Siberian Forest Classification With Fused Data Sets

K.J. Ranson[1], V.I. Kharuk[2], K. Kovacs[3] and G. Sun[4]

[1] NASA's Goddard Space Flight Center, Code 923, Greenbelt, MD, USA

[2] V.N. Sukachev Institute of Forest, Academgorodok, Krasnoyarsk, Russia

[3] Science Systems and Applications, Inc. Lanham, MD, USA

[4] Department of Geography University of Maryland, College Park, MD, USA

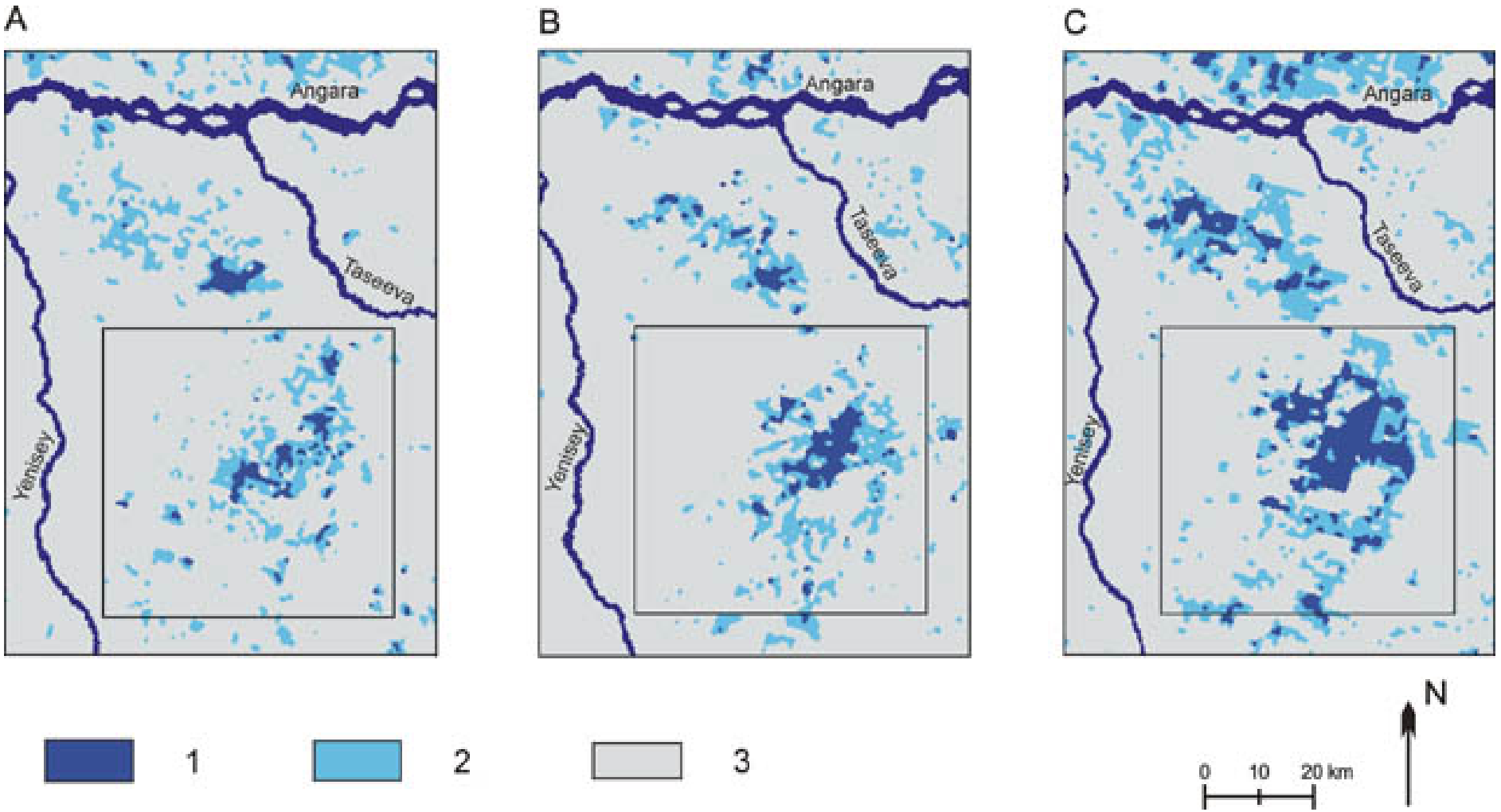
I. INTRODUCTION

The vast Siberian forests are undergoing changes due to natural and anthropogenic factors including insects, fires, logging, air pollution and mineral exploration.

Need to know the state of the Siberian boreal forest in terms of cover type and abundance .

Magnitudes and rates of change of impacts are critical for understanding the carbon balance of the area.

AVHRR data (1.1 km resolution) was used to monitor insect outbreaks in Siberia and has been used extensively to measure fire scars across the boreal forest.



An outbreak of Siberian silkworm was monitored using AVHRR data by the Sukachev Forest Institute. The three images show the progression of damage from June 7 through August 16, 1995. Dark Blue = severe damage, Blue = moderate damage and Grey = undamaged or undetected damage.

OBJECTIVES

1. Use high resolution optical and radar data to map insect damaged areas in Siberia.
2. Evaluate existing satellite data resources for this task
3. Apply results to larger scale problem using lower resolution and wider swath data.

Use of the two technologies was expected to improve results of previous classification maps (AVHRR only).

II. STUDY SITE

- Located in central Siberia and in the Niznee Priangar'e region.
- Area has low relief and soils are mainly spodosols (podzols).
- Climate is continental

  Annual precipitation is 400-450 mm

  Mean annual temperature is +2.6˚ C

  minimum of -54˚ C (December) and maximum of +36˚ C (July).
- Vegetative growth period is about 100 days.

- Dominant species is Siberian fir (*Abies sibirica*); other species include Siberian pine (*Pinus sibirica*), spruce (*Picea obovata*), pine (*Pinus silvestris*), larch (*Larix sibirica*), aspen (*Populus tremula*), and birch (*Betula verrucosa*).
- Forests cover 95% of the territory.
- Stands are of average productivity (corresponding to a III-IV site index on the European scale) with wood stocking of 200-230m^3/hectare and mean age of 135 years.

