EC ENVIRONMENT AND CLIMATE PROGRAMM

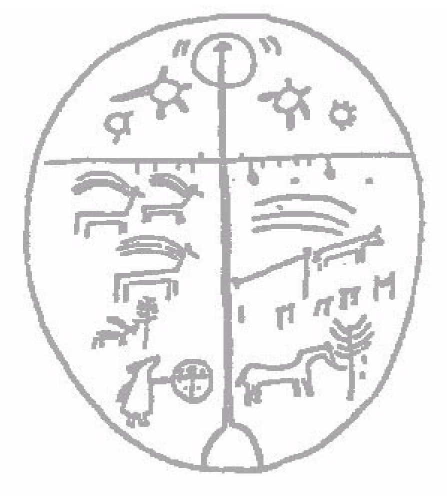
THEME 3: SPACE TECHNIQUES APPLIED TO ENVIRONMENTAL MONITORING

AREA 3.3: CENTER FOR EARTH OBSERVATION

2nd Progress Report

SIBERIA

SAR IMAGING FOR BOREAL ECOLOGY AND RADAR INTERFEROMETRY APPLICATIONS



July 1999

List of Partners:

Country	DE	FR	UK	FI	SE	AT	RU	CH
Teams	2	1	3	1	1	1	3	1

This report describes the work done during the second six month period of the SIBERIA project (January to June 1999). 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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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
SSC	Swedish Space Corporation
UWS	University of Wales, Swansea
VTT	VTT Technical Research Centre
WP	Work package

EXECUTIVE SUMMARY

This report describes the work done during the second six month period of the SIBERIA project (February to July 1999). 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 valuable 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) for retrieving 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 has made good progress. Currently reference data from totally 31 test areas and 9 test territories are available to the project.

SIBERIA uses the advantages of dual-frequency, interferometric, and multi-temporal SAR products from the ERS and JERS missions. Thanks to a recent international effort, that ensured the systematic acquisition of ERS and JERS imagery plus ERS-Tandem images over Siberia, these data became available. Despite of the principal availability of ERS and JERS data, the delivery of SAR products to the Methodological Team has been retarded. In case of ERS, the problem has been that the implementation and quality checking of the processing chain took longer than expected. In total 339 ERS SAR images covering 113 scenes have been ordered and received from ESA. For each scene, an ERS-1/ERS-2 tandem pair from fall 1997 and one image from 1998 are available. Interferometric processing of the ERS data is carried out at DLR-DFD. If the coherence of the tandem pair allows to do so then a DEM is produced and the image data are processed to geocoded terrain corrected (GTC) products. If no DEM can be generated then geocoded ellipsoid corrected (GEC) products are produced, with a rough geometric correction using a 30 arc seconds global DEM being applied to the data. So far, GTCs for 15 scenes and GECs for 17 scenes have been produced.

With respect to JERS SAR, only sample imagery has yet been available. The problem had been that NASDA had had technical problems reading the JERS raw data which were recorded at the mobile receiving station in Mongolia in 1998. Thanks to the support of Dr. Reiniger from DLR-DFD, a solution could be found on April 22: DLR-DFD carries out the reading and synchronisation of the Ulaanbaatar data after which the data are processed to JERS Level 0 products at NASDA. Gamma is then producing calibrated JERS imagery and, over selected test sites, interferometric products. It is expected that the first JERS data will be available to the methodological team in August.

With the increasing availability of ground truth information and ERS SAR imagery methodological questions could be addressed accordingly. Procedures for calculating geocoded incidence angle masks (GIMs), masking of shadow and layover areas, co-registration of satellite and GIS data, calibration of ERS images, filtering, rule- and data based classification, accuracy assessment, and data transfer have been developed and tested. However, no final methods have been defined yet because of the non-availability of the JERS data and because some of the procedures need more testing.

The results so far suggest that the ERS coherence and the JERS amplitude are the most important parameters for forest and land cover classification. Using ERS data alone, it is in general possible to distinguish forests from burnt forests, clearcut areas, and other land cover classes, but the separation of forest classes cannot be achieved. Therefore IIASA and their Russian partners have outspoken their concern that the derived products may not be useful at an enterprise level. However, the capabilities of radars to generate reliable baseline maps (even though perhaps only a forest/non-forest map) is acknowledged - or on a regional scale much appreciated. Also, it remains to be investigated how much JERS SAR can contribute to the project’s aims.

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 second six month period of the project (February to July 1999), but parts of the 1st progress report have been integrated into the present summary report so that the text becomes comprehensible without having to refer to the first report.

A major forest management task for Siberian foresters is to protect their forests against natural and human-induced disturbances. For example, in 1994 large forest territories in the Krasnoyarsk Kray were devastated by the Siberian moth (Dendrolimus superans sibiricus), the most destructive defoliator of conifer forests in Northern Asia (Figures 1-1 and 1-2). Outbreaks can defoliate millions of acres and occur at intervals of 8 to 11 years. The larvae feed on most conifers in the pine family, but outbreaks occur in fir, spruce, Siberian pine, and larch forests[1].

Figure 1-1: Larva of the Siberian moth[1].

Figure 1-2: Map of the Siberian moth's range (orange) and areas where outbreaks have occurred (red)[1].

According to Siberian foresters, the Project consulted, their biggest concern is man-induced forest fires which constitute an estimated 95 % of all fires. 1998 was considered a bad year for forest fires in Siberia, but this year's fires may have destroyed 10 times the surface area of 1998 (Figure 1-3). On July 14, 1999 a state of emergence was declared in the Krasnoyarsk region where fires have ravaged an estimated 54,000 hectares (Agence France Presse, 1999).

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. Besides these imminent problems, forest inventories are needed to plan forest management activities. 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 of which just a few are:

- 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.

[1] From http://www.fs.fed.us/ne/home/siberian.html

- 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.

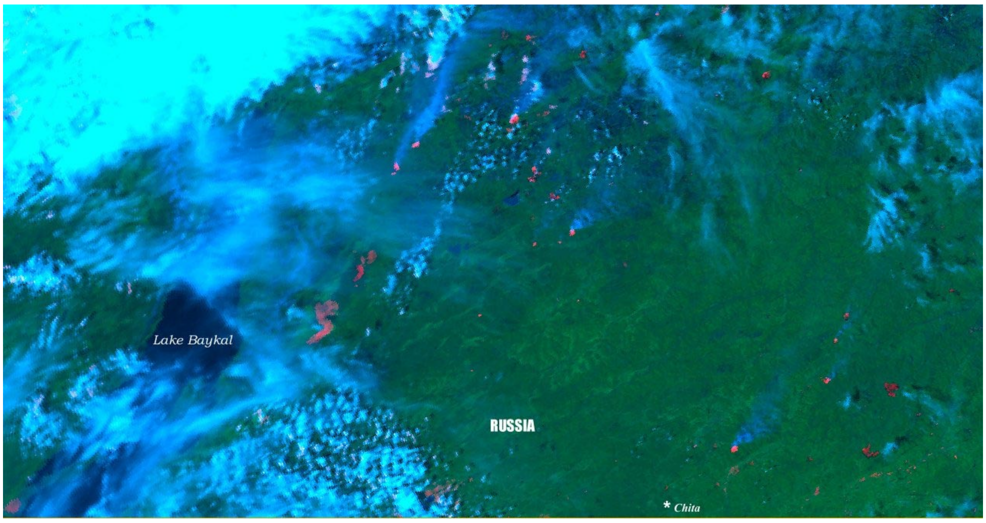

Figure 1-3: Forest fires in the last week of June 1999 in the region east of Lake Baykal. NOAA AVHRR-14 colour composite produced by NESDIS/OSEI[2].

Remote sensing may help to alleviate some of the problems connected with the Russian forest inventory system. 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 that ensured the systematic acquisition of these data over Siberia. Particularly the support of Dr. Reiniger from DLR-DFD is acknowledged who made the installation of a mobile ground receiving station in Ulaanbaatar, Mongolia, possible.

The approach of SIBERIA is to identify the customer's key problems and policy issues and then to develop a remote sensing technology based on these demands in order to achieve a real implementation and service to the policy settings. In this process the constraints of current operational satellite systems have to be clearly identified and addressed.

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

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[2] From http://www.osei.noaa.gov/Events/Fires/

- 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, changes have taken place at NERC and VTT. At NERC, Dr. Stephen Plummer has taken over the responsibilities from Dr. John Baker. Also, Mr. David Gaveau, who joined NERC in January this year, has been appointed to work on SIBERIA. The continuity of the work at NERC is guaranteed through Dr. Heiko Baltzer. At VTT, Yrjö Rauste is now responsible for carrying out WP 5500.

3.2. Meetings

The 2nd Progress Meeting had been additionally scheduled due to severe delays of the JERS-1 data delivery and the connected delay of our work schedule. The meeting was hosted by UWS and was held on April 19-20, 1999. The following decisions and conclusions were made:

- For ERS scenes with 50% DEM-possibility DLR-DFD should produce both a GEC and a GTC;
- JERS calibration coefficients should be “frozen” to guarantee uniform calibration for all JERS imagery;
- A rough geometric correction should be applied to ERS and JERS GECs using a 30 arc-seconds global DEM;
- Until JERS data are available, apply “Minimum Map Approach” rules: with ERS data not more than 2-3 non/forest classes, one forest class, water, agriculture and man-made classes can be identified; Goldstein’s phase filter is now used in DFD’s InSAR Processing Chain;
- Disclaimer in Contract with Gamma and SSC for software code developed within SIBERIA.

Further meetings were:

- Special IGBP-Transect Meeting at University Bayreuth (co-ordinator of meteorological flux stations), February 10. Participants from DLR-HF: Dr. Christiane Schmullius, Mr. Jan Vietmeier, Mrs. Andrea Holz, and Dr. Wolfgang Wagner;
- JERS Processing Meeting at DLR, April 23: Dr. Masanobu Shimada, head of NASDA's processing department visits DLR to discuss details of dedicated special processing procedures for SIBERIA project. Participants from DLR-HF: Dr. Christiane Schmullius, Dr. Wolfgang Wagner;
- C. Schmullius: Organisation of Invited Special Session on "Microwave Remote Sensing of Boreal Forests" at International Geoscience and Remote Sensing Symposium (IGARSS) '99 in Hamburg.
- On July 22 a meeting between the SIBERIA Coordinator Dr. Christiane Schmullius and IIASA took place in Laxenburg to pin-point the problems and status-quo. Participants from IIASA: Prof. Sten Nilsson, Prof. Anantoly Shvidenko, Mr. Alf Oeskog, Mr. Micheal Gluck, and two post-doc students. Prof. Shaun Quegan participated via a phone link.

3.3. Siberia Excursion

From May 30 to June 12, 1999 a large part of the SIBERIA team participated in a field trip to Siberia which had been planned by IIASA and its Russian partners. In this place, we would like to take the opportunity to thank the indefatigable Prof. Anatoly Shvidenko, our masterfully guide and translator!

Participants: Anatoly Shvidenko/IIASA, Vjacheslav Rozhkov/Moscow, Michael Gluck/IIASA, Thuy Le Toan/CESBIO, Malcolm Davidson/CESBIO, Shaun Quegan/SCEOS, Jiong-Jiong Yu/SCEOS, Adrian Luckman/UWS, Kevin Tansey/UWS, John Baker/NERC, David Gaveau/NERC, Yrjö Rauste/VTT, Christiane Schmullius/DLR, Wolfgang Wagner/DLR, Jan Vietmeier/DLR, Andrea Holz/DLR.

The objective of the excursion was to get hands-on experience about Russian forests to aid the interpretation of the radar imagery and to learn more about the Russian forest inventory system. Several test sites in the regions around Krasnoyarsk and Irkutsk were visited. At these sites Russian foresters explained the local forest characteristics and the GIS and remote sensing maps were compared to the actual conditions.

Also, a number of forest institutes in Krasnoyarsk and Irkutsk were visited and presentations were given:

- Institute for Geology, Landuse, and Nature Resources, Krasnoyarsk;
- State East Siberian Forest Management Enterprise, Federal Forest Service of Russia, Krasnoyarsk;
- Sukachev Forest Institute, Siberian Division of the Russian Academy of Sciences, Krasnoyarsk;
- State Forest Institute/Forest Committee, Krasnoyarsk;
- Biophysical Institute, Russian Academy of Science, Irkutsk;

A detailed documentation of the excursion can be found in Appendix B.

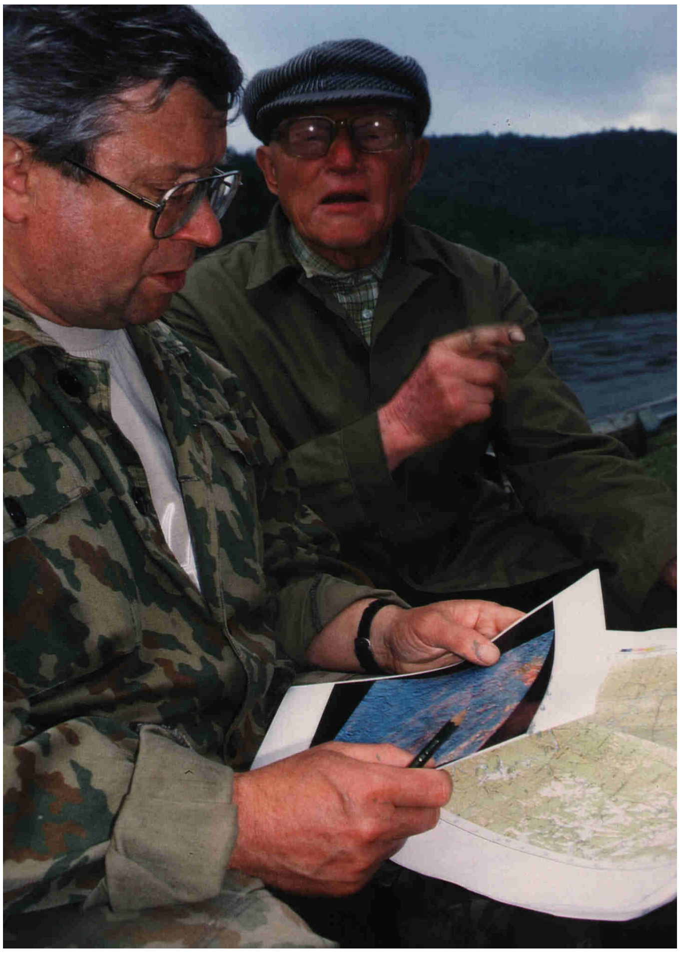


Figure 3-1: An old Russian forester helps in the interpretation of the SAR images. Dr. Vladminir Sokolov from the Sukachev Institute of Forest is holding the radar map in his hand.

3.4. 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. Currently, the UWS web site is password protected.

   UWS: http://sunset.swan.ac.uk/siberia/
   IIASA: http://www.iiasa.ac.at/Research/FOR/siberia/index.html

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 chapter
5. FTP Servers at UWS, DLR-DFD, and IIASA.
6. Regular phone calls.

3.5. Working Notes

The following working notes were produced:

- Coherence (Malcolm Davidson - CESBIO - February 1999).
- Filtering (S. Quegan and J.J. Yu - SCEOS - February 1999).
- Analysis of Backscatter and Coherence as Functions of Age - Bratsk site (J.J. Yu and S. Quegan - SCEOS - March 1999).
- Estimation of Coherence (Nico Adam, Michael Jubig - DLR - October 1998 - Old document from DLR).
- Image Generation of the DLR Interferometric Processor (Bernhard Rabus, Nico Adam - DLR - October 1998 - Old document from DLR).
- SUN RASTER file format (DLR - October 1998).
- Working Note on Calibration using CALIT (Jan Wietmeier - DLR - 25th March 1999).
- Working Note on Intellectual Property Rights (A. Luckman and K. Tansey - UWS - 29th March 1999).
- Working Note on Linking Ground Data and SAR Images for Test-site Ust-Illimsk (Heiko Balzter - ITE - 24th April 1999).
- Analysis of ERS SAR Information Content of the Ulkanskii (Lake Baikal) Test Territory (K. Tansey and A Luckman - UWS - 6th May 1999).
- State of JERS SAR Processing over SIBERIA (Gamma Remote Sensing - 7th May 1999).
- Methods of Accuracy Assessment in the Siberia Project (Heiko Balzter - ITE - 21st June 1999).
- ERS SAR Ordering and Assignation (W. Wagner, DLR-HF, April and May 1999).
- JERS SAR Prioritisation (W. Wagner, May 1999).

3.6. Publications

Following papers have been published:

Dammert P.B.G., U. Wegmüller (1999) JERS INSAR DEM Quality Assessment for a Boreal Test Site, Proceedings IGARSS’99 Hamburg, June 1999

ESA (1999) A DLR receiving station in Ulaanbaatar, Mongolia, in support of the 'SIBERIA' project, In "A supplement to EOQ 61", February 1999.

Etzrodt, N.; Zimmermann, R.; Dempewolf, J.; Ziegler, W.; Vietmeier, J.; Holz, A. (1999): Classification of Central Siberian Forest Types by Combining interferometric Radar Remote Sensing (ERS Tandem Mission, JERS), Topographical Data and Ecophysiological Information. In: Proceedings of IGARSS'99, the IEEE International Geoscience and Remote Sensing Symposium, 28. June - 02. July 1999, Hamburg, Germany, Volume II, Crop and Forest Monitoring and Classification, pp. 720-722.

Schmullius, C., A. Holz, J. Vietmeier (1999) SIBERIA - Results from the IGBP Boreal Forest Transect, IGARSS'99, Hamburg, Germany, 28 June - 2 July 1999, pp. 2118-2120.

Schmullius, C.; Holz A.; Zimmermann, R. (1998): SIBERIA - First ERS Tandem Results from the IGBP Boreal Transect. - In: Proceedings of IGARSS'98, the IEEE International Geoscience and Remote Sensing Symposium, 6-10 July 1998, Seattle, USA, Vol. IV, pp. 1815-1817.

Schmullius, C.; Holz, A.; Vietmeier, J. (1999): Projekt SIBERIA - erste Radarsatellitenaufnahmen der Wälder Sibiriens werden ausgewertet. -In: DLR-Nachrichten - Mitteilungen des Deutschen Zentrums für Luft- und Raumfahrt, Sonderheft Umwelt, Februar 1999 / G12625.

Schmullius, C.; Holz, A.; Zimmermann, R. (1998): SIBERIA - First ERS Tandem Results from the IGBP Boreal Forest Transect. - In: Second International Workshop on "Retrieval of Bio- and Geo-physical Parameters from SAR Data for Land Applications", 21-23 October 1998, ESTEC, Noordwijk, Netherlands, ESA Publication, Poster Session 1: Forestry.

Tansey, K., A. Luckman, C. Schmullius (1999) Mapping Boreal Forest in Siberia with ERS SAR Interferometry, Remote Sensing Society Conference, Cardiff, September 1999.

Wiesmann A., T. Strozzi, U. Wegmüller (1999) JERS SAR processing for the boreal forest mapping project SIBERIA, Proceedings IGARSS'99 Hamburg, June 1999b.

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 February 1999 to July 1999. List of responsible partners and deliverables: UWS - D21, CESBIO - D22, DLR-HF/DLR-DFD/Gamma - D23, IIASA - D24, NERC - D25, SCEOS - D26. 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 2nd Progress Meeting at the University of Wales, Swansea, April 19-20, 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.

Milestone 1 is contained in Annex A. Milestones 2 and 3, as well as the major milestone (MM1) "Methodology Synthesis" have yet not been accomplished due to 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 is now being synchronised at DFD and processed at Dr. Shimada's new processor at NASDA. The first JERS-1 Level 0 products have been sent to Gamma at the writing of this report in Week 30.

The late JERS-1 data delivery causes a delay for MM1, the Methodological Synthesis, of at least three months. Therefore, the start of the handover phase for operational map production at SSC has to be shifted and SSC's Work Packages will start three months later as planned.

4.1. External Deliverables for EC

Item	#	Title	Work Packages Involved	Due Date
Reports	2	Mid-Term/ 2nd Progress Report	1100-1300, 2100-2300, 3100-330, 4100, 4300-4500, 5000-5140, 5210-5240, 5310-5340, 5400, 5500, 7400, 7500	T0 + 12
Deliverable	32	Comments to CEO	1200	T0 + 12

Table 4-1: Reports to EC.

Deliverable 32 is described in Chapter 9.

4.2. Internal Deliverables and Milestones

Item #	Title	Work Packages	Due Date
	Deliverables		
21	Computational Issues IV	5010-5050, 5150, 5250, 5350	T11/12
22	Quantification of Image Info II	5020, 5120, 5220, 5320	T11/12
23	Processing Status II	2100-2300, 3100-3300	T11/12
24	Reference Data III	4300, 4400	T11/12
25	Accuracy Assessment II	4500, 5040	T11/12
26	Classification Methodology II (Draft for MM1: Methodology Synthesis)	5020, 5030, 5130, 5230, 5330, 5400	T11
	Milestones		
1	Forest Data Base Structure Defined	4100, 4400	T11/12
2	Co-Registration Strategy	5010	Delay
3	Quantification of Image Information Defined	5020	Delay
	Major Milestones		
1	Methodology Synthesis	5000, 5130, 5230, 5330, 5400	Delay

Table 4-2: Internal deliverables and milestones.

4.3. External Deliverables for Third Parties

Deliverable #	Title	Work Packages	Due Date	Responsible Partner
35	EWSE Update I	7300	T12	DLR – HF
36	Public Info	7400	T12	DLR – HF

Table 4-3: External deliverables.

Deliverable 35:

The EWSE Webpage is being updated with material from the SIBERIA progress reports. Links are installed to the two project webpages: SIBERIA Project Page at UWS (http://sunset.swan.ac.uk/siberia– this page is currently protected by a password), SIBERIA Ground Truth Page at IIASA (http://www.iiasa.ac.at/Research/FOR/siberia/index.html).

Deliverable 36:

Public information activities have been:

- meetings and discussions with World Expo Representatives – unfortunately without result because of costs,
- participation in the IGOS/GOFC activities,
- SIBERIA leaflet distribution through ESA's Earth Observation Quarterly (important note: although information has been sent, this leaflet contains no information about the funding agencies to our large regret).

The **Customer Requirement Documents** for the reporting period are contained in

Deliverables 25 and 28:	Accuracy Assessment I, II and III, and
Milestone 1:	Forest Database Structure.

The **Technology Implementation Plan** for the reporting period consists of

Deliverables 26: Classification Methodology II, and Major Milestone 1: Methodology Synthesis; and Deliverables 25 and 28: Accuracy Assessment II and III.

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.

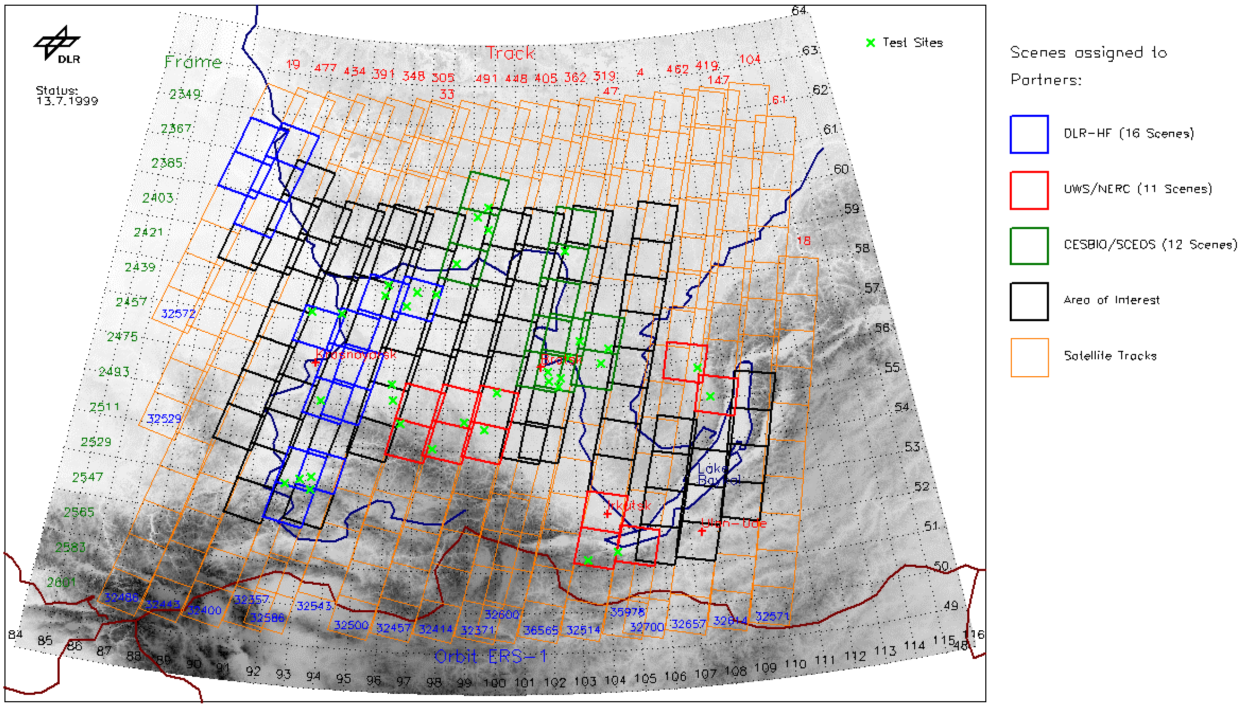


Figure 5-1: Overview over the selected ERS SAR scenes (boxes with thick frame) and partner responsibilities.

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. An overview over the selected ERS SAR scenes (for each of which one ERS tandem pair and one image from 1998 is available) is given in Figure 5-1. Also indicated is the project partner who is responsible for the processing and analysis of the respective scenes. For the scenes with black thick frames the responsible partner has not been identified yet. In total 113 scenes with each three images were selected.

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 5-2 gives an overview of the processing status at DLR-DFD. So far 15 GTC and 17 GEC have been produced.

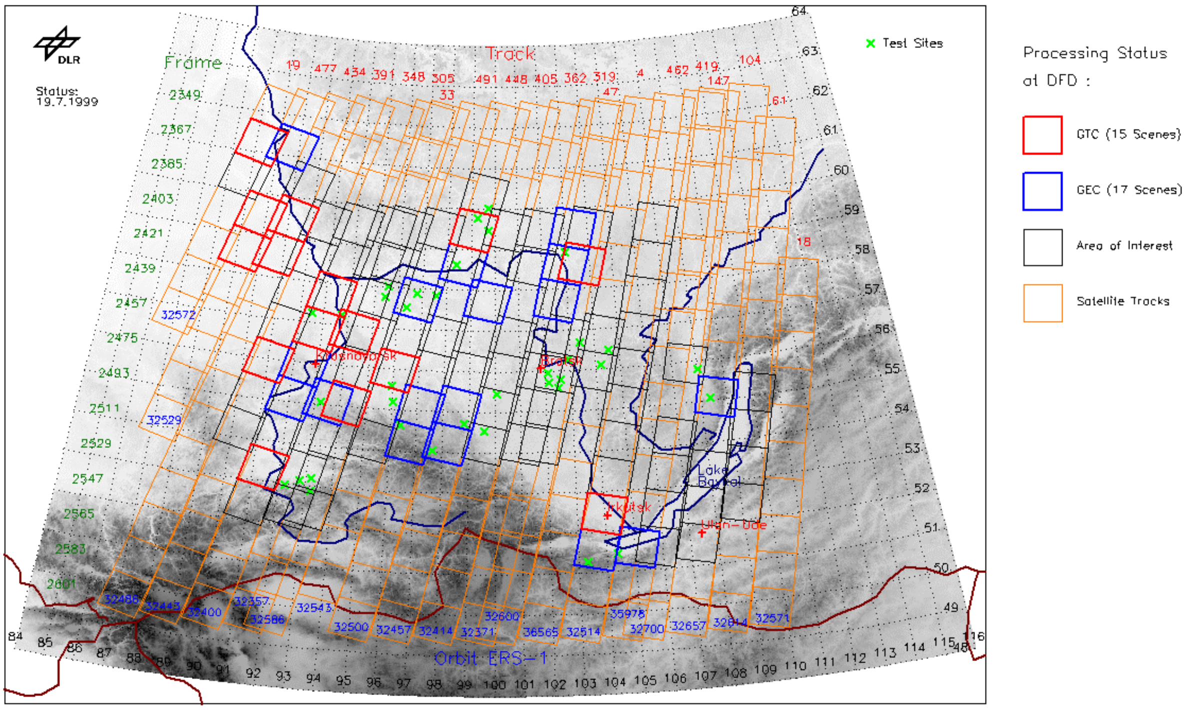


Figure 5-2: Processing status at DLR-DFD.

5.2. JERS Synthetic Aperture Radar

As described in the first progress report, JERS data from 1998 recorded at the mobile receiving station of DLR-DFD in Ulaanbaatar could not be made available although they comprise the best available data set for the purpose of the project. The problems were that NASDA had had technical problems reading the Ulaanbaatar tapes and that no budget was foreseen to carry out this task at DLR-DFD. Thanks to the support of Dr. Reiniger from DLR-DFD a solution could be found on April 22. Dr. Reiniger offered that DLR-DFD carries out the reading and synchronisation of the Ulaanbaatar data. Then the synchronised data are sent on DLT's to Dr. Shimada, NASDA, who processes these data with the EORC processor to JERS Level 0 products. Interferometric processing of these data is finally carried out by Gamma. The synchronisation of the complete JERS coverage at DLR-DFD and the processing to JERS Level 0 products at NASDA is expected to be finished by the end of July/beginning of August.

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. The RSP tracks were finally selected based on the Ulaanbaatar operations maps. Data quality is not known at the moment, but it is expected that a rather complete coverage of the entire area with at least one JERS image can be achieved. For about 60 % of the area, repeat pass coverage is expected. Figure 5-3 shows the location of the JERS tracks with even RSP numbers.

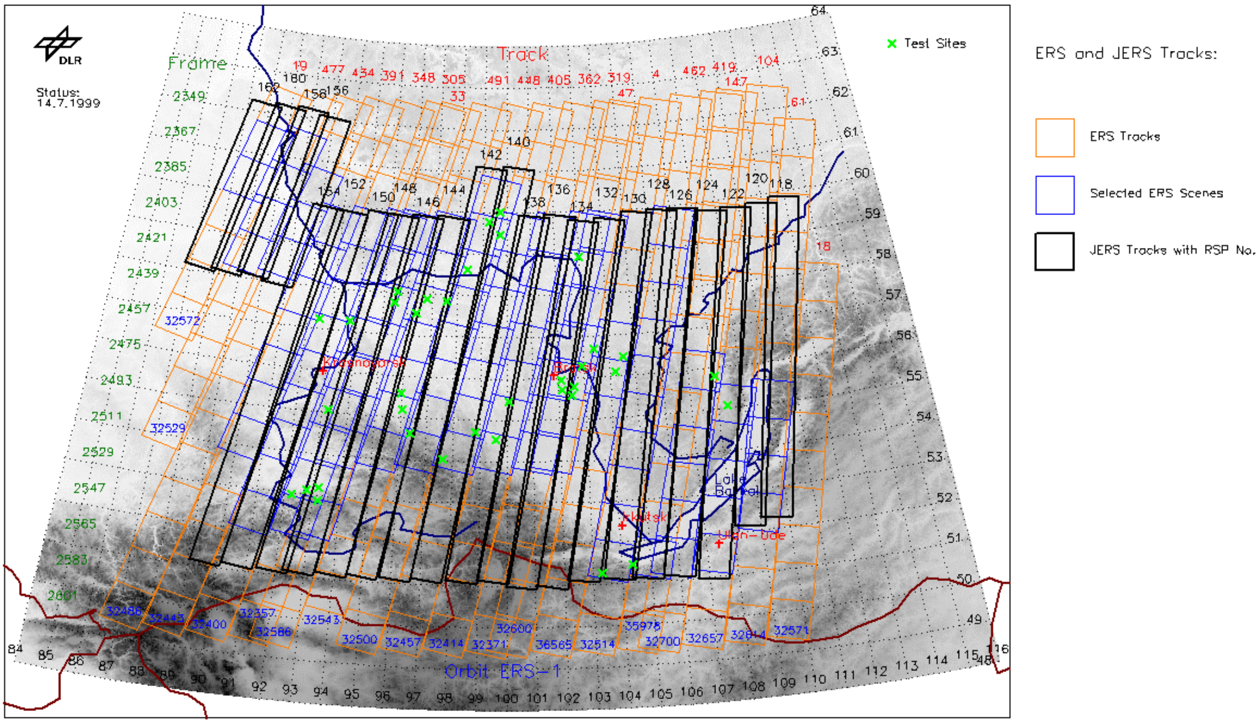


Figure 5-3: Overplot of JERS tracks over the ERS scenes. Shown are only JERS tracks with even RSP numbers which can be seen above the respective tracks.

5.3. Optical Imagery

A survey of the availability of high-resolution optical satellite data over the test sites was made by VTT. Landsat data was identified as the primary choice because a single scene covers a wide area. In many test sites of SIBERIA project, the subsites are tens of kilometres apart and cannot be covered with a single scene if the scene dimension is of the order of 40 or 60 km. The data situation of the test sites is summarised in Figure 5-4 and Table 5-1. Since a major drop in price of Landsat data is expected to take place in summer 1999, no Landsat data have been ordered yet. A survey on the availability of data from the Russian RESURS satellite is underway at the Swedish Space Corporation.

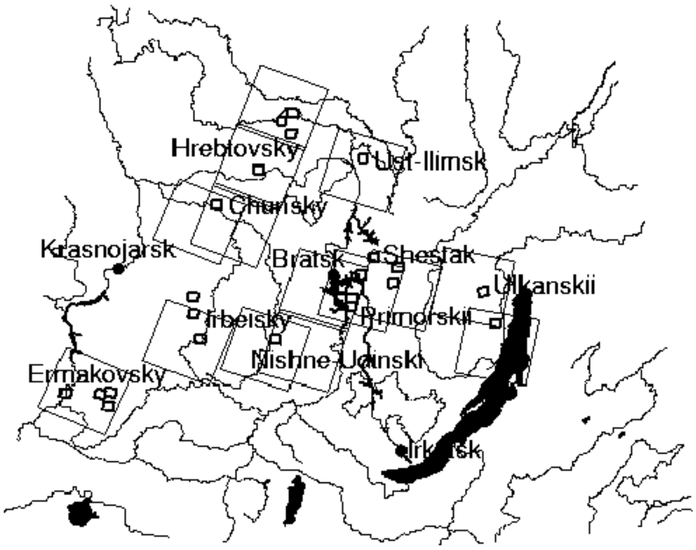


Figure 5-4: Test sites and corresponding Landsat scenes.

Ermakovsky	1991
Irbetsky	1989
Chunsky	[1991]
Hrebtovsky	1990
Nishni-Udinsky	winter
Primorskii	1993
Ust-Illimsk	nothing
Ulanskii	[1989]
Shestak	winter

Table 5-1: The best Landsat scenes for the test sites.

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". The meteorological data span the time periods from September 15 to October 31, 1997 and from May 1 to August 15, 1998. The nominal time step of the records is 3 hours, but depending on the variable or station other time steps (6, 12, 24 hours) occur. Also, in many instances, the series are incomplete. The data base contains the following variables: pressure, windspeed, temperature, dew point, weather, cloudiness, precipitation and others. 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 (Figure 5-5). 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.

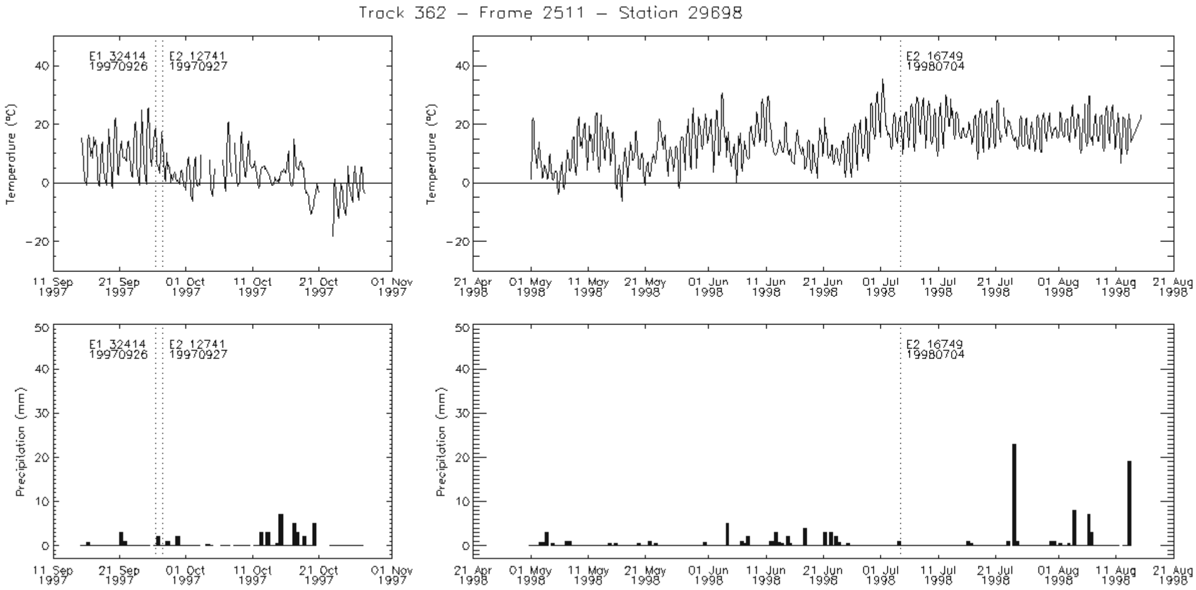


Figure 5-5: Temperature and precipitation series from station 29698 near Nizhneudinsk (99.03°E, 54.88°N). The acquisition dates of the ERS satellite acquisitions are indicated by vertical lines.

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 (Table 6-1).

