FY02

Progress Report
And Proposal for 3rd Year Funding

COMBINED SATELLITE MAPPING OF SIBERIAN LANDSCAPES: NATURAL AND ANTHROPOGENIC FACTORS AFFECTING CARBON BALANCE

Submitted to : Dr. Garik Gutman, LCLUC Program Manger
Dr. Waleed Ablati, Polar Programs Manager
NASA HQ
Earth Science Enterprise

Principal Investigator: Dr. K. Jon Ranson
Biospheric Sciences Branch - Code 923, Goddard Space Flight Center, Greenbelt, MD 20771
TEL: 301-614-6650, FAX: 301-614-6695, EMAIL: jon.ranson@gsfc.nasa.gov

Co-Principal Investigator: Dr. Slava Kharuk
Sukachev Institute of Forest, Krasnoyarsk, Russia

Co-Investigator: Dr. Guoqing Sun
Dept. Geography, University of Maryland, College Park, MD 20742

July 17, 2002

Abstract

Siberia is an immense area stretching from the Ural Mountains on the west to the Russian Far East with total territory similar in size to the continental United States. The Siberian forests are an important source/sink of carbon with total carbon storage in Western Siberia estimated to be 4300 MT, and in Eastern Siberia about 12500 MT. Estimated annual carbon depositions are 20 and 60 MT/yr, respectively. Siberian forests are undergoing changes due to several natural and anthropogenic factors including insects, fires, logging, pollution and mineral exploration. This work is conducted by a team of scientists from NASA, University of Maryland and Sukuchev Institute of Forest and will develop and employ methods to map forest type and identify forest disturbances within the Siberian boreal forest using satellite data. This project benefits from a recent study funded by NASA's Terrestrial Ecology Program by incorporating multitemporal RADARSAT-1 data sets into ongoing analyses of combined satellite data. The approach proposed herein is especially suited for areas with frequent cloud cover and long seasonal duration of low solar illumination such as Siberia.

We are developing methods to improve mapping capabilities by using standard beam and ScanSAR RADARSAT-1 images to reveal disturbance and successional patterns within landscape classes. This project examining disturbance types with higher resolution (~30m) RADARSAT Standard Beam and Landsat 7 data and larger area mapping with lower resolution satellite data i.e., RADARSAT-1 ScanSAR, MODIS, and AVHRR. Detailed assessments also focus on two sites along the taiga-tundra ecotone to determine feasibility of using RADARSAT-1 data for verifying the northward expansion of the taiga forest in response to climate change (Kharuk et al. 1999). Results are validated with ground truth available through the Sukachev Institute of Forest in Krasnoyarsk.

During the first year.s efforts we examined the utility of various radars for wildfire burn area mapping. In addition the first merger of MODIS and Radarsat data was accomplished. During the second year an in-depth analysis of disturbance mapping was performed using combinations of radar and Landsat data. The proposed third years effort will apply these findings to larger area analyses with MODIS and Radarsat data and use multiple angle Radarsat to detect the tundra-taiga ecotone in central Siberia

Keywords: 1) Research Fields carbon cycle, forest conversion, land cover classification, 2) Geographic Area/Biome, Siberia/Boreal forest 3) Remote Sensing; Radarsat, Landsat, MODIS, IKONOS, ASTER and 4) Methods/scales. Data fusion, local/regional scales.

Combined Satellite Mapping Of Siberian Landscapes:

Natural And Anthropogenic Factors Affecting Carbon Balance

This report was prepared using the format suggested by Dr. Garik Gutman for his LCLUC projects. It has been modified to include information more pertinenet to the Dr. Waleed Ablati's Polar Program's ADRO.

ESE Science Questions

How are global ecosystems changing?

What are the changes in global land cover and land use, and what are their causes?

How is the Earth's surface being transformed, and how can such information be used to predict future changes?

LCLUC related questions.

a) What are the changes in land cover and/or land use (monitoring/mapping activities)?

Changes in forest cover are due to fire, insects, logging, mineral exploitation and pollution disturbances and migration of forest species.

b) What are the causes of LCLUC?

Disturbed areas may change to new forest or other vegetation types in response to climate change, ecosystems changed from disturbance. Human habitat is also impacted by disturbance.

c) What are the consequences of LCLUC?

Change in forest cover changes carbon balance and forest succession trajectories

ADRO2 and Polar Programs related questions

a. Encourage the efficient use of RADARSAT-1's archived data sets to aid specific applications;

b. Demonstrate the ability of RADARSAT-1 data to be used effectively in support of disaster assessment or relief efforts;

c. Extend the ability of RADARSAT-1 data to be used in operational environments.

d. Characterize forest cover, particularly in areas of frequent cloud cover, both as a primary source of information as well as a secondary source for filling in regional and global data sets when optical remote sensing data are insufficient.

e. Explore the ability to quantify changes in above-ground biomass of vegetation experiencing re-growth following a disturbance or change in land cover or use.

