Carbon Dynamics in Boreal Forests

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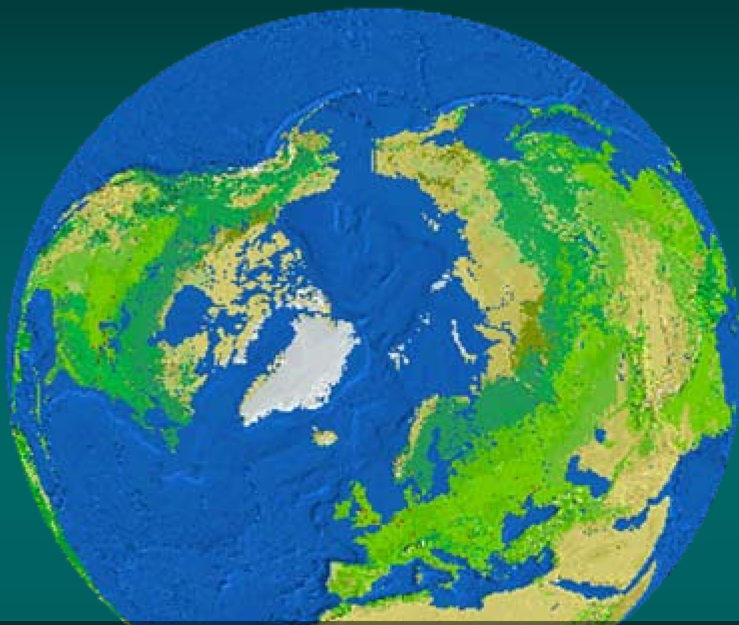
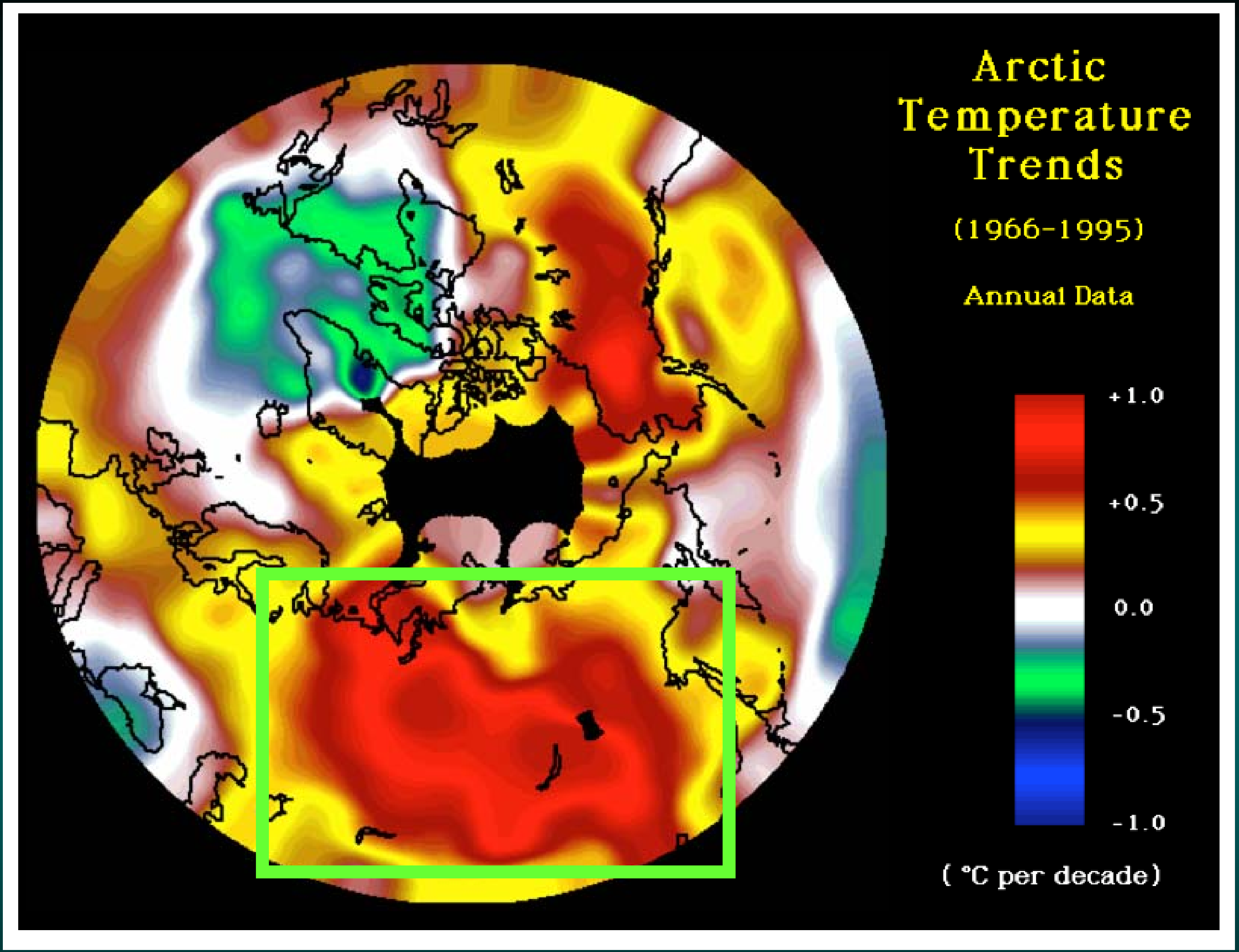
With much appreciated help from our colleagues:

Sergey Bartalev, Warren Cohen, Ivan Csiszar, Dmitry Ershov, Vladimir Elsakov, Mark Friedl, Evgeny Gordov, Alexander Iseav, Debra German, Vyacheslav Kharuk, Zengyuan Li, Tatiana Loboda, Juliya Kurbatova, Eugeny Lupian, Jeff Masek, Alexander Maslov, Jeff Morisette, Nancy Sherman, Jacquelyn Shuman, Andrew Varlagin, Nadezda Tchebakova, Amber Soja, Vladimir Trush, Curtis Woodcock, Natalia Vandysheva, Xiangming Xiao, Xiaodong Yan, Ningning Zhang and Mykola Zalogin

The Boreal Region

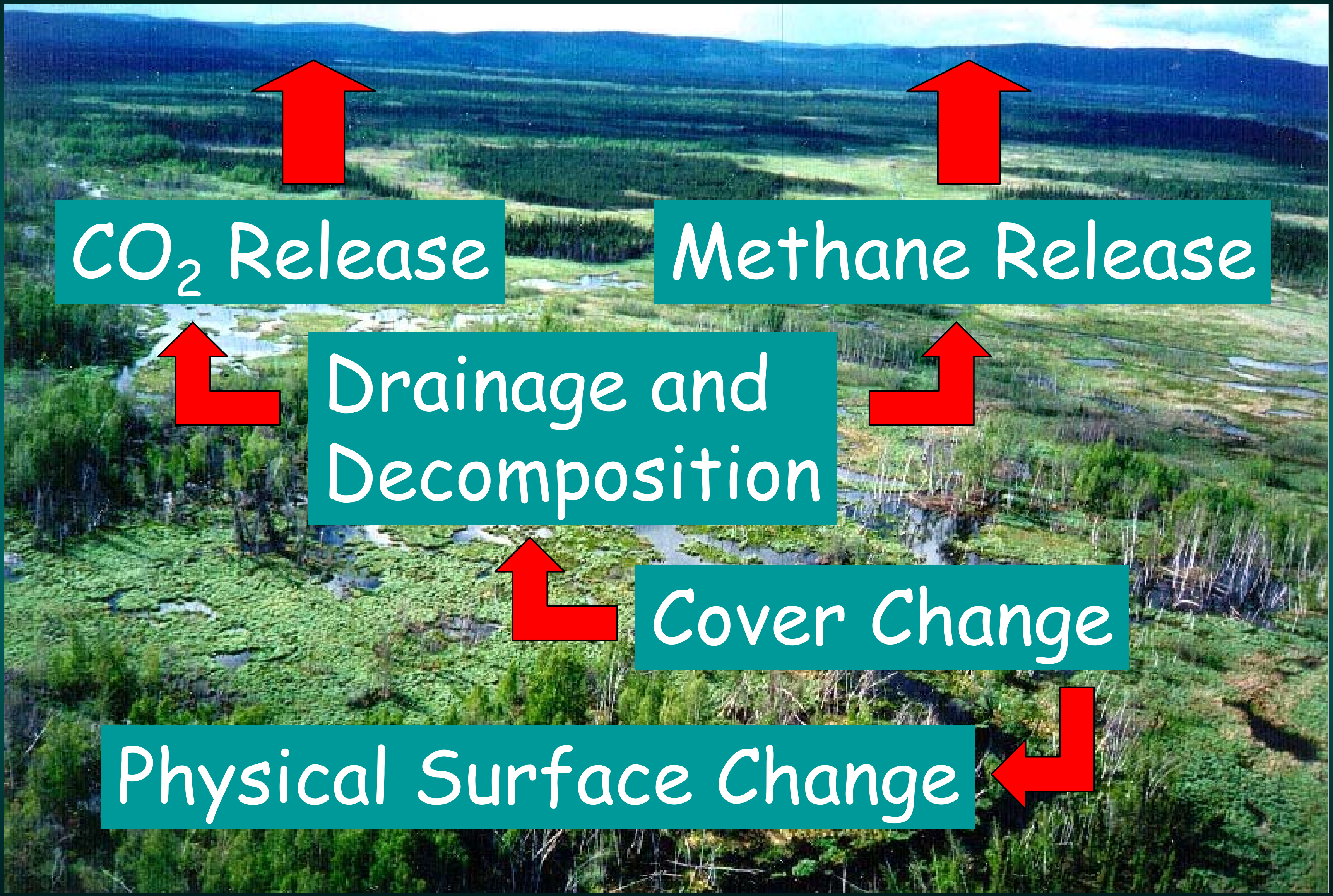


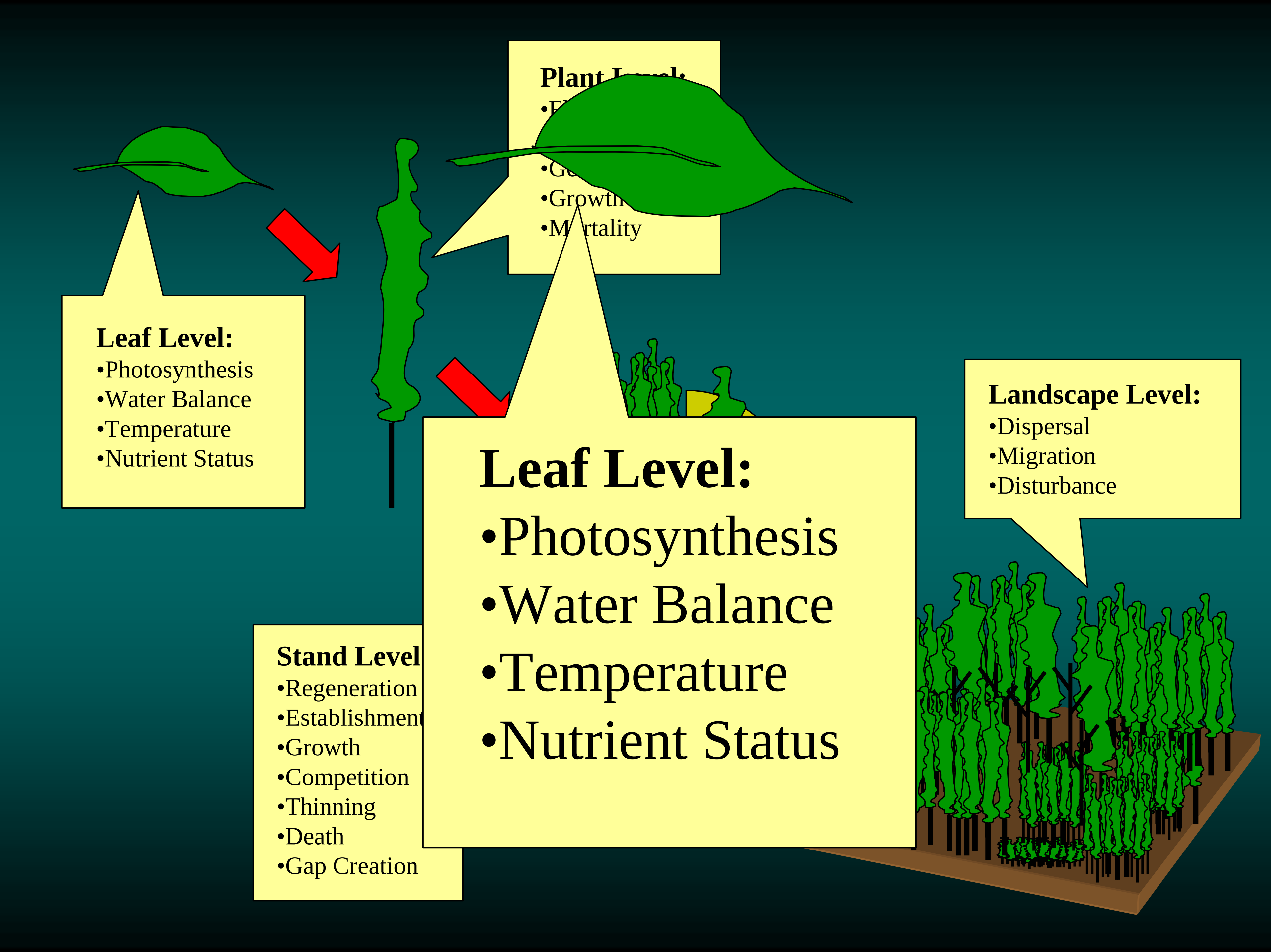
Biome	*Area (10^6 ha)*	*Soil Carbon (Pg)*	*Plant Biomass Carbon (Pg)*	*Total Carbon (Pg)*
Boreal Forest	**1509**	**624**	**51**	**675**
Tropical Forest	1756	216	159	375
Temperate Forest	1040	100	21	121



Observed Warming Trend From: Serreze, MC, et al. 2000. Observational Evidence of Recent Change in the Northern High-latitude Environment. Climatic Change 46:159-207.

Implications of Change:




Leaf Level:
•Photosynthesis
•Water Balance
•Temperature
•Nutrient Status
Plant Level:
•Growth
•Mortality
Stand Level
•Regeneration
•Establishment
•Growth
•Competition
•Thinning
•Death
•Gap Creation
Landscape Level:
•Dispersal
•Migration
•Disturbance
Leaf Level:
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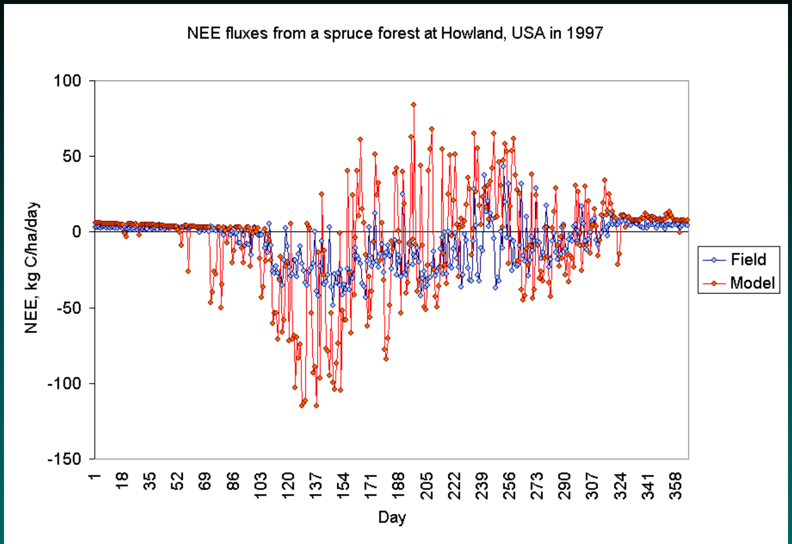
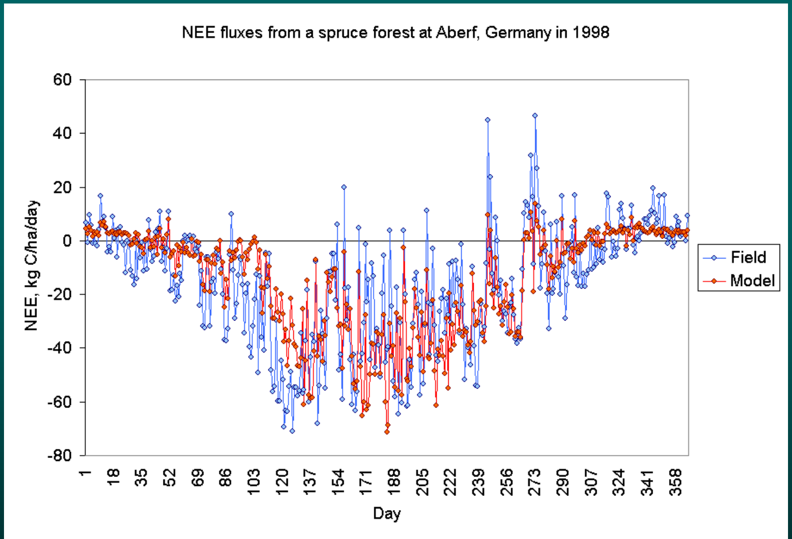
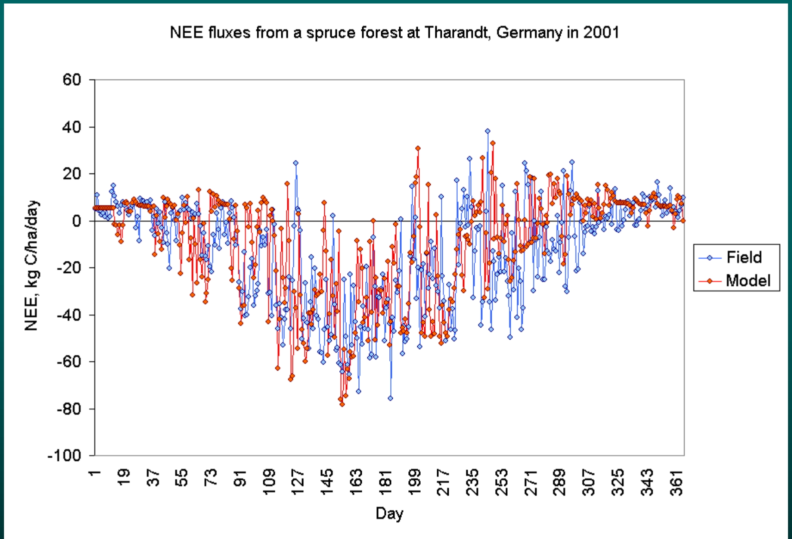
•Nutrient Status

