LAI in Post-fire Siberian Boreal Forests

HQ Program Review Presentation
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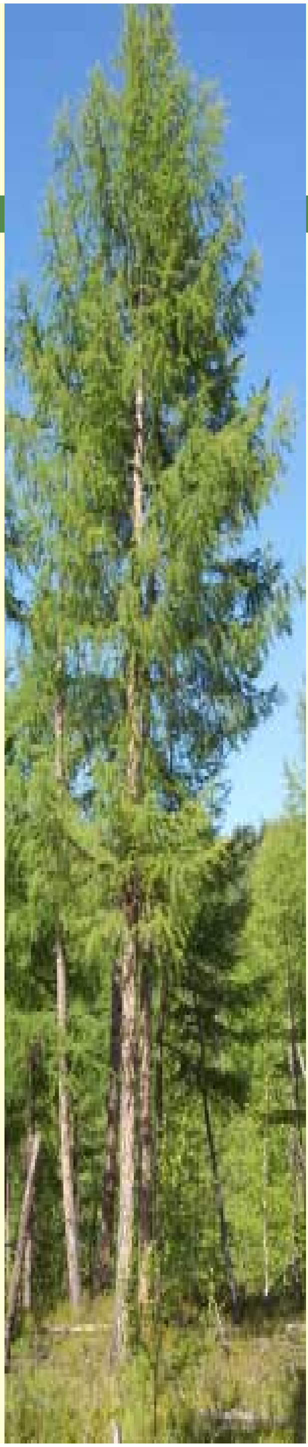


Primary Collaborations / Participants

- **Sukachev Institute of Forestry**: **Dr. Slava Kharuk**, Dr. Gregory Kofman, **Anastassia Nelzina** (graduate student) *(and many others!)*
- **South Dakota School of Mines and Technology (SDSMT)**: **Dr. Lee Vierling**, Xuexia Chen (graduate student), Rachel Smith (graduate student)
- **Canada Centre for Remote Sensing (CCRS)**: Dr. Jing Chen, **Sylvain Leblanc**
- **University of Arkansas**: Jessica Brooks (graduate student)
- **NASA Langley Research Center / University of Virginia**: **Amber Soja**

Fire in Boreal Forests

- Fire is the primary disturbance factor of boreal forests.
- **Fire** regime is ***intimately related to*** **carbon storage**.
  - Direct combustion
  - Changing patterns of secondary succession
  - Altering the ground layer (decomposing litter and organic soil)
  - Nutrient release
  - Stand age distribution

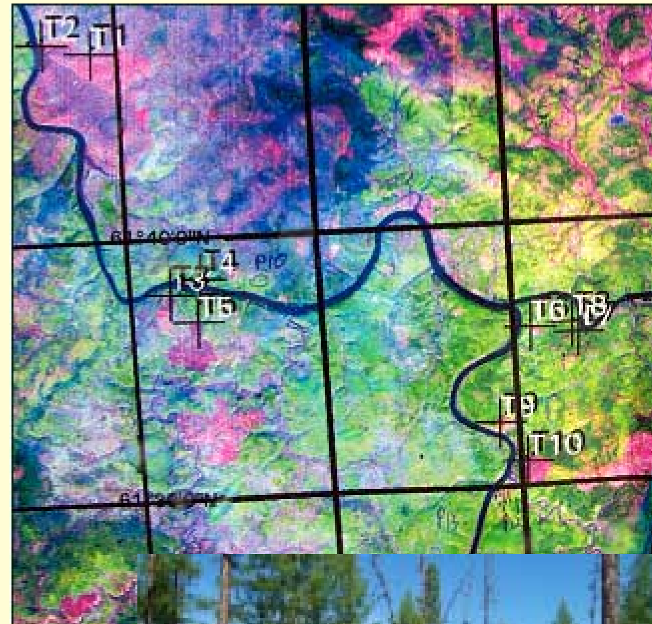
Photos: http://www.fire.uni-freiburg.de/other_rep/research/rus/rus_re_1.htm

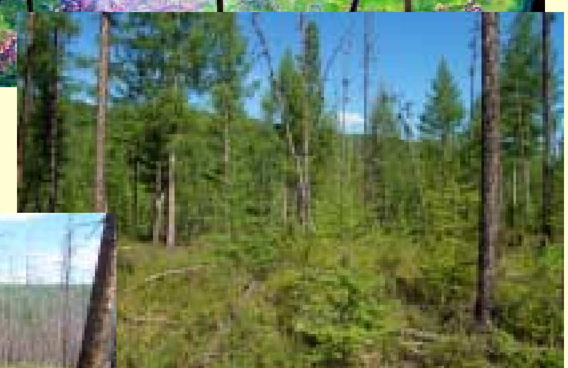
Climate Change

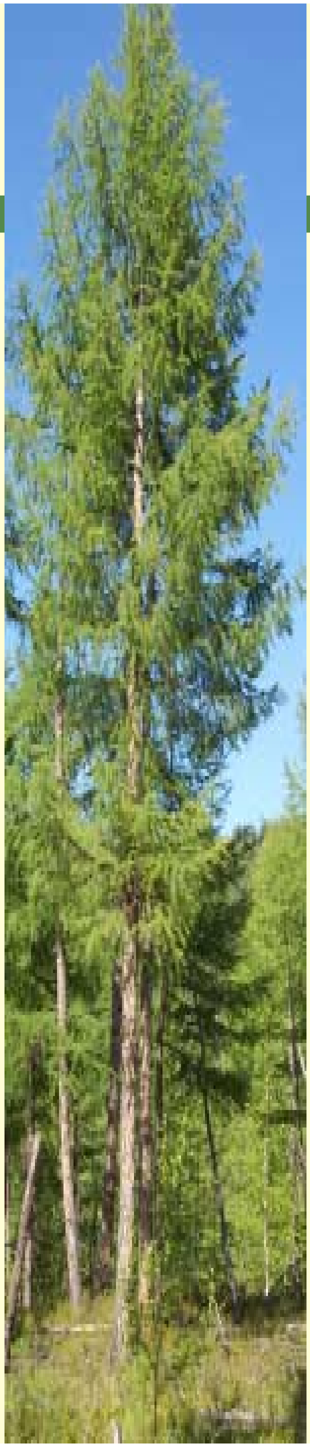
- **Global warming will affect the carbon storage of boreal forests**.
  - Vegetation shift (boreal to temperate mixed-deciduous)
  - Warming and drying of ground layer (increased decomposition)
  - Changes to the fire regime (longer, more severe fire season)
- Could result in a **carbon release of 25 – 80 Pg** in the next 50-100 yrs until ecosystems reach a new equilibrium.

Russian Boreal Forests – Our Interests

- Russia contains 3/4 of the world's boreal forest.
- More-or-less excluded from global scientific study by international scientists until the early 1990's.
- High scientific interest in this area because of lack of previous knowledge (and data access) and current issues facing boreal forests.
- MODIS land product va