Proportion of the themes that are covered in this project: Carbon 30%, GOFC (mapping/monitoring of forest cover & change detection) 30%, other: Remote Sensing Science 40% , Proportion of Social Science 0%

Goals:

The goal of the project is to produce land cover maps and change maps that can be used to determine the extent and rate of natural and anthropogenic impacts on the Western Siberian boreal forest. Multitemporal RADARSAT-1 data provides a unique perspective to complement optical satellite data analysis and should enable more detailed and accurate mapping of the disturbances that are under study. This is especially relevant for detecting more subtle changes from encroachment of forest into artic and alpine tundra.

ACCOMPLISHMENTS

FY01:

Acquired Radarsat ScanSAR and ST4 data requested for Summer 2000, - Data request submitted to ASF May 2001 for multiangle ST beam Radarsat data,

Acquired MODIS, Landsat, ASTER and IKONOS data of selected sites. Coverage of 1999 or 2000 Landsat data obtained for all sites, MODIS coverage for September 8 day period acquired, Some ASTER data ordered through USGS, IKONOS data order through SSC data buy.

Conduct field surveys. Two field expeditions conducted by Sukachev Institute of Forest during the summer.

Began to merge data sets and initiate image analysis. JERS, ERS, Radarsat with Landsat 7. MODIS with Radarsat Scansar WB

Disseminate Results. Presented some initial results at IGARSS 2001 in Sydney, Australia. CEOS SAR Workshop in Tokyo April 2001. Prepared and submitted journal papers.

FY02:

Developed procedures for detailed assessment of disturbance types with high resolution (~30m) SAR and Landsat-7 data and larger scale mapping with lower resolution satellite data i.e., MODIS, RADARSAT-1 ScanSAR and AVHRR. Preliminary analysis conducted of taiga-tundra ecotone sites to determine the feasibility of SAR plus optical data for verifying the northward expansion of the taiga forest in response to climate change. Assimialte data from ground truth studies in selected sites to verify classification results. Conduct additional field surveys in disturbed areas.

Publish results. (Ranson et al., 2001, Kharuk et al., 2001, Sun et al., 2002), several articles submitted or in press.

FY03: Pending

Original approach/method

Modifications/adjustments made to overcome some problems during the period of performance.

The proposed study is designed to improve the methods of forest mapping in Siberian region for determining the magnitude and rate of change of natural and anthropogenic impacts on Siberian land cover.

Use AVHRR (1.1km) and MODIS (0.5 km) optical data and RADARSAT-1 data (0.1 km) to map the 600 X 3000 km area.

Evaluate resulting map of boreal cover and disturbance type over areas where detailed ground truth information is available.

Examined in detail areas of known change using higher resolution satellite sensors (e.g., Landsat ETM+ and RADARSAT standard beam).

Determine characteristic features related to forest disturbances using image analysis techniques including decision tree classification and spatial texture analysis.

Evaluated accuracy of results comparing map results with areas of known forest type (from field. Point-by-point comparison with ground truth map and 2) correspondence of observed spatial patterns.

Timeline: (Accomplishments in bold)

	FY01				FY02				FY03			
	1	2	3	4	1	2	3	4	1	2	3	4
Order Data												
Radarsat				**X**				X				
Landsat		**X**										
IKONOS		**X**										
MODIS			**X**	**X**	**X**	**X**						
SRTM						X						
VCL										X		
Data Fusion		**X**		**X**		**X**						
Image Analysis		**X**			**X**	**X**			X	X	X	
Field Studies			**X**	**X**			X		X	X	X	
Team Meetings					**X**				X			X
Publish Results			**X**					X				X

Bold indicated task accomplished.

Progress for the second year of the ADRO 2 and LCLUC Programs

We are developing methods to improve existing mapping capabilities by using standard beam and ScanSAR RADARSAT-1 images to reveal disturbance patterns within landscape classes. This project is developing procedures for detailed assessment of disturbance types with high resolution (~30m) RADARSAT Standard Beam and Landsat 7 data and larger scale mapping with lower resolution satellite data i.e., RADARSAT-1 ScanSAR, MODIS, and AVHRR. Detailed assessments will also consider portions of the taiga-tundra ecotone to determine feasibility of using RADARSAT-1 data for verifying the northward expansion of the taiga forest in response to climate change (Kharuk et al. 1999b). Results will be validated with ground truth acquired through efforts of the Sukachev Institute of Forest in Krasnoyarsk.

Data acquisition. We have acquired additional Landsat 7 ETM+, JERS, ERS and Radarsat data sets for several of our intensive test sites in Siberia. A temporal set of MODIS data has been acquired for the period July 2001 through June 2002. In addition we were able to acquire a few IKONOS images over three of our test area. These data are being used to augment our ground truth measurements. For example, IKONOS images of the Sayani mountains are being evaluated for estimating forest density using a technique developed by Prof. O. Niemann at University of Victoria.

