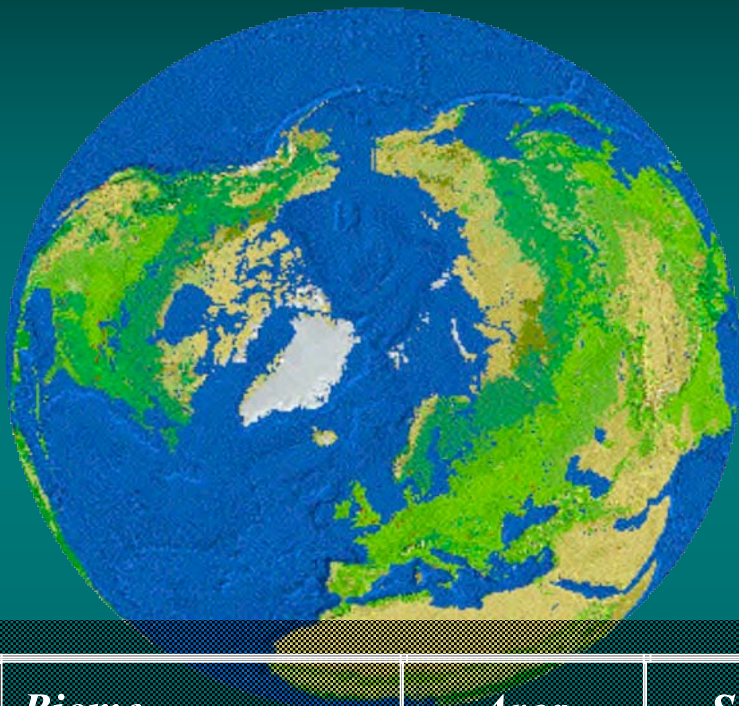
The Boreal Region



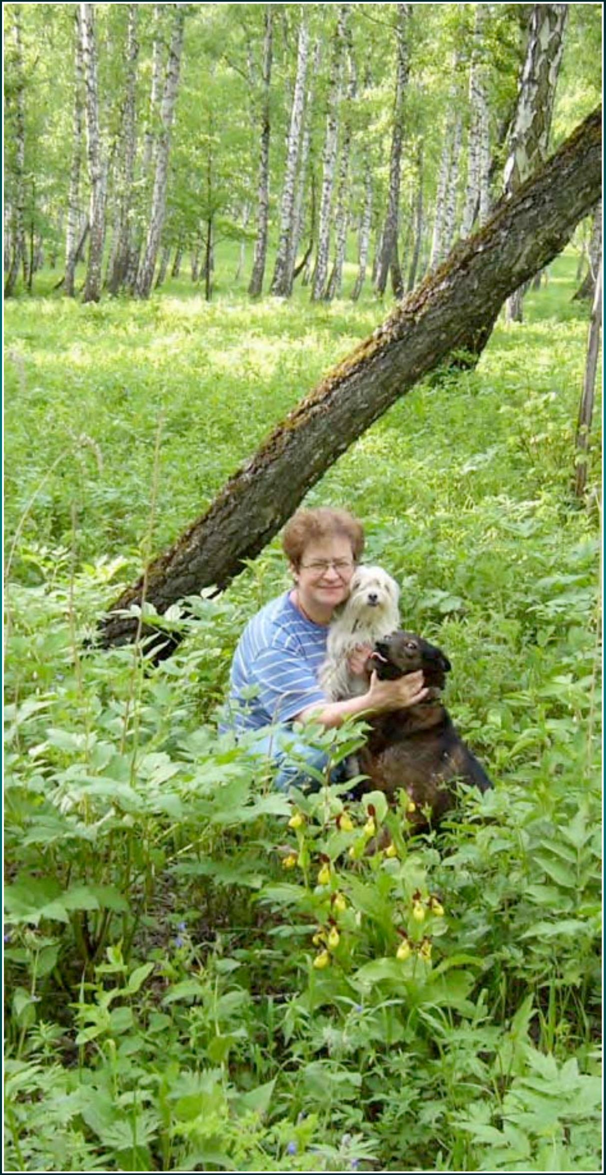
Biome	*Area (10□ ha)*	*Soil Carbon (Pg)*	*Plant Biomass Carbon (Pg)*	*Total Carbon (Pg)*
Boreal Forest	**1509**	**624**	**51**	**675**
Tropical Forest	1756	216	159	375
Temperate Forest	1040	100	21	121

How Might a Climate Warming Change the Vegetation of the NEESPI Region?

The most straight-forward approach would be to use the current relations between climate and vegetation to interpret the future pattern.

But at what level does one resolve the vegetation?

- Biome Level
- Species or Functional Type Level



Siberian Bioclimatic Model:

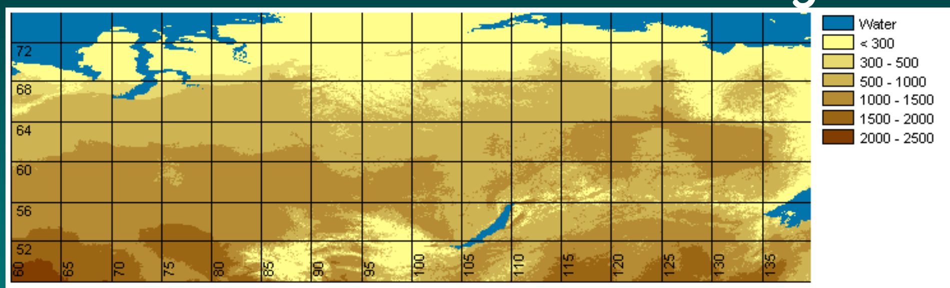
Three principal climatic constrains representing plant requirements for:

1. Water stress tolerance (an annual moisture index, a ratio GDD_5/annual precipitation), and
2. Cold resistance (negative degree-days)
3. Warmth (growing degree-days, base 5°C).