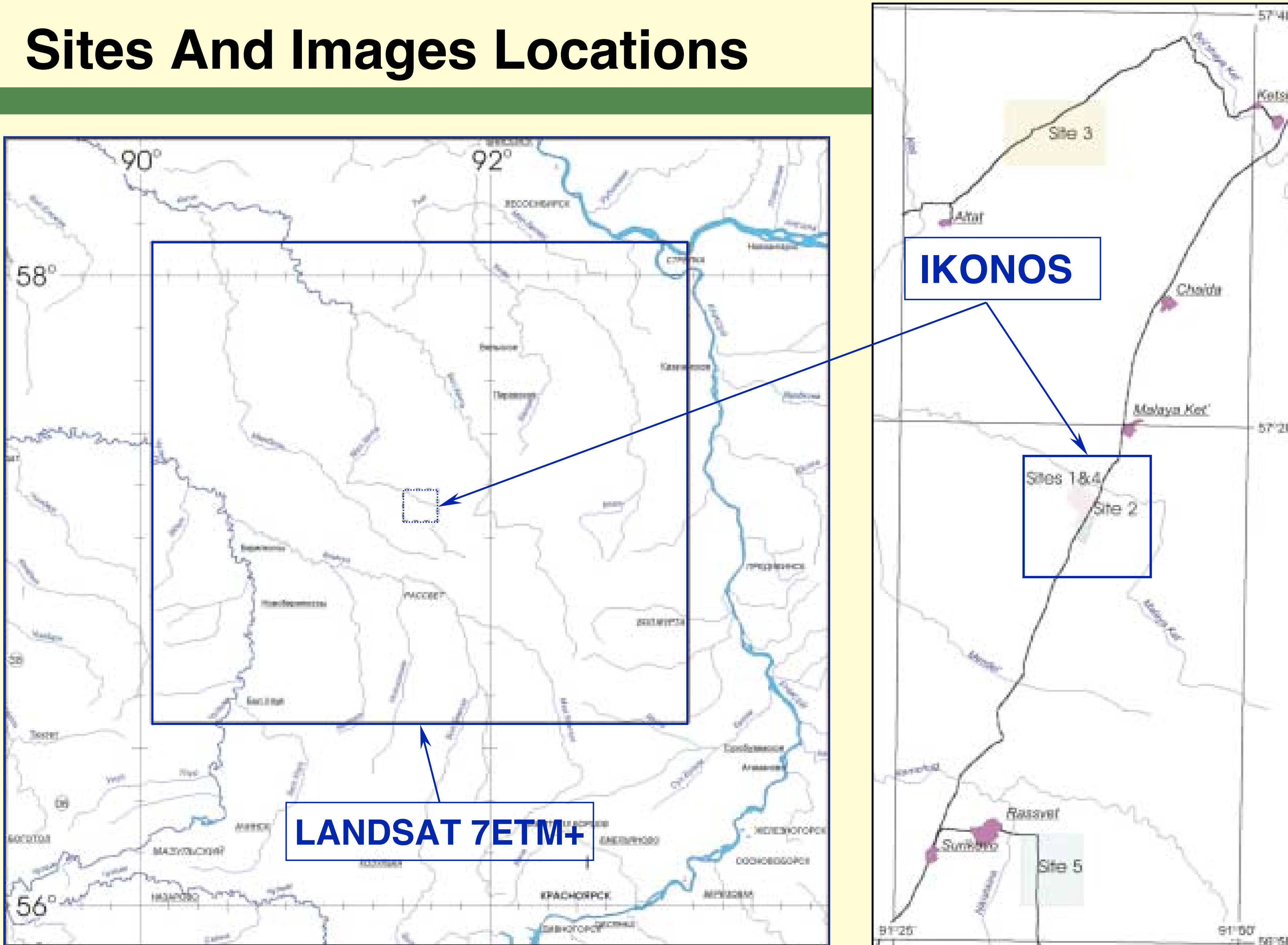


Goals

- **Determine leaf area index (LAI) across a chronosequence of post-fire Siberian boreal forest.**
  - Correlation of sampling techniques (direct v. indirect)
  - Relationship of LAI and post-fire age
  - Range of LAI present across post-fire age
  - Provide LAI data for EOS/MODIS land validation
- **Link remotely sensed data to surface data for LAI mapping**
  - Correlation of surface and remotely sensed LAI
  - Correlation of remotely sensed LAI and surface LAI to MODIS LAI product (incl., Field Validation of MODIS LAI Product)
  - Explore BRDF to improve LAI
- Modeling for extrapolation of LAI to broader scales

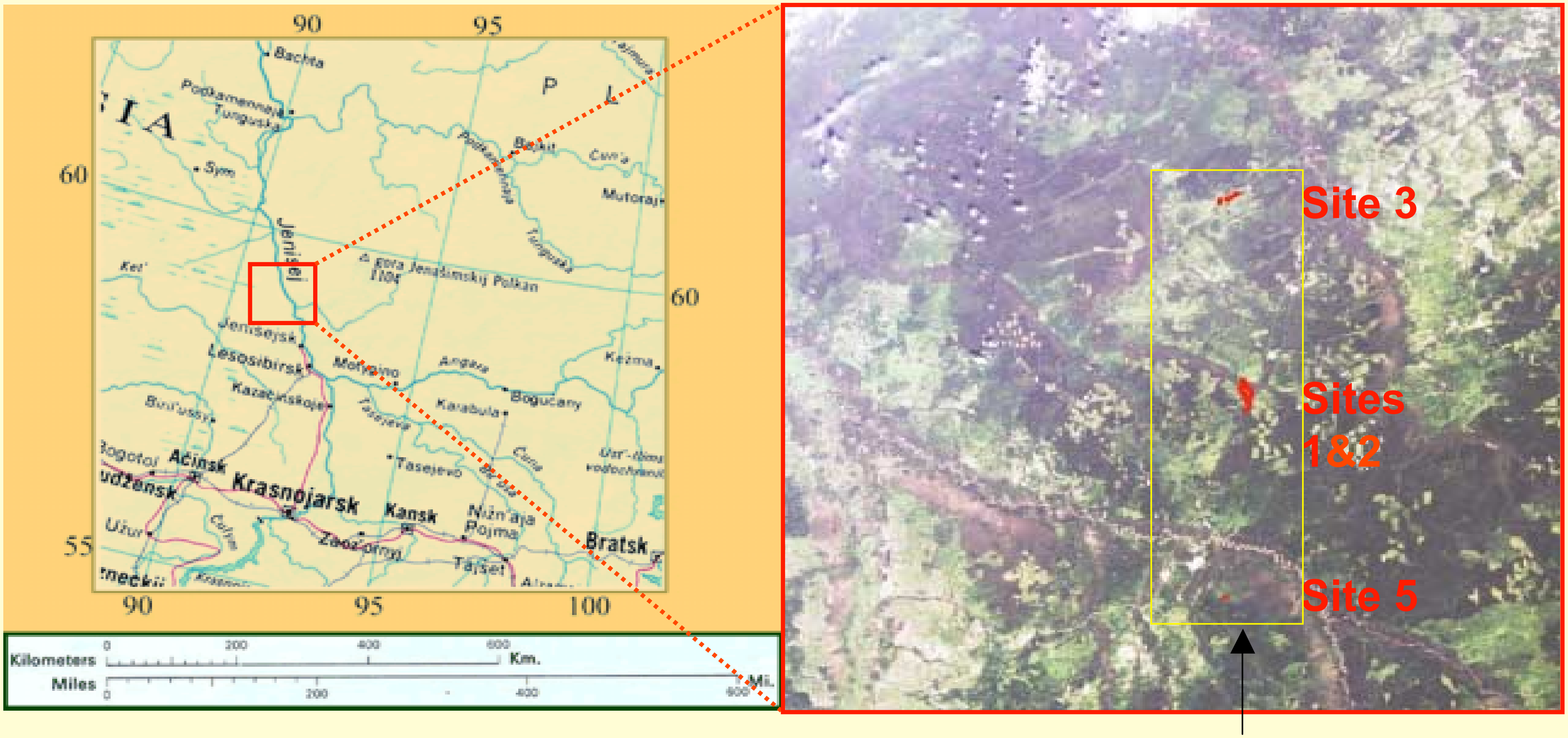

Study Area
located within
Krasnoyarsk Krae
RUSSIA
KAZAKSTAN
MONGOLIA
Angara
Study Area

Sites And Images Locations



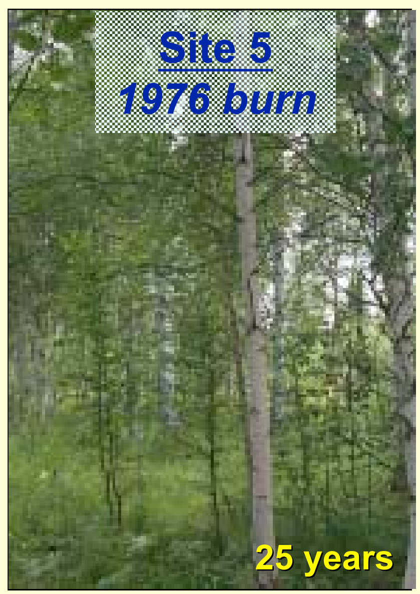
Sites And Image Analysis Focus Area

Study sites in the central Siberian region of Krasnoyarsk

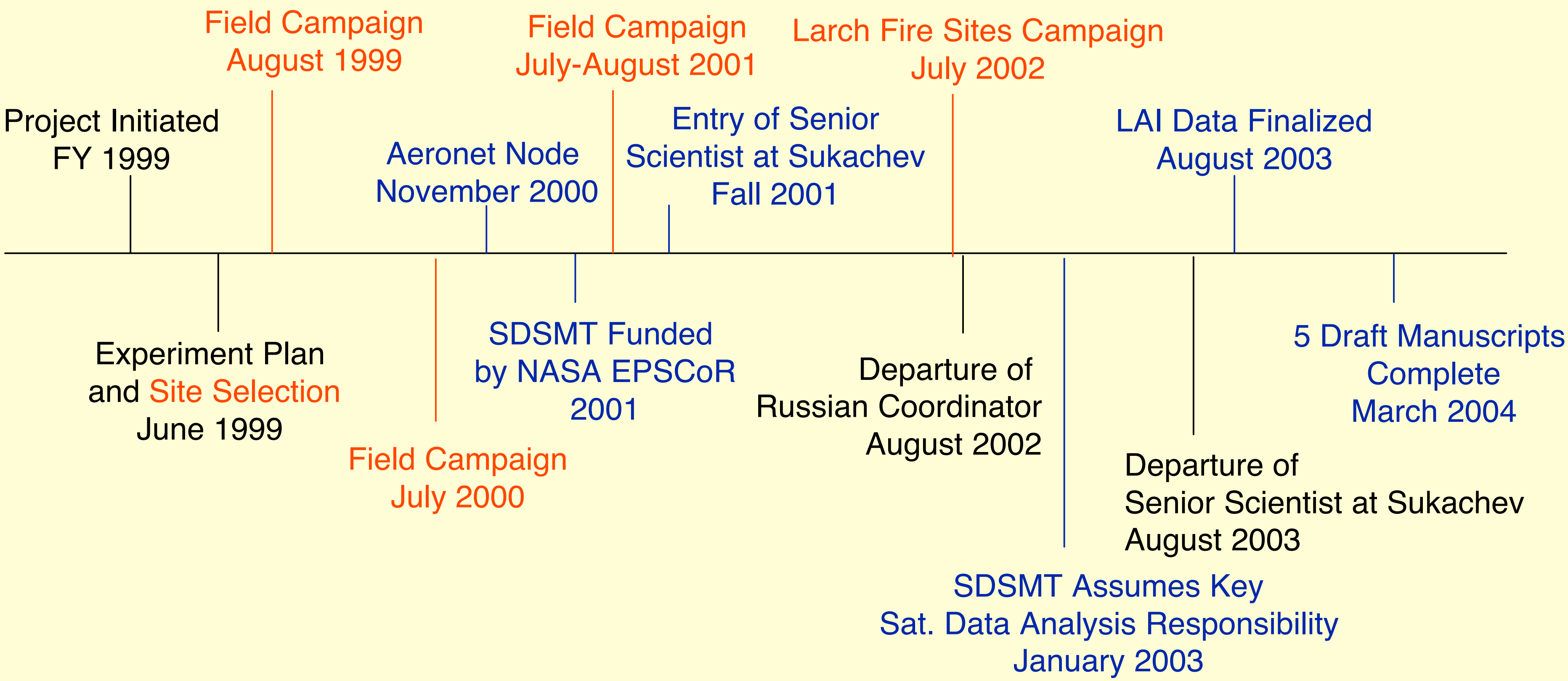


Region of interest for image analysis

Post-fire Age Classes (chronosequence)