Disturbance Analysis Using different radar systems and Landsat 7 for identifying forest landscape classes, especially those related to disturbance (fires, insects and logging), we found that the results were limited when using each single channel radar alone, however JERS and ERS were found to be useful for identifying certain classes. JERS was most useful for separating forest from disturbed classes with no standing trees. ERS was more useful for separating forest classes from disturbed classes where trees are left standing. Radarsat, on the other hand, was the least effective individual radar for this study. Repeating this analysis with 2001 ST5 and ST6 may improve the results. Figures 1 and 2 show the radar and Landast images for the wild fire and insect damaged study areas, respectively.

Combining the radars improved the identification of classes over results obtained with any single radar. Generally, if one radar sensor was found to have high separability for a pair of classes, adding additional radars did not greatly increase the separability. If all radars had low separability, combining the radars had very little benefit. In both sites the low separabilities found between forest and damaged forest classes indicates that classes that have large trunks present are not possible to separate using even combined radar sensor data.

Regarding the detection of disturbance, the available data was acquired over a two-year period therefore careful comparison of radars for burn scar detection was not possible. Changes in surface soil moisture can greatly change the backscatter from burn scars as shown and verified by other researchers. We plan to continue to seek and analyze radar images acquired on similar dates to provide further information on this process.

Landsat 7 ETM+ data proved the most useful of any single remote sensing system for recognizing forest type and discriminating between disturbance types. Even with non-growing season images, as was the case for the fire damaged site, the results were very promising. Combining the Landsat data with the available radar data improved the separability of classes and the overall classifications. The results also indicate that the combination of radar and Landsat 7 may be especially useful for recognizing other forest types by utilizing the structural information of radar and spectral information of Landsat 7. As radar and Landsat 7 data becomes more widely available combining these data sets should improve the accuracy of forest mapping activities. However, there is extra effort and cost involved in registering different image types.

Taiga-Tundra Study - Preliminary work was done to examine the ability of Radarsat standard beam data to detect encroachment of tree species into the Arctic tundra (eg. See Figure 5). We acquired several Radarsat images over two polar sites (Table 1). Figure 3 shows a composite of Radarsat images of the Ary Mas ecotone study area in northern Siberia. For comparison a Landsat 7 image is also shown in Figure 3. In these image the tundra is toward the top and the taiga is at the bottom of the images. Figure 4 shows the backscatter profile (smoothed using an FFT low pass filter with a window size of 20 pixels) along a transect of 12 km (400) pixels across the ecotone. We selected this transect to cross a small lake for reference purposes in this example. A change in NDVI indicates a change in the type of vegetation present. Note the reduced level after the lake. The radar data also shows this quite well for the ST4 (39^{o}) and

ST6(44 ^{o}) beams. Not surprisingly the ST2 (27^{o}) angle shows no distinction between the tundra and taiga. We also have a series of Radarsat images for an alpine tundra area in the Polar Urals that we plan similar analysis (Figure 5). This will require dealing with the strong topographic effects in the data. We would like to examine the potential of other ST beams in the third year of this study.

Web Site Development

We have developed a web site highlighting project activities and accomplishments. Electronic versions of some of our latest publication can also be found there. The URL for the site is

http://fedwww.gsfc.nasa.gov/SMP/SMP_site/index.html.

Papers Published during the second year of the project:

2002 Sun, G., K.J. Ranson and V.I. Kharuk. 2002 Radiometric slope correction for forest biomass estimation from SAR data in the Western Sayani Mountains, Siberia. Remote Sensing of Environment, 79: 279-287.

2001 Ranson, K. J., K. Kovacs, G. Sun, V. I. Kharuk, Characterization of forests in Western Sayani mountains, Siberia from SAR data, *Remote Sensing of Environment*, 75;188-200.

2001 Ranson, K. J, G. Sun, R.G. Knox, E.R. Levine, J. F. Weishampel and S.T. Fifer. Northern Forest Ecosystem Dynamics Using Coupled Models And Remote Sensing, Remote Sensing of Environment, 75:291-302.

2001 Kharuk V.I., Kozukhovskaya, Pestunov I.A., K. J. Ranson, and G.M. Tzibulsky, Siberian silk moth outbreak monitoring based on NOAA/AVHRR images,// Issledovaniya Zemly iz Cosmosa (Russian J. of Remote Sensing), No. 1:80-86.