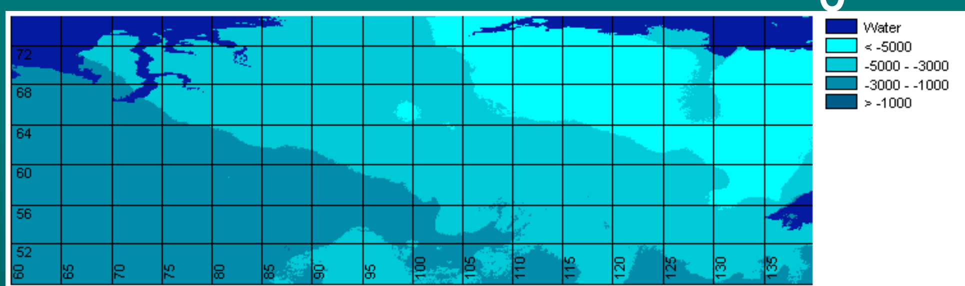
These "envelopes" have limits for each vegetation class, tree species and even climatypes of species in climatic space

Climatic surfaces for Siberia

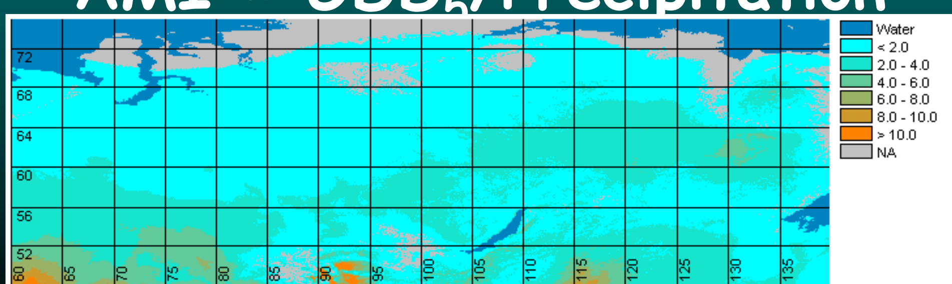
GDD_5



DD_0



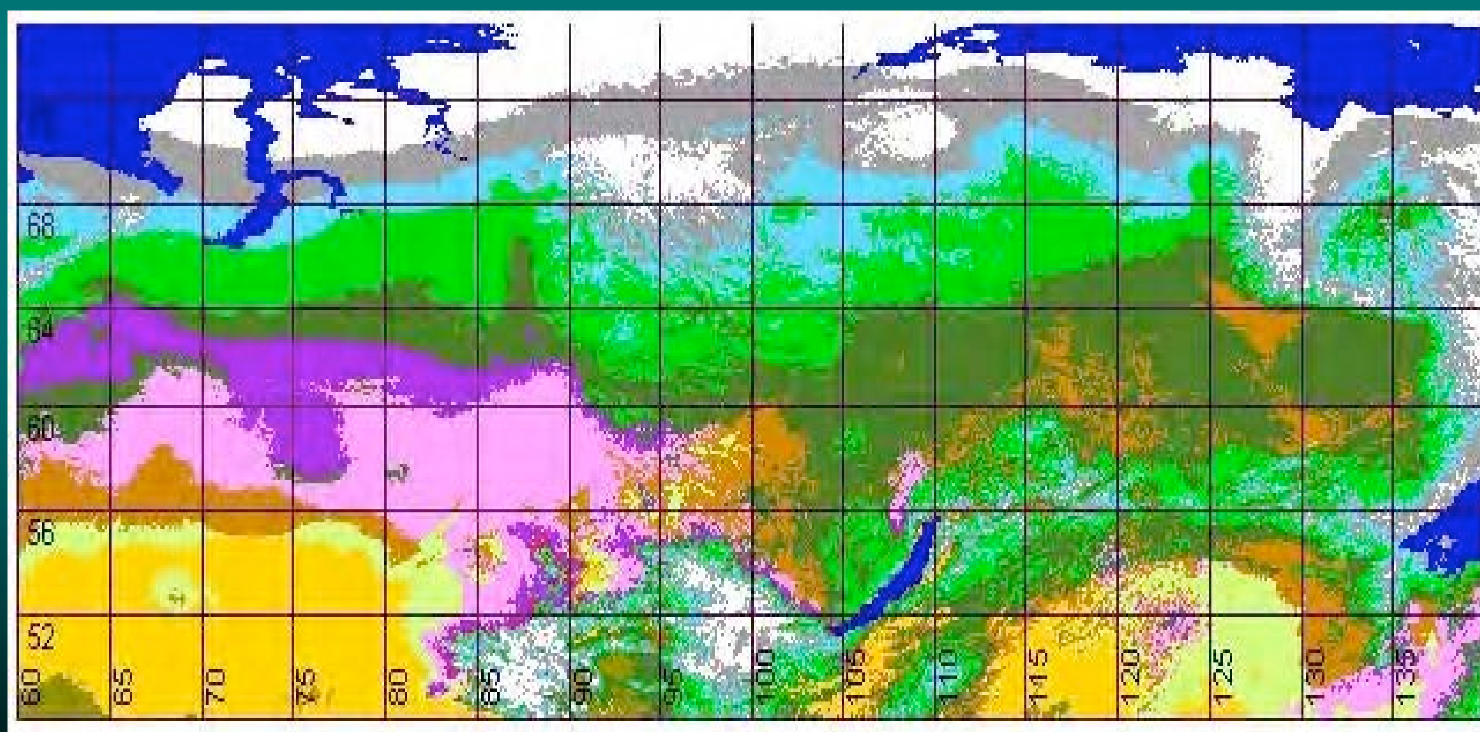
$AMI = GDD_5$/Precipitation



- Data from about 1000 Siberian weather stations were used to map climatic variables.
- Hutchinson's (2000) thin plate splines were used to produce climate surfaces on DEM grids (1 km) for monthly temperature and precipitation.
- GDD_5 and DD_0 surfaces were produced from regressions (R^2 > 0.9) driven by monthly temperatures (T_1 and T_7).
- AMI was calculated as the ratio of the GDD_5 surface to the precipitation surface.

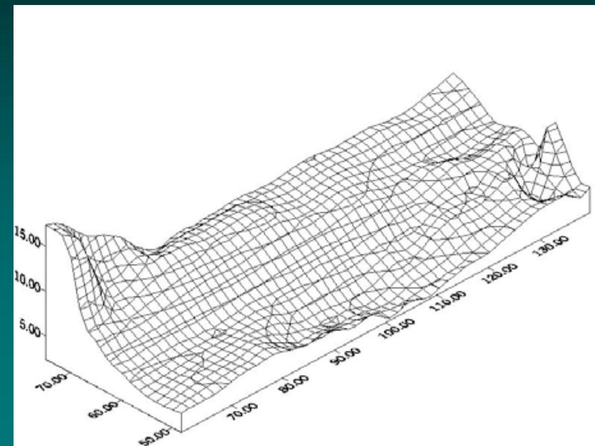
Current Vegetation Patterns in Russia

- Water (0)
- Tundra (1)
- Forest-tundra (2)
- Northern dark taiga (3)
- Light taiga (4)
- Middle dark taiga (5)
- Light taiga (6)
- Southern dark taiga (7)
- Light taiga (8)
- Forest-steppe (9)
- Steppe (10)
- Semi-desert (11)
- Broadleaved (12)
- Temperate forest-steppe (13)
- Temperate steppe (14)
- Ice (15)