Study Principal Events Timeline

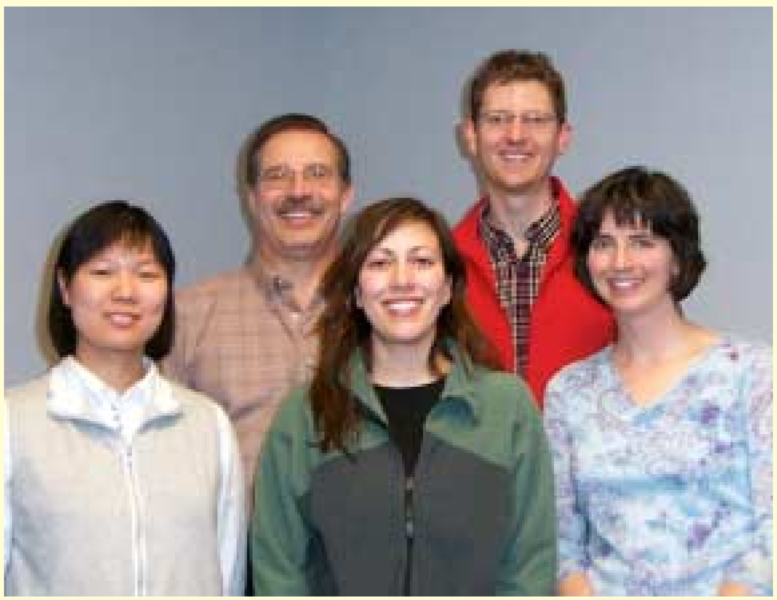


NASA/GSFC - SDSMT formal **EPSCoR** Program Collaboration

Leaf Area Index for Fire Chronosequences of the Black Hills and Southern Siberia: A Comparative Study

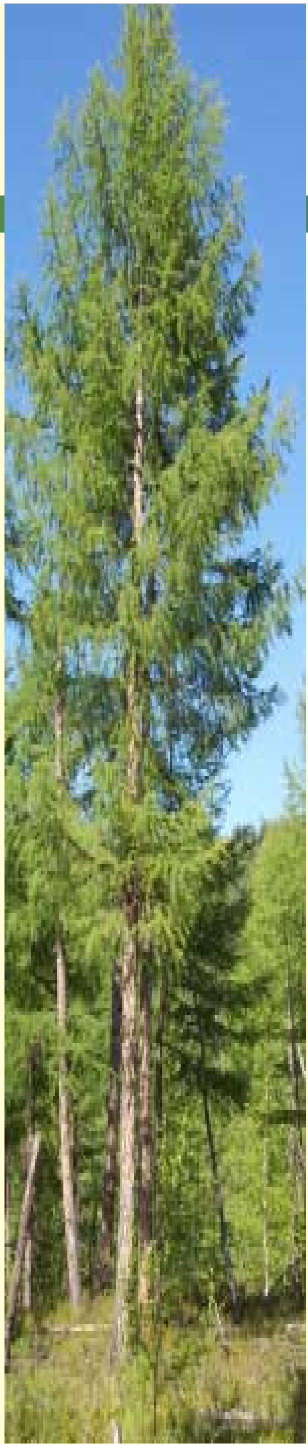
South Dakota School of Mines and Technology

Institute of Atmospheric Sciences



EPSCoR: Experimental Program to Stimulate Competitive Research
(Note: Dr. Sherry Farwell, formerly SDSMT Dean of Graduate College new director of EPSCoR)

Don Deering, Lee Vierling
Xuexia Chen, Rachel Smith, Alexis Conley



Approach

- Site selection based on fire history, accessibility, and human influence
- Sampling design based on BigFoot study site in BOREAS NSA
- Combination of direct (destructive) and indirect (optical) sampling to provide LAI
- IKONOS, Landsat, MODIS data for remote sensing segment
- Spectral reflectance of understory
- MISR data for BRDF exploratory investigation
- LAI simulation with BIOME-BGC

Optical LAI Theory

effective LAI
(i.e., "plant area index")

woody-to-total
area ratio
(sampled tree)

needle-to-shoot
area ratio
(sampled tree)

element
clumping
index
(TRAC)

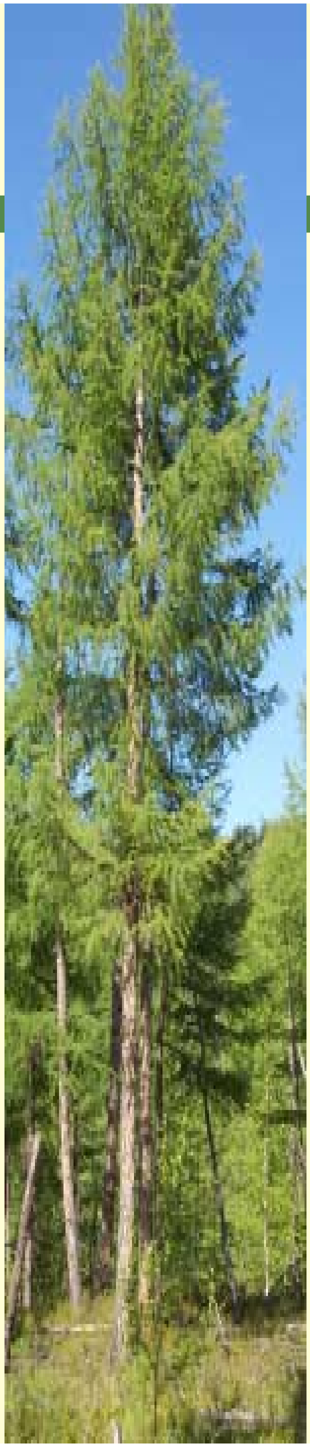
Leaf Area Index (optical) $= (1 - \alpha) * L_e * \gamma_E / \Omega_E$

LAI-2000, TRAC,
Hemispherical
photography

New technique developed in this study for determining specific leaf area (associated with γ); surface area relationship to length

α and γ vary according to different types of forests (each unique forest could have its own value)

LAI model per Chen, 1996 for coniferous forests



Data Collected and Analyzed

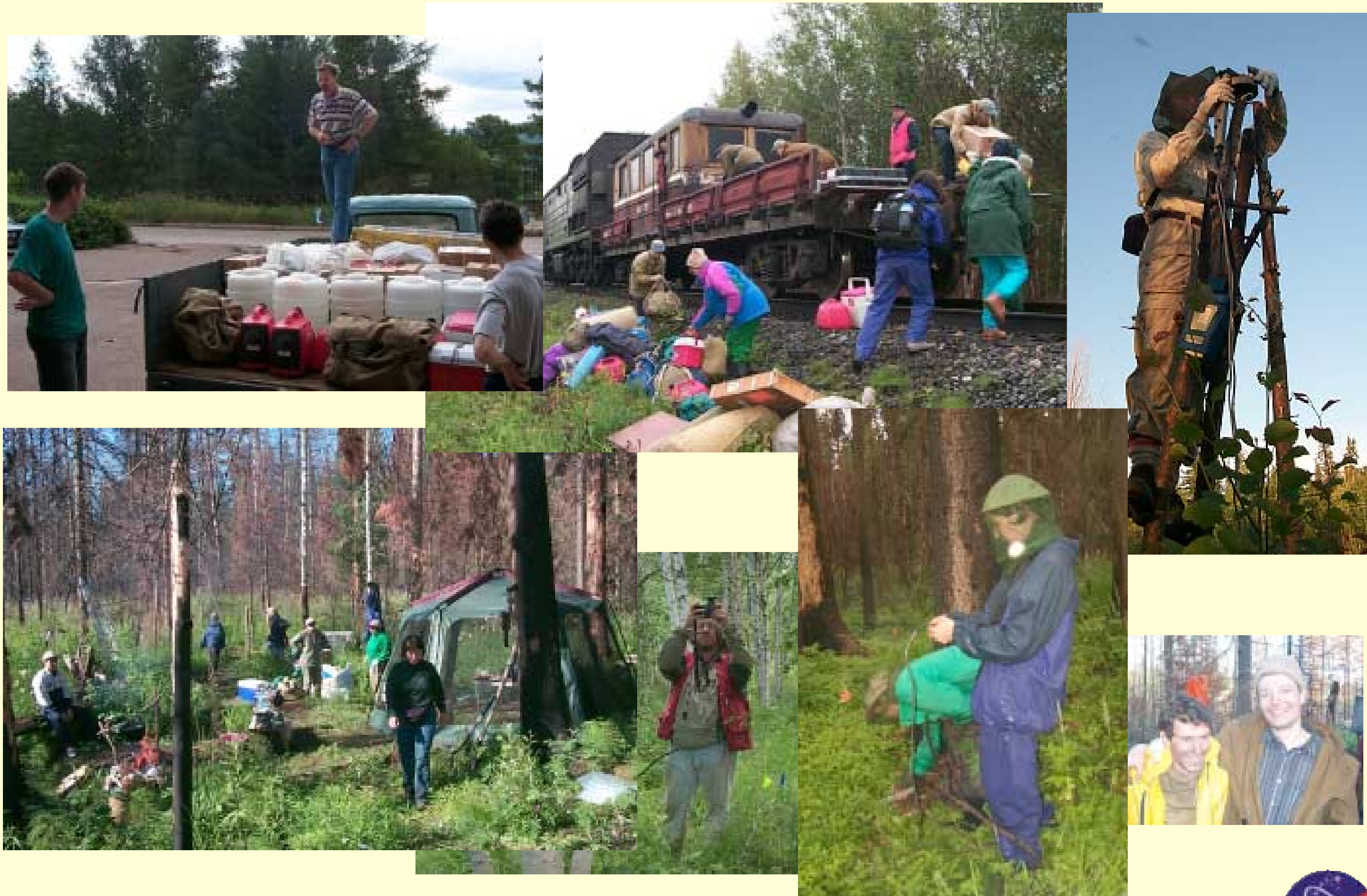
- Three field campaigns: 1999, 2000, 2001
- Indirect LAI across fire chronosequence:
  - **0, 1, 2, 13, 25, and 100+ years post fire**
  - **LAI-2000** and Hemispheric Photography (effective LAI)
  - Destructive sampling (alpha and gamma)
  - **TRAC** (omega)
- Direct (destructive) for 100+ years post fire
  - New Specific Leaf Area technique developed by Sukachev Institute (G.Kofman) based on surface area relationship to length
- Sampling Frequency
- Comparison to Canada (BOREAS)
- Species composition
  - Canopy and ground cover
  - Soils data: chemistry, texture

