scatter of γ only two forest classes were defined in the first step. The following simple classifier based on (I-4) was proposed:

if $\gamma < \frac{\gamma_0 + \gamma_\infty}{2}$ then low density forest class with $v < 70$ m^3/ha (I-5a)

if $\gamma \geq \frac{\gamma_0 + \gamma_\infty}{2}$ then high density forest class with $v \geq 70$ m^3/ha (I-5b)

Of course, the problem is that the two parameters γ_0 and γ_∞ are not known a-priori and need to be estimated from the coherence images. Two approaches could be pursued. The first one is to visually identify bare ground surfaces and dense forests in the image and to assume that γ_0 and γ_∞ are equal to the average γ values of these regions. The second approach is to use statistical parameters of the γ distribution to estimate γ_0 and γ_∞. The analysis of the common data based demonstrated that the 0.1 and 0.9 percentiles of the coherence distribution ($\gamma_{0.1}$ and $\gamma_{0.9}$) are good estimators of γ_0 and γ_∞ and hence can be used to determine the threshold value in I-5.

Enterprise	No.	Year	Mask	Tr.	Fr.	Prd.	Coh1	Coh9	% Cor	Kappa
Bolshemurtinskii	1	1998	0	348	2457	GTC	0.3	0.6	84.4	66.9
Bolshemurtinskii	2	1998	0	348	2457	GTC	0.2	0.7	96.3	91.1
Bolshemurtinskii	3	1998	15	348	2457	GTC	0.2	0.4	76.5	29.9
Bolshemurtinskii	4	1998	0	348	2457	GTC	0.3	0.6	88.5	76.7
Bolshemurtinskii	1	1998	10	305	2457	GTC	0.2	0.5	84.2	68.5
Bolshemurtinskii	2	1998	10	305	2457	GTC	0.2	0.4	79.5	37.5
Bolshemurtinskii	1	1998	10	305	2457	GEC	0.2	0.5	86.8	73.7
Bolshemurtinskii	2	1998	10	305	2457	GEC	0.2	0.3	82.7	43.2
Chunsky	1	1998	50	491	2439	GEC	0.2	0.3	78.6	40.2
Chunsky	2	1998	5	491	2439	GEC	0.2	0.6	94.7	89.3
Chunsky	3	1998	0	491	2439	GEC	0.3	0.8	88.9	77.6
Ermakovsky	1	1996	100	305	2529	GEC	0.2	0.3	66.2	19.3
Ermakovsky	2	1996	50	305	2529	GEC	0.2	0.3	64.3	7.6
Ermakovsky	3	1996	100	305	2529	GEC	0.2	0.3	71.0	25.6
Ermakovsky	4	1996	20	305	2529	GEC	0.2	0.3	79.5	47.7
Ermakovsky	1	1996	20	33	2529	GEC	0.2	0.6	78.6	46.3
Ermakovsky	2	1996	100	33	2529	GEC	0.3	0.5	54.5	24.7
Ermakovsky	3	1996	50	33	2529	GEC	0.2	0.4	68.6	15.2
Hrebtovsky	1	1996	-9999	448	2421	GEC	0.2	0.4	71.1	36.4
Hrebtovsky	2	1996	-9999	448	2403	GTC	0.4	0.6	63.2	24.6
Hrebtovsky	3	1996	-9999	448	2403	GTC	0.4	0.6	63.7	6.8
Hrebtovsky	4	1996	-9999	448	2385	GTC	0.4	0.8	65.7	30.9
Irbeiskii	11	1993	50	491	2475	GTC	0.2	0.6	61.9	6.5
Irbeiskii	12	1993	-9999	491	2475	GTC	0.2	0.6	73.9	37.5
Irbeiskii	13	1993	-9999	491	2475	GTC	0.2	0.6	79.0	50.1
Irbeiskii	2	1993	-9999	491	2511	GEC	0.2	0.6	84.7	61.9
Irbeiskii	3	1993	-9999	448	2511	GEC	0.2	0.4	56.6	-2.6
Lake_Baikal_South	1	1998	-9999	462	2565	GEC	0.2	0.4	61.3	13.5
Lake_Baikal_South	2	1998	-9999	419	2565	GEC	0.2	0.6	86.9	62.5
Nishni_Udinskii	1	1997	-9999	362	2511	GTC	0.3	0.8	79.8	59.9
Nishni_Udinskii	2	1997	-9999	362	2493	GTC	0.3	0.8	91.8	82.2
Nishni_Udinskii	3	1997	-9999	405	2493	GEC	0.2	0.4	61.2	13.9
Nishni_Udinskii	4	1997	-9999	405	2511	GEC	0.2	0.4	60.3	13.2
Primorskii	1	1996	-9999	47	2475	GTC	0.4	0.7	77.7	54.8
Primorskii	2	1996	-9999	47	2475	GTC	0.3	0.6	65.4	32.8
Primorskii	3	1996	-9999	47	2475	GTC	0.3	0.6	64.9	32.2
Primorskii	4	1996	-9999	47	2475	GTC	0.3	0.6	89.2	67.0
Shestak	1	1998	-9999	47	2457	GEC	0.2	0.5	82.5	45.1
Shestak	3	1998	-9999	4	2457	GEC	0.2	0.3	68.6	17.2
Shestak	4	1998	-9999	4	2475	GEC	0.2	0.3	68.5	17.5
Ulkanskii	1	1998	-9999	147	2475	GEC	0.2	0.4	87.8	70.0
Ulkanskii	2	1998	-9999	104	2493	GEC	0.2	0.4	75.0	35.0
Average							0.2	0.5	75.3	41.7

Table I-2: Accuracy analysis of coherence model for determining two forest classes. The columns are: Name of forest enterprise, testsite number, inventory year, estimated percentage of masked area (-9999 is the missing value), track, frame, product (GEC or TGC), 0.1 and 0.9 percentiles of coherence distribution, percentage of correctly classified polygons, and κ.

This simple threshold model was tested for all testsites. It can be seen in Table I-x that both the percentage of correctly classified polygons and κ vary strongly from site to site and from image to image. For example, κ may take on values around 90 % (near perfect classification) but also values around 0 % (no information gain from classification). Three factors that may affect the classification method are image quality, topography, and the time gap between the last forest inventory and the SAR image acquisition. It was found that that the dominating factor is the spread of the γ distribution which is expressed by the difference $\gamma_{0.9}$ - $\gamma_{0.1}$ (Figure I-8). Therefore the difference $\gamma_{0.9}$ - $\gamma_{0.1}$ can be used as a quality indicator of the coherence images, with low values of $\gamma_{0.9}$ - $\gamma_{0.1}$ indicating a poor classification accuracy.

To summarise the findings:

- ERS coherence images are in general useful for separating two forest classes (growing stock volumes smaller and greater than 70 m^3/ha);
- The use of three forest classes cannot be recommended;

- The classification accuracy is affected by image quality and to some extent by topography;
- These findings apply both to GTC and GEC products.

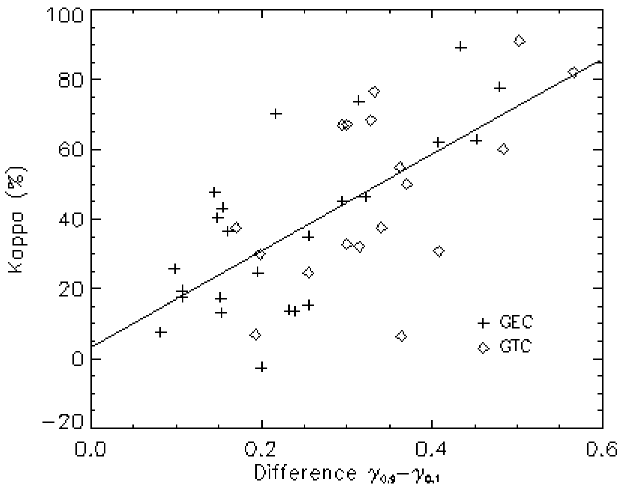

Figure I-8: Accuracy coefficient κ versus the difference of the $\gamma_{0.9}$ and $\gamma_{0.1}$ percentiles of the coherence distribution for two forest classes. The solid line represent the fitted regression line.

I.7.3. Use of ERS Backscattering Coefficient for Forest Classification

Like for the ERS coherence a common data base analysis was carried out to get a better understanding about the usefulness and limitations of the ERS backscatter images for forest classification. In the majority of testsites a simple threshold method did not allow to distinguish forests from non-forested areas (without knowing the spatial context). One of the reasons is that high topography leads to rather strong erratic variations in σ^0. This is shown in Figure I-9 that shows the standard deviation of σ^0 for all dense forest stands (v > 100 m^3/ha) within a given testsite versus the area fraction that would be masked out if the masking algorithm would be applied. It can be observed that the standard deviation of σ^0 increases from about 0.5 dB for relatively flat areas to over 2 dB over rugged terrain. This means that only for relatively flat areas σ^0 can be used for classification.

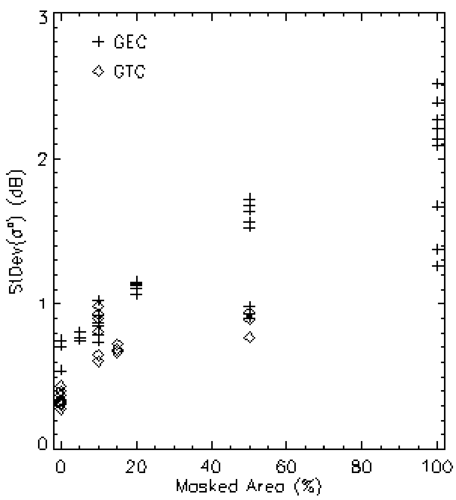

Figure I-9: Standard deviation of ERS backscattering coefficient σ^0 for growing stock volumes greater than 100 m^3/ha. On the left hand side the standard deviation of all three image is plotted versus testsite number, and on the right hand side versus the estimated percentage of the masked out test site area. Diamonds indicate GTC products and the crosses GEC products.

Besides topography, soil moisture influences the information content of ERS σ^0 images. If it is dry or frozen, non-forested areas have a lower backscatter than dense forest areas which allows a certain degree of separability. However, if it is wet σ^0 of forest and non-forest areas are similar. One suggestion to determine if it is dry/frozen or wet is to identify non-forest areas using the ERS coherence and extract the level of backscatter. If σ^0 is lower than about -9/-10 dB then the ERS σ^0 image could possibly be used to improve the classification.

I.8. References

Schreier, G. (1993): Geometrical properties of SAR images. In: Schreier, G. (Editor): SAR Geocoding: Data and Systems, Wichmann, Karlsruhe, 103-134.

II. Deutsches Fernerkundungsdatenzentrum (DLR-DFD)

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II.1. Responsibilities

DLR-DFD is the responsible partner for the interferometric processing of the ERS SAR data (WP 2100), DEM generation (WP 2200), geocoding of the amplitude and coherence maps (WP 2300), and the archiving of the data (WP 2400).

II.2. Interferometric Processing of Tandem Pairs (WP 2100)

The order of processing of the required products is described in a harmonised priority list that being regularly updated. The processing is performed in several steps. At first the input ERS Single-Look Complex Images (SLCI) products are processed to interferograms, intensity images and the coherence map. A by-product the so called "valid mask" indicates homogeneous areas where no phase unwrapping errors can be expected. The decision whether the DEM is derived and the images are terrain corrected or - as backup - registered to a coarse elevation model (GLOBE) is based on this mask, but also the coherence map and the appearance of the interferogram are considered.

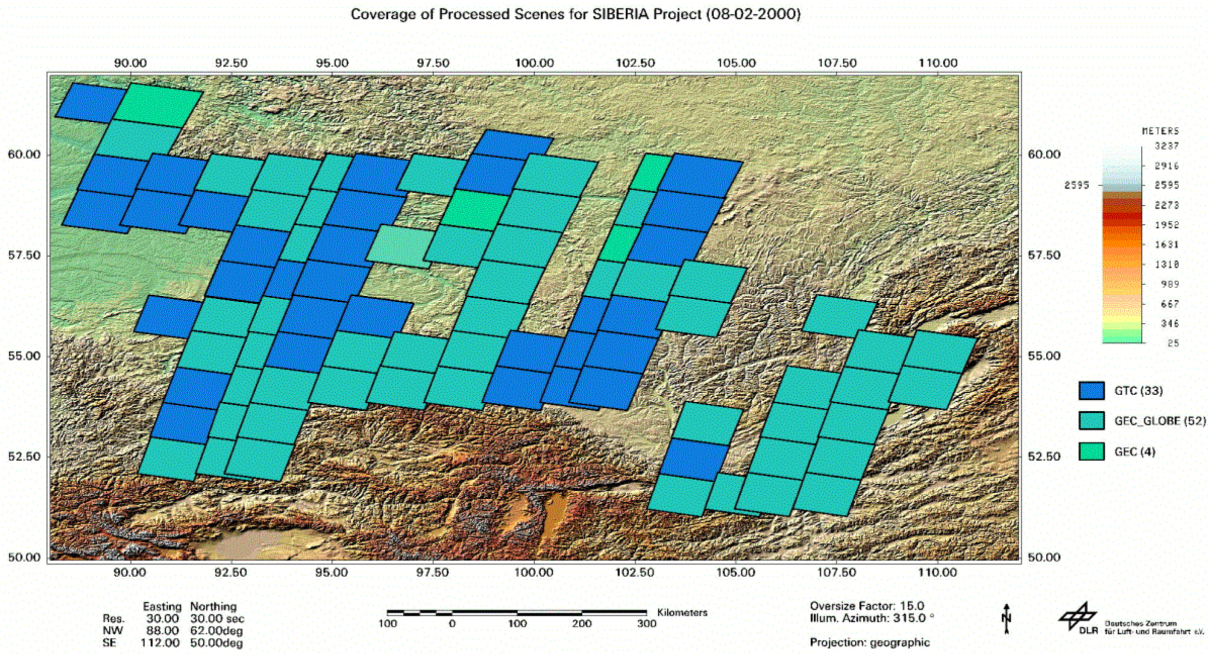

Figure II-1: The image shows the SIBERIA test area between 88° and 112° east and 50° to 62° north. The frames processed to geocoded terrain corrected products appear in blue. Green frames are GECs and blue-green indicates those data sets were the coarse DEM was considered.

Until February 8h, 2000 95 SLCI ERS Tandem pairs and the co-registered spring data set were interferometrically processed.

II.3. DEM Generation (WP 2200) and Geocoding of Amplitude Images and Coherence Maps (WP 2300)

In total 85 geocoded products were delivered to the Siberia project server.

33 DEMs could be derived enabling a terrain correction of the three amplitude images and the coherence map.

Due to low coherence 52 interferometric data sets could only be registered and geocoded using a coarse DEM (GLOBE-product).