Siberian Mapping Project - Disturbance Test Areas

1) Priangar'e 94˚ 30' E / 57˚ 30' N, insect outbreak

2) Noril'sk - 89˚ E / 69˚ 20' N, forests damaged by pollution;

3) Western Sayani - 93˚ 14'. E / 53˚ 4' N logging in mountains

4) Boguchan, 97˚ 30'E/59˚ N, fire damaged

5) Tahamo, 96˚ 20' E/60˚ 20'N oil field- permafrost disturbance of larch forest.

Newly damaged stands – Summer 2000

Dead Stands

Local Insect Damage In the Priangar’e Region

Inside an insect damaged forest stand. Summer 2000.


21 3:32

III. DATA

Radarsat

C-band (5.3 GHz, 5.7 cm wavelength)

ScanSAR Wide Beam data

500 km swath, 50 m resolution, 34 deg. incidence angles
Images were also corrected for the change in effective scattering area from near to far range.

Data Acquired August 1, 2000

Standard Beam 4

100km swath, 12.5 m pixel spacing, 36 deg. incidence angle

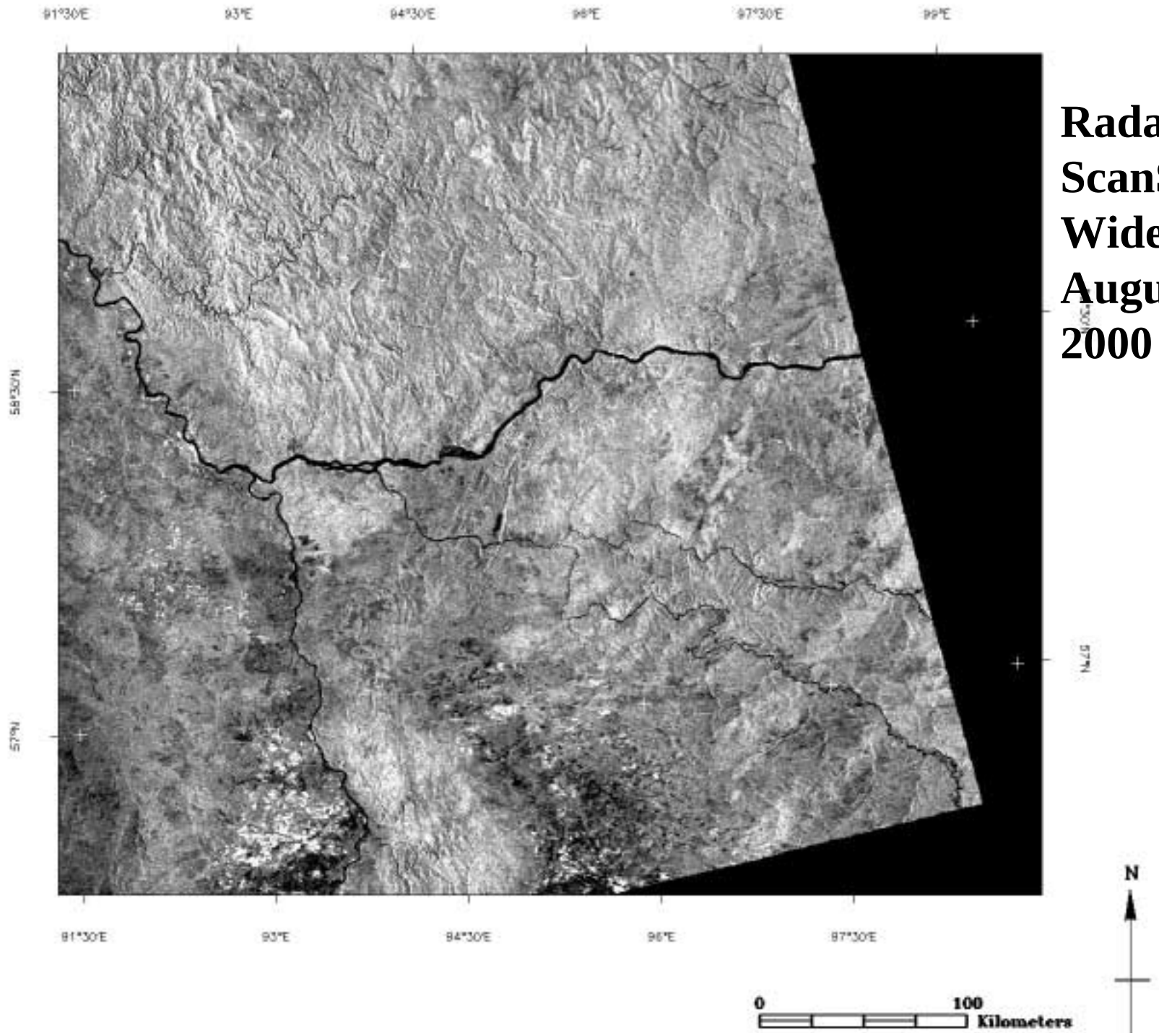
Data acquired August 28, 1999

JERS-1

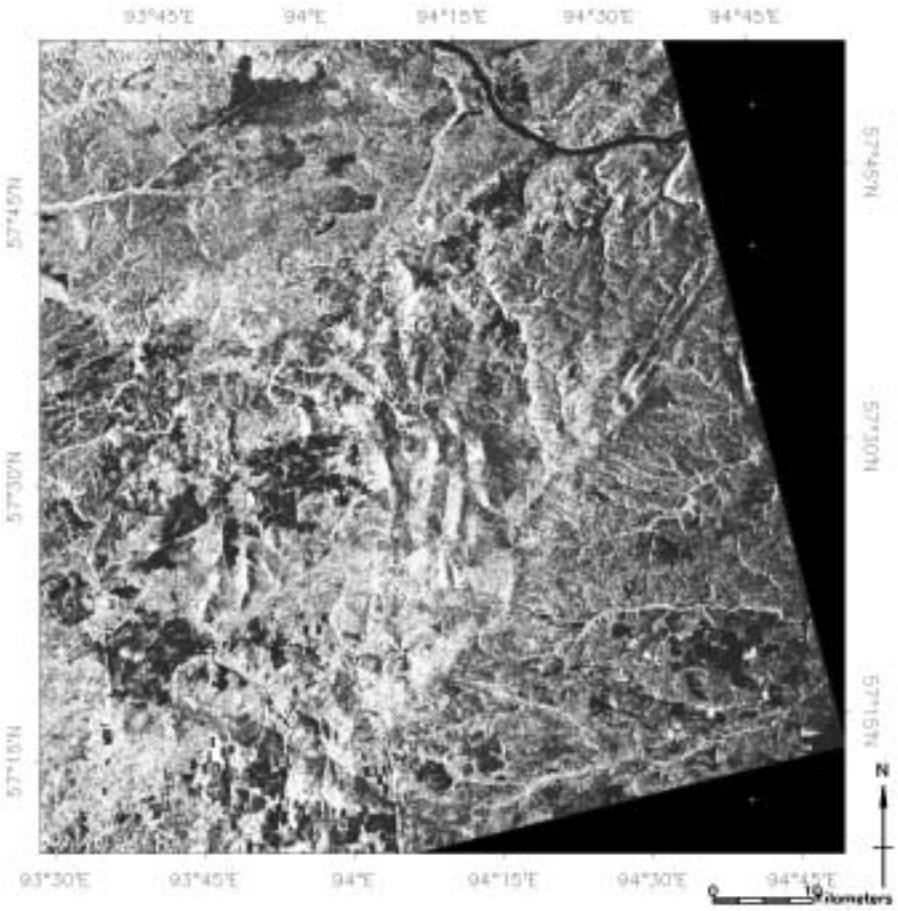
L-band (1.25 GHZ, 24 cm wavelength)