Forest Lands	Non-Forest Lands
forested areas*	arable lands
plantations (unclosed)	hayfields
nursery & seed orchards	pastures
natural sparse forest	water reservoirs
unforested areas	roads, kvartal boundaries
burns	urban
dead stands	bogs
cut areas	sand
grassy glades	glaciers
	rocks, steep slopes

*Table 6-1: Current land cover / land use categories from Russian forest inventory (excluding forested areas. *See Figure 6-1 for forested area classification.*

Characteristics of forest areas can be organised hierarchically, however, this organisation should not be considered constraint on the classification process (i.e. classification can start at any level of this hierarchy). If all levels of this classification were identified then there would be 60 boxes.

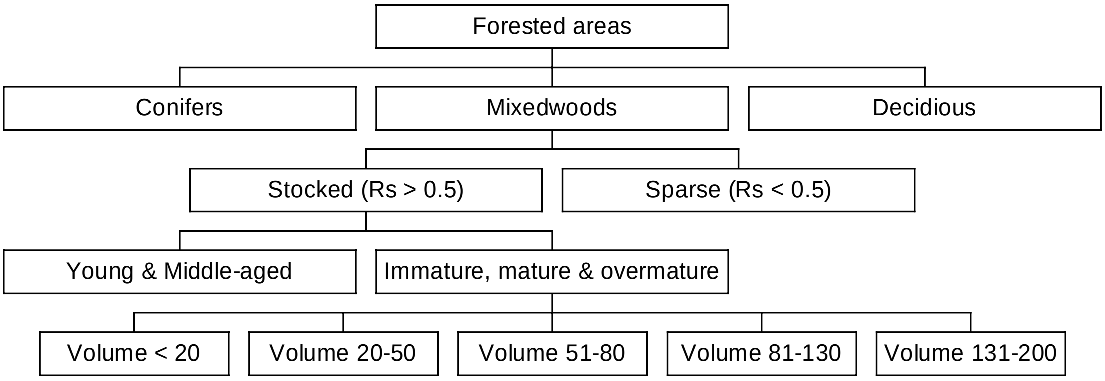


Figure 6-1: Proposed forest area classification possibilities. Forested area is organised (top to bottom) by species composition, stocking (Rs = relative stocking), age and volume.

IIASA and its Russian partners have also selected test site locations, and reference data selection and compilation is under way.

The basic principles used in selecting areas with ground reference information were that there should be 4 to 7 test territories ranging from 300,000 ha to 1,500,000 ha each, containing 20 to 35 key test areas 20,000 ha to 100,000 ha each. The Test territories were chosen subjectively to represent:

- specific zonal regularity of forests & vegetation
- impact of macro-relief (mountains)
- impact of human transformation of vegetation

Test areas were chosen to represent:

- landscape diversity
- basic-land-use categories
- main forest association
- diversity of human impact
- forest diversity (productivity, stocking, etc.)

So far, reference data for 31 test 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 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.

With the increasing availability of ground truth information and ERS SAR imagery methodological questions could be addressed accordingly. However, progress in the methodological development has still been hampered by the fact that only sample imagery from JERS has been available.

Because of the large area of interest, the large number of consortium partners, and the many possible combinations of hard- and software in use at the various partners, it is necessary to define common methods and strategies to secure compatibility and comparability of the work done at the various partners. It is the objective of work packages 5010 to 5050 to define common methods on various aspects:

- 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)

Due to the side looking geometry of SAR systems topography causes considerable geometric and radiometric distortions in the ERS and JERS images. The objective of this work package is to define methods for calibrating the radar images and for co-registering the ERS and JERS images and the ground truth data.

Digital Elevation Model (DEM):

A prerequisite for topographic correction is the availability of a DEM that will be produced in all areas where the coherence of the ERS tandem pairs allows doing so. If an InSAR DEM is available then DLR-DFD produces geocoded terrain corrected (GTC) co-registered ERS imagery. If no InSAR DEM is available then geocoded ellipsoid corrected (GEC) images are produced. A coarse geometric correction is carried out on the GECs using a 30 arc seconds global DEM.

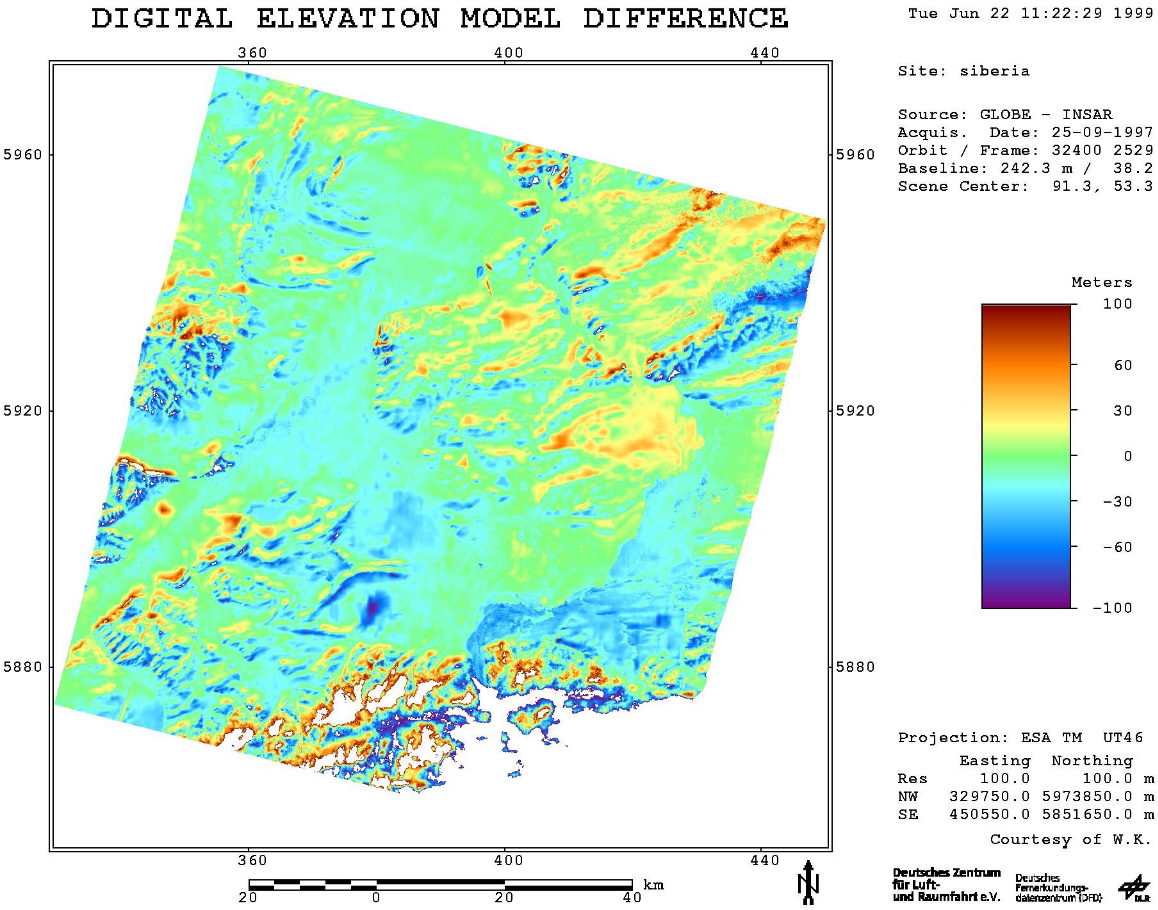


Figure 7-1: Difference of DEM derived from ERS tandem pair (INSAR) with a global digital elevation model with a raster width of 30 arc seconds (GLOBE).

The quality of the InSAR DEMs is checked at DLR-DFD by comparing it with the global DEM which gives a qualitative impression about the overall quality of the InSAR DEM (Figure 7-1). Over relatively gently sloping terrain the quality of the InSAR DEMs is believed to be good, but over steep mountainous areas significant deviations to the global DEM are observed. Also, the magnitude of small scale noise related to low coherence is not known. Attempts at SCEOS to assess this noise did not lead to any firm conclusion because there was no reliable reference with which to compare the InSAR DEM.

Geocoded Incidence Angle Mask (GIM):

Knowledge of the local incidence angle is necessary for accurately calibrating the backscattering coefficient σ^0 and also for classification because different surface classes show different dependencies of σ^0 on the incidence angle. To calculate geocoded incidence angle masks (GIMs) from the InSAR DEMs the c-programme "inci", which has been developed by DLR-HF, is now generally used. Testing of the programme is still under way. One problem appears to be the noise of the InSAR DEMs which has a strong impact on the estimation of the incidence angle.

Shadow and Layover:

For GTCs, a strategy to manage the extreme cases of the topographical effects, layover and shadow, is defined. Due to the steep look angle of the ERS sensors, shadow areas can generally be neglected and layover areas are masked out using a threshold for the incidence angle. The procedures to mask out areas not to be used in map classification also consider the layover areas inside the GEC products.

Geolocation Accuracy of ERS InSAR Products

DLR-DFD performs a check of the geolocation accuracy of the ERS InSAR products by comparing control points derived from topographic maps and ERS SAR intensity images. As an example, the residuals of the scene shown in Figure 7-1 are presented in Table 7-1. The statistics shows no systematic errors. The maximum deviations are in the range of 3-4 pixels as the spacing is 50 m. The tiepointing accuracy is limited to approximately 100 m due to the scale of the reference map and the identification accuracy within the SAR image. It also should be noted that the used topographic maps are colour copies of the originals which can result in large displacements.

	Difference Easting	Difference Northing
Maximum	-174.8 m	-172.5 m
Minimum	146.7 m	168.16 m
Mean	14.0 m	0.7 m
St. Deviation	96.1 m	106.0 m
RMS	92.3 m	100.5 m

Table 7-1: Geolocation accuracy of InSAR products.

Co-registration of Radar Imagery:

All three ERS images are acquired from almost the same satellite positions. Therefore the disturbances due to topography are almost the same and the co-registration of the images does not present a problem, both for the GTC and GEC images. A procedure for the co-registration of the ERS image triplet has been adapted in the processing chain of DLR-DFD.

The viewing geometry of the JERS satellite differs to some extent from the one of the ERS satellite but over flat areas the co-registration of JERS images to ERS images using tiepoints or automatic registration based on backscatter intensity cross-correlation seems to present no problem. Co-registration techniques over hilly areas are currently under assessment.

Co-registration of Radar and Ground Truth Data:

If GTC products are available then the co-registration of the satellite images and the ground data is no problem. However, GEC to map registrations certainly represent difficulties that are particularly serious in hilly areas. Without a good DEM this problem appears insoluble in significant relief.

Masking of Hilly Areas:

In GEC, but also in GTC images geometric and radiometric distortions will cause erroneous classifications and therefore strategies to mask out problematic areas need to be defined. Three different approaches are currently considered:

- Using thresholds of amplitude values below which (shadow) and above which (layover) relevant landuse classes are not occurring under usual conditions.
- Layover areas are easy visible for experienced eyes that masking out of this areas could be done by hand.
- A third solution could be to use the low resolution DEM GTOPO30, which is available for all over the globe. A procedure using this DEM still has to be developed and tested as well as for the other solutions.

7.2. Information Content (WP 5020)

The objective of this work package is to quantify the information content of the available SAR data with respect to the forest information requirements and to determine a common set of classes for the overall forest map. So far, work has focused on the ERS SAR data and on understanding the significance of the ground truth data base with respect to the radar data. Some preliminary analysis of the JERS data from the NASDA archive have also been carried out and have demonstrated the high importance of these data for the project. Nevertheless, progress in this work package is lacking behind time schedule due to the delay in data availability.

Significance of Ground Truth Data Base:

The Siberia excursion was particularly important for clarifying the meaning of the ground truth data base for the methodology team. The problem is that the data base has been designed for forest management and its attributes can often not directly be related to the physical quantities measured with radar systems. For example, the forest data base distinguishes between the age classes "young", "middle-aged", "immature", "mature", and "overmature". In the comparison with the radar data it needs however be considered that these age groups are region-specific calculations that take into account forest site quality, dominant species and legislative requirements. Another example is that the dominant tree species, which is given for a specific stand, is not the dominant species in number, but in economic value.

Relationship of SAR parameters with Land Cover Classes:

During the Siberia excursion a fairly limited number of land cover classes was encountered: forest, agriculture, pasture, hayfield, bog, wetland, inland water (rivers and lakes), and settlements. Wheat is the dominant crop. Below the likely radar signatures at the dates of the available images (September/October 1997 and June/July 1998) are summarised:

Wheat: In September/October fields are harvested with different roughness states due to tillage. ERS coherence is expected to be high and ERS intensity may range from low (harvested fields) to high (ploughed fields), with level depending on the soil dielectric (soil moisture, freezing conditions). In June/July fields are probably fully grown. JERS is expected to be low depending on soil moisture.

Pasture/hayfields: In September/October vegetation is low (pasture) or high and sparse (dialectically speaking) for hayfields. Coherence is high with low to medium backscatter depending of the soil dielectric. In June/July vegetation may be low for pasture to high for hayfields. JERS is expected to be low.

Wetlands/bogs: Vegetation is generally low and the surface is presumably smooth. If not frozen the surface dielectric is high. Coherence is high for all dates. Backscatter from both ERS and JERS depend on surface roughness and freezing conditions. If the wetlands are covered by water then the coherence may be low.

Inland water: Low coherence and variable ERS backscatter related to variable water surface roughness. JERS backscatter is fairly low due to high incidence angle. When the water is frozen then the coherence may be high.

Settlements: Generally high coherence and high backscatter, depending on environmental conditions. Also, coherence may be low if there are many trees in the settlement.

Relationship of SAR parameters with Forest Parameters:

The seven dominant tree species in Siberia are pine (pinus sylvestris), spruce (abies sibirica), fir (picea abies), larch (larix sibirica), cedar (pinus sibirica), birch (betula pendula) and aspen (populus tremula). Experience gained at the Siberia excursion showed that clearcutting is generally done in blocks or strips. Fire seems to occur everywhere, and the regeneration after fire or clearcutting is mostly natural (there are few plantations). The species composition in most regenerating forest can differ from one "stand" to the next, sometimes separated by a narrow fire break.

So far, the analysis of the ERS SAR data has shown that the coherence is most suitable ERS parameter for forest classification:

- Normally, grown forests (not burnt, no clearcut) cannot have high coherence. Possible exceptions are deeply frozen forest and deciduous forest under leaf-off conditions.
- Burnt forest are generally characterised by medium to high coherence, even some years after the fire has occurred. Some burnt areas have significant numbers of remaining trees (hence moderate to high biomass but few leaves) leading to high coherence caused by these static targets. In case of ground fires, which have left high tress with leaves, coherence may be low.
- Clearcut areas generally have medium to high coherence.

It needs however be considered that the coherence is not only depending on the scattering properties of the observed target, but also on the observation geometry (baseline), environmental effects (rainfall, freezing conditions), the time difference between the master and slave image, and topography. Therefore the relationship between coherence and ground parameters can change from one tandem pair to the next. Also, the size of the pixel window, which is used to estimate the coherence, is important. Differences in the estimates of the coherence using 20 and 80 pixel windows can be as much as 0.1 - 0.15. Methods will have to be developed to deal with the variable character of the coherence. One possible approach is to scale the coherence between two fixed values for each image.

Other preliminary findings with respect to the ERS SAR data have been:

- In terms of backscatter and coherence, the effect of small changes in species composition within forest are expected to be negligible.
- In general, ERS coherence is found to decreases with tree age but the relationship is not strict and site dependent (Figures 7-2).

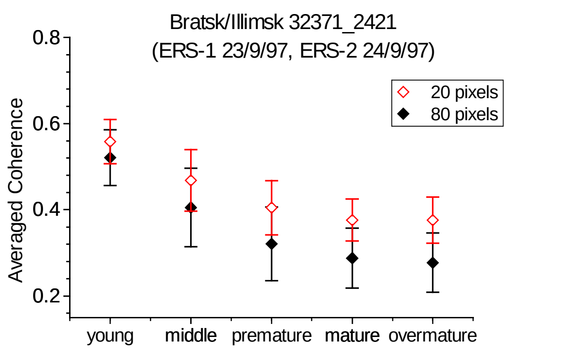


Figure 7-2a: ERS coherence versus tree age for Bratsk.

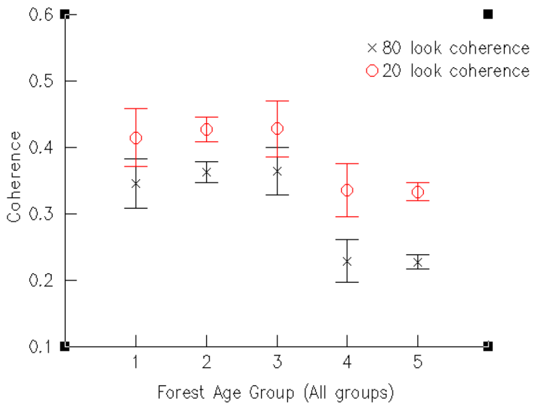


Figure 7-2b: ERS coherence versus tree age for Ulkanskii.

- There appears to be a relationship between the maximum ERS coherence that may occur and the growing stock volume. As Figure 7-3 shows there are no coherence values greater than 0.4 (20 pixel estimate) for a growing stock volume greater than 200 m^3/ha. Below this value of stock volume estimates of coherence increase up to 0.55, however the spread of values for areas with low stock volumes (between 30 and 200 m^3/ha) the range of coherence estimates is large.

- No clear relationship between ERS coherence and relative stocking in % could be discerned (Figures 7-4).
- The sensitivity of the ERS backscattering coefficient σ^0 to tree age, stock volume, and relative stocking is not significant.

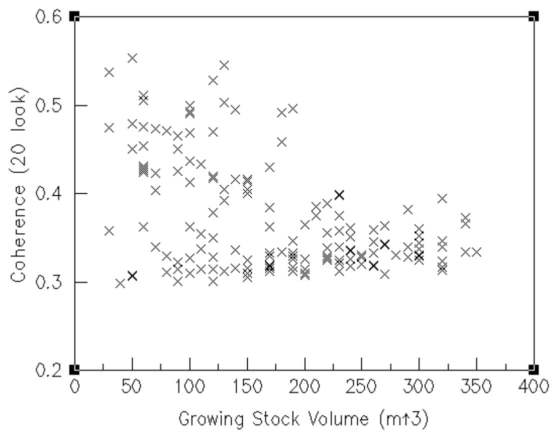


Figure 7-3: ERS Coherence versus growing stock volume for Ulkanskii.

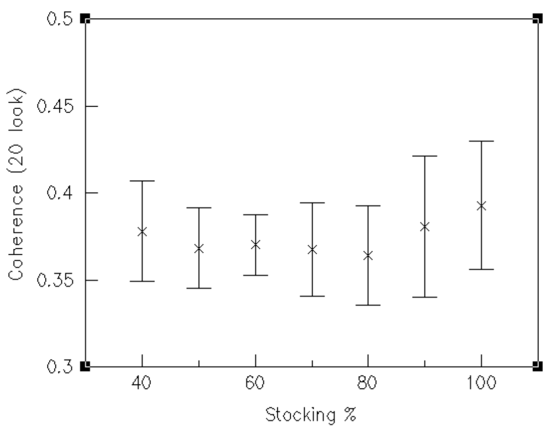


Figure 7-4a: ERS coherence versus relative stocking for Ulkanskii.

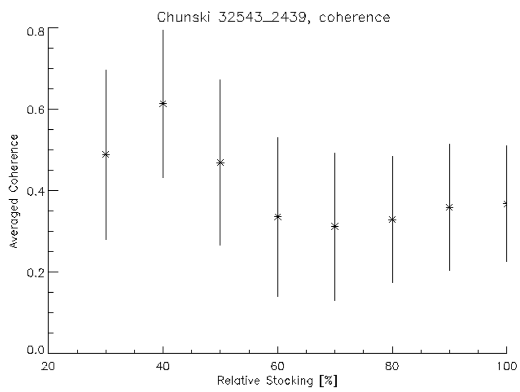


Figure 7-4b: ERS coherence versus relative stocking for Chunski.

Besides the ERS coherence, the JERS intensity is the most sensitive parameter to forest and other land use classes. For example, in Figure 7-5 a plot of the JERS and ERS backscatter intensities versus tree age is shown. While for ERS no relationship is apparent, JERS increases from young to mature forests.

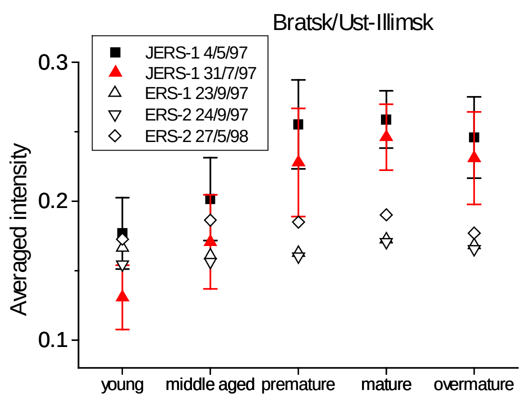


Figure 7-5: Plots of backscattering coefficient versus age for Bratsk.

7.3. Pre-processing and Classification (WP 5030)

Calibration of ERS SAR Images:

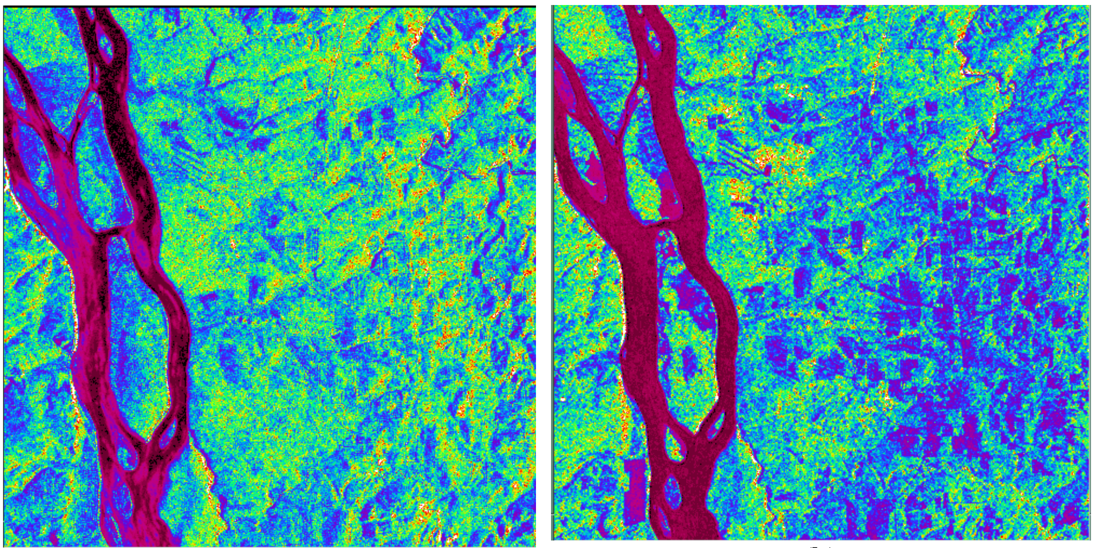
The calibration of both the GTC and GEC images is performed at the project partners with the freeware program "calit" which has been developed by DLR-DFD. Testing of "calit" in the phase of the project has revealed several problems, but now the performance of the software is believed to be good. If a GTC is available then "calit" calculates calibrated σ^0 images using the GIM images as input. In case of the GECs "calit" assumes that the Earth's surface is flat which causes radiometric distortions of σ^0 in mountainous areas.

Calibration of JERS SAR Images:

The calibration of the JERS SAR data is performed at Gamma. The calibration factor required for absolute calibration was validated with NASDA processed and calibrated data over a tropical forest site and good agreement was found. First analysis of the JERS SAR images over the SIBERIA area showed that σ^0 is somewhat higher than expected, especially for the forested areas. However, this is not expected to create an immediate problem as exactly the same procedure will be applied to all images, hence the classification methodologies should not be affected.

Filtering:

The need for filtering is at present unknown, since it needs to be integrated into the whole classification procedure, not considered as a stand-alone step. However, a multi-image filter geared to the properties of multi-temporal ERS data (and which can also be used with JERS data) has been developed, successfully implemented and distributed to the team. Figure 7-6a shows an original JERS image of the Bratsk area, and its multi-channel filtered version is given as Figure 7-6b. It was filtered in combination with one ERS Tandem acquired in September 97, one ERS in spring 98 and another JERS image from the 44-day repeat cycle. The effect of speckle reduction can be clearly observed. A working note documenting the multi-channel filtering algorithm was supplied to team members. Other filters are available (for example, simulated annealing reconstruction applied to the multi-image data from Ust-Illimsk were tested) but so far there has been no systematic effort to compare them. Any decisions about filtering should follow the current data analysis effort.



(a) (b)

Figure 7-6: ERS image from Bratsk: a) original JERS acquired on 4/5/97, b) filtered version of (a).

Rule-Based Classification:

The preferred approach to classification is rule-based, as then

- the connection to forest responses is transparent,

- the robustness of the approach is more easily assessed,
- the error sources are relatively easy to identify.

The formation of the rules requires good knowledge of the responses of the forest and non-forest classes, including regional and temporal effects. For this purpose a data base from all test sites is being set up under the co-ordination of SCEOS. This database will enable data from all sites to be compared and assessed, so that a suitable classification procedure for the project can be developed. Once the data base is formed it will be possible to:

- define the filtering necessary to translate our stand-based measurements into radiometric accuracy requirements at the pixel level;
- produce a threshold based decision scheme;
- assess the feasibility of a consistent scheme across the whole SIBERIA area;
- assess the error sources and likely extent of error.

CESBIO tested a simple hierarchical classification methodology on the Ust-Illimsk dataset in order to estimate the accuracy and robustness of such methods for Siberian forest classification. The method uses thresholds - which are computed on the basis of ERS coherence and JERS backscatter distributions obtained from training samples – in order to assign a class to each image pixel. The classification is done in two steps: first ERS coherence information is used to identify three land-use categories which are (1) recent clear cut (2) regrowth or old-clear cut and (3) water or mature forest areas, then JERS backscatter information is used to distinguish among water and mature forest areas.

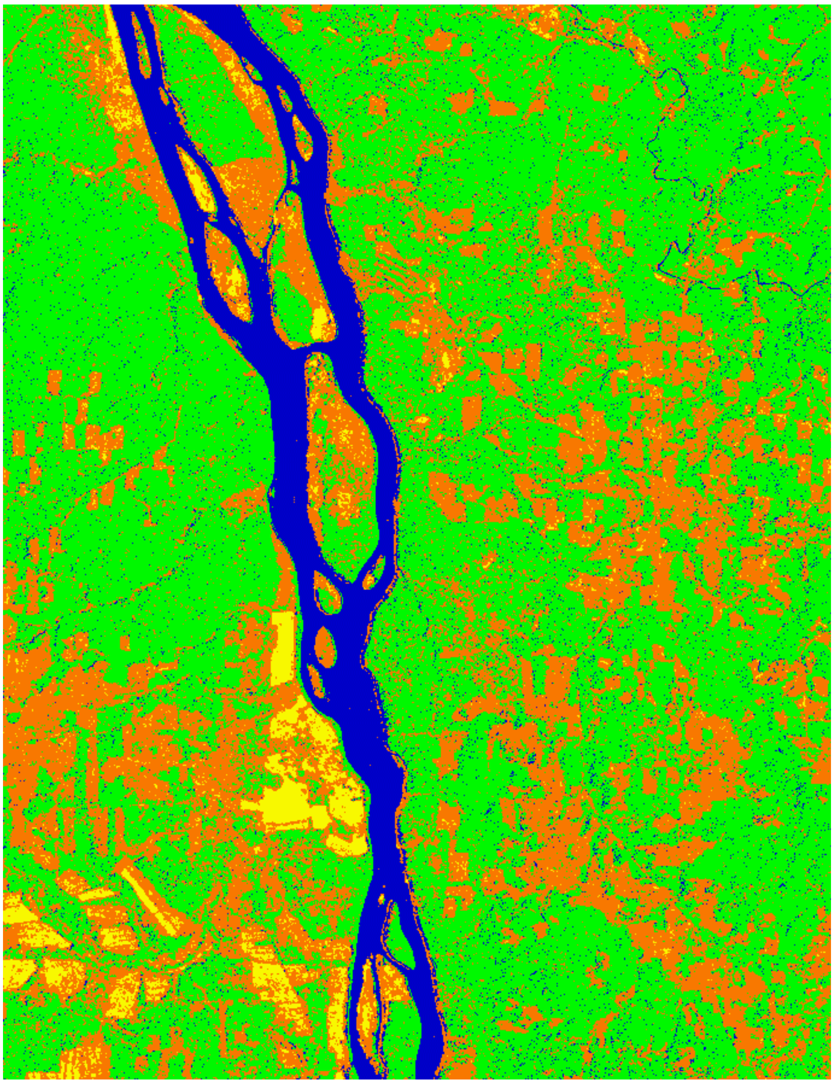


Figure 7-7: Ust-Illimsk classification illustrating the results obtained using the hierarchical thresholding method.

blue = water
green = mature forest
orange = forest regrowth
yellow = clear-cut

	Ground Truth			
Classification	Water	Mature forest	Forest regrowth	Clear-cut
Water	99.8	2.5	3.4	0
Mature forest	0.2	97.0	5.0	0
Forest regrowth	0	0.5	87.0	15.0
Clear-cut	0	0	4.6	85.0

Table 7-2: Confusion matrix for hierarchical threshold classification. Overall accuracy of the classification was estimated to be approximately 95%.

The classified image is given in Figure 7-7 and the associated confusion matrix is given in Table 7-2. The overall accuracy of around 95% is quite high. Water and mature forest are especially well classified. Some misclassification takes place between the regrowth and clearcut areas however. This is due in part to the natural overlap between these two categories since the transition from one class to the next takes place slowly. At the same time it is likely that the distinction among these two classes could be improved by choosing more complex decision surfaces for classification instead of the simple thresholding used here.

Data Based Classification:

Data based approaches for classification already exits. NERC has developed a new contextual classification algorithm which exploits spatial a priori knowledge in the SAR images to improve map accuracy. The iterated contextual probability (ICP) classifier has been applied to data from the Ust-Ilimsk test site and shown good results (Figure 7-8). The ICP classifier is available to the team and will be available to SSC as compiled code. Other data based classification approaches like maximum likelihood classification (MLC) are also available and their appropriateness can readily be assessed once the database is complete. However, the ICP (which can use MLC as its initial estimate) should significantly improve the quality of the MLC. The problem with data based approaches is transferability:

- can decision boundaries defined in one place be transferred elsewhere?
- how sensitive are these boundaries to location (i.e., can they be used unchanged over wide areas or are they very local)?
- how are the training sets selected for supervised approaches?
- how do assign physical classes to clusters (unsupervised approaches)?
- what are the likely error sources and how do they vary from region to region?

However, data based classifiers are likely to be of use in the project and are considered in parallel/synergy with rule-based approaches.

7.4. Accuracy Assessment (WP 5040)

Within the methodology team NERC is responsible for accuracy assessment issues. The progress towards the work package objectives is summarised below.

Definition of Methods:

A literature review on accuracy assessment has been carried out. Having completed a theoretical assessment of the published methods, a synthesis has been made available to the methodology team by the working note 'Methods of Accuracy Assessment in the SIBERIA project' from 21 June 1999.on the Siberia web page. The procedure for accuracy assessment involves estimating geometric accuracy, classification accuracy and map accuracy, and requires keeping track on all possible error sources during the processing chain, from interferometric processing to classification. Software code has been written at NERC/ITE and was distributed to the team.

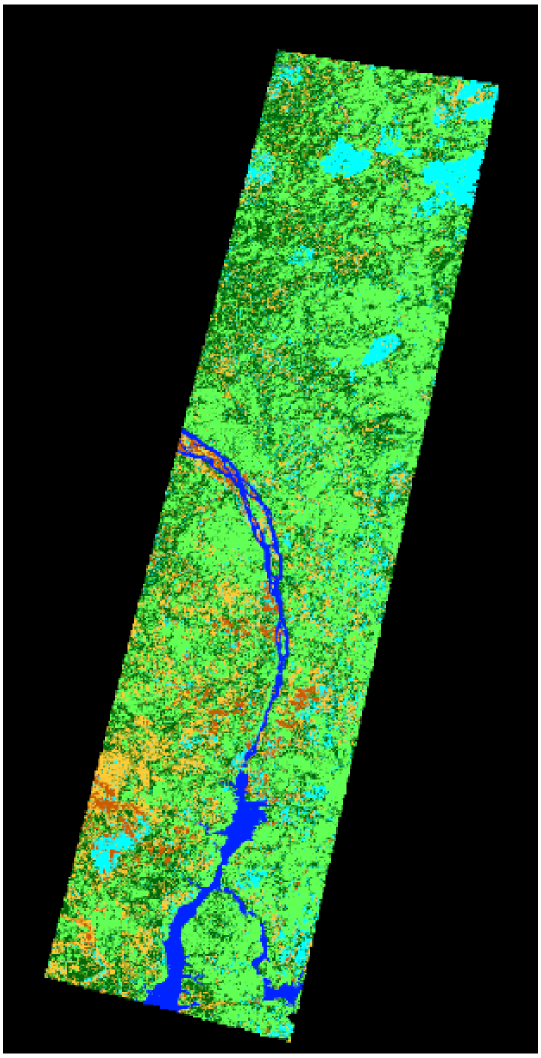


Figure 7-8: Classification of the entire mosaic of ERS-1/2 and JERS-1 images at Ust-Ilimsk.

dark blue: river
light blue: bogs
dark green: deciduous forest
light green: coniferous forest
yellow: clearcuts and birch regrowth
brown: agriculture and bare soil.

Synthesis of the assessment of results on a training test site:

The methods described above have all been applied to SAR data at the test site Ust-Ilimsk. The required accuracy statistics have been calculated and presented in talks at the Siberia meetings in Toulouse and Swansea. Figure 7-9a shows an application of the ICP classification of forest age at Ust-Ilimsk, and Figure 7-9b compares the edges (in red) between young and mature forest with an optical image from the SPOT satellite. It shows very good agreement.

Analysis of the implications for large scale mapping:

The software for accuracy assessment can be applied to a large number of images. However, it requires ground data, so that its application is restricted to the test sites where ground data are available. The accuracy of the large-scale map has to be assessed by a synthesis of results from all test sites with ground data. A sampling strategy needs to be defined, and the implications of latitude and size of the test sites on the estimated statistics need to be assessed. It also has to be examined what the implications of terrain correction for the achievable accuracy are, i.e. use of GEC or GTC data products from DLR for classification.

(a) (b)

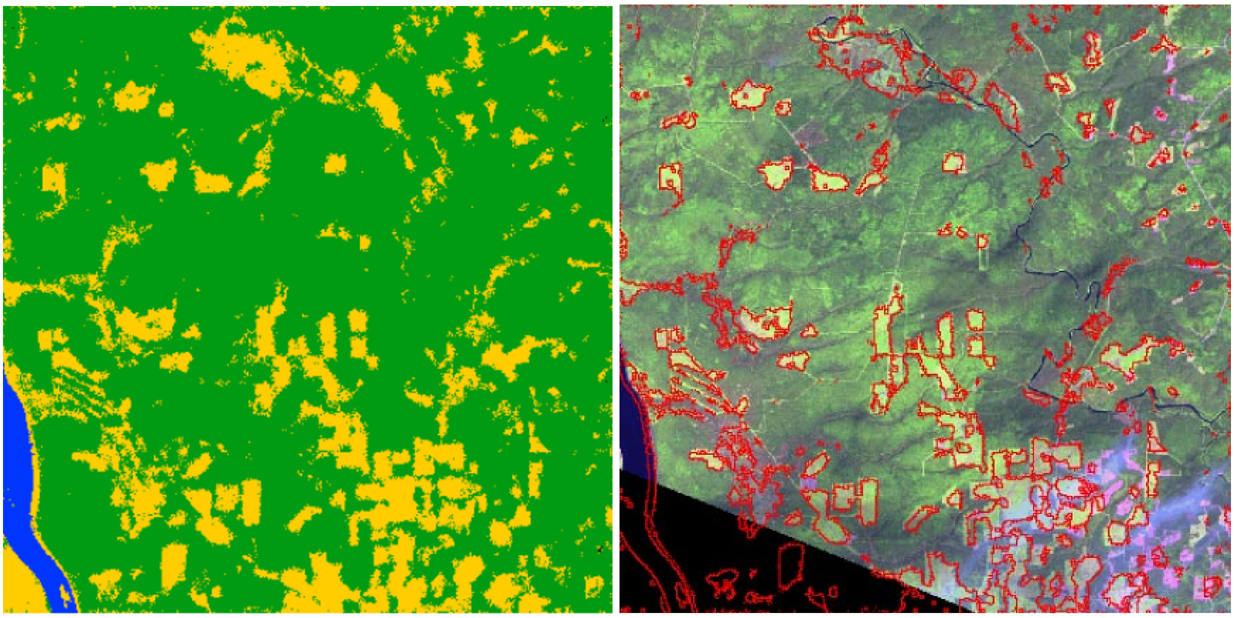


Figure 7-9: a) ICP classification of forest age at Ust-Ilimsk. Yellow: Young forest (clear-cuts and birch regrowth), green: mature forest, blue: Angara river. b) Laplacian edge detection filter from SAR (red) applied to (a), overlaid with a SPOT scene.

7.5. Computational Issues (WP 5050)

The objectives of this work package are to facilitate the efficient transfer of algorithms and data between SIBERIA partners and to ensure that there are no technical impediments to the implementation of the chosen methods. More specifically, the aims are addressed by:

1. Email 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

The official requirements of the project state that these objectives have to be satisfied by month 12 (July 1999). However, due to the delay in data delivery and processing as outlined, previously in this report, Objective 5 is not yet complete. The remaining objectives have been solved or remain open to modifications and developments. It is a property of this Work Package that continuous modifications and developments in software are required to solve possible problems.

In summary, the following progress has been made in WP 5050. Objectives 1 and 2 have been fully satisfied. The latest solution to managing email 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. Objective 3 has been satisfied through discussions and then recommendations presented to the team. The same is true of Objective 4 (see below). The involvement of UWS in this work package needs to be flexible in terms of answering other institution’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. It is understood that all relevant partners have been able to read and process data from these sources and that the formats used are therefore adequate. As mentioned previously Objective 5 (estimates of processing time and storage space) cannot be addressed yet, as the working methodology has not been finalised.