Additional Publications:

Submitted papers

2002 Ranson, K. J., K. Kovacs G. Sun, V. I. Kharuk. Disturbance recognition in the boreal forest using radar and Landsat 7, Submitted to Canadian J. Remote Sensing Accepted pending revision

2002 Kovacs, K. Ranson, K.J., and Sun, G. Evaluating the effects of incidence angle on radar backscatter and comparing different methods of radiometric correction of SAR images, in revision .International Journal of Remote Sensing (IJRS)

2002 Kharuk V. I., Ranson K. J., Kuz'michev V. V., Im S. T. Landsat based analysis of insect outbreaks in southern Siberia, Canadian J. Remote Sensing, Submitted

2002 Kharuk, V.I., K.J. Ranson, A.G. Kozuhovskaya, Y.P. Kondakov, L.A. Pestunov, NOAA/AVHRR satellite detection of Siberian silkmoth outbreaks in eastern Siberia. In revision to IJRS

2002 Kharuk V.I., Ranson K.J., Burenina T.A., Fedotova E.V. NOAA/AVHRR data in mapping of Siberian forest landscapes along the Yenisey transect, International J. Remote Sensing, accepted.

Symposium Presentations

2002 Ranson, K.J. , K.Kovacs and G. Sun ,Accounting for Topographic Slope Effects on Radar Backscatter in Siberian Forests, IGARSS02, Toronto, Canada

2002 Ranson, K.J., G. Sun, K.Kovacs and V.I. Kharuk. Utility of SARs for mapping forest disturbance in Siberia. IGARSS02, Toronto, Canada.

2002 Sun G., and K. J. Ranson. Modeling Lidar and Radar Returns of Forest Canopies For Data Fusion, IGARSS02, Toronto, Canada.

2001 Kovacs, K., K. J. Ranson. V. I. Kharuk, and G. Sun, Siberia Landscape disturbance study, Eos Trans. AGU, 82(47), Fall Meeting Suppl., San Francisco, USA 2001.

2001 Ranson, K. J., K. Kovacs, V. I. Kharuk, and G. Sun, Siberia landcover analysis with MODIS and Landsat, Eos Trans. AGU, 82(47), Fall Meeting Suppl., San Francisco, USA 2001.

2001 Kharuk, V.I. and K.J. Ranson, Antropogenic impact on the middle Siberian taiga caused by gold mining, Nice France,
2001 Sun, G. and K.J. Ranson terrain effect on forest radar backscatter: modeling and correction, CEOS SAR Meeting, Tokyo, Japan, May 2001.
2001 Ranson, K.J., G. Sun, V.I. Kharuk and K. Kovacs, Siberian Forest Classification With Fused Data Sets, IGARSS01, Sydney, Australia, 9-13 July.
2001 Ranson, K.J., G. Sun , V.I. Kharuk and K.Kovacs. Fire scar and logging detection in the boreal forest using radar and optical sensors. Proc. IGARSS'01, Sydney, Australia, 9-13 July.
2001 Sun, G. and K. J. Ranson, Terrain effects on forest radar backscatter: modeling and correction, Proc. IGARSS'01, Sydney, Australia, 9-13 July.