75 km swath. 12.5 m pixel spacing, 38.9 deg. Incidence angle

Data acquired May 19, 1997

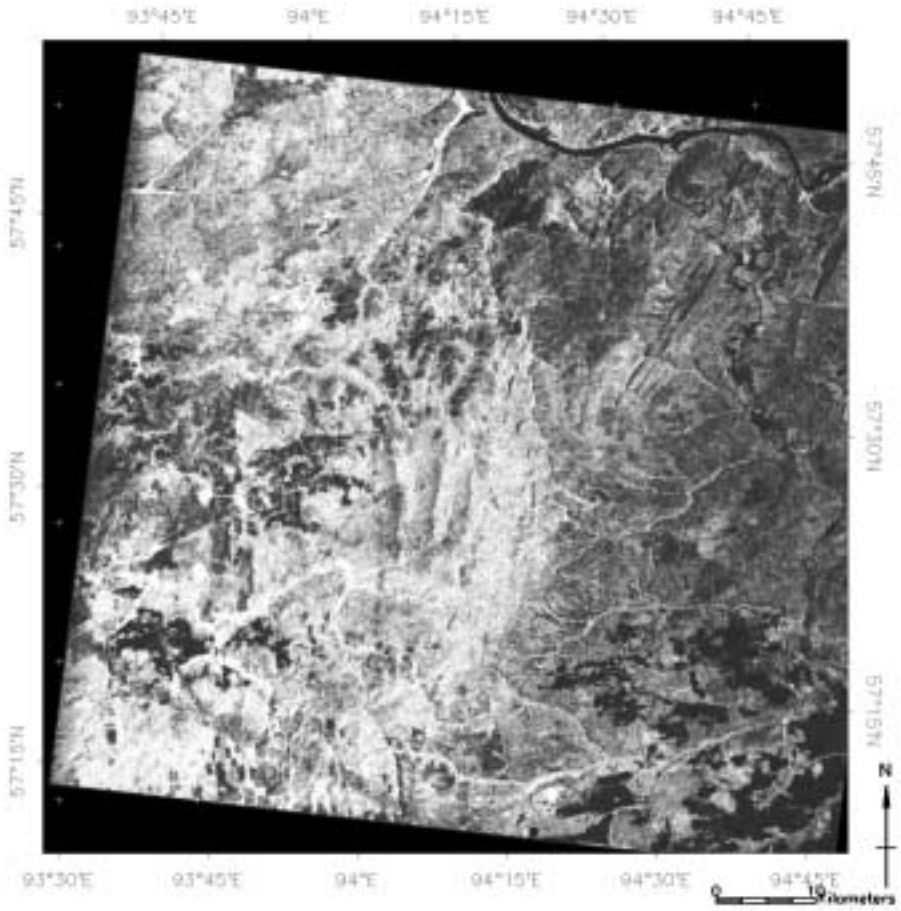


Radarsat ScanSAR Wide August 1, 2000



Radarsat ST-4

29-Aug-99



JERS –1

19-May-97

Landsat 7

180 km swath,

30 m resolution

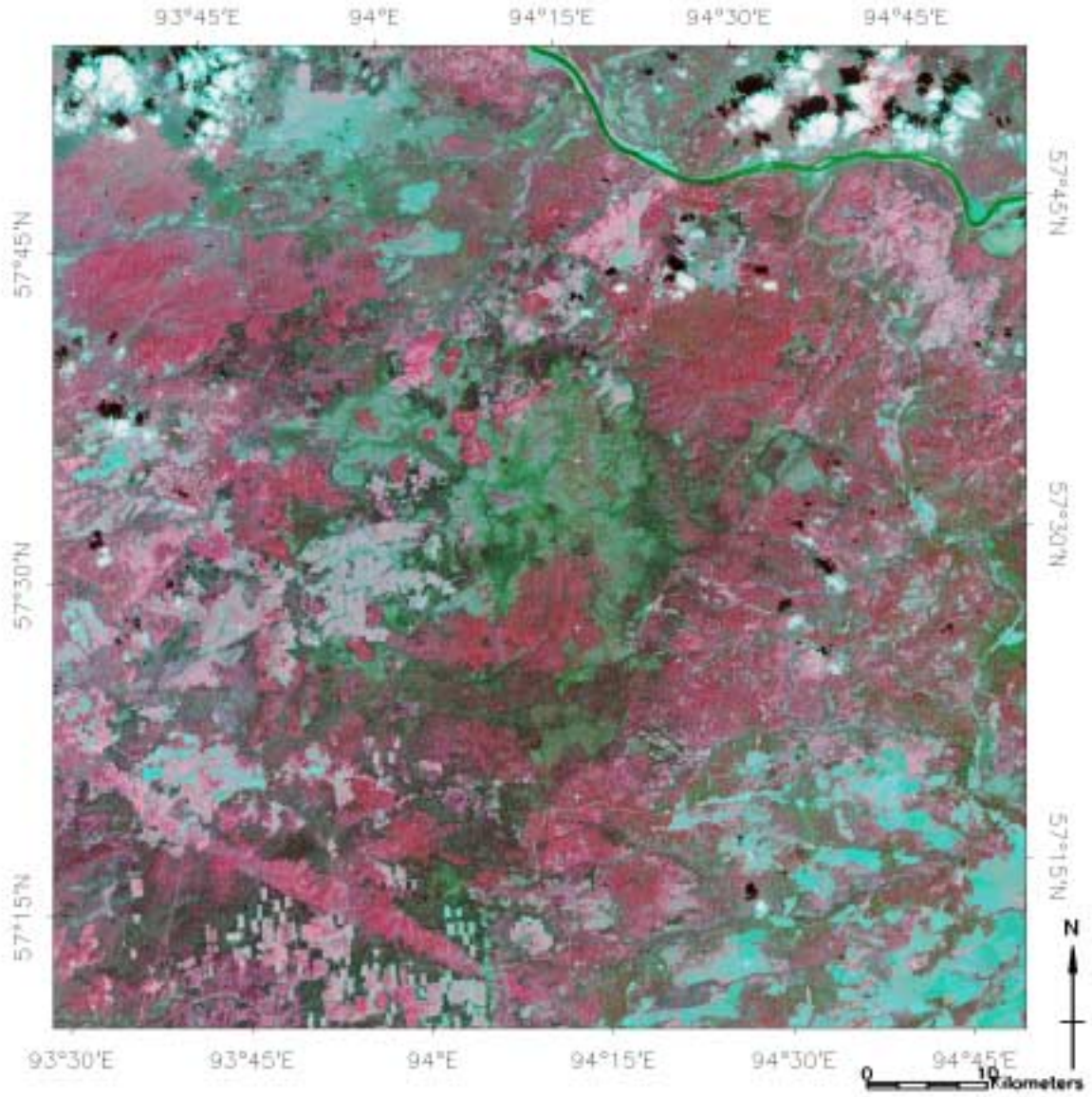