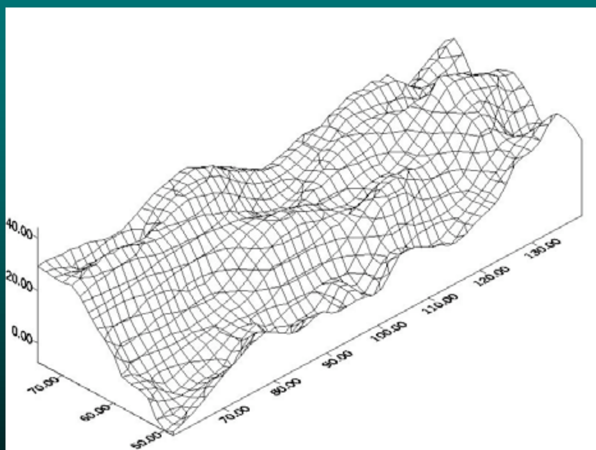


Climate change by 2090 for Siberia (Hadley Center, HadCM$_3$GGa1)

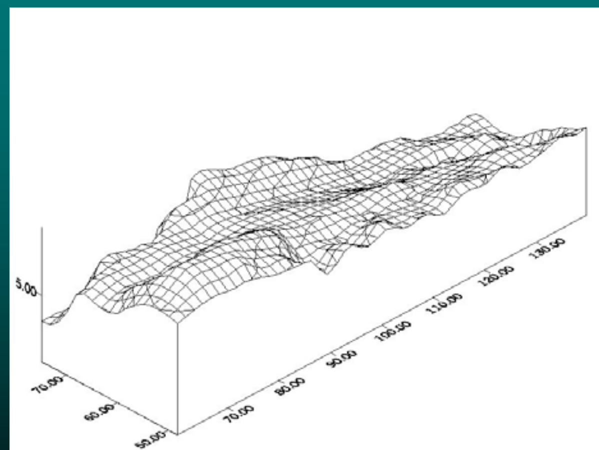
January temperature (+4/+9°C)



Precipitation (-4/+25%)

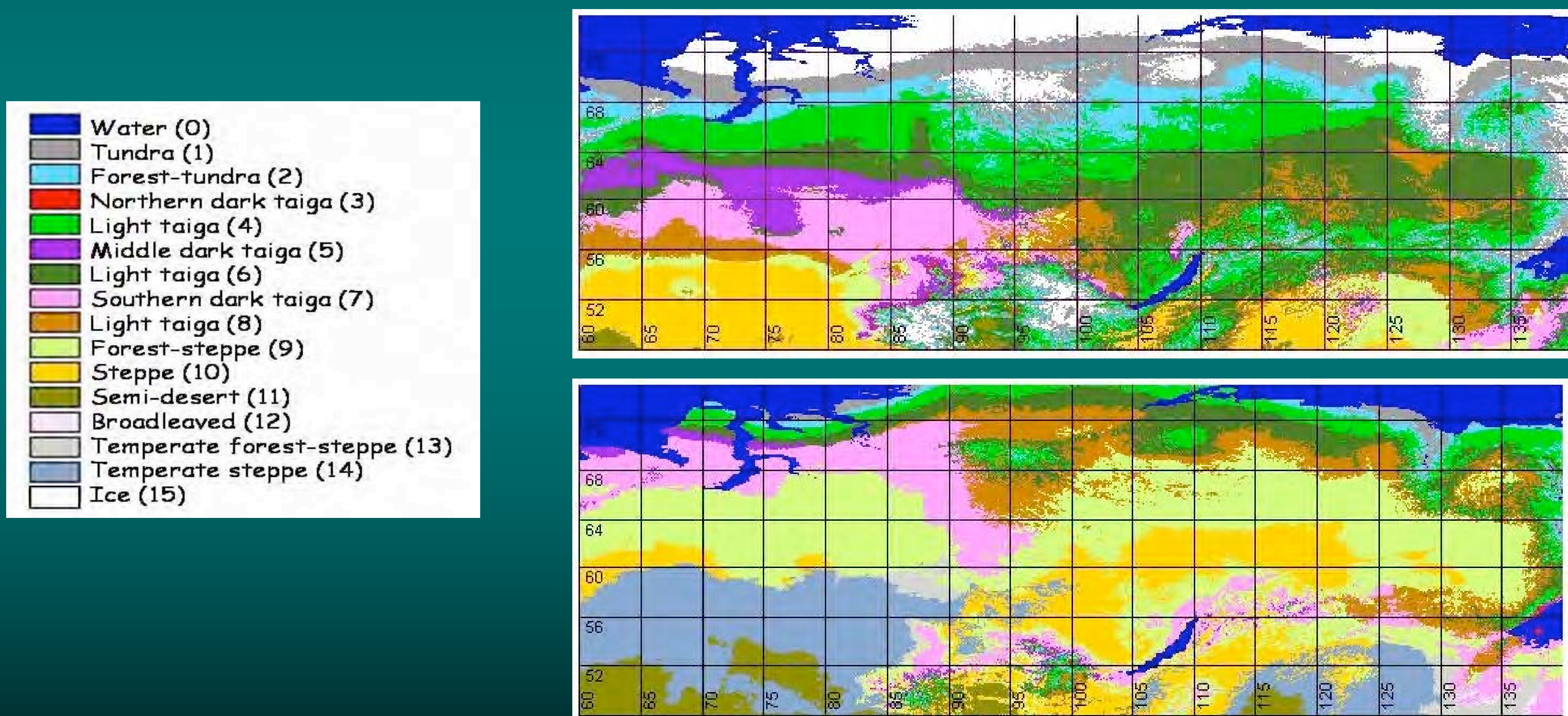


July temperature (+4/+6°C)