Progress has been made since the 1st EU Siberia Progress report. Further to the information collected on the questionnaire distributed to all partners during the kick-off meeting in Vienna a range of solutions were presented. The results of these solutions are now presented.

- 1st SIBERIA Progress report stated: 'UNIX is universally used. All partners have access to PC's'. This is still valid.
- 1st SIBERIA Progress report stated: 'For software development C is familiar by all partners, although C++ is preferred by SSC'. Solution: A series of image processing tools and algorithms (polygon averaging, mutitemporal filtering etc.) have been scripted in C and made available to the team members.
- 1st SIBERIA Progress report stated: 'Establish the compatibility of similar SAR processing steps that are carried out using different software applications'. Solution: These steps will all be taken using the same (or similar) program code that will be verified or scripted by UWS. The aim is to look at collating the data from many sites and we will provide some of the tools to do that.
- 1st SIBERIA Progress report stated: 'Investigate the use of Gamma software for specific processes such as co-registration of ERS-1 and JERS-1 GEC products'. Solution: Still to be assessed due to a lack of JERS-1 imagery.

Objective 6, which was added in view of partner's expressing concerns about the property rights, has been investigated by UWS. A course was attended, run by a firm of solicitors, and help and advice is available from EU sources. A working solution was agreed upon

- 1st SIBERIA Progress report stated: 'Investigate legal aspects of sharing source code between partner institutions'. Solution: A working note has been produced which specifies certain conditions and restrictions on the use of programs developed for SIBERIA. Furthermore, all work and publications should acknowledge information sources and should be copyrighted to the Siberia project and to their host institution, e.g. © Siberia, 1999, UWS, 1999. Programs when executed contain the same information so there can be no excuses for 'not knowing' when all the copyright information is provided for program users.

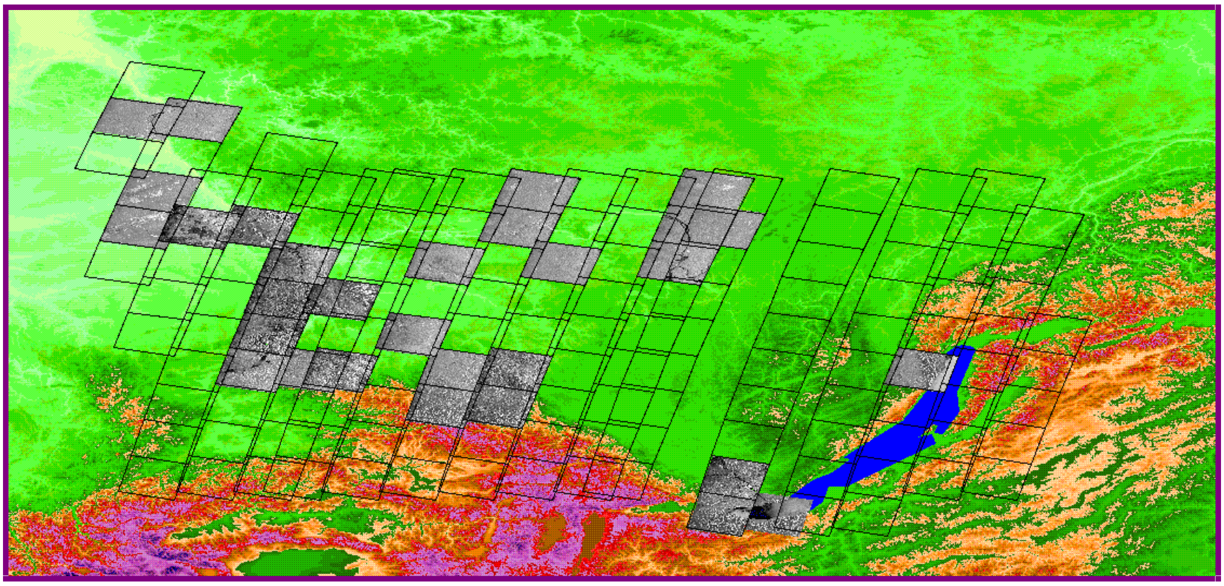


Figure 7-10: Interactive image location picture to aid and locate ERS images in the project area as found on the UWS Siberia Web site.

In addition to addressing the deliverables agreed at the start of the project, considerable progress has been made on developing a web-site for cataloguing of data, distribution of documents and meta-data and charting the progress of all aspects of the project including data delivery, processing and field data delivery. The feeling in the SIBERIA project seems to be that this is a valuable tool for the SIBERIA consortium and should continue to be the focus of the Computational Issues Work Package (WP5050). In addition to the features reported in the 1st Siberia Progress report (ERS and JERS image scenes, links to member institutions, FTP instructions, E-mail listings, interactive image information interrogation etc.) new features of the UWS Siberia Web site (http://sunset.swan.ac.uk/siberia/) are:

- Lists of working notes produced by partners and there full content available for downloading.
- ERS and JERS status lists (produced by Wolfgang Wagner at DLR).
- Meteorological data for weather stations inside the project area (produced by Wolfgang Wagner at DLR).

An example of the ERS SAR coverage as displayed on the Web site is shown in Figure 7-10.

8. Encountered Problems

The main problems that have been encountered in the second phase of the SIBERIA project are:

- The improvement of the ERS SAR processing chain has taken somewhat longer as expected but the resulting operational products are now of high quality. However, because of the late availability of ERS image products the number of test sites, for which both the ERS SAR and ground data were available, was limited. It is expected that full coverage of the test sites will be achieved in August.
- So far, only a small number of JERS SAR data from the NASDA archive have been available for methodological development. In April 1999 an agreement with Dr. Reiniger from DLR-DFD and Dr. Shimada from NADSA could be found to allow processing of the 1998 Ulaanbaatar JERS data. However, a unexpected problems caused a further delay until now (Week 30): e.g. break-down of DLR’s MDA tape recorder, loss of tape recorder in the mail, damage of tape record after final delivery, further program changes to NASDA’s processor. It is expected that the first Ulaanbaatar JERS data will be available to the methodological team in August.
- Initially, the methodological team had problems with understanding the relevance and irrelevance of the various attributes of the extensive ground-truth database. However, thanks to the excellent communication with IIASA and their Russian collaborators and the intensive discussions during the Siberia excursion a good understanding has now been obtained.

The problems have created a delay of three months. This influences the start of the hand-over period for the operational classification methodology to SSC. This delay causes no threat to the overall project objectives, but causes a delay for the conclusion date of the project.

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. This has been a challenging task for both sides, finding its -sometimes frustrating- climax during the field trip.

Why frustrating? Until now, very few JERS data were available for analysis, so the work of the methodological team focused on the ERS SAR interferometric products. These analysis have confirmed the high information content of ERS Tandem coherence with respect to low biomass classes (< 50 t/ha) and hence the capability to map burned or logged areas. This is interesting from a scientific perspective, but it does not satisfy the original expectation of our Russian partners: volume classes and species composition in closed forest stands. However, the capabilities of radars to generate reliable baseline maps (even though perhaps only a forest/non-forest map) is acknowledged - or on a regional scale much appreciated, as we learned during visiting the director of the Krasnoyarsk Federal Forest Service which contains 4% (!) of the world’s forests.

To pin-point the problems and status-quo better, an additional meeting took place at IIASA on July 22, 1999. Participants were the SIBERIA Coordinator Christiane Schmullius, the Methodology Coordinator Shaun Quegan (by phone link) and all involved IIASA personal (Sten Nilsson, Anantoly Shvidenko, Alf Oeskog, Micheal Gluck, and two post-doc students). The following issues were discussed:

- status of methodology work (which variables can be expected with which accuracy, time schedule),
- focus of applications with reference to project objectives,
- additional dedicated workshop at IIASA (e.g. to implement further thematic map infos into classification methodology),
- biomass parameter generation (where, when, how -e.g. fractional biomass),
- procedures for further up-to-date infos (e.g. verification of discovered burned areas),
- SSC's shifted schedule and change of final product (besides maps also printed original color composites),
- co-registration problems.

But on top of the above more specific 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 until now 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. Since the Methodology Team still had not worked with JERS-1 data, this suggestion was put aside. The methodological work will continue in the same direction and scale as described in the Technical Annex. However, due to the importance of this regional product, a small dedicated INTAS project is planned to generate a 1:1,000,000 map for the Krasnoyarsk Kraj.

The above concerns demonstrate our customer's interest in the SIBERIA's progress, its achievements, and direction. This close interaction with "pure" users is more than rewarding for the remote sensing team - it challenges the analyses techniques and leads them in a - at the same time - satisfying and frustrating direction away from mere science to applications. This is the "soil" on which remote sensing can survive. It has been laid out by the CEO philosophy. The SIBERIA team would like to thank CEO after an indeed very difficult first year, for the opportunity to work in this direction.

10. Outlook

Two critical issues of the project, data availability and establishment of data processing flows, have now been solved and by September/October the satellite and ground truth data bases for the test sites should, to a large extent, be completed. By the end of 1999, 80 of the 115 ERS-frames should have been be processed and a considerable part of the JERS data. Therefore it is expected that methodological development will make good progress within the next months. Also, the data base will be sufficient for the start of the operational classification at SSC.

The next big task of the methodology team is to establish a large common database for all SIBERIA test sites which contain selected forest attributes and radar data (ERS and JERS amplitude, coherence, ratios). This data base will serve to establish the classification rules. The prospects look good that these two important steps can be achieved until December 1999, when the next SIBERIA meeting will take place.

INDIVIDUAL PARTNER REPORTS

I Institut für Hochfrequenztechnik (DLR-HF)

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I.1. Administrative Issues

Meetings:

- Dr. Christiane Schmullius, Mr. Jan Vietmeier, and Dr. Wolfgang Wagner participated in the interim meeting in Swansea.
- Dr. Christiane Schmullius, Mr. Jan Vietmeier, Mrs. Andrea Holz, and Dr. Wolfgang Wagner took part in the Siberia excursion.
- Special IGBP-Transect Meeting at University Bayreuth (coordinator of meteorological flux stations), February 10th. Participants: Dr. Christiane Schmullius, Mr. Jan Vietmeier, Mrs. Andrea Holz, and Dr. Wolfgang Wagner
- JERS Processing Meeting at DLR, April 23: Dr. Masanobu Shimada, head of NASDA's processing department visits DLR to discuss details of dedicated special processing procedures for SIBERIA project.
- C. Schmullius: Organisation of Invited Special Session on "Microwave Remote Sensing of Boreal Forests" at International Geoscience and Remote Sensing Symposium (IGARSS) '99 in Hamburg.
- On July 22 a meeting between the SIBERIA Coordinator Dr. Christiane Schmullius and IIASA took place in Laxenburg to pin-point the problems and status-quo. Participants from IIASA: Prof. Sten Nilsson, Prof. Anantoly Shvidenko, Mr. Alf Oeskog, Mr. Micheal Gluck, and two post-doc students. Prof. Shaun Quegan participated via a phone link.

Project Documents and Technical Notes:

- Vietmeir, J., Working Note on "Calibration using CALIT", 25th March 1999.
- Wagner, W., Working Note on "ERS SAR Ordering and Assignation", April and May 1999.
- Wagner, W., Working Note on "JERS SAR Prioritisation", May 1999.
- Holz, A., C. Schmullius, Siberia Field Trip Diary, July 1999, see Annex B.

Publications:

Schmullius, C., A. Holz, J. Vietmeier (1999) SIBERIA - Results from the IGBP Boreal Forest Transect, IGARSS'99, Hamburg, Germany, 28 June - 2 July 1999, pp. 2118-2120.

Schmullius, C.; Holz A.; Zimmermann, R. (1998): SIBERIA - First ERS Tandem Results from the IGBP Boreal Transect. - In: Proceedings of IGARSS'98, the IEEE International Geoscience and Remote Sensing Symposium, 6-10 July 1998, Seattle, USA, Vol. IV, pp. 1815-1817.

Schmullius, C.; Holz, A.; Zimmermann, R. (1998): SIBERIA - First ERS Tandem Results from the IGBP Boreal Forest Transect. - In: Second International Workshop on "Retrieval of Bio- and Geo-physical Parameters from SAR Data for Land Applications", 21-23 October 1998, ESTEC, Noordwijk, Netherlands, ESA Publication, Poster Session 1: Forestry.

Schmullius, C.; Holz, A.; Vietmeier, J. (1999): Projekt SIBERIA - erste Radarsatellitenaufnahmen der Wälder Sibiriens werden ausgewertet. -In: DLR-Nachrichten - Mitteilungen des Deutschen Zentrums für Luft- und Raumfahrt, Sonderheft Umwelt, Februar 1999 / G12625.

Etzrodt, N.; Zimmermann, R.; Dempewolf, J.; Ziegler, W.; Vietmeier, J.; Holz, A. (1999): Classification of Central Siberian Forest Types by Combining interferometric Radar Remote Sensing (ERS Tandem Mission, JERS), Topographical Data and Ecophysiological Information. IGARSS'99, 28. June - 02. July 1999, Hamburg, Germany, pp. 720-722.

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 the first three tasks has been continuously performed and is reported below.

I.3. Project Coordination (WP 1000)

Considerable effort has been put into solving the problem of the non-availability of the JERS data. After many discussions with DLR-DFD, NASDA, Gamma, and ESA the problem could finally be solved mainly thanks to the support and help of Dr. Reiniger from DLR-DFD and Dr. Schimada from NASDA.

Other tasks carried out include data acquisition and processing prioritisation (see next chapter), regular contact with project partners, compilation of the mid-term report, and representation of the SIBERIA project to the outside.

I.4. Data Acquisition and Processing Prioritisation (WP1150)

DLR-HF has been the responsible partner for co-ordinating the establishment of ERS and JERS SAR image data bases and for determining the processing sequence according to data availability and methodological progress. Also, a meteorological data base for supporting the interpretation of SAR images was established.

I.4.1. ERS Synthetic Aperture Radar

The specific tasks with respect to the ERS SAR image data base have been:

1. Selection of ERS SAR images;
2. Ordering of images from ESA;
3. Prioritisation of processing sequence at DLR-DFD.

The SAR data used in the SIBERIA project were acquired in two campaigns in 1997 and 1998 with the mobile receiving station of DLR-DFD in Ulaanbaatar, Mongolia. The aim of the ERS SAR 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 respectively. The selection criteria for choosing the images (in order of significance) were:

1. Only descending (day-time) satellite passes;
2. Ground truth test sites are covered;
3. Geographic limits are 51-62°M and 88-112°E;

4. Mountainous areas in the south are avoided;
5. High quality SAR data are preferred;
6. ERS SAR tandem data from fall 1997 are preferred to tandem data from 1998;
7. The preferred acquisition time of the summer 1998 image is July/August.

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. Another difficulty was that not all images recorded with the mobile receiving station in Ulaanbaatar were included in the meta data bases of ESA and therefore the operations maps of the Ulaanbaatar station had to be checked manually.

An overview over the selected ERS SAR scenes is given in Figure I-1. The geographic location of the scenes is determined by unique combinations of track and frame numbers which can be seen on the top and on the left side of the image respectively. For each of the scenes shown in Figure I-1 one ERS-1/ERS-2 tandem pair and one image from 1998 (with the exception of the scene with track 19 and frame 2385 in the upper left corner of the study area) are available. The three images are identified by orbit number respectively acquisition date. The orbit numbers of the ERS-1 tandem pair image is shown on the bottom of the image. Figure I-1 also shows which partner is responsible for the processing and analysis of which scenes. DLR-HF is the responsible partner for processing the scenes with the thick blue frames, UWS and NERC for the red ones, and CESBIO and SCEOS for the blue ones. For the scenes with black thick frames the responsible partner has not been identified yet.

The orbit number and acquisition dates of the image triplets are listed in Table I-1. Also included under the column "Q" is a letter indicating the quality of the images. An H indicates high quality, M, medium and L , low. If the letter is in lower case (h,m,l) it means that there is a number of missing lines in the scene (e.g. h means that the quality of the data is good but missing lines are present: it is usually the first or the last frame of an acquisition that has fewer lines than the standard product).

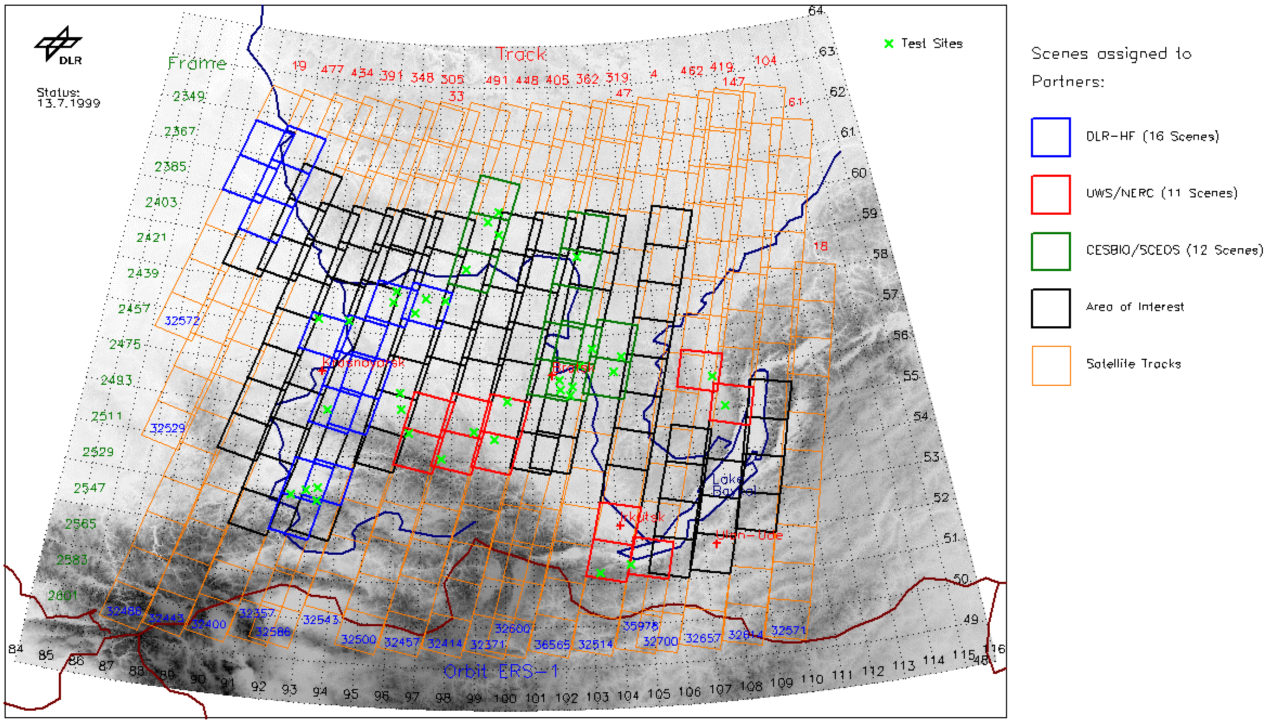

Figure I-1: Overview over the selected ERS SAR scenes (boxes with thick frame) and partner responsibilities.

Scene			ERS-1 Tandem				ERS-2 Tandem				Third Image			
Track	Frame	Partner	M	Orbit	Date	Q	M	Orbit	Date	Q	M	Orbit	Date	Q
4	2457	C/S	E1	36565	19980713	H	E2	16892	19980714	l	E1	36064	19980608	H
4	2475	C/S	E1	36565	19980713	l	E2	16892	19980714	H	E1	36064	19980608	H
19	2367	HF	E1	32572	19971007	l	E2	12899	19971008	H	E2	16907	19980715	H
19	2385	HF	E1	32572	19971007	h	missing				E2	16907	19980715	H
33	2403	open	E1	32586	19971008	H	E2	12913	19971009	H	E2	16921	19980716	h
33	2421	open	E1	32586	19971008	H	E2	12913	19971009	H	E2	16921	19980716	H
33	2439	HF	E1	32586	19971008	H	E2	12913	19971009	H	E2	16921	19980716	H
33	2457	open	E1	32586	19971008	H	E2	12913	19971009	H	E2	16921	19980716	H
33	2475	HF	E1	32586	19971008	H	E2	12913	19971009	H	E2	16921	19980716	H
33	2493	HF	E1	32586	19971008	H	E2	12913	19971009	H	E2	16921	19980716	H
33	2511	open	E1	32586	19971008	H	E2	12913	19971009	H	E2	16921	19980716	H
33	2529	HF	E1	32586	19971008	H	E2	12913	19971009	H	E2	16921	19980716	H
33	2547	open	E1	32586	19971008	H	E2	12913	19971009	H	E2	16921	19980716	H
47	2403	open	E1	32600	19971009	H	E2	12927	19971010	H	E2	16935	19980717	H
47	2421	open	E1	32600	19971009	H	E2	12927	19971010	H	E2	16935	19980717	H
47	2439	open	E1	32600	19971009	H	E2	12927	19971010	H	E2	16935	19980717	H
47	2457	C/S	E1	32600	19971009	H	E2	12927	19971010	H	E2	16935	19980717	H
47	2475	C/S	E1	32600	19971009	H	E2	12927	19971010	H	E2	16935	19980717	H
47	2493	open	E1	32600	19971009	H	E2	12927	19971010	H	E2	16935	19980717	H
47	2511	open	E1	32600	19971009	H	E2	12927	19971010	H	E2	16935	19980717	H
61	2493	open	E1	32614	19971010	H	E2	12941	19971011	H	E2	16949	19980718	H
61	2511	open	E1	32614	19971010	H	E2	12941	19971011	H	E2	16949	19980718	H
61	2529	open	E1	32614	19971010	H	E2	12941	19971011	H	E2	16949	19980718	H
61	2547	open	E1	32614	19971010	H	E2	12941	19971011	H	E2	16949	19980718	H
104	2493	U/N	E1	32657	19971013	H	E2	12984	19971014	H	E2	16491	19980616	m
104	2511	open	E1	32657	19971013	H	E2	12984	19971014	H	E2	16491	19980616	m
104	2529	open	E1	32657	19971013	H	E2	12984	19971014	H	E2	16992	19980721	h
104	2547	open	E1	32657	19971013	H	E2	12984	19971014	H	E2	16992	19980721	H
104	2565	open	E1	32657	19971013	H	E2	12984	19971014	H	E2	16992	19980721	H
147	2475	U/N	E1	32700	19971016	h	E2	13027	19971017	H	E2	16534	19980619	m
147	2511	open	E1	32700	19971016	H	E2	13027	19971017	H	E2	17035	19980724	H
147	2529	open	E1	32700	19971016	H	E2	13027	19971017	H	E2	17035	19980724	H
147	2547	open	E1	32700	19971016	H	E2	13027	19971017	H	E2	17035	19980724	H
147	2565	open	E1	32700	19971016	H	E2	13027	19971017	H	E2	17035	19980724	H
305	2403	open	E1	32357	19970922	H	E2	12684	19970923	H	E2	16692	19980630	H
305	2421	open	E1	32357	19970922	H	E2	12684	19970923	H	E2	16692	19980630	H
305	2439	open	E1	32357	19970922	H	E2	12684	19970923	H	E2	16692	19980630	H
305	2457	HF	E1	32357	19970922	H	E2	12684	19970923	H	E2	16692	19980630	H
305	2475	HF	E1	32357	19970922	H	E2	12684	19970923	H	E2	16692	19980630	H
305	2493	HF	E1	32357	19970922	H	E2	12684	19970923	H	E2	16692	19980630	H
305	2511	open	E1	32357	19970922	H	E2	12684	19970923	H	E2	16692	19980630	H
305	2529	HF	E1	32357	19970922	H	E2	12684	19970923	H	E2	16692	19980630	H
305	2547	HF	E1	32357	19970922	H	E2	12684	19970923	H	E2	16692	19980630	H
319	2403	C/S	E1	32371	19970923	H	E2	12698	19970924	H	E2	16205	19980527	H
319	2421	C/S	E1	32371	19970923	H	E2	12698	19970924	H	E2	16205	19980527	H
319	2439	C/S	E1	32371	19970923	H	E2	12698	19970924	H	E2	16205	19980527	H
319	2457	C/S	E1	32371	19970923	H	E2	12698	19970924	H	E2	16706	19980701	h
319	2475	C/S	E1	32371	19970923	H	E2	12698	19970924	H	E2	16706	19980701	H
319	2493	open	E1	32371	19970923	H	E2	12698	19970924	H	E2	16706	19980701	H
319	2511	open	E1	32371	19970923	H	E2	12698	19970924	H	E2	16706	19980701	H
348	2403	open	E1	32400	19970925	H	E2	12727	19970926	H	E2	16735	19980703	H
348	2421	open	E1	32400	19970925	H	E2	12727	19970926	H	E2	16735	19980703	H
348	2439	open	E1	32400	19970925	H	E2	12727	19970926	H	E2	16735	19980703	H
348	2457	HF	E1	32400	19970925	H	E2	12727	19970926	H	E2	16735	19980703	H
348	2475	open	E1	32400	19970925	H	E2	12727	19970926	H	E2	16735	19980703	H
348	2493	open	E1	32400	19970925	H	E2	12727	19970926	H	E2	16735	19980703	H

Table I-1: ERS SAR images. "M" stands for mission (ERS-1 or ERS-2) and "Q" is a quality indicator. For further explanations see text.

348	2511	open	E1	32400	19970925	H	E2	12727	19970926	H	E2	16735	19980703	H
348	2529	open	E1	32400	19970925	H	E2	12727	19970926	H	E2	16735	19980703	H
348	2547	open	E1	32400	19970925	H	E2	12727	19970926	H	E2	16735	19980703	H
362	2403	open	E1	32414	19970926	H	E2	12741	19970927	H	E2	16749	19980704	H
362	2421	open	E1	32414	19970926	H	E2	12741	19970927	H	E2	16749	19980704	H
362	2439	open	E1	32414	19970926	H	E2	12741	19970927	H	E2	16749	19980704	H
362	2457	open	E1	32414	19970926	H	E2	12741	19970927	H	E2	16749	19980704	H
362	2475	open	E1	32414	19970926	H	E2	12741	19970927	H	E2	16749	19980704	H
362	2493	U/N	E1	32414	19970926	H	E2	12741	19970927	H	E2	16749	19980704	H
362	2511	U/N	E1	32414	19970926	H	E2	12741	19970927	H	E2	16749	19980704	H
391	2403	open	E1	32443	19970928	H	E2	12770	19970929	H	E2	16778	19980706	H
391	2421	open	E1	32443	19970928	H	E2	12770	19970929	H	E2	16778	19980706	H
391	2439	open	E1	32443	19970928	H	E2	12770	19970929	H	E2	17279	19980810	H
391	2457	open	E1	32443	19970928	H	E2	12770	19970929	H	E2	16778	19980706	h
391	2475	open	E1	32443	19970928	H	E2	12770	19970929	H	E2	16778	19980706	H
391	2493	open	E1	32443	19970928	H	E2	12770	19970929	H	E2	16778	19980706	H
391	2511	open	E1	32443	19970928	H	E2	12770	19970929	H	E2	16778	19980706	H
405	2403	open	E1	32457	19970929	H	E2	12784	19970930	h	E2	16792	19980707	H
405	2421	open	E1	32457	19970929	H	E2	12784	19970930	H	E2	16792	19980707	H
405	2439	open	E1	32457	19970929	H	E2	12784	19970930	H	E2	16792	19980707	H
405	2457	open	E1	32457	19970929	H	E2	12784	19970930	H	E2	16792	19980707	H
405	2475	open	E1	32457	19970929	H	E2	12784	19970930	h	E2	16792	19980707	H
405	2493	U/N	E1	32457	19970929	H	E2	12784	19970930	h	E2	16792	19980707	H
405	2511	U/N	E1	32457	19970929	H	E2	12784	19970930	h	E2	16792	19980707	H
419	2565	U/N	E1	35978	19980602	H	E2	16305	19980603	H	E2	16806	19980708	H
434	2385	open	E1	32486	19971001	H	E2	12813	19971002	H	E2	16821	19980709	H
434	2403	open	E1	32486	19971001	H	E2	12813	19971002	H	E2	16821	19980709	H
434	2421	open	E1	32486	19971001	H	E2	12813	19971002	H	E2	16821	19980709	H
448	2385	C/S	E1	32500	19971002	H	E2	12827	19971003	H	E2	16835	19980710	l
448	2403	C/S	E1	32500	19971002	H	E2	12827	19971003	H	E2	16835	19980710	H
448	2421	C/S	E1	32500	19971002	H	E2	12827	19971003	H	E2	16835	19980710	H
448	2439	open	E1	32500	19971002	H	E2	12827	19971003	H	E2	16835	19980710	H
448	2457	open	E1	32500	19971002	H	E2	12827	19971003	H	E2	16835	19980710	H
448	2475	open	E1	32500	19971002	H	E2	12827	19971003	H	E2	16835	19980710	H
448	2493	U/N	E1	32500	19971002	H	E2	12827	19971003	H	E2	16835	19980710	H
448	2511	U/N	E1	32500	19971002	H	E2	12827	19971003	H	E2	16835	19980710	H
462	2403	open	E1	32514	19971003	H	E2	12841	19971004	H	E2	16849	19980711	H
462	2421	open	E1	32514	19971003	h	E2	12841	19971004	H	E2	16849	19980711	H
462	2439	open	E1	32514	19971003	H	E2	12841	19971004	H	E2	16849	19980711	H
462	2457	open	E1	32514	19971003	H	E2	12841	19971004	H	E2	16849	19980711	H
462	2475	open	E1	32514	19971003	m	E2	12841	19971004	H	E2	16849	19980711	H
462	2493	open	E1	32514	19971003	h	E2	12841	19971004	H	E2	16849	19980711	H
462	2511	open	E1	32514	19971003	H	E2	12841	19971004	H	E2	16849	19980711	H
462	2529	open	E1	32514	19971003	H	E2	12841	19971004	H	E2	16849	19980711	H
462	2547	U/N	E1	32514	19971003	H	E2	12841	19971004	H	E2	16849	19980711	H
462	2565	U/N	E1	32514	19971003	H	E2	12841	19971004	H	E2	16849	19980711	H
477	2367	HF	E1	32529	19971004	H	E2	12856	19971005	H	E2	16864	19980712	H
477	2385	HF	E1	32529	19971004	H	E2	12856	19971005	H	E2	16864	19980712	H
477	2403	HF	E1	32529	19971004	H	E2	12856	19971005	H	E2	16864	19980712	H
477	2421	open	E1	32529	19971004	H	E2	12856	19971005	H	E2	16864	19980712	H
491	2403	open	E1	32543	19971005	H	E2	12870	19971006	H	E2	16878	19980713	m
491	2421	open	E1	32543	19971005	H	E2	12870	19971006	H	E2	16878	19980713	H
491	2439	HF	E1	32543	19971005	H	E2	12870	19971006	H	E2	16878	19980713	H
491	2457	open	E1	32543	19971005	H	E2	12870	19971006	H	E2	16878	19980713	H
491	2475	open	E1	32543	19971005	H	E2	12870	19971006	H	E2	16878	19980713	H
491	2493	open	E1	32543	19971005	H	E2	12870	19971006	H	E2	16878	19980713	H
491	2511	open	E1	32543	19971005	H	E2	12870	19971006	H	E2	16878	19980713	H

Table I-1 cont.

I.4.2. JERS Synthetic Aperture Radar

As described in the first progress report, JERS data from 1998 recorded at the mobile receiving station of DLR-DFD in Ulaanbaatar could not be made available although they comprise the best available data set for the purpose of the project. The problems were that NASDA had had technical problems reading the Ulaanbaatar tapes and that no budget was foreseen to carry out this task at DLR-DFD. Thanks to the support of Dr. Reiniger from DLR-DFD a solution could be found on April 22. Dr. Reiniger offered that DLR-DFD carries out the reading and synchronisation of the Ulaanbaatar data. Then the synchronised data are sent on DLT's to Dr. Shimada, NASDA, who processes these data with the EORC processor to JERS Level 0 products. Interferometric processing of these data is finally carried out by Gamma. The synchronisation of the complete JERS coverage at DLR-DFD and the processing to JERS Level 0 products at NASDA is expected to be finished by the end of July/beginning of August.

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. Table I-2 summarises the data which were chosen based on the Ulaanbaatar operations maps. The location of the tracks can be seen in Figure I-2.

RSP	Date	Priority	RSP	Date	Priority
118	19.05.98	27	142	12.06.98	18
120	21.05.98	28	142	26.07.98	19
120	04.07.98	29	144	14.06.98	20
122	23.05.98	3	144	28.07.98	21
122	06.07.98	4	146	16.06.98	1
123	24.05.98	30	146	30.07.98	2
123	07.07.98	31	148	18.06.98	9
124	25.05.98	32	148	01.08.98	10
126	10.07.98	33	149	02.08.98	22
128	29.05.98	34	151	21.06.98	23
128	12.07.98	35	151	04.08.98	24
129	30.05.98	36	152	22.06.98	25
131	01.06.98	11	152	05.08.98	26
131	15.07.98	12	154	24.06.98	37
132	02.06.98	5	154	07.08.98	38
132	16.07.98	6	156	09.08.98	39
134	04.06.98	7	157	27.06.98	40
134	18.07.98	8	157	10.08.98	41
136	06.06.98	13	159	29.06.98	42
138	08.06.98	14	160	30.06.98	43
138	22.07.98	15	161	01.07.98	44
140	10.06.98	16			
140	24.07.98	17			

Table I-2: Selected JERS tracks and prioritisation.

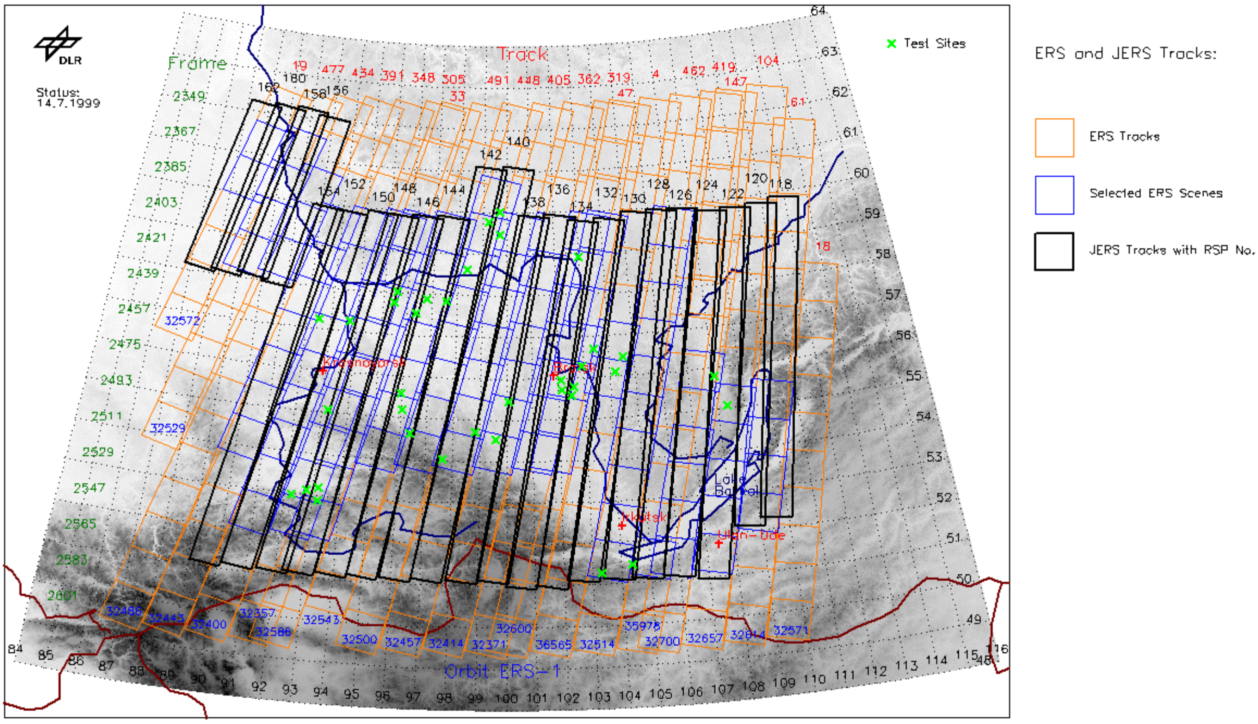

Figure I-2: Overplot of JERS tracks over the ERS scenes. Shown are only JERS tracks with even RSP number which can be seen above the respective tracks. Tracks with uneven RSP numbers are in-between their neighbours with the even numbers.

I.4.3. 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". The location of the stations can be seen in Figure I-3 and Table I-2.