6 - 30m reflective channels

1- 60m thermal

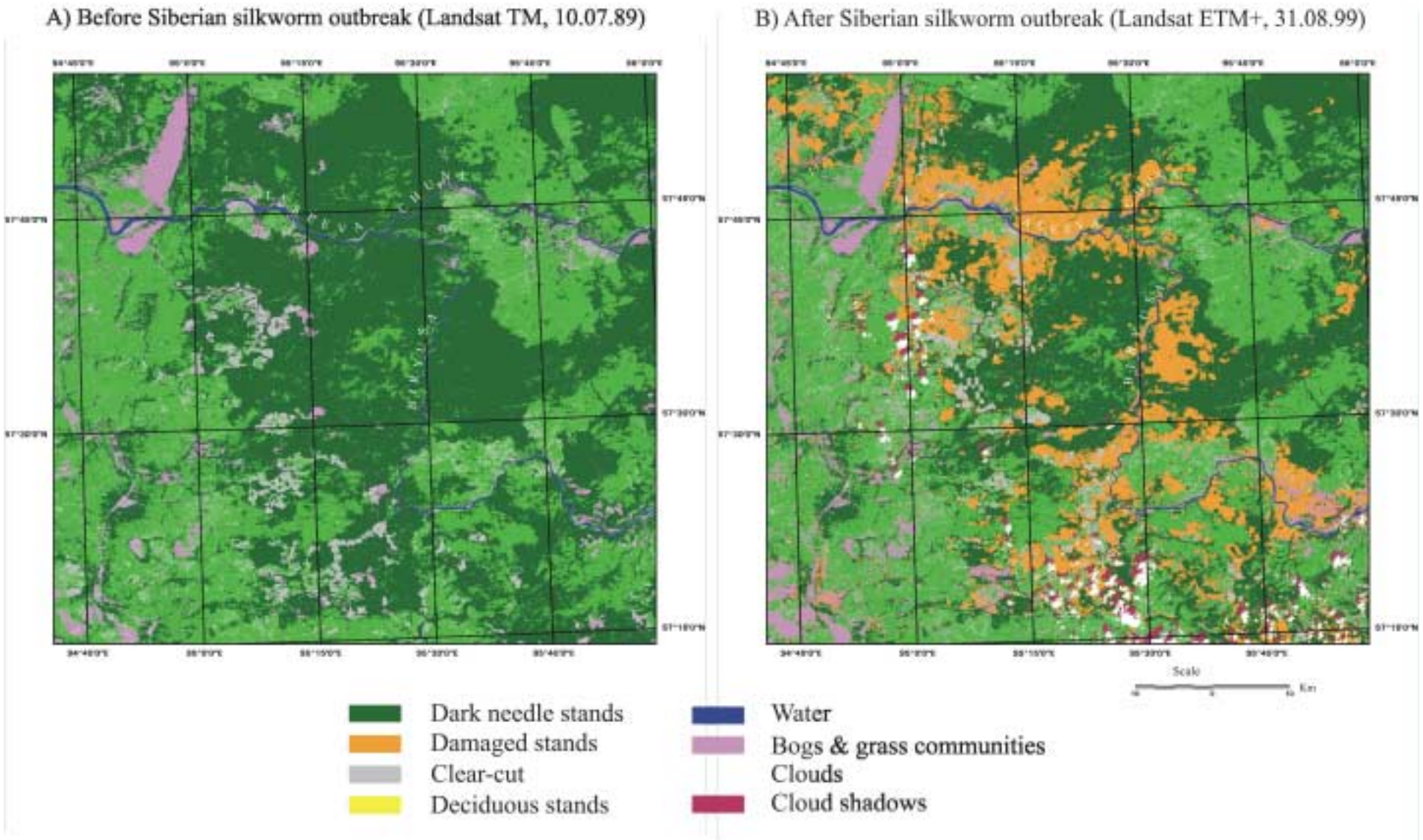
1 -15 m panchromatic

Acquired on July 22, 2000

Cloud cover <10%



Landsat Maps of Insect Damage in Priangar'e



1989 and 1999 Landsat data also were classified by scientists at Sukachev Institute of Forest based on field observations.