Testing of Forest-DNDC against observed NEE fluxes

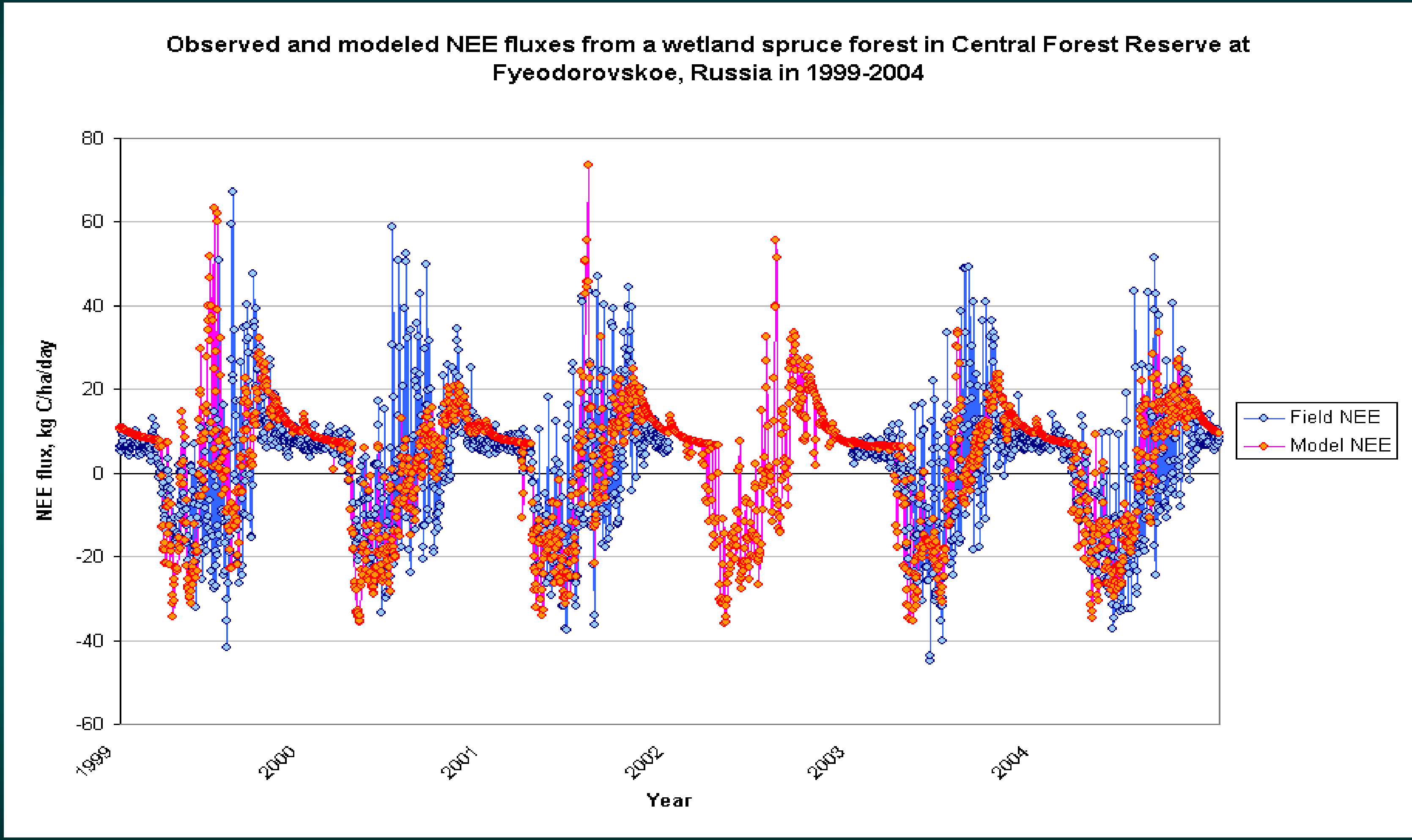






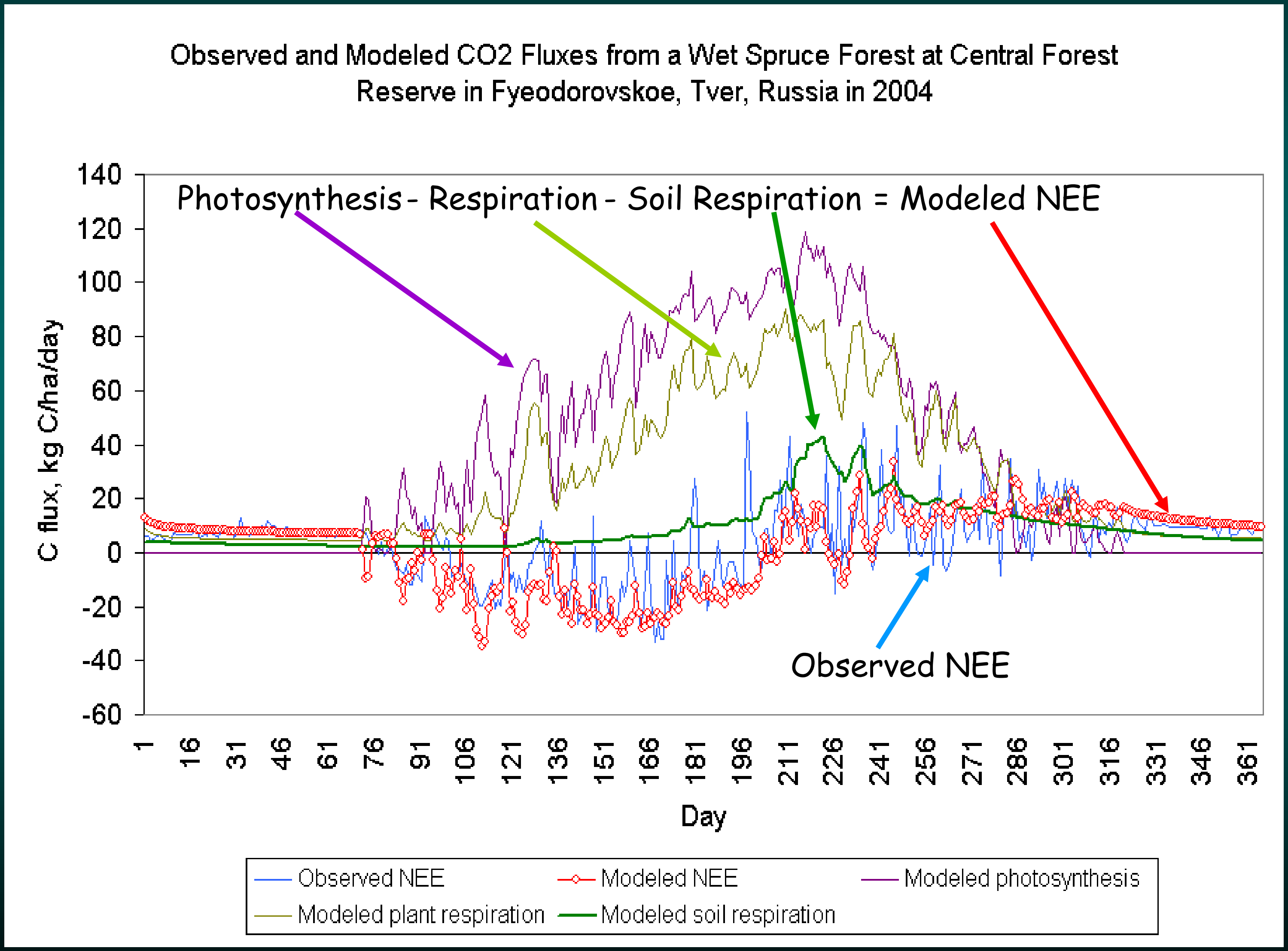
Comparison between observed and Forest-DNDC modeled NEE fluxes.

Testing of Forest-DNDC against observed NEE fluxes

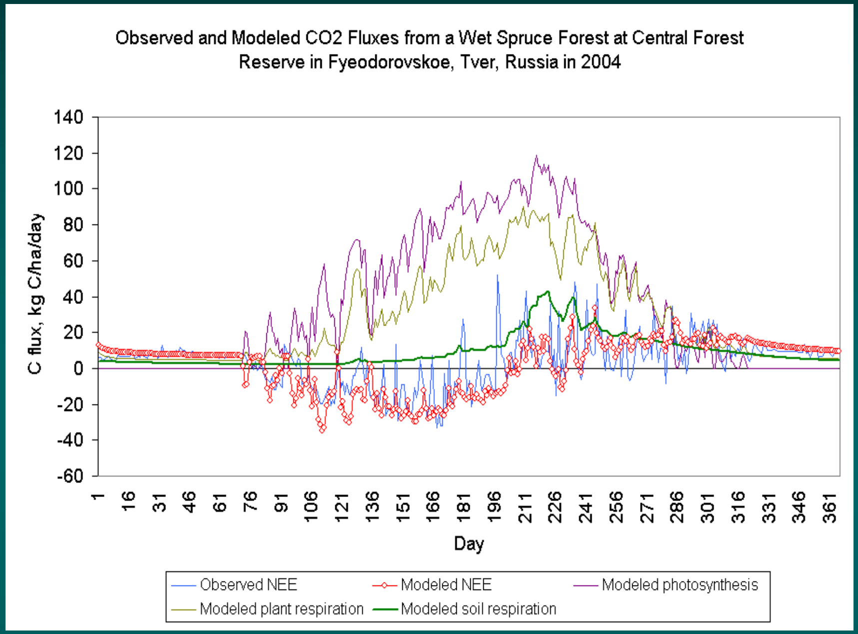


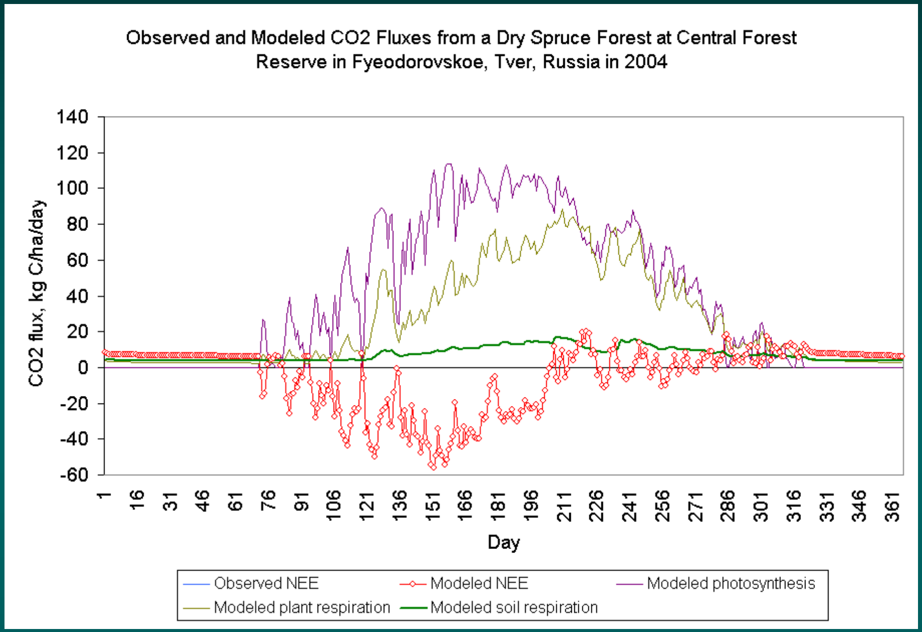
Comparison between observed and Forest-DNDC modeled NEE fluxes.

Modeled C fluxes composing NEE: Soil is a key factor determining sink or source



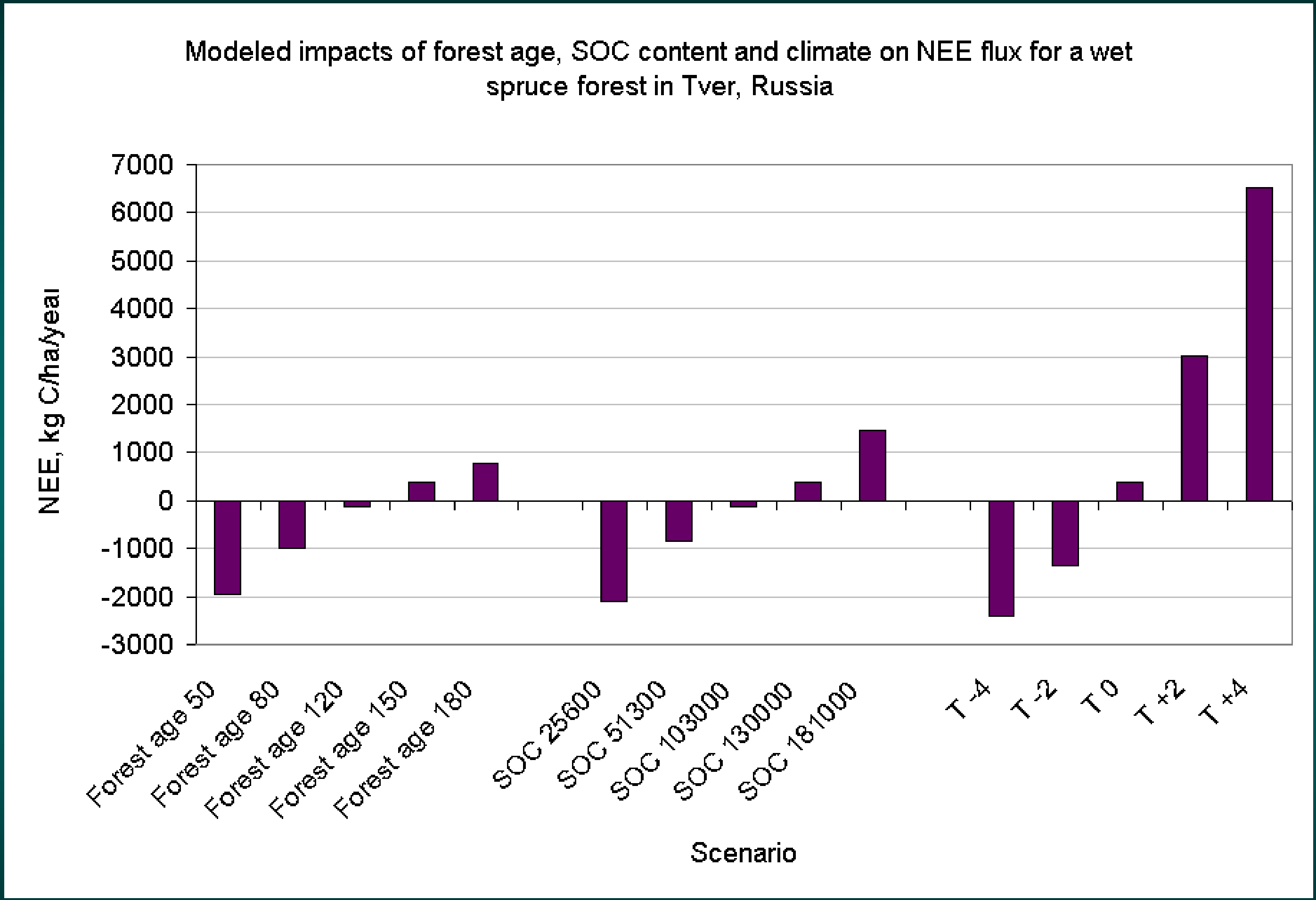
Modeled C fluxes composing NEE: Soil is a key factor determining sink or source