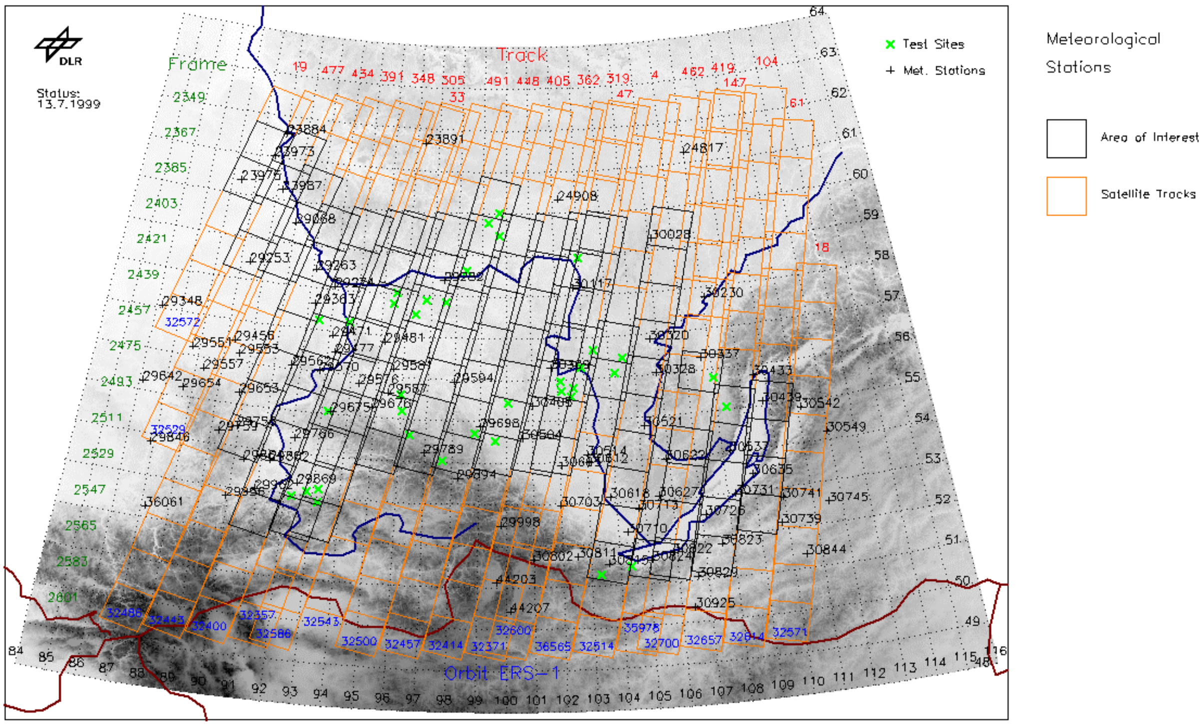

Figure I-3: The location of the meteorological stations in the SIBERIA study area.

WMO No.	Longitude	Latitude	WMO No.	Longitude	Latitude	WMO No.	Longitude	Latitude
23678	87.95	63.15	29653	89.82	55.30	30549	111.95	54.20
23884	90.02	61.60	29654	87.65	55.22	30554	113.58	54.47
23891	96.37	61.67	29675	93.37	55.08	30603	102.05	53.93
23966	84.08	60.35	29676	94.88	55.25	30612	103.07	54.00
23973	89.63	61.03	29698	99.03	54.88	30618	103.77	53.13
23975	88.37	60.35	29756	89.93	54.50	30622	105.90	53.97
23987	90.23	60.25	29759	89.28	54.33	30627	105.53	53.10
24507	100.23	64.27	29766	92.13	54.37	30635	109.02	53.42
24639	118.33	63.28	29789	96.97	54.22	30650	112.78	53.20
24724	112.50	62.03	29846	86.88	53.82	30664	115.62	53.53
24726	113.87	62.53	29862	91.32	53.77	30703	101.98	52.97
24738	117.65	62.15	29864	90.37	53.72	30710	104.32	52.27
24817	108.02	61.27	29869	92.42	53.30	30713	104.77	52.82
24908	102.27	60.33	29894	98.22	53.63	30726	107.13	52.57
24923	114.88	60.72	29956	89.92	52.80	30731	108.28	52.98
24944	120.42	60.40	29962	90.92	53.05	30739	109.78	52.17
29068	91.02	59.50	29998	99.82	52.50	30741	109.97	52.77
29253	89.37	58.43	30028	106.17	59.28	30745	111.55	52.53
29263	92.15	58.45	30054	112.58	59.45	30758	113.48	52.08
29274	93.00	58.08	30117	102.75	58.20	30764	115.17	52.65
29282	97.45	58.38	30157	112.87	58.32	30802	100.98	51.68
29348	86.22	57.07	30230	108.07	57.77	30811	102.53	51.73
29363	92.27	57.63	30253	114.23	57.85	30815	103.60	51.53
29430	84.92	56.50	30309	101.75	56.28	30822	105.85	51.72
29456	89.32	56.53	30320	105.70	56.87	30823	107.60	51.83
29471	93.13	56.90	30328	105.83	56.05	30824	105.12	51.57
29477	93.28	56.50	30337	107.62	56.32	30829	106.65	51.10
29481	95.22	56.85	30372	118.27	56.90	30844	110.47	51.35
29551	87.75	56.22	30405	101.03	55.38	30859	114.52	51.10
29553	89.58	56.23	30433	109.55	55.78	30925	106.45	50.37
29557	88.32	55.75	30439	109.75	55.12	30949	111.97	49.57
29562	91.67	56.10	30455	113.62	55.47	30961	115.58	50.95
29570	92.75	56.03	30469	116.77	55.12	36061	87.17	52.27
29576	94.33	55.80	30504	100.63	54.60	44203	99.67	51.12
29581	95.63	56.20	30514	103.02	54.17	44207	100.15	50.43
29587	95.47	55.63	30521	105.22	54.80	44212	92.08	49.98
29594	98.00	55.95	30537	108.27	54.03	44256	114.40	49.55
29642	86.12	55.23	30542	111.15	54.85			

Table I-2: WMO number, longitude and latitude of meteorological stations.

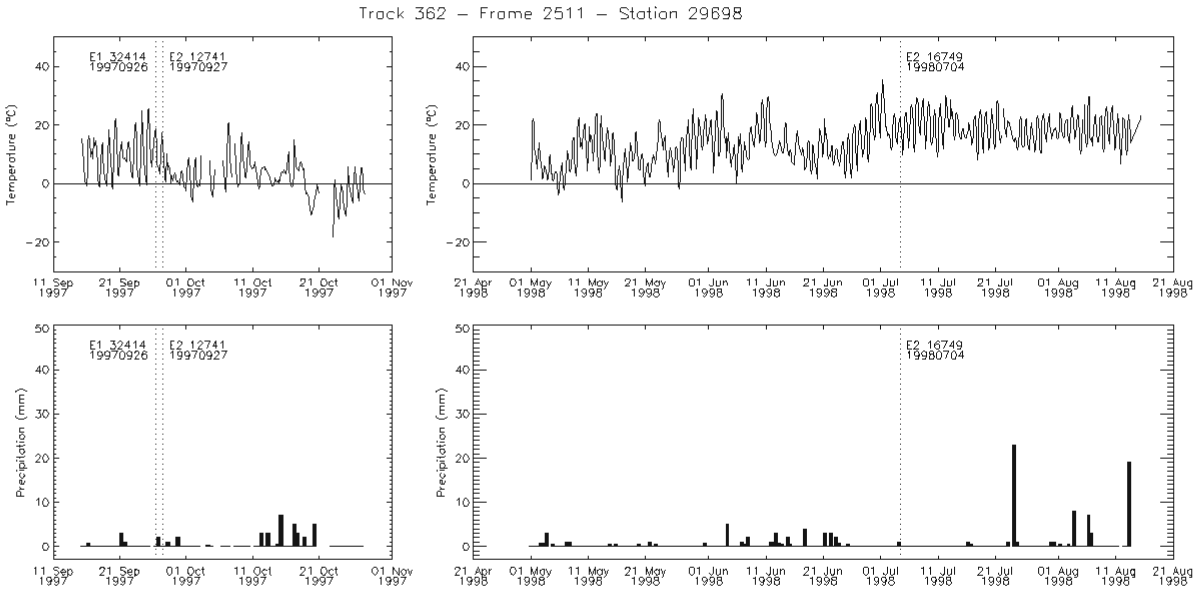

Figure I-4: Temperature and precipitation series from station 29698 near Nizhneudinsk (99.03°E, 54.88°N).

The meteorological data span the time periods from September 15 to October 31, 1997 and from May 1 to August 15, 1998. The nominal time step of the records is 3 hours, but depending on the variable or station other time steps (6, 12, 24 hours) occur. Also, in many instances, the series are incomplete. The data base contains the following variables: pressure, windspeed, temperature, dew point, weather, cloudiness, precipitation and others. To allow easy checking of the meteorological conditions during the satellite acquisition dates, plots of temperature and precipitation series were prepared and put on the Swansea web page (Figure I-4). 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 a vertical line in the plots.

I.5. SAR Geometry (WP 5010)

Geocoded Incidence Angle Mask and Radiometric Calibration:

The tests of the program performing the GIM generation are still in progress. One problem appears to be due to the unknown accuracy of the InSAR DEM provided by DLR-DFD. Mainly the noise of the DEM is making problems. Even over flat areas the incidence angles can reach the threshold value for masking out layover areas. For evaluation of the errors using the InSAR product it was decided to compare it with an accurate conventional DEM from other sources. In addition, different filters to reduce the noise of the DEM have been tested.

Tests of the program "calit" used for calibrating the SAR images showed that there are some errors regarding the radiometric correction of geocoded products (GEC as well as GTC). The errors were mainly due to frame rotation of the geocoded products and were removed step by step together with DLR-DFD. A release note as well as the corrected calit-version have been made available on the ftp-server. It is not possible to correct the topography dependent disturbances of the amplitude images if no DEM is available. For this case two solutions are possible:

- Masking out high topography areas;
- Using the ratio between two amplitude images to remove the topographic effect. For the second solution the ratio between two amplitude images would be the base for classifications. The information content of this product should be investigated together with the responsible partner (WP 5020).

Co-registration of ERS and JERS Images:

Until now only a few JERS images have been available to the project. Therefore the testing of procedures for the co-registration of JERS images to ERS images was restricted. In general, due to the side looking geometry of SAR, the co-registration is much more easier for flat areas than for high relief areas. To preserve comparability it is recommendable that all partners perform the co-registration using the same method and/or using the same software. Dependent on the available image product (ERS GEC or GTC) different procedures are possible.

The easiest way to register a JERS image to an ERS image is using tiepoints. This can be carried out using standard image processing software, e.g. PCI, ENVI or ERDAS, that works properly for GEC products as well as for GTC products but only over flat areas. If the images are covering hilly areas two methods are possible:

- Using the SARSIM tool provided by the PCI software.
- Using a co-registration tool provided by GAMMA Remote Sensing.

Only if a DEM is available (GTC product) it is possible to co-register images using SARSIM. In addition, not all partners have access to the PCI software. The program provided by GAMMA is capable to co-register JERS images to GEC images as well as GTC images. But the co-registration is not foreseen to be done by GAMMA. Hence the use of the GAMMA software would be connected with additional costs, either to pay the additional work done by GAMMA or to buy the software to carry out the co-registration by the partners themselves.

Until now the co-registration using tiepoints is applied and tested and works properly for flat areas. The test of the SARSIM tool is still in progress and the GAMMA software is not tested yet. The main problem represents the case if no DEM is available and the images are covering high topography areas. This case is directly connected with the backup solution for the calibration of the ERS images if no DEM is available (WP 5012) and the decisions to mask out areas not to be used in map classification (WP 5017). Because the amplitude images as well as the coherence products are disturbed by the topography it is recommended to mask out the high topography areas, anyway.

Masking of Hilly Terrain:

The masking out of areas not to be used in map classification is playing a key role for the calibration of GEC products and for the co-registration of JERS images to GECs. Different procedures to carry out the masking have to be developed and tested. Three solutions have been chosen to solve this issue. One of them is using thresholds of amplitude values below which (shadow) and above which (layover) relevant landuse classes are not occurring under usual conditions. Layover areas are easy visible for experienced eyes so masking out of these areas could be done manually. The problem of both suggested methods is, that only areas with extreme values can be masked out. Areas with smaller influences by topography can not be considered, which can easily lead to misclassifications. A third solution could be using the low resolution DEM GTOPO30 (covering the whole globe) as it is available for everyone. A procedure using this DEM has to be developed and tested still.

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

Along the IGBP-Transect the following data sets have been available in the reporting period:

- 1 GEC plus two JERS-1 scenes (November 96 and April 97 from NASDA archive),
- 1 GTC plus two JERS-1 scenes (November 96 and April 97 from NASDA archive),
- forest GIS information was not available for these frames.

Further 1 GEC and 1 GTC frame were available with GIS information, but without JERS-1 data.

Co-registration Issues:

Co-Registration of ERS with JERS-1 data has been performed on the above mentioned GEC (Frame 2493, Track 305) and GTC (Frame 2493, Track 33). On the GEC level, simple pass-point techniques have been used and showed the expected problems of relief displacement over hilly terrain. Co-registration of the JERS-1 images to the GTC has been tested using the EASI/PACE's radar co-registration package, but with no results yet. Also, one GEC (Frame 2439, Track 491) was co-registered with the GIS data.The observed difficulties were

- the difficulty to find ground control points due missing visible features in the GIS polygons (no roads, villages or rivers),
- temporal off-set between ground-truth acquisition and satellite images (e.g. new burned areas in satellite images),
- relief displacement where high topography.

Assessment of Information Content:

A preliminary comparison of an ERS GEC with the ground truth data base from the Chunski test area was conducted. ERS backscatter and coherence (together with their standard deviation) were plotted as function of relative stocking (Figure I-5). The centre coordinates of the investigated frame is 57.74 N, 96.76 E and is located slightly south of the Angara river. The plot of coherence versus relative stocking shows a general trend of decreasing coherence with higher relative stocking values, with the exception of the increase of coherence from 30 to 40 % relative stocking. The reason for the latter observation is not known, but it might be speculated that the influence of the undergrowth to the coherence increases for lower values than 40% relative stocking. The variability of the backscattering coefficient σ^0 are too high and there is no apparent trend in the data. During the field trip, the Methodology Team has decided that relative stocking is not a radar-relevant ground-truth parameter.

Only growing stock volume will be used in the future, in addition biomass will be calculated by IIASA for selected polygons.

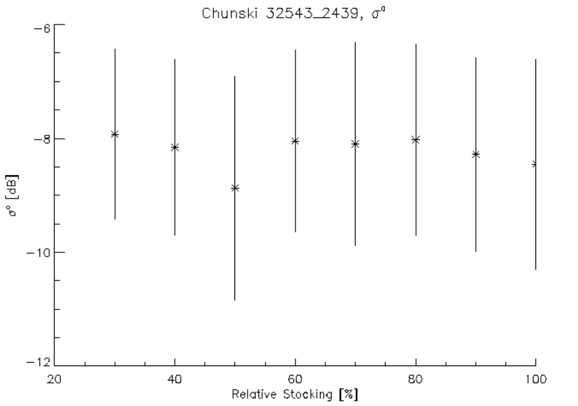

Figure I-5a: ERS backscattering value σ^0 versus relative stocking for Chunski.

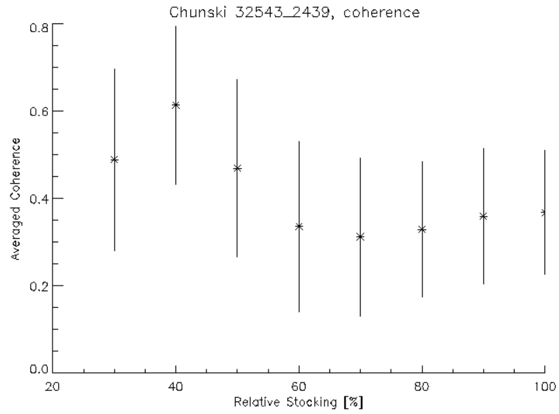

Figure I-5b: ERS coherence versus relative stocking for Chunski.

Figure I-6 shows a scatterplot of ERS amplitude versus Tandem coherence values. No absolute numbers are illustrated along the axes, since downscaling from 16 to 8 bit had been performed (the axes cover a range of 0 to 255 digital numbers). The scattergram allows the following first interpretations:

- Forest/non-forest can only be distinguished using coherence.
- Further discrimination of undisturbed forest in various forest types is not possible using ERS only.
- Coherence and amplitude can be used to classify several low biomass classes, e.g. different types of re-growth and wetland vegetation.

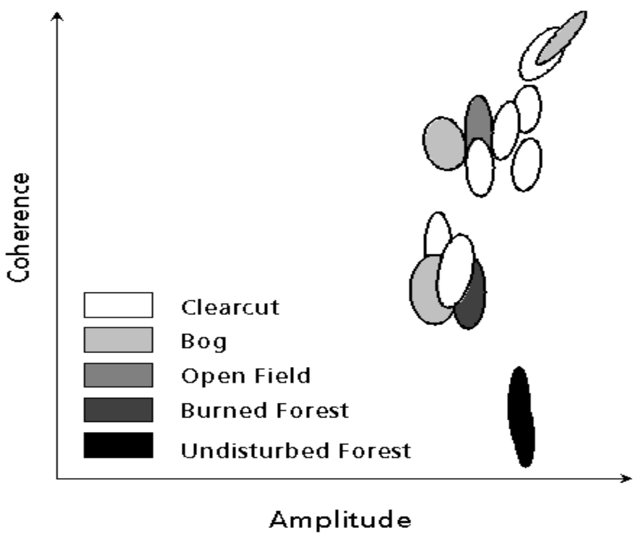

Figure I-6: Scattergram of ERS-1 amplitude from October 5, 1997 versus Tandem coherence from October 5/6, 1997. Ellipses were drawn using one standard deviation.

Pre-processing and Classification:

- Applied Filters: Gamma Map filtering (3 x 3 window) has been applied and showed satisfying results, the suggested SCEOS-filter was also applied (only first results).
- Extraction of GIS parameters was performed for the Chunski GEC. The following parameters were chosen: relative stocking (Figure I-5) and general land categories (as input to Figure I-6).

- Classification has not been performed yet, therefore the validation and accuracy assessment WP 5140 has not been pursue.

Hardware/software Developments:

- "Calit" code was corrected for radiometric errors based on geometrical effects.
- ArcView procedures were developed for rasterising of GIS polygons and attributes.
- The SCEOS filter has been successfully installed (main problem: only compatible on Linux operating systems).
- IDL procedures were developed to:
  - extract automatically the GIS-regions,
  - consider mis-registration (i.e. reject mixed pixels along polygon boundaries), and
  - automatically extract radar signatures per GIS parameter to construct "Radar/GIS-Database" for development of operational classification methodology.

II Deutsches Fernerkundungsdatenzentrum (DLR-DFD)

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II.1. Administrative Issues

Personnel: In 1999 two DLR-DFD employees were additionally assigned to the Siberia team. Dominic Scales responsibility is the software maintenance while Michael Specht was added as the second project operator.

Meetings: Achim Roth and Nico Adam participated in the interim meeting in Swansea.

Project Documents and Technical Notes:

Nico Adam, Implementation of the Coherence Estimation, Technical Note, March 1999.

II.2. 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.3. Progress

- **Consideration of a coarse DEM**: In order to improve the image geometry of those products where no terrain correction can be applied the consideration of a coarse DEM was incorporated. This procedure replaces the backup solution GEC (ellipsoid correction).
- **Coherence estimation**: The parameters for the coherence estimation were revised. In order to improve the classification results the coherence is now derived from 80 looks.
- **Integration of topographic maps**: The map sheets covering the test area were integrated into the system. The tie-pointing is based on topographic maps in a scale of 1:200 000. The corresponding adjustment corrects the interferogram’s phase offset and a possible phase ramp.

II.4. Interferometric Processing of Tandem Pairs (WP 2100)

Following a priority list provided by DLR-HF the products are processed sequentially. At first all input products (SLCIs) are processed to interferograms, intensity images and coherence maps. Additionally a mask indicating homogeneous areas where no phase unwrapping errors can be expected is produced. The decision whether the data are terrain corrected or - as backup - registered on a coarse is based on this mask together with the coherence map and the appearance of the interferogram.

Until July 15, 1999, 45 SLCI ERS Tandem pairs together with the co-registered spring data set were interferometrically processed.

II.5. DEM Generation (WP 2200) and Geocoding of Amplitude Images and Coherence Maps (WP 2300)

In total 34 geocoded products were delivered to the Siberia project server. 16 DEMs could be derived enabling a terrain correction of the corresponding interferometric products. Due to low coherence 14 products could only be ellipsoid corrected. The consideration of a coarse DEM (GLOBE-product) was applied to 10 interferometric data sets.

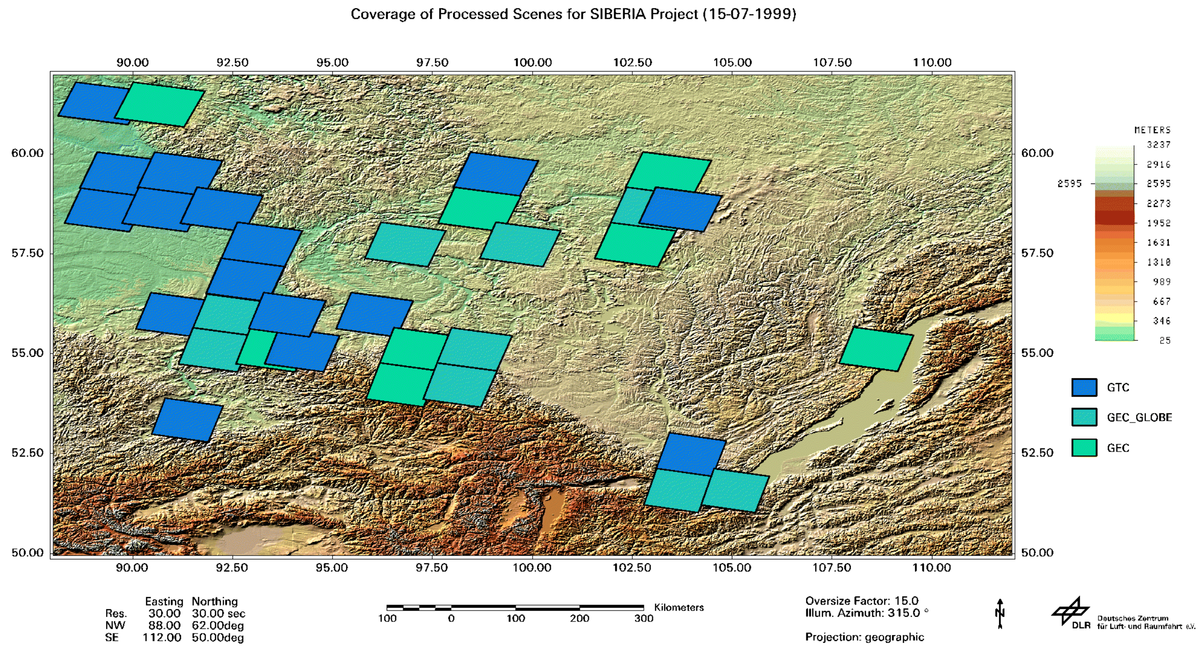

Figure II-1: Processing status at DLR-DFD, July 1999.

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

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 the correction 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.

II.5.1. DEM Quality Control

Before the delivery of the products the validity of the interferometrically derived DEM is proved in two steps. At first the differences to a coarse 30 arc seconds global elevation model (GLOBE-model) for each pixel are calculated. Image II-2 shows the DEM, while image II-3 presents the corresponding difference image (reference model minus InSAR DEM). The colour coding of the difference image ranges from –100m (pink) to +100 m (brown). Areas where with low differences appear in green.

Due to the limited quality of the reference model the check aims at the detection of gross errors like global phase ramps. Image II-3 shows no systematic change in the differences, neither from near to far range, nor from early to late azimuth. A phase ramp would result in a systematic pattern, over-laying the differences caused by the different resolutions of the height models.

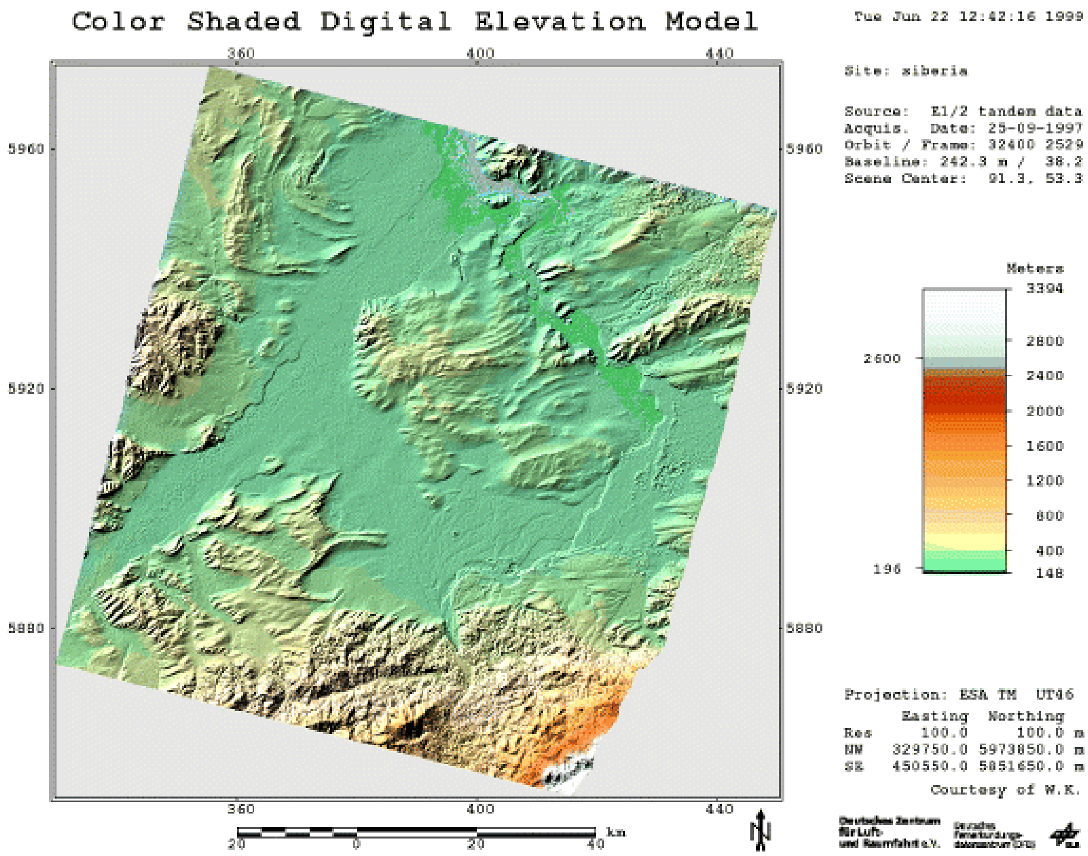

Figure II-2: Colour shaded DEM.

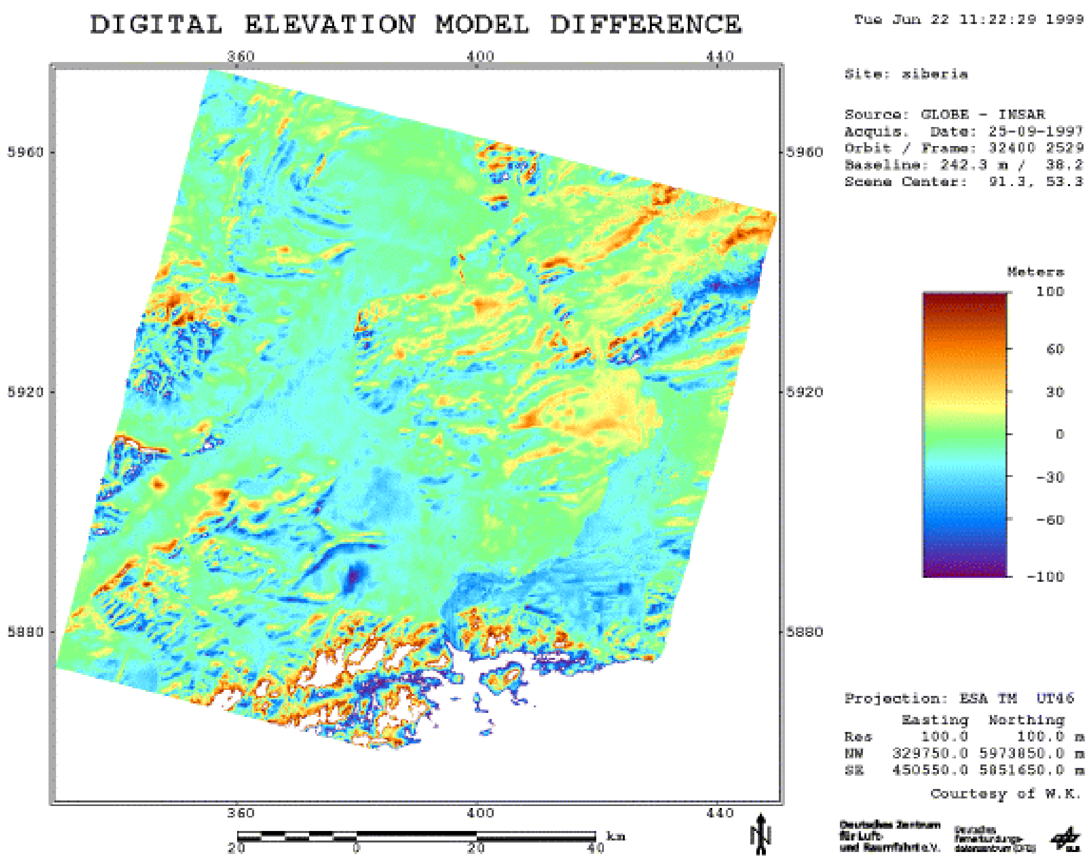

Figure II-3: Comparison of InSAR DEM with a global digital elevation model.

The height values of the GLOBE reference model represent an area of 1 km^2 while the interferometric DEM is generated with 50 m pixel spacing. The coarser spacing causes a smoothed appearance of the relief. The white area in the south west corner indicates differences greater then 100 m. This part shows a mountainous area covered with forest. The steeper slopes together with a loss of coherence due to the vegetation causes a degradation of the DEM's quality. In this area the DEM is systematically higher then the reference DEM.

In a second step the location accuracy is determined. Control points are derived from the topographic map and the intensity image. The residuals of the scene related to image II-2 are presented in Table II-1. The statistics shows no systematic errors. The maximum deviations are in the range of 3-4 pixels as the spacing is 50 m. The tiepointing accuracy is limited to approximately 100 m due to the scale of the reference map and the identification accuracy within the SAR image.

	Difference Easting	Difference Northing
Maximum	-174.8 m	-172.5 m
Minimum	146.7 m	168.16 m
Mean	14.0 m	0.7 m
St. Deviation	96.1 m	106.0 m
RMS	92.3 m	100.5 m

Table II-1: Geolocation accuracy of InSAR products.

II.6. 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.

III International Institute for Applied System Analysis (IIASA)

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III.1. Administrative Issues

Siberia Excursion:

IIASA Planned and arranged of a field trip for the partners to Krasnoyarsk and Irkutsk Oblasts in Siberia from May 31 to June 13. The objective of the trip was to make on-site inspections of forests to be classified and quantified. Among the points covered were:

- Visits at different Forest Enterprises including demonstrations of requirements in forest management.
- Visits to representative forest stands where selected forest variables were studied and compared to products produced from the radar data.
- A scientific seminar at the V.N. Sukachev Institute to share results and experiences in classification and estimation of forest variables using radar and optical data achieved by SIBERIA Project and Russian scientists.

Prof. Anatoly Shvidenko and Mr. Michael Gluck participated in the field trip.

Project Documents and Technical Notes:

Gluck, M., A. Shvidenko, SIBERIA Project Ground Truth Data Workbook, Technical Note, May 1999. (please refer to Appendix A).

III.2. Responsibilities

IIASA is the responsible partner for "Classification requirements and ground truth" (WP 4000). This report describes the work and progress performed by IIASA and its Russian partners in the second six-month period of the SIBERIA project (January 1999 to June 1999).

The work in this period has continued the earlier initiated work packages as follows:

- Design and definition of the structure and content of the foreseen forest database including determination and description of the forest variables to be classified and estimated, WP 4100.
- The collection and compilation of the reference data, WP 4300.
- Support in classification development, WP4400.

III.3. Design and Definition of Structure and Content of Forest Data Base: Determination of Forest Variables (WP 4100)

Building upon the forest variable information presented at the Toulouse meeting (see IIASA section in first progress report), we have produced a document entitled "SIBERIA Project Ground Truth Data Workbook" (please refer to Appendix A.) This document addresses the following topics:

Description of the Russian Forest Inventory and Planning (FIP) System.

- Definitions of all ground truth data variables.
- Relationships between selected forest variables.
- Estimated accuracy of forest variables.

III.4. Reference Data Collection and Compilation (WP 4300)

During the period reference data from 19 test areas originating from 6 test territories (forest enterprises) has been produced and delivered. Currently reference data from totally 31 test areas and 9 test territories are available to the project (Figure III-1).

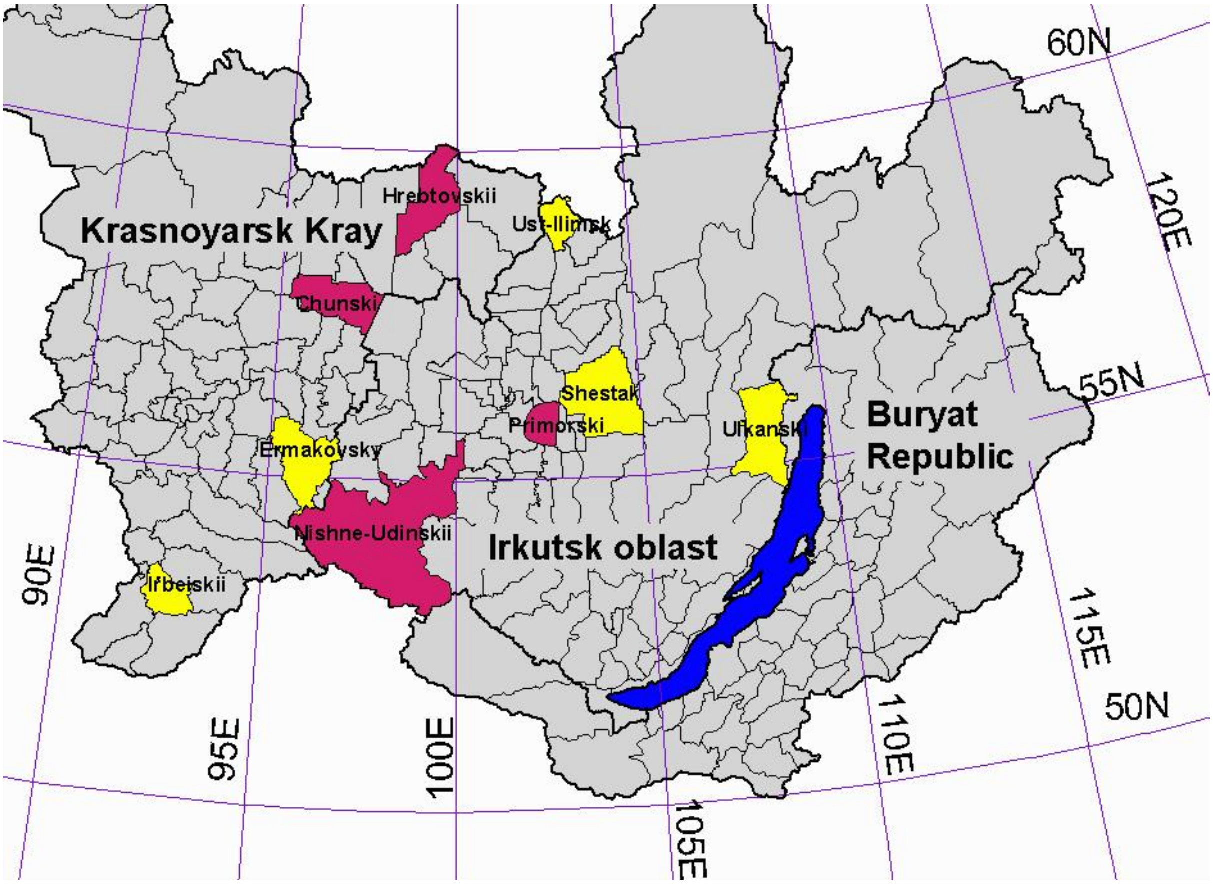

Figure III-1: The location of the test territories and the test areas with available reference data in SIBERIA are presented above. Areas in red represent new test areas produced during this period in addition to yellow areas available since fall 1998.

All forest maps are produced in ArcInfo format (shapefile or coverage) and are unprojected (geographic) or UTM projected. A standard forest attribute database in dbase format, with a single record per forest stand has been created for each test territory and this file is now joined to the GIS coverage.

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

Twenty additional test areas are reserved for accuracy assessment and IIASA will provide the location of these areas as soon during summer 1999.

III.5. 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 assessment and comments of the results within the test areas. The second objective is to revise the classification requirements if necessary. During the period IIASA has performed the following two support activities:

- Establishment of a Question and Answer Web page.
- Planning and arrangement of a study tour for the partners to Siberia

Currently IIASA is awaiting the first classification results (WP 5020, 5030 & 5040) to be assessed before a revision of classification requirements can be made.

III.6. IIASA Question and Answer Web Page

IIASA has established 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 to utilise the data. Examples of issues that have been covered are as follows:

- Issues regarding the utilisation of the reference data in used software environments.
- Land use classes & forestry terms
- Issues related to the geometry of the database
- Test territory locations
- Land Category Definitions
- Questions regarding database attributes

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 participated in the 2-week Siberia field trip. Dr. Thuy Le Toan also attended the interim meeting in Swansea.

Project Documents and Technical Notes:

Davidson, M., Working Note on "Coherence", February 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. Understanding the Ground Truth Data Base

Considerable time was spent analysing and understanding the Ust-Illimsk forest parameter database provided by IIASA in conjunction with SAR data. The analysis of the database, along with the subsequent on-site visits during the field trip in Siberia, made it clear that the database was designed for forest exploitation (or forest conservation for the Baikal site) and care needs to be taken in interpreting the data for remote sensing purposes. For instance the age parameter does not refer to stand age (e.g. of a plantation forest) but the age of the dominant species in a stand. Also dominant species is not dominant in number, but in economic value which is in order of decreasing value cedar, pine and deciduous trees. Because of these inconsistencies (from a remote sensing point of view) and because of highly variable site productivity from one area to the next, stand age cannot be considered a good indicator of wood volume. This aspect is illustrated in Figure IV-1 using Ust-Illimsk data provided by IIASA. Thus when assessing the information content of SAR data, growing stock volume, not stand age, because of its physical interpretation is the preferred forest reference parameter.