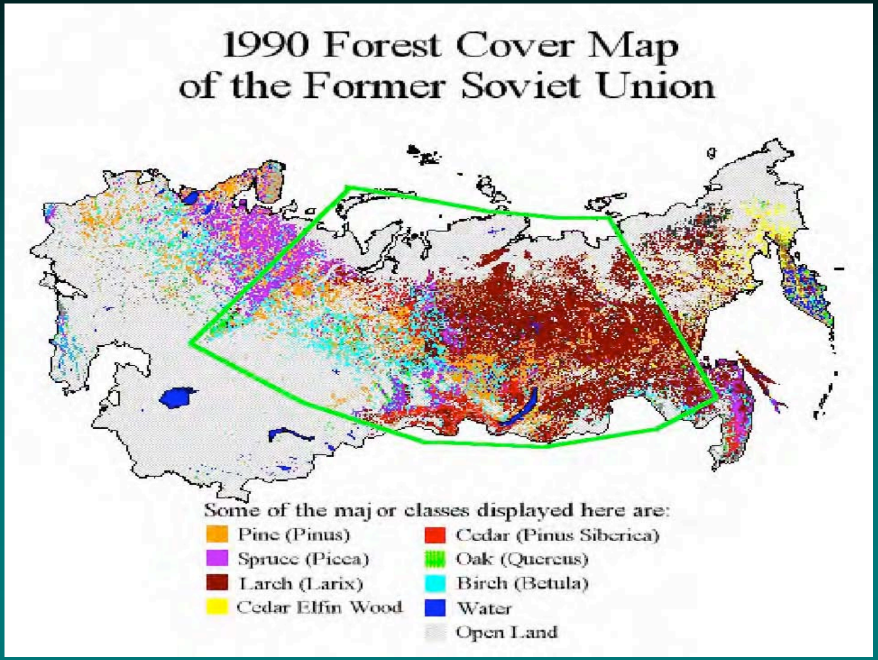
Vegetation change in Siberia by 2090

Current



2090

So from a static approach, there are significant shifts at the vegetation level.

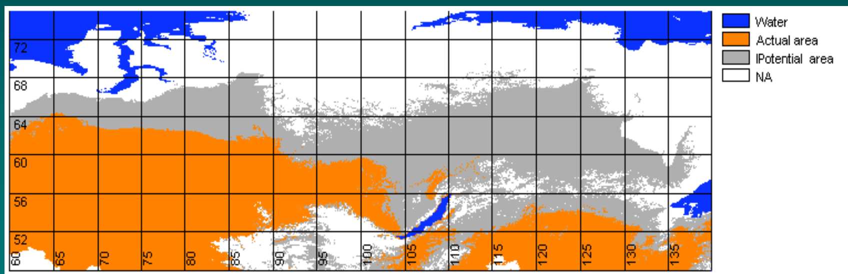


Are these seen if we evaluate species as well?

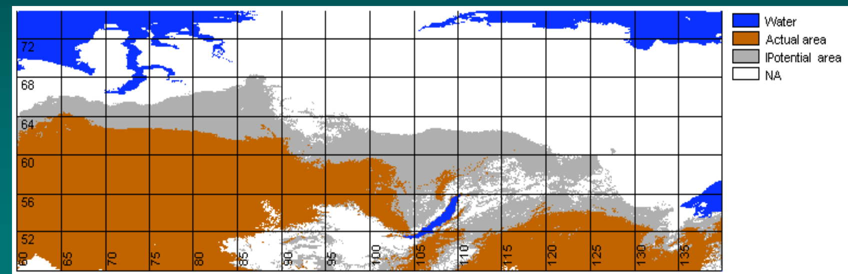
Larix spp.	51.5%
Pinus sylvestris	17.5%
P. sibirica	5.5%
P. obovata	5.0%
Abies sibirica	3.0%