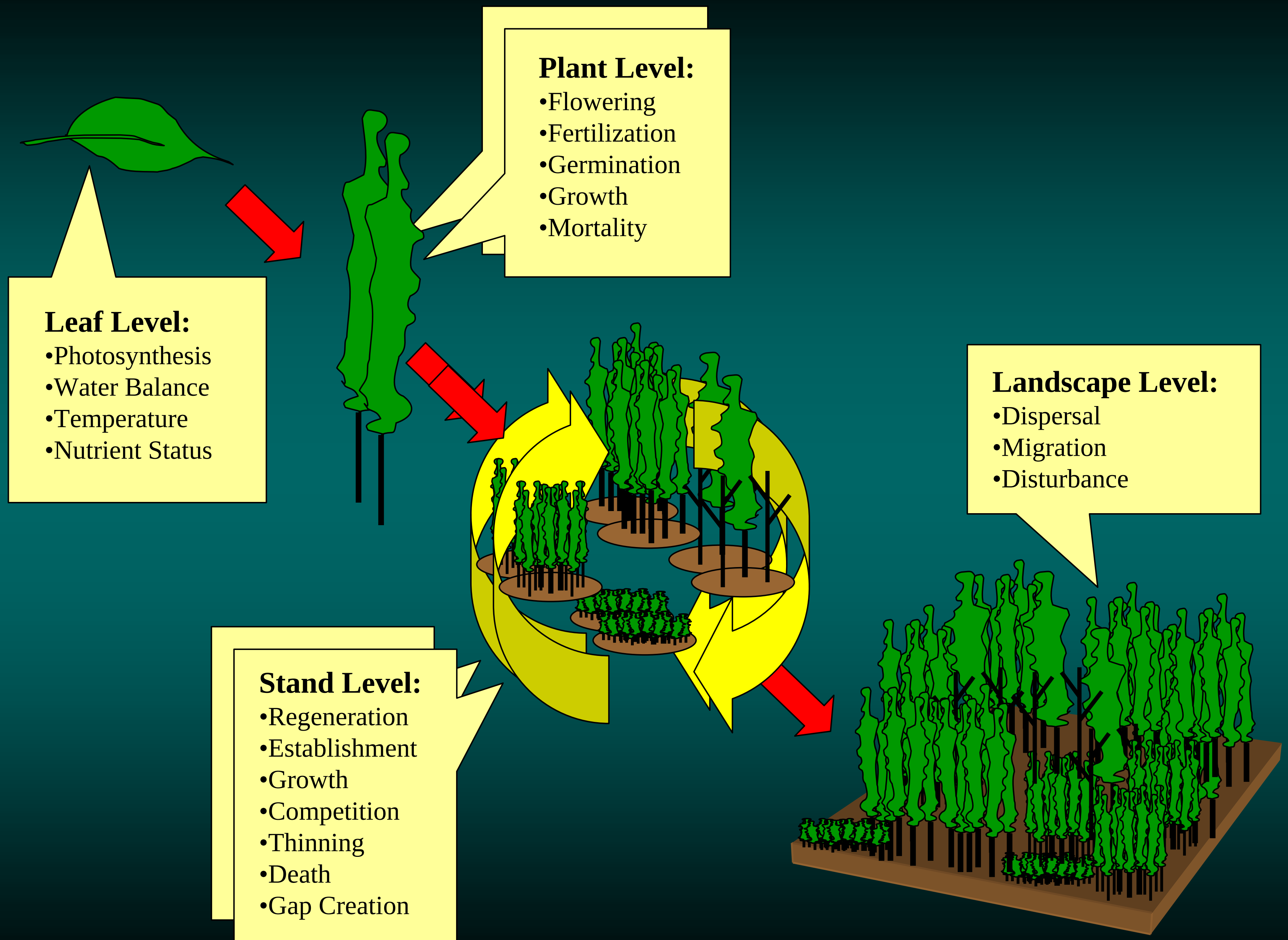


Stand	Photosynthesis kgC ha^{-1} yr^{-1}	Plant respiration kgC ha^{-1} yr^{-1}	Soil respiration kgC ha^{-1} yr^{-1}	GPP kgC ha^{-1} yr^{-1}	NEE kgC ha^{-1} yr^{-1}
WSF	13132	10361	3481	2771	711
DSF	14162	9616	2683	4546	-1863

Impact of forest age, SOC and temperature on C dynamics



NEE was sensitive to forest age, SOC content and temperature. Along with increase in forest age, SOC content or temperature, the forest shifted from a sink to a source of atmospheric CO_2 although the mechanisms underlying the NEE changes were different.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•Migration
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FAREAST: A Boreal Forest Simulator

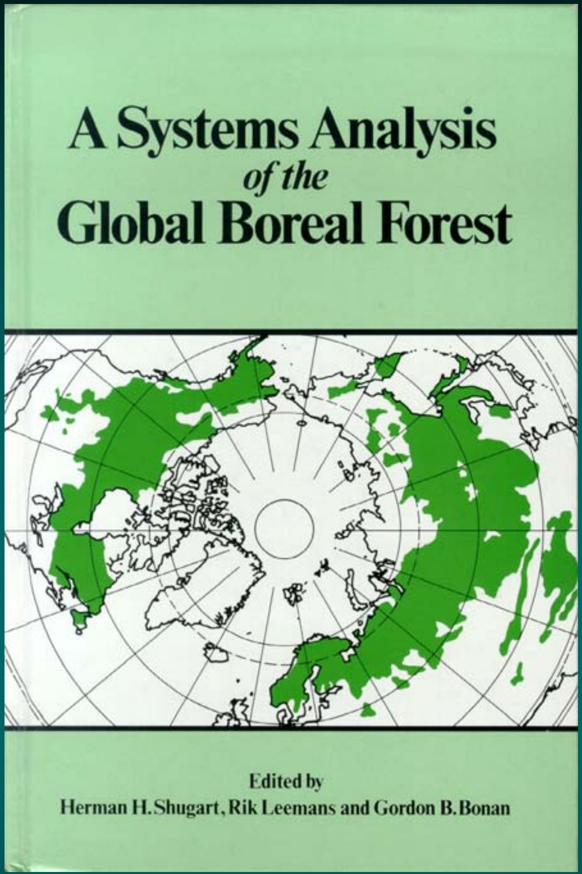
Growth:
- Available Light
- Soil Moisture
- Site Quality
- Growing-Degree Days
- Depth of Thaw
- Diameter
- Age
- Height

Mortality:
- Stress
- Fire
- Insects
- Age

Regeneration:
- Available Light
- Soil Moisture
- Site Quality
- Depth of Thaw
- Seed Bed
- Seed Availability
- Sprouting
- Layering

Data Needs:

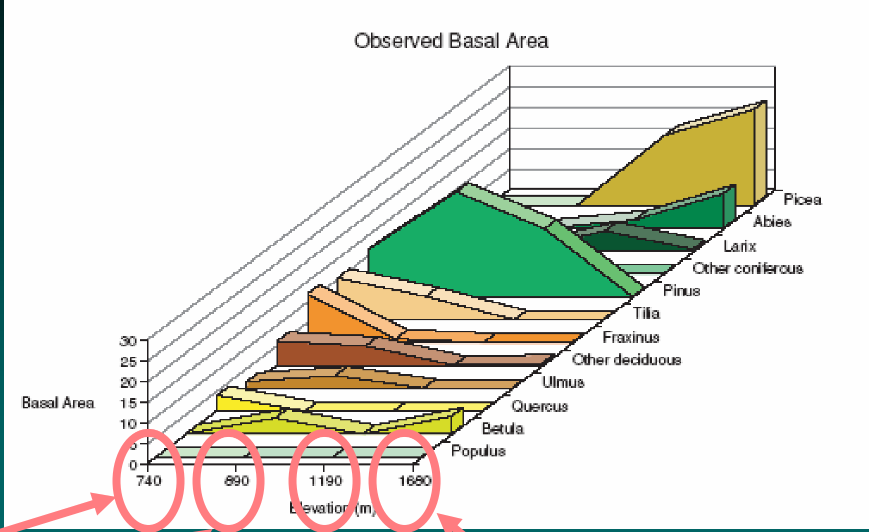
Process information on the silvicultural features of the boreal tree species, allometric equations, light extinction coefficients, and other biological, biophysical and physical aspects of stand dynamics.



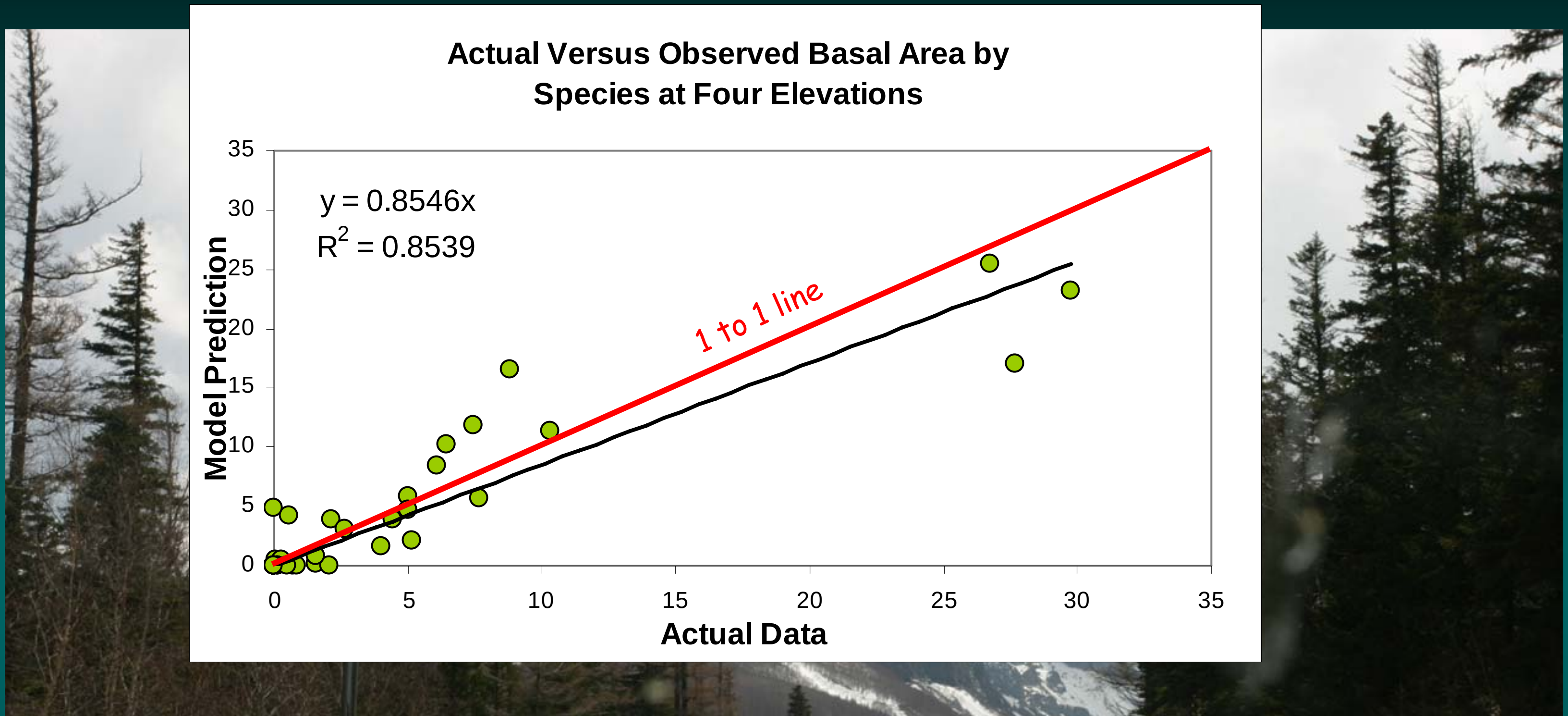
Much of this has been derived from earlier synthesis activities but there remains a need for a characterization of the fundamental processes, particularly thermal fluxes and ice-related processes.

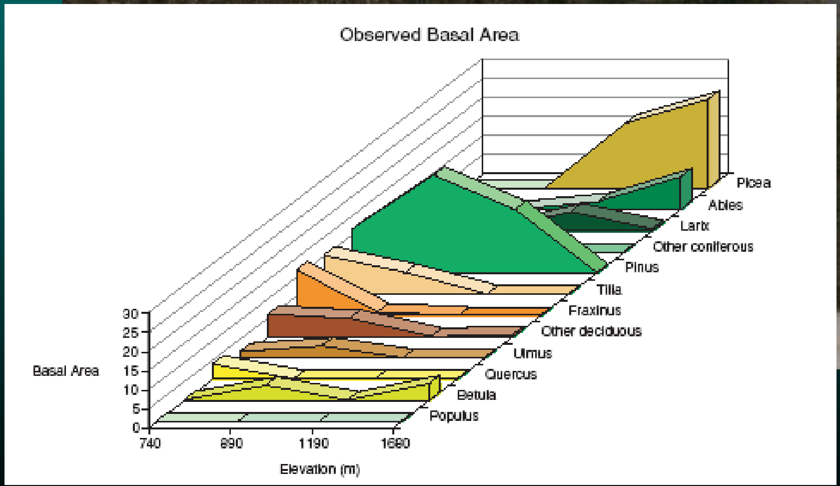
Testing Individual-based Models of the Boreal Forest

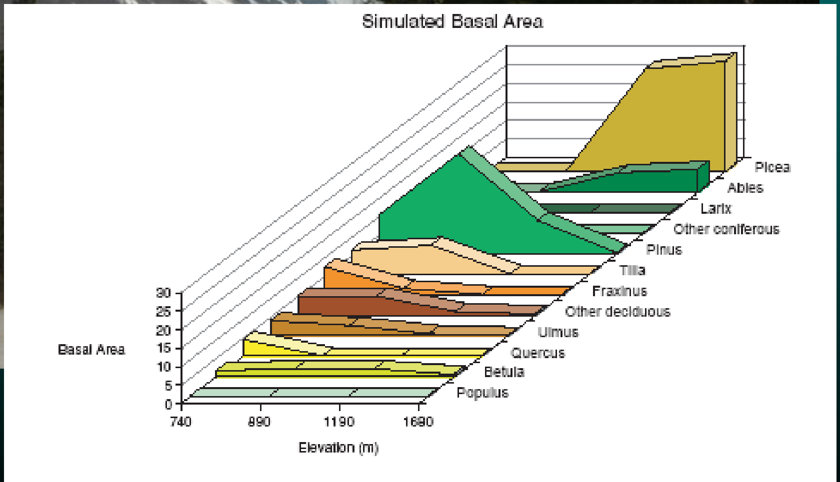
Chang Bai Shan Vegetation Gradient



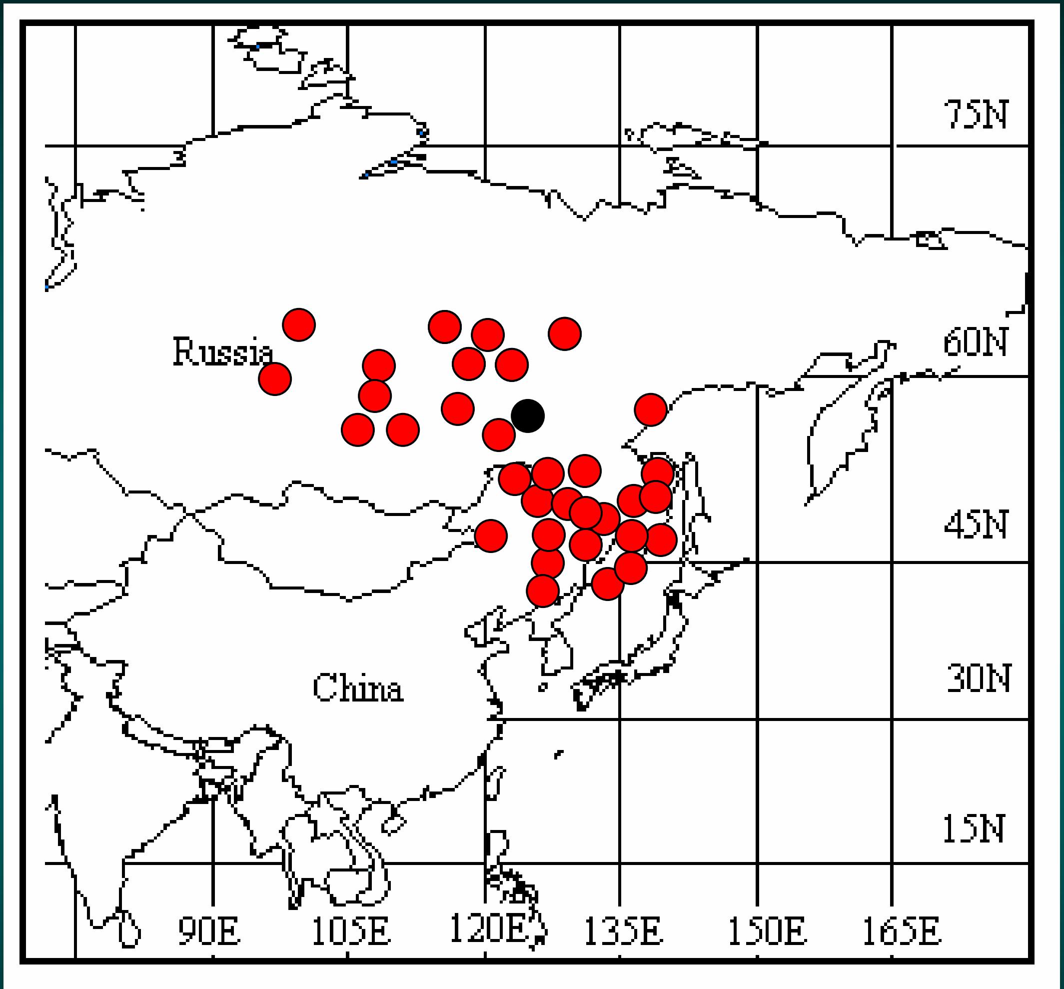
Tests of the FAREAST Model on Mountain Gradients