II.4. Archiving of ERS SAR Products (WP 2400)

All interferometric ERS products that have been delivered to the project ftp-site are additionally archived on magnetic tapes (DLT).

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III.1. General Issues

This midterm progress report describes the work of IIASA and its Russian partners in the third six-month period of the SIBERIA project (July to December 1999).

The work in this period has built upon previously-initiated work packages as follows:

- The collection and compilation of the reference data (WP 4300);
- Support in classification development (WP 4400).

In addition, IIASA has made preparations for an:

- Accuracy assessment and cross-check with the Russian State Account (WP 4500).

In the 4th quarter, IIASA's next steps will be to continue working with the methodological team to support classification development (WP 4400) and carry out the accuracy assessment (WP 4500). Specifically, we will be working closely with ITE Monks Wood in their accuracy assessment (WP 5040) of classification results.

IIASA will also maintain communication with our Russian Partners to keep them abreast of the project development and to plan for the implementation of the final forest map (WP 7000).

III.2. Reference Data Collection and Compilation (WP 4300)

During this quarter, reference data from seven test areas originating from two test territories (forest enterprises) were produced and delivered. Currently, reference data from 38 test areas and 11 test territories are available to the SIBERIA Project (Figure III-1).

All reference data is available on request to the Project partners at the IIASA Internet site http://www.iiasa.ac.at/Research/FOR/siberia.

III.3. Support of Classification Development including Revision of Classification Requirements (WP 4400)

The first objective of this work package is to support and give feedback to the methodology teams by assessing and commenting on the results within the test areas. The second objective is to revise the classification requirements if necessary.

During the period IIASA has performed two support activities:

- Maintaining the Question and Answer Web page;
- Evaluating "Strange Polygons".

Currently, IIASA is awaiting the assessment of the first classification results (WP 5020, 5030) before revising classification requirements.

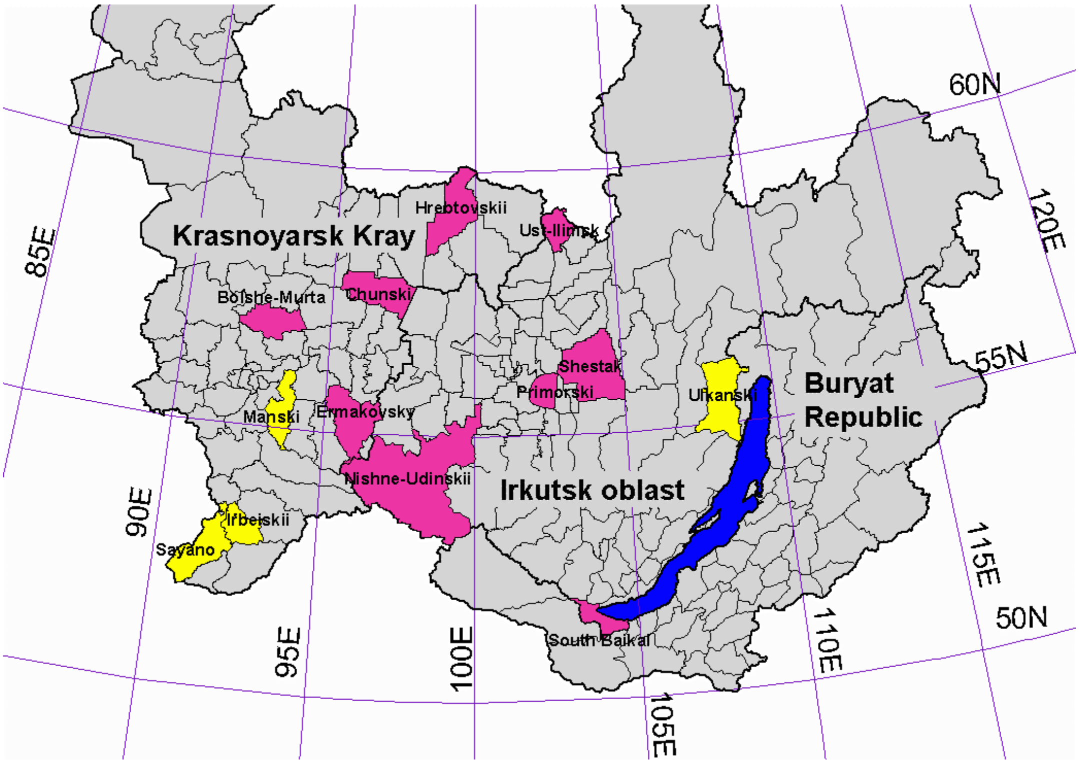

Figure III-1: The location of the test areas within the test territories (named) with available reference data in SIBERIA is presented above. Test territories in pink are currently available to the methodological team, whereas the test territories in yellow contain 12 test areas reserved for accuracy assessment and data available to partners.

III.3.1. IIASA Question and Answer Web Page

IIASA has continued to update the Question and Answer Web page (http://www.iiasa.ac.at/Research/FOR/siberia/) to address the questions from the SIBERIA partners regarding the reference data and the way in which to utilise the data.

III.3.2. Evaluation of "Strange Polygons"

“Strange Polygons” are those areas (or forest map polygons) where the satellite measurements do not initially agree with what is expected based on IIASA's ground truth information. IIASA has worked with the methodological team and our Russian partners to resolve these differences in information. In many cases, the measurements from the radar images show areas of recent change not present in the current forest inventory. Detailed explanations for each these “strange polygon” areas can be found on the IIASA's Question and Answer Web Page.

III.4. Accuracy Assessment and Cross-Check with Russion State Account (WP 4500)

The objective of this work package is to assess the full test sites in order to select the best combination of satellite measurements to classify and estimate the selected forest variables for the final map production. IIASA's tasks in this work package are the technical implementation of the accuracy assessment paying particular attention to the assessment of the classification accuracy. To prepare for implementation, 12 test areas were reserved for accuracy assessment (WP 4500) (Figure III-1), which IIASA will carry out in close collaboration with ITE Monks Wood (WP 5040). This task will be completed once IIASA receives the first classification results (WP 5020, 5030 & 5040) prior to handing-over the classification methodology to Sattelus (WP 6000).

IV. Centre d'Etudes Spatiales de la Biosphere (CESBIO)

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Further personnel: Dr. Malcolm Davidson, Mr. Didier Dendal

IV.1. Administrative Issues

Meetings: Dr. Thuy Le Toan and Dr. Malcolm Davidson attended the interim meeting in Kiruna, Sweden from Dec.11-Dec.14, 1999.

Project Documents and Technical Notes:

- Davidson, M., Working Note of histogram generation, January 2000.
- Le Toan, T. and M. Davidson, Coherence analysis of all processed test sites, October 1999

IV.2. Responsibilities

The responsibilities of CESBIO are:

- Quantification of ERS/JERS SAR Information Content (WP 5020)
- Analysis and Validation at Bratsk/Ust-Illimsk together with SCEOS (WP 5200)

In addition, CESBIO has been the leading remote sensing partner to explore the significance of the various ground truth parameters with respect to the radar data.

IV.3. Information Content (WP 5020)

Considerable time was spent on interpreting the information content of the ERS intensity, ERS coherence and JERS intensity images as a function of the forest volume and land cover class. Overall our analysis of the extensive database of radar signatures put together by the Siberia methodology team have shown that, for most sites, a threshold to discriminate between forest/non-forest classes is in general possible. For instance well developed forest stands (i.e. those with volume levels >150 m3/ha) at different test sites are usually characterised by ERS tandem coherence values lying roughly within the range of 0.2 to 0.4. whereas the ranges for less developed forests are higher. Figure IV-1 illustrates the average coherence values as a function of forest volume class computed on the basis of histograms for selected polygons from the various test sites. In terms of the applying thresholds to classification we observe that

- Very low volume forest (<50 m3/ha) can on average be distinguished from well-developed forests having volume levels greater than 150 m3/ha.
- Intermediate volume forests exhibit coherence lying in-between these two ranges but generally overlap with either low-volume or high-volume classes.

- Overall there is a relatively high variability in average coherence for a given class. This is due to a number of factors including polygon misregistration (especially in areas of high relief) accuracy of volume estimate, regrowth of forest since inventory as well as environmental factors.

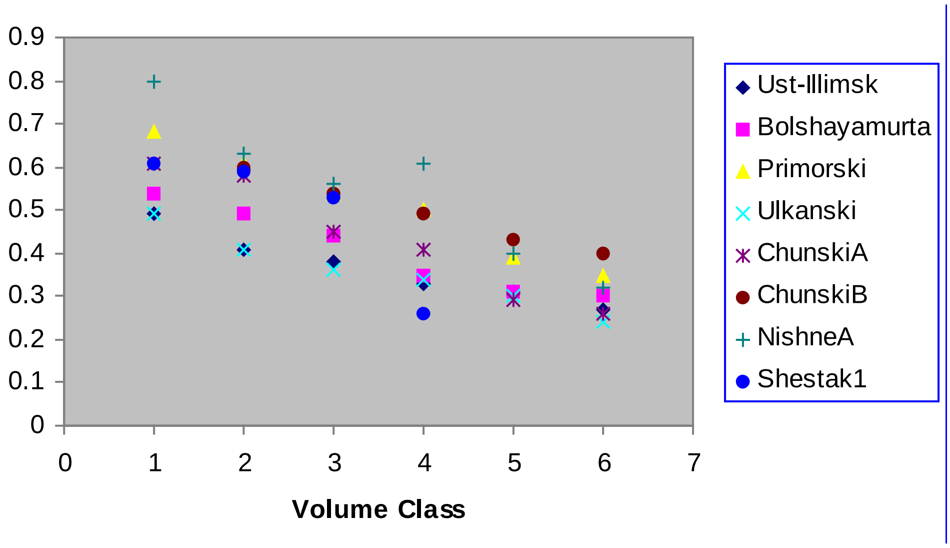

Figure IV-1: Average coherence values as a function of forest volume classes. The volume classes 1 to 6 correspond to volume ranges of 0-20, 20-50, 50-80, 80-130, 130-200 and >200 m^3/ha respectively.

Further complicating the threshold-based classification procedure has been the issue of the influence of environmental factors and their effects on the relationship between coherence and forest volume, and consequently on the stability of thresholds discriminating the various volume classes. This aspect was investigated at CESBIO in the case of the Hrebtovsky site. The work highlighted the role weather conditions can play on the coherence-land cover relationships. A visual illustration of such effects is given in Figure IV-2 which includes in part (a) a colour composite of the two ERS intensity tandem images and (b) the associated coherence image. The effect of weather conditions can be seen by a comparison of coherence from Hrebtovski North (frame 2403) and South (frame 2411). The image pairs have been acquired on 9/10 October 1997, on two consecutive frames. The coherence image is dark on the South frame, whereas on the North frame, the coherence image is brighter almost everywhere, except at its south-west corner. When the two coherence images are put next to each other, we can attribute the effect to rain. This is confirmed by the temporal change image between October 9 and 10: parts of images of low coherence correspond to high temporal change. Rain data recorded at the meteorological station on the Southern site show rainfall between October 9 and 10. In this case the strong change in ERS intensity over a very short time period can be attributed to rain in the southern half of the image and freezing conditions in the upper.

The impact of such localised changes in coherence due to weather conditions can be summarised as follows. For supervised methods, the images need to be segmented in rain/ no rain regions before estimating local thresholds to be used in the classification. The segmentation could be done e.g. semi automatically using tandem ratio intensity. For unsupervised methods such as ISODATA the rain should be included in the cluster label.

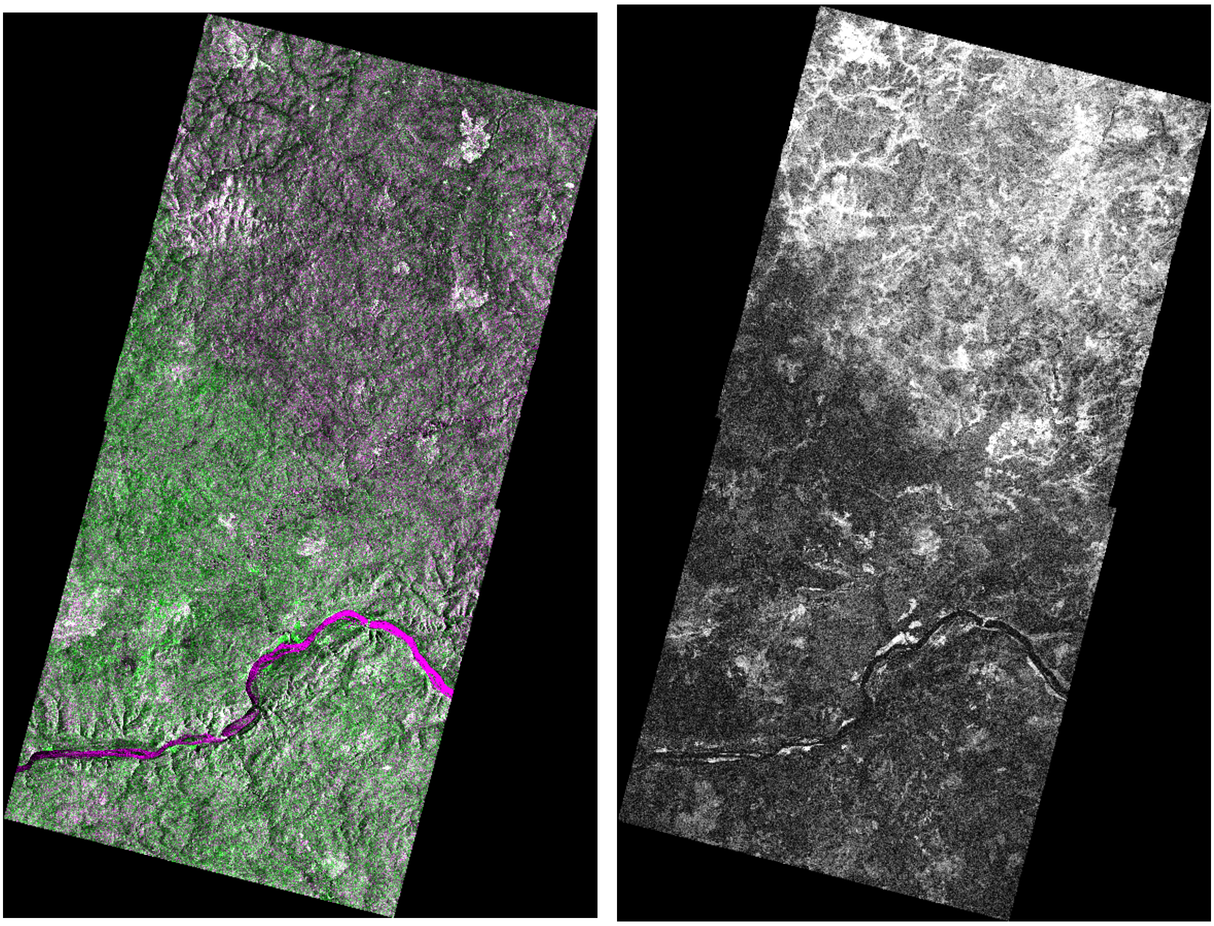

Figure IV-2: Illustration of environmental effects both on (a) display of intensity images of the ERS tandem pair and (b) corresponding ERS tandem coherence image. The green and purple coloured areas in (a) which reflect the changes local environmental conditions are associated with areas of low and high coherence in (b) respectively.