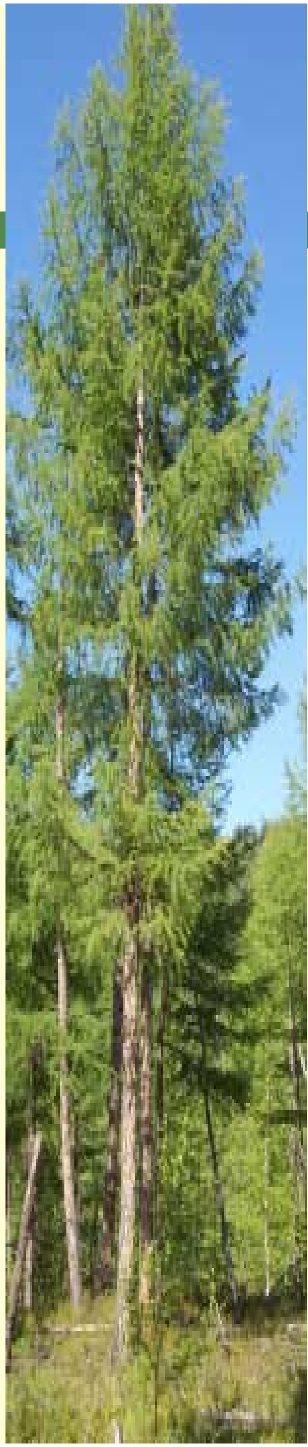
Campaign Field Crews

2000

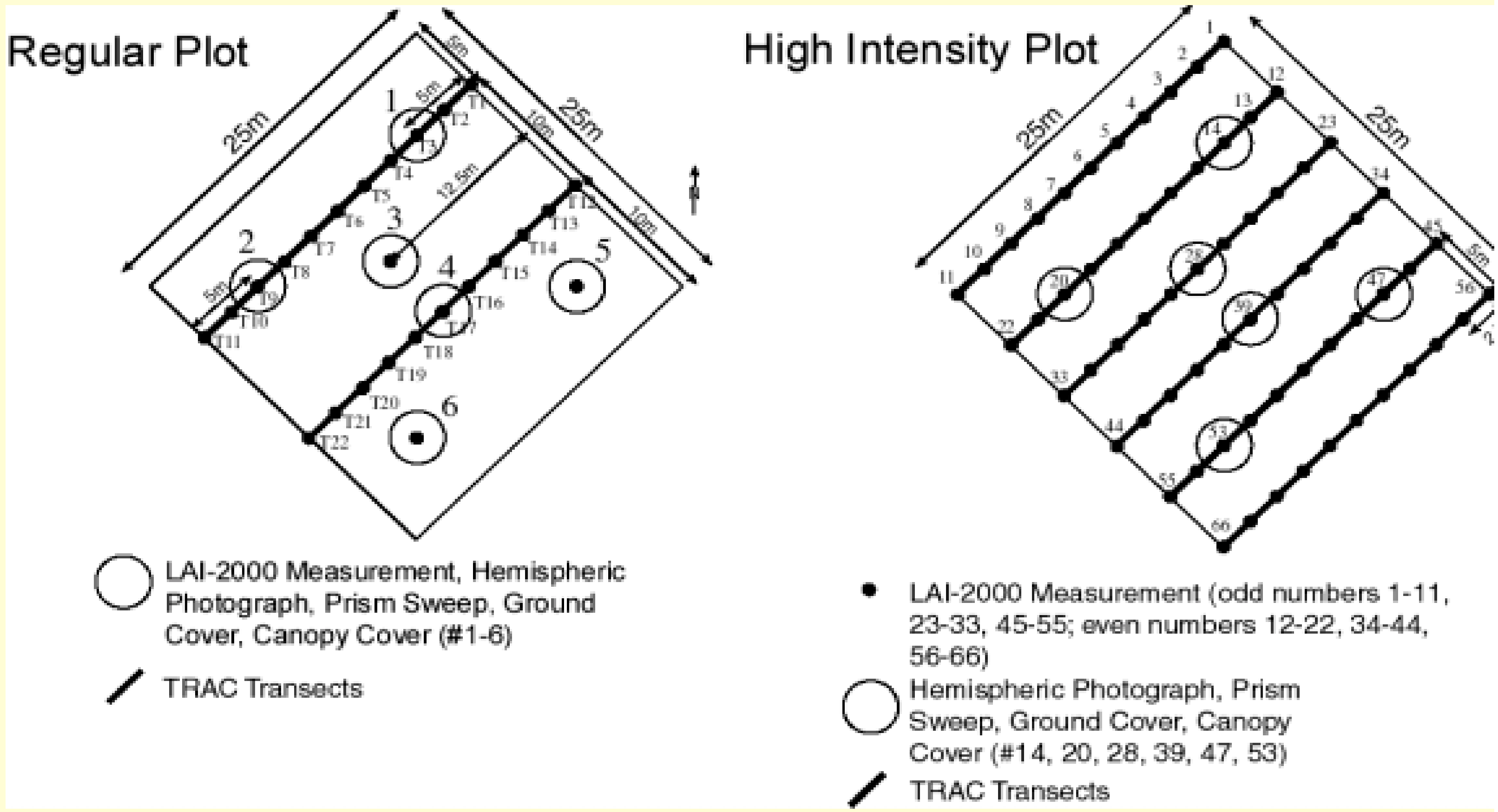
1999

2001





Plot Design (modeled after Bigfoot)



Field Collected Site data follows typical post-fire progression for major stand characteristics of coniferous boreal forest

Post-fire Age	Latitude and Longitude	Dominant Overstory Species	Number of stems per ha	Overstory Tree Height (m)	DBH* (cm)	Dominant Ground Cover Species	Other Ground Cover	Sampling dates
0-2	57° 16' N 91° 37' E	Dead mixed dark coniferous (*Abies sibirica*, *Picea obovata*, and *Pinus sibirica)* with some *Betula pendula* and *Populus tremula*	**n/a**	n/a	10.1-51.4	grasses, sedges, shrubs, ferns, moss, and young tree shoots	Needles, bare soil, and wood debris	August 19-25, 1999; July 13-24, 2000; July 6-8, 2001
13	57° 34' N 91° 32' E	Young deciduous broadleaf with some young coniferous *Betula*, *Salix*, *Sorbus*, *Abies*, *Picea*, *Pinus sibirica*	**368-10,032**	2.7-11.25	2.2-8.1	grasses, shrubs, moss, and trees seedlings	Dead wood from fallen trees	August 1-7, 2000
25	56° 57' N 91° 33' E	Deciduous broadleaf *Populus* with *Betula*	**560-3184**	3.7-15.2	3.5-10.9	grasses, shrubs, and moss		July 8-12, 2001; August 18, 2001
100+	57° 16' N 91° 37' E	Mixed dark coniferous (*Abies*, *Picea*, and *Pinus sibirica). Betula* and *Populus* also present	**1232-1936**	16-25.9	14.3-34.2	grasses with moss and shrubs	Some dead wood	August 19-25, 1999; July 13-24, 2000; July 6-8, 2001

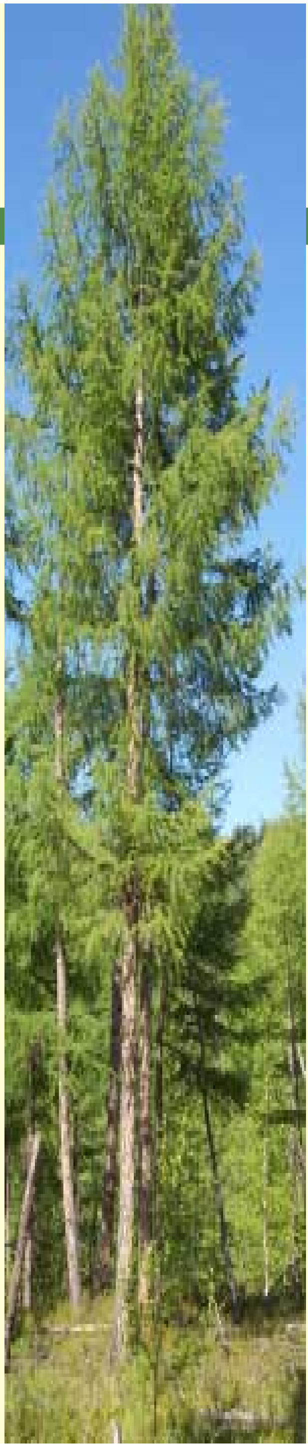
Our primary forest stands show evidence of being among the most dense boreal forests in the world.