Test sites in China and Russia



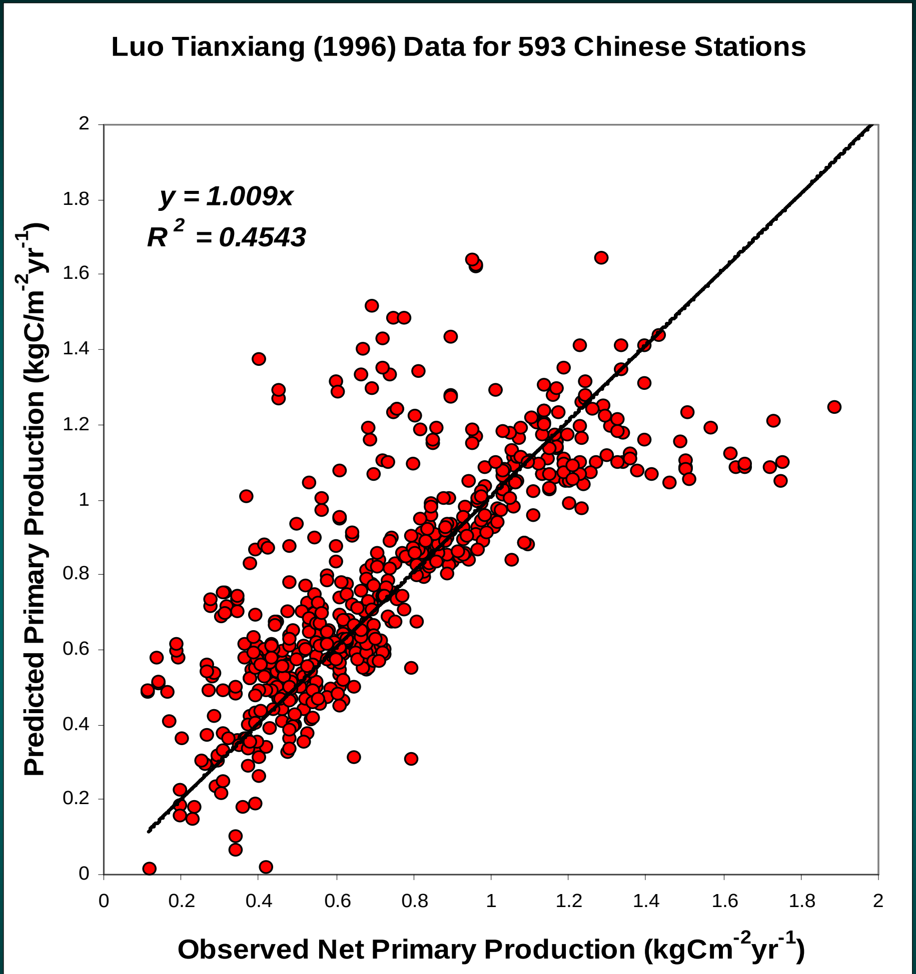
85% Correct (Validation Mode)

95% Correct (Verification Mode)

Gap Models Simulate Cover Dynamics <u>and</u> Carbon Dynamics.

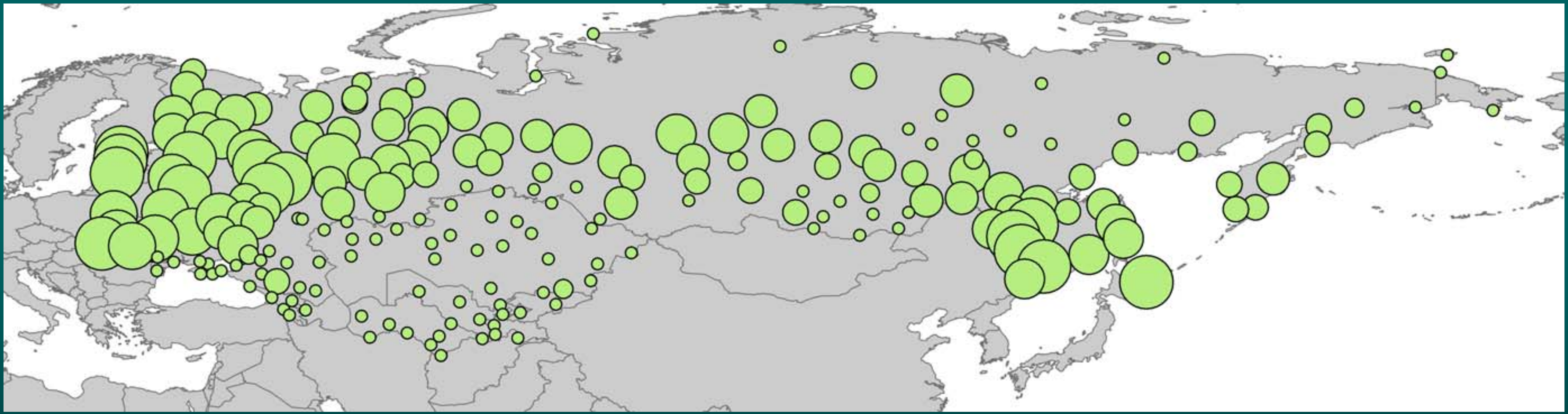
Simulated Net Primary Production ($kgCm^{-2}yr^{-1}$) for 593 Chinese Forest Survey Stations versus Observed Data

Validation Mode (Unfitted Data)



Observed data from: Luo Tianxiang. 1996. Patterns of net primary productivity for Chinese major forest types and their mathematical models. Ph.D. thesis. Commission for Integrated Survey of Natural Resources, Chinese Academy of Sciences, Beijing. (in Chinese).

By running the FAREAST model (200 simulated plots for 700 years starting with an open plot) for 234 weather stations in the NEESPI region, one obtains both the expected successional dynamics and mature forest condition.



Size of circles indicates the biomass of mature (700-year-old) forests across the NEESPI region.

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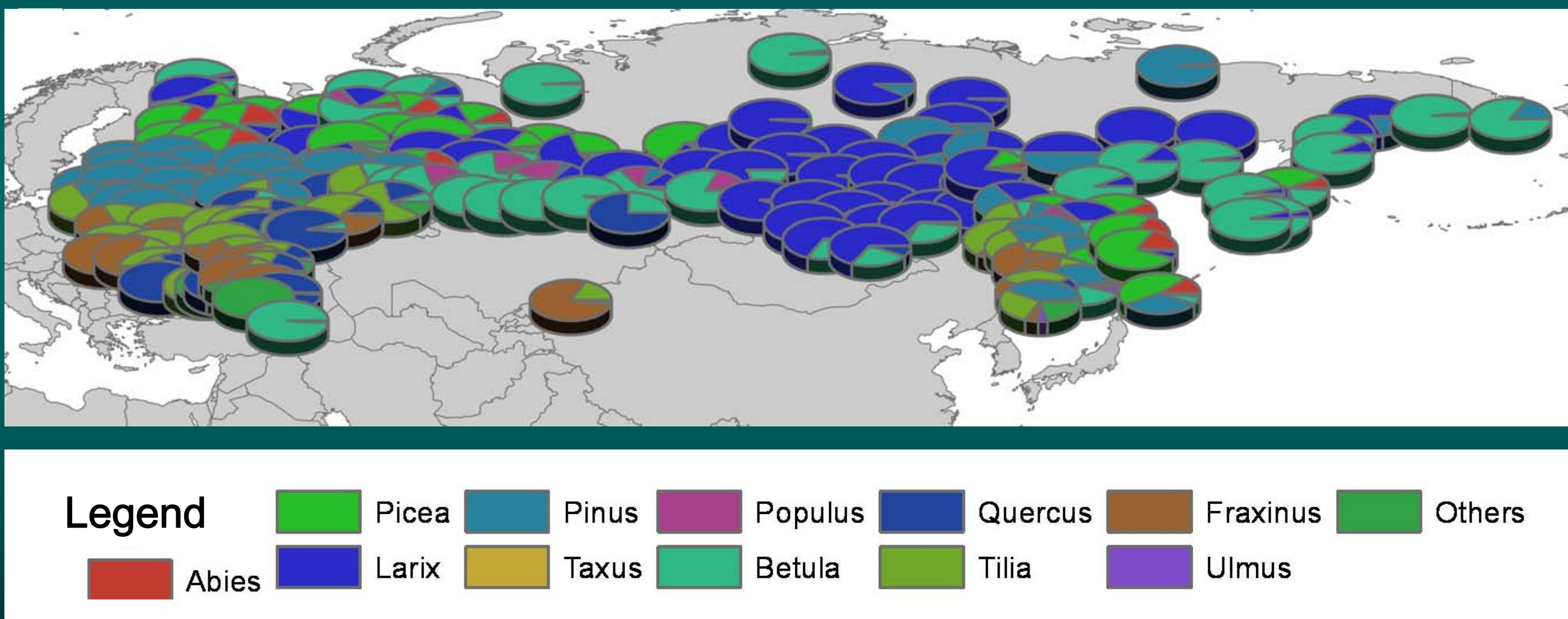
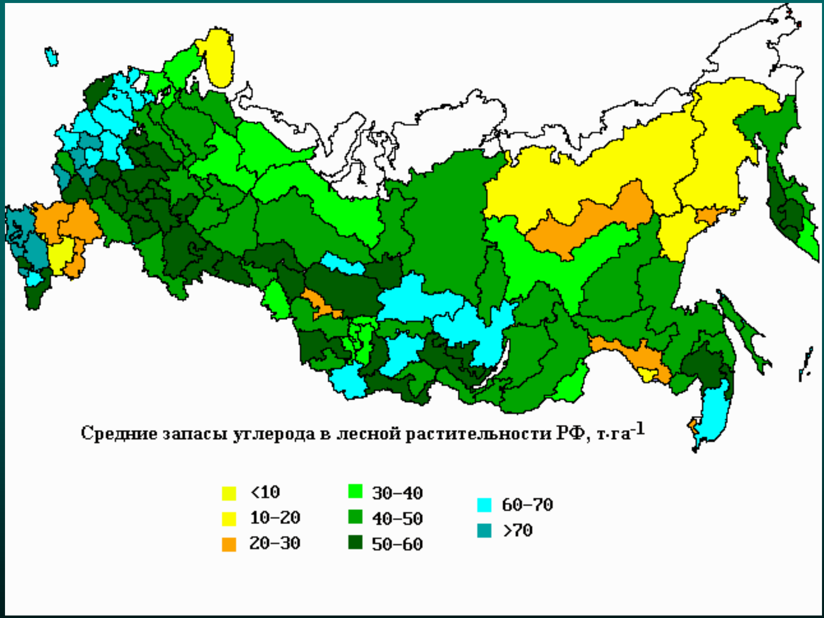


Size of pie slices indicates the biomass composition of mature forests across the NEESPI region.

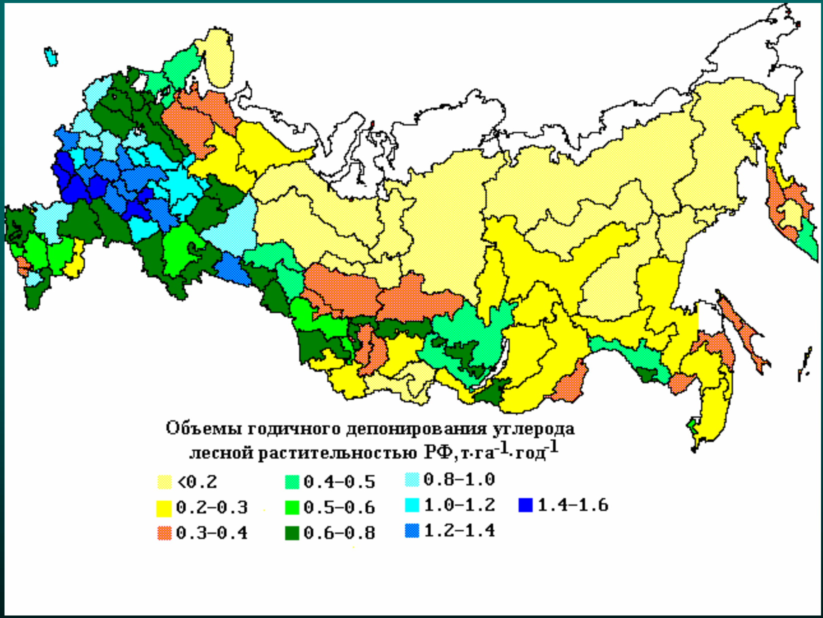
How does one know the reliability these predictions? How does one determine the highest priorities for additional model development?

There are data for testing these predictions but the comparisons involve knowing the history of disturbance and harvest regimes for vast land areas

Carbon Store in Forest Lands of Russia (tC ha^{-1})

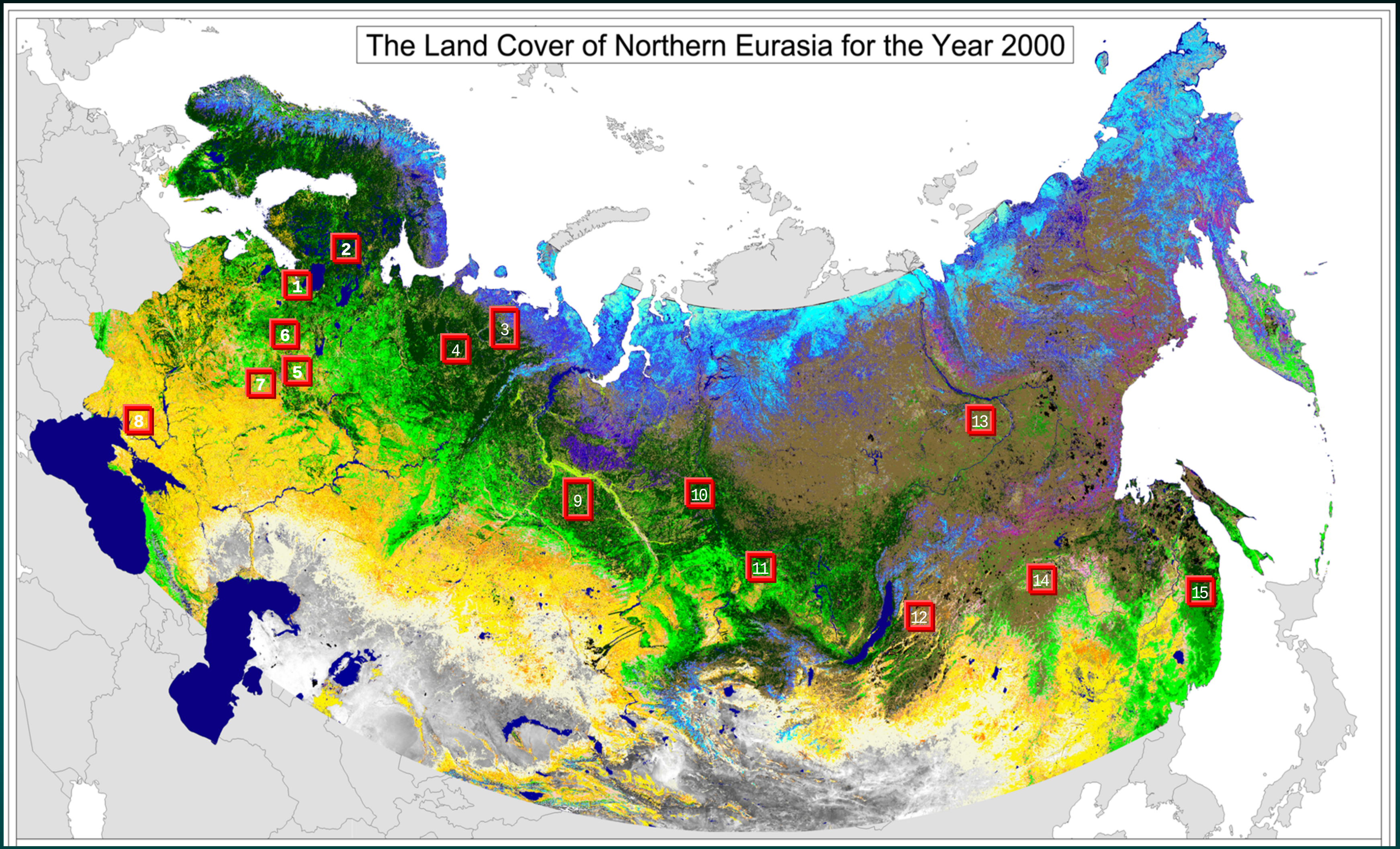


Annual Carbon Accumulation in Forest Lands of Russia (tC ha^{-1} yr^{-1})