In terms of land-cover types other than forest information about the characteristic radar signatures was obtained through image interpretation and the extraction of associated histograms. The main results of our analysis in terms of ERS coherence and JERS intensity information (which are expected to provide the bulk of the information needed in the final classification scheme) are given in Table IV-1.

Land Cover	**ERS coherence**	**JERS intensity**
Agriculture (wheat harvested with different tillage states)	High	Low to medium depending on roughness and moisture
Pasture, Hayfields	High	Low
Bogs	High	Low
Inland water	Low (High if frozen)	Very Low
Settlements	High	High

Table IV-1: ERS signatures for various land cover classes.

IV.4. Classification

A possible hierarchical classification scheme was suggested at the December meeting in Kiruna. The scheme is based on our understanding of the relationships between ERS and JERS radar signatures and the land-cover classes of interest in the Siberia project. The classification scheme includes

- The flagging of radar data affected by weather conditions through the use of ERS intensity information
- The use of JERS summer intensity images to identify non-forest categories such as water, agricultural fields, bogs and urban areas
- The use of ERS coherence information to identify low and high volume forest cover

The approach itself is illustrated in Figure IV-3. The different decision rules to be adopted in the classification could use thresholding or statistical models, both based on the analysis of the radar database as a function of surface type or parameter.

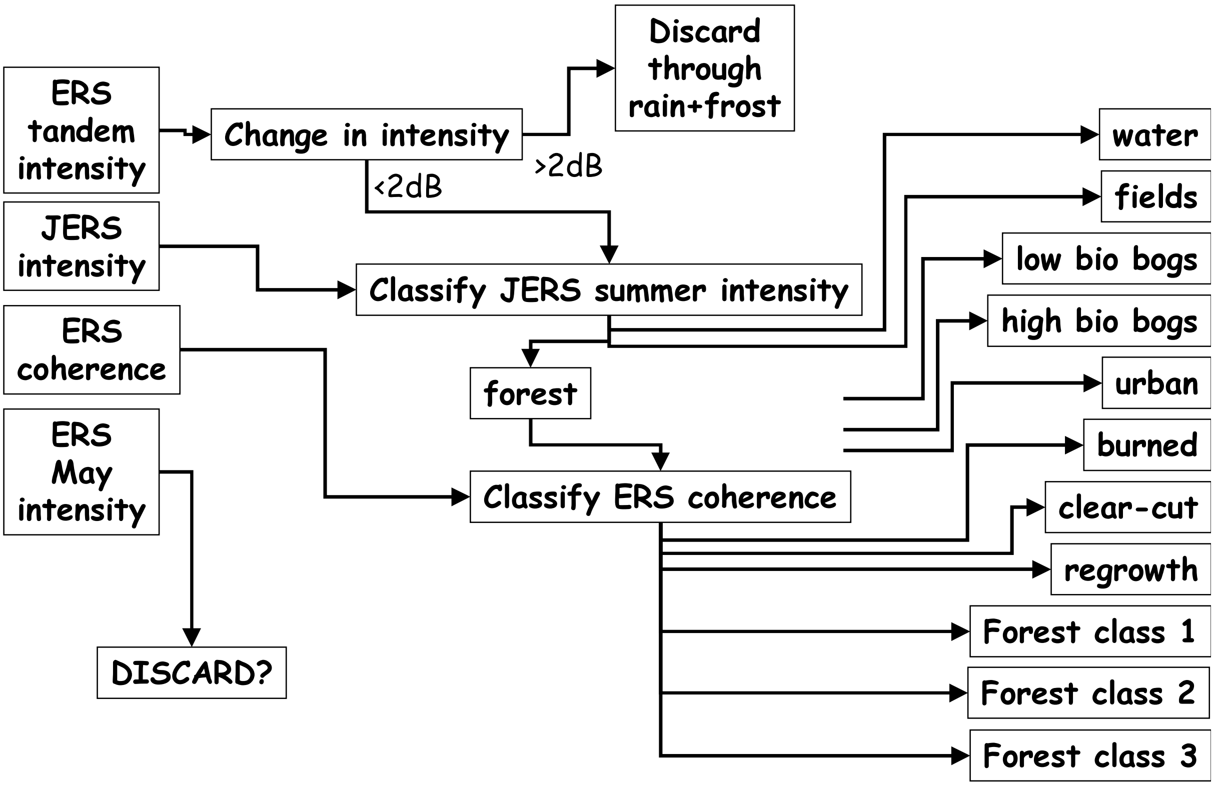

Figure IV-3: A suggested supervised classification approach based on interpretation and statistical analysis of the database.

For image frames with available ground data, this approach could be applied and refined for each individual frames. The number of classes and the performance of the classification could be optimised. However, for a robust, single method to be applied to a large number of frames, without ground database for many of them, there is a need to develop more unified methods. To this respect, a study is currently carried out to evaluate unsupervised methods. The objective is to interpret the clusters obtained by unsupervised methods in terms of the land use and forest classes, based on the knowledge of distributions (histograms) of those classes in the radar database. An unsupervised algorithm, the ISODATA software, has been modified by SCEOS and coupled to the ICP algorithm from ITE. The results obtained on several sites by SCEOS are currently being analysed. An example in the case of the Ust-Illimsk test site is given in Figure IV-4. Here the supervised approach adapted to 4 land-use classes is compared to 4-class modified ISODATA approach, obtained by SCEOS. The 4 clusters correspond to classes of water, mature forest, young forest, clearcut and open areas. ERS intensity, coherence and JERS data have been used. The result shows a good agreement between the two, showing that in this case, unsupervised methods can be used. More analyses need to be done in order to derive a common method (unified number and meaning of classes), taking into account of the wide range of conditions encountered on different image frames.

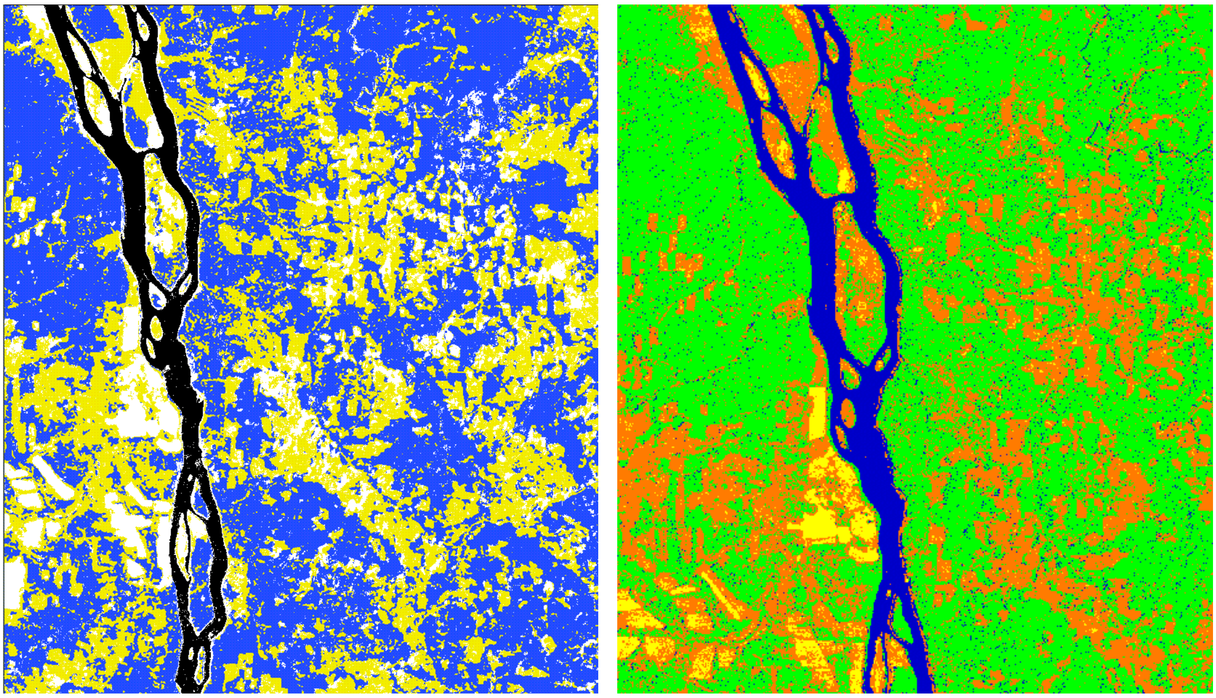

Figure IV-4: Comparison of the Ust-Illimsk results of the unsupervised ISODATA classification (SCEOS) for 4 classes (left) and the corresponding 4-class supervised hierarchical classification (right) (CESBIO).

IV.5. Problems and Comments

The testing of the various classification algorithms has been hindered by the slow availability of JERS data. The number of final classes in the classification can only be established once the complete JERS dataset has been analysed and included in the classification procedures.

V. Sheffield Centre for Earth Observation Science (SCEOS)

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V.1. Administrative Issues

Meetings: Prof. Shaun Quegan and Ms. Jiong Jiong Yu participated in the weekly-based telephone conferences and the hand-over meeting held at SSC between 11th – 14th December in Kiruna, Sweden.

Project Documents and Technical Notes:

- Quegan, S, Comments on sample sizes, October 1999
- Yu, J. J. and S. Quegan, Investigation of image properties in the Siberia project, November 1999

V.2. Responsibilities

The responsibilities of SCEOS are:

- Coordination of methodological development (WP 5000)
- Pre-processing and Classification (WP 5030)
- Analysis and Validation at Bratsk/Ust-Illimsk (WP 5200)

V.3. Coordination of Methodological Development (WP 5000)

- From the monthly reports submitted to SCEOS, important points were extracted, clarified and then summarised as monthly summary reports. They were provided to the methodological team and project coordinator for monitoring the project progress.
- As part of construction of a large database, a specification of graphs expected for each test site was issued by SCEOS and distributed to the partners. This was to enable a common base for comparing results from all the sites in order to seek a suitable classification strategy.
- Analysis of the central database uses the plotting program provided by DLR. These plots are available for each test site on the SIBERIA web site.

V.4. Pre-Processing and Classification: Improved ISODATA Classification and Interface to ICP Algorithm (WP 5030)

Rule-based classification is, in principle, preferred for its transparent connection to forest backscatter properties and easily-identified error sources. This kind of classification requires detailed knowledge of the targets being investigated and the identification of classification invariants. After the common database was set up and data from all sites were compared, it became clear that a simple rule-based method independent of data frames and test sites is unlikely to be applicable to all test sites in Siberia. For example, if the classification is based on image ratios, then different thresholds would be required at various test sites in order to account for different regional factors such as weather and ground conditions. Therefore, it became clear that we need to link data-based classifiers to physical insight. The following classifiers were considered and investigated:

- Maximum likelihood classification (MLC)
- Fuzzy c-means clustering
- ISODATA clustering

MLC is one of the most well-known supervised methods, available in most commercial software, but relies on overall stability or the need to retrain on different frames. For many frames, in the whole Siberian coverage, there is no ground data to drive MLC. Fuzzy c-means and ISODATA are both unsupervised, hence use less labour than MLC, but have no physical content. The test images run by Chalmers University indicated that Fuzzy c-means is capable of producing well classified images. However, this software is not widely available. Whilst Fuzzy c-means uses soft partitions in classification, as a special case to the Fuzzy algorithm, ISODATA classifies images using hard partitions. The ISODATA tool embedded in ERDAS/IMAGINE software gives worthwhile results. However, histogram measurements showed that this particular tool fails to take advantage of useful information in the input channels. In particular, it assumes all clusters are spherical and of the same size.

(a) (b)

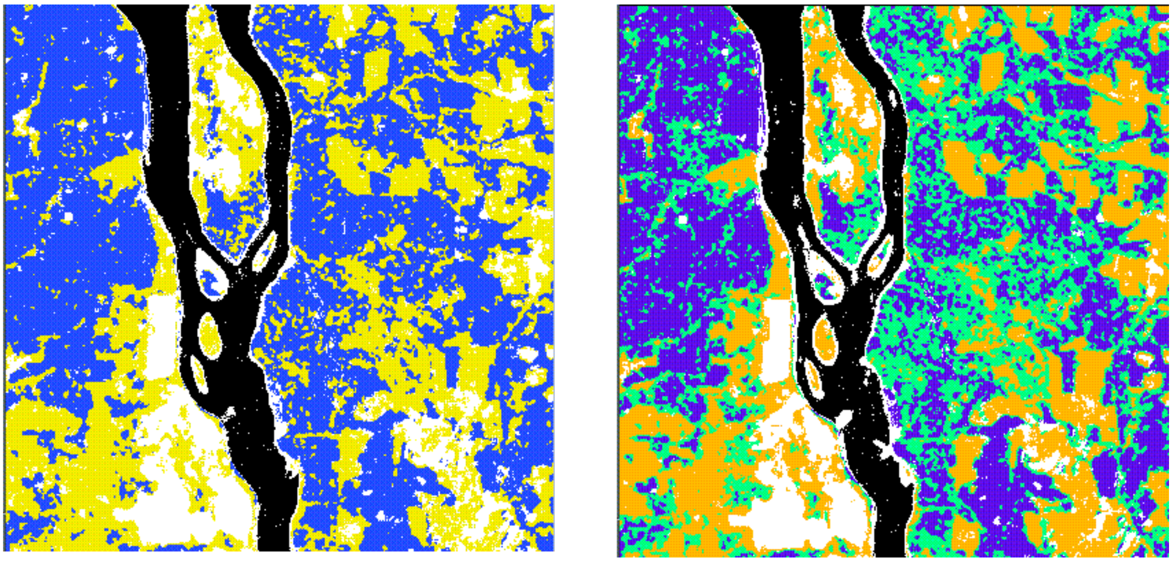

Figure V-1: Improved ISODATA classifications from Bratsk obtained after 20 iterations: (a) 4-cluster and (b) 5-cluster, based on multi-channel filtered ERS Tandem pair, one ERS-2 and two JERS intensity images (in dB), as well as an 80-pixel coherence image (filtered using a 3x3 window).