MODIS Data

MODIS Surface reflectance gridded products (MOD13) were used.

14-day composite tiles were obtained for late August through December 2000. August 28- September 10 composite was selected.

Reprojected to Lambert Conformal Conic at 500 m resolution.

#	Bandwidth (nm)	IFOV
1	NDVI	250
2	EVI	250
5	620-670	250
6	841-876	250
7	459-479	500
8	2105 -2155	500
9	Viewing Zenith Angle	500
10	Solar Zenith Angle	500
11	Relative Azimuth Angle	500

IV. METHODS

- High res. images registered to Landsat using PCI software
- Training Set Selection – Field surveys, helicopter overflights and Landsat analysis.
- Divergence – Individual sensors and combinations – Battacharyya Distance
- Maximum Likelihood Classification – Individual sensors and Combinations

V. RESULTS

	Class Descriptions
1 CF	coniferous forest
2 DF	deciduous forest and regenerating clear cuts
3 DC	insect damaged conifer
4 DM	insect damaged mixed
5 CC	clear cuts and grasses
6 BA	bogs, exposed soil, urban areas and fresh clearcuts
7 WR	water

Class Divergence – Landsat 7

Landsat 7 subset image (6 reflective bands)					7/22/2000	
class	1CF	2DF	3DC	4DM	5CC	6BA
2DF	1.99166					
3DC	1.86005	1.99958				
4DM	1.95109	1.86288	1.68977			
5CC	2.00000	1.99842	1.99996	1.99980		
6BA	1.99979	1.99999	1.99699	1.99918	1.99529	
7 WR	2.00000	2.00000	2.00000	2.00000	2.00000	2.00000
avg	**1.96878**					
min	**1.68977**					
max	**2.00000**					

Class Divergences - Microwave

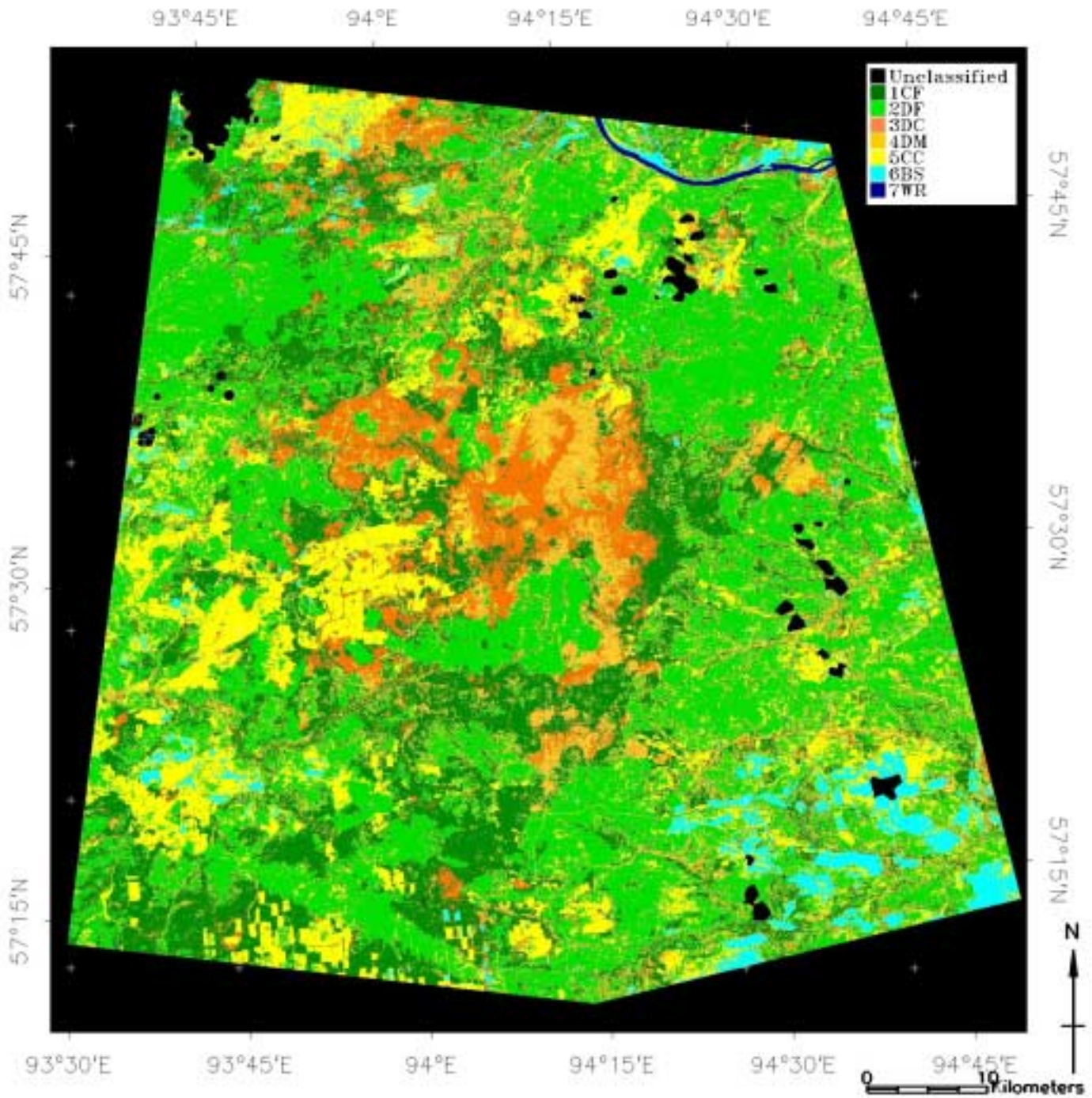
JERS image (1 band)				5/19/1997		LHH
class	1CF	2DF	3DC	4DM	5CC	6BA
2DF	0.28450					
3DC	0.05310	0.44804				
4DM	0.39730	0.06185	0.54649			
5CC	1.47372	0.63105	1.70826	0.76192		
6BA	1.99630	1.89831	1.99976	1.97938	1.84726	
7 WR	2.00000	1.99785	2.00000	1.99999	1.99990	1.36462
avg	**1.30712**					
min	**0.05310**					
max	**2.00000**					