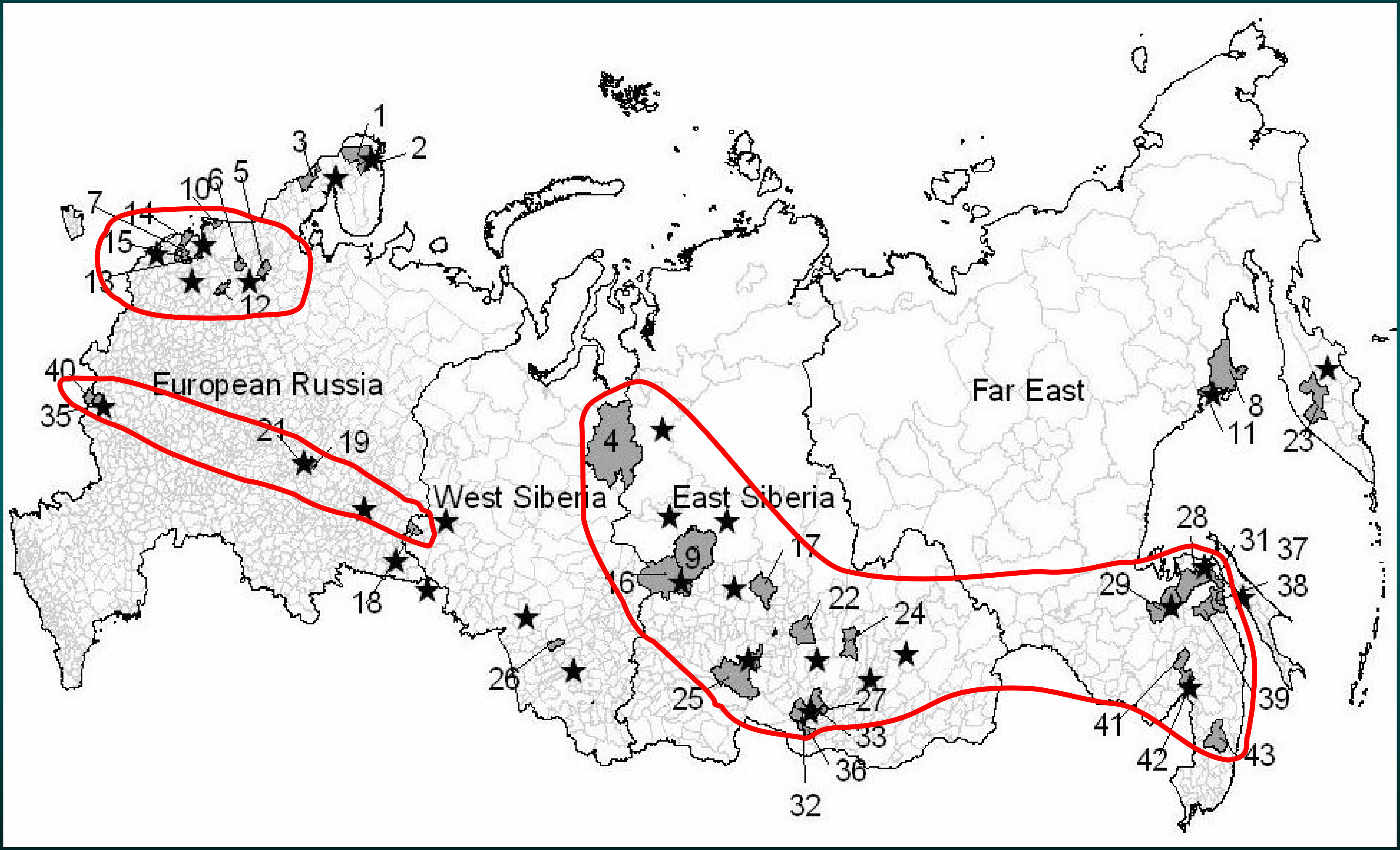
WHAT IS NEEDED?

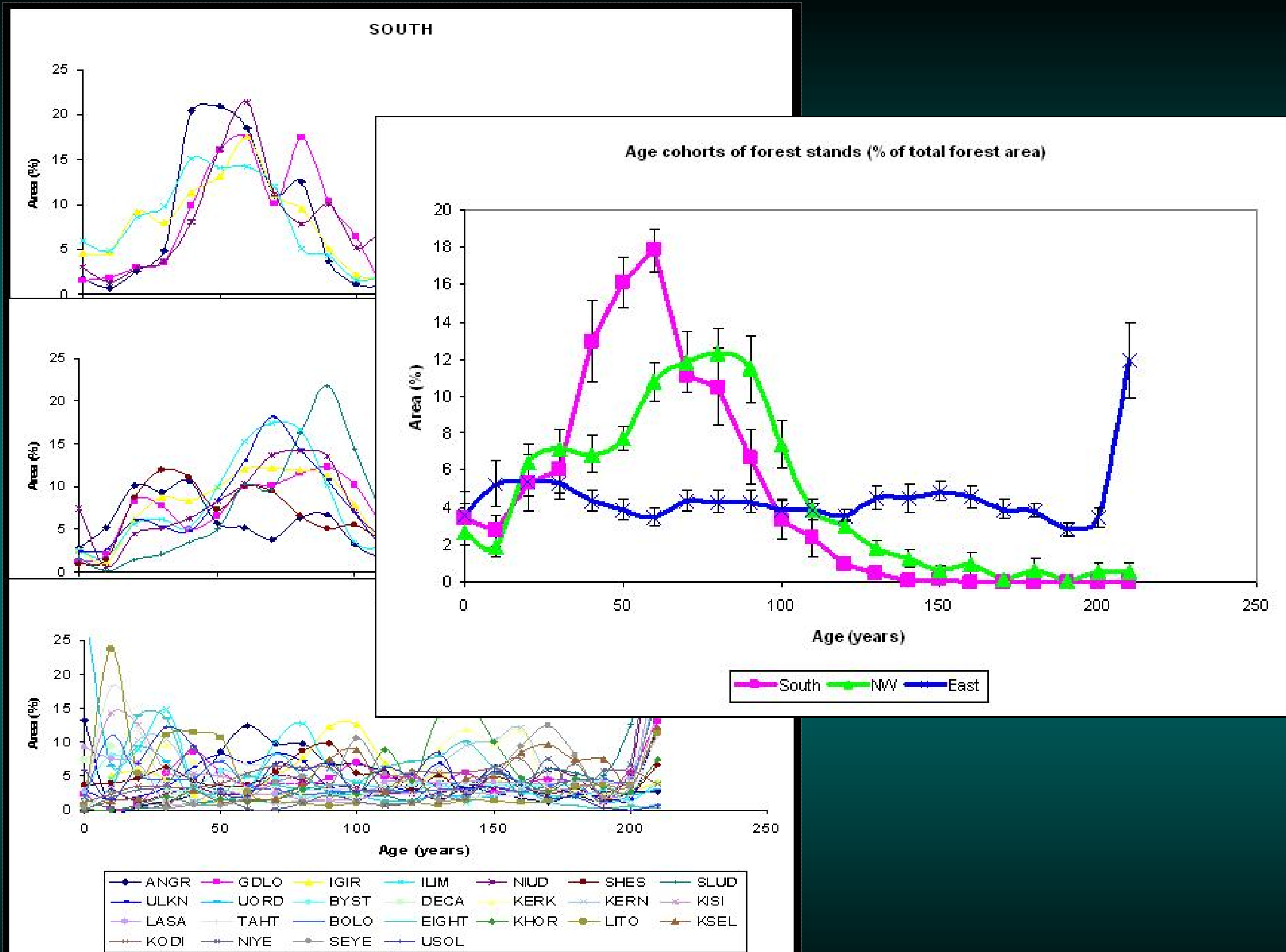
We need to develop a system for monitoring and validating the distribution and change in land cover across Northern Eurasia (Разработать систему мониторинга и валидации карт растительного покрова и его изменений)



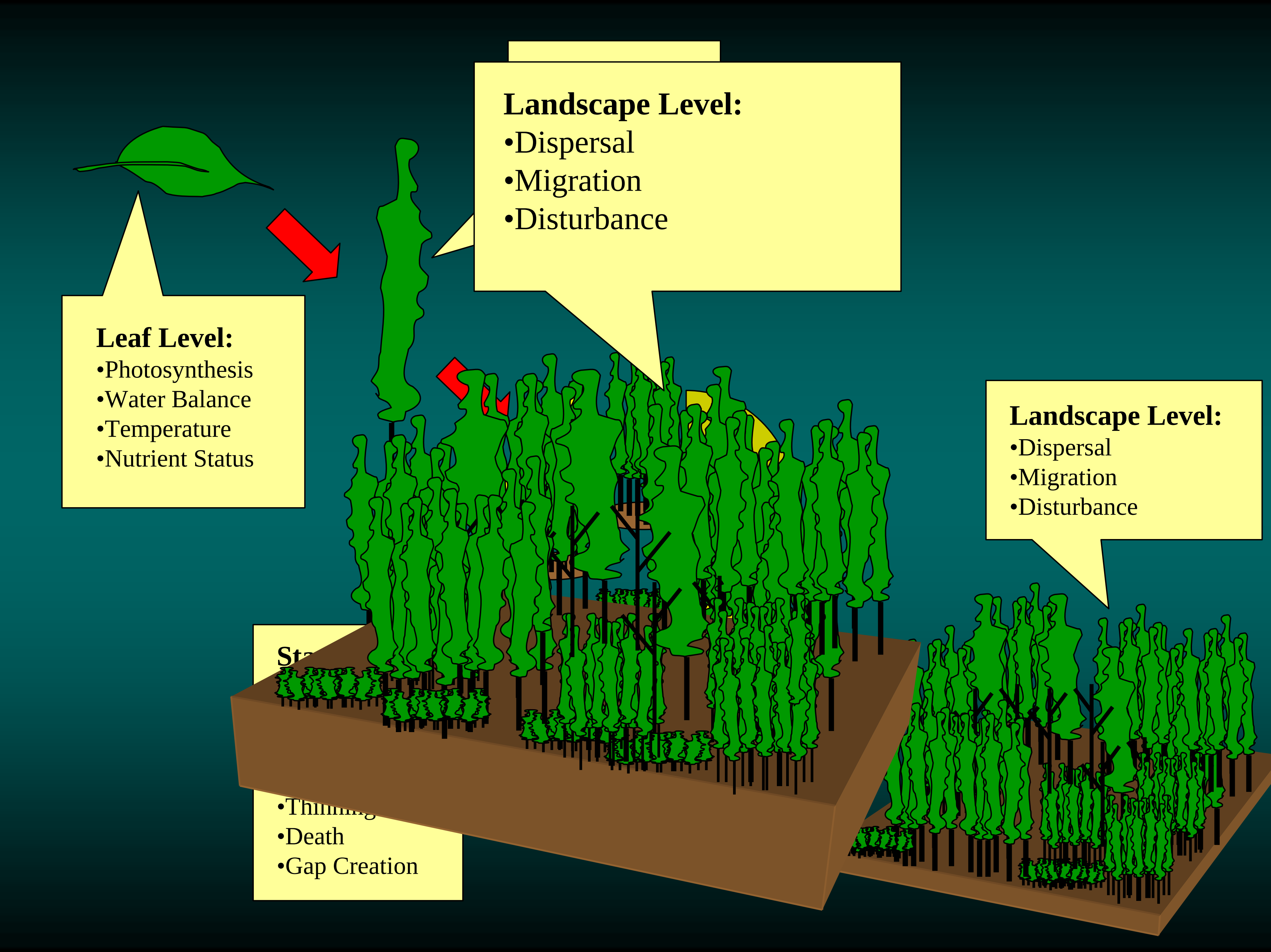
Location of NELDA test sites (Map was created at EC JRC as part of GLC 2000 project, Bartalev *et al.* 2003)

Age cohorts of forest stands as a footprint of past disturbance





SOUTH
Area (%)
Age (years)
ANGR
GDLO
IGIR
ILIM
NIUD
SHES
SLUD
ULKN
UORD
BYST
DECA
KERK
KERN
KISI
LASA
TAHT
BOLO
EIGHT
KHOR
LITO
KSEL
KODI
NIYE
SEYE
USOL
Age cohorts of forest stands (% of total forest area)
Area (%)
Age (years)
South
NW
East


Landscape Level:
•Dispersal
•Migration
•Disturbance
Leaf Level:
•Photosynthesis
•Water Balance
•Temperature
•Nutrient Status
Landscape Level:
•Dispersal
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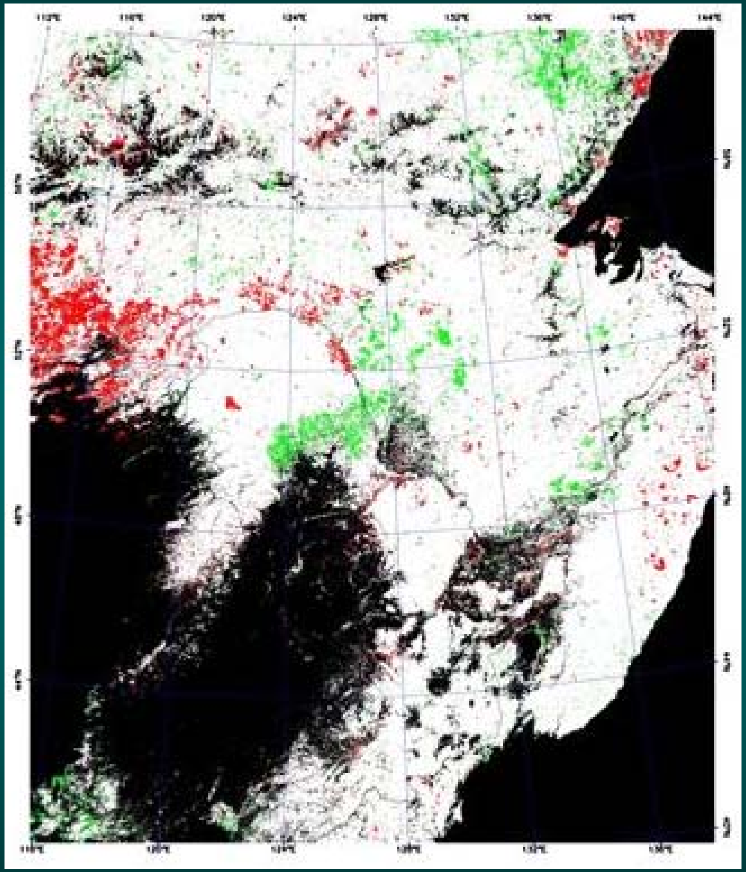
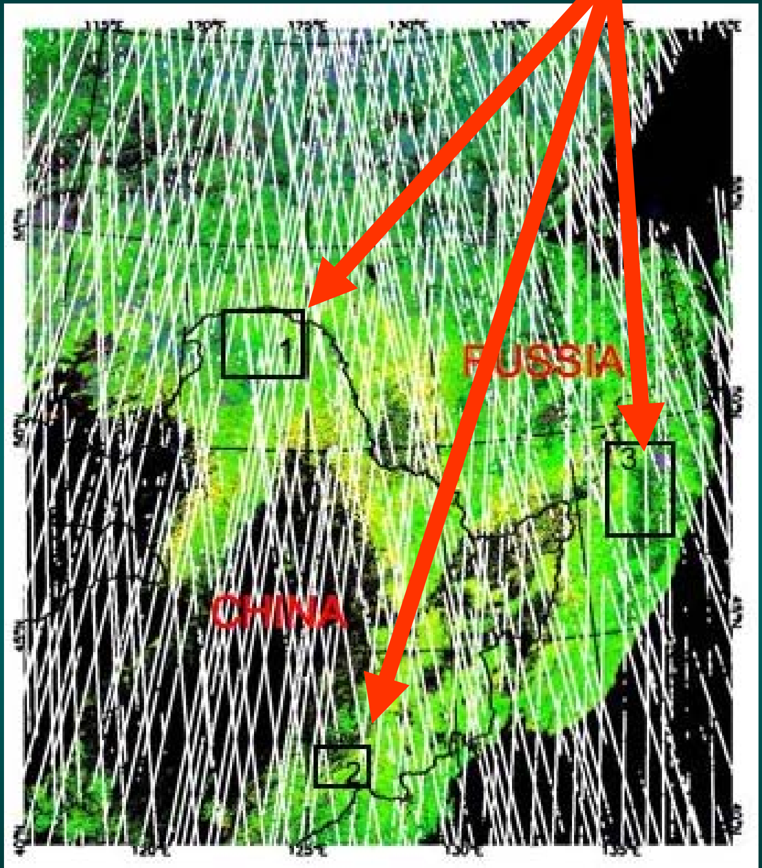
•Death
•Gap Creation