As an improvement, instead of simply measuring the distance to cluster means, as is done in IMAGINE, a modified ISODATA algorithm was developed at SCEOS which calculates the likelihood that a data point belongs to various classes assuming a multi-variant Gaussian distribution. Examples of 4-cluster and 5-cluster classifications obtained after 20 iterations are shown as Figures V-1a and V-1b, using as input data multi-channel filtered ERS Tandem pair, one ERS-2 and two JERS intensity dB images, as well as an 80-pixel coherence image of the Bratsk test area. Class–histograms taken from input data (not shown here) indicate that, this makes much better use of the useful information in the input channels than the IMAGINE version of ISODATA. This improved ISODATA algorithm is pixel-based, hence the classified images will not be blurred. Given enough iterations, well smoothed outputs can be achieved. These outputs can be further refined using NERC's ICP algorithm (refer to Chapter VII for more information). The advantages of using both ISODATA and ICP (or just one of them) is still being investigated. To update the classification procedure, the interpretation of the clusters provided by these algorithms must be provided (this may also lead to merging of clusters). This is based on the analysis of the results in the database and physical principles (see CESBIO and DLR sections).

V.5. Analysis and Validation at Bratsk/Ust-Illimsk (WP 5200)

V.5.1. Data Analysis

Polygon based data analysis was carried out at the test sites of Bratsk, Promiskii and Hrebtovsky. Various plots relating available satellite data to ground truth were generated using the IDL plotting program supplied by DLR. It was found that due to the time gap between acquisitions of the ground truth and satellite data, for the same type of plot, strange behaviour was observed at some sites. As an example, Figure V-2 shows plots of 80-pixel coherence versus growing stock and volume, with Bratsk data shown in (a) and Hrebtovsky in (b). Figure V-2a demonstrates typical characteristics of this kind of plot. Coherence is highest at small stock volumes, which is mainly associated with young stands, non-forest areas or clear-cut. As trees get older, i.e. stock volume increases, there is a decrease in coherence. The points in Figure V-2b, however, do not follow this expected trend, but appear rather random. After making inquiries to the Russian partners, it was confirmed that there was a fire at the Hrebtovsky area after the inventory was updated but in the same year. This explains why many points which, according to the database, have high stock volume (> 140 m^3/ha) also have high coherence in Figure V-2b.

(a) (b)

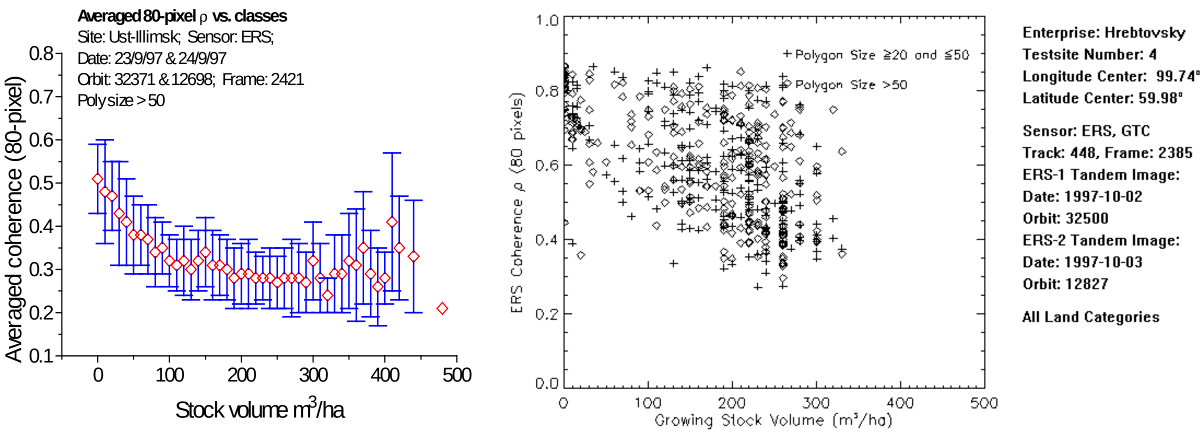

Figure V-2: Plots of 80-pixel coherence against growing stock volume of (a) Bratsk and (b) Hrebtovsky test sites.

Other partners also reported that for similar types of plots, different means and saturation levels were observed at different test sites due to various regional factors. Hence the need to exploit unsupervised methods (as well as physical reasoning) for the Siberia project, as already discussed in WP5030 above.

V.5.2. Investigation of Image Properties

Image properties can have a big impact on the data handling, error analysis and image operations such as filtering. Three important aspects of image properties, namely spatial correlation, equivalent number of looks (ENL) and texture were investigated using the Bratsk data set, including the coherence (80-pixel and 20-pixel), ERS and JERS intensity images. The main results are as the following.

1. The ERS and JERS intensity data are GAMMA distributed, with ENLs greater than 12 (probably around 14 - 15) for the ERS data and 6 for the JERS data;

2. The pixels in the JERS data are almost uncorrelated; ERS data has high correlation at lag 1 and lag 2. The correlation at lags > 1 in the 80-pixel and 20-pixel coherence images is insignificant. Correlation is only significant at lag = 1 in 80-pixel coherence;
3. Two measures, namely the coefficient of variation and the normalised log, have been used for examining the texture information in both ERS and JERS data. Both measurements show no evidence for texture in vegetated areas in either data set. The results of the normalised log are shown as Figure V-3. It can be seen that the observed “texture” is feature-related, mainly arising from the river and topography.

(a) (b)

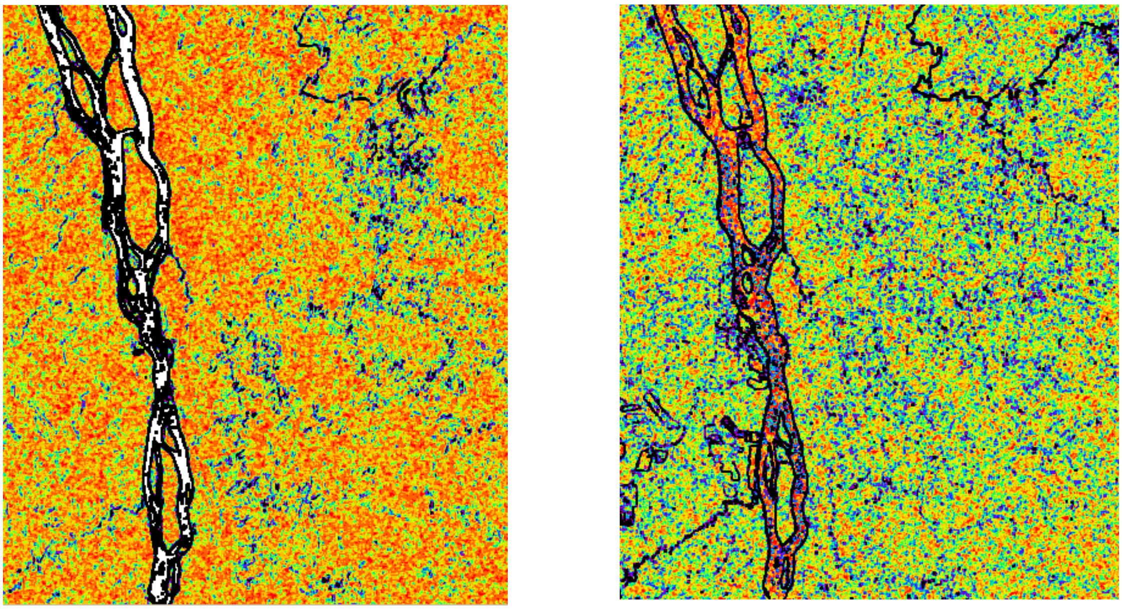

Figure V-3: Normalised log measurement of (a) ERS and (b) JERS, estimated using a 5x5 window.

The correlation in ERS data means that multi-look averaging will result in an equivalent number of looks smaller than the theoretical value. The evidence above suggests that methods developed for the Gamma distribution are appropriate for both ERS and JERS data.

V.6. Problems and Comments

- The central database is still incomplete as not all JERS data have arrived or been processed. However, analysis based on existing data suggests that rule-based classification using single threshold schemes will not be able to correctly classify all test sites in this project. Instead, a data-based unsupervised approach, ISODATA, which will be linked to physical class interpretation appears a more productive and pragmatic approach.
- The unsupervised improved ISODATA algorithm seems capable of generating very sensible results at the Bratsk test site. The immediate task to be carried out is to test this algorithm on various test sites. If the results can be explained using physical interpretations, a final classification approach (i.e. the *alpha-classifier*) for the Siberia project can be considered to be established.

VI. University of Wales Swansea (UWS)

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VI.1. Administrative Issues

The issues and concerns surrounding the delay in the data delivery, staffing concerns and officially delaying the project by three months have mostly been resolved. JERS data providing at least one coverage collected during June-July 1998 is now being delivered.

Meetings: Both Dr. Adrian Luckman and Dr. Kevin Tansey attended the SIBERIA progress meeting held in Kiruna, Sweden in December 1999.

Presentations:

A presentation was made at the annual Remote Sensing Society conference, held in Cardiff in September 1999. The paper was entitled ‘Mapping Boreal Forest in Siberia with ERS SAR Interferometry’, by K.Tansey, A.Luckman & C. Schmullius. It was published in the conference proceedings. Full acknowledgement is given to all other SIBERIA member institutions.

Working Notes:

- K. Tansey, Analysis and interpretation of strange outliers at the northern Irbeiskii test site, September 20, 1999.
- K. Tansey, Comparison of slope estimates from INSAR DEM and the GTOPO'30 DEM, September 20, 1999.
- H. Balzter, K. Tansey, Ground offsets during coregistration of JERS-1 and ERS images, January 14, 2000.
- K. Tansey, J. Vietmeier, S. Quegan, A. Luckman, Siberia Operational Processing Manual for ERS GTC Products, January 18, 2000.
- K. Tansey, Results of the Application of the Topography Mask to the Resampled GTOPO'30 DEM for 2 ESR Frames, January 20, 2000.
- K. Tansey, Report on coregistration using γsoftware, January 31, 2000.

VI.2. Responsibilities

Apart from those tasks for which all partners have responsibility, the tasks specifically assigned to UWS are:

1. Work Package 5050: Computational Issues (sole responsibility)
2. Work Package 5300: Computational Issues (lead partner sharing responsibility with NERC)

This document describes the progress made in these work packages towards the overall aim of the SIBERIA project as well as the developments in administrative aspects of this project within UWS. This document covers the period since the last progress report was submitted in July 1999.

VI.3. Computational Issues (WP 5050)

The deliverables for this Work Package due at or before the 3rd progress report on month 18 include:

1. E-mail distribution list
2. FTP server
3. Specification for common data transfer formats and methods
4. Specification for appropriate software packages or tools
5. Information on expected data storage requirements and computing processing time for methodological implementation
6. Investigate intellectual property rights issues

Items 1 and 2 have been fully satisfied. The latest solution to managing e-mail distributions is a series of lists available on the UWS SIBERIA web-site. The UWS FTP server is operational and has already proved to be a vital resource for partners sharing image, document and meta-data information.

Item 3 has been satisfied through discussions and then recommendations presented to the team. The same is true of Item 4 (see below). Our involvement on this work package needs to be flexible in terms of answering other people's requirements when problems occur. The FTP-site solves methods of data transfer. Formats are largely defined by the sources of all SAR data in the project, namely DLR-DFD and GAMMA. We believe that all relevant partners have been able to read and process data from these sources and that the formats used are therefore adequate. Item 5 (estimates of processing time and storage space) has been addressed. These estimates were based on existing data storage and future data deliveries. The information was presented to Satellus (who will be responsible for the majority of the image processing during the map production stages). Item 6, which was added after discussion between groups, has been addressed to the satisfaction of all project partners. The solutions to issues and problems raised by the work packages stated above were presented in the 2nd SIBERIA progress report. Since this report the following specific computational issues have been addressed:

- Collation of the most current and fully tested programs that are required for the pre-processing stages of the ERS products. These include calibration, topography masking and filtering.
- Addition of the front-ends and copyright information to the executable processing scripts.
- Publication of the 'SIBERIA Operational Manual, Version 1'.
- Delivery of 32 ERS GTC products, a list of working notes, source code, compiled binaries and full documentation (including the SIBERIA operational manual) to Satellus.
- Resampling and filtering of the GTOPO'30 DEM to enable operational implementation of the topography masking program. The products were sent to Satellus.
- Investigation of the co-registration between ERS and JERS data using the GAMMA software. The successful conclusion of this work was the agreement by Satellus to lease the software from GAMMA.
- Currently, UWS is assisting with the operational implementation of a pre-classification procedure called ISODATA.

In addition to addressing the deliverables agreed at the start of the project, continued development and improvement of the UWS SIBERIA WWW site has been achieved. The site now serves to inform the public and promote the research being undertaken on the project. Encouraging feedback, on how informative the site is, has been received from colleagues in institutions not linked to SIBERIA. The web site serves also, as a catalogue of image data, for the distribution of documents and meta-data and for charting the progress of all aspects of the project. Within the project itself, the feeling seems to be that this is a valuable tool for the SIBERIA consortium and should continue to be developed as a Computational Issues Work Package (WP5050).

The web site at http://pipeline.swan.ac.uk/siberia/ now contains the following information:

- **Home Page -** lists funding, general objectives, geographical location (a map) and partner institution information.
- **What's New -** lists all the new and important project developments and recently acquired images.
- **E-mail Listing** – lists full SIBERIA group and methodology sub-group e-mail addresses

- **ERS/JERS Coverage** – lists all ERS and JERS images that have been processed. From here thumbnail and low-resolution images can be viewed. Provision is made for searching the SIBERIA project region by geographical location via point and click images.
- **Field Data** – lists important field data information and links to the IIASA web site.
- **Working Notes** – lists SIBERIA technical notes, results, EU reports and conference papers. The notes can be downloaded in either html or pdf format.
- **ERS/JERS Status** – lists the ERS and JERS satellite orbit information over the SIBERIA area.
- **Weather Data** – lists weather data for climate stations in the region.
- **Database Plots** – lists the plots of image information against forest parameters.

VI.4. Methodological Development at Lake Baikal (WP 5300)

Progress of the methodological development in the Lake Baikal region has been significant during the second half of 1999. Analysis was made towards the methodological development of the other test sites assigned to UWS (Nishni Udinskii and Irbeiskii test territories). This progress is mainly the result of continued ERS processing and the delivery of registered JERS-1 imagery from GAMMA. Currently there is full ERS coverage of all the test sites assigned to UWS (a total of nine) and JERS-1 coverage for six test sites.