IV.4. Information Content (WP 5020)

The quantification of ERS/JERS SAR information content work done at CESBIO has focussed on ERS coherence and JERS backscatter information since previous studies have shown these channels to be most sensitive to forest and other land-use classes. Our analysis has shown that ERS tandem coherence information is more sensitive to forest volume classes than JERS backscatter information. Generally an overall drop in coherence as a function of growing stock volume is observed. For Ust-Illimsk coherence estimates ranged from 0.65 to 0.3 as growing stock volume ranged from 0-300 cubic meters per hectare. However coherence generally saturates for stock volumes above 100 cubic meters per hectare. JERS backscatter information was found to be less sensitive to forest stock volume exhibiting a dynamic range of approximately 3 dB for growing stock volumes between 0-300 cubic meters per hectare. JERS data was found to contain useful information on other land-use classes however. For instance mature forest and water surfaces are easily distinguished using JERS intensity data whereas they are virtually indistinguishable using coherence information only.

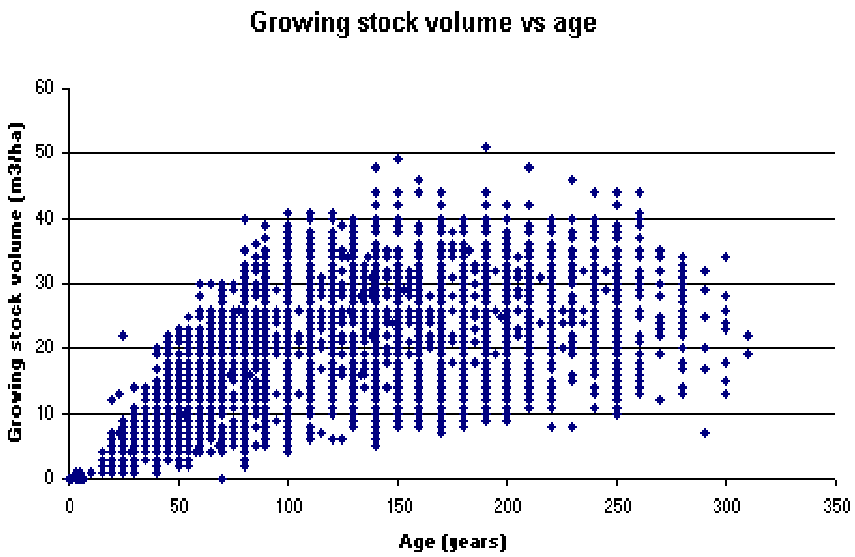

Figure IV-1: Plot of growing stock volume versus stand age using data extracted from the IIASA Ust-Illimsk database. A large scatter is observed due to highly variable site productivity across the test site.

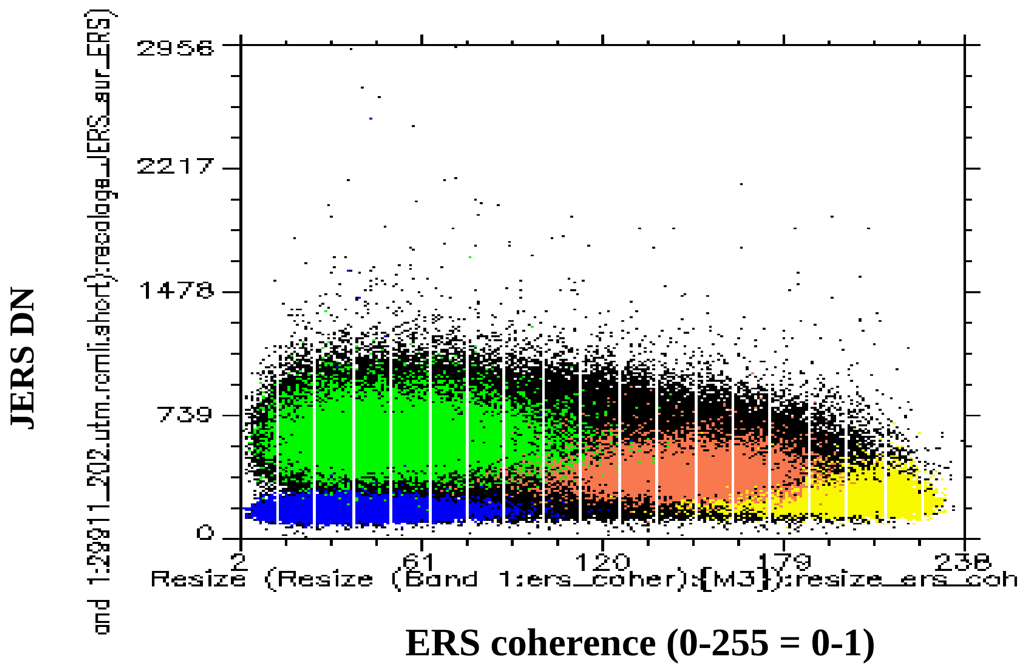

Figure IV-2: Scatterplot illustrating the information content and separability of ERS tandem coherence (X axis) and JERS-1 backscatter (Y-axis) in terms of four distinct land-use classes. The colours blue, green, red and yellow refer to to the classes water, mature forest, forest regrowth and clear-cut respectively

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

A simple hierarchical classification methodology was tested on the Ust-Illimsk dataset in order to estimate the accuracy and robustness of such methods for Siberian forest classification. The method uses thresholds - which are computed on the basis of ERS coherence and JERS backscatter distributions obtained from training samples – in order to assign a class to each image pixel. The classification is done in two steps: first ERS coherence information is used to identify three land-use categories which are (1) recent clear cut (2) regrowth or old-clear cut and (3) water or mature forest areas, then JERS backscatter information is used to distinguish among water and mature forest areas. The methodology used is illustrated in Figure IV-3. The classified image is given in Figure IV-4 and the associated confusion matrix is given in Table V-1. The overall accuracy of around 95% is quite high. Water and mature forest are especially well classified. Some misclassification takes place between the regrowth and clear –cut areas however. This is due in part to the natural overlap between these two categories since the transition from one class to the next takes place slowly. At the same time it is likely that the distinction among these two classes could be improved by choosing more complex decision surfaces for classification instead of the simple thresholding used here.

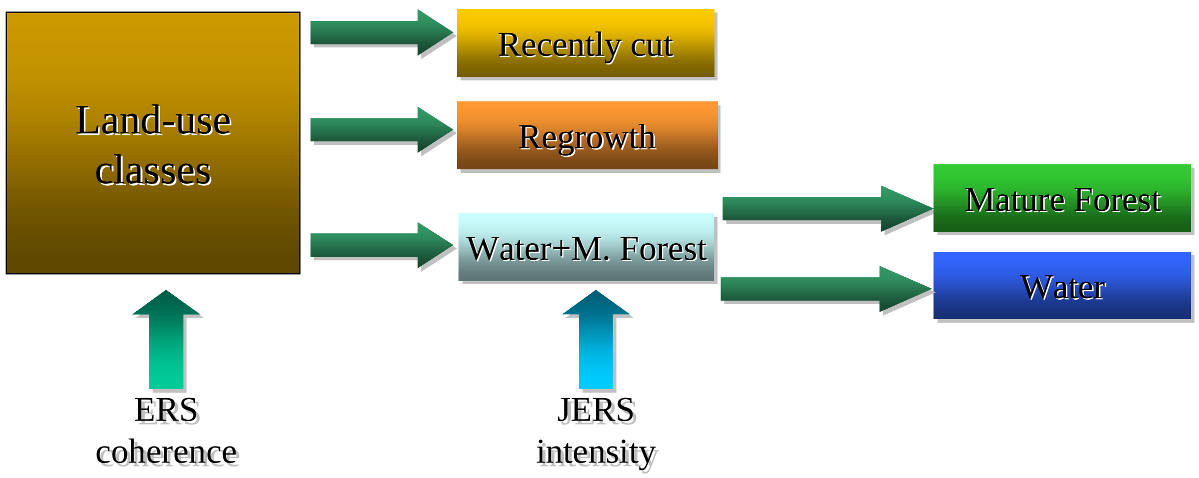

Figure IV-3: Hierarchical classification approach used for the classification of Ust-Illimsk land-use classes.

	Ground Truth			
Classification	Water	Mature forest	Forest regrowth	Clear-cut
Water	99.8	2.5	3.4	0
Mature forest	0.2	97.0	5.0	0
Forest regrowth	0	0.5	87.0	15.0
Clear-cut	0	0	4.6	85.0

Table IV-1: Confusion matrix for hierarchical threshold classification. Overall accuracy of the classification was estimated to be approximately 95%.

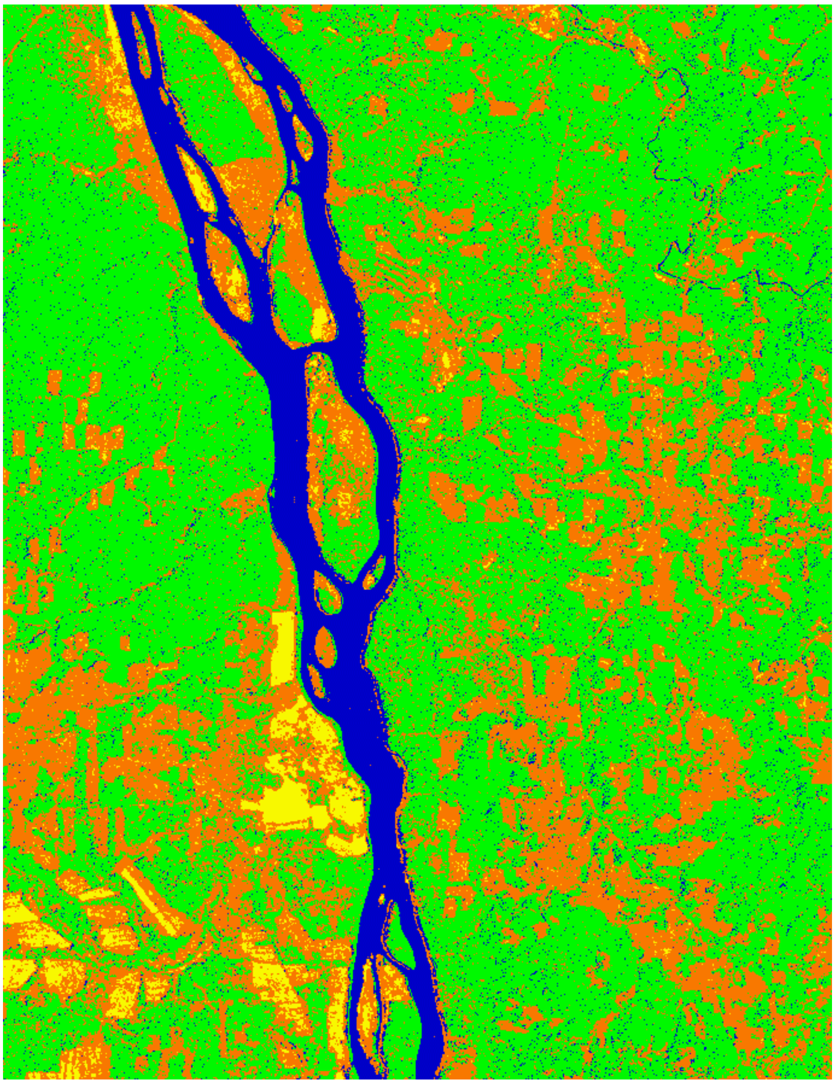

Figure IV-4: Ust-Illimsk subarea classification illustrating the results obtained using the hierarchical thresholding method. The colours blue, green, red and yellow correspond to water, mature forest, forest regrowth and clear-cut areas respectively.

IV.6. Problems and Comments

- While the initial classification results for Ust-Illimsk appear promising, the thresholds used for the classification are likely to be site and time dependent. It is therefore important to assess the robustness and variability of these thresholds over the various test sites in order estimate the robustness and likely accuracy of the overall forest map. This requires stronger links with other methodology teams.
- The effect of topography on the classification process still needs to be assessed quantitatively since the assessment of results so far has concentrated on relatively flat areas around Ust-Illimsk.

V Sheffield Centre for Earth Observation Science (SCEOS)

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V.1. Administrative Issues

Meetings: Prof. Shaun Quegan and Mrs. Jiong Jiong Yu participated in the interim meeting in Swansea and in the Siberia excursion.

Project Documents and Technical Notes:

- Quegan, S, and J.J. Yu, Filtering, February 1999
- Yu, J.J., and S. Quegan, Analysis of Backscatter and Coherence as Functions of Age - Bratsk site, March 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)

- Monthly progress reports were supplied to the WP5000 coordinator. Clarification was sought from Team members on aspects of their reports which were unclear and this was used in providing monthly summary reports to the Methodology Team and Project Coordinator.
- Following the Siberia Field Trip, a note of remarks/actions was distributed to team members, whose responses were collected and summarised.
- A large central database is being set up under our co-ordination with other team members. This database will enable data from all the test sites to be compared and assessed, so that a suitable classification procedure for the project can be developed.

V.4. Pre-processing and Classification: Multi-Channel Speckle Filter (WP 5030)

A multi-channel speckle reducing filter adapted to the needs of the Siberia project has been developed and implemented. This multi-channel intensity filtering makes use of the general result that speckle is minimised for each of M channels (as measured by normalised variance, i.e., reciprocal of equivalent number of looks [ENL] or squared coefficient of variation) by forming the expressions

$$J_k = \sum_{i=1}^{M} A_{ki} I_i \quad k = 1, ..., M$$

where the transpose of the vector A_k is given by

$$A_k^t = \sigma_k \frac{C_I^{-1}\sigma}{\sigma \cdot C_I^{-1}\sigma}.$$

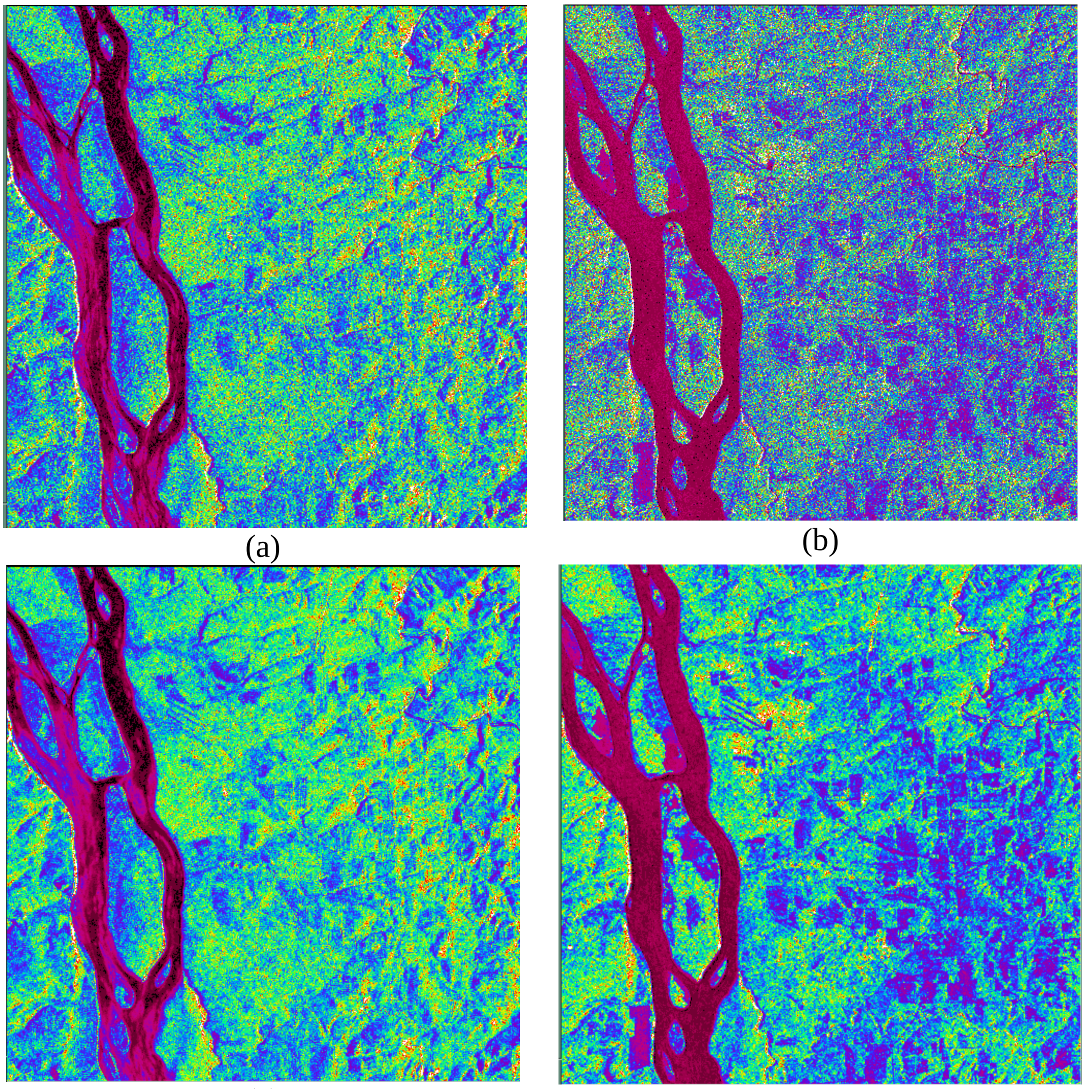
Here

$$\sigma^t = (\sigma_1, ..., \sigma_M) = (\langle I_1 \rangle, ..., \langle I_M \rangle)$$

is the vector of mean intensities and

$$C_I(i,j) = \langle I_i I_j \rangle - \langle I_i \rangle \langle I_j \rangle$$

is the covariance matrix of intensity between the channels. Both σ and C_I need to be estimated locally. This procedure therefore takes as input *M* images and outputs *M* speckle-reduced images. A working note documenting the filter algorithm was distributed among team members.



(a) (b)

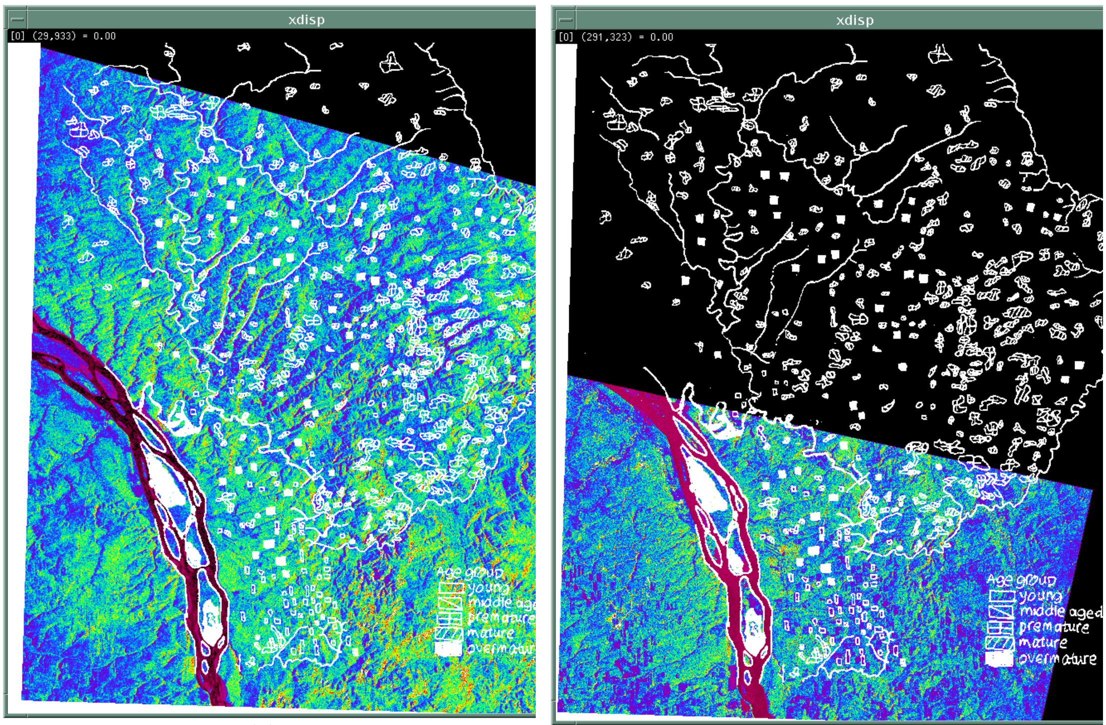
(c) (d)

Figure V-1: Bratsk: (a) original ERS-2 acquired on 24/9/97, (b) original JERS acquired on 4/5/97, (c) filtered version of (a), (d) filtered version of (b).

This filter enables images from different sensors, either correlated or uncorrelated, to be jointly filtered. In addition, because of the use of local weighting, structures in filtered images are preserved even when the parameters are not estimated adaptively. Figure V-1 (a, b) shows original ERS-2 and JERS images of the Bratsk area. The effect of filtering them in combination with one ERS Tandem pair and another JERS image from the 44-day repeat cycle, using a window size of 5 x 5 pixels, is shown as Figure V-1 (c,d). Note the improved quality; for example, some linear features covered by speckle, hence hard to distinguish in (a,b) are revealed in (c,d) [e.g. the short diagonal lines in the upper part of the image, to the right hand side of the river]. The degree of speckle reduction in the JERS image appears greater than in ERS. This visual impression, however, will shortly be quantified by examining the equivalent number of looks (ENL) in the images.

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

In February, in order to carry out data analysis whilst the digitised ground data was unavailable, a hard copy of the age map of the Bratsk area was scanned and registered to the available ERS and JERS images (see Figure V-2). A listing of the used SAR data is given in Table V-1.The backscatter and coherence were analysed as functions of age. The plot of coherence versus age is shown in Figure V-3, in which two data sets are present, one resulting from a processing window of 80-pixels, another 20-pixels. It can be seen that the coherence declines with age, exhibiting sensitivity between age classes. The difference between the two data sets is smallest for young stands, and increases when the stands get older. This is caused by the positive bias in the coherence estimator, which increases as coherence and the window size decrease. Figure V-4 shows the plots of mean intensity versus age, with standard error bars of JERS data. The JERS data show much more sensitivity than ERS in terms of age discrimination -- increasing as the stands get older, reaching a peak at the age of "mature", then decreasing a little at "overmature". The error bars indicate that, in JERS images, the young and middle aged can be clearly separated from the mature stands, and the young and overmature classes can be well discriminated from each other, because their error bars do not overlap. The preliminary results indicate that it is possible to separate age groups using JERS and coherence data, whilst ERS backscatter shows much less sensitivity. A working note about this analysis was provided to team members.



(a) (b)

Figure 2: Scanned age map registered to (a) ERS data, frame 2421, and (b) JERS data, row 202.

	Sensor	Format	Data Type	Acquisition date	ERS Frame /JERS Row	Orbit
1	ERS-1	Intensity	GEC	23/9/97	2421	32371
2	ERS-2	Intensity	GEC	24/9/97	2421	12698
3	ERS-2	Intensity	GEC	27/5/98	2421	16205
4	ERS-1/2	Coherence (20-pixels)	Generated from (1) and (2)			
5	ERS-1/2	Coherence (80-pixels)	Same as above			
6	JERS-1	Intensity	GEC	4/5/97	202	28593
7	JERS-1	Intensity	GEC	31/7/97	202	29911

Table V-I: List of analysed SAR data of the Bratsk test site.

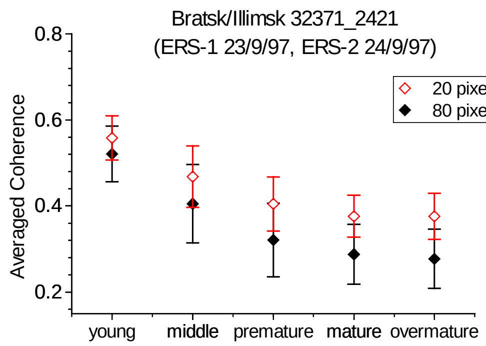


Figure V-3: Averaged coherence vs. age from the Bratsk test area.

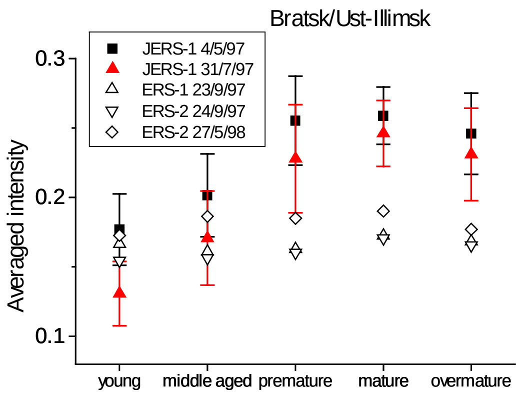


Figure V-4: Plots of mean log σ^o versus age.

Preliminary classification of the Bratsk area was carried out, by thresholding ERS coherence, JERS intensity and JERS intensity ratio images (see Figure V-5 for the overlay of these 3 images). This gives rise to three rules:

1. ERS coherence: Pixels are classified as forest (F) if the coherence is lower than 0.65 (the saddle point in the biomodel histogram); otherwise, the pixels are classified as non-forest (NF);
2. JERS intensity: Pixels with intensity values between -7.5dB and -5.5dB are classified as forest (F); otherwise, non-forest (NF);
3. JERS intensity ratio: Pixels with change less than 1.10dB are in the forest (F) class; otherwise non-forest (NF).

The above rules are based on the characteristics of forest in SAR images, i.e. low coherence, a certain range of intensity values and stable temporal backscatter. Figure V-6a shows the overlay of the three "classifications", with coherence in red, intensity in green and ratio in blue. The false-colour in the overlay represents 8 possible combinations of classifications, which are interpreted in Figure V-6b. For example, most of the river is misclassified as forest in both coherence and intensity ratio, because of its low coherence and little temporal change between the two JERS images (4/5/97 and 31/7/97). However, the river is correctly classified as non-forest using intensity, because its value is lower than the forest areas. This preliminary work raises three questions:

1. How do we weight the single-parameter classifications when they are combined?
2. Do we use a hard or soft (fuzzy) threshold?
3. What are the known explanations to the rules and can we take account of them?

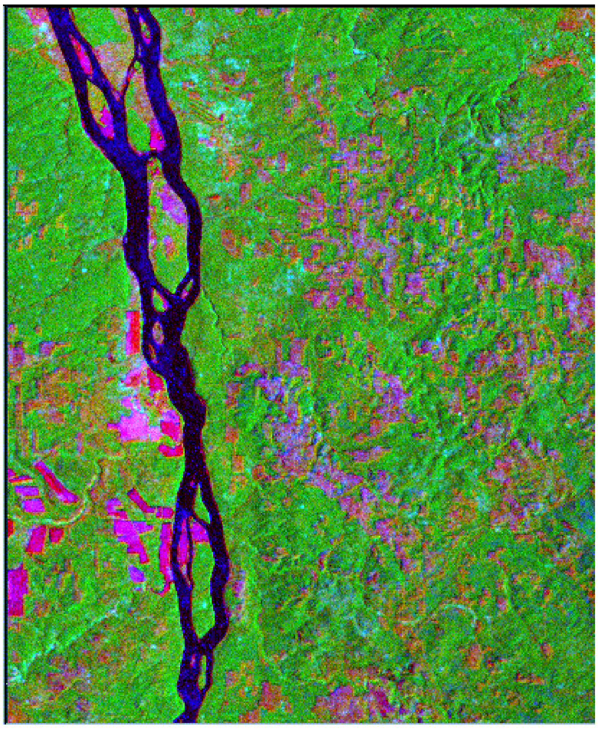
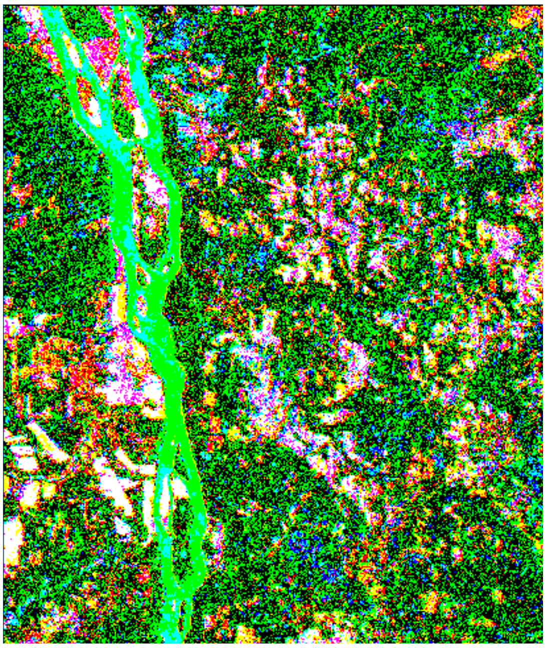


Figure V-5: Overlay of coherence (red), JERS-1 dB intensity (4/5/97, green) and dB difference between two JERS-1 images acquired on 4/5/97 & 31/7/97 (blue) of the Bratsk area. The agricultural areas and young forest stands can be clearly distinguished by their magenta colour in the overlay.



(a)

	Coherence T=0.65	Intensity* -7.5<F<-5.5	dBdif T=1.0
white	NF	NF	NF
green	F	NF	F
red	NF	F	F
blue	F	F	NF
yellow	NF	NF	F
cyan	F	NF	NF
black	F	F	F
magenta	NF	F	NF

(b)

Figure V-6: Overlay of 3 forest/non-forest classification results of the Bratsk area. F = Forest; NF = Non-Forest; using JERS intensity image acquired on 4/5/97 (multi-channel filtered); # using dB difference between JERS images acquired on 4/5/97 and 31/7/97 (multi-channel filtered).*

Also, first work on data analysis and parameter extraction has been carried out over the Bratsk area. For this purpose the rasterised ground data of the Bratsk area were registered to the available satellite SAR images. Figure V-7 shows a plot of backscatter against the available land classes within the forest area defined by the ground data.

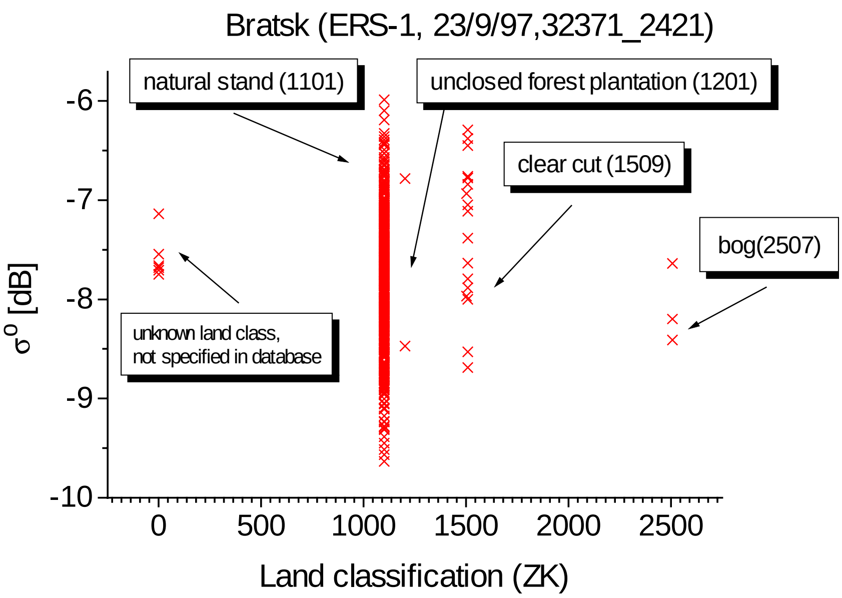


Figure V-7: Plot of backscattering coefficient vs. land classes within the defined forest area.

Further activities have been:

1. Re-calibration was carried out using updated "calit" software.
2. Following verbal agreement, the Bratsk data were transferred to the following research groups and classified using different algorithms:
   - J. Askne & P. Dammert (University of Chalmers): unsupervised classification methods based on fuzzy c-means clustering.
   - C. Oliver (DERA, UK): multi-channel segmentation and filtering.

   The two results, together with results from other methods, will be compared and assessed at SCEOS, as part of selecting the preferred classification method for the project.
3. In order to decide whether the INSAR DEM needs to be smoothed before forming the GIM, we attempted to assess the level of noise in the InSAR DEM. However, the results cannot be fully interpreted without access to a 'true' DEM and further investigation is required.

V.6. Problems and Comments

- The generation of the local incidence angle mask has not been thoroughly solved, which hampers the calibration of the GTC data.
- ERS data is generally available for all WPs. However, the achievable number of classes in the final classification will not become definite until JERS data are delivered.
- Through the Siberian trip and work at CESBIO, we understand much better the relevant components of the ground data in the project and have confidence in the data quality (although noting the implications of the time gap between the ground truth and the SAR images).
- At this stage, a crucial activity is to set up a clear strategy for the central data base, otherwise data overload and data management will present problems.

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. The one remaining issue, the delivery of the JERS-1 SAR products is currently being addressed.

Meeting at UWS: A progress meeting was held at UWS, April 19-20, 1999. It was a productive meeting, used to discuss ideas and prepare the team for the visit to Siberia in June of this year. Unfortunately, no representative of IIASA was present at the meeting even though many of our questions were related to the forest data that they have kindly provided.

Siberia excursion: Dr. Adrian Luckman and Dr. Kevin Tansey participated in the Siberia excursion.

Publications: A presentation and paper has been submitted to the annual Remote Sensing Society conference, held in Cardiff in September. The paper is entitled ‘Mapping Boreal Forest in Siberia with ERS SAR Interferometry’, by K.Tansey, A.Luckman & C. Schmullius. It will be published in the conference proceedings. Full acknowledgement is given to all other SIBERIA member institutions.

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 February 1999.

VI.3. Computational Issues (WP 5050)

The deliverables for this Work Package due at or before the 2nd progress report on month 12 include:

1. Email 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 email 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) cannot be addressed yet, as the working methodology has not been finalised.

Further to the information collected on the questionnaire distributed to all partners during the kick-off meeting in Vienna a range of solutions were presented. These were discussed in the 1st Siberia progress report. The results of these solutions are now presented.

- 1st SIBERIA Progress report stated: 'UNIX is universally used. All partners have access to PC's'. This is still valid.
- 1st SIBERIA Progress report stated: 'For software development C is familiar by all partners, although C++ is preferred by SSC'. Solution: A series of image processing tools and algorithms (polygon averaging, mutitemporal filtering etc.) have been scripted in C and made available to the team members.
- 1st SIBERIA Progress report stated: 'Establish the compatibility of similar SAR processing steps that are carried out using different software applications'. Solution: These steps will all be taken using the same (or similar) program code that will be verified or scripted by UWS. The aim is to look at collating the data from many sites and we will provide some of the tools to do that.
- 1st SIBERIA Progress report stated: 'Investigate the use of Gamma software for specific processes such as co-registration of ERS-1 and JERS-1 GEC products'. Solution: Still to be assessed due to a lack of JERS-1 imagery.

Item 6, which was added in view of partner's expressing concerns about the property rights, has been investigated by UWS. A course was attended, run by a firm of solicitors, and help and advice is available from EU sources. A working solution was agreed upon

- 1st SIBERIA Progress report stated: 'Investigate legal aspects of sharing source code between partner institutions'. Solution: A working note has been produced which specifies certain conditions and restrictions on the use of programs developed for SIBERIA. Furthermore, all work and publications should acknowledge information sources and should be copyrighted to the Siberia project and to their host institution, e.g. © Siberia, 1999, UWS, 1999. Programs when executed contain the same information so there can be no excuses for 'not knowing' when all the copyright information is provided for program users.

In addition to addressing the deliverables agreed at the start of the project, considerable progress has been made on developing a web-site for cataloguing of data, distribution of documents and meta-data and charting the progress of all aspects of the project including data delivery, processing and field data delivery. The feeling in the SIBERIA project seems to be that this is a valuable tool for the SIBERIA consortium and should continue to be the focus of the Computational Issues Work Package (WP5050). The WEB site at http://sunset.swan.ac.uk/siberia/ contains the following information (from 1st SIBERIA progress report):

- Links to all partner institutions and to the `request for field data' web-site at IIASA.
- A 'WHAT'S NEW' page that lists all the recent developments on the SIBERIA project.
- E-mail distribution list details.
- Instructions on how to access the UWS-based FTP server.
- Listings of all SIBERIA processed SAR data. Separate tables are included for ERS and JERS SAR data. Distinction between images is made in the first instance by frame followed by track.

Following a link from the frame number, further important attribute information can be accessed (data location, geographic location, data format etc.). Provision is made for searching the data archives by geographical region. This enables the user to ascertain whether processed data are available for their particular region of interest.

- Fully interactive thumbnail images linking to samples images of intensity and coherence (where interferometric products are obtainable).

Recent additions made to the UWS web site since the last report are:

- Lists of working notes produced by partners and there full content available for downloading.
- ERS and JERS status lists (produced by Wolfgang Wagner at DLR).
- Meteorological data for weather stations inside the project area (produced by Wolfgang Wagner at DLR).

An example of the ERS SAR coverage as displayed on the Web site is shown in Figure VI-1. Unfortunately, the web site is password protected because of the nature of the material on there. It is hoped to secure unrestricted access to the web site in the near future.

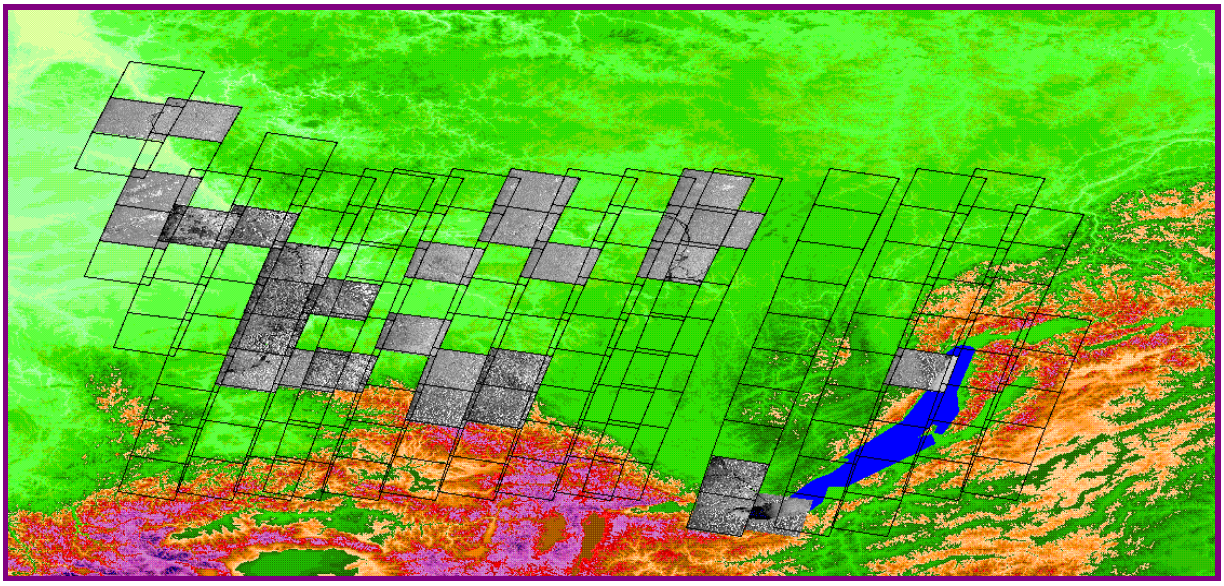

Figure VI-1: Interactive image location picture to aid and locate ERS images in the project area.