LAI Comparisons with Published Data

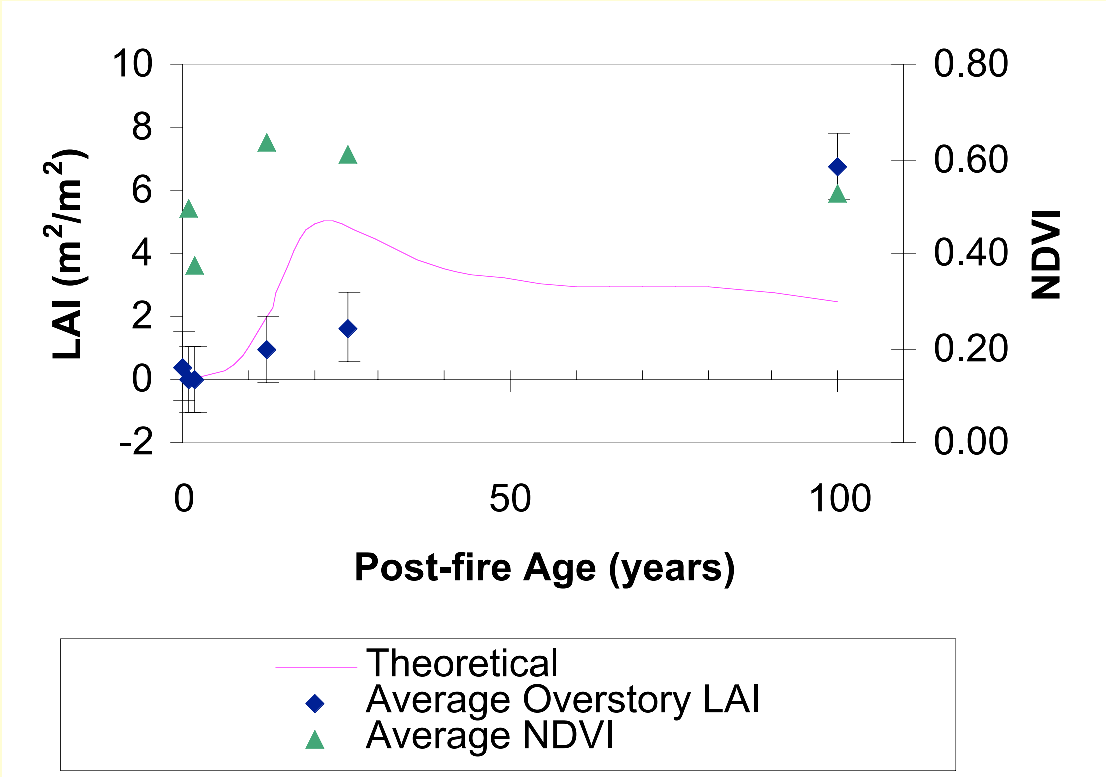
	Optical LAI	**Allometric LAI**
SIBERIA		
mixed dark coniferous	**4.3-8.7**	**10.4-13.6**
Scots pine (D.Shultze's site in Siberia		0.6-2.5[1]
BOREAS		
Old Black Spruce	**4.0-4.8**	**5.0-6.3**
Old Jack Pine	1.9-2.6	2.2-2.5
Southern Study Area	3.45±3.21	
Northern Study Area	3.08±2.47	
SCANDINAVIA		
Euroflux (Finland)	4[3]	

Our central Siberia conifer sites have higher canopy LAI than other regions with comparable species as reported;

[1]Data source Wirth et al., 1999; Zimmerman et al., 2000
[2]BOREAS data sources: Chen et al., 1997, Gower et al., 1997, Scurlock et al., 2001
[3]Valentini et al., 2000.



LAI across the Post-fire Chronosequence

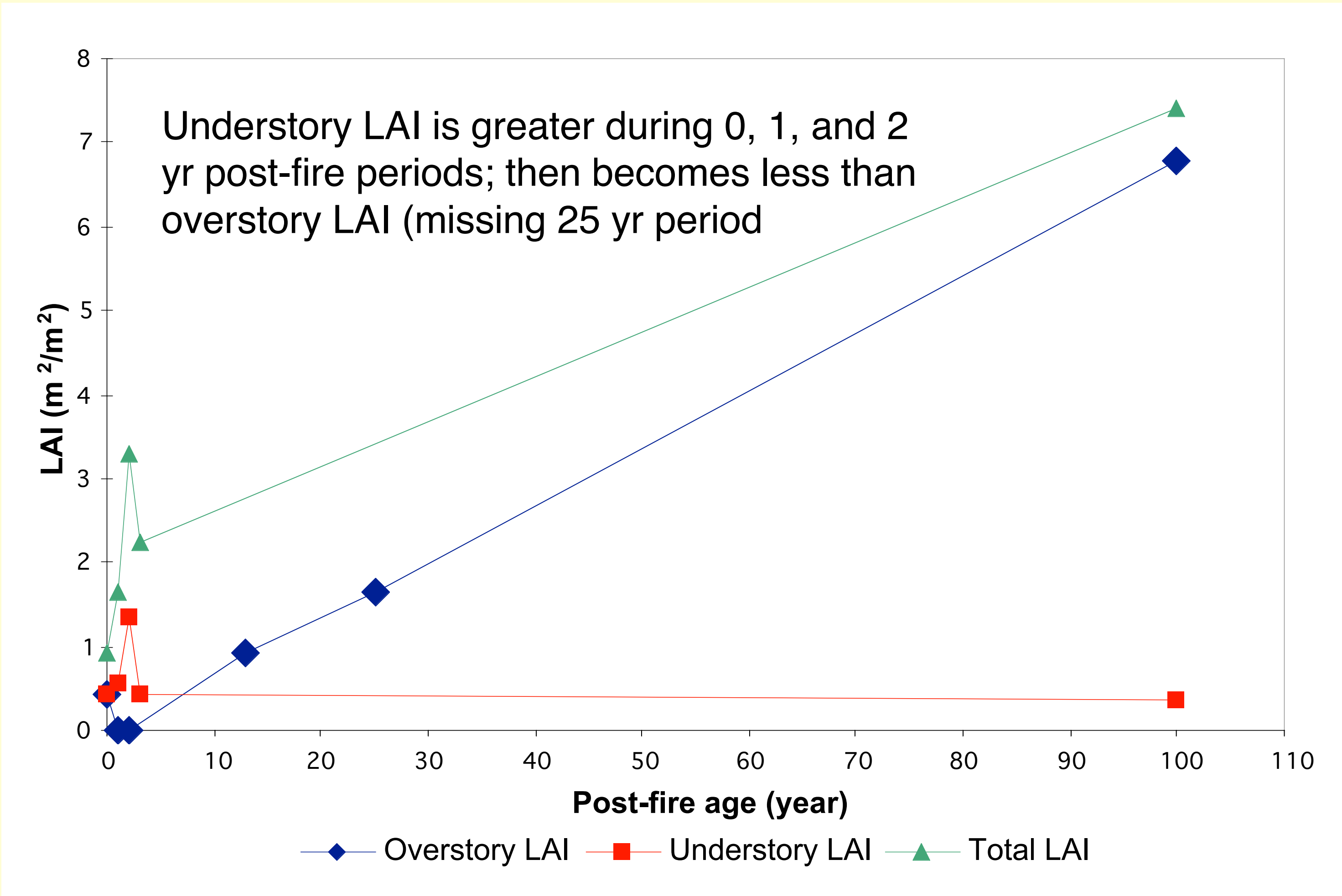


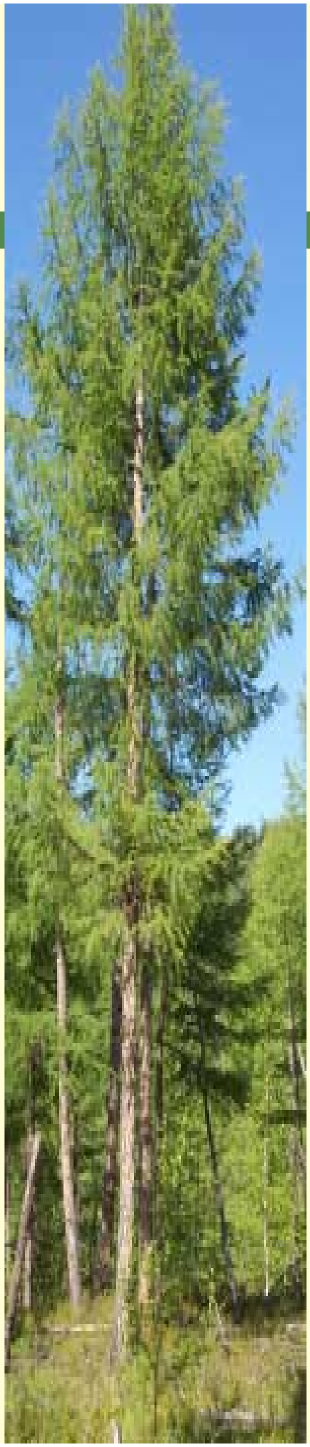
NOTE: Peak LAI occurs not in the successional forest (as might be expcted) but in the primary forest
(actual coring: 25-175 yr range); ETM+ NDVI, of course, is *total* LAI

Note: Generally we present overstory LAI because couldn’t collect understory for 25 year post-fire site (no place to ref. instr. LAI-2000