Documented in the previous progress report were results from analysis at one of the Ulkanskii test sites near Lake Baikal. As a consequence of these results and other results from methodology partners, the information content contained in ERS and JERS-1 images were accumulated for all test sites that were being analysed. This significant task was started at the beginning of autumn. UWS assisted in the analysis by developing tools to extract the necessary information from the remotely sensed data and the field data. UWS also developed tools to plot the data for visual interpretation but this latter stage proved time consuming. As a result, colleagues from DLR then developed a tool to generate the required plots and set the standard for the SIBERIA common database format. With slight alterations to the database creation programs (developed by UWS), and the DLR plotting programs, the required information could be presented for interpretation very quickly. The results of this work are available for viewing on the UWS SIBERIA web site (database plots link).

Our WP 5300 partner, the Centre for Ecology and Hydrology (CEH), Institute of Terrestrial Ecology (ITE), comprising Dr. Heiko Balzter, Dr. David Gaveau and Dr. Stephen Plummer, conducted an analysis into texture measures of ERS amplitude and coherence at the southern Lake Baikal test site. Three different texture measures were examined with three different input channels:

- standard deviation over a 7x7 window for ERS-1 amplitude, ERS-2 summer amplitude (2) and ERS coherence (estimated using 80 pixels)
- entropy over a 7x7 window for ERS-1, ERS-2 (2) and ERS coherence
- contrast over a 7x7 window for ERS-1, ERS-2 (2) and ERS coherence

The assessment of ERS texture statistics was undertaken using Principal Component Analyses (PCA). A PCA reduces a multidimensional feature space to orthogonal principal components which are derived from linear combinations of the input variables. The principal components are ordered according to the proportion of the variation in the data they can explain. Here, the criterion for considering a principal component (PC) as not negligible is that it explains more than 5% of the overall variance. Four principal component analyses were undertaken:

A random sample of 10,000 pixels was taken from the area covered by the polygon ground database (Figure VI-1a and b), masking out mountainous areas.

- PCA1: 3 ERS amplitudes, ERS coherence and all 9 texture statistics
- PCA2: 3 ERS amplitudes, ERS coherence and the 3 standard deviation channels
- PCA3: 3 ERS amplitudes, ERS coherence and the 3 entropy channels
- PCA4: 3 ERS amplitudes, ERS coherence and the 3 contrast channels

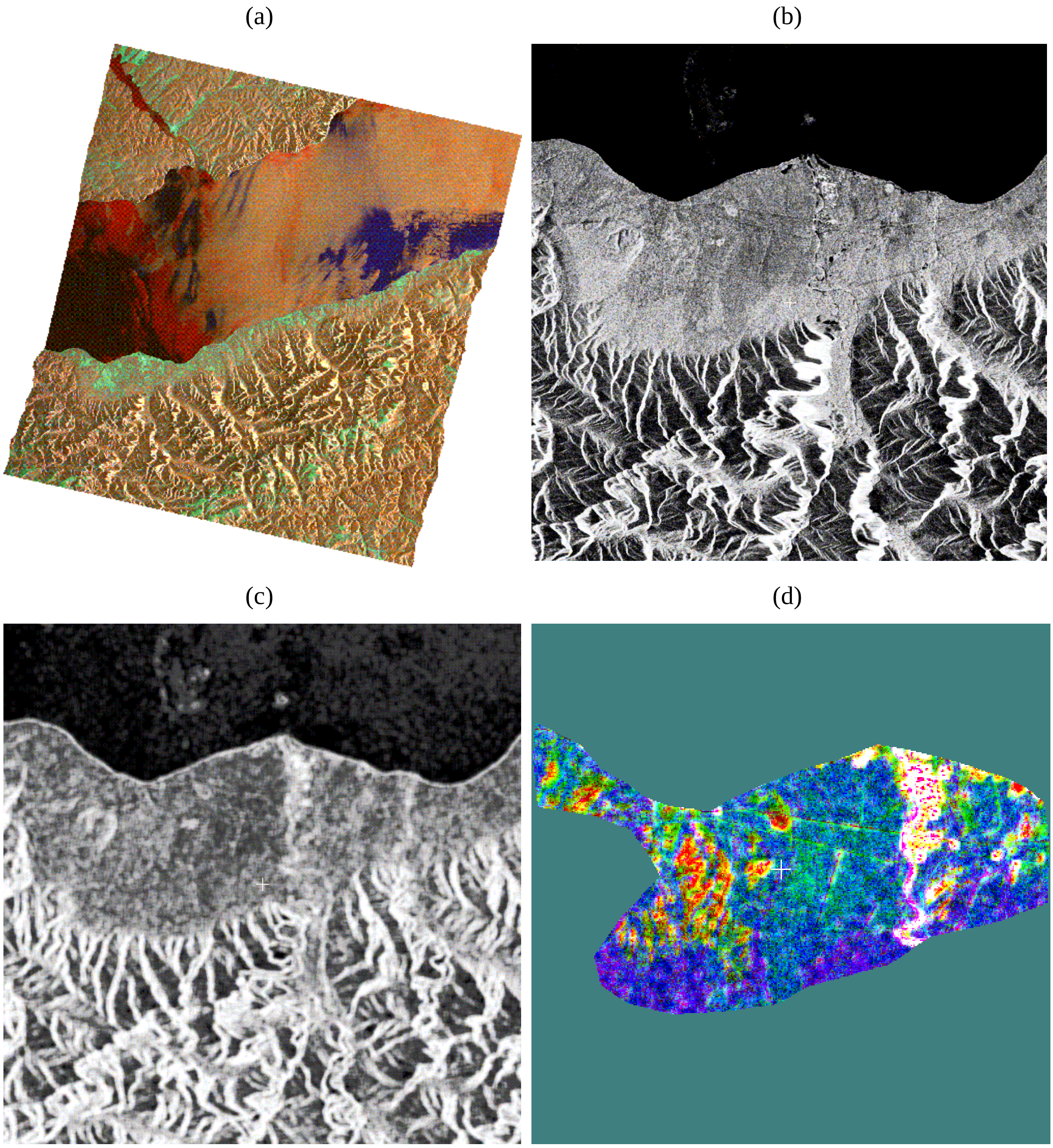


Figure VI-1: Texture analysis at Lake Baikal South. (a) Overview of ERS frame 35978_2565, (b) amplitude of the second ERS-2 pass for the area of interest, (c) entropy of the amplitude of the second ERS-2 pass over a 7x7 window, (d) RGB colour composite of the first three principal components from PCA2. In (d) the coloured background is caused by the linear enhancement.

PCA1 was used to evaluate the joint use of several texture measures. PCA2 to PCA4 were used to compare the information content of each single texture statistic.

Figure VI-1c shows an example of the entropy for the area of interest. PCA1 reduced the 13 input variables to 5 PCs (5% criterion). The most important PC (i.e. component 1) is determined mainly by different texture statistics from ERS amplitude (1) and ERS coherence. PCA2 yielded five, PCA3 six, and PCA4 five PCs. Irrespective of the texture statistic used, roughly the same number of PCs was found to be significant. In all cases, the most important PC explaining more than 40% of the variation in the data was determined mainly by the texture statistics, and only secondarily by the amplitude and coherence. Figure VI-1d shows an image based on the three most important principal components from PCA2 (with the standard deviations as texture information) as red, green and blue. From visual judgement, there is a high potential of texture for classification.

The high contributions of the texture statistics to all most important principal components for PCA1 to PCA4 is evidence for the importance of including at least one texture measure for the amplitudes and one for the coherence in the development of the classification methodology. Based on these results we asked whether texture statistics are related to land use and forest structure.

This has been investigated at the same test site, Lake Baikal South. Polygons included in the analysis have a minimum size of 20 pixels (after erosion of 1 pixel at the boundaries). Polygons with high topography have been excluded from the analysis. For each polygon, the three texture statistics standard deviation, entropy and contrast over a 7x7 window have been averaged and written to a database using programs provided by UWS.

The relation between image texture and land use is presented as boxplots. The boxes of the boxplots show the 25%-quantile Q25 as lower limit of the box, the median Z within the box, and the 75%-quantile Q75 as upper limit of the box. The whiskers show the closest data point to

Q25 - 1.5 x (Q75 - Q25) and Q75 + 1.5 x (Q75 - Q25). Figure VI-2 shows an example of boxplots of the three texture measures for the ERS-1 amplitude (a1). Only the land use classed as bogs (ZK = 2507) can be separated by the texture information. Which texture statistic is being used plays a minor role, and even the choice between a1, a3 or the coherence does not make a difference.

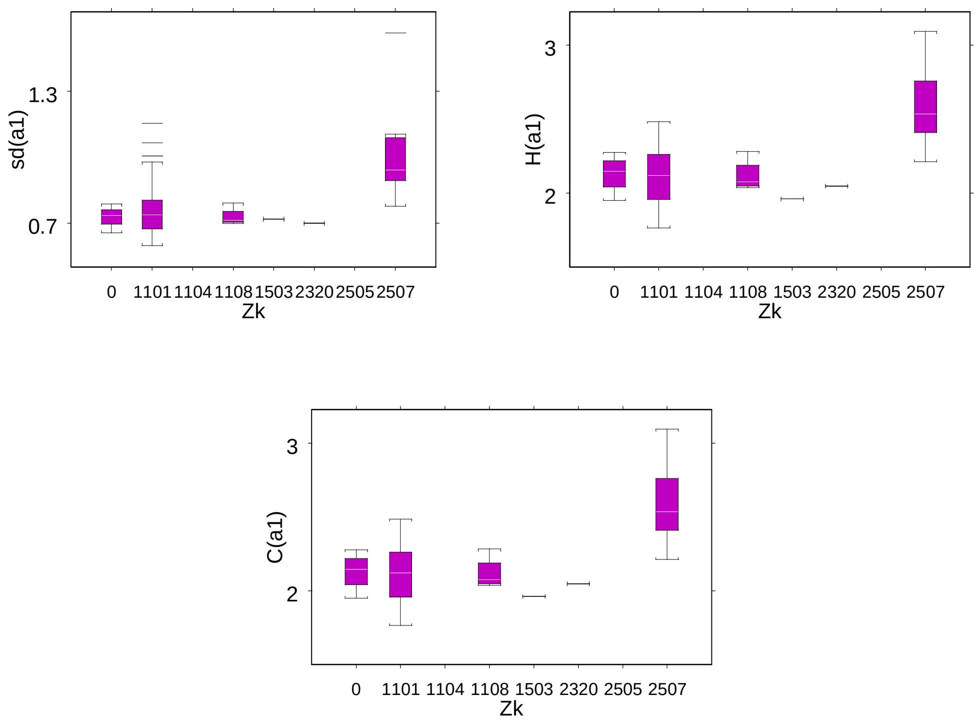


Figure VI-2: Mean texture statistics of ERS amplitude (a1) per land use class.

Conclusions from this texture analysis at one test site are:

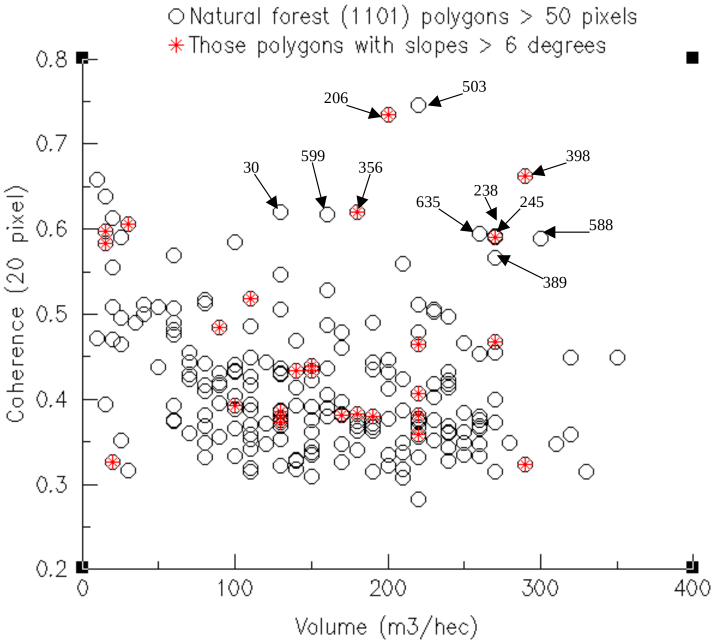
- Bogs (ZK=2507) can easily be separated from any other land use class at test site Lake Baikal South using image texture.
- The observed discrimination is valid for any of the texture statistics: standard deviation, entropy and contrast within a 7x7 window, as well as the coefficient of variation within a polygon.
- The same relationship holds whether the texture is based on amplitude 1, amplitude 3, intensity 1, intensity 3 or coherence.

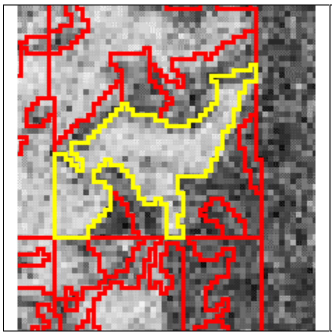
- There is no relationship between texture and total growing stock at this test site.
- Image texture can easily be calculated and should be considered to classify bogs in the final classification methodology.

In addition to the progress being made in the methodological development at Lake Baikal and other sites, UWS has undertaken or contributed to the following research and working notes:

- Working note on the, ‘Analysis and interpretation of strange outliers at the northern Irbeiskii test site’ (September 1999). This document attempts to explain the occurrence of outlying data points that do not correlate well with physical or theoretical principles/models. Recommendations were made to IIASA to re-check the field data for selected polygons. The results that came back confirmed that, in certain cases, the field data available to us did not represent the present conditions, i.e. areas in which forest clearance was caused by fire after the field inventory was taken and before the image data were acquired. An example of an erroneous polygon is shown in Figure VI-3.

- Suggestion to IIASA that they correct the field data after it was discovered that some polygons were being ignored in the analysis stages because the unique number assigned to every forested stand in Russia was not unique. IIASA responded immediately by sending out corrected field data.





Polygon No. 503

Bright high coherence region.
Adjacent to other clear cut regions.
Described as natural forest with >200 m^3/ha stock volume
Most likely clear cut since the last field inventory.

Figure VI-3: Results of the investigation into the occurrence of outlying data points in the northern Irbeiskii region as described in a working note. In this example, polygon number 503 comes under investigation as the imagery indicates a region of high coherence, yet the database informs us that the stand is forested with a large growing stock volume. These strange polygon numbers were sent to IIASA who asked their colleagues in the Russian Forestry departments to investigate these polygons further and report back the current situation.