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

Progress of the methodological development in the Lake Baikal region is still severely hampered by data availability. Many locations suffer from high relief. To account for this, the Baikal study area has been reduced in size mainly focusing on the western side of the lake. To summarise; there are four ERS scenes available and no JERS-1 data yet. Of the four scenes one is of very poor quality (low coherence estimates). Ground data is restricted to one scene in the northern section of the Baikal region for which analysis is presented here and one scene at the south-western tip of Lake Baikal, which has problems with registration and geocoding. Results at this latter site have to be re-calculated. Similar problems occur at the other test territory that was designated to UWS and NERC ITE called Nishni-Udinsky. Only ellipsoid corrected products (GEC) are available and registering the ground data to these image products is proving difficult. The main cause of these difficulties is the terrain and the lack of an accurate digital elevation model (DEM).

Analyses of ERS SAR intensity and coherence products are shown below for the Ulkanskii test territory (yellow in Figure VI-2) on the western side of Lake Baikal. The southern Ulkanskii test area (in shades of black and red), for which only ERS imagery are available at this time, is located at 108.38°E, 55.06°N. Also shown are the ERS frame and track details (note that the frame used was ERS-1 orbit 32657 and not 32514 as indicated in Figure VI-2).

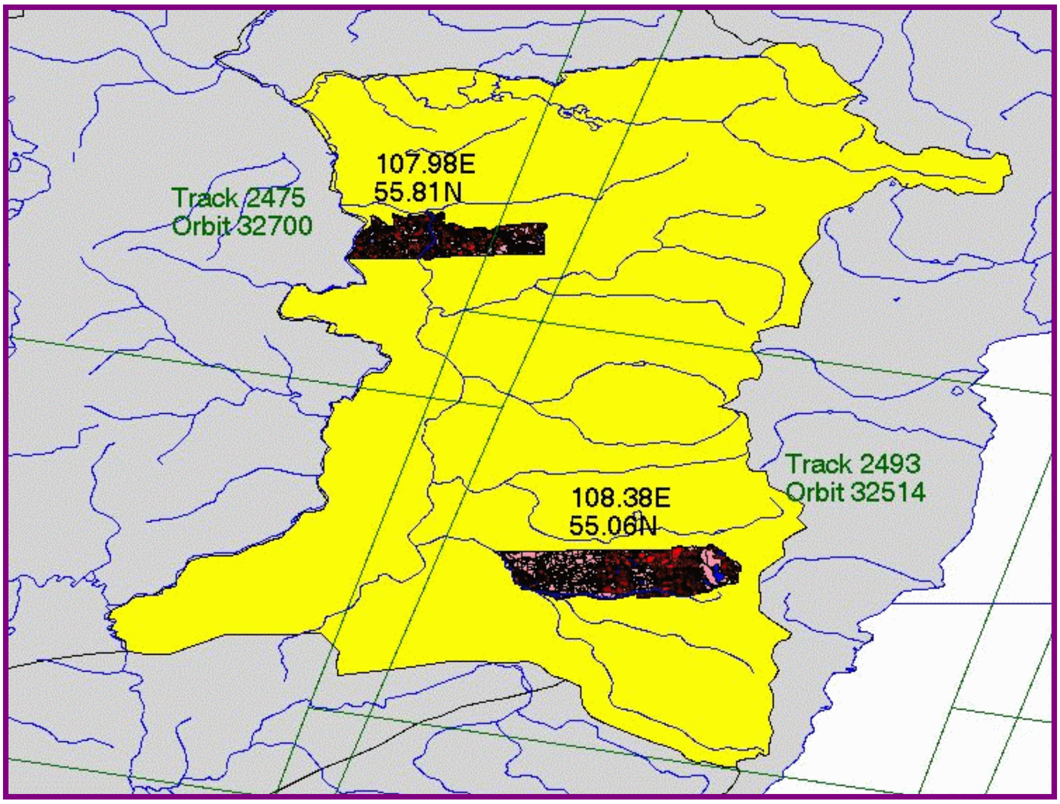

Figure VI-2: Outline of the Ulkanskii test territory on the western shores of Lake Baikal. (© IIASA, 1998).

The following results and observations can be stated:

Backscatter and Tree Age:

- The sensitivity of the backscatter coefficient with tree age is not significant for any of the images observed (ERS1/2 tandem and ERS-2 spring/summer) (Figure VI-3).
- A large (1.3 dB) difference is observed between tandem images. This has been shown to not be due to calibration of the imagery but can be explained by changes in the physical properties of the scatterers in the scene (Figure VI-3).
- The mean standard error is large for young, immature and mature trees, small for overmature trees (Figure VI-3).

Coherence and Tree Age:

- Differences in the estimate of coherence using 20 and 80 pixels can be as much as 0.12 (the 20 pixel estimate is greater) supporting findings by SCEOS (Figure VI-4).
- Considering all forest types (coniferous and deciduous) the coherence is not sensitive to dominant species age until the forest is dominantly mature. A reduction in the coherence is then observed (Figure VI-4).
- The standard error of estimation for coherence is small for overmature (in this case coniferous) forest (Figure VI-4).
- The estimates of coherence for deciduous dominated forest are more distributed than for coniferous woodland. A wide spread of values is also observed for young coniferous woodland (Figure VI-5).
- There seems to be a large difference (> 0.1) between immature deciduous and coniferous forest (Figure VI-5).
- If forest types are segregated, then the reduction in coherence is observed for coniferous forest between classes, middle-aged (class 2) and immature (class 3), and not between classes mature

(class 4) and overmature (class 5) as the data suggests would happen if tree type is not accounted for (Figure VI-5 & Figure VI-6a)

- Coherence increases with deciduous forest age class (this data set is limited by the number of samples) although more data are needed to confirm this observation (Figure VI-6b).

Backscatter and Stock Volume:

- There appears to be no relationship between this parameter and ERS backscatter (Figure VI-7).

Coherence and Stock Volume:

- The relationship between these two parameters is stronger than that for backscatter, there are no coherence values greater than 0.4 (20 pixel estimate) for a growing stock volume greater than 200 m^3/ha. Below this value of stock volume estimates of coherence increase up to 0.55, however the spread of values for areas with low stock volumes (between 30 and 200 m^3/ha) the range of coherence estimates is large (Figure VI-8).

Backscatter and Stocking (%):

- There appears to be no relationship at all between ERS backscatter and stocking given in % (Figure VI-9).

Coherence and Stocking (%):

- There appears to be no sensitivity of the ERS coherence estimate to stocking % (Figure VI-10).

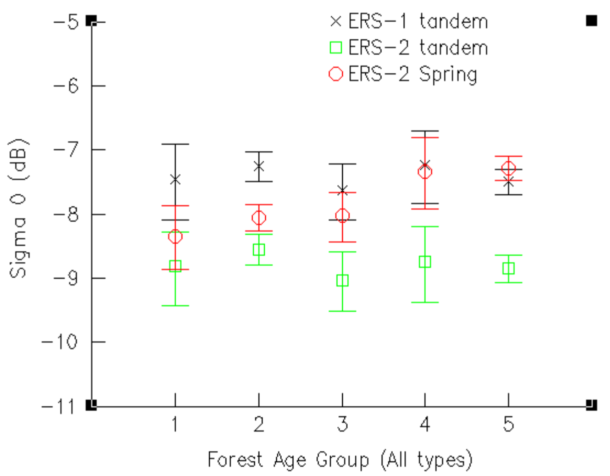

Figure VI-3. Backscatter versus tree age

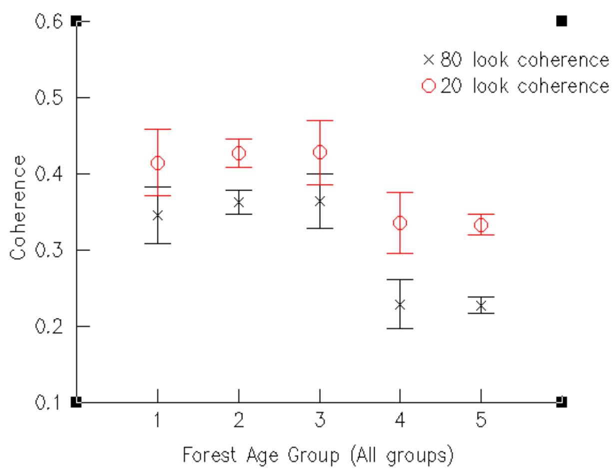

Figure VI-4. Coherence versus tree age

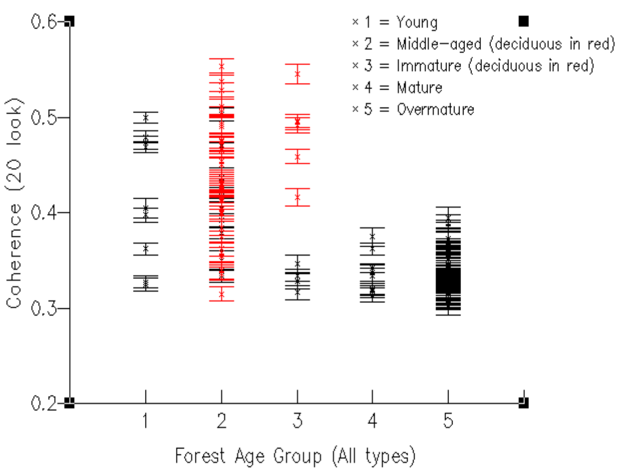

Figure VI-5. Coherence versus forest type

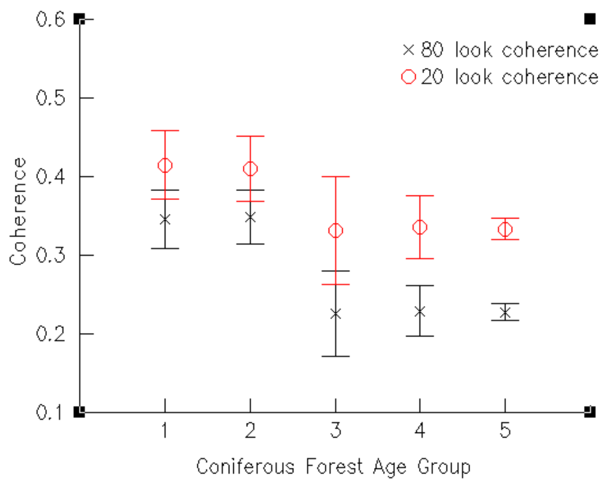

Figure VI-6a. Coherence versus coniferous forest age

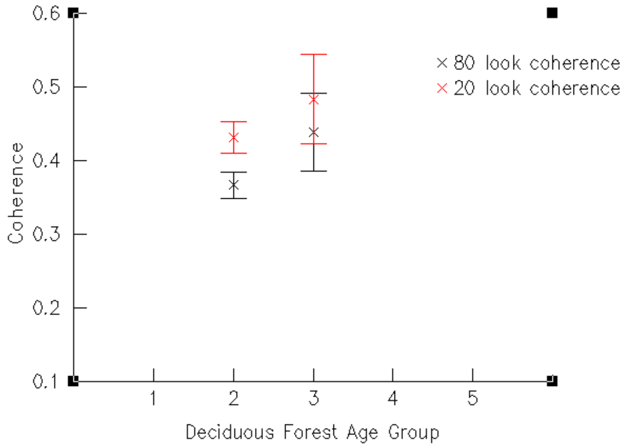

Figure VI-6b. Coherence versus deciduous forest age

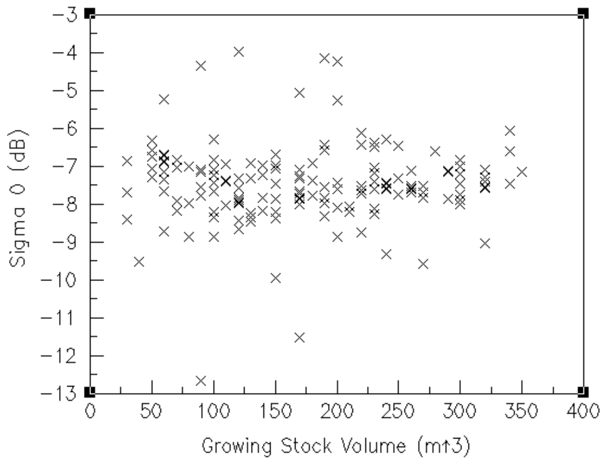

Figure VI-7. Backscatter versus growing stock volume

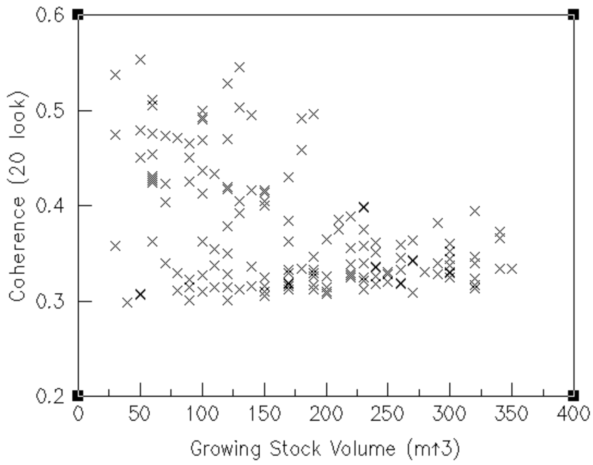

Figure VI-8. Coherence versus growing stock volume

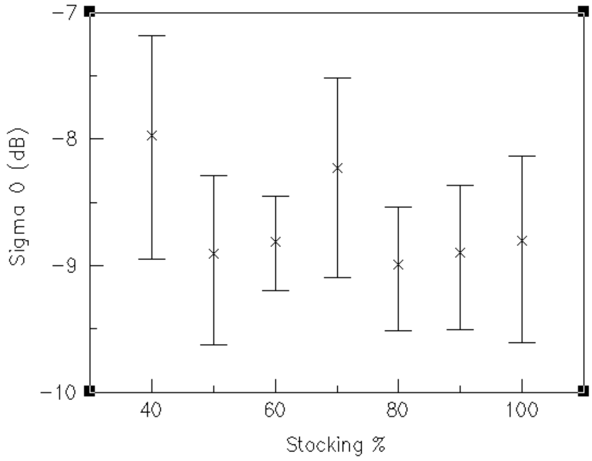

Figure VI-9. Backscatter versus stocking %

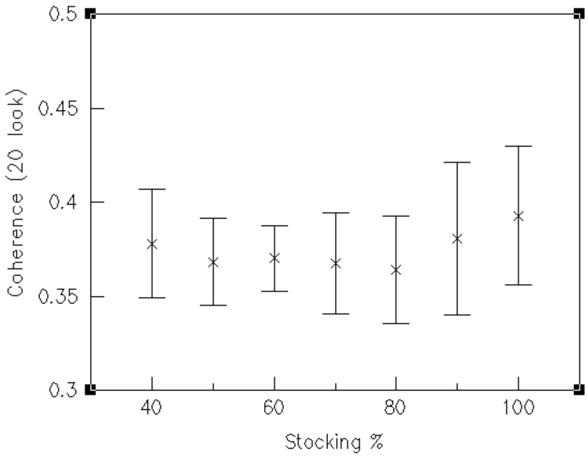

Figure VI-10. Coherence versus stocking %

VI.5. Future Plans for Methodological Development

As a direct result of the field trip to Krasnoyarsk, Irkutsk and Lake Baikal, the methodology teams decided upon a rule-based approach. The implications of this strategy on our work packages are as follows:

- Unified analysis and collation of the information content contained within images for which field data are available. We will provide the necessary programs to ensure compatibility of methods. Consultation will be made with UWS on the structure of the database that will contain the collated information. The work at Baikal and Nishni will be directly compared to other sites.
- The information contained within the imagery, especially the coherence channel can be explained by a number of factors (occurrence of forest fires, altitude, rate of re-growth etc.). These factors need to be explored further to understand causes of low and medium coherence in images.

VII Natural Environment Research Council (NERC)

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VII.1. Administrative Issues

Personnel: As was anticipated in the 1st Progress Report, Dr. Stephen Plummer took over Dr. John Baker's PIship. Dr. Heiko Balzter is still allocated to the project and ensures continuity of the work, being primarily responsible for WP 5040. Mr. David Gaveau, who joined NERC in January, is working on WP 5300 with UWS, concentrating on the southern test site at Lake Baikal.

Meetings: Dr. Heiko Balzter and Mr. David Gaveau participated in the Swansea meeting. Dr. John Baker and Mr. David Gaveau participated in the Siberia excursion.

Project Documents and Technical Notes:

- Monthly Work Package Reports to SCEOS
- Status Report in May 1999 to DLR
- Working note on the georegistration and recoding of the GIS for Ust-Ilimsk
- Working note on Accuracy Assessment
- Report on the field trip to the methodology team

Publications:

'The Iterated Contextual Probability Classifier - An Application to Forest Age Classification in Siberia', Presentation at IGARSS'99 in Hamburg, 28/6-2/7/99

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.

NERC will be working on the southern part of the test site of WP 5300, for which currently only ERS data are available. JERS and ground data are awaited in the near future.

VII.3. Methods of Accuracy Assessment (WP 4040)

As pointed out in the 1st Progress Report, an accuracy report should contain an assessment of

- geometric accuracy: standard deviation in x and y direction during co-registration;
- classification accuracy: coefficient of agreement (CA) for training areas to assess their quality;
- map accuracy: co-occurence matrix, class-specific errors of commission and of omission, overall accuracy and CA between classification and ground data.

A theoretical assessment of different coefficients of agreement was reported in the working note 'Methods of Accuracy Assessment in the SIBERIA project' from 21 June 1999. The kappa coefficient (κ) was recommended to be used by the methodology team.

VII.4. Analysis and Validation at Lake Baikal (WP 5300)

VII.4.1. Improving Map Accuracy

A new contextual classification algorithm has been developed at ITE to exploit spatial *a priori* knowledge in the SAR images to improve map accuracy. The iterated contextual probability (ICP) classifier has been applied to a small part of the Ust-Ilimsk test site, and its improvement of classification accuracy has been assessed by calculating the increase of κ compared to a Maximum Likelihood classification of two forest age classes.

VII.4.2. The ICP Algorithm

The algorithm is based on a Bayesian classification using adaptive *a priori* probabilities, as described for polarimetric SAR data by Van Zyl and Burnette (1992). Assuming a multivariate Gaussian distribution of radar backscatter and coherence, the likelihood of observing a vector Y with d elements given a particular class i is estimated from the spectral signatures with mean μ_i. Its probability density function is given by Devijver and Kittler (1982):

$$P(y|\theta)=(2\pi)^{-\frac{d}{2}}|\Sigma|^{-\frac{1}{2}}\exp\left(\frac{1}{2}(Y-\mu_i)^T\Sigma^{-1}(Y-\mu_i)\right)$$

where Σ^{-1} is the inverse of the covariance matrix and d is the number of spectral channels. y denotes the true backscatter vector and θ the true class to which it belongs.

The likelihood contains the spectral information from the SAR image, including location, size and shape of the d-dimensional hyperellipsoids and correlation between the channels. In the first iteration, uniform *a priori* probabilities are assumed. According to Bayes' theorem, multiplication of the *a priori* probabilities with the likelihood and normalisation gives the *a posteriori* probabilities:

$$P(\theta|y)=\frac{P(\theta)P(y|\theta)}{P(y)}$$

Up to this step, the classification is a standard maximum likelihood classification. To refine the classification result iteratively, contextual information on the *a posteriori* class probabilities associated with each pixel is taken into account. For a predefined window size w, any window contains $\delta=w^2$ pixels, the *a posteriori* probabilities of a pixel belonging to a given class are averaged and used as a contextual *a priori* probability in the next iteration. Finally, the weight of the contextual against the spectral information can be adjusted by raising the contextual probabilities to the power β:

$$P_i(\theta) = \left(\frac{\sum_{\delta_i} P_{\delta_i}(\theta|y)}{n_\delta} \right)^\beta$$

The normalisation constant is determined by pixel-wise summation over all products for each class:

$$P(y) = \sum_i \left(P(y|\theta) P(\theta) \right)$$

Adjustable parameters in this procedure are the window size, the number of iterations and the contextual weight.

For computational reasons, some additions have been made to the algorithm:

- For incomplete windows, the pixel values are kept constant. This affects only *w*/2 pixels at the edges of the image.
- The algorithm identifies a NULL pixel as belonging to the margins outside the geocoded image, if the pixel has only unclassified neighbours either to the right or to the left. The pixel is then kept unclassified.
- If a pixel is assumed to be unclassified because it is far away (more than 10 standard deviations) from all clusters in featurespace, it is treated as an outliner. Given *d* classes, each class gets the *a priori* probability of 1/*d* and enters the next classification iteration. This assumes that there may be pixels with highly exceptional signatures, which would belong to one of the classes on the ground.

VII.4.3. Evaluation of ICP for Forest Age Classification at Ust-Ilimsk

A simple classification has been carried out with the three classes 1) young and middle-aged forest, 2) pre-mature, mature and over-mature forest, and 3) water, for a 400 x 400 pixel sub-area of test site Ust-Ilimsk. Training areas were used to perform a Gaussian Maximum Likelihood classification which was then used to initialise the ICP algorithm. ICP was run for 10 iterations, a 5 x 5 window and a weight of 2. Input channels were:

- ERS-1 23/09/1997 intensity
- ERS-2 24/09/1997 intensity
- coherence
- ERS-2 27/05/1998 intensity
- JERS-1 04/05/1997 intensity
- JERS-1 31/7/1997 intensity

No calibration or filtering was performed.

The result after 10 iterations is shown in Figure VII-1a. A Laplacian edge detection filter was applied to the classified map to determine new clearcuts since the GIS was assembled (1991 to 1997). The results are consistent with a SPOT scene with little cloud cover (Figure VII-1b). The coefficient of agreement κ can be increased by the use of ICP (Figure VII-2). Only a few iterations are required to achieve most of this improvement from 0.29 to 0.43 (Figure VII-2).

Assuming that the new clearcuts are picked up accurately by the SAR sensors, the Russian GIS was updated with the new clearcuts derived from Figure VII-1b. This caused κ to increase from 0.43 to 0.77. The classified area has changed considerably since 1991 which explains the low accuracy.

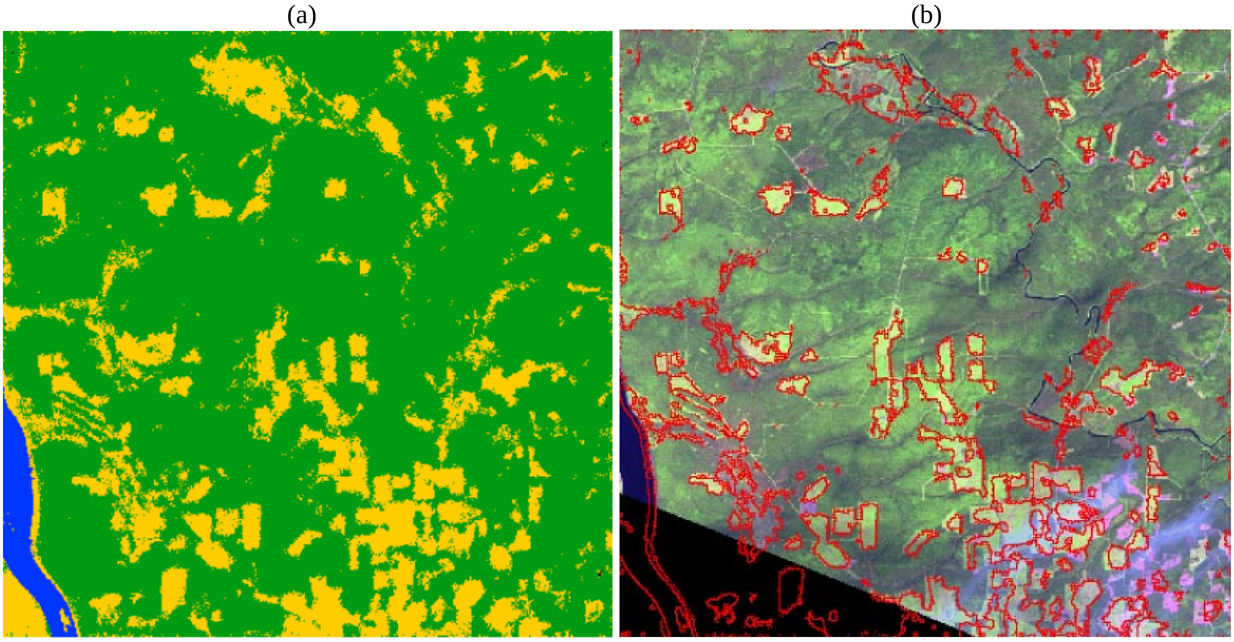


Figure VII-1: a) ICP classification of forest age at Ust-Ilimsk. Yellow: Young forest (clear-cuts and birch regrowth), green: mature forest, blue: Angara river. b) Laplacian edge detection filter from SAR (red) applied to (a), overlaid with a SPOT scene.

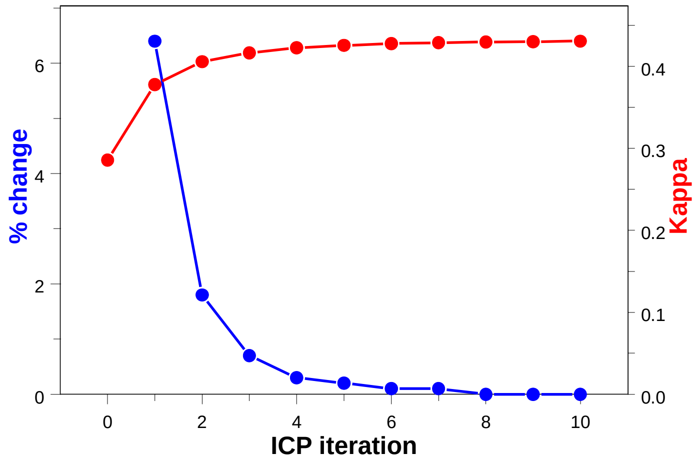
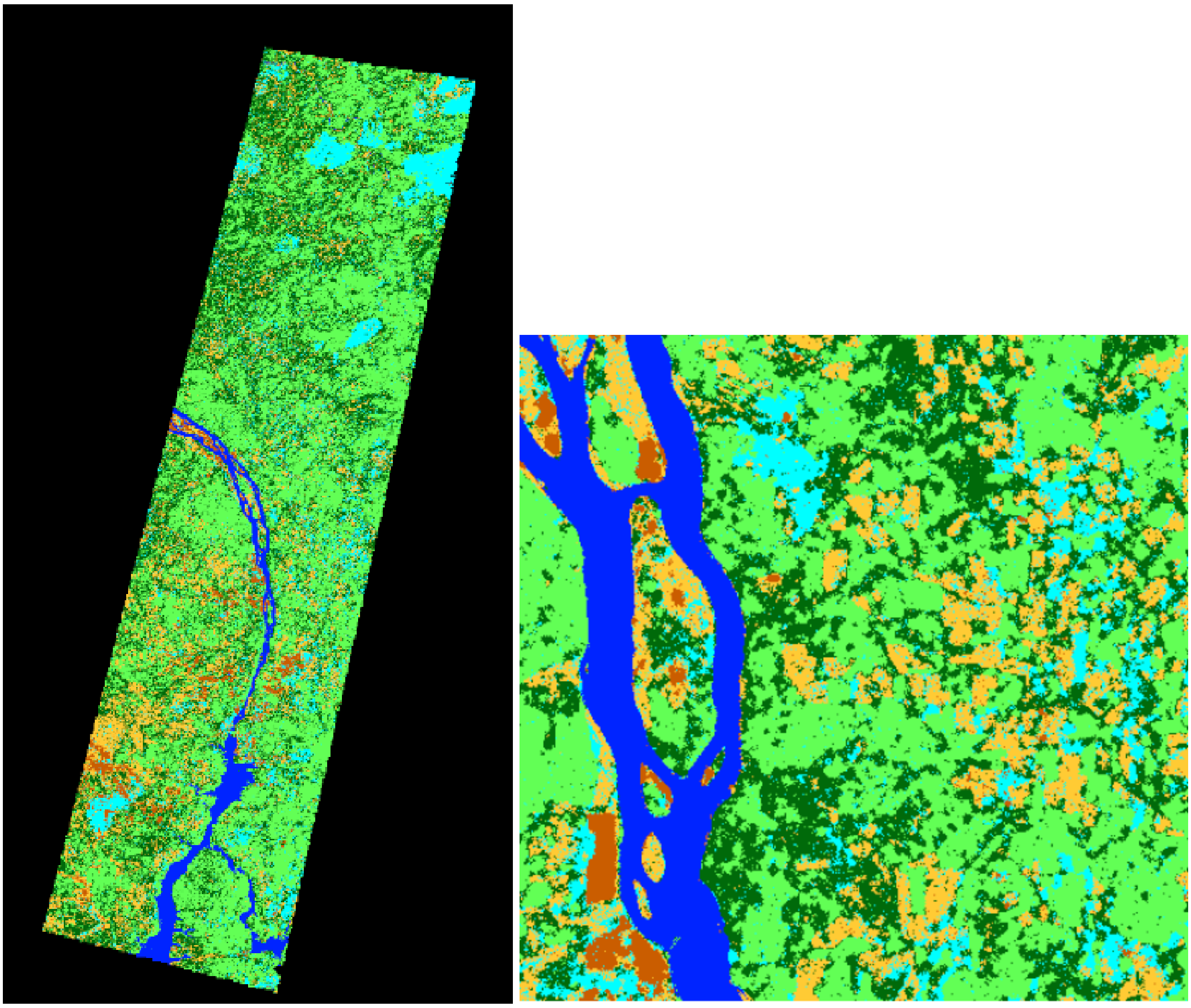


Figure VII-2: Increase of κ and decrease of the proportion of changing pixels with the number of iterations of ICP.

VII.4.4. Classification of Structural Forest Types with the Full Mosaic at Ust-Ilimsk

Having demonstrated that ICP can improve map accuracy, another Maximum Likelihood classification with 6 classes based on structural forest types has been carried out. The classes are 1) deciduous forest, 2) coniferous forest, 3) agriculture and bare soil, 4) water, 5) clearcuts and birch regrowth, and 6) bogs. ICP was run with a 5x5 window, 3 iterations and a weight of 2. The resulting thematic map stretches over more than 300 km in N-S direction and is shown in Figure VII-3a. Figure VII-3b provides a higher resolution sub-area of this classification. Despite the poor separability of coniferous and deciduous forest (Bhattacharrya distance of ca. 0.3) when using maximum likelihood, the ICP output visually corresponds well to the ground data.



(a) (b)

Figure VII-3: a) Mosaic of three ERS scenes and a JERS strip for Ust-Ilimsk. b) 20 x 20 km sub-area. Dark blue: river, light blue: bogs, dark green: deciduous forest, light green: coniferous forest, yellow: clearcuts and birch regrowth, brown: agriculture and bare soil.

An assessment of this classification should include

- an accuracy assessment;
- checking whether the light blue areas in the northern part of the image in Figure 3a are burnt areas that are misclassified as bogs, i.e. finding a signature for an additional class 'burnt stands' from other test sites;
- finding more reliable training areas for bogs;
- checking whether the classes are homogeneous with respect to total growing stock and topography.

VII.5. References

Devijver, P. A. and Kittler, J., 1982, Pattern recognition, (London: Prentice-Hall).

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

VIII.1. Administrative Issues

The work packages of VTT were scheduled to start in May 1999. Some preparatory work on the availability of high-resolution optical satellite data was made already before the Swansea meeting in Swansea (April 1999). The work in VTT Automation is on schedule.

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.

VIII.2. Responsibilities

VTT is the partner responsible for investigating the synergy between the SAR and optical data (WP 5500). Here first work on WP 5510 is reported.

VIII.3. Availability of High-Resolution Optical Satellite Data

Landsat data was identified as the primary choice for high-resolution satellite data because a single scene covers a wide area. In many test sites of SIBERIA project, the subsites are tens of kilometres apart and cannot be covered with a single scene if the scene dimension is of the order of 40 or 60 km. A survey was made on the archived Landsat data over the test sites of the project. Figure VIII-1 and Table VIII-11 summarise the data situation of the test sites.

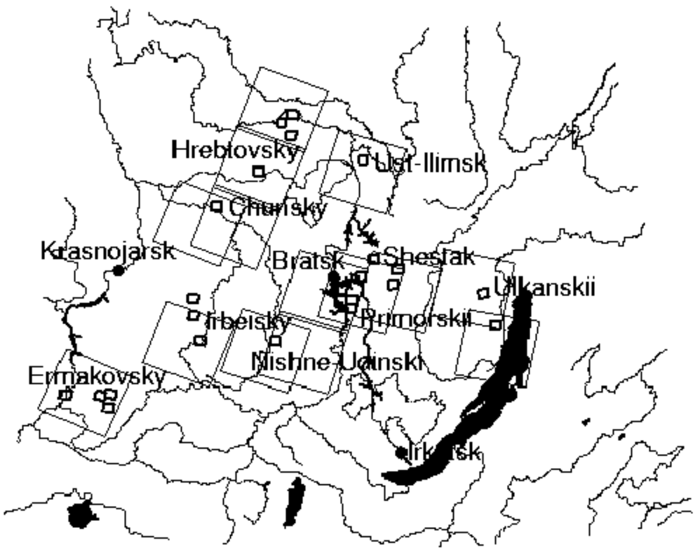

Figure VIII-1: Test sites and corresponding Landsat scenes.

Ermakovsky	1991
Irbetsky	1989
Chunsky	[1991]
Hrebtovsky	1990
Nishni-Udinsky	winter
Primorskii	1993
Ust-Illimsk	nothing
Ulanskii	[1989]
Shestak	winter

Table VIII-1: The best Landsat scenes for the test sites.

Since a major drop in price of Landsat data is expected to take place in summer 1999, no Landsat data have been ordered yet. A survey on the availability of data from the Russian RESURS satellite is underway in Swedish Space Corporation.

VIII.4. Classification of SPOT Multi-spectral Data

In absence of Landsat data, a preliminary classification experiment was made in the Ust-Ilimsk test site using the Spot XS scene provided for the project by IIASA.

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 apriori. 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. Figure 2 shows the classification result for the Ust-Ilimsk test site (a part of it).

There are some obvious misclassifications between bare soil and clouds, especially at the margins of clouds. The cloud situation of this Spot XS scene is very typical also for the Landsat data archived over the test sites. When other optical data sets are classified over the test sites, special emphasis should be put on the classification of cumulus clouds and cloud shadows.

Based on previous experience on classification of optical data over boreal forest, other misclassifications can be expected to be present, especially on the class boundary between grasses and deciduous forest.

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.

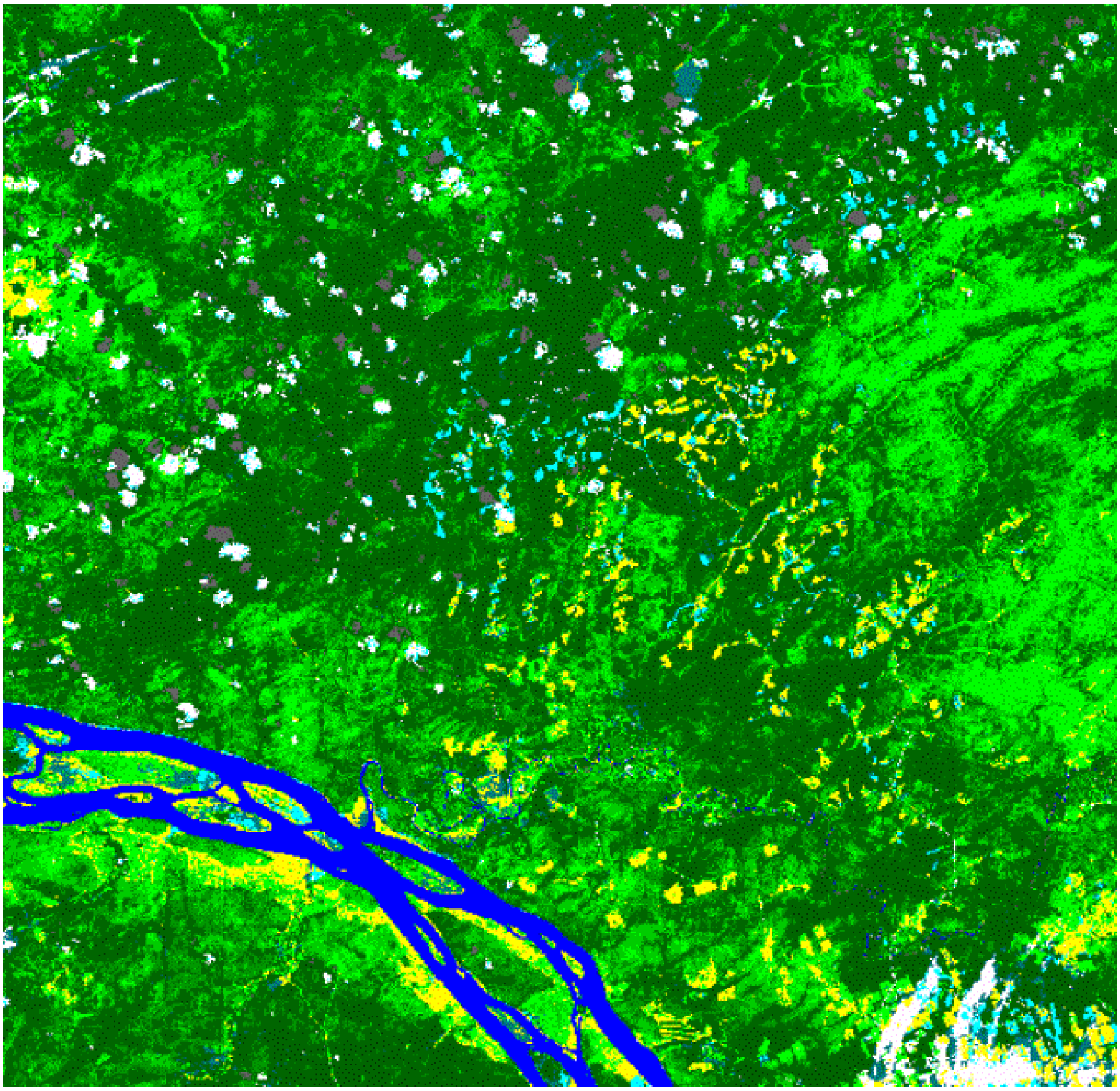

Figure VIII-2: Classification result of SPOT XS data of the Ust-Illimsk test site. The colours are: dark green = coniferous forest, light green = deciduous forest, medium green = mixed forest, light blue = bare soil, yellow = grass covered, blue = water, white = clouds, and grey = cloud shadows.