Major conifer distributions in Siberia

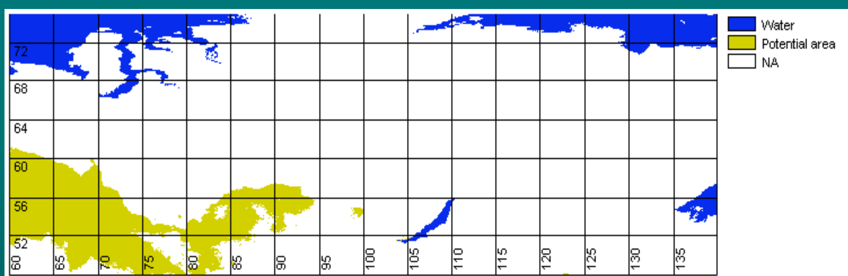
Pinus sylvestris



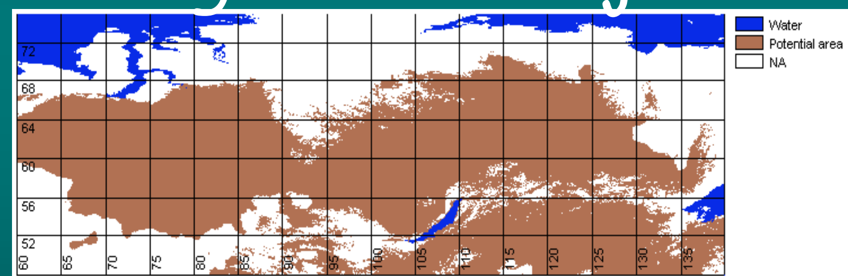
Larix sibirica



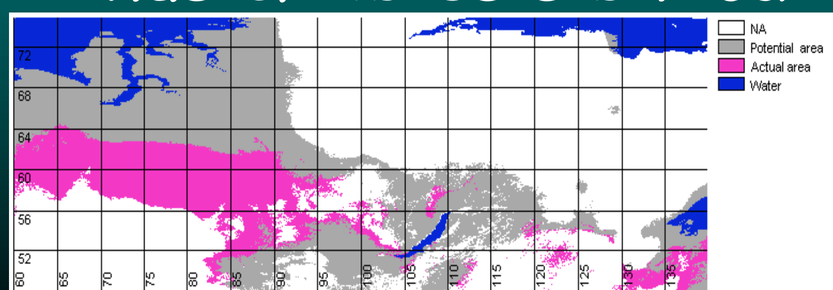
Larix sukaczewii



Larix gmelini & cajanderii