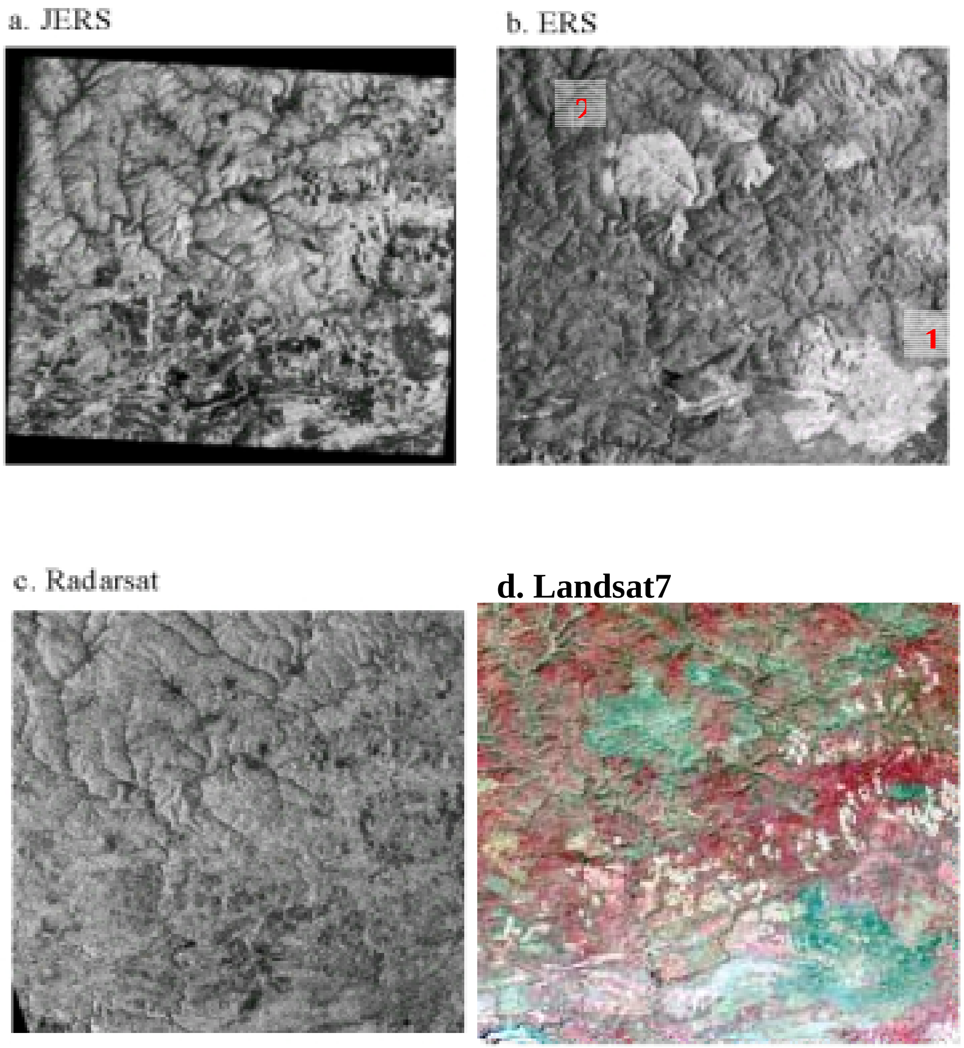

Figure 1. .a: JERS (LHH), b. ERS (CVV) c. Radarsat (CHH) and d. Landsat 7 images (Red = (NIR, 0.75 - 0.90 μm), Green = (Red, 0.63 - 0.69 μm), Blue= (Green, 0.525 - 0.605 μm) over the Boguchany fire damaged site. Major fires scars are labeled in the ERS image.

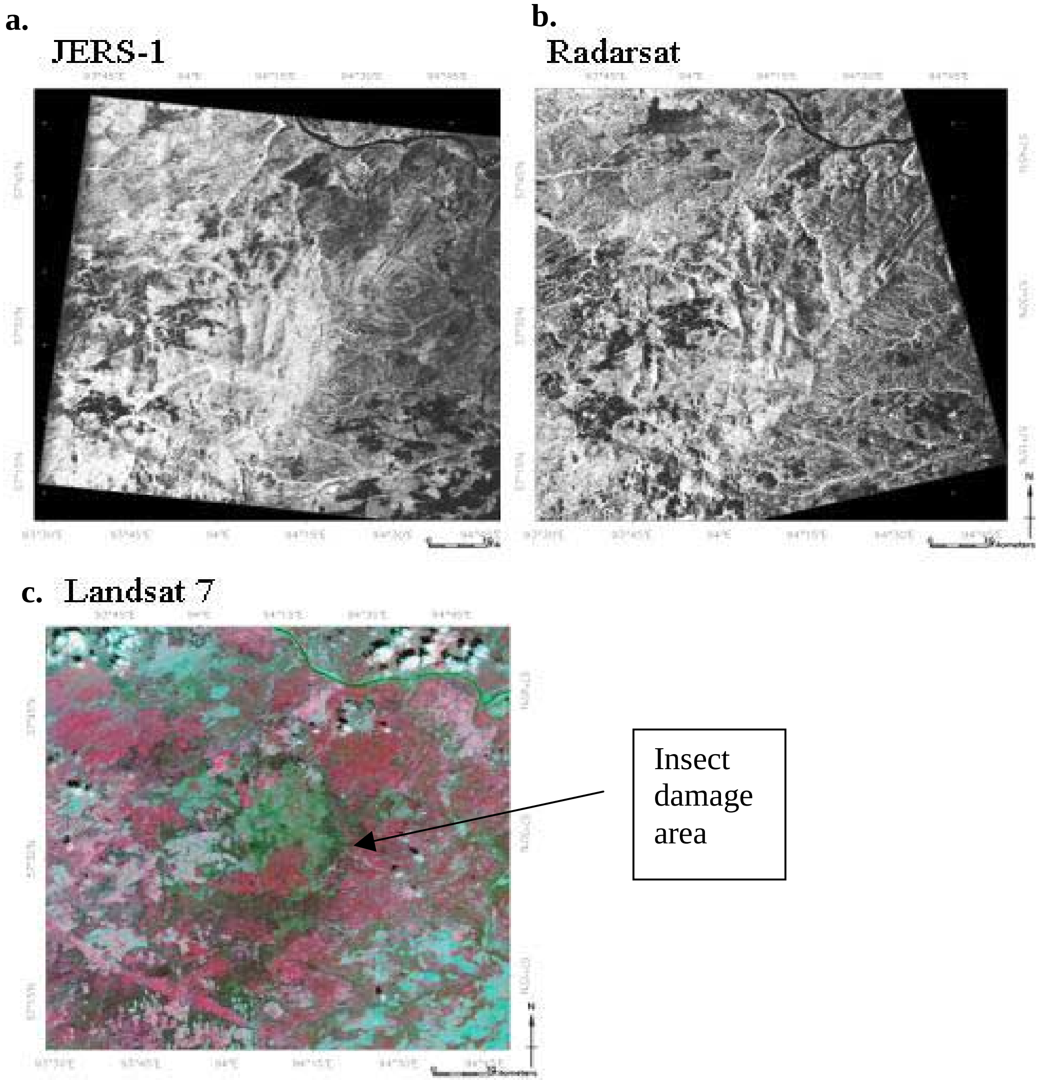

Figure 2. a. The JERS (LHH), b. Radarsat (CHH) and c. Landsat 7 images (Red = (NIR, 0.75 - 0.90 µm), Green = (Red, 0.63 - 0.69 µm), Blue= (Green, 0.525 - 0.605 µm) over the Priangar'e insect damge site. ERS data was not available for this site.