IX Gamma Remote Sensing Research and Consulting AG (Gamma)

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Further personnel: Dr. Tazzio Strozzi, Dr. Andreas Wiesmann

IX.1. Administrative Issues

Meetings: Dr. Strozzi participated in the interim meeting in Swansea.

IGARSS'99 Hamburg: U. Wegmüller, T. Strozzi, A. Wiesmann

Project Documents and Technical Notes:

Wiesmann A., U. Wegmüller, T. Strozzi: Working Note on the order and processing of JERS SAR Data within the SIBERIA project, June 1999a.

Publications:

Dammert P.B.G., U. Wegmüller: JERS INSAR DEM Quality Assessment for a Boreal Test Site, Proceedings IGARSS'99 Hamburg, June 1999.

Wiesmann A., T. Strozzi, U. Wegmüller: JERS SAR processing for the boreal forest mapping project SIBERIA, Proceedings IGARSS'99 Hamburg, June 1999b.

IX.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.

IX.3. JERS Data Acquisition Status

IX.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 Ulaanbaatar, Mongolia, in autumn 1997 and spring 1998. The Ulaanbaatar data fit the needs of the project better, however technical and manpower problems delayed the synchronisation of these data so that up-to-date no Ulaanbaatar data could be processed by Gamma. Several scenes covering the test areas have been processed using archived data of NASDA. Additional investigations were performed using JERS data over a boreal forest test site in Sweden (Dammert and Wegmüller, 1999). These data were selected for the available interferometric data pairs and high quality reference DEM.

IX.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 is on one complete summer-time coverage of the selected area. Archived data were ordered via NASDA (Osamu Isoguchi, isoguchi@restec.or.jp). Data from the DLR receiving station were ordered via DLR.

#	RSP	ROW	Date	Area	Ordered	Delivered	Processed
1	134	200-204	970504			1.9.98	16.11.98
2	134	205-209	970504			21.9.98	16.11.98
3	134	202-209	970731			13.10.98	16.11.98
4	148 150	200-210 200-210	961123 970404 961125 970406	Krasnoyarsk	5.2.99	23.3.99	13.4.99
5	120	200-210 122 124 128 130 132 134	970717 970719 970721 970725 970727 970729 970731	Lake Baikal	25.2.99		
6	148 150	211-213 211-213	961123 970404 961125 970406	Krasnoyarsk	7.4.99	20.4.99	21.4.99
7	118-138 140-142 144-1154 156-162	200-214 198-214 200-214 196-202	9807/08	Global coverage	21.5.99 Priorities set by W. Wagner (DLR-HF)		
8	118-138 140-142 144-1154 156-162	200-214 198-214 200-214 196-202	9805/06	Global coverage	21.5.99 Priorities set by W. Wagner (DLR-HF)		

Table IX-1: Ordered JERS SAR data.

IX.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.

IX.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 was applied.

#	RSP	ROW	Product	Processed	Distributed
1,2,3	134	200	SAR, baseline to large for INSAR	16.11.98	
4,6	148	200-213	SAR, INSAR	21.4.99	21.4.99
4,6	150	200-213	SAR, INSAR	21.4.99	21.4.99

Table IX-2: Processed JERS data distributed to the project partners.

IX.4. Fine Registration with ERS SAR Data

Mainly because of the limited accuracy of the JERS orbit data the registration between geocoded ERS and geocoded JERS data with offsets up to hundreds of meters is far from being perfect. This accuracy is not sufficient for the interpretation of the combined data at a local scale. Therefore, a fine registration step is required. 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-polarisation, 23° incidence angle and L-band, H-polarisation, 35° incidence angle, the technique worked well for a frame north of Ust-Ilimsk.

Appendix A

SIBERIA Project Ground Truth Data Workbook
May 1999

A.1. Introduction

This document is a guide to the ground truth data provided to the SIBERIA Project and can be thought of as a *workbook* for our Siberian Field Trip. It is not, however, a definitive report regarding Russian Forest Inventory standards or measurements. Finally, thanks to everyone who contributed questions to our Question & Answer page.

A.2. Forest Inventory

This is a brief description of forest inventory -- a complete review of remote sensing methods used in Russian Forest Inventory is forthcoming. Two types of inventory are completed for Russian forests depending on forest management requirements: on-ground (so called *lesourtroistvo*) Forest Inventory and Planning (FIP) for intensively managed forests and survey of remote unmanaged forests, basically in Siberia and the Far East. The SIBERIA project forests are located in areas inventoried by the first method.

FIP is completed in each Russian Forest Enterprise every 10 to 20 years. Approximately 70 percent of Russian forests are inventoried by FIP. Boundaries of primary inventory units (SKNR) (stands for forested areas although they may be other land classes) are, as a rule, interpreted from 1:10,000 or 1:20,000 scale aerial photos. SKNRs are basically resolved from air photos on the basis of dominant species composition, age, relative stocking, site index, origin, vertical structure, quality of growing stock and forest homogeneity. On ground measurements are used to provide final estimates of variable and verify photo interpretation. Most of the ground truth data in the SIBERIA project area is based on 1:25,000 scale photos. There are three categories of FIP that define details and accuracy of the forest inventory results.

The survey of remote forests is accomplished for the rest of Russia's forested area using a "photo-statistic" or multi-stage sample design. The first stage uses RESURS or COSMOS-based images (1:275,000 scale) to stratify the forest into forest groups (e.g. recently burned forest, mainly larch forest, etc.). Lower stages of the sample design use large-scale (1:2000-1:7000) air photo transects to estimate forest variables. The bottom stage of the sample design involves ground sample plots in which exact measurements of forest variables are made.

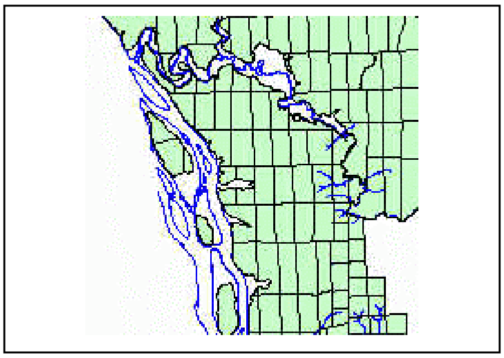
A.3. Forest Variable Definitions

Unique

In our attribute data, we have combined forest district (GIR), kvartal (KV), and stand (SKNR) into a Russia-wide unique (UNIQUE) identifier that we use to relate forest data polygons to our databases.

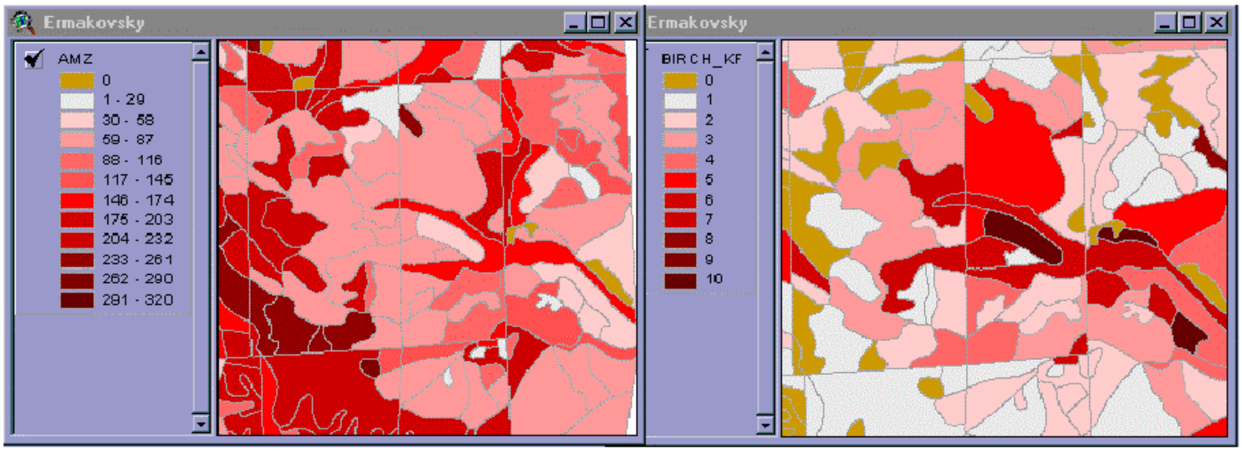
Kvartal (KV)

A kvartal is an administrative area ranging from 50 to 4000 ha. Kvartal boundaries can be natural (e.g. rivers or mountains) or artificial. For example, if you look at the Ust Ilimsk area on the right you see what look like boxes across the forest. These follow an old German system of creating forest compartments as part of the management of the forest. You may see the effect of these administrative units in the cutting patterns in the forest -- harvested areas as a rule follow kvartal boundaries.



Primary Inventory Unit (SKNR)

Each kvatal is divided into primary inventory units (SKNR) (in forested areas these are sometimes called stands). A SKNR is a relatively homogenous area in terms of tree species composition, age, height origin, site index and relative stocking. Some SKNR boundaries have an ecological origin, etc. (e.g. the edge of an area once burned by fire) and others are kvartal boundaries. The SKNR boundaries are constant but, when we look at the forest according to different attributes (e.g. age or species composition), they may become more or less pronounced. We see this if we, for example, look at a section of the Ermakovsky test area. The image on the left shows the forest displayed according to age (AMZ) whereas the right image shows the proportion of birch (BIRCH_KF). We see that the contrast among the SKNRs is very different.



It is important to recognise that SKNR boundaries are based on subjective, human interpretation, usually of aerial photos, and that they are not always visible in small-scale satellite-based remotely sensed images, but can often be recognised on large-scale images.

Area (AREA_HA)

This is the vertical projection of the area of the SKNR as reported in the forest inventory. You may notice that the GIS files also contain an "AREA" item. This is the area as measured by the GIS in square meters. The GIS area is sensitive to shifting caused by georeferencing, therefore we advise that the forest inventory area (AREA_HA) be used for analysis purposes.

Land Category (ZK)

These are the basic categories of land for which the entire landscape is classified.

1101 - natural stand

A stand of growing trees resulting from natural regeneration following a forest disturbance. By definition, these stands have relative stocking greater or equal to 10 for young age groups and greater than or equal to 30 for all other age groups.

1102 - unclosed natural forest

Forests with relative stocking of 10 to 40 for young age groups and 10 to 30 for all other age groups *if this condition is a result of climatic conditions* (i.e. altitude or climate), otherwise they are classes as sparse forests (1400)

1104 - low productivity forest

According to "All-Russia Manual", these are mature and overmature exploitable forests of site index *Va* and *V*, and forests of higher productivity if growing stock is less than 40 m^3/ha in European Russia and less than 50 m^3/ha in Siberia. These criteria can be regionally adjusted.

1108 - forest plantation

A stand of growing trees, raised artificially, either by sowing (seeds) or (most commonly) planting. A forest plantation must have at least a relative stocking of 30 for young trees and 20 for mature (less than this it is an unclosed forest plantation). In some plantations, if they have been intensively managed, one may be able to see the trees in rows.

1201 - unclosed forest plantation

This is basically a younger stage of the forest plantation. If you imagine looking down from above on a young forest in which you can still see the forest floor then the canopy is considered "unclosed" (and relative stocking is less than 30 for young trees and 20 for all others). In terms of forest management this means that there is still the possibility of competing vegetation (shrubs, grasses, etc.) to outgrow the planted trees and compete for sunlight and water resources.

1400 - sparse forest

The same relative stocking as in 1102, however, this state is the result of natural (e.g. fire) or human-induced disturbances.

1503 - burned forest

The full name of this category is burned and dead forest. This is a land category that describes areas that have experienced a "stand replacing" fire. This means that the "surviving" trees have a relative stocking of less than or equal to 10. If between 10 and 30 percent (relative stocking) survive the fire then it is classed as a sparse forest (category 1400)

1507 - stand marked for cutting

Stands planned to be cut during the year of forest inventory.

1509 - clear-cut areas

These are areas that are harvested under the clear-cut silvicultural system. They have a relative stocking of less than 10. This is a system of regenerating even-aged forest stands in which new seedlings become established in fully exposed micro-environments after most (some individual trees may remain standing) of the existing trees have been removed. Regeneration can originate naturally or artificially. Clear-cutting may be done in blocks, strips or patches. Once regrowth occurs the area could be classed into unclosed forest plantation (1201). Check the inventory update date of the test territory (this information is located on each test territory page) to verify before what date this harvest occurred.

Other - non-defined.

2102 - agriculture, hay

2103 - agriculture, pasture

2110 - stream

2308 - lake

2507 - bogs

2505 - exposed rock

2512 - talus

2540 - quarry or gravel pit

Relative Stocking (SKAL)

Let's break relative stocking down into two parts -- "relative" and "stocking". Stocking is an expression of the adequacy of tree cover on an area in terms of basal area. Basal area is the area of the cross section of a tree trunk near its base, usually 1.3m above the ground (also called breast height). Basal area is a way to measure how much of a site is occupied by trees. The term basal area is used to describe the collective basal area of trees per hectare. Relative stocking is a comparison of the stocking of a particular stand to what the ideal stocking would be under perfect management conditions. The ideal conditions are a function of site quality and can vary according to the species composition and age of the stand. There are yield tables developed for Russia that would describe fully stocked stands.

Growing Stock Volume (TUR1H)

In general, growing stock volume (TUR1H) is the STEM volume for all living species in a stand. Specifically, however, only in young stands are all stems considered. In all other stands trees must be greater or equal to 6 cm at "breast height" (1.3 m) to be included in the growing stock. The trees that are excluded from this measurement only represent about 1 percent of the volume -- so it OK to say that this variable considers all trees. It is expressed in cubic meters per hectare.

NOTE: The Ust Ilimsk database has volume in 10m3/ha units!!

Age of Dominant Species (AMZ)

This can be considered as the age of the stand expressed in years. Age *groups* are region-specific calculations that take into account forest site quality, dominant species and legislative requirements. In general, however, the age groups for the SIBERIA project area can be defined using simply the age of the dominant species. The table below shows the age thresholds for the age groups in our project area.

Species	Young	Middle-aged	Immature	Mature	Overmature
Pine, spruce, fir & larch	1-40 years	41-80 years	81-100 years	101-140 years	>140 years
Cedar	1-80 years	81 - 160 years	161 - 200 years	201 - 240 years	>240 years
Aspen & birch	1-20 years	21-50 years	51-60 years	61-70 years	>70 years

Composition (KF)

Composition is the proportion of a species in a stand on a scale of 1 to 10 (e.g. PINE_KS = 1 means 10 percent of the growing stock of the trees in the main canopy layer of the stand are pine)

Height (H)

An estimate of the average tree height of the dominant species in the stand. Expressed in meters.

Diameter (D)

An estimate of the average tree diameter of the dominant species in the stand based on a quadratic average. The diameter is measured at 1.3m or "Breast height". Expressed in decimetres.

A.4. Forest Variable Relationships

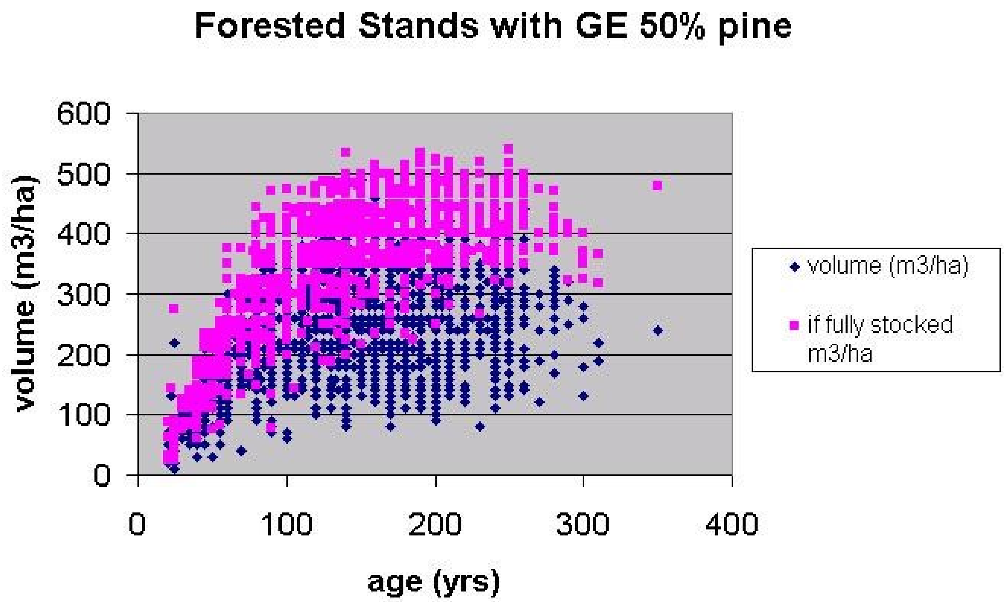
In this section we discuss the relationships among the variables with particular attention to how these relationships affect remotely sensed measurements.

Age, volume and stocking

In general, stand volume increases with age until maturity is reached after which the stand starts to loose volume through death and decay. When examining stand volume it is important to also look at the relative stocking of the stand. For example, we can consider three stands with the same volumes:

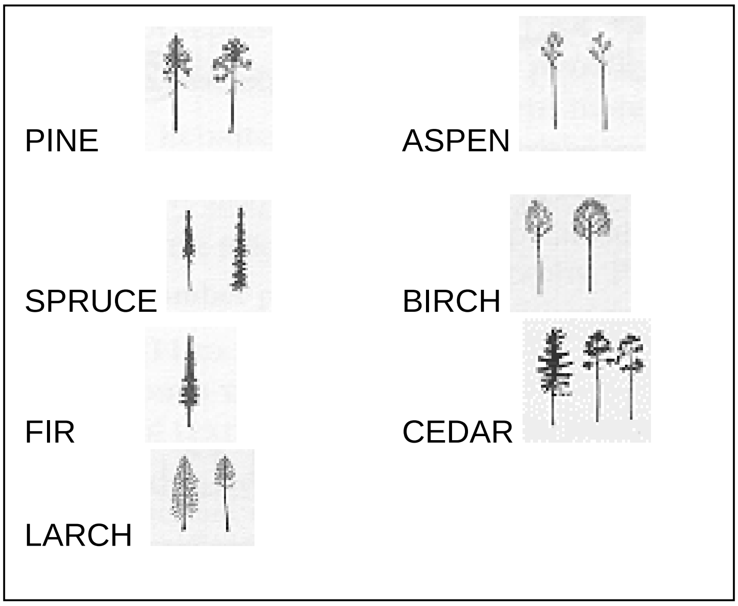
Stand	Age	Age Group	Relative Stocking	Composition	Volume
1	200	Overmature	40%	60% pine, 40%larch	150
2	60	Immature	70%	10%pine, 30%larch, 60% birch	150
3	50	Middle age	90%	100% birch	150

This does not follow the pattern we would expect until we consider stocking. These stands have different ages (and are in different age groups) but the general pattern is that the older stands have lower relative stocking. This affects the expected relationship between age and volume, however, if we calculate what the volumes *would be* if these stands were *fully stocked* (i.e. SKAL = 10) then stand one would have 375 m^3/ha, stand two 214 m^3/ha and stand three 167 m^3/ha. We can plot the forested stands from the Ust-Ilimsk test territory this way to also see this relationship.

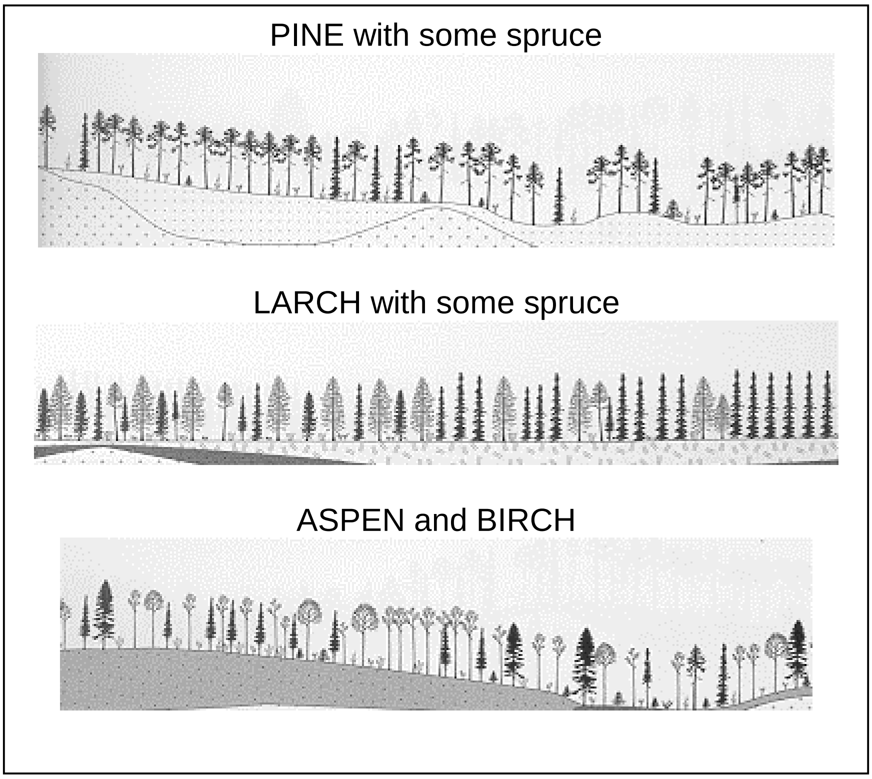


Species and Canopy Characteristics

The canopy structure of forests varies according to species composition, age, relative stocking and height. Radar-based measurements can also be affected by season and weather conditions. The following figure shows the basic form for individual trees (from Racey *et al*. 1996).



Here are some hypothetical cross-sections of forest stands (from Racey *et al*. 1996)

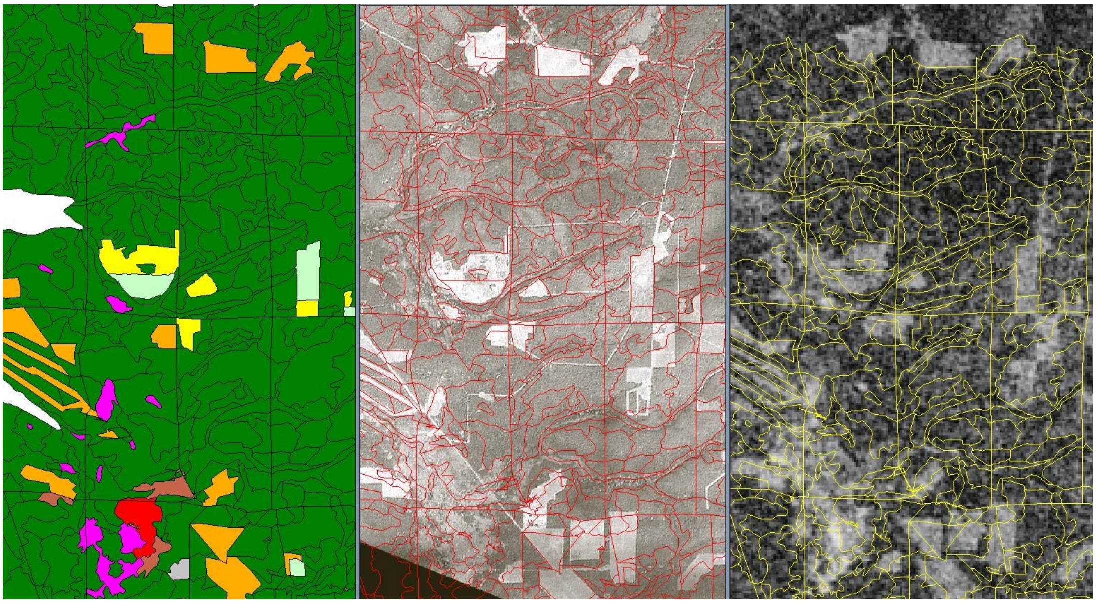


Disturbed Areas

One of the most important information requirements is to know the extent and type of forest disturbance. Forest can be disturbed naturally by biotic (e.g. fires or wind) or biotic (e.g. insects and disease) sources and through human-caused activities (e.g. harvesting, pollution). Probably the most easily detected disturbances in the SIBERIA study area are clear-cut harvesting and forest fires. The forest data must be carefully queried, however, to these areas. For example, to find recently disturbed areas in the Ust Ilimsk test territory, we should use the select clear cut stands (ZK = 1503), unclosed forest or plantations (ZK = 1102 or 1201), burned and sparse forest (ZK = 1509 and 1400) and forest stands with a young age (e.g. AMZ < 10). The figure below shows this selection and compares it to SPOT XS4 and ERS data for the same area.

Some notes:

- Some clear-cut areas still have standing trees.
- Burned areas generally have many standing dead trees.
- There may only be undetectable (remotely sensed) differences between clear-cut, plantation and young forests.
- Some clear-cut areas are not indicated in the ground truth due to the age of the data.
- Wetlands may have similar physiognomic features to recently disturbed areas and may actually have "dry surfaces" during the summer months.

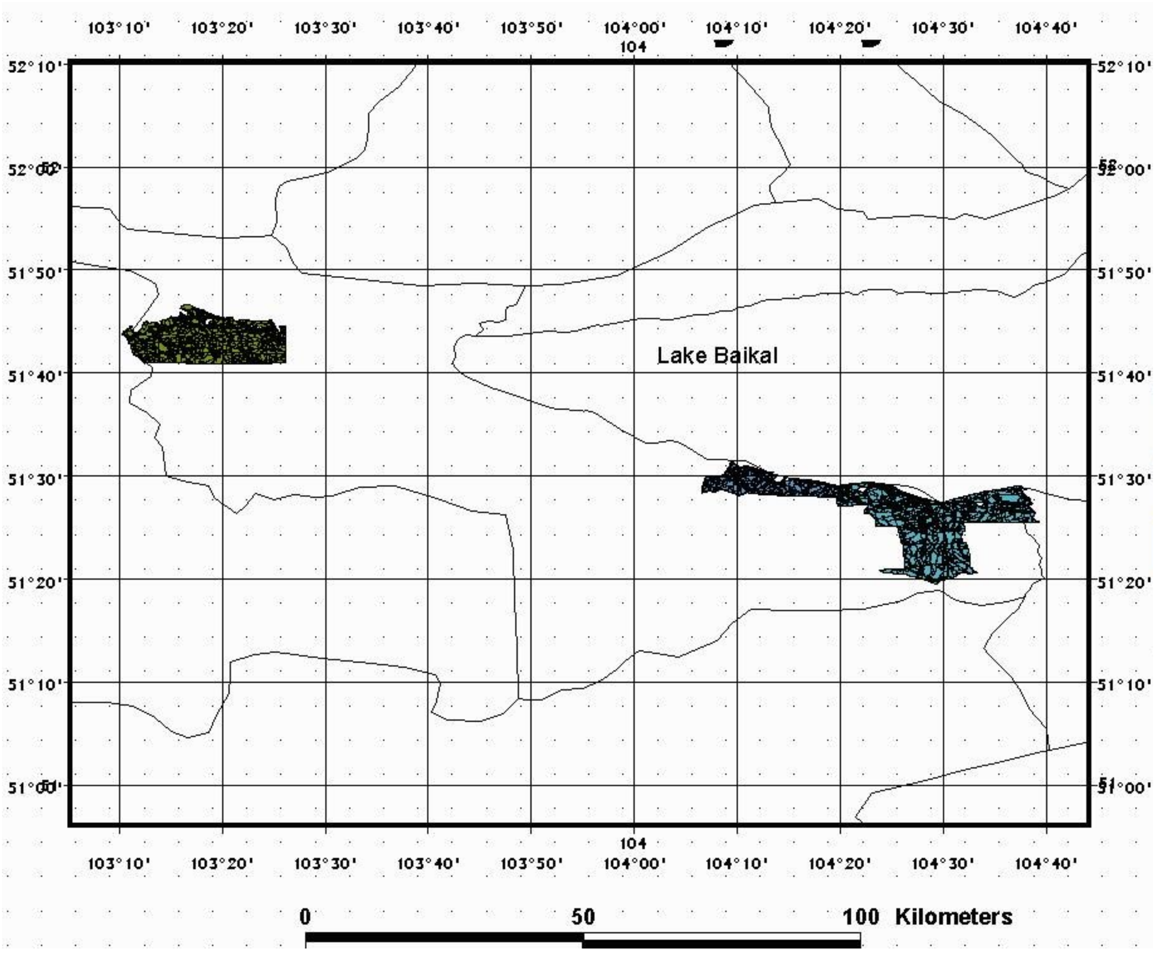


Left to right, forest map (mustard = clear cut areas, pale green = plantation, yellow = forest < 10 years, red = burned areas, pink = bogs and brown = not classed), SPOT XS4 and ERS1 coherence images with forest map polygons.

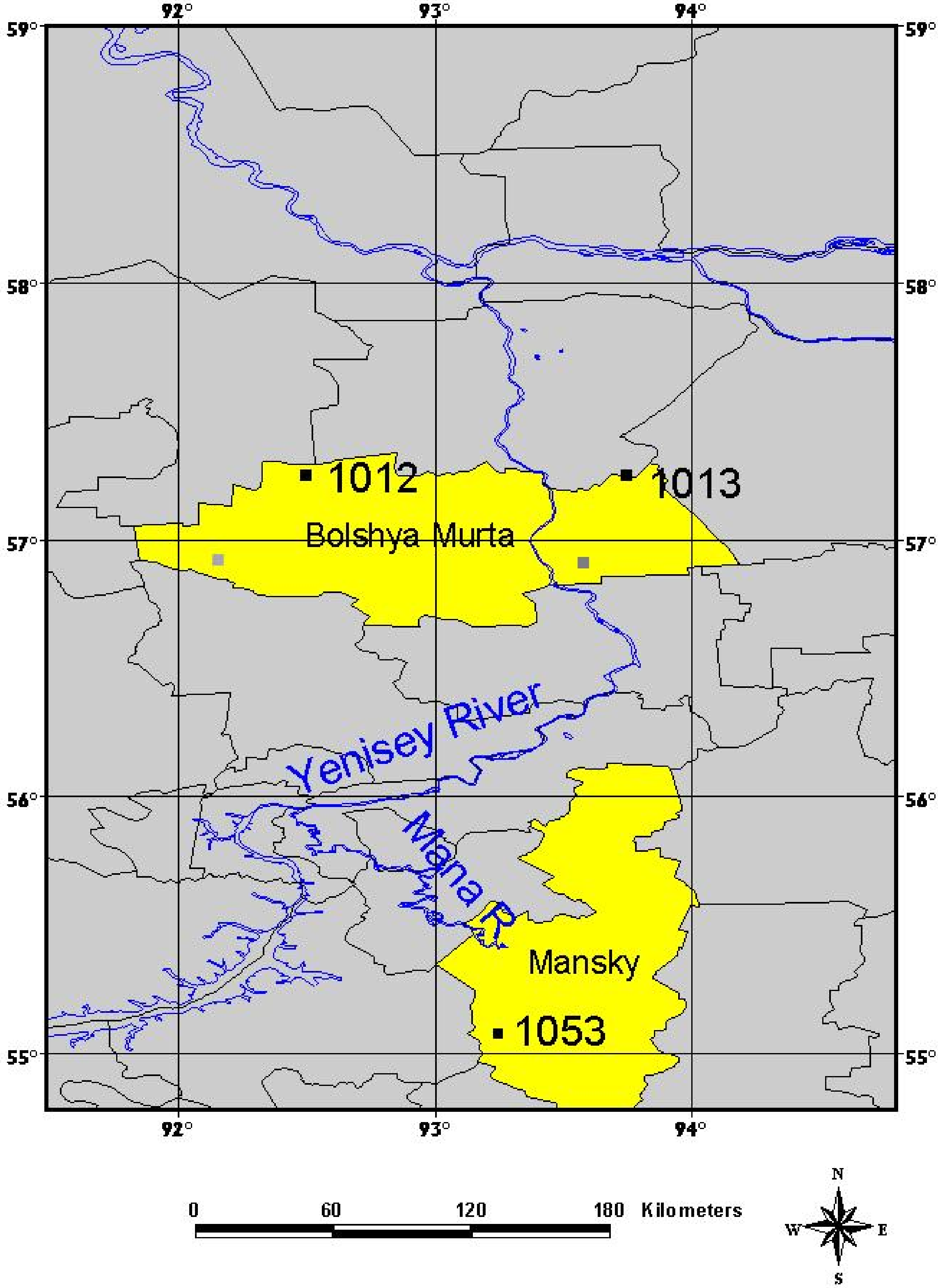
A.5. Forest Variable Estimate Accuracy

Here are the required inventory standards as described in the Russian Forest Inventory handbook. As the table below shows, the required inventory accuracy increases, as stands become ready to harvest. In general, however, one can see that the required accuracy is between 10 and 20 percent.

WHEN?	Growing stock - within XX percent	basal area (used for stocking) within XX percent	height within XX percent	composition within X percent (1 = 10 %)	diameter within XX percent
Stands to harvested	15	12	8	1	10
Stands to be thinned (pre-commercial)	20	16	10	1.5	10
All other stands	20	16	10	1.5	12



Baikal Field Trip Sites



Krasnoyarsk Field Trip Sites

Appendix B: SIBERIA Excursion Documentation

(original notes by A. Holz, edited by C. Schmullius)

PARTICIPANTS:

Anatoly Shvidenko/IIASA, Vjacheslav Rozhkov/Moscow, Michael Gluck/IIASA, Thuy Le Toan/CESBIO, Malcolm Davidson/CESBIO, Shaun Quegan/SCEOS, Jiong-Jiong Yu/SCEOS, Adrian Luckman/UWS, Kevin Tansey/UWS, John Baker/NERC, David Gaveau/NERC, Yrjö Rauste/VTT, Christiane Schmullius/DLR, Wolfgang Wagner/DLR, Jan Vietmeier/DLR, Andrea Holz/DLR.

SUNDAY, MAY 30, 1999, MOSCOW

Arrival of team members at Moscow International Airport Sheremetevo II. Transport to Hotel Minsk (on Tverskaja street near city center). Visit of Red Square. Departure from Hotel at 17 h to the National Airport Domodedevo. Take-off for Krasnoyarsk at 22:50 h local time (Moscow: 2 hours time difference from Central European Daylight-Savings Time, Krasnoyarsk: 6 hours time difference to CEDST).

MONDAY, MAY 31, 1999, KRASNOYARSK

Arrival: 07:15 h local time at Krasnoyarsk Airport. Transport to Hotel "Oktjabrskaja", prospect Mira 15, Krasnoyarsk.

15:00 Institute for Geology, Landuse and Nature Resources

Presentation by Dr. Vladimir Sokolov, SIBERIA-Partner:

Forest can be divided in 4 different categories (see also viewgraphs that have been provided as handouts):

- Forest with highest protection and possible future activity = forest far north in Krasnoyarsk Kray. Practically no harvest until now, but permafrost region. Protection needed.
- Developing forest areas north of Krasnoyarsk, rich forest, forest is exploited.
- Stabilising forest use around Abakan, no logging because of forest's stabilising function.
- Exhausted forest resources around Krasnoyarsk.

In the forests of Krasnoyarsk Kray are mainly 7 species: fir, spruce, pine, cedar, larch, aspen, birch.

Forest stem volume in Krasnoyarsk Kray is more then 6 billion m^3 of coniferous forest. 53 million cubic meters per year can be harvested and the forest still stays sustainable. Actual numbers 1993: 13 million m^3, 1995: 9 m^3, plan for 2000: 16 m^3. Territory is huge and remote sensing and other methods are useful to keep inventory up-to-date.

The total SIBERIA project area covers 6 different ecoregions. Forest management practices are changed according to the local conditions. These regions also need inventory methods adjusted to the ecology. The primary inventory units for different ecosystems here in Krasnoyarsk Kray are typically about 25-30 ha.

Leskhoz = Russian forest enterprise, that is a management unit with separate budget etc. There are 57 different forest enterprises in the Krasnoyarsk Kray.

16:00 "State East Siberian Forest Management Enterprise, Federal Forest Service of Russia", Krupskaya 42.

Presentations given by Dr. Victor Skudin (SIBERIA Partner) and Dr. Vajaskan.

This enterprise started about 40 years ago with airphotos for logging information. Forest inventory intervals: 10-15 years. Goldmining and other activities are also observed. The goal is to improve the forest management. Questions to be answered are e.g. how much soil is destroyed etc. Airphotos at scales of 1: 60 000 and 1: 25 000 were presented. In 1994, big forest losses to infestation by Siberian Moth.