FOREST DISTURBANCE AND TYPE MAPPING USING MODIS DATA



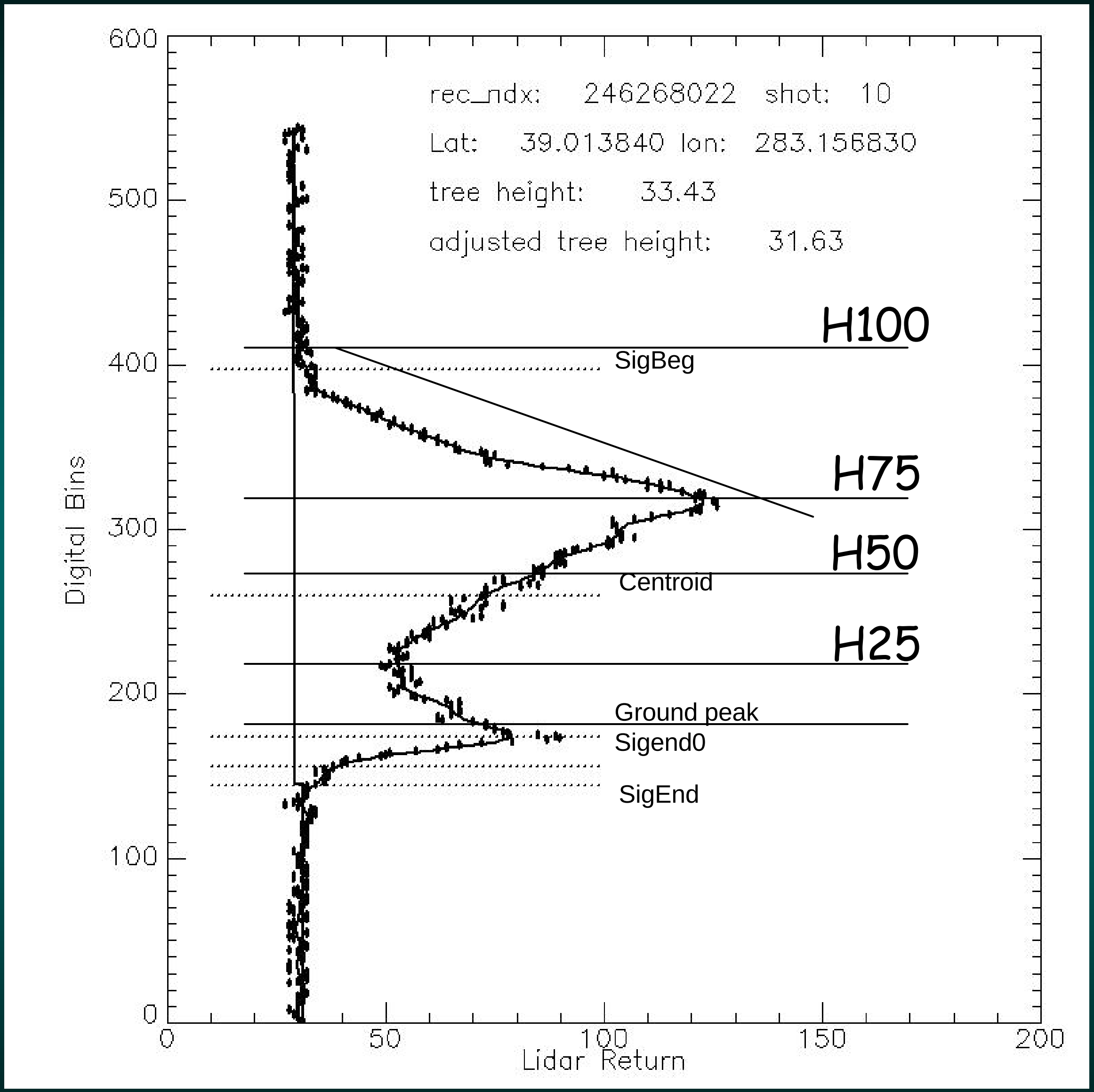
Changes of forests during year 2003.

Test Sites



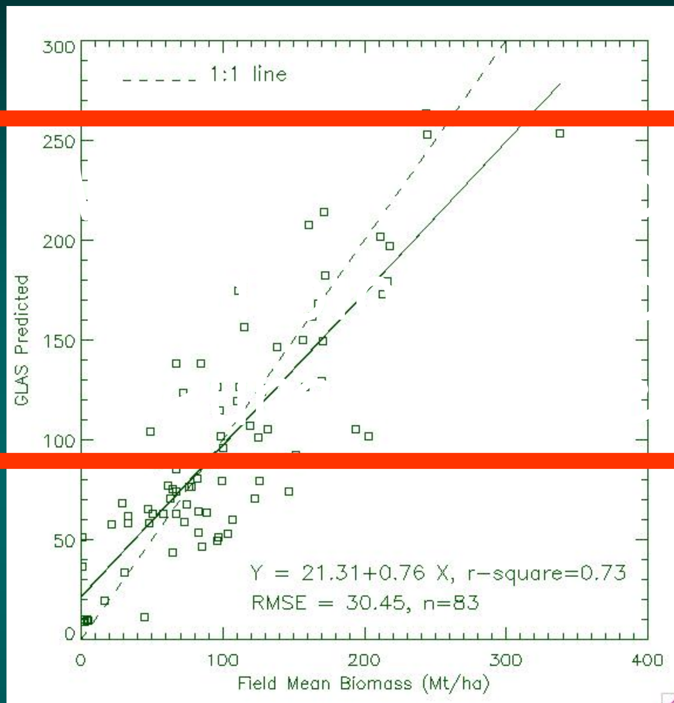
Current (2005) forest types overlaid with GLAS footprints (L2A).

GLAS WAVEFORM PROCESSING



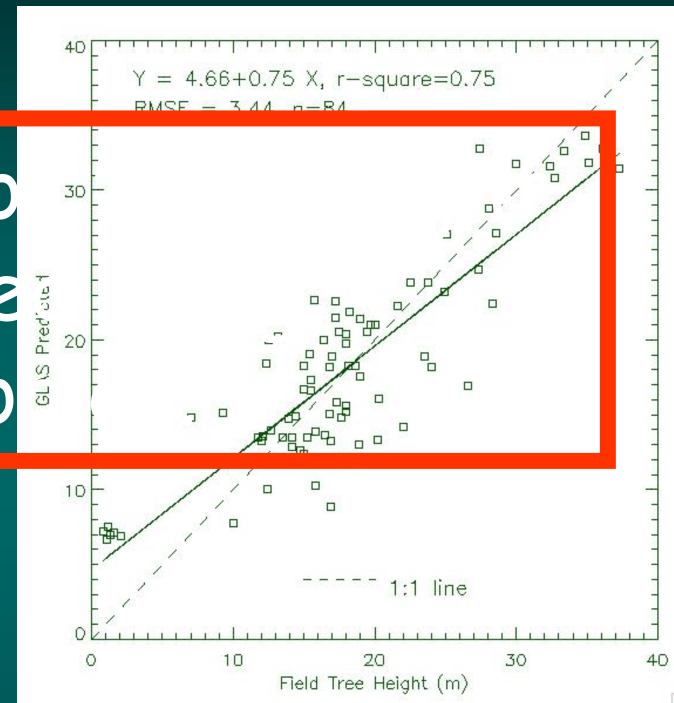
1) Smooth
2) Noise estimation
3) Find signal beginning and ending
4) Find ground peak
5) Calculate top tree height and 'slope corrected' tree height
6) Calculate heights of energy quartiles
7) Assume ground peak is symmetric, find the ratio of waveform energy from canopy to ground
8) Calculate the front Slope

Biomass prediction from GLAS Data



The variables used are total length of waveform, top tree height, heights of 25% and 75% quartile waveform energy and their transforms.

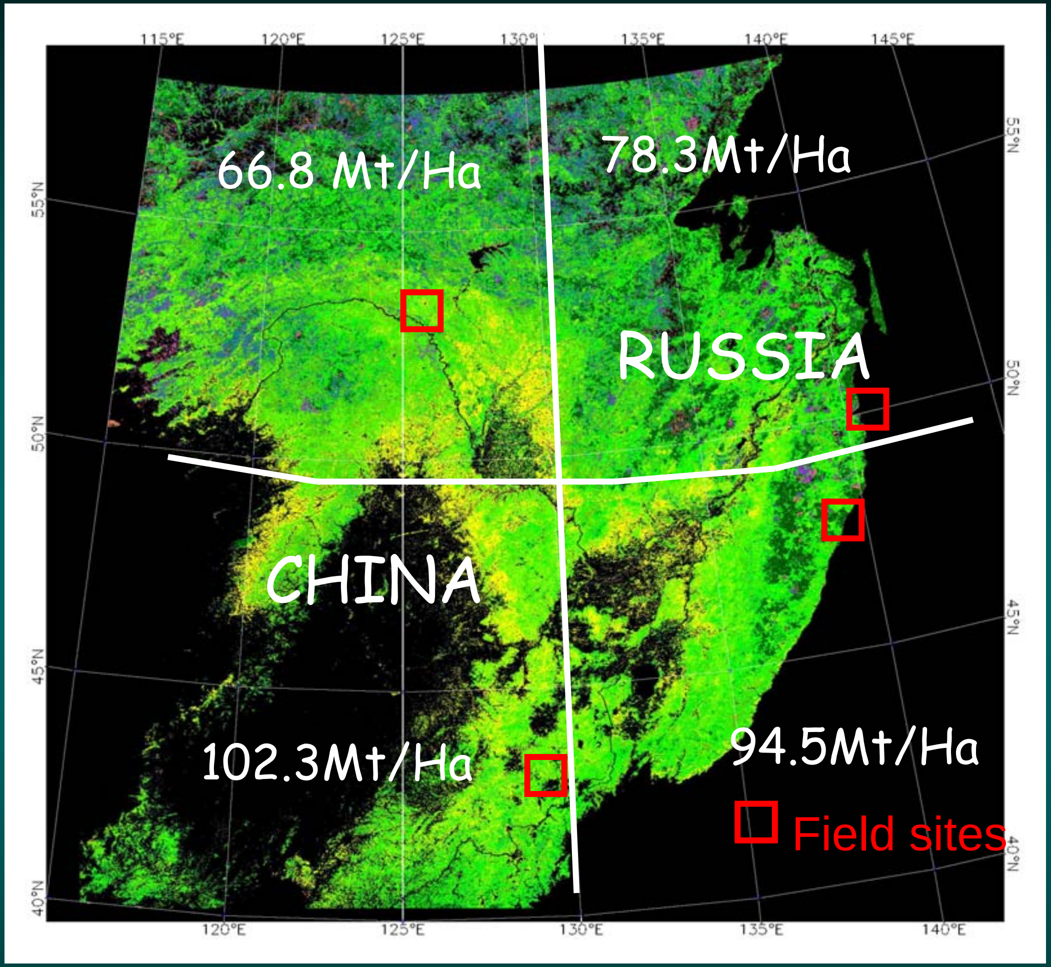
Tree Height prediction from GLAS Data



The variables used are total length of waveform, height of waveform centroid, quadratic canopy height, height of 25% quartile waveform energy and their transforms.

Biomass

Study area (40°-58° N 115°-142° E)



Total 543,081 GLAS shots with a local slope less than 10°.

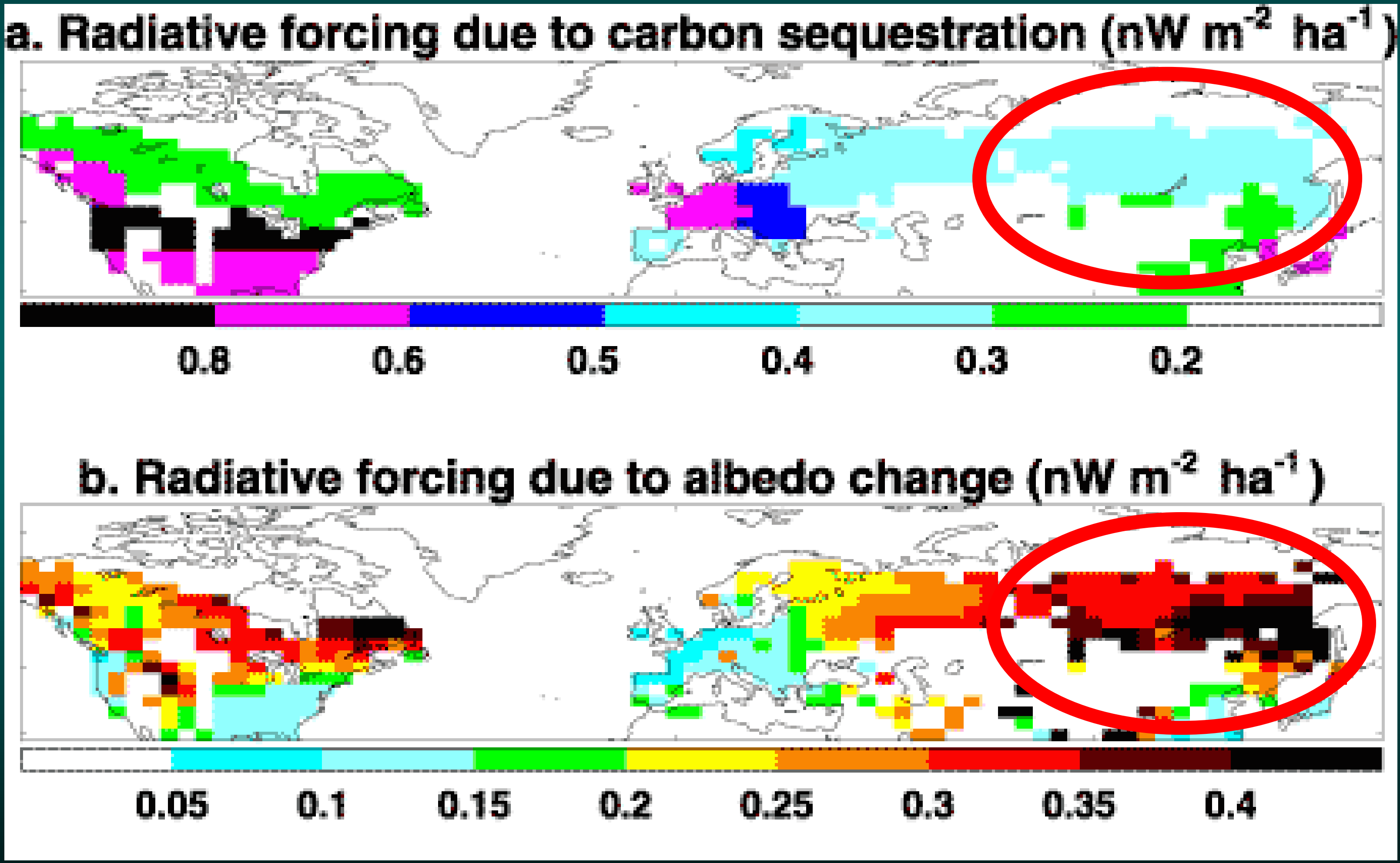
296,433 (54.5%) shots were in forests

Average biomass over the forested area is 79 Mt/ha or 7.9 Kg/m^2

A recent study by Huang and Xia (2005, Forest Resource Management) from National Bureau of Forestry, China found that average biomass in this part of China at 2003 was 80.2 Mt/Ha. Biomass changes from 150Mt/Ha at Changbai Mountain area (south-east) to 50 Mt/Ha in some areas at Daxinanling (north-west). The average biomass (in white) of the four sub-regions are consistent with their results.

Eurasian Land Cover Change in response to climate change may be more complex than merely "painting-by-numbers" of vegetation onto climate.

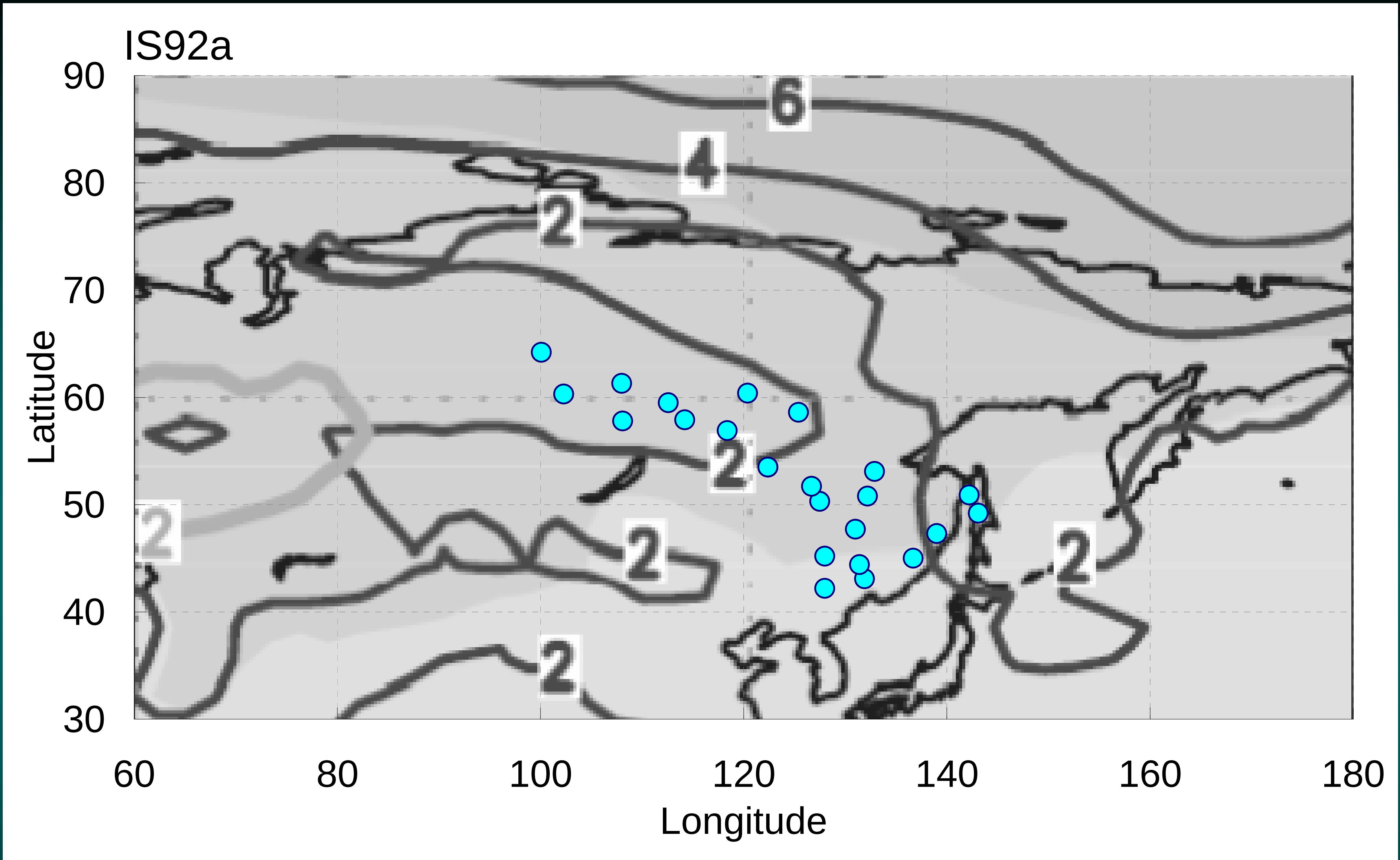
"… in large parts of the temperate and boreal forest areas, the decrease in surface albedo by forestation is as important as carbon sequestration in its forcing of climate. As a result, forest carbon sinks in these regions could exert a much smaller cooling influence than expected, or even exert an overall warming influence."