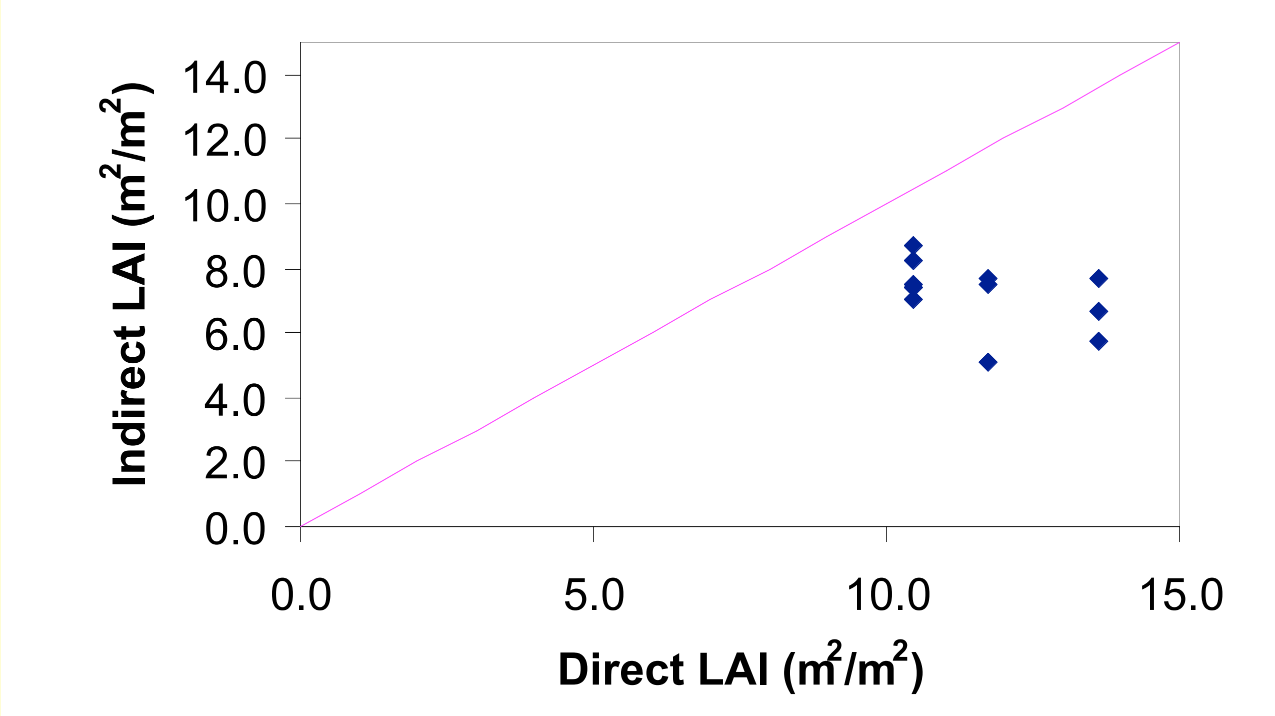
Note: Theoretical Model (overstory only) based on Waring and Running, 1998, Euro and NA forests

LAI across the Post-fire Chronosequence





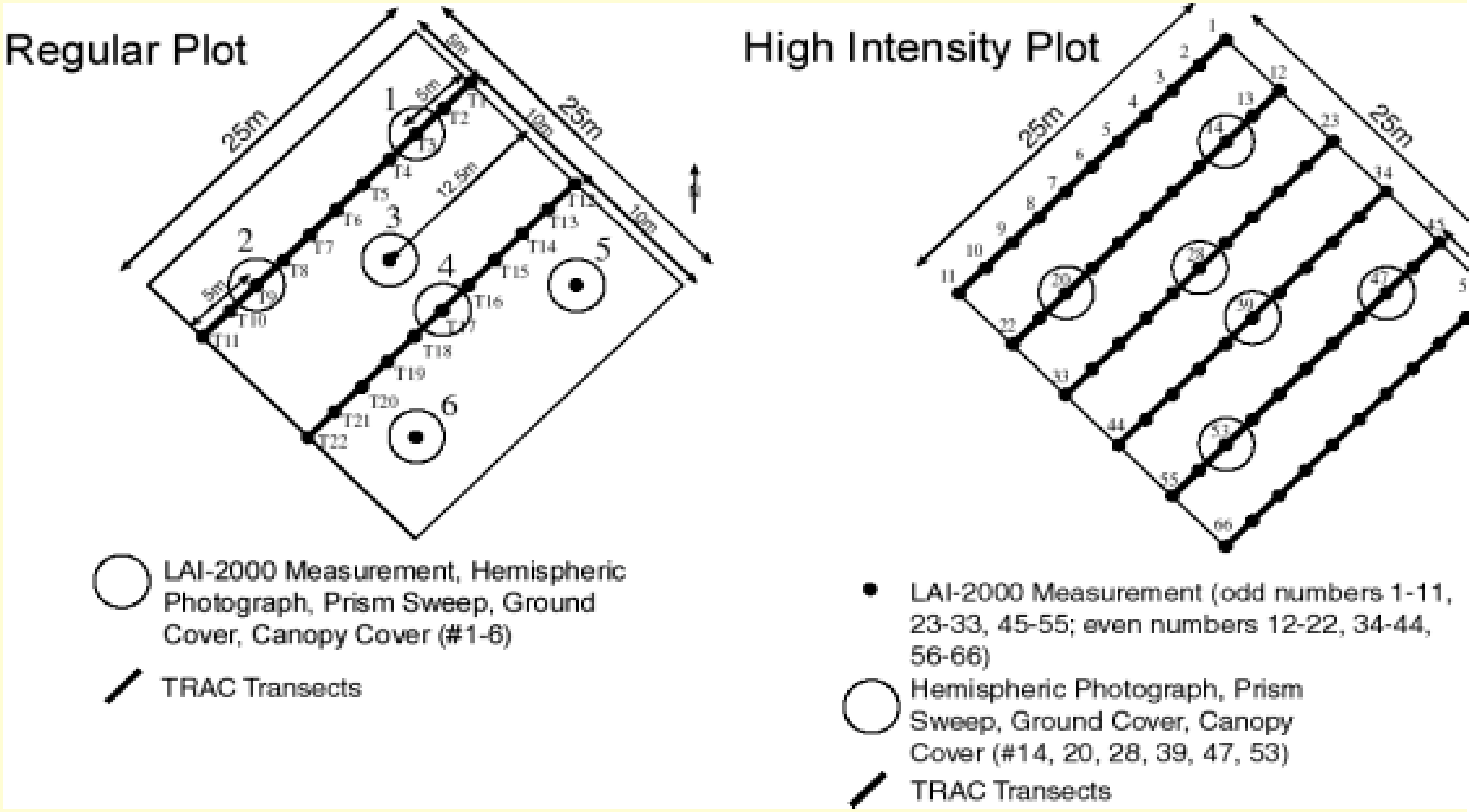
Comparison of Indirect and Direct LAI for 100+ Year Site



Poor correlations between Direct and Indirect LAI Methods:

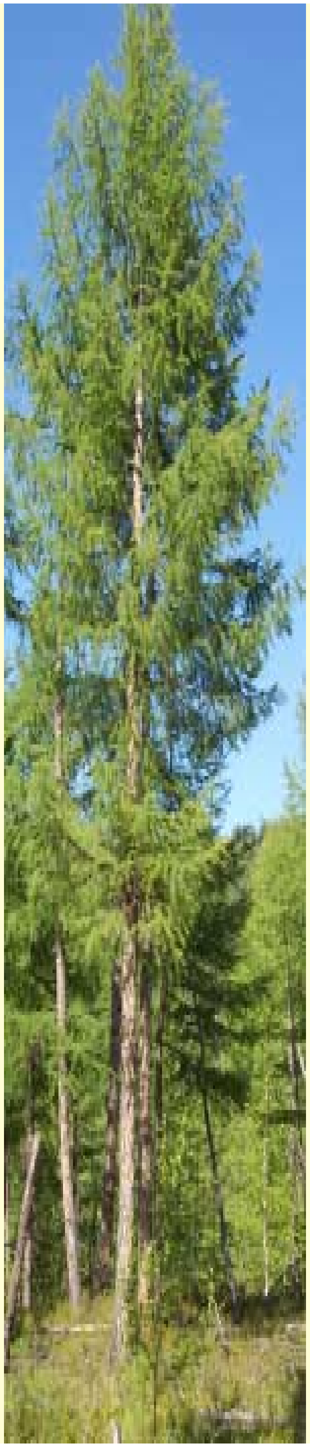
1) Indirect methods tend underestimate and direct methods tend to overestimate
2) Indrect method tends to saturate due to its inability to detect small gaps in the dense canopy; conclusion: Undersampled for sufficiently accurate direct approach and Forest Service prohibited more cutting.