Today maps are produced digitally with Russian GIS-software. Formats are compatible to other systems like ArcInfo. This has been started 3 years ago. Forest enterprise maps are at the scale of 1:250,000 and 1:25,000 (this scale is confidential material). No relief is printed on maps, because topography is secret information.

Other sources of remote sensing data are used as well like: NOAA/AVHRR, Russian satellite systems like Resurs etc. But so far no satisfactory results were achieved with remote sensing data.

In 1980, big clear-cut areas were observed with air photography. This was mainly important for State Agencies to estimate tax payments.

Inventory technique: single areas are outlined on air photography, then every sector is visited and forest parameters measured.

Tour through the institute:

In one room the forest maps are produced. Smallest unit is called "blanchet", like the French word. Scale 1:1,000. Stand = smallest unit, can be forest or clear cut etc.

Maps are compatible to topographical maps with Russian coordinate system (S42). Basis are topographical maps and airphotos at 1: 25.000 scale. Airphotos are acquired on infrared film. From the airphoto interpretation, polygones are derived for the GIS. Then maps are produced. Each polygon is connected with an online info sheet (attribute file). Resulting maps are in Gauss-Krueger projection. (Question: why are the maps in Gauss-Krueger while everything else is in S42?) DEM's are not produced, see remark above.

Five different forest enterprises are served by this institute. 4 Mio hectares have been digitised this year within 6 months and with 20 people.

18:00 Internal SIBERIA Team-Meeting: (about progress of last two months since Swansea-meeting)

DLR: Within 2 month, repeat-pass JERS-1 data from the 1998-acquisition will be available. Meteorological data for all test sites for this field trip have been investigated and presented in temperature and precipitation time-plots. We had problems with JERS co-registration to ERS DEM.

IIASA: Will provide biomass for each stand, but must be calculated first from various stand tables.

USW: Time intensive software providing has to change (e.g. filtering software for different computer platforms and operations systems). Worked on GIS and co-registration to SAR data.

CESBIO/SCEOS: Bolshaya Murta color-composite for field trip, handout for Prdivinsky test site. Keep concentrated on low productivity, since high biomass saturates the SAR-data. Note: mistakes happened earlier because of different scales/units in GIS.

TUESDAY, JUNE 1, 1999, BOLSHAYA MURTA

8:00 Departure to Bolshaya Murta. On our way North, we saw the transition zone between taiga and steppe = forest steppe, with the typical black steppe soil (Tschernosem).

10:20 Arrival at Bolshaya Murta State Forest Enterprise

Presentation by Director Victor Padgornov:

This region belongs to the South-Taiga vegetation zone. 540 000 ha forest, allowable harvest is 1 Mio m^3 per year. Actually just 20% are cut. The enterprise includes 7 forest districts, 2 wood processing plants and 1 production unit for repair of electrical equipment. Total staff 200 employees, including 95 “state forest guards”, about 40 are staff engineers and technicians, 50 are quarter-rangers, 85% of the staff are graduated. The number of staff could be kept even after the economic decline of Russia. In 1995, one of the first GIS-systems for forest management has been developed here.

Forest protection and reforestation is the major task.. Reforestation is natural. 25 years ago, prescribed forest burning was forbidden, but large amount of dry material (left-over logging material) is dangerous fuel for forest fires. Now prescribed burning is scientific experiment with American foresters.

In the past, 85-90% of the logging activities were clear-cuts. Since selective harvest has started, productivity increased: 200-300 m^3 was usual, now > 400 m^3. Two techniques: regular selective harvest and gradual selective harvest. Best tree age for harvest: 100 years. Range of age classes differ with species: coniferous species have 6 age classes (each 20 years), birch has 6 age classes (each 10 years).

In 1991, last forest inventory. Major tree species spruce and fir, on Eastern side after big forest fires: birch. Very good coniferous re-growth. Young stands = low productive areas < 50 t/ha. Also big forest losses after Siberian Moth infestation in the 50’s and 60’s. Here, 30 – 100 m^3 dead material on ground. Areas that have been destroyed by insects can be identified as clear-cuts in remote sensing images. A GIS is established and updated regularly, partially by airphotos, most by ground inspections.

In this enterprise also co-operation with Americans on carbon budget analysis – 1000 test plots all over Taiga.

What is economic future? Demand for high-quality industrial wood. Big part of forest is overmature, but only 20% of allowable cuts can be done due to economical situation. Hope, that Krasnoyarsk paper plant will increase production. Major problems are on political level, not on the local activities.

Lunch in Bol’shaya Murta.

Transport to key area 1012, about 57° 17‘N, 92° 39‘E.

Succession with small, young *Betula pendula* after clear-cut, very few *Salix*. Inventory Unit 25. Underground very wet, with puddles, herbaceous undergrowth, mainly grass. Airphotos of this area from 1990 show that here was a total clear-cut, no vegetation. Residuals are *Pinus sibirica*, *Picea sibirica* and *Abies sibirica* (for common names, see Table B-1). Species composition here as indicated in GIS: 40 % Spruce, 20 % Fir, 20 % Cedar, 20% Birch. How the clear-cut areas look depends on the post-harvest treatment (burning etc.).

The ground-truth is established as follows:

1. on airphotos, boundaries of homogeneous forest stands are delineated as polygons,
2. each polygon is then inspected on the ground and the following parameters measured (list not complete, compare GIS):

- average tree height and dbh (diameter at breast height = 1.35 m per definition) for each species that is listed as dominant;
- relative stocking, scaled from 0 – 10: for example 8 means 80% of possible stocking (only trees are included which have a minimum dbh of 6.1 cm, trees of a dbh < 6.1 cm belong to undergrowth;
- main species in undergrowth are registered as well;
- "bonitet" is registered only for dominant species;
- age.

This is Quartal No. 10: 270 m^3/ha growing stock, undergrowth is herbaceous: lots of moss, farn, trefoil, horse-tail, rubus arcticus (a kind of raspberry), very wet ground.

Walk to a second clear-cut area. Here, residuals of former stand visible. Without fire this will be a coniferous stand again, now this stand is covered mainly by *Betula* (4 m height). In the forest inventory this area is possibly marked as clear-cut since the inventory was made several years ago.

Further walk into undisturbed forest: mainly *Pinus sibirica* with 80%. *Pinus sibirica* is very valuable wood and can only be harvest under very controlled conditions due to old Soviet regulations.

Dinner and overnight-stay in Bol'shaya Murta.

WEDNESDAY, JUNE 2, 1999, PREDIVINSKY

Transport to Predivinsk on the Eastern shore of Yenisey

Visit of forest enterprise "logging land and wood processing enterprise"

Meeting with Director Dr. Vladimir Michaelevitch, also associated Professor at the University in Krasnoyarsk.

The enterprise was founded in 1930. Main tasks are logging and construction work. Here is the basis station for technical wood processing of the University of Krasnoyarsk. Today the enterprise is in a horrible economic situation – the main task is to survive. One method: economic diversification. Products are: special medicine oil from *Abies*, agricultural production unit, honey production, licences for gold mining, providing road constructions, wood transportation ships. The enterprise has special social enterprises like kindergarten, cafes, shops etc.. Everything possible is done here, to keep the staff and to maintain the social structure. "If Russians would prefer Russian products, Predivinsky would be ahead!". Forest harvest per year: 160 – 170.000 m^3, of which 30 % *Picea*, 30% *Abies*, 20% *Populus*, 10% *Betula*, 10% other species. The enterprise is also starting to produce log with western standard. But wood has to be transported 6000 km to any market: to the West (Europe) or to the east (Japan).

A long-term project exists with American scientist on sustainable forest management (financing through World Bank: 60 Mio USD). In the past, harvesting occurred mainly unorganised – large amounts of dead material was left in the logged areas, which is a dangerous amount of fuel for forest fires. Nowadays, natural reforestation with various species. Since this region belongs to the transition zone between steppe and forest, forest regrowth has permanently to be monitored.

There are 970 employees in this enterprise. The forest area only of this enterprise covers 22.000 km^2 = 2,2 Mio ha (that is about half the size of the forest in France) – Finland has 50 Mio ha, Russia 68 Mio ha. 3 Mio people are employed in Russia in the forest industry. Lesosibirsk, a big city on the Yenisey further North, is more or less completely based on forest industry. Demand for domestic products exists, but companies cannot pay!

Transport to ground-truth site NE of Predivinsky, approximately at 50°12'N, 93°42'E (site N 3).

Walk to Quartal 23 on border between 22 and 23. The two stands are the same, the border is artificial. It is the border between low biomass and natural low productivity, cleared about 35 years ago. Main species are *Pinus sylvestris, Betula, Sorbus*. Initially it was *Betula* and as undergrowth coniferous, but eventually a coniferous forest will establish if no fire occurs. In case of fire, *Betula* and *Pinus sylvestris* will survive and in 100 years just *Pinus sylvestris* will be left. The residuals of *Pinus sylvestris* here are about 250 years old. Sensitivity to fire in order: *Abies* (very sensitive), *Picea*, *Larix*, *Pinus sylvestris* (not very sensitive to fire).

Drive to next stop further north: house surrounded by pasture, west of it low biomass/high coherence area (biomass ca. 30 t/ha, scrubs and little trees not higher than 3 m, mainly *Betula* and *Salix*). South of the house: pasture and forest (natural stand, No. 21). Comparison with ERS images shows that forests of less than 50 t/ha can be distinguished. The low biomass area was cleared 20 years ago, about 1973-1975. This area thus is younger but has same biomass than the above regrowth site in Quartal 23. Result: age is not a discriminator! Possible explanation is difference in regeneration. In 1981, a plantation was planted, because regeneration was bad. Belt of mother-trees (=residuals) is visible behind the low biomass area and was also recognised on the SAR image.

End of September (time of SAR images): no leaves on trees. Litter fall is finished at end of September.

Drive back to Predivinsky: short stop at place where log piles (clearly visible on ERS image, high coherence).

Early dinner in Predivinsky, ferry over Yenisey, transport back to Krasnoyarsk.

Observations: huge fields with islands of forest and bare black soil/Tschernosem (soil had been ploughed shortly, remainders of last harvest visible); wind-erosion protection using tree lines (3-4 rows of *Populus*).

21.00 Reflection Measurement Station

Measurements of forest reflectance and brightness with different spectrometers and radiometers. Small forest plantations (ca. 10 m x 50 m ?) with different species compositions had been planted between two measurement towers. Sensors were moved along a wire between these towers. Height of towers approximately 30 meters, distance ca. 500 m. This remote sensing experimental station had been operating from 1960-85.

22.00 Arrival in Krasnoyarsk

THURSDAY, JUNE 3, 1999, KRASNOYARSK:

9.30 Visit of the "Sukachev Forest Institute, Siberian Division of the Russian Academy of Sciences".

Introduction by Dr. Abaimov

The Sukachev Forest Institute is the oldest in the structure of the Academy of Sciences. Founded 1944 in Moscow. 350 employees, including 100 scientists, 30 professors and 80 PhD students, so more than 25% are PhD students. There are also branches in Tomsk and Novosibirsk. It includes the Siberian International Centre for Ecological Boreal Research. A receiving station for remote sensing data exists (NOAA/AVHRR, and Russian sensors).

During the last ten years, 30 scientific projects have been undertaken with institutes from the USA, Switzerland, Japan, Korea, Sweden, Norway, Poland, and Germany. Publications in international journals. In the past 25 years, more then 200 books have been published.

Presentation by the Deputy Director Dr. Fedor Pleshikov

There are two levels of monitoring: regional level (Siberia) and local level (selected regions of Siberia). Remote sensing data is used: NOAA/AVHRR, Kosmos, Landsat-TM, Resurs, Spot. GIS is used for regional subsystems.

A map of forest transformation was presented: changed/damaged regions, based on remote sensing data. The area of pine forest decreased, area of young stands increased twice. Forest fires are the main problem, detailed maps exist since 1987-93. Further map presentations on:

- classification with 4 different classes of transformation;
- analysis of dynamics of forests during the last 20 years;
- stages of reforestation and productivity of regeneration stages;
- maps of fire temperature extracted from AVHRR;
- index of fire danger. 50% of fires could be reliably recognised by NOAA/AVHRR;
- maps of Siberian Moth damage (forecast possibilities are also investigated).

Work in the IGBP-NES Transect has been started in the last years. Several observation stations are located in this area. Thematic maps 1: 50 000 have been prepared. In a circle of 1 ha around each observation station intensive measurements took place. Measurement stations are distributed all along the Transect. With RESURS, maps of forest productivity were generated and verified including maps of biomass and storage of soil organics. Special investigations along the Angara river to investigate restoration of vegetation after fire.

Presentation by Dr. Vyacheslav Cherkashin (manager of GIS group)

Map generation on local and regional scale. Map sector O-46 is the most investigated part around Krasnoyarsk.

- Maps of Russian forest, soil maps, vegetation and climate etc. exist at scale 1: 1 Mio.
- Dendrochronology maps are used for prediction of forest productivity.
- Maps of carbon content in vegetation and soil.
- Regional maps on species composition and age structure, landscape, forest types.
- Maps of fire history and classes of biological regimes were used to generate a fire danger map at 1 : 1 Mio.

Major case study for ecological management: Bol’shaya Murta, because of extensive moth infection in 1994-96 and large areas have changed from coniferous to deciduous. Here, maps are available at 1: 250.000. Landscape maps in “3D” and maps of possible fire-succession vegetation. SPOT and airphotos are used, remote sensing methods in general are exploited since 1976. The GIS also consists of 1: 25.000 maps.

Different levels for maps scales:

- local level 1: 500 000 to 1: 100 000
- subregional level 1: 100 000 to 1: 1 000 000
- regional level 1: 1 000 000 and smaller

Presentation by Dr. Christiane Schmullius

Overview of objectives and status-quo of the SIBERIA Project.

Presentation by Dr. Thuy LeToan

What can we extract from radar information? First started with physical models of trees (*Pinus nigra*), establishment of a tree growth model: 4 orders of branches, 9000 cylinders, position, orientation etc. are considered. Scattering contributions were estimated on *Pinus pinaster*.

Backscatter coefficient increases with phytomass, saturation at about 100 t/ha for L-band (50 t/ha for C-band). Comparison of classification results for different classes of clear-cuts with SPOT data from Yrjö Rauste. First results from ERS data..

Presentation by Guest-Professor Nobuyuki Abe, Niigata University, Japan

Study along the Yenisey in the region of Tuva, with OPS-Sensor on JERS-1. Classification of different tree species (*Pinus sylvestris*, *Pinus sibrica*) and their density. NDVI from different tree species. Co-operation between Sukachev Forest Institute and the Niigata University, Japan since 5 years.

Presentation by Dr. Slava Kharuk

He was one of the main investigators for the Spectral Reflectance Measurements Station, we had visited. He is a co-operation partner of Jon Ranson, NASA Goddard Space Flight Center. Images from SIR-C/X-SAR used for classification of vegetation.

Lunch at Academy-Restaurant

15:00 Federal Forest Service, Forest Committee for the Krasnoyarsk Region

Meeting with Director Dr. Vladimir N. Vekshin

6% (!) of the World’s growing stock belongs to Krasnoyarsk Kray. Total land area is 14 % of Russian territory. 160 Mio ha total forest land. Coniferous forest is more than 60 %. 57 different administrative levels belong to this forest agency, 52 forest enterprises (biggest forest enterprise is near the arctic circle = Taimyr, 22 Mio ha), national parks, forest protection centre. 5500 employees, 3500 forest guards. Krasnoyarsk Kray covers very diverse geographical regions, since it stretches almost from 50 – 80 degrees latitude.

Main tasks: fire protection, reforestation, insect protection, harvest. Wood harvest: 53 Mio m³ = 25 Mio ha during Soviet Era by selective logging. Perestroika caused decline to 6 Mio ha. 50% export to Japan, China, Chita, Buriatia and Mongolia.

40.000 ha have been burned out. 25 planes are used for forest fire fighting. 500 people are employed. All forest is federal property. 95% of this forest is managed by this Committee. The State’s responsibility: to protect forest! 1000 – 1500 forest fires per year = 100–120.000 ha. Last year only 12.000 ha burnt (very lucky because cold and rainy May and June and good preparation of people). Most important are prophylactic measurements, e.g. education in schools. Of 400 fires this year, 95% were caused by people, 25% in May and June by dry lightning. In July and August mainly dry lightning causes forest fires. Along the front of clouds lightning is produced: a line of fire along this track. Helicopters are following this line.

Only 40% of Krasnoyarsk Kray are under fire protection and thus observation. Every 10-12 years airphoto campaigns. To update, the data from the SIBERIA-project even in the scale of 1: 1 or 2 Mio would be very useful (even a forest/non-forest map) because of the size and difficult access to major parts of the district.

Siberian Moth “interval” every 10-12 years. 1 Mio ha was destroyed. Forest treated with two insecticides: Desos (French) and Dipel (American). Forest Patological Service works on better predicting how many moths are where.

11.-12.000 ha annually new planted forest. Existing undergrowth is protected. 100 nurseries for seedlings. 6 – 7 Mio ha harvested area from these plantations.

Krasnoyarsk Kray is the geographical centre of Russia, therefore unfortunately highest prices for transport (markets to the East and the West are 6000 km away). Only high quality wood can be sold, for example the Angara pine (Ангарская сосна). This pine has to be 120 years old for harvest. Wood rings show very regular pattern. Natural reforestation only.

In the former Soviet Union, 30% of all forest enterprises had higher debts than benefits. Benefits of healthy industry went to “sick”. This ensured 100% employment and management of forests. Regionally varying cost for transport was compensated by the Ministry of Transport. State regulations existed. A lot of wood was exported to republics like Tchetchenia. The demand for wood is still high, but there are now new custom regulations, that make it impossible to export wood to these independent states. Major problems are outside forestry: political and economical problems in Russia.

16.30 Free time in Krasnoyarsk

18.00 Internal SIBERIA Methodology Meeting

- Preparation of Mansky field site visit (originally planned location cannot be visited due to landslide – we have to use full-frame image prints, cannot use zooms).
- Discussion on classification rules.
- Discussion on GIS-parameters: necessity of biomass calculations.

20.00 Dinner (Restaurant close to Hotel)

FRIDAY, JUNE 4, 1999, MANSKY

8.00 Transport to Narva on the Mana River, southeast of Krasnoyarsk

11.00 Visit of the Mansky Forest Enterprise

Without further introduction who we are and what we are here for, we rushed in the door and asked a lot of questions and started a big discussion:

> “On our ERS images are big areas with medium coherence, sharply seperated from areas with low coherence. Both seem to be forest. But what is the difference? What are the causes for the different coherence values?”

Answers: In this area there have been several burnings. 1990 has been a very serious fire, after that only slow regeneration, and a new fire in 1997, but smaller and less intense than 1990. Since 1993, sites in the middle of the ERS scene (where coherence is medium) have been harvested. The topographical map was produced 1984. Large (medium coherence) region underwent harvesting in the 70’s. Two weeks ago all that forest burnt again.

In the coherence image, the recognisable areas from West to East: Closed Cedar Forest – “border” - *Picea, Abies, Betula* (heavily harvested forest 1975 - 1980’s).

Introduction to the Enterprise by its quarter-ranger

The area of this forest enterprise is 418.000 ha and has 70 workers. The enterprise owns a wood mill. Wood processing for local population. 500 ha per year is planted forest. 10.000 m3 is the current forest harvest. Forest fire protection: 100 guards, 12 chemical stations. 1 Helicopter and 12 personal. This is one of the few airstations for fire fighting.

Mansky is divided into two forest regions: mountain and plain forests. The forest consists basically of *Picea* and *Abies*, and further of *Betula* and Cedar. The boundary is basically formed by harvest due to ecological conditions. The Western forests mainly consist of Cedar stands, that strictly and only used for pine nut harvest.

25./26.05.99 a ground-fire went throughout 25 km of forest. It destroyed 70% of our GIS key area. A visit today it is not possible.

12.00 Embarkment onto two boats and transport to "Garden Eden" (93°34' E, 55°42' N)

Along the riverbanks (hilly terrain) mixed forest consisting of *Pinus sylvestris*, *Larix*, *Betula*, *Picea.*, *Pinus sibirica*, further *Populus* and *Picea* (*P.sibirca* mainly on steep slopes. Question of nutrients and drainage?). Where flat terrain (meadows): mainly *Betula* and *Salix*, especially on the islands in the river only *Salix*.

After lunch, transport down the Mana river to the village Bolshaya Ungut (93°25' E, 55°44' N). Short lecture by Thuy LeToan: in the ERS images, here at the village high amplitude and high coherence are visible - roofs of houses can cause high backscatter, even from wooden houses with wooden roofs.

A retired forest fire engineer who has worked here for 40 years gave us some information. In 1997, a very severe fire occurred and the regeneration of the forest was very slow. During the 1970-1980's intensive harvests. Therefore 1975, houses for about 400 people were build. Mainly *Picea*, *Abies* and some Cedar grew here before the harvest and the fire. Nowadays this is not longer an industrial zone, it is strictly protected. This zone stretches until the boarder which is recognisable in the ERS images.

Spontaneous organisation of visit of burnt forest north of the Mana river (93°22' E, 55°50' N). Only one 4-wheel drive vehicle was available. Participants: LeToan, Quegan, Schmullius, Shvidenko, Gluck, and 2 forest guards. Visit of 1990-fire area, where it meets the less severe 1997-fire area. The severe fire in 1990 had totally burned the forest. Now, nine years later, re-growth consisting of bushes and small birch trees (height < 2 m) was visible. This area has very high coherence values. Next to it, is a region of medium coherence. This had been undisturbed forest until the ground-fire went through it in 1997. Very interesting is the fact, that although the top of the canopy was still green (not burned) and only the lower ¾ of the tree were burned, this area can be recognised due to higher coherence. The fire-boarder runs along a valley with riparian vegetation (very moist, local swamps). This boarder is easily visible on the coherence image (running diagonally from SW to NE) due to medium versus low coherence areas.

19.30 Dinner (fresh fish, local schnaps, beautiful singing)

01.00 Arrival in Krasnoyarsk

SATURDAY, JUNE 5, 1999, KRASNOYARSK –DIVNOGORSK

10.00 City Tour, Visit of Yenisei Dam

13.00 Lunch

15.00 Visit of Botanical Garden at Sukachev Forest Institute

Lecture by Prof. Anatoly Shvidenko:

500 tree and shrub species in Russia. 7 tree species cover 85 % of Siberia: larch, birch, spruce, aspen, cedar, Scotch pine, fir: *Abies, Picea, Pinus sylvestris, Pinus sibirica, Larix, Betula, Populus*. 80-82% are coniferous forests.

Larch covers about 35%, forming the Northern and Southern tree line. *Larix sibirica* and *Larix dahurica* survives temperatures of –60°C and up to +21°C monthly mean temperature. Larch has a growing stock volume of about 100-300 cubic meter per hectare. The average for all Russian tree species is about 180 m^3/ha. The average leaf-on time period is from mid-May until beginning of October.

Of Birch, 30-35 different subspecies exist. They are divided into softwood and hardwood. Hardwood species, e.g. *Betula ermanii* only East of Lake Baikal. Siberian species: *Betula pendula* (or *varucosa* – old name). Litter fall is about 1^{st} of September. Only 3-5% of forest harvest is birch.

SUNDAY, JUNE 6, 1999, TRANS-SIBERIAN RAILWAY FROM KRASNOYARSK TO IRKUTSK:

13.00 Departure to Train Station

15.00 Departure of Train N250

MONDAY, JUNE 7, 1999, IRKUTSK

11:00 Arrival in Irkutsk: Welcome by Dr. Leonid Vaschuk, Irkutsk Regional Forest Management Service, SIBERIA-partner.

13.00 Transport to Russian Academy of Science in Irkutsk, Biophysical Institute.

Presentation by Dr. Leonid Vaschuk Irkutsk Regional Forest Management Service, SIBERIA-partner.

Irkutsk region contains 58 forest enterprises, which are managed by the State Forest Department. Total forest land 65.7 Mio ha plus one national park and two national forest reserves. 80% of Irkutsk Oblast is covered with forest. 9.2 Mio m^3 growing stock, of which 5.4 Mio m^3 are available for harvest. 2 % of the World's forest belongs to Irkutsk Oblast. 6.4 % of the harvest belongs to highly valuable wood. Dominant species are coniferous, covering 45 Mio ha. 5.4 Mio m^3 of mature forest, ready for harvest. 2100 forest fires in 1998. 38 forest fires today and yesterday registered. 45 fires probably by now. 98% are ground-fires, 2% are crown fires. 80% of all fires are human caused.

The amount of harvested wood dropped, maximum was in 1988. 40.7 Mio ha harvested in 1988. 12.6 Mio ha harvested in 1998. This is typical for the entire country. In the former Soviet Union, Irkutsk produced 10-11% of all Russian wood production.

Presentation by Dr. Christiane Schmullius

Overview of objectives and status-quo of the SIBERIA Project.

Discussion: Forest enterprises have to update their ground-truth every year on the basis of air photography. Question about defoliation monitoring - LeToan: defoliation should be better seen with shorter wavelengths than ERS.

Presentation by Prof. Vjacheslav Rozhkov, Dokuchaev Soil Institute, Moscow, SIBERIA-Partner

This institute controls the SIBERIA GIS-Database. Soil maps of all areas are available in the scale of 1: 100.000 to 1: 5 Mio. Landscape maps are now available at some scales.

Presentation by Prof. Mikheev, Geography Institute of the Siberian Branch of the Akademy of Science

Laboratory since 20 years, development of remote sensing methods, cartography, research on natural environments ecological investigations with remote sensing. Some work has been done in Krasnoyarsk Kray also, but now mainly in Irkutsk.. Unfortunately no radar data available. Basically optical data from Russian systems used. Mainly dealing with forest.

Presentation of GIS project for Olchon island. RESURS data is here available since October 1995. Also, some Landsat and SPOT images.

Presentation by Prof. Shamov, Institute of Plant Physiology:

The institute possesses several laboratories for ecological and dendrochronological research. Biological indicator system for biosystems along the Baikal. No remote sensing methods are used until now. Close co-operation with Geographical institute. The maps presented were generated at the Geographical Institute. Threat-maps for different insects at scale 1: 7.5 Mio. in co-operation with a Moscow forest department. Protection of endangered plants. Investigation of pollution, e.g. from Baikalsk paper mill. About 20% of damaged needles are in highly polluted areas.

17.00 Irkutsk City Tour

20.00 Internal SIBERIA Methodology Meeting

Lessons learned. Preparation of Baikal field site visit.

Brief lecture by Dr. LeToan: Coherence drops with increasing growing stock volume. In slopes this relationship becomes unclear, measurements are very scattered. The drop of coherence can be caused by bad geometry. If there is no DEM, then there is no correction of coherence as well. High coherence areas can appear in areas of dense vegetation due to geometrical aspects.

TUESDAY, JUNE 8, 1999, IRKUTSK – LAKE BAYKAL

9.00 Logistics (changing money, buying airtickets)

10.00 Departure to Lake Baykal

13.00 Lunch in Slyudyanka

14.00 Transport to Marble Quarry "Pereval" (103°30' E, 51°40' N)

Presentation by Company Geological Advisor

The marble is transported in a cable car over a distance of about 3 km. 2000 tonnes are transported per day at the moment. Marble is used for cement and decorative purpose. What it is used for depends on the mineral composition. The exploitation is done above-ground. 1 tonne costs about 2 USD at the moment. Lake Baikal is 460 m above sea level, our stop at about 1500 m at the top of the quarry.

The forests in the surrounding of the quarry consist mainly of cedar (*Pinus sibirica*). Cedar needs moisture and good soils, it is a typical tree for more humid areas. Wind exposition is also important. Other tree species of a mixed cedar forest are *Picea* and *Larix*.

16.00 Slyudyanka Forest Enterprise

Presentation by Forest Quarter-Ranger

A production plant for wild berries existed, but was closed due to economical problems. This Forest Enterprise is the most southern one of the Irkutsk Oblast. Its East-West extension is about 120 km, bordering to the East the Buryat Republic. Fires are mainly caused by people due to their economic situation. Unemployed people use more the forests for hunting and collecting plant and berries. The slope exposition has in the Slyudyanka area not a very strong impact, but this impact is increasing towards South (to Mongolia) up to extreme cases where the north-slope is forest-covered and the south-slope forest-free.

Cedar (*Pinus sibirica*) is the dominant species in 60 % of the forests. 80% of the total area is covered by forest. Protection of fire and insects is the main task. 2000 m^3 of wood are processed. Cedar nuts are collected as a selling product, only every 4-5 years. Forest is within Baykal watershed protection zone, so harvest is prohibited. Just selective log harvest for local demand and sanitary cutting.

After the Baykalsk Cellulose Kombinat started working in 1962, the fish population as well as berry harvest and forest vitality were strongly impacted.

18.00 Visit of Nature Museum, Slyudyanka

Very interesting museum with a good collection of local minerals and presentation of regional animals. (We expressed our thanks in the guest-book and Anatoly gave a donation to the museum since they are momentarily not able to pay the electricity bill.)

19.00 Transport to Guesthouse in Tibilti/Ckotimport (103°10' E, 51°50' N)

Driving East from Slyudyanka along the road to the Tunka basin, we passed one of the ground-truth sites: GIS Key Area 19 next to the road, Polygon 176 and 171. In this wetland site, *Betula* and *Pinus sylvestris* are dominant. The wetland area along the road shows on the coherence image high values. Small ridges into the swamp with higher forest densities can also be recognised with lower coherence values.

Long discussion about clustering of GIS-polygons based on other GIS-parameters (e.g. landscape, soils). Explanation of phytomass = ALL parts of tree including roots. In GIS data, look for dominant species and %-values, because e.g. a birch forest with cedars will be called “cedar forest”, due to economical importance of cedar.

21.00 Dinner, Sunset over Tunka Cordilleres, Campfire

WEDNESDAY, JUNE 9, 1999, FORESTS VISITS AT SW-SHORE OF LAKE BAYKAL

9.00 Transport to Cedar Forest and Upland Area (103°25' E, 51°45' N)

For cedar nut production, re-growth is supported by planting cut branches. After 15 years, the cedars are producing nuts. These cedars are 65 years in average. Undergrowth mainly horse-tail and grass. On the opposite slope a slope-bog is visible, caused by varying geological/pedological layers.

Drive further up-hill into the forest until bridge (polygon 87, Stand 2.): forest damaged by Siberian Moth. 7-8 years ago a ground-fire took place. The north side of this valley has low coherence, high backscatter: dense forest with mainly *Pinus sylvestris* and some *Pinus sibirica, Betula, Picea.* Comments: probably more backscatter from stems on slopes, as they can be seen very well, better than on flat areas (Quegan), backscatter cannot be used here because of the slope influence (LeToan).

11.30 Transport to Tourist Camp “Cneshnaya”

13.30 Lunch at Camp

14.30 Departure for Field Visits (104°30' E, 51°30' N)

The series of visited ground-truth sites during the following two days, familiarised the team with various low biomass cover types, where the coherence images showed high coherence values. This approach seemed to be the most fruitful, because so far the lesson had to be learned, that with ERS-images alone no discrimination of closed forest could be done. Therefore, the emphasis was now on understanding high-coherence surface types.

First stop along road, west of Vuidrino

Different *Betula* stands. North of the road young re-growth. No exact answer on age (inventory list said 40 years, but stand looked younger). Ground-truth verification failed due to braking American equipment. South of the road also *Betula* forest, older and with coniferous re-growth.

The inventory measurements were prepared by airphotos. Polygons were verified in the field with geodetical instruments. Roads and other artificial features are also used for boarder determination. Species composition, biomass, height etc. have been measured.

Walk into forest (Area 19)

The inventory has been done 15 years ago, now only birches are here. Average age is 30 years, average height 8 meters, relative stocking 0.5, growing stock volume 35-45 cubic meters per hectare.

Some few meters further on we have the next stand: 50% *Betula*, 30% Cedar, 20% *Picea* and *Pinus*. Forest stand is marked as Cedar! *Explanation*: where coniferous species together build 50 % of the stand, there conifers are dominant by definition. Here, the dominant conifer is Cedar, therefore the stand is marked accordingly (even though as a single species only 30%). Birch is not interesting for forest harvest.

Some meters further on, 3 polygons meet:: very young birch (behind is a polygon with older birch stands), one with bog and the one with 30 % cedar, which was just visited.

Second bus stop further West

Large bog: sphagnum moss, wool grass, single very small birch trees. These are quite old: 15 years. Northwest of the bog, railroad tracks of the Trans-Siberian railway.

Third bus stop at Bridge over Xara Murin near Village Murino

15 years ago this was a hayfield, now small *Betula*, *Salix* (30 %) and shrubs. Phytomass: 10-15 to/ha.

Walk to Riparian Area along River

Mosaic of meadows (very wet), old-growth of aspen and bogs.

18.30 Return to Tourist Camp and Dinner

TUESDAY, JUNE 10, 1999, BAYKALSK AND LAKE BAYKAL

9:00 Departure for Field Visits

Bus Stop between Colsan and Murino at indigenous forest: Forest classification types: virgin, natural and anthropogenically influenced forest.

The succession stages of forests after burning are:

1. first 20 years only *Betula*
2. *Picea* and *Cedar* are growing below *Betula*
3. 100 years late, birch forest has turned into coniferous forest

Betula is generally not a dominant species, just for a short period after burning or clear-cut. Here, 30-35% *Pinus sibirica*, 30-35% other coniferous, 40-30% *Betula*. Exposition-dependent differences visible: cedar prefers the warmer slopes.

Field visit to high-coherence area (burnt forest) on hill slope, South of Colsan (104°10' E, 51°30' N)

In the late 60’s strong fires, 1996 again fire (partly only ground-fire). Three years ago, 3 parallel power lines have been built (visible on ERS images). In GIS, *Betula* and *Salix* less than 1 m height, now 3 Meter. The ground-fire in 1996 was not very severe, 1997 grass started to re-grow. The fire was burning from the river up-hill. About 30 ha have been destroyed.

13.00 Lunch in Baykalsk

14.00 Visit of Baykalsk Cellulose Combinat

16.30 Embarkment on Forest Department Vessel to cross Baykal

17.30 Internal SIBERIA Methodology Meeting

Protocol of Remarks:

- Better preparation would have been necessary, but JERS data was not been available (LeToan).
- SSC will only produce frames where ERS-Tandem + Amplitude 3 (summer 1998) + JERS are available and the quality is good (Schmullius).
- Good, if we get 1 or 2 classes inside the forest, outside 3 or 4 classes (bogs, burnt areas, water, urban areas) (Quegan).
- Keep experimenting with unsupervised classification, find something robust and simple (LeToan).
- Use additional information, e.g. elevation model with 1km resolution (Luckman).
- Degree of slope is a limit of processing, it is not known yet but for sure the area around Baikal will be on that limit (Quegan).
- JERS must be the key as longer wavelength means a more stable coherence (Baker).
- 1-1.5 dB difference is expected between leaf-off/leaf-on situation. But there is more to learn, since different species behave different in time and geographical location. Look at the histograms to distinguish classes (especially for non-forest classes: agriculture, shrubs, bare soil). Focus on low productivity and low biomass areas. IIASA has no non-forest information, so algorithms have to be transferred to SSC, with which to classify only about 5 landcover-classes (not various agriculture/pasture-classes) (LeToan, Quegan).
- Coherence values will not be the same from one image to another! (LeToan)
- No idea how variable the coherence is for low biomass, we only looked on a few places (Quegan).
- We have to develop together the methodology for SSC, everyone can test on own testsites and develop ideas (Wagner)
- Concentrate on non-forest, since we have a detection problem distinguishing forest classes (Quegan).
- Put infos about own analyses on the web, that everybody can learn (Luckman).
- Pay attention to forest that is not in polygons, since it is under agricultural management (Quegan).

Actions to take for further image analysis:

- Use stock volume and then biomass for every polygon you select!
- Use for every polygon the following parameters in this order:
  - stock volume
  - biomass
  - % of deciduous forest, % of coniferous forest
  - slope
  - strange flag (something contradictory, for example high coherence but forest)
- Calculate change in amplitude and coherence.
- Select first images with strange values first and with anomalies to understand variation and problems.

Decisions:

- Use GTOPO-30 as input and info.
- All teams build up a SIBERIA database: need to understand statistics of backscatter and coherence for low/high biomass classes, growing stock classes.

Questions:

- Has biomass to be calculated for all polygons? Answer: Biomass will be calculated by IIASA for representative (necessary) polygons – not all.

- Are component biomass calculations useful? Answer: perhaps –since ERS and JERS backscatter originates from different parts of canopy.

19.00 Arrival at Palavinnui-Beach (104°20' E, 51°50' N)

(...who could ever forget this last night on the shore of Baykal, despite rain and lighting...)

FRIDAY, JUNE 11, 1999, LAKE BAIKAL - LISTVJANKA

9:00 h departure with the boat to Listvjanka (near the start of the Angara river). Arriving at about 11 h, with following **visit of the Limnological Museum**. The afternoon was spent in a hotel the hill side of Listvjanka. 20:00 back to Irkutsk by bus.

SATURDAY, JUNE 12, 1999, IRKUTSK – MOSKAU

05:25 h departure (by bus) to the Irkutsk Airport.

07:00 h Flight to Moscow Sheremetevo I

end of journey

Scientific name:	**common name in English:**	**common name in German:**	**common name in Russian:**
Coniferous:			
Abies sibirica	fir	Tanne	пихта
Picea sibirica or abies or obovata	spruce	Fichte	ель
Pinus sylvestris	scotch pine	Kiefer	сосна
Pinus sibirica	cedar	sibirische Kiefer	седр
Larix dahurica, sibirica and sukachova	larch	Lärche	лиственница
Deciduous:			
Populus tremula	aspen	Zitterpappel oder Espe	тополь
Populus balsamifera?	?	Pappel (?)	осина
Betula pendula	common birch	Hänge-Birke	береза
Betula pubescens	birch mainly in bogs	Moor-Birke	береза
Salix	willow	Weide	ива
Alnus	alder	Erle	ольха
Sorbus sibirica	rowan-tree or mountain-ash	Eberesche oder Vogelbeerbaum	рабина

Table B-1: Major Siberian Tree Species.