- Working note on the, ‘Comparison of slope estimates from the INSAR DEM and the GTOPO’30 DEM’ (September 1999). This working note served to clarify the potential problems between those ERS images terrain-corrected using an INSAR DEM and those ERS images terrain-corrected using the GTOPO’30 DEM. This working note also indicated if estimates of slope could be utilised for developing a topography mask.
- Working note on, ‘Ground offsets during coregistration of JERS-1 and ERS images’ (with Heiko Balzter, CEH-ITE, January 2000). This paper provided an estimate of the possible offset errors between JERS and ERS imagery. The results started an interesting debate, concluding in another working note by DLR and an overall appreciation of the potential errors being obtained by all SIBERIA partners.
- Working note on the, ‘Results of the Application of the Topography Mask to the Resampled GTOPO'30 DEM for 2 ERS Frames’ (January 2000). This working note documents the results from testing procedures of the topography masking program developed by DLR. The output image products from the program are compared with each other, in order to define the optimal settings of the internal topography masking parameters for the most appropriate operational implementation of the program by Satellus.
- Working note on the, ‘Report on coregistration using GAMMA software’ (January 2000). This note described the procedure, an estimate of the processing load and results from the fully automated coregistration procedure available from GAMMA. In Figure VI-4, a false colour composite image shows a coregistered ERS coherence, ERS intensity and JERS intensity image, an output from this processing stage.

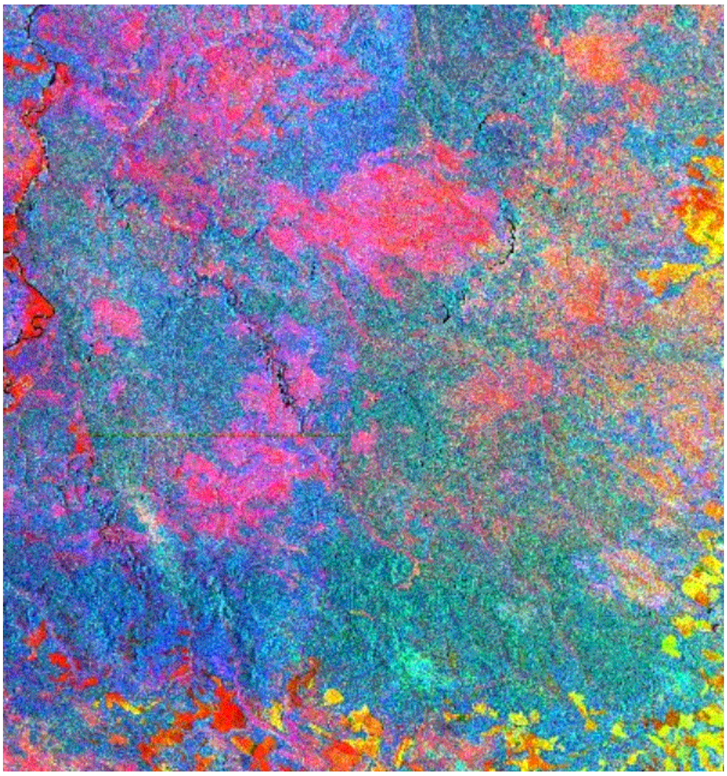


Figure VI-4: False colour composite comprising RED = ERS tandem coherence, GREEN = ERS intensity, BLUE = JERS intensity. In this example, 4 JERS image products have been coregistered to the ERS image, using software developed by GAMMA. The JERS data were acquired in summer 1998 and were coregistered initially to an ERS intensity image acquired during the same season.

- Development of code fragments, shell scripts and front end tools for operational implementation of the pre-processing and processing stages that have been tested up to the present day (see WP5050 for further details).

- Publication and delivery to Satellus of version 1 of the ‘SIBERIA Operation Processing Manual’ (January 2000).

VI.5. Future Plans for Methodological Development

Current and future plans for methodological development are based around the interpretation of the classification algorithms that are being considered by the SIBERIA partners. More specifically, UWS’s future plans are:

- Testing of the recommended classification procedures on the Ulkanskii, Nishni Udinskii and Irbeiskii field test sites.
- Collaboration with other SIBERIA methodology teams in the interpretation of the classification results into physical classes.
- Provide assistance to Satellus and GAMMA concerning the operational implementation of the automated coregistration procedure.
- Complete the SIBERIA common database plots when the remaining JERS images become available.

VII. Natural Environment Research Council (NERC)

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Further personnel: Dr. Heiko Balzter, Mr. David Gaveau, Consultant Dr. John Baker

VII.1. Administrative Issues

Meetings: Dr. Heiko Balzter and Mr. David Gaveau participated in the Kiruna meeting.

Dissemination of Results to Team:

- Monthly Work Package Reports to SCEOS
- Status Report in May 1999 to DLR
- Provision of software to the project team:
  1. C code for the ICP algorithm
  2. C code for calculation of Kappa coefficient
  3. EXCEL spreadsheet for calculation of Kappa coefficient
  4. EXCEL spreadsheet on the required minimum number of pixels per polygon for the polygon database
- Presentation at the meeting of the methodology team in Kiruna (11-14 December 1999)
- Mean and standard deviation of ERS backscatter intensities and coherence per polygon have been calculated. The resulting table has been merged with the ground data attributes. This polygon database has been made available on the Swansea server.

Publications:

Gaveau, D.L.A., Balzter, H. and Plummer, S. (1999): Boreal forest InSAR classification properties. Proceedings of the CEOS SAR Working group meeting, Toulouse, 26-29 Oct. 1999.

Publications in preparation:

- Baker, J.R. and Balzter, H.: The Iterated Contextual Probability classifier - Improvements in classification accuracy of radar images from boreal forests
- Balzter, H., Talmon, E., Gaveau, D., Tansey, K., Oeskog, A., Nilsson, S., Roth, A.. and Schmullius, C. (2000): Accuracy assessment of a large-scale forest map of Central Siberia derived from multi-sensor satellite-borne Synthetic Aperture Radar interferometry (InSAR). Accuracy 2000, 12-14 July 2000, Amsterdam
- Le Toan, T., Balzter, H., Davidson, M., Gaveau, D., Luckman, A., Quegan, S., Schmullius, C., Tansey, K., Wagner, W. and Yu, JJ (2000): Assessing SAR information content for large scale forest mapping in Siberia, IGARSS 2000.
- Quegan, S., Yu, J.J., Balzter, H. and Le Toan, T. (2000): Combining unsupervised and knowledge-based methods in large-scale forest classification, IGARSS 2000.
- Schmullius, C., Baker, J.R., Balzter, H., Davidson, M., Gaveau, D., Gluck, M., Holz, A., Le Toan, T., Luckman, A., Marschalk, U., Nilsson, S., Quegan, S., Roth, A., Shvidenko, A., Strozzi, T., Tansey, K., Vietmeier, J., Wagner, W., Wegmueller, U., Wiesmann, A., and Yu, J.J.: SAR

Imaging for Boreal Ecology and Radar Interferometry Applications. International Journal of Remote Sensing

- Wagner, W., Vietmeier, J., Schmullius, C., Le Toan, T., Davidson, M., Quegan, S., Yu, J.J., Luckman, A., Tansey, K., Balzter, H. and Gaveau, D. (2000): The use of coherence information derived from ERS Tandem pairs for determining forest stock volume in SIBERIA, IGARSS 2000

Working notes since the second Progress Report:

- Treatment of extreme topography in GEC and GEC_GLOBE images
- Classification of boreal forest (Ust-Ilimsk) with Maximum Likelihood Classification
- Analysis of the information content of three texture measures of ERS amplitude and coherence
- Boxplots of texture statistics against land use class
- The Iterated Contextual Probability classifier (ICP)
- Coherence analysis for 7 test sites
- Ground offsets during co-registration of JERS-1 and ERS images

VII.2. Responsibilities

The tasks assigned to NERC are WP5040 (Accuracy Assessment) and participation in WP 5300 (Analysis and Validation at Lake Baikal) sharing responsibilities with UWS.

The objectives of WP 5040 are

- the definition of methods for accuracy assessment of the classification methodology, and the physical and statistical implications of the methods;
- the synthesis of the assessment of results on a training test site;
- an analysis of the implications for large scale mapping;
- the development of methods for accuracy assessment of the large-scale map.

The objectives of WP 5300 are

- the implementation of developing methodologies at the test site and feedback to the methodology team;
- the generation of a geocoded classification map of the test site based on all available data;
- the evaluation of implications of reduced data availability for the large-scale map.

Progress on WP 5300 is reported elsewhere led by UWS.

VII.3. Technical Progress

The main outcomes of WP 5040 since the second Progress Report are:

- geometric accuracy: ground offset estimates during co-registration of JERS and ERS GTC images due to different DEMs
- classification accuracy: interface between ISODATA (WP 5030) and ICP (WP 5040) to develop a data-driven contextual classifier
- map accuracy: spatial accuracy assessment to distinguish recent clearcuts from classification errors

VII.3.1. Geometric accuracy: Ground offsets of JERS-1 and ERS GTC images

ERS images are processed to GTC (geocoded terrain corrected) products by DLR whenever the quality of the interferometric coherence permits it. The digital elevation model (DEM) from the ERS tandem pair is used for geometric terrain correction and radiometric calibration. For JERS-1 several reasons make it impossible to use the same GTC production. The ERS InSAR DEM can not be used for JERS-1 terrain correction because images (orbits) overlap only partially. The adopted solution that Gamma Remote Sensing uses for JERS-1 geometric correction and geocoding is based on the public domain DEM GTOPO30. One pixel of this DEM is 30 arc seconds compared to 50 m in the InSAR DEM. However, GTOPO30 is not used for radiometric calibration. The different DEMs for terrain correction of JERS-1 and ERS imagery create a geometric error in the co-registration step of JERS-1 to ERS-1.

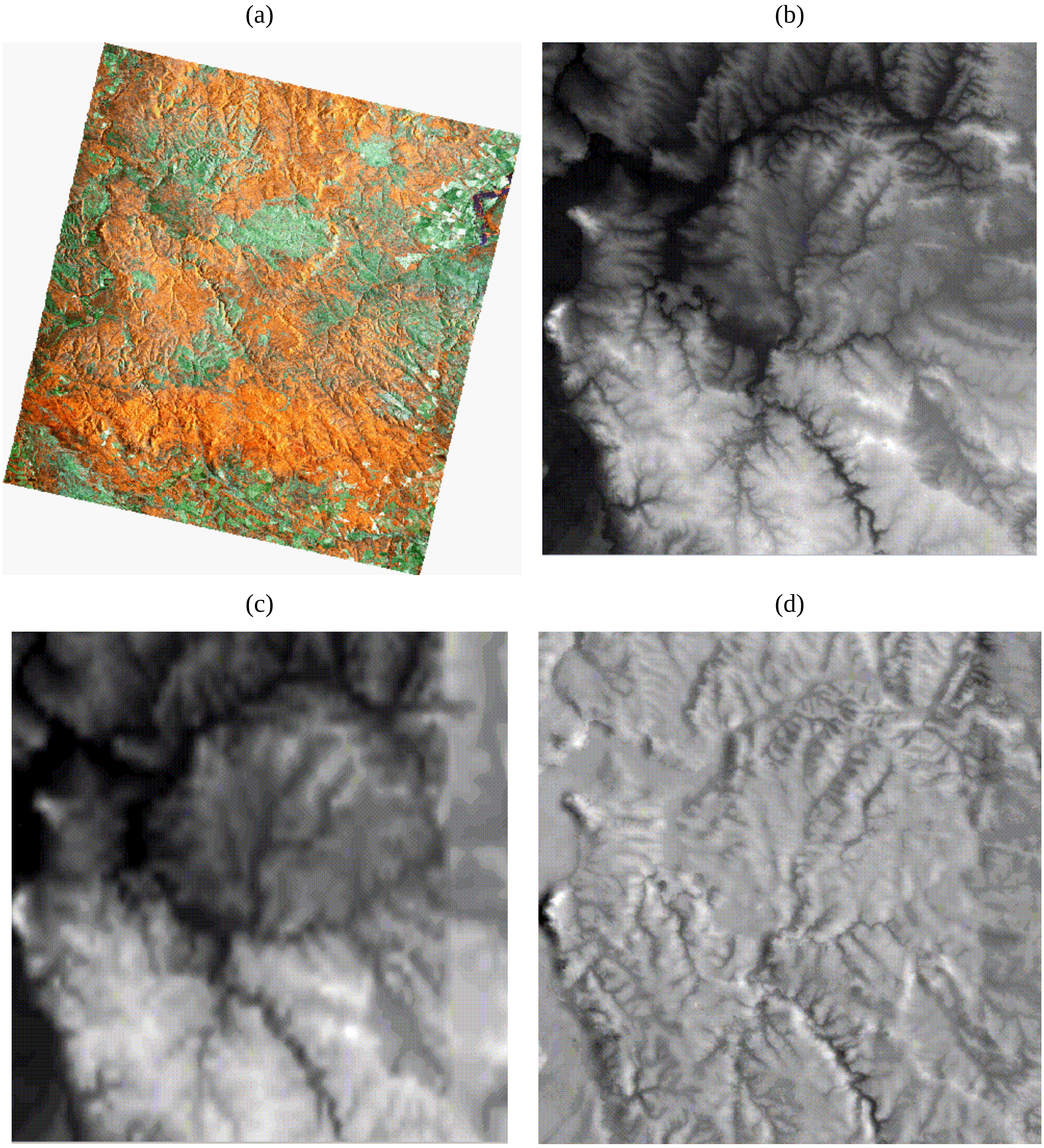

Figure VII-1: Analysis of the ground offsets during co-registration of JERS-1 to ERS GTC images. a) False colour composite of frame 32414_2493 (GTC) covering the Ukarsk region of the Nishni-Udinskii test territory. b) GTC InSAR DEM used for geometric correction and radiometric calibration of ERS-1 image. c) GTOPO30 DEM used for geometric correction of JERS-1 image. d) Height difference image between GTOPO30 DEM and InSAR DEM.

For a GTC product to be produced, there must be significant areas of high coherence to enable the interferometric phase to be unwrapped and the DEM extracted. Areas of high coherence, in the Siberia project, are normally associated with development (or natural/non-natural forest clearance). A GTC is also more likely to be produced in the low lying regions where topographic variation is relatively small. In mountainous regions the terrain is also likely to be forested resulting in low coherence. To test the GTC an error analysis has been carried out for the test site Ukarsk, an area with some topographic variation (Figure VII-1). The geometric errors are probably the worst-case scenario for a GTC scene in the Siberia region. If the topography becomes more significant, there will be reduced opportunity for development and the area is likely to be forested. This results in low coherence and no InSAR DEM, therefore the GTOPO30 DEM is used and registration should be better with the JERS with also uses the GTOPO30 DEM. The error in the latter case are only due to the different incidence angles.

The test site Ukarsk is located in the north-east of the territory covered by ERS frame 32414_2493 (track 362). The product 32414_2493 is geocoded and terrain corrected (GTC). The ERS frame is characterised by extensive regions of high coherence in the south and east of the frame (Figure VII-1a).

Figures VII-1b and VII-1c shows the two DEMs used for geocoding. GTOPO30 is much coarser than the InSAR DEM, which results in large differences in height for small-scale features such as little rivers and valleys. Figure VII-1d gives a visual impression of the differences between the two DEMs. The histograms of height values confirmed this. The InSAR DEM at this test site is on average 47 m lower than GTOPO30. Given approximately normal distribution, 95% of the difference values are included in the interval between -114 m and 20 m.