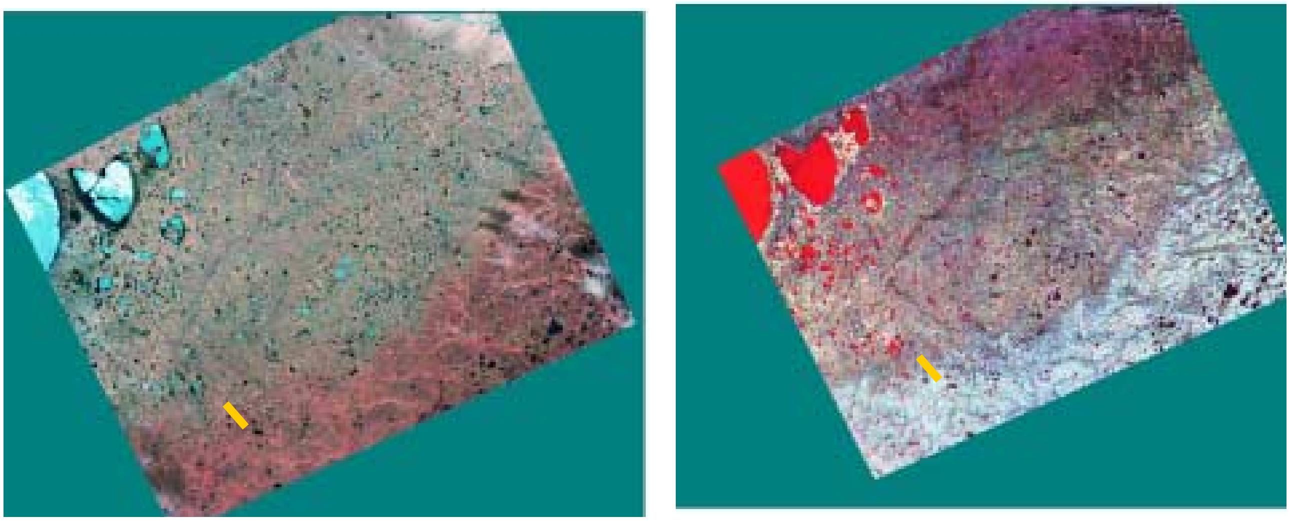

Figure 3. Landsat 7 Bands 432 (left) and Radarsat (ST2,ST4, ST6) (right) composite images of the Ary Mas Ecotone Area. Yellow line shows location of transect used in Figure 4 below.

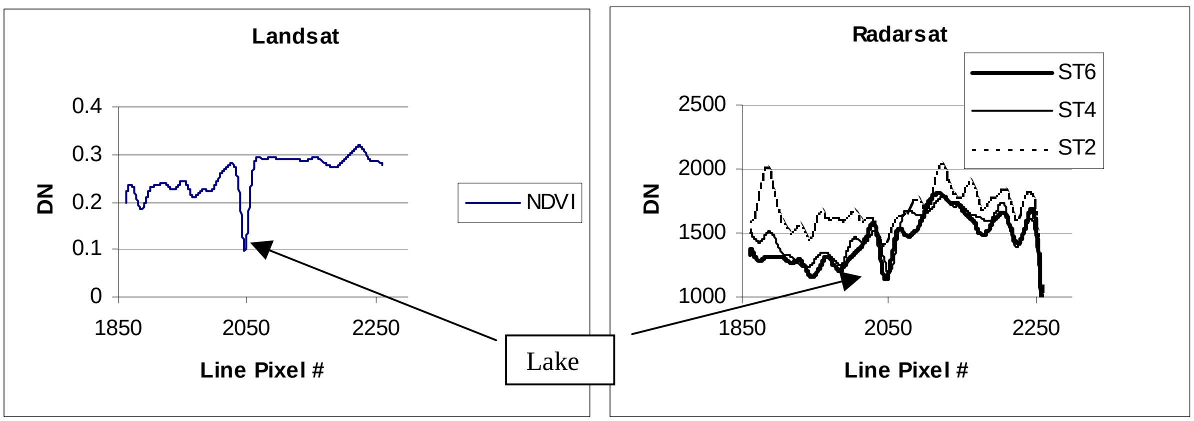

Figure 4. Comparison of Landsat 7 and Radarsat Standard Beam images of observed treeline at Ary Mas.