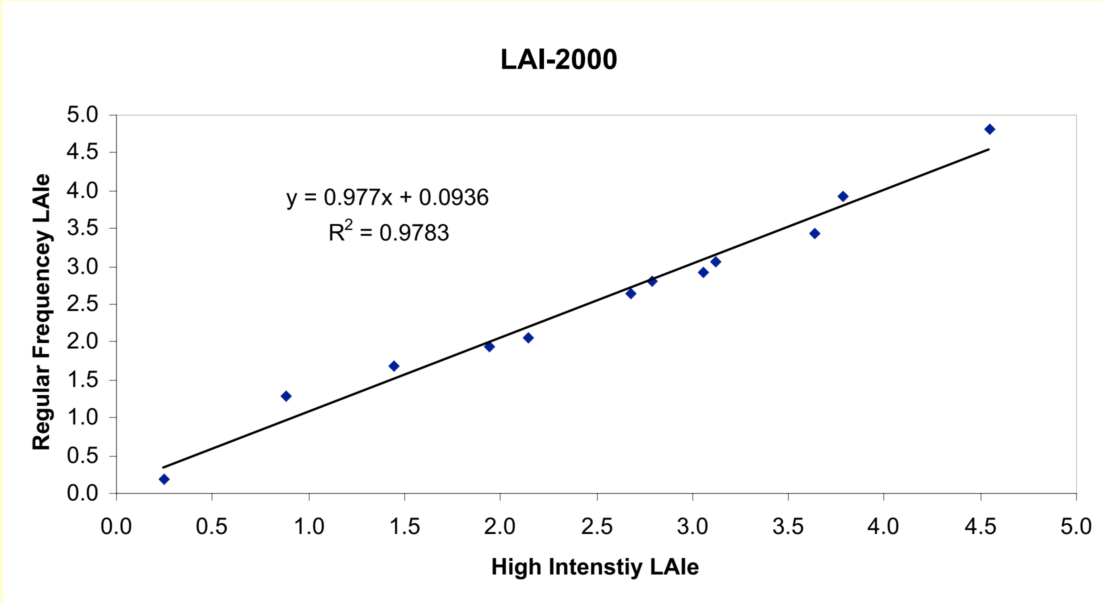
Plot Design



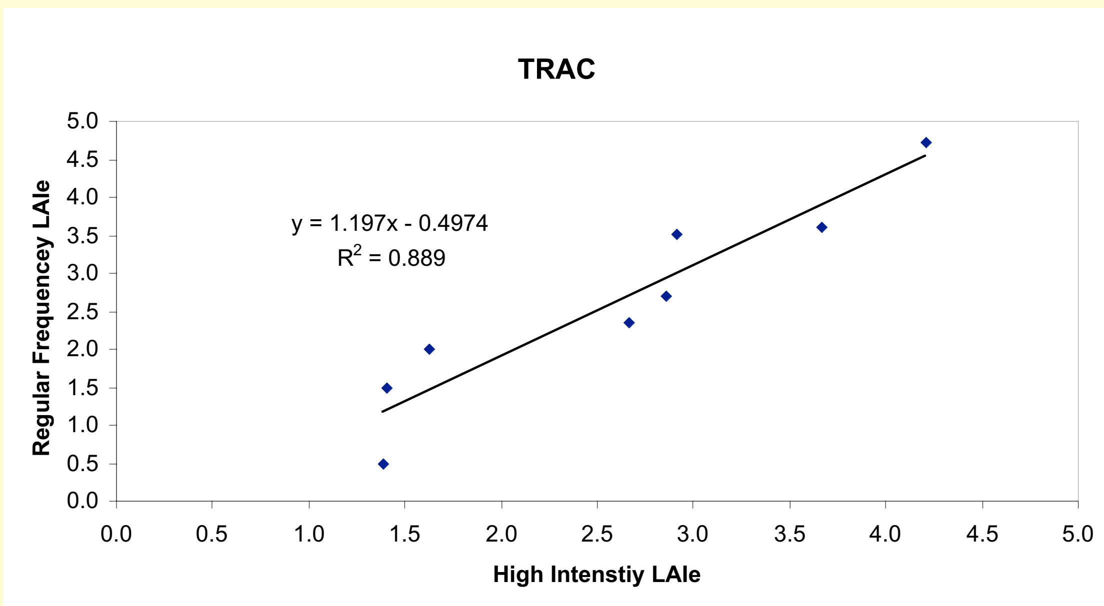
Concern over adequate sampling with “regular” plot;
therefore, ran “high intensity” plots (two of 5)

Sampling Frequency Comparison for Indirect Methods





LAI-2000 does a great job (high correlations) – footprint of what it measures is large



TRAC also did a good job

(note: all sites not included in both data sets)

Field Data Summary

- LAI data has been collected and is provided for a remote Siberian forest
- LAI roughly follows the theoretical post-fire successional trend
- LAI of these Siberian forests are greater than reported elsewhere
- Direct and Indirect methods were not well correlated
- “High intensity” sampling frequency yielded the same result as the “regular intensity” sampling

Remote Sensing Research Highlights

- Development of a "Temporally Invariant Cluster" normalization method to improve change detection using multi-temporal, cross-platform imagery
- Elucidation of NDVI and EVI (Enhanced Vegetation Index, Huete et al. 1997) applications for remote sensing of vegetation structure (including LAI and canopy shadowing effects) along burn chronosequences
- Investigation of the RSR (Reduced Simple Ratio; Brown et al. 2000) relationship with LAI in fire chronosequences
- Development of a relevant scaling approach for relating IKONOS and ETM+ imagery to MODIS imagery in post-fire landscapes, including investigations of spatio-temporal variation in MODIS LAI product
- Improvement in how canopy-specific calibration coefficients (necessary to calculate LAI in needleleaf forests) must be used when investigating recently disturbed forests

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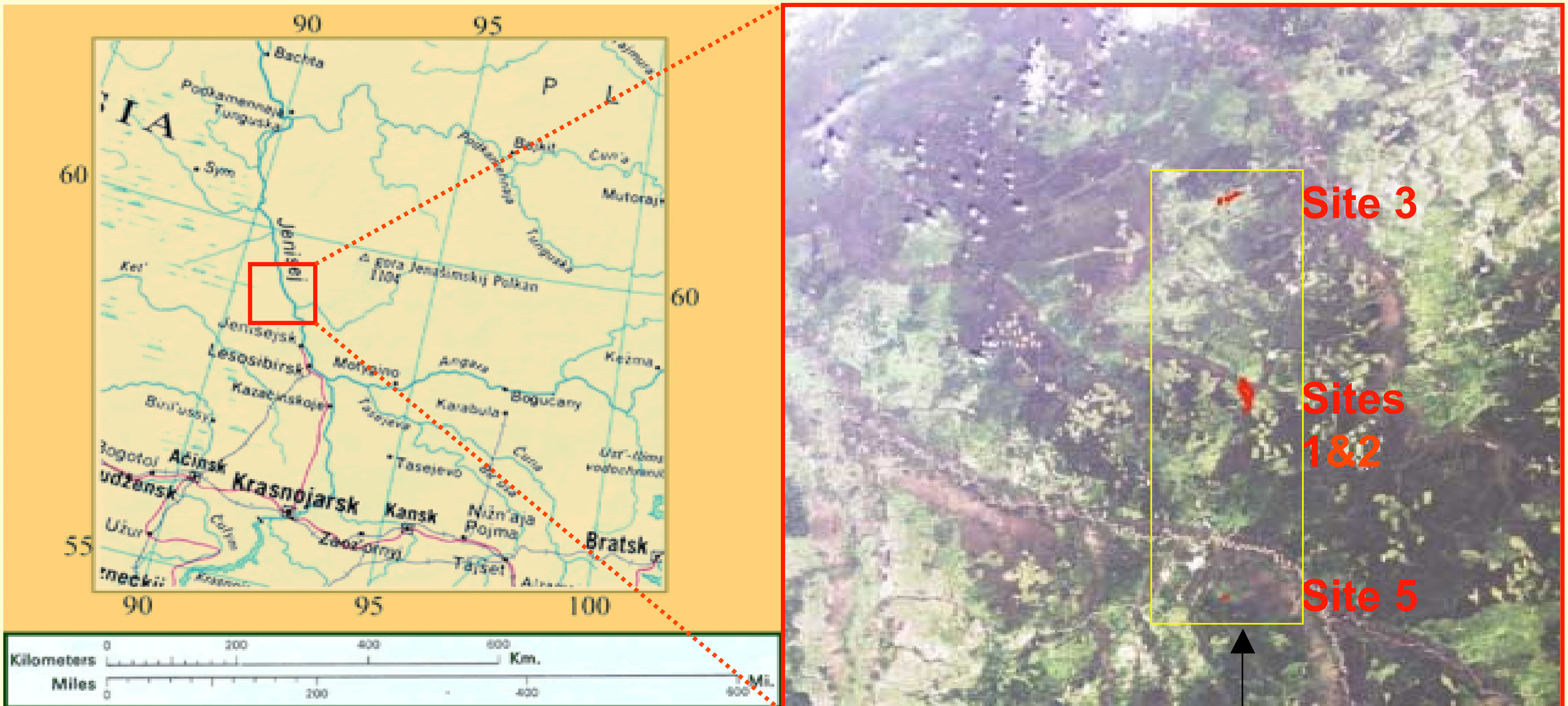
Image Normalization is often necessary for accurate change detection

Study sites in the central Siberian region of Krasnoyarsk



Region of interest to normalize for change detection

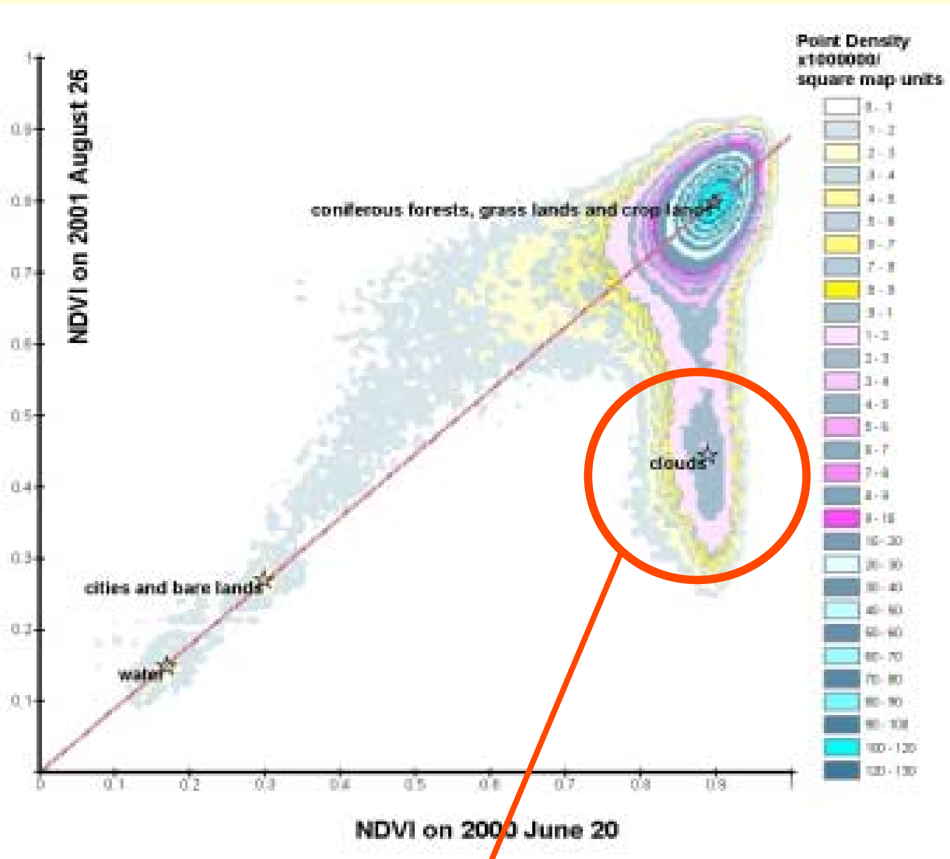
Temporally Invariant Cluster Normalization Methodology