The ground offset Δg can be estimated from the elevation height h and the incidence angle θ (Schreier 1993, p. 120):

$$\Delta g = \frac{h}{\tan\theta}$$

The height difference between GTOPO30 and the InSAR DEM is regarded as h in the equation above. The maximum height difference in the 95% interval of 114 m causes Δg=146 m, or 3 pixels.

VII.3.2. Classification Accuracy: ISODATA and ICP

Classification has the objective to label a number of objects (pixels) with one of n classes. The labelling process unavoidably contains errors caused by outliers, extreme values, unusual pixel signatures or geometric errors in the image data. A good classification algorithm minimises these errors.

Traditional classification approaches often neglect the information in an image about spatial neighbourhood relationships between adjacent pixels. A standard maximum likelihood classification is based solely on information about the pixel grey values in the image. It does not matter where in the image the particular pixel is situated. The pixel is labelled with the class having the most similar signature (mean and standard deviation of grey values) to the pixel itself. However, in practice pixels of the same class tend to appear in clusters, and the neighbourhood of a pixel provides potentially valuable extra information. This is illustrated in Figure VII-2. The left image shows a SAR image of Ust-Ilimsk. The spatial location of the pixels is kept as information in this image. If this spatial information was neglected, the pixel coordinates could be assigned randomly, keeping the spectral but losing the spatial information. This has been done in the right image of Figure VII-2. Clearly, it would seem a waste to classify the right image rather than the left one. Note, however, that this is exactly what is done by most traditional classification algorithms, such as ISODATA, K-Means or MLC.

The Iterated Contextual Probability Classifier (ICP) developed in WP5040 provides a solution. In collaboration with WP 5030 (SCEOS) an interface between the data-driven ISODATA algorithm and ICP has been developed (Figure VII-3).

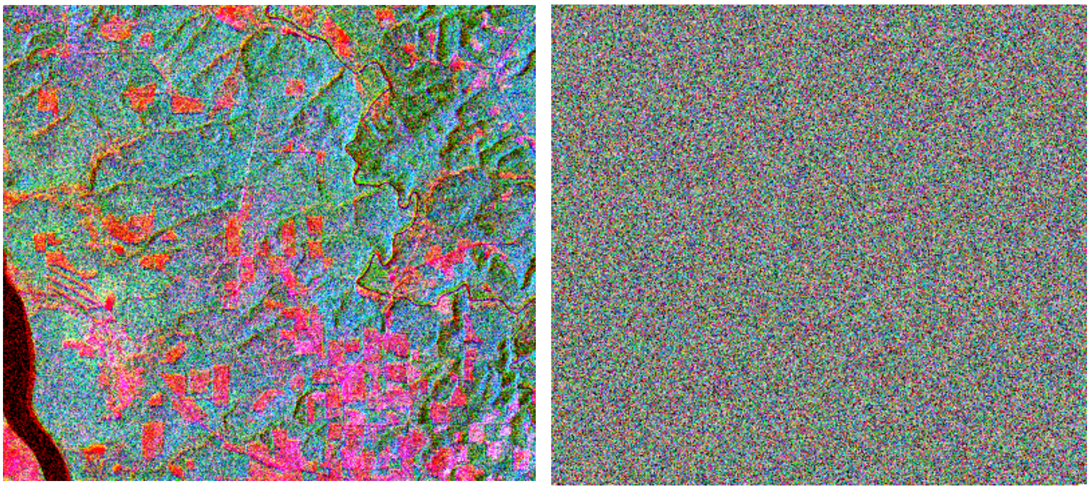

Figure VII-2: SAR image of part of the Ust-Ilimsk study area in Siberia. ERS coherence (red), JERS-1 intensity (green) and ERS-1 intensity (blue). Left: Pixels are shown at their geocoded location. Right: The same pixels but with randomly assigned coordinates.

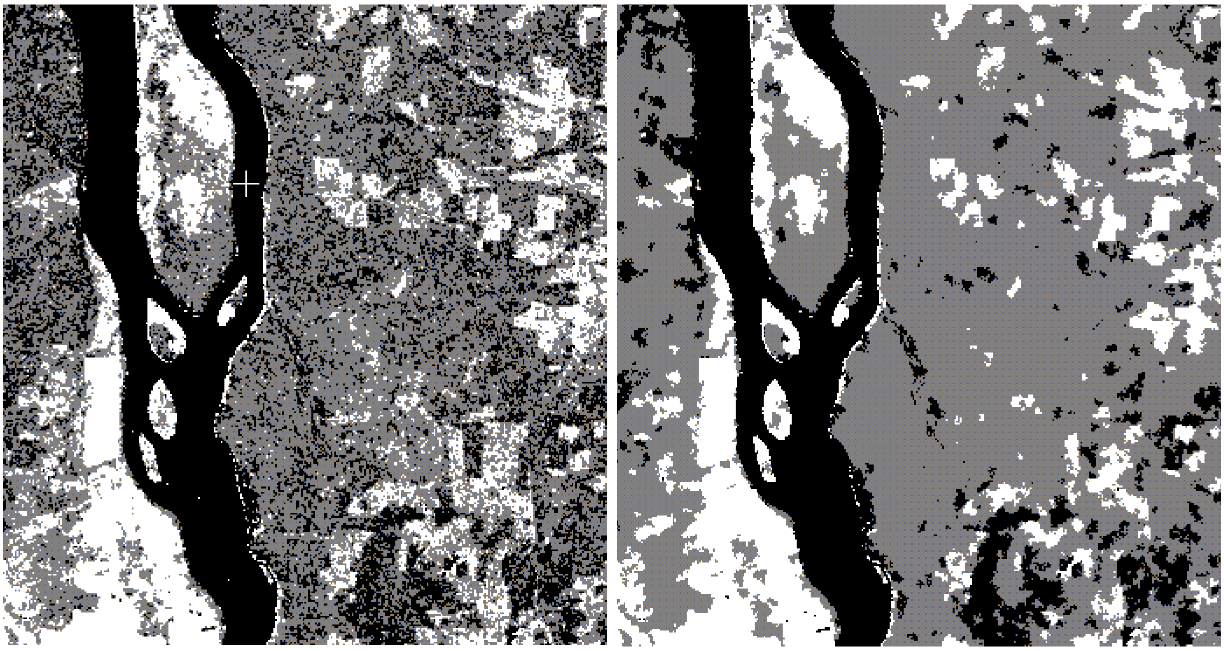

Figure VII-3: Classified image of part of the Ust-Ilimsk study area in Siberia. Left: Result from ISODATA, provided by SCEOS. Right: Result from ISODATA, followed by ICP.

VII.3.3. Map Accuracy: Spatial Accuracy Assessment

During the investigation of methods of accuracy assessment it became clear that the varying age of the inventory year of the GIS ground data plays a major role. For large time lags between ground and remote sensing data acquisition, more changes are likely to have taken place on the ground, like harvesting, selective logging, forest fires or replanting. These land use changes are easily seen as misclassifications by the Kappa coefficient. The relationship between map accuracy and the age of the ground data is shown in Figure VII-4.

Another error is introduced during co-registration of JERS-1 and ERS-1 images, and of GIS polygons and ERS-1. This error is present only at the boundaries of land use polygons.

An intelligent method of spatial accuracy assessment takes account of these problems by

1. eroding polygon boundaries before calculation of the Kappa coefficient;

2. visually checking classification errors.

Step 1 can be carried out operationally by the polygon erosion C program provided by UWS.

Step 2 requires creation of pseudo-colour images of individual cells in the error matrix, particularly where the ground data show “forest” and the more recent classification shows “clearcut”. Isolated pixels are likely to be real misclassifications, but coherent patches of regular shape are more likely to be clearcuts that have been made after the inventory. Irregular coherent patches of this type are likely to be forest fire scars.

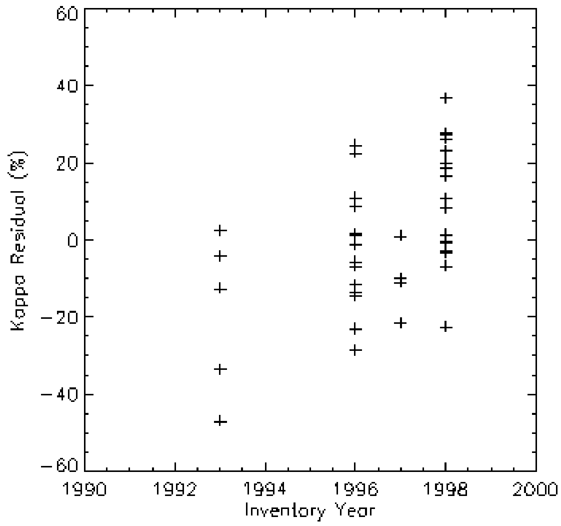

Figure VII-4: Relationship between map accuracy (Kappa) and the inventory year of the ground data for the coherence-based classification by Wolfgang Wagner. Points represent test sites. The Kappa residuals show the deviation between observed Kappa and expected Kappa based on image quality. The residual values increase for more recent inventory years (Courtesy of DLR).

VII.4. Conclusions

- The co-registration of JERS-1 and ERS-1 GTC products results in pixel displacements caused by the different DEMs. The expected pixel displacements of 95% of the image will vary between 0 and 3 pixels, and will be 1 or 2 pixels on average. A polygon erosion of 2 pixels will be able to reduce the problem significantly. Intelligent contextual classification methods need to be applied to correct the classified map for the ground offsets between JERS-1 and ERS-1.
- Because of the varying information content of the image frames, a data-driven algorithm like ISODATA looks more promising than a generalised maximum likelihood approach. The contextual information of neighbouring pixels can be included by a few iterations with ICP. A combination of both is likely to give the highest accuracy.
- The problem of land cover changes between the last forest inventory and the SAR data acquisition has been identified in the First and Second Progress Report. A method of spatial accuracy assessment is proposed to avoid the Kappa coefficient mixing up land use change, co-registration error and map accuracy.

VII.5. References

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Van Zyl, J. J. and Burnette, C. F., 1992, Bayesian Classification of Polarimetric SAR Images Using Adaptive a priori Probabilities, International Journal of Remote Sensing, 13, 835-840.

VIII. VTT Technical Research Center (VTT)

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Further personnel: Dr. Tuomas Häme, Brita Veikkanen, Kay Andersson, Laura Sirro

VIII.1. Administrative Issues

The work packages of VTT were begun in May 1999. Some preparatory work on the availability of high-resolution optical satellite data had been made already before May 1999. The budgeting constraints delayed the analysis of Landsat data. Landsat Thematic Mapper (TM) scenes covering Primorskii and Irbeisky (2 sub-sites out of 3) test sites were bought in December 1999.

Meetings: Yrjö Rauste participated in the meeting of the methodology team in Swansea 18-20 April 1999 and in the Siberia excursion 30 May - 12 June 1999.

Personnel: At VTT Automation, Yrjö Rauste, Tuomas Häme, Brita Veikkanen, Kaj Andersson, and Laura Sirro have participated in the work of SIBERIA project during the reporting period.

Tuomas Häme	Staff	August 1998
Yrjö Rauste	Staff	January 1999
Brita Veikkanen	Staff	September 1999
Kaj Andersson	Staff	September 1999
Laura Sirro	Staff	January 2000

VIII.2. Responsibilities

VTT is the partner responsible for investigating the synergy between the SAR and optical data (WP 5500).

VIII.3. Analysis of High-Resolution Satellite Data

Landsat TM data were purchased in December 1999 for two test sites: Primorskii and Irbeisky. The scenes are fairly cloud free. The Primorskii scene was acquired on 19 July 1999 and the Irbeisky scene on 8 July 1999. The analysis has so far concentrated on the Primorskii site.

A classification method (Häme et al, 1998) developed earlier for change detection applications was adopted. In this method, a set of 2-by-2 pixel groups are selected from the scene to be classified. A threshold on the variability within a pixel group is defined a-priori. All 2-by-2 neighbourhoods with a variability less than the defined threshold are included in the sample population. The sample population is then used in an unsupervised classification scheme. The classes produced by the unsupervised classification of the sample population are then used in a final stage to classify the whole scene. The clusters produced by the classification method are labelled afterwards in an interactive process using ground data.

Band	Wavelength
1	0.45 ... 0.52 µm, blue
2	0.52 ... 0.60 µm, green
3	0.63 ... 0.69 µm, red
4	0.76 ... 0.90 µm, near infrared
5	1.55 ... 1.75 µm "short-wave" infrared
6	10.4 ... 12.5 µm Thermal infrared)
7	2.08 ... 2.35 µm mid infrared

Table VIII-1: Wavelengths of the bands in the Landsat Enhanced Thematic Mapper sensor (ETM).

The classification of the Primorskii test site used bands 1 to 7 of the (enhanced) Thematic Mapper, excluding the thermal band 6. Wavelengths for these bands are shown in Table VIII-1. A sample classification is shown in Figure VIII-1. No quantitative analysis of the classification accuracy has been made yet. The classification agrees fairly well with stand boundaries in the ground database. Smoke or thin cloud present in some stands causes misclassifications. Shadows of cumulus clouds also cause some isolated misclassifications in some stands.

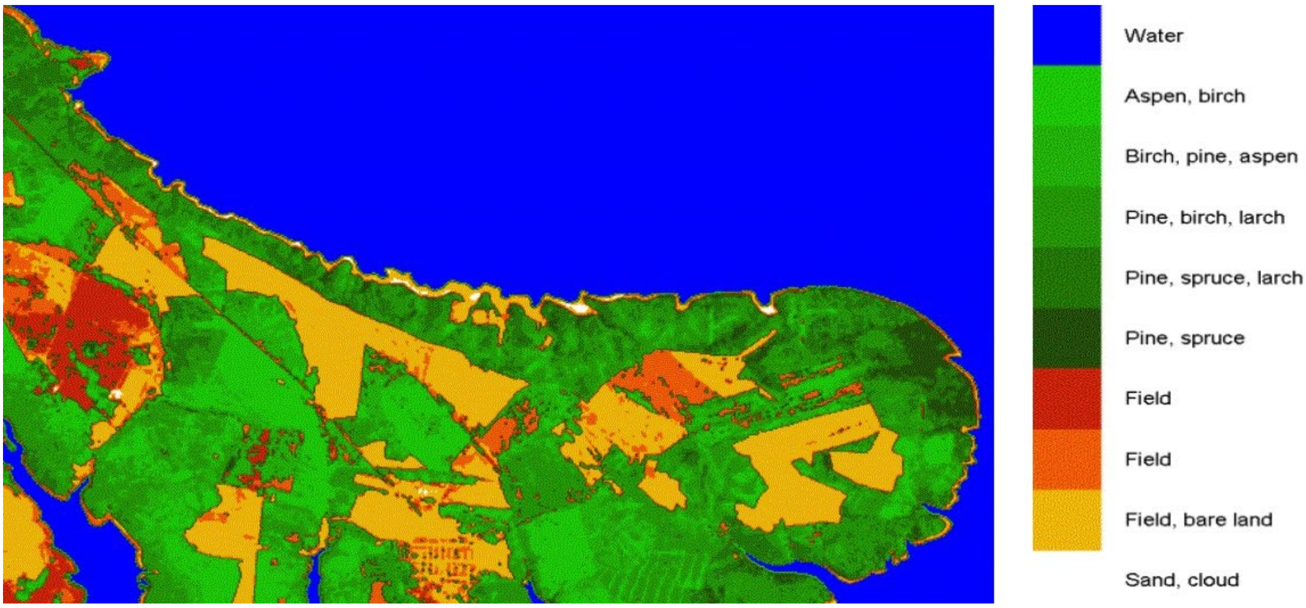

Figure VIII-1: A sample of the classification result for the Primorskii study site.