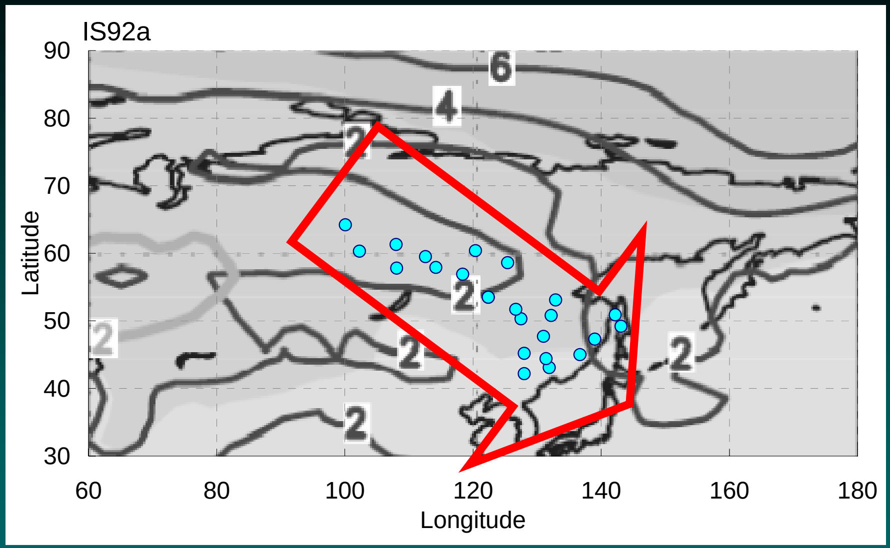
From: Richard A. Betts. 2000. *Offset of the potential carbon sink from boreal forestation by decreases in surface albedo*. Nature 408:187-190.

Siberian pine regeneration under a Larch canopy

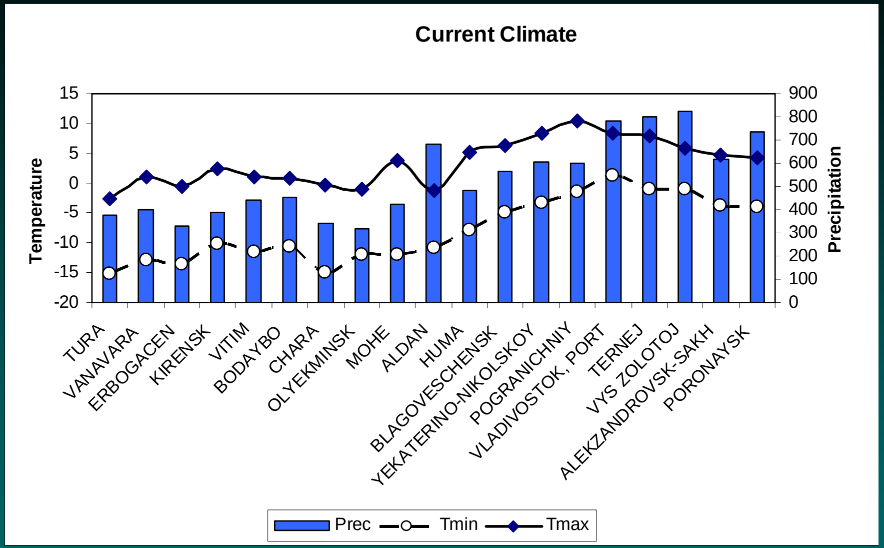
Replacing Larch with Evergreen Conifers has an effect on albedo in winter that is analogous to growing trees.



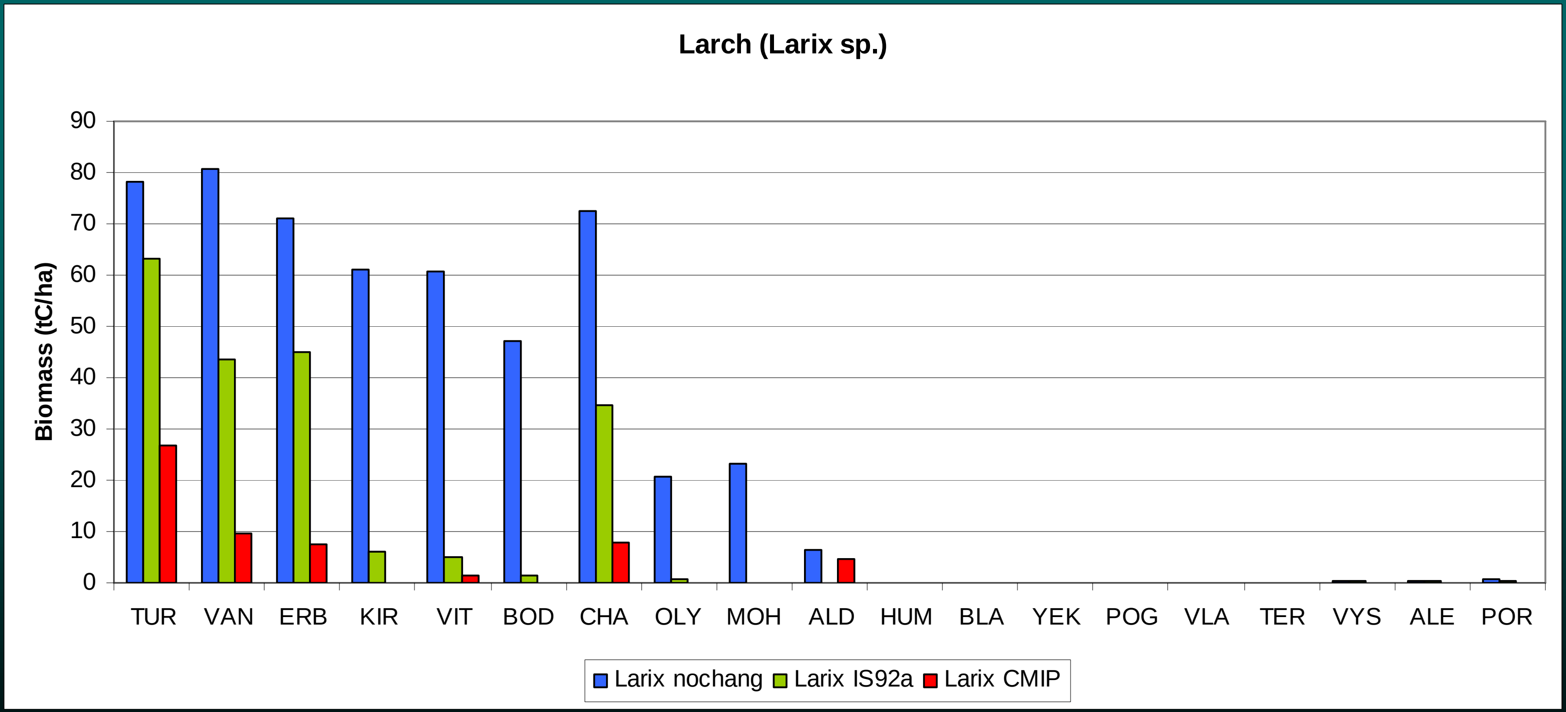
Multi-model-ensemble annual-mean change of the temperature (Gray shading), its range (Unit:℃) mean change divided by the multi-model standard deviation for the IPCC-DDC scenario IS92a (GS: greenhouse gases and Sulphate aerosols) for the year 2021 to 2050 relative the period 1961 to 1990.



IS92a
Latitude
Longitude

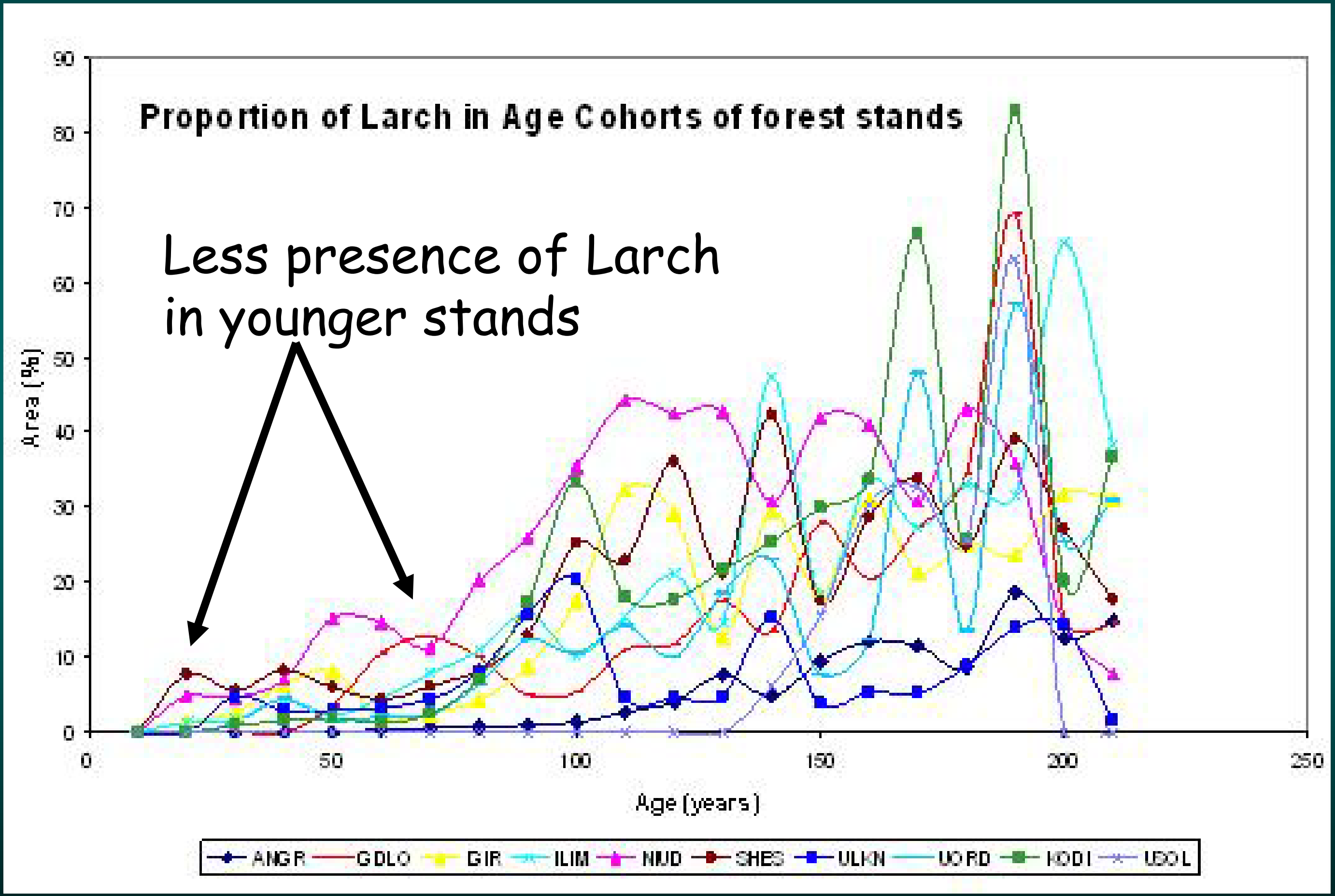


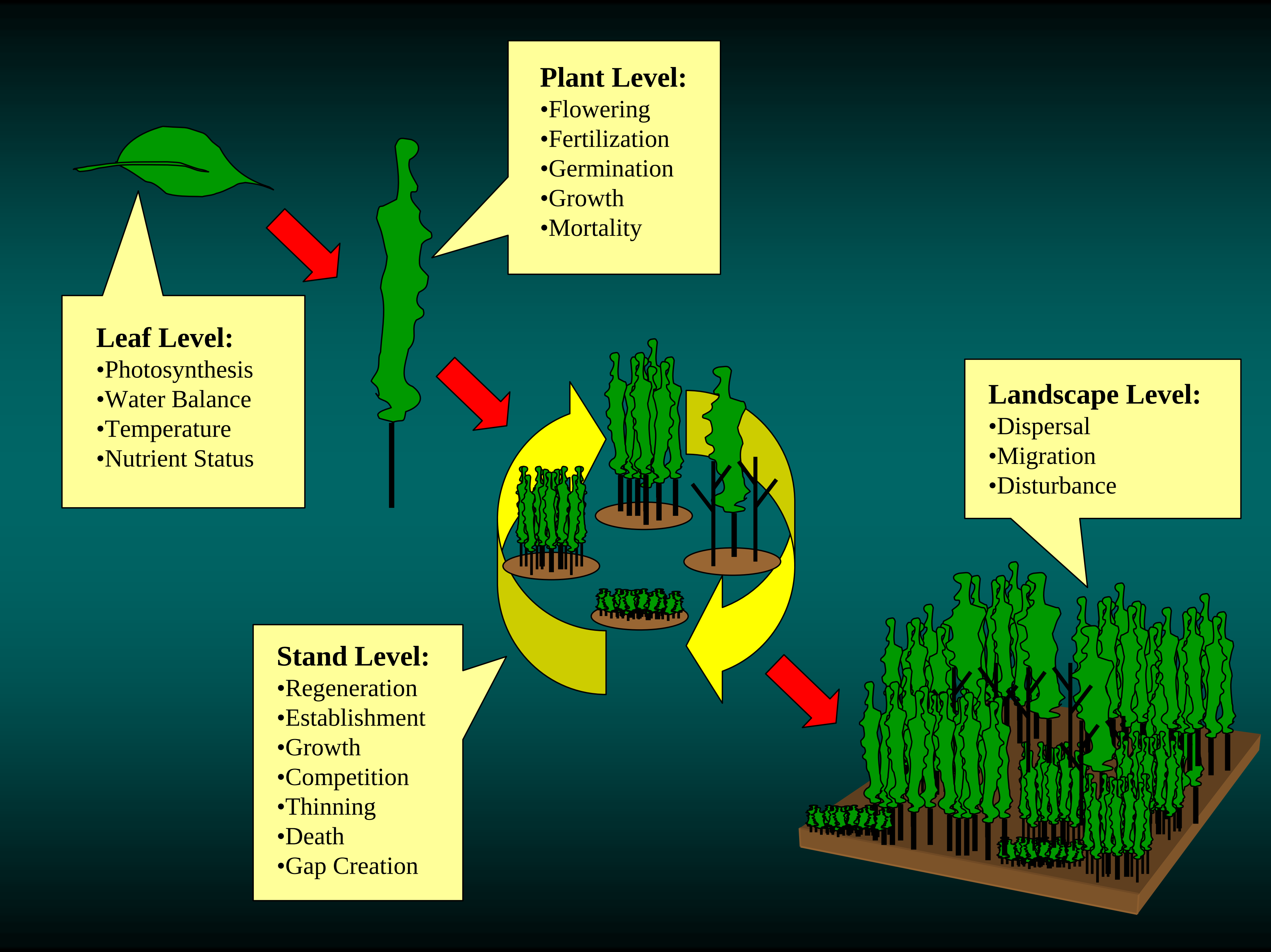
Current Climate
Temperature
Precipitation
TURA
VANAVARA
ERBOGACEN
KIRENSK
VITIM
BODAYBO
CHARA
OLYEKMINSK
MOHE
ALDAN
HUMA
BLAGOVESCHENSK
YEKATERINO-NIKOLSKOY
POGRANICHNIY
VLADIVOSTOK, PORT
TERNEJ
VYS ZOLOTOJ
ALEKZANDROVSK-SAKH
PORONAYSK
Prec
Tmin
Tmax



Larch (Larix sp.)
Biomass (tC/ha)
TUR
VAN
ERB
KIR
VIT
BOD
CHA
OLY
MOH
ALD
HUM
BLA
YEK
POG
VLA
TER
VYS
ALE
POR
Larix nochang
Larix IS92a
Larix CMIP