Table 1. Radarsat ST data acquisitions used for Ary Mas and Polar Ural tundra-taiga ecotone studies.

scene	site	date	in pix size (m)		out pix size (m)		incidence
			range	azimuth	range	azimuth	angle
R1_29982_ST2_182	Ary Mas	08/02/01	8.117	5.275	48.702	31.650	27.738
R1_30025_ST3_182	Ary Mas	08/05/01	11.595	4.898	69.570	29.388	34.102
R1_30168_ST4_181	Ary Mas	08/15/01	11.595	5.045	69.570	30.270	36.56
R1_30068_ST5_181	Ary Mas	08/08/01	11.595	5.201	69.570	31.206	39.224
R1_30111_ST6_181	Ary Mas	08/11/01	11.595	4.525	69.570	27.150	44.14
R1_29955_ST2_168	Polar Ural	07/31/01	8.117	5.269	48.702	31.614	27.664
R1_29998_ST3_168	Polar Ural	08/03/01	11.595	4.895	69.570	29.370	34.043
R1_30241_ST4_168	Polar Ural	08/20/01	11.595	5.043	69.570	30.258	36.491
R1_30141_ST5_168	Polar Ural	08/13/01	11.595	5.199	69.570	31.194	39.169
R1_29941_ST6_168	Polar Ural	07/30/01	11.595	4.925	69.570	29.550	44.099
R1_29148_ST7_282	Polar Ural	06/05/01	11.595	5.14	69.570	30.840	47.043

Figure 5. Aerial photo of Ary Mas ecotone area. Encroachment of forest into tundra is from left to right.

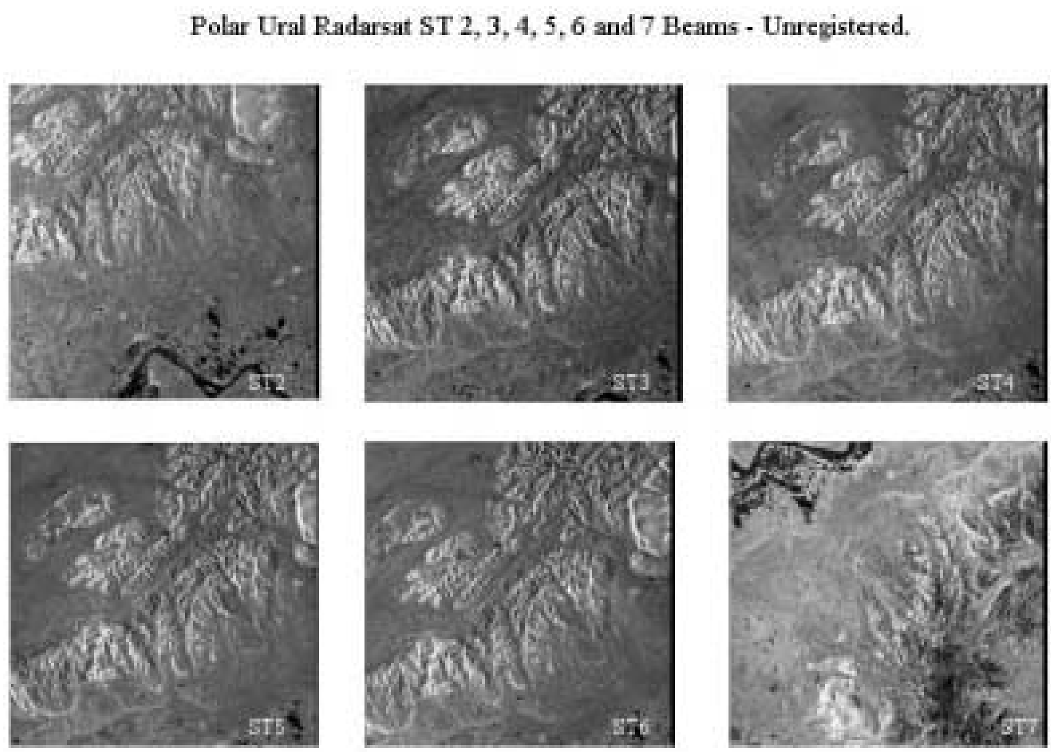

Figure 6. Series of Radarsat standard beam images of Polar Ural site. Changes in treeline in this area may indicate changing climate.

Proposed Third Year Activities

As discussed above the apparent northward expansion of the taiga forest into the tundra may be an indicator of global warming. This phenomenon requires high resolution optical and RADARSAT-1. We propose to use Landsat-7 data with RADARSAT-1 standard beam data within the previously identified ecotone study areas (see Figure .2). Classification techniques described above will be used. Textural information will closely examined using the RADARSAT-1 data. We also see the possibility of using ASTER with its higher resolution visible and near infrared channels to good advantage here. In addition, the data from the off-nadir cameras of MISR will be examined to see if they are useful for identifying areas of sparse tree cover. This will greatly aid in trying to apply the result to a larger transect area. In addition, since we are approved investigators for the recently launched ESA Envisat ASAR, we can acquire HH and VV data of our sites for analysis and comparison with Radarsat. The InSAR capabilities of ASAR make it attractive for forest cover and disturbance studies by examining coherence patterns.