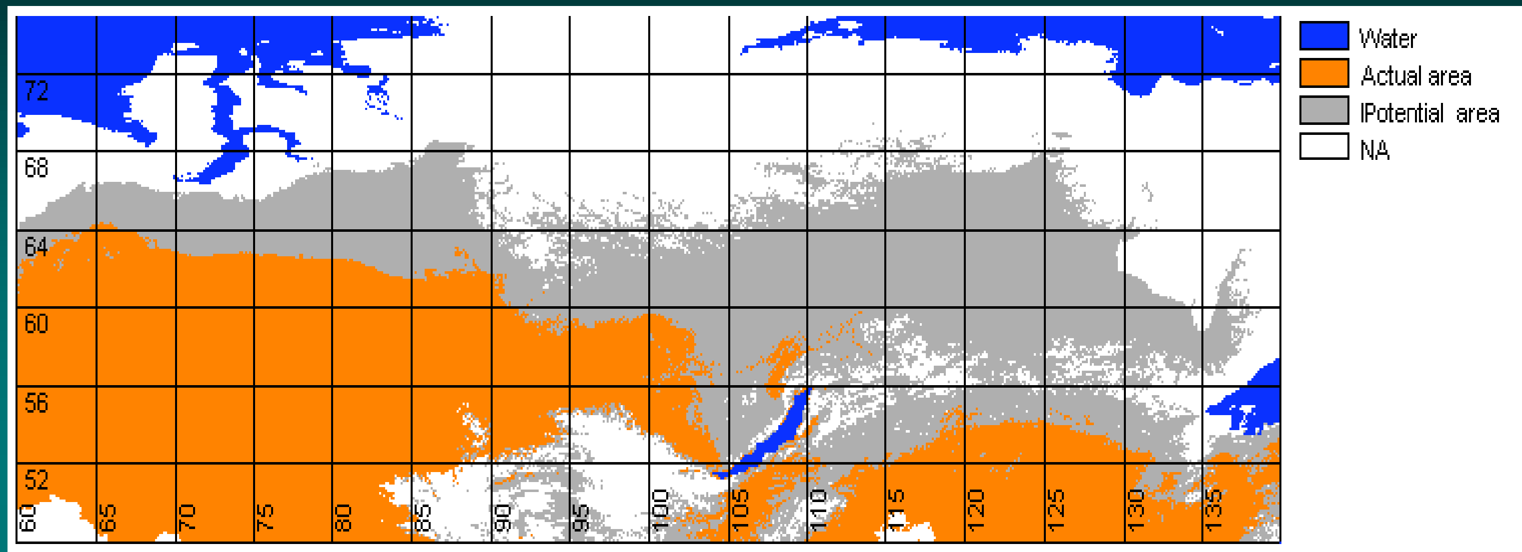


Pinus & Abies sibirica

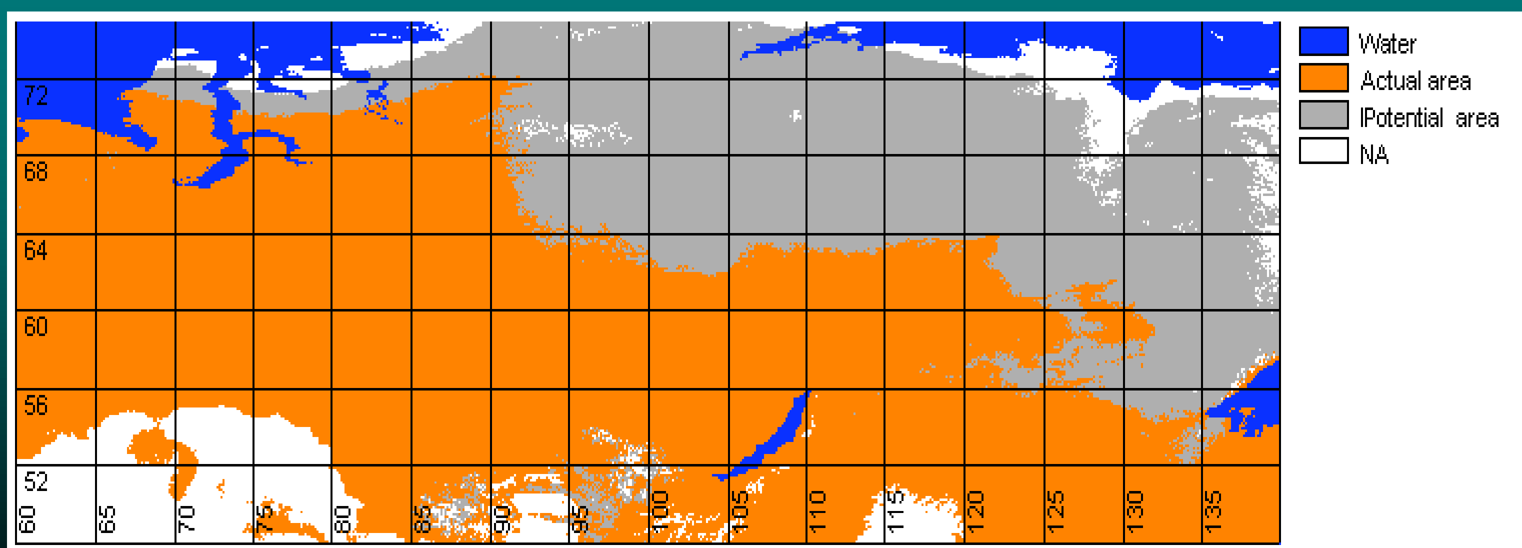


Distribution of *P. sylvestris* in Siberia

Current

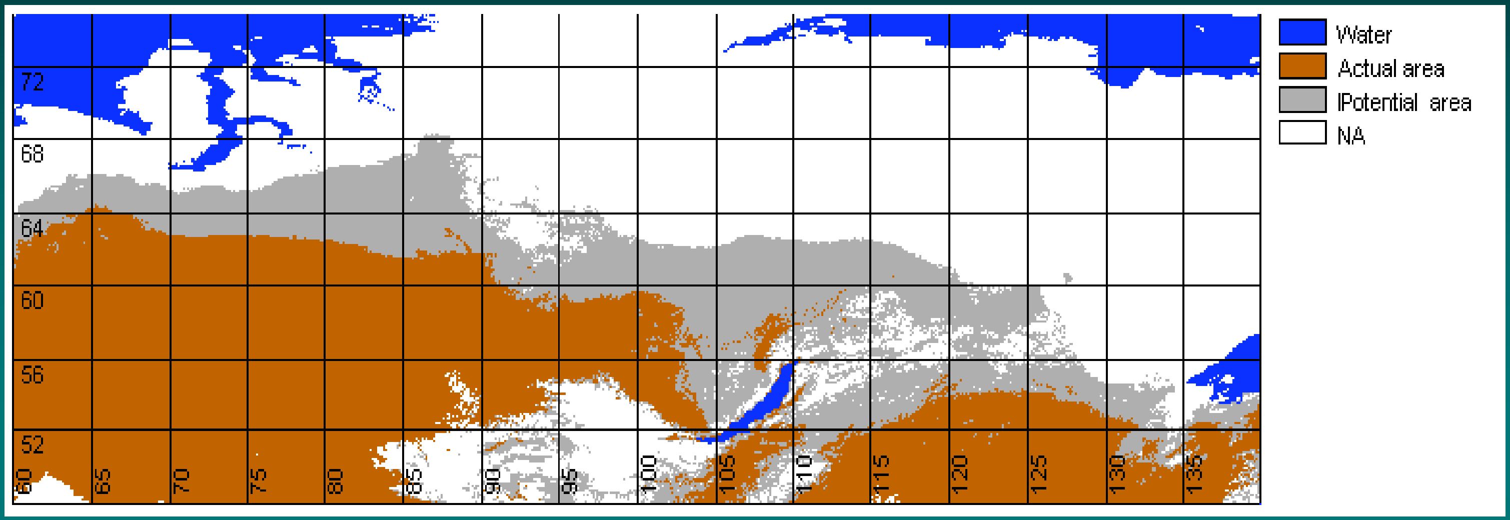


2090

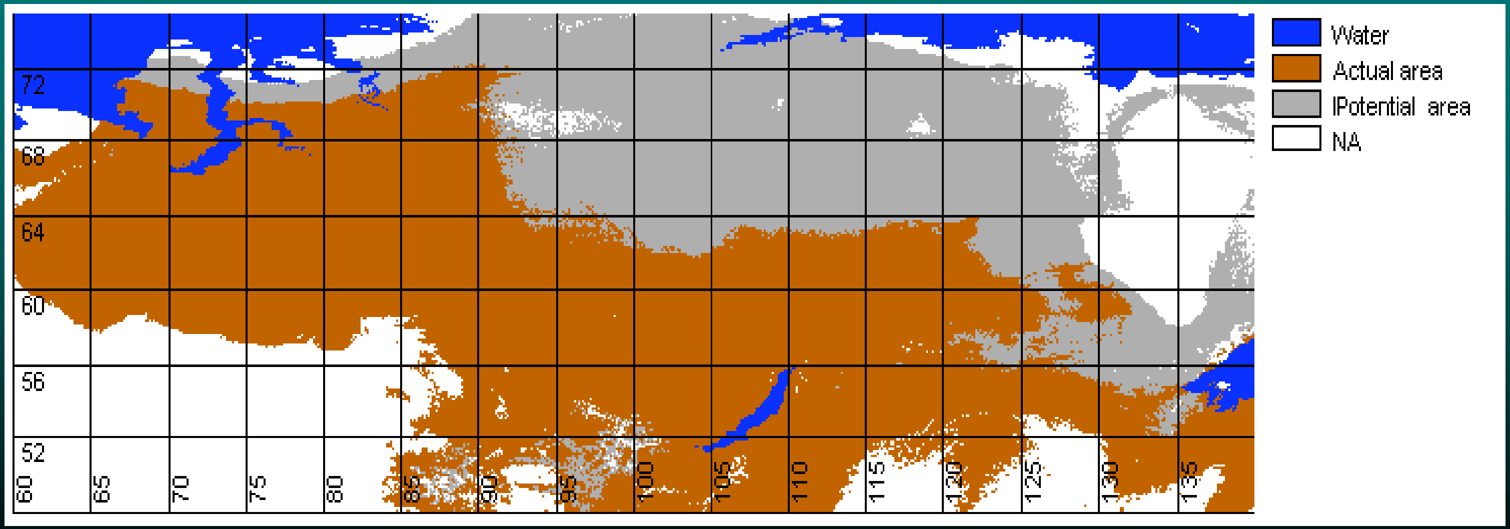


Distribution of *L. sibirica* in Siberia

Current

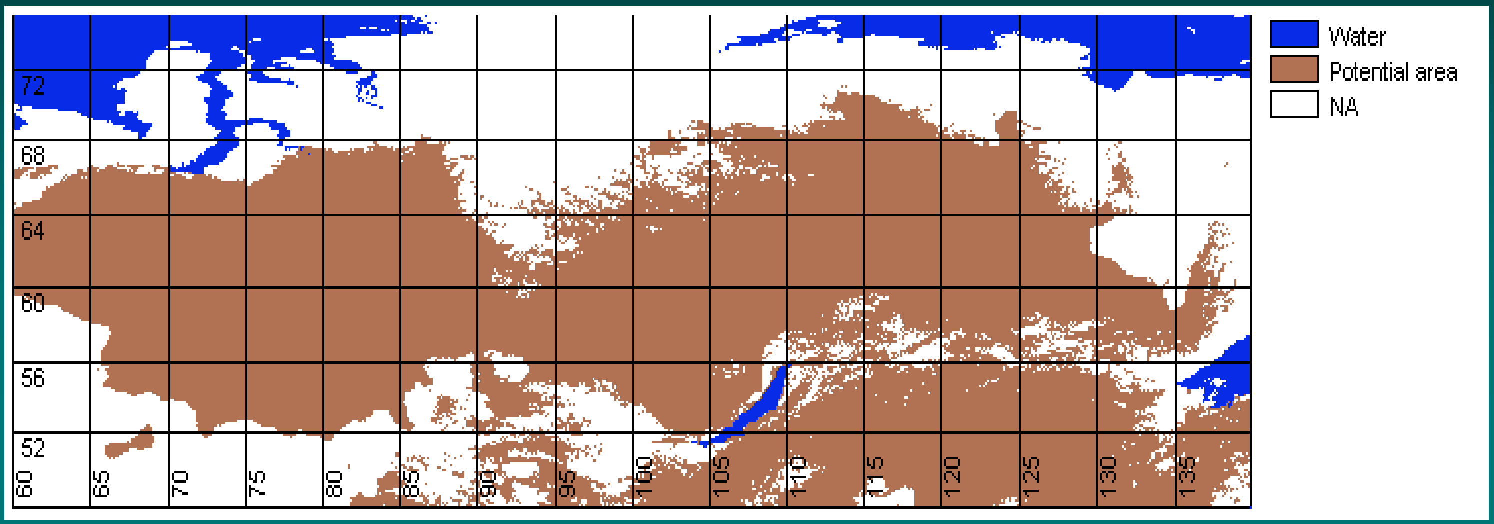


2090

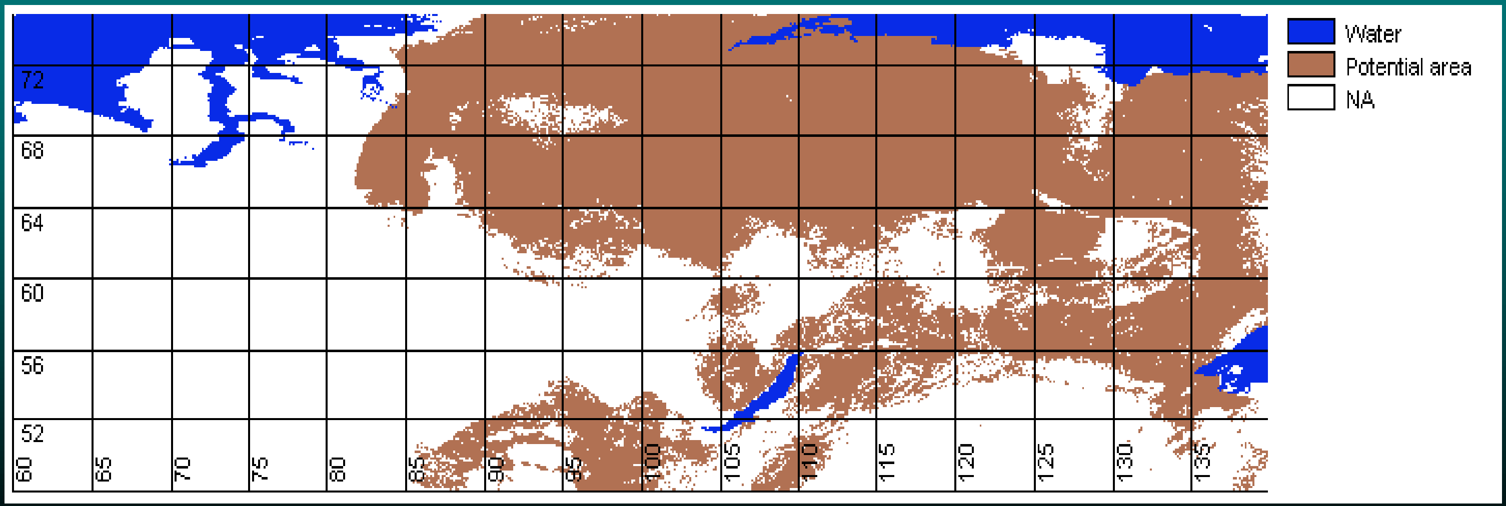


Distribution of *L. dahurica* in Siberia

Current

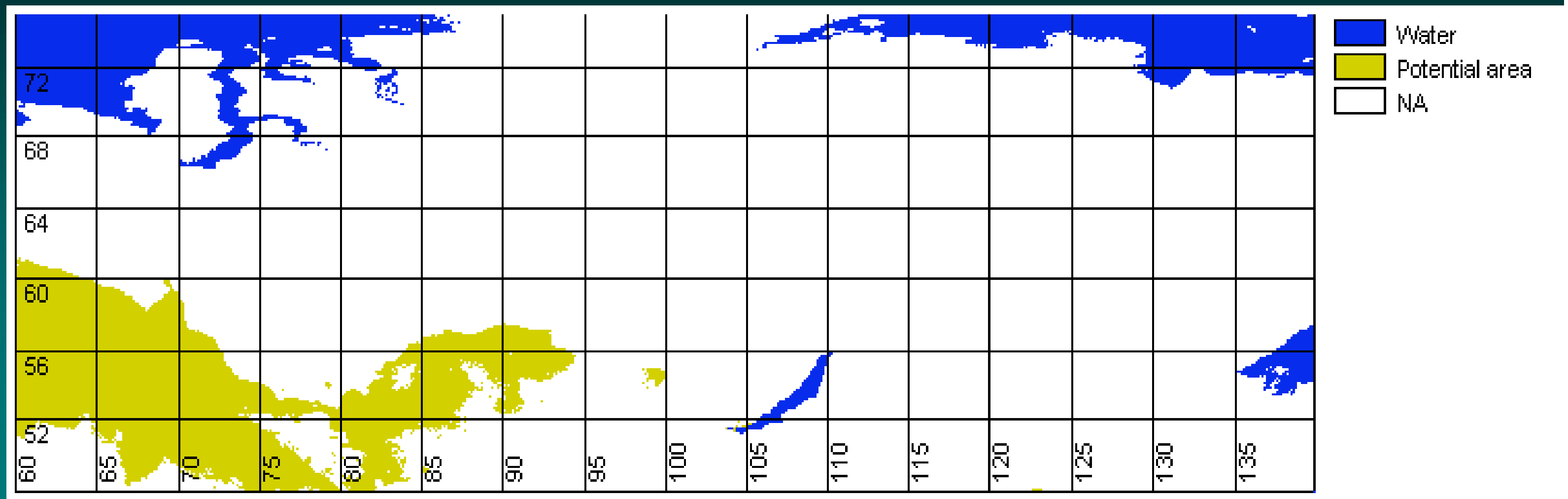


2090

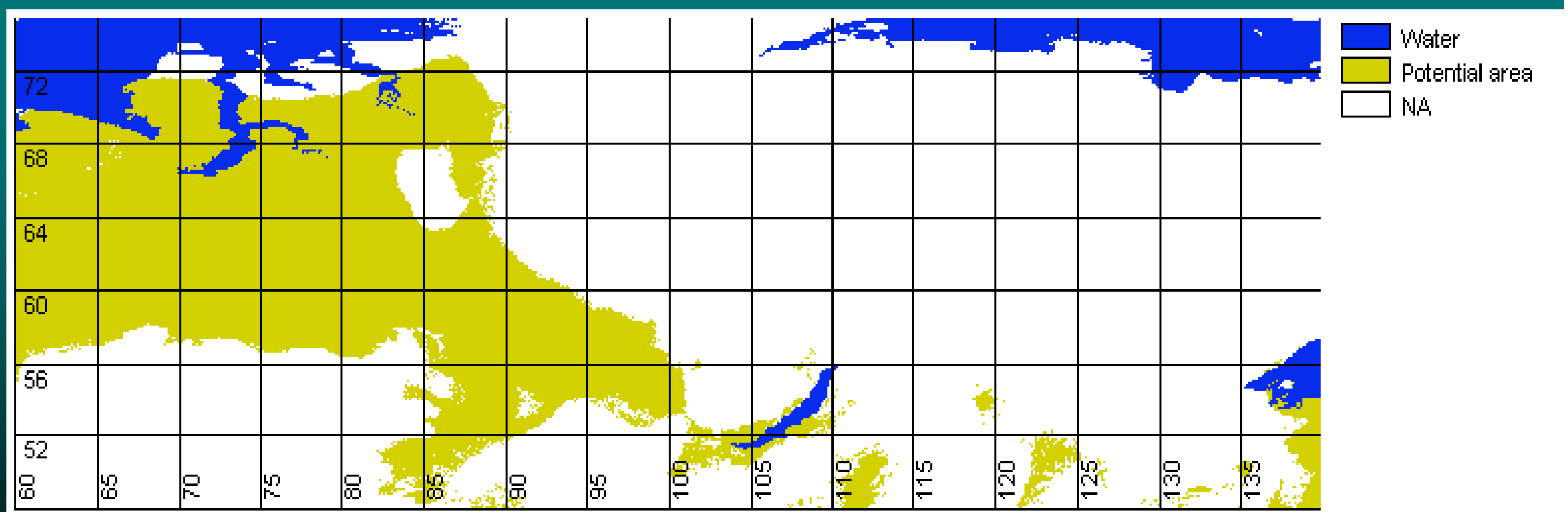


Distribution of *L. sukaczevii* in Siberia

Current

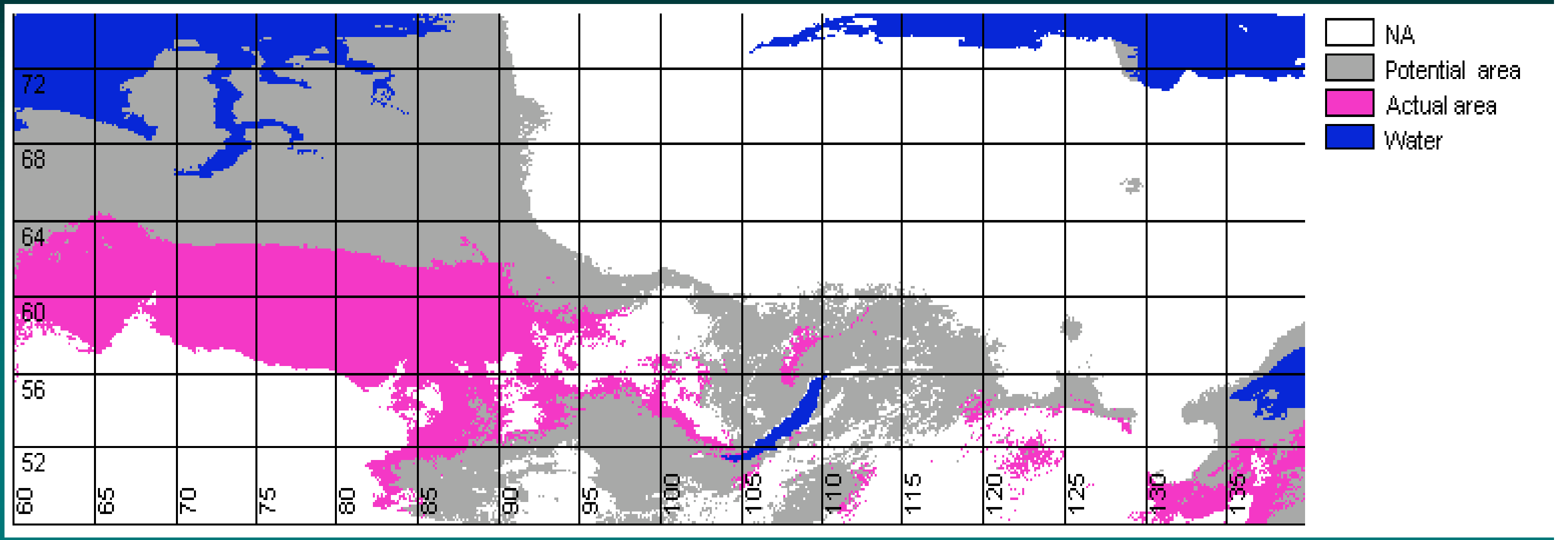


2090

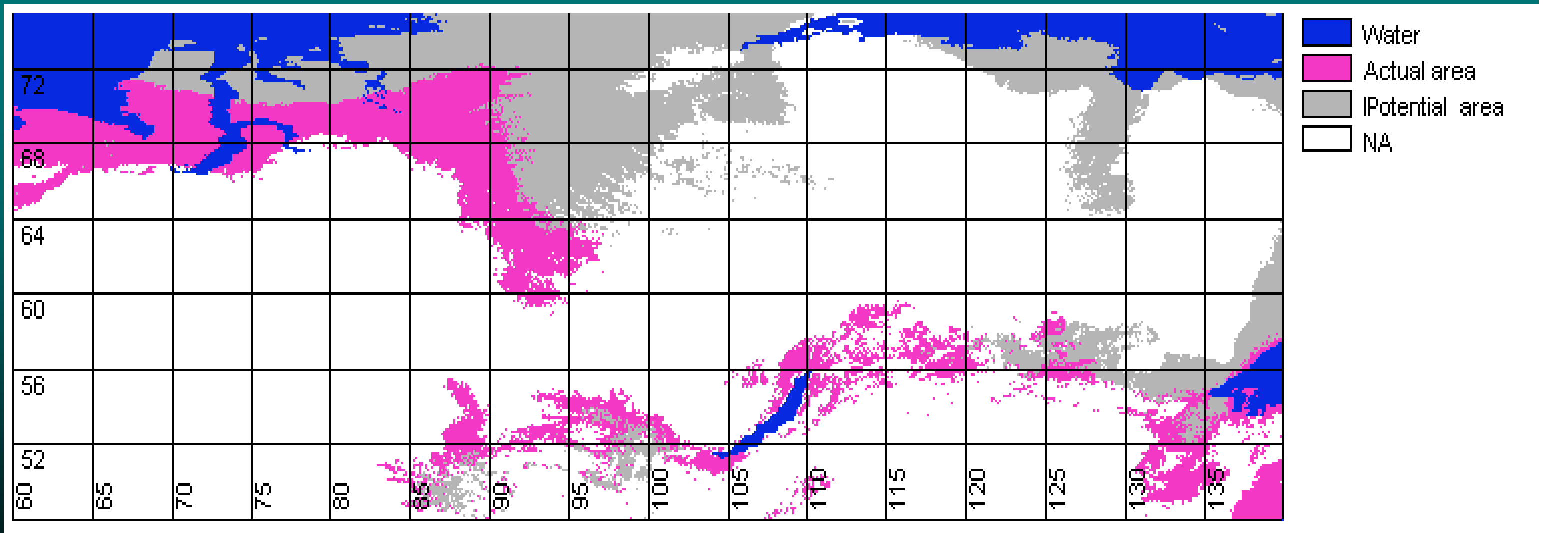


Distribution of *Pinus sibirica* in Siberia

Current