Relating Model Results to Actual NELDA Project Data

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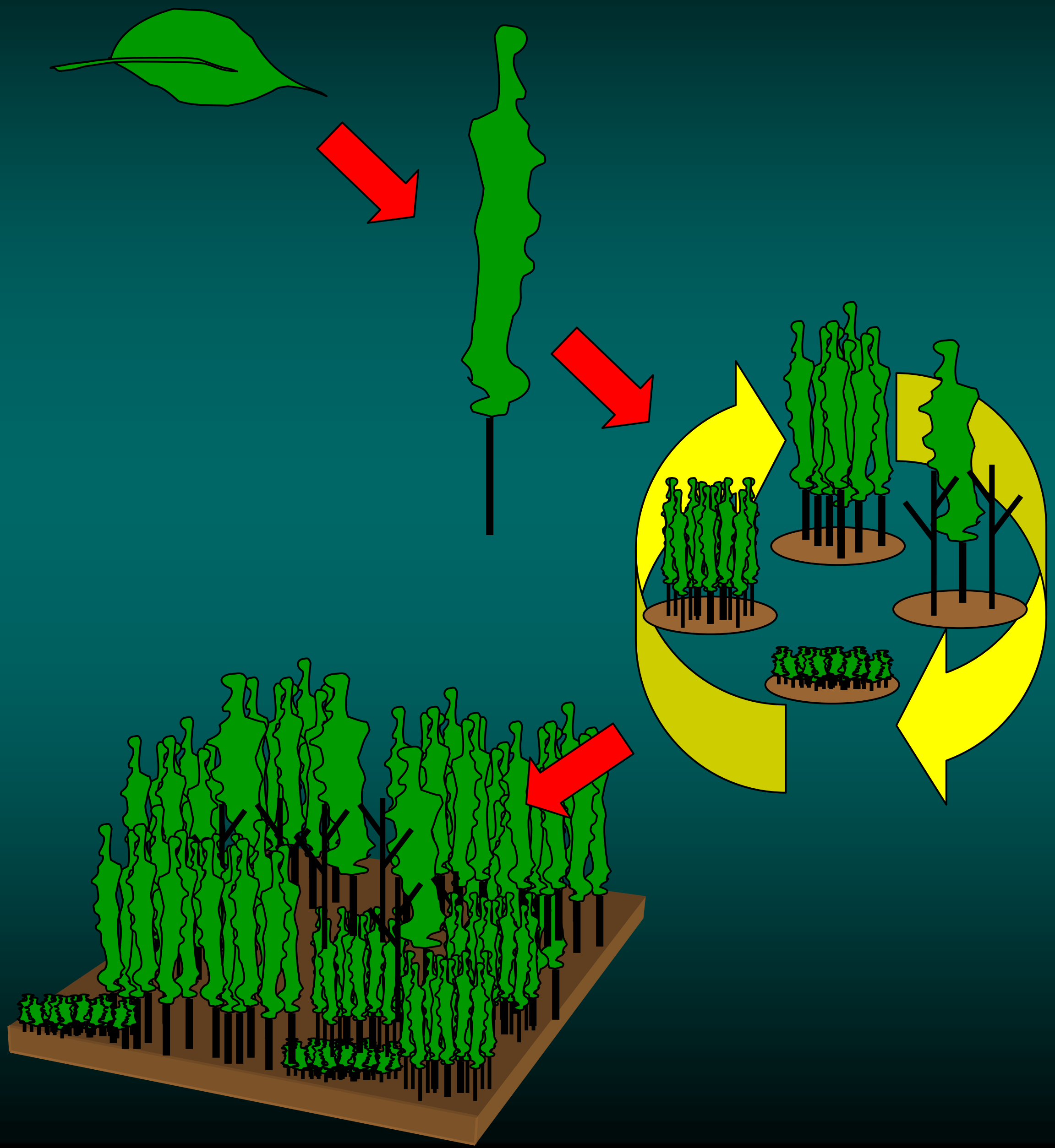
Plant and Soil Processes

sturbances

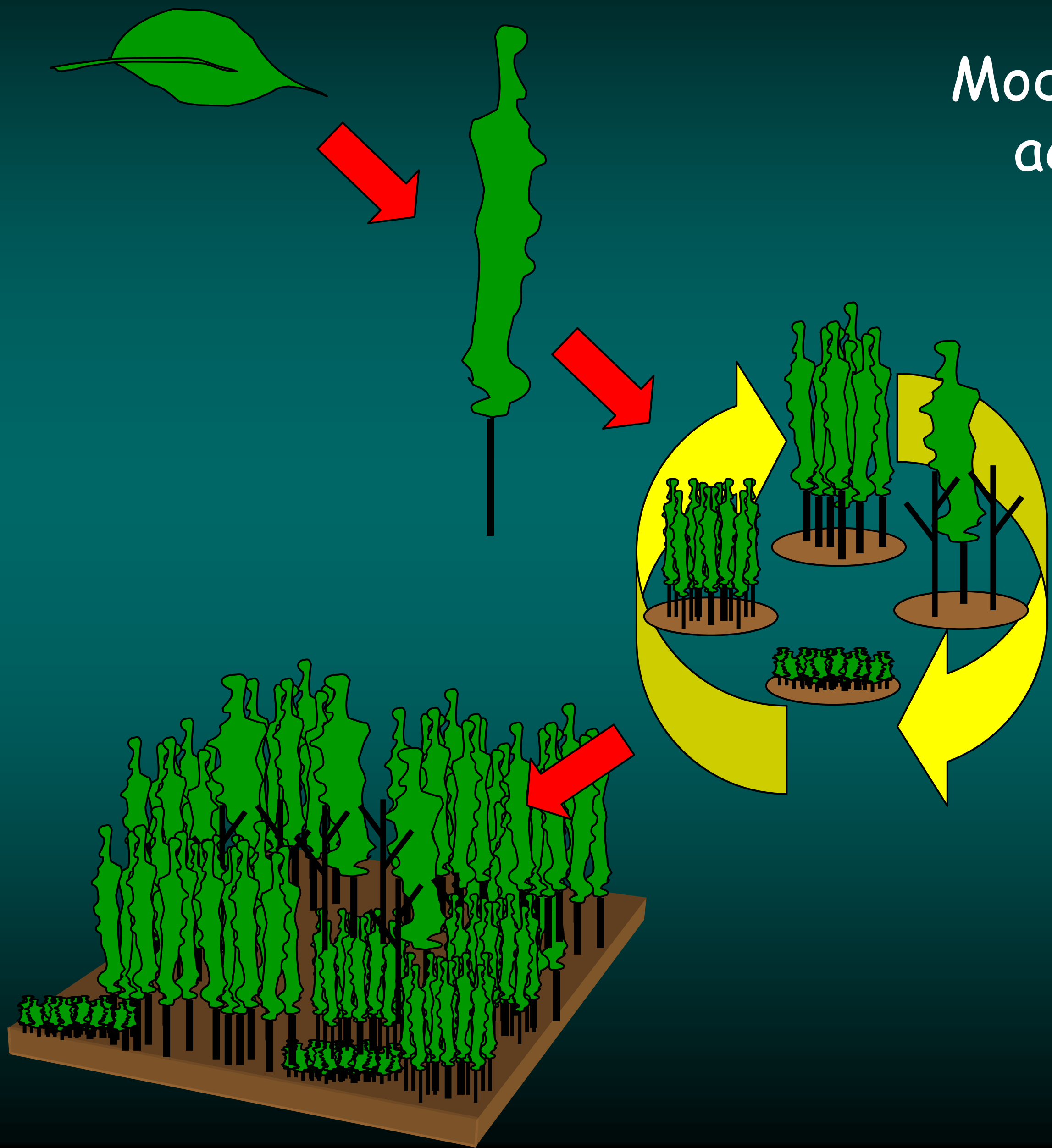
Climate Cha

Where do we stand?



Where do we stand?

Models and observations across multiple scales.



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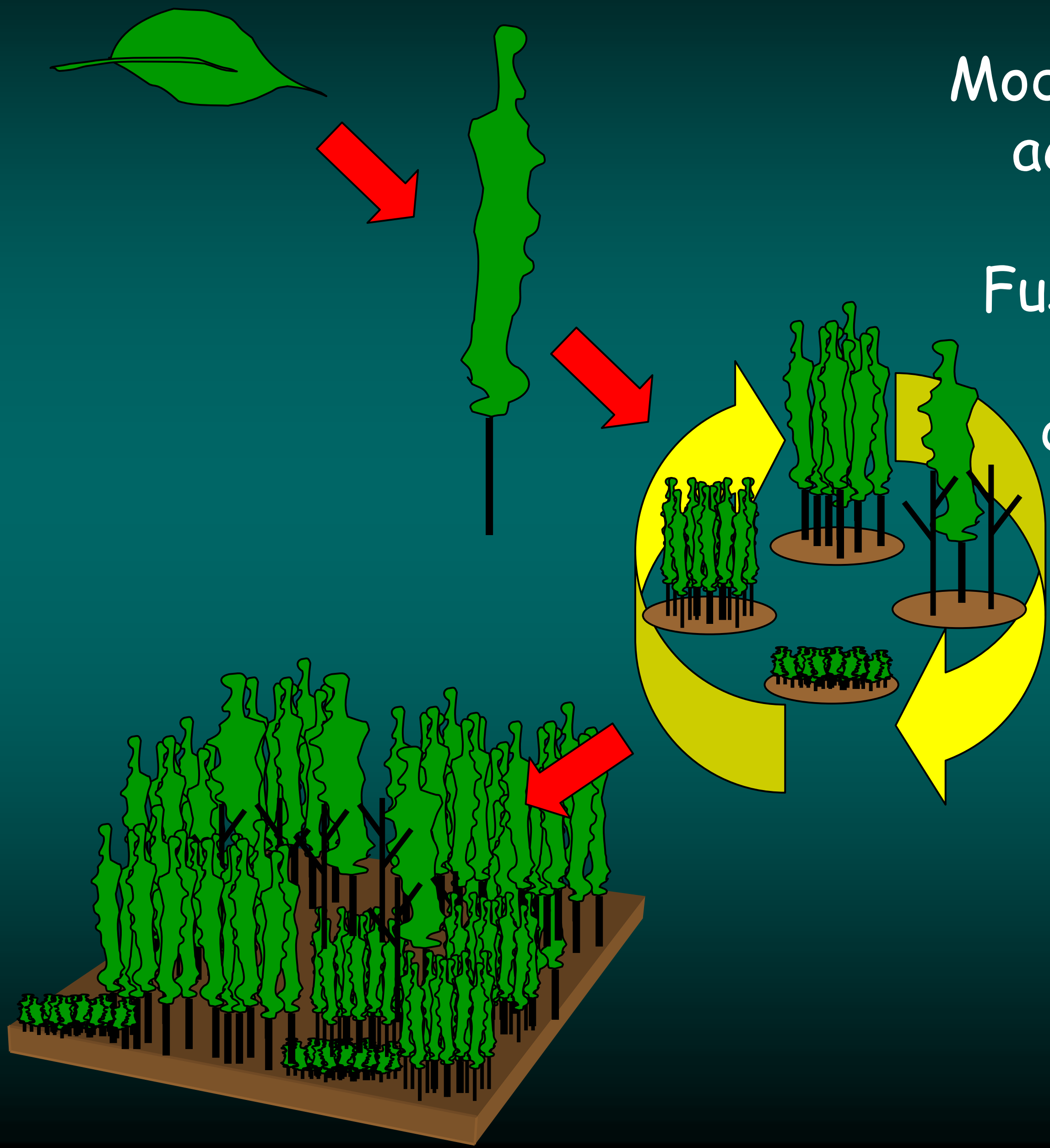
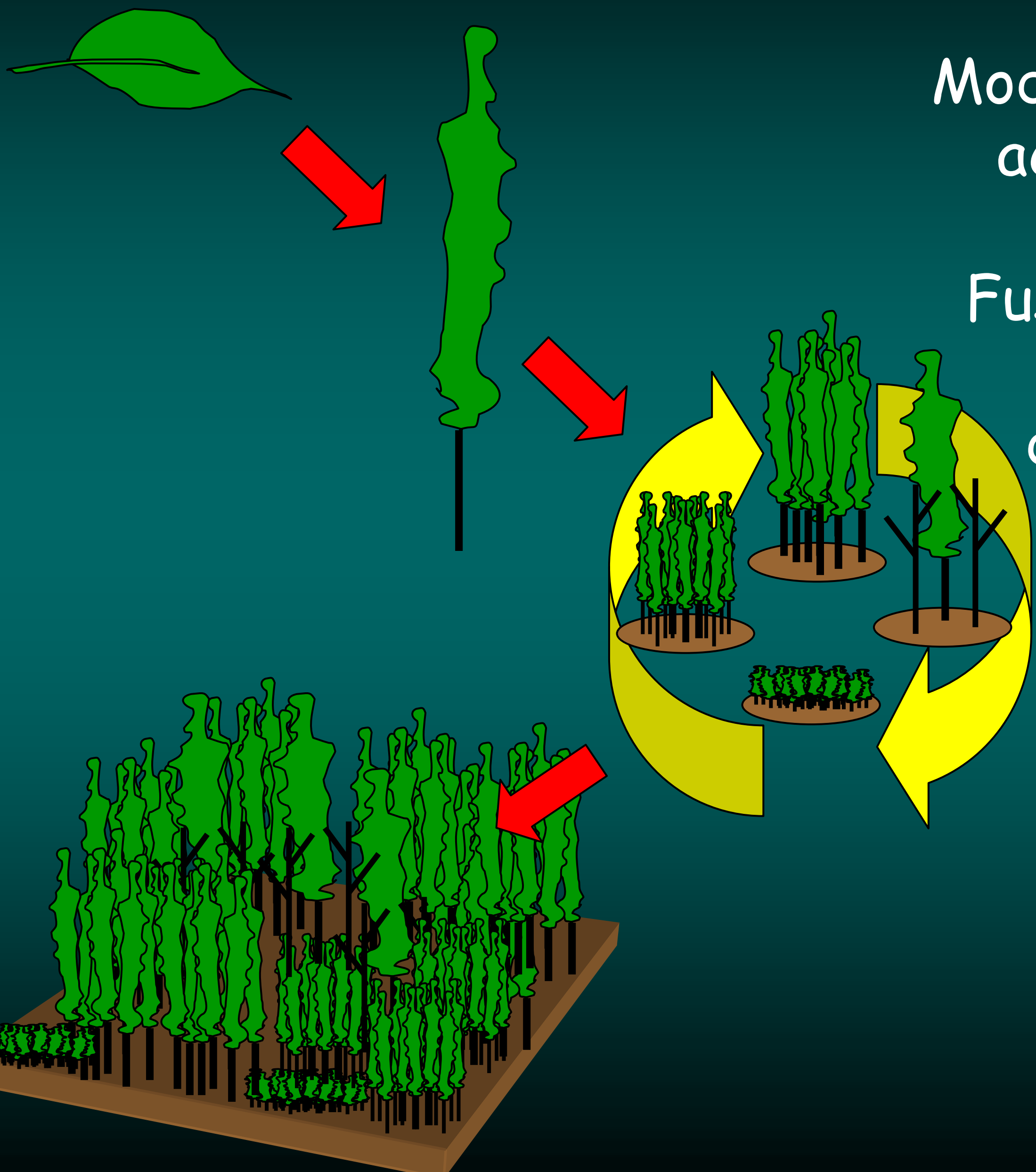


Models and observations across multiple scales.

Fusion among different sensors with different resolutions and capabilities.

Where do we stand?



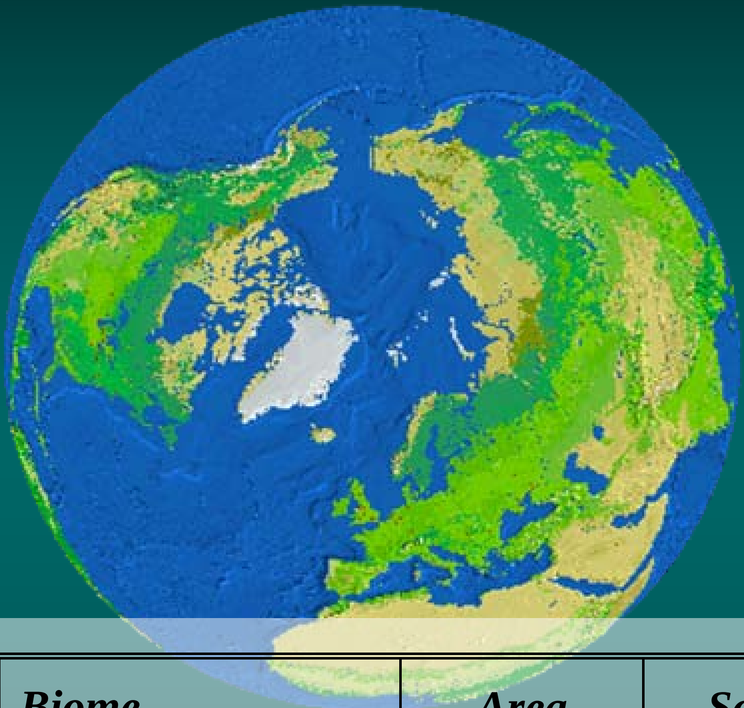
Models and observations across multiple scales.

Fusion among different sensors with different resolutions and capabilities.

Development of an increased capability to represent land dynamics as an essential part of the Earth's systems.


THE END

The Boreal Region



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