VIII.4. AVHRR Mosaicking

NOAA AVHRR mosaics were prepared for the SIBERIA study area using onboard recorded and archived data. Only data from NOAA-14 satellite was used to exclude possible satellite-to-satellite calibration problems. Data from the first afternoon pass of the satellite were used to obtain approximately the same illumination conditions in all scenes used.

All scenes input to the mosaicking process were first calibrated. The radiometric calibration of AVHRR thermal bands 3, 4, and 5 was based on the data included in the HRPT data stream (calibration using the on-board calibration target). Calibration of visible and near infrared band 1 and 2 utilised calibration coefficients provided by NOAA.

Atmospheric correction was made to all scenes. The correction utilised the SMAC program. The atmospheric optical depth (0.1 ... 0.15) was obtained through experimenting. A BRDF (Bi-directional

Reflectance Distribution Function) model was used to normalise the scenes. The scenes were normalised to correspond to the configuration of nadir view with a sun zenith angle of 45 degrees.

Image geo-coding was based geometric parameters supplied by NOAA. Revision of geo-coding was done using GCPs (Ground Control Points) obtained by image correlation.

First trial mosaics were made per year. Careful study of the satellite data archive proved that a completely cloud free mosaic was impossible for all three summers (1997, 1998, and 1999) studied. To produce a complete, cloud free mosaic, the following mosaicking strategy was adopted:

1. production of yearly mosaics taking always data from the scene that had the highest NDVI (Normalised Differential Vegetation Index)
2. combination of the three yearly mosaics by computing a pixel-wise average of all mosaics that have data in the pixel.

The mosaicking strategy above has the advantages that

1. it finds data in and around glaciers in mountainous areas and
2. it produces a slightly less noisy image (due to the averaging) than an NDVI-maximising algorithm alone.

Figure VIII-2 shows the mosaic for the two first AVHRR bands (near infrared in red, visible in green, and average of these two bands in blue). Figure VIII-3 shows the mosaic for all three bands included in the mosaicking (mid infrared or 3.7-μm band in red, near infrared in green, and visible in blue). As the mid-infrared band is sensitive to the temperature of the target area, this band is not very suitable to quantitative analysis of forest types or forest biomass. Temperature of the pixels included in the mosaic may have varied in a random way within a range of +/- 10 degrees. In visual analysis this band can be used to make a difference between rock surfaces of the mountain areas (bluish colours in Figure VIII-3) from the presumably bare-soil dominated low-land areas (reddish colours in Figure VIII-3).

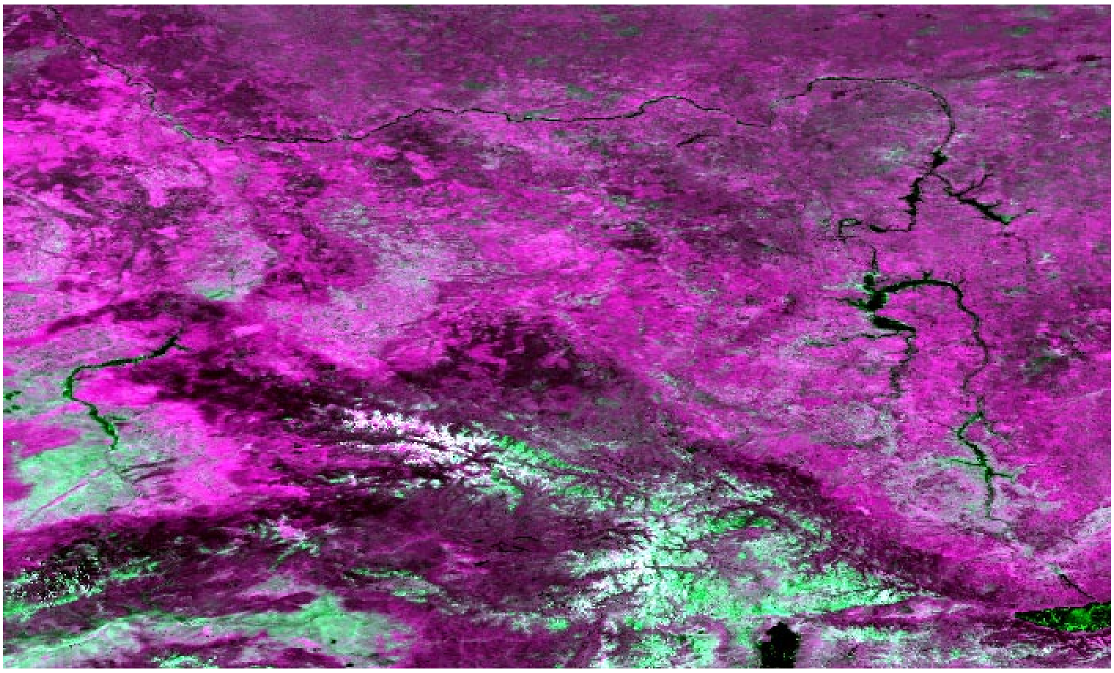

Figure VIII-2: NOAA AVHRR mosaic over summers 1997-1999. Red = band 2 (near infrared), Green = band 1 (visible), and blue = average of bands 1 and 2.

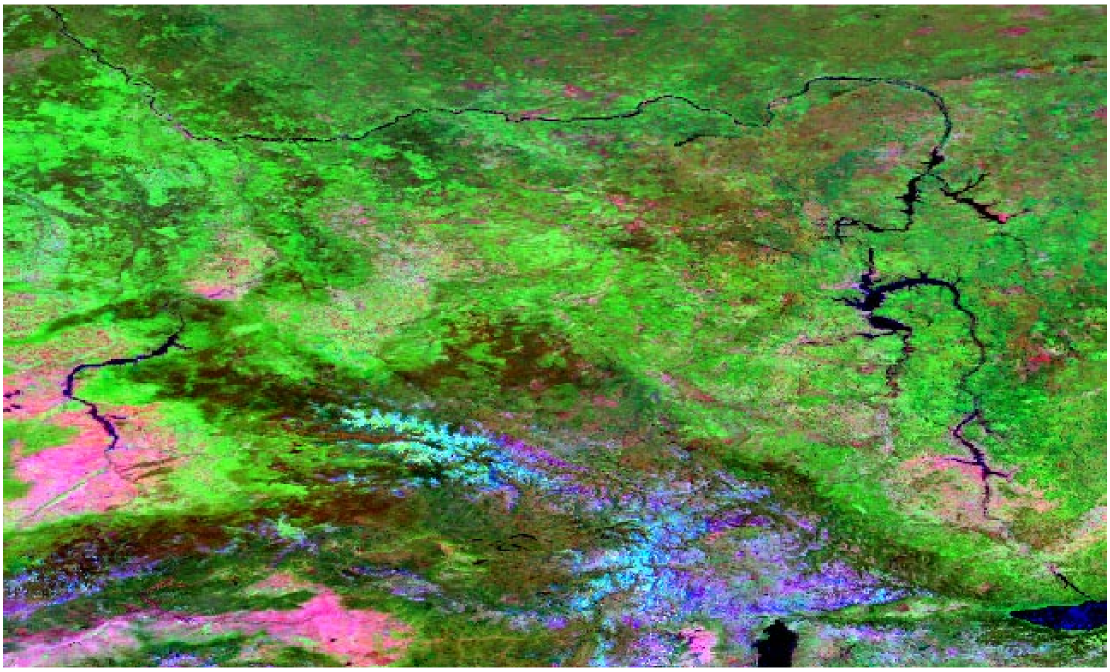

Figure VIII-3: NOAA AVHRR mosaic. Blue = visible, green = near infared, and blue = mid infrared.

The mosaics extend from the Krasnoyarsk region in West to Irkustsk region in the East. The South-western end of lake Baikal can be seen in the lower right corner of Figure VIII-2. The large reservoir South of Krasnoyarsk can be seen as a dark feature close to the left edge of the figure. Rivers Yenisey and Angara are visible for the most part of their length in the mosaic.

Major landscape units can be seen in the mosaic. Due to their low reflectance in visible and near infrared wavelengths, larger continuous coniferous forests have shades of dark red in Figure VIII-2 and dark green in Figure VIII-3. Zones containing more deciduous forests surround the coniferous forest areas. Deciduous forests have a red shade in Figure VIII-2 and green in Figure VIII-3. This is due to the higher near infrared reflectance of deciduous trees. Areas dominated by various forms of agriculture have a reddish-grayish tone Figure VIII-2 and various reddish-yellowish tones in Figure VIII-3. Agricultural areas also tend to have a higher pixel-to-pixel variance due to the higher dynamic variation of the reflectance within the growing season.

VIII.5. References

Häme, T., Heiler, I. & San-Miguel Ayanz, J. 1998. An unsupervised change detection and recognition system for forestry. International Journal of Remote Sensing 19(6):1079-1099.

IX. Satellus

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IX.1. Administrative Issues

Meetings: Sattlus hosted the 3rd progress meeting from December 11 to 14, 1999 in Kiruna. Dr. Torbjörn Westin, Marianne Orrmalm, Hans Jonsson and Roland Utsi participated in the meeting.

IX.2. Responsibilities

The responsibilities of Satellus AB are:

- Co-registration of multitemporal ERS and JERS scenes (WP 6050)
- Classification according to Methodology (WP 6100)
- Mosaicking and Map Production (WP 6200)

IX.3. Co-registration of ERS and JERS Scenes (WP 6050)

Software, documentation and operational manual for the pre-processing steps including calibration, filtering and masking were delivered to Satellus from the methodological team in the beginning of February. A first verification of the procedures and the operational manual was performed and an approval of the deliveries was made.

A test of the software, available at Satellus, for co-registration of JERS to ERS images, was also performed in the beginning of February. Gamma software for co-registration was at the same time tested at UWS. Due to the shorter production time with the Gamma software Satellus decided to lease the software for co-registration in the Siberia project from Gamma. The Gamma software has not yet been delivered.

IX.4. Classification according to Methodology (WP 6100)

Satellus has followed the discussions concerning the classification methodology in meetings and in working notes. No software is delivered or tested yet.

IX.5. Mosaiking and Map Production (WP 6200)

A proposal of the design of the colour composite maps will be prepared and presented as soon as the co-registration of the JERS to ERS data is working at Satellus.

X. Gamma Remote Sensing Research and Consulting AG (Gamma)

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X.1. Administrative Issues

Meetings: A. Wiesmann attended the progress meeting in Kiruna and a meeting at CEOS. U. Wegmüller attended a meeting in Swansea.

Papers:

Wiesmann A., U. Wegmüller, T. Strozzi: JERS SAR processing for the boreal forest mapping project SIBERIA, Proceedings CEOS Meeting'99 Toulouse, Oct 1999.

X.2. Responsibilities

Within the SIBERIA Project Gamma Remote Sensing is mainly responsible for the JERS data processing. Thus this report focuses on JERS processing related subjects.

X.3. JERS Data Acquisition Status

X.3.1. Data Availability

On one hand SAR data are available from NASDA's data archive, on the other hand the mobile receiving station of DLR was deployed in Ulaanbataar, Mongolia, in autumn 1997 and spring 1998. The Ulaanbataar data fit the needs of the project better, however technical and manpower problems delayed the synchronisation of these data. Up to date 29 tracks of about 15 scenes (total of 435 scenes !) have been processed. Most of the tracks have interferometric coverage so that not only the backscattering and texture images were computed but also the coherence images. The data were sent to UWS for distribution via FTP server.

X.3.2. Data Orders

JERS data within SIBERIA are needed a) for global coverage, b) for INSAR coverage of selected test sites, and c) for multi temporal coverage of selected test sites. The highest priority was changed at the Kiruna meeting from one complete summer-time coverage to complete coverage of the test areas. Archived data were ordered via NASDA (Osamu Isoguchi, isoguchi@restec.or.jp). Data from the DLR receiving station were ordered via DLR.

X.3.3. Data Format

Data were either delivered with a CEOS Leaderfile and data-file header or without CEOS Leaderfile but with a special state vector file. In the second case the required auxiliary information was extracted from raw data line headers and an auxiliary ASCII file.

X.3.4. Data Processing

SAR processing was done with Gamma's Modular SAR Processor (MSP). A special effort is made to ascertain good radiometric calibration of the JERS processing. The MSP processor accounts for JERS sensitivity gain control (STC), and automatic gain control (AGC). In addition it corrects for JERS range antenna pattern and applies radio frequency interference (RFI) filtering. Gain saturation correction is not applied.

To determine the calibration factor required for the absolute radiometric calibration of JERS SAR processing with the MSP Masanobu Shimada (NASDA) kindly made JERS RAW data and information on two active calibrators available. Once the MSP JERS calibration factor was determined it was validated with NASDA processed and calibrated data over a tropical forest site. Good agreement was found.

To facilitate the SAR processing of large data sets as required in the Siberia experiment the MSP offers the option to concatenate JERS raw data of consecutive frames of an orbit.

Within the SIBERIA project terrain corrected geocoding using a coarse resolution global DEM GTOPO30 was applied.

X.4. Fine Registration of JERS and ERS Images

The registration accuracy received during the data processing (e.g. terrain corrected with GTOPO30) is of the order of a few hundred meters. To improve the registration and for compatibility with the ERS images a fine registration between geocoded ERS and geocoded JERS data is needed. Registration based on backscatter intensity cross-correlation is operationally used for the automatic fine registration of multiple images of the same sensor. We tried the same methodology for the registration of the geocoded JERS data to the geometry of the geocoded ERS data. In spite of the evident large differences in the backscattering at C-band V-polarization, 23° incidence angle and L-band, H-polarization, 35° incidence angle, the technique worked well for a frame north of Ust-Ilimsk.