RADARSAT image (1 band)				8/28/1999		CVV
class	1CF	2DF	3DC	4DM	5CC	6BA
2DF	0.73320					
3DC	0.46753	0.04222				
4DM	0.83658	0.01463	0.06584			
5CC	1.77202	1.02863	1.02220	0.85925		
6BA	0.85997	0.61422	0.51050	0.55841	0.48388	
7 WR	2.00000	1.99996	1.99986	1.99991	1.99638	1.73161
avg	**1.02842**					
min	**0.01463**					
max	**2.00000**					

CONFUSION MATRIX FOR JERS AND RADARSAT								
CLASSIFICATION								
Areas	Percent Pixel Classified by Code							
Code	Pixels	1CF	2DF	3DC	4DM	5CC	6BS	7WR
1CF	11486	**74.99**	1.52	16.49	6.91	0.00	0.09	0.00
2DF	14550	10.71	**17.07**	28.21	29.51	14.49	0.00	0.00
3DC	10514	21.69	3.60	**59.59**	14.99	0.14	0.00	0.00
4DM	5061	4.60	11.78	17.62	**60.74**	5.20	0.06	0.00
5CC	9340	0.00	5.70	0.03	4.48	**89.52**	0.28	0.00
6BS	4343	0.00	0.00	0.00	0.00	0.00	**99.91**	0.09
7WR	1389	0.00	0.00	0.00	0.00	0.00	0.65	**99.35**
Average accuracy=		**71.59%**			Confidence	Level :		
Overall accuracy=		**60.89%**			99%	+/- 0.00631		
Kappa Coefficient=		0.53385			95%	+/- 0.00479		
Standard Deviation =		0.00245			90%	+/- 0.00402		

CONFUSION MATRIX FOR LANDSAT7								
CLASSIFICATION								
Areas	Percent Pixel Classified by Code							
Code	Pixels	1CF	2DF	3DC	4DM	5CC	6BS	7WR
1CF	11486	**99.30**	0.00	0.40	0.30	0.00	0.00	0.00
2DF	14550	0.00	**99.30**	0.00	0.60	0.00	0.00	0.00
3DC	10514	1.20	0.00	**96.10**	2.70	0.00	0.00	0.00
4DM	5061	0.10	1.50	2.10	**96.30**	0.10	0.00	0.00
5CC	9340	0.00	0.00	0.00	0.00	**99.90**	0.10	0.00
6BS	4343	0.00	0.00	0.00	0.00	0.10	**99.90**	0.00
7WR	1389	0.00	0.00	0.00	0.00	0.00	0.00	**100.00**
Average accuracy=		**98.67%**			Confidence	Level :		
Overall accuracy=		**98.58%**			99%	+/- 0.00157		
Kappa Coefficient=		0.98261			95%	+/- 0.00119		
Standard Deviation =		0.00061			90%	+/- 0.00100		

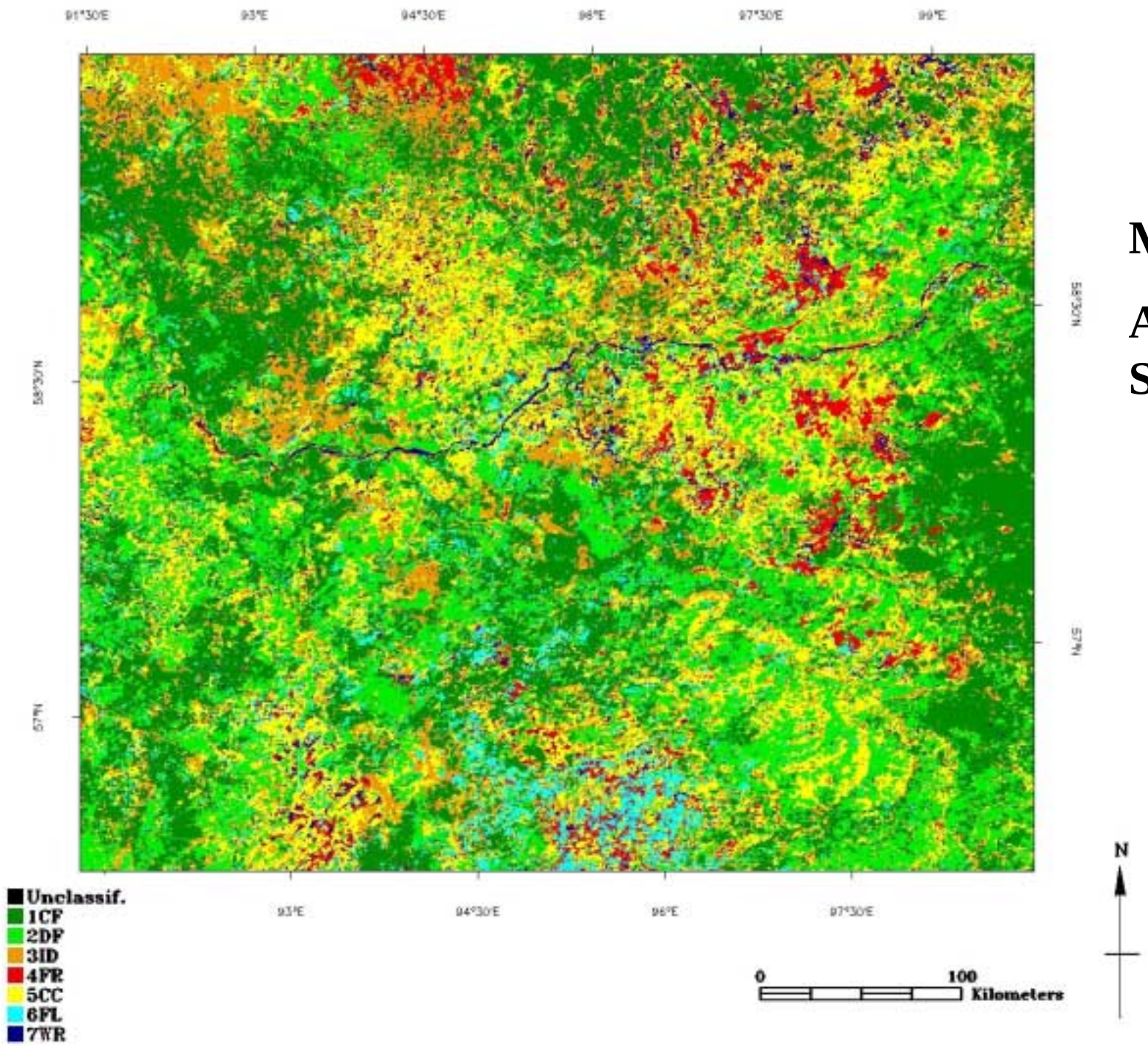
CONFUSION MATRIX FOR LANDSAT 7, JERS AND RADARSAT								
CLASSIFICATION								
Areas	Percent Pixel Classified by Code							
Code	Pixels	1CF	2DF	3DC	4DM	5CC	6BS	7WR
1CF	11486	**99.33**	0.01	0.46	0.20	0.00	0.00	0.00
2DF	14550	0.01	**99.33**	0.00	0.63	0.03	0.00	0.00
3DC	10514	1.10	0.00	**97.44**	1.46	0.00	0.00	0.00
4DM	5061	0.04	1.44	1.03	**97.45**	0.04	0.00	0.00
5CC	9340	0.00	0.01	0.00	0.01	**99.96**	0.02	0.00
6BS	4343	0.00	0.00	0.00	0.00	0.02	**99.98**	0.00
7WR	1389	0.00	0.00	0.00	0.00	0.00	0.00	**100.00**
Average accuracy=		**99.07%**			Confidence	Level :		
Overall accuracy=		**98.98%**			99%	+/- 0.00133		
Kappa Coefficient=		0.98752			95%	+/- 0.00101		
Standard Deviation =		0.00052			90%	+/- 0.00085		



Landsat 7, JERS and Radarsat Combined classification

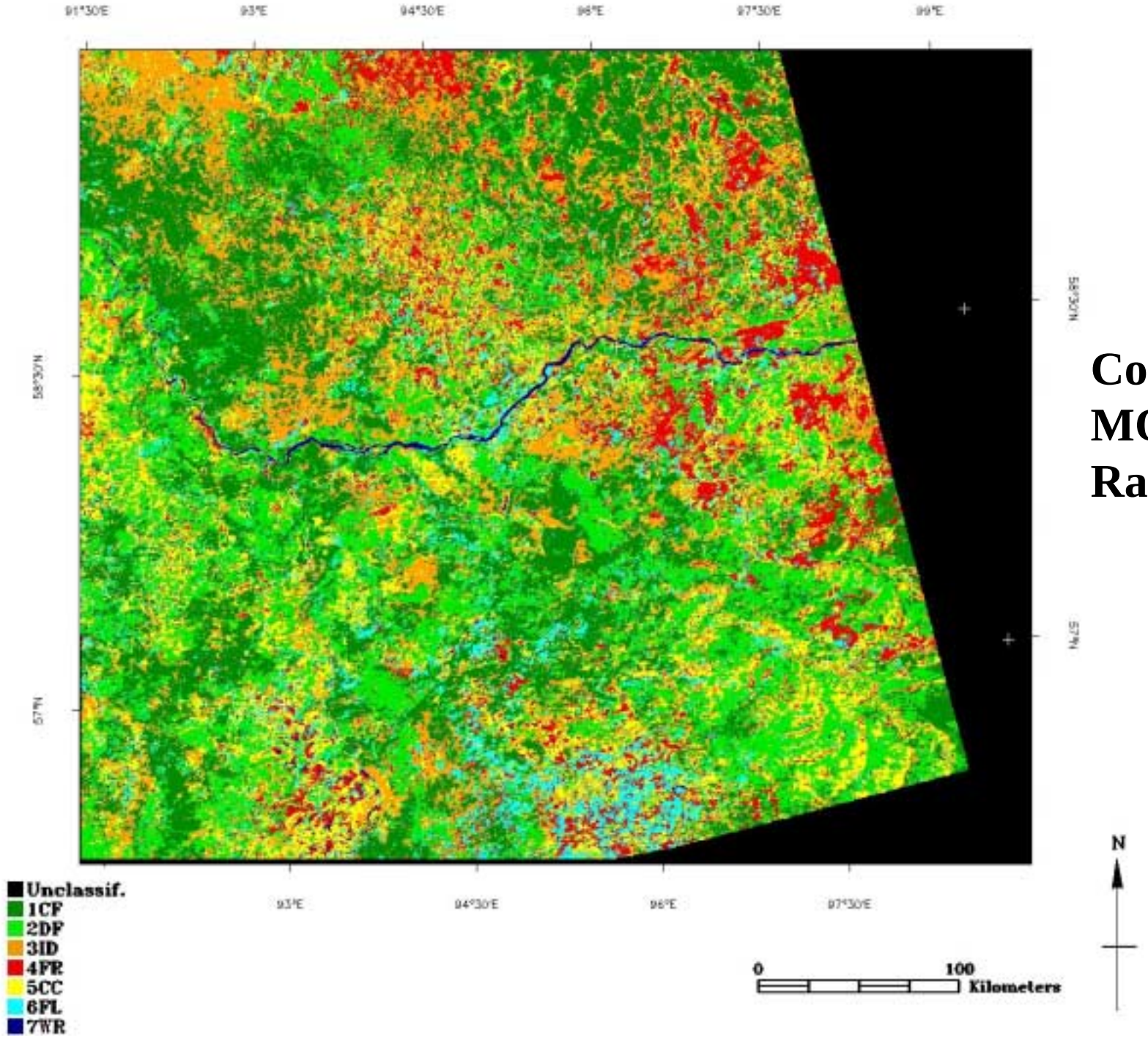
MODIS Separabilities					8/28/00-9/12/00	
class	1CF	2DF	3ID	4FR	5CC	6FL
2DF	1.956327					
3ID	1.530702	1.985251				
4FR	1.997116	1.995017	1.960739			
5CC	1.973007	1.924112	1.821785	1.68497		
6FL	1.966746	1.974458	1.959921	1.242913	1.509214	
7WR	1.999264	1.999962	1.996808	1.924095	1.986764	1.988536
avg	**1.87129**					
min	**1.24291**					
max	**1.99996**					
Radarsat SWB Separabilities						
class	1CF	2DF	3ID	4FR	5CC	6FL
2DF	0.271962					
3ID	0.781260	0.328463				
4FR	1.604882	1.343497	0.603534			
5CC	1.624932	1.394362	0.719686	0.027567		
6FL	1.701906	1.538783	1.015134	0.250396	0.121763	
7WR	1.972972	1.952395	1.736959	0.970497	0.719693	0.272262
avg	**0.99776**					
min	**0.02757**					
max	**1.97297**					

CONFUSION MATRIX FOR MODIS AND RADARSAT								
CLASSIFICATION								
Areas	Percent Pixel Classified by Code							
Code	Pixels	1CF	2DF	3ID	4FR	5CC	6FL	7WR
1CF	655.00	86.41	2.44	9.92	0.00	0.15	1.07	0.00
2DF	761.00	1.71	95.27	0.00	0.26	1.45	1.05	0.26
3ID	390.00	7.95	0.77	86.41	0.26	4.62	0.00	0.00
4FR	1244.00	0.00	0.00	0.16	83.28	7.40	8.28	0.80
5CC	144.00	0.00	4.17	9.72	1.39	77.78	6.25	0.69
6FL	222.00	3.60	3.15	0.00	6.31	3.60	83.33	0.00
7WR	338.00	0.00	0.00	0.00	0.89	0.59	1.78	96.75
Average accuracy=		**87.03%**			Confidence	Level :		
Overall accuracy=		**87.59%**			99%	+/- 0.01695		
Kappa Coefficient=		0.84671			95%	+/- 0.01288		
Standard Deviation =		0.00657			90%	+/- 0.01081		



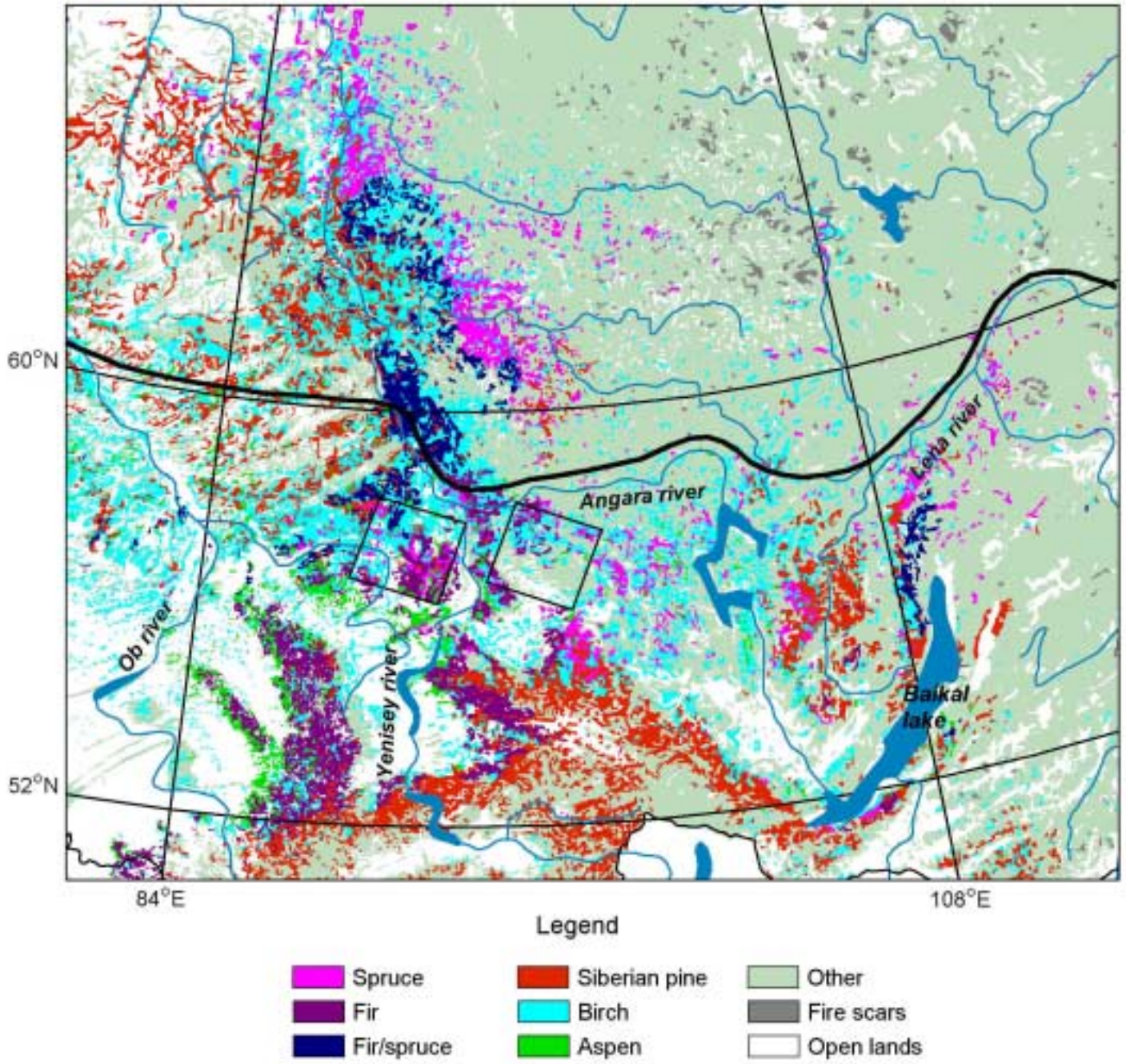
MOD13

Aug 28-
Sep 10, 2000



Combined MODIS Radarsat

Siberian Silkmoth Actual and Potential Food Base



VI. CONCLUSIONS

- Landsat best single data set for overall classification.
- Radars individually can separate forest and non-forest and improve classification when combined with Landsat.
- MODIS provides good overall forest cover classification
- Radarsat SWB at 500m provided separability of forest non-forest and improved classification of deciduous forest and fire scars.
- We will continue to refine these methods to develop a method to use high and low resolution optical and microwave data for our forest disturbance studies.
- Looking forward to using Envisat and ALOS PALSAR data sets