The Polar Ural site is mountainous so correction of topographic effects is required. We have NIMA DTED level 3 data for this area and will use it if we find it suitable. We will also look for ASTER VIS/NIR data and use the orthorectification module in PCI to develop a DEM for this area. (SRTM does not cover this extreme northern site).

During the first year we produced a land cover and disturbance classification of a 300X300 km area within our larger transect (Ranson et al, 2001). We were limited to this area by the then poor coverage of MODIS data. We were able to use a single 16 day composited MODIS data set with the RADARSAT-1 ScanSAR Wide B data. However , the results were encouraging as reported last year. We have now acquired a full year of MODIS data for our area and have requested an additional ScanSAR coverage. A goal for the third year's work would be to finalize this land cover and disturbance map of the entire Siberian transect using our techniques developed in the first phase of this project and these new data sets. In addition, SRTM topography data is only now becoming available for our area. This will be incorporated to reduce the effects of topography in the portion of the transect below 60^{o} N latitude.

In our original proposal we had planned to use VCL to provide control points for SRTM data to produce accurate DEMs in our study area (see Sun et al. 2000). This is no longer probable beacuase of uncertainties in the VCL program. However, we have some control information from field studies and would make use of ICESAT measurements during this performance period if they become available.

EXPECTED RESULTS

Large area (600X3000km) map of landcover and disturbance of central Siberia.
180X180km maps of ecotone in Polar Ural and Ary Mas sites
Several Peer Reviewed Publications
Symposium Presentations
Team Meeting Presentations
Final report delivered to Program Managers

COST PLAN

Projects costs include support for a half-time technician to assist in data acquisition, ingest, registration and analysis. Funds for Dr. Sun's activities on this project require approximately $40k/yr support for a 30% effort in FY03. The work at Sukachev Institute of Forest is important to the success of this project and $20K supports field measurements, data processing and image analysis. Dr. Ranson's salary and benefits for his 20% level of effort are covered elsewhere and are not charged to the project.

Dr. Kharuk will travel to GSFC for consultation regarding the image data analysis, to assist field data assimilation and prepare journal articles. One trip is anticipated this year and $4K has been budgeted to cover travel, per diem expenses and modest consulting fees. One trip each to professional or science meetings by Dr. Sun and Ms. Katalin Kovacs, the project data analyst, has been budgeted at $3K. Ranson's travel is covered by another source.

Computer maintenance, provided by a private vendor, and systems administration provided by Laboratory for Terrestrial Physics Information Science Branch is budgeted at $3K/yr and $2K/yr, respectively. This rate is equivalent to support of one workstation and will be prorated among the three machines used by project personnel. Purchases of mass storage devices to accommodate the large volume of satellite data required by the project have been purchased already. An additional $1k has been budgeted to cover miscellaneous small purchases of software licenses and expendable field supplies.

RADARSAT-1 costs incurred because of foreign ground station fees and processing costs have been estimated at $2000 .

Required assessments by GSFC management are budgeted at the rate of $12/FTE/yr for FY03 for Civil Service and contractor employees. In addition, the Biospheric Sciences Branch, Laboratory for Terrestrial Physics and Earth Sciences Directorate levy assessments of 5%/yr, 1.5/yr and 1% /yr, respectively, on funded research to cover non-civil service administrative, secretarial and other business office costs.

BUDGET SUMMARY Year 3

For period from _____Oct 1, 2002____ to _______Sept. 30, 2003_______

• Provide a complete Budget Summary for year one and separate estimates for each subsequent year.
• Enter the proposed estimated costs in Column A (Columns B & C for NASA use only).
• Provide as attachments detailed computations of all estimates in each cost category with narratives as required to fully explain each proposed cost. See *Instructions For Budget Summary* on following page for details.

	A	B (NASA USE ONLY)	C (NASA USE ONLY)
1. Direct Labor (salaries, wages, and fringe benefits)	67.5		
2. Other Direct Costs:			
a. Subcontracts	20		
b. Consultants			
c. Equipment	0.0		
d. Supplies	1.0		
e. Travel	7.0		
f. Other			
3. Facilities and Administrative Costs	19.2		
4. Other Applicable Costs:			
5. SUBTOTAL--Estimated Costs	115.7		
6. Less Proposed Cost Sharing (if any)	0		
7. Carryover Funds (if any)			
a. Anticipated amount: 0			
b. Amount used to reduce budget	0		
8. Total Estimated Costs	115.0		XXXXXXX
9. APPROVED BUDGET	XXXXXX	XXXXXXX	