- Geo-register two images
- Calculate NDVI and EVI
- Input data from both images into scatter plot
- Create point density map
- Identify normalization function through analysis of Temporally Invariant Clusters
- Normalize target image to base image

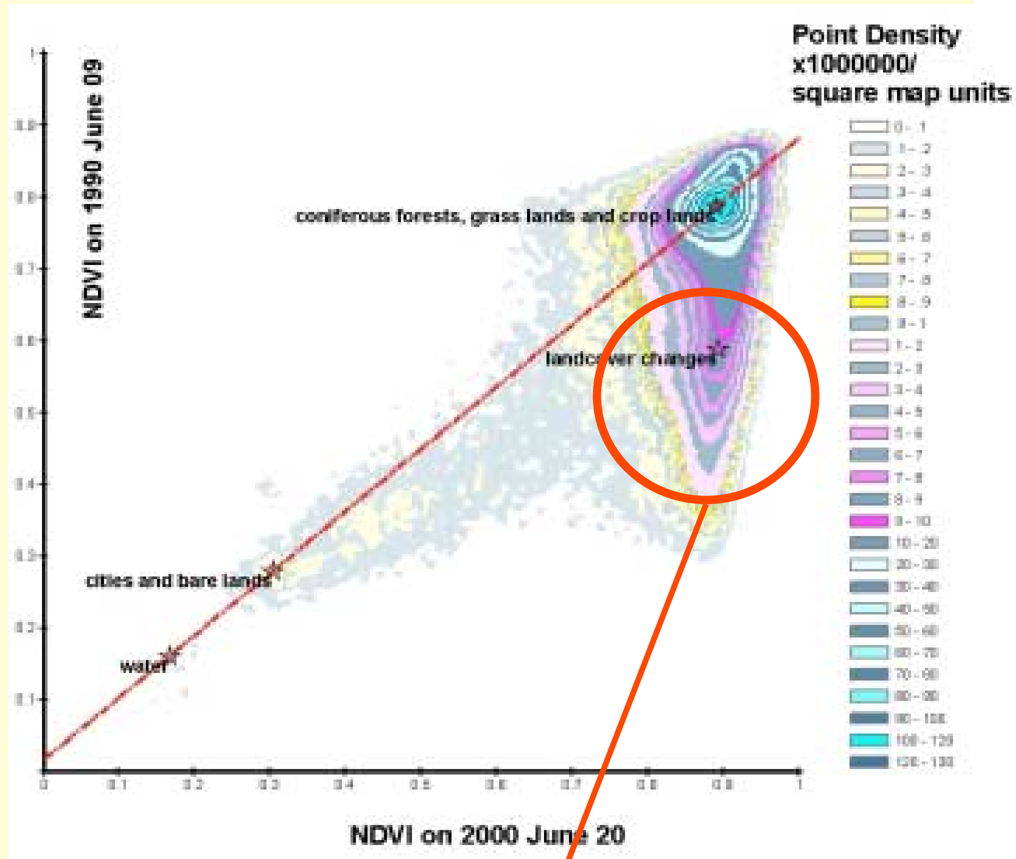
Images used in analyses: 1990 (L4 TM), 2000 (L7 ETM+), 2001 (L7 ETM+)

NDVI-based normalization regressions

2001 image vs. 2000 image (both L7 ETM+)



1990 image (L4 TM) vs. 2000 image (L7 ETM+)

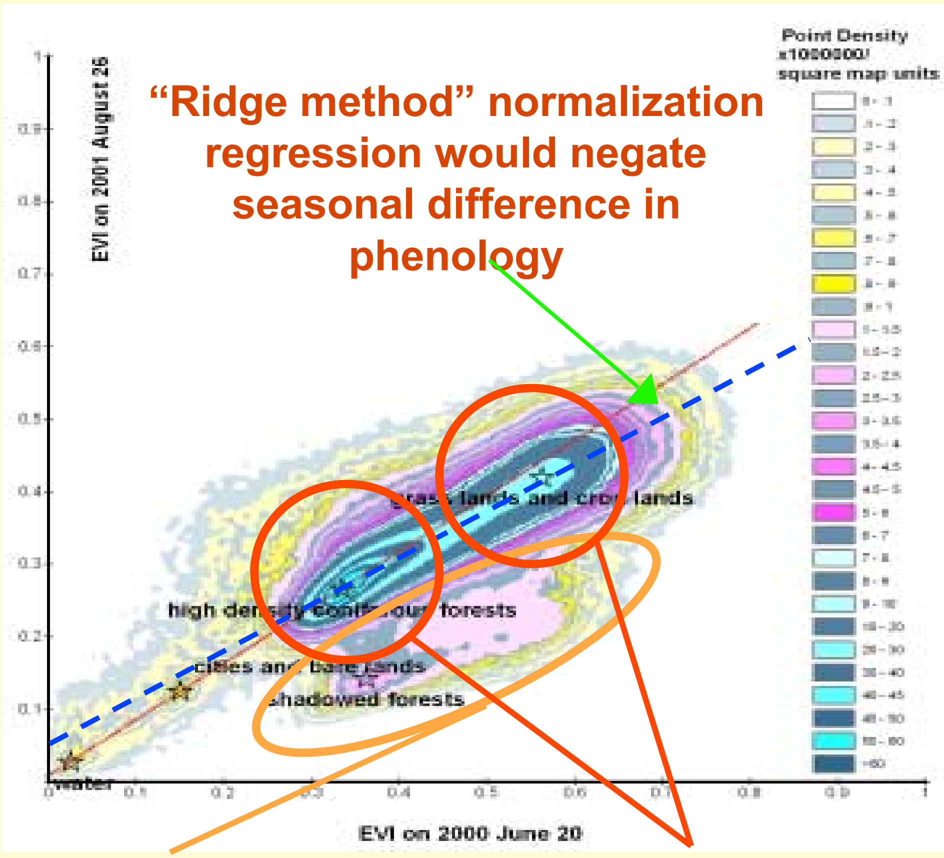


Main change: clouds in 2001

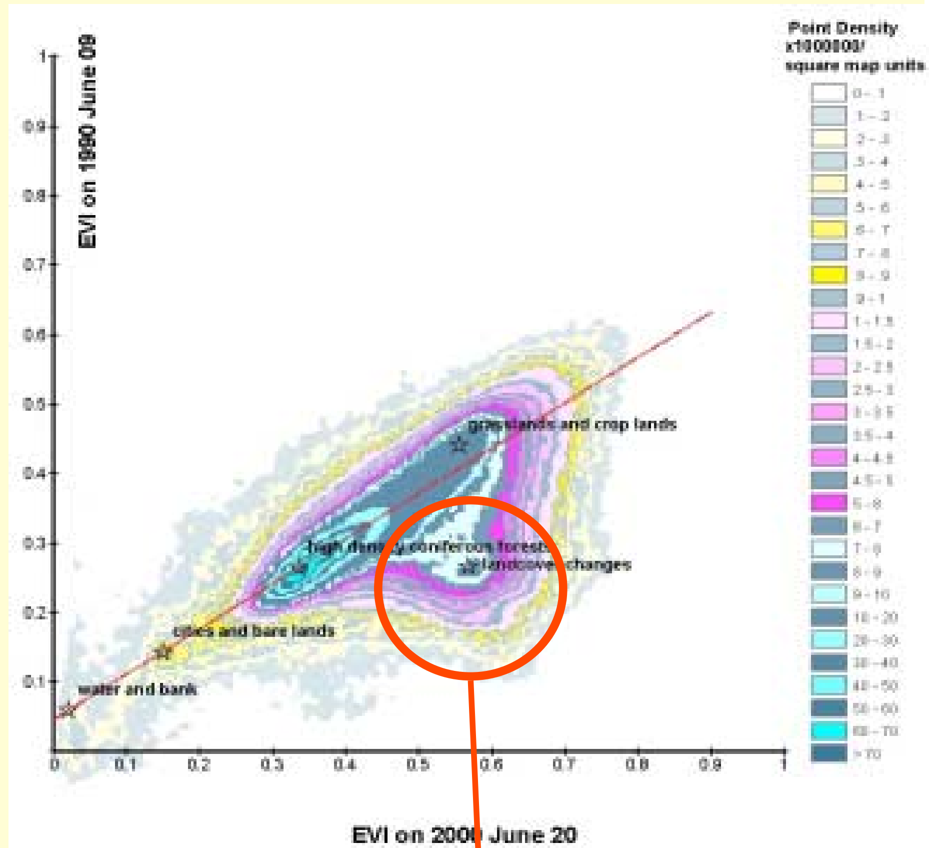
Landcover change detected, but difficult to specify type of change

EVI-based normalization regressions

2001 image vs. 2000 image (both L7 ETM+)



1990 image (L4 TM) vs. 2000 image (L7 ETM+)



1. Shift in EVI due to cloud *shadowing* of vegetation (*not* due to cloud pixels themselves)

2. This is why EVI produces discernable separation of crop/grass (few shadows) from forest (high self-shading)

Landcover changes between 1990 and 2000 can now be specified as a shift from high density forest to crop/grass (not possible to do with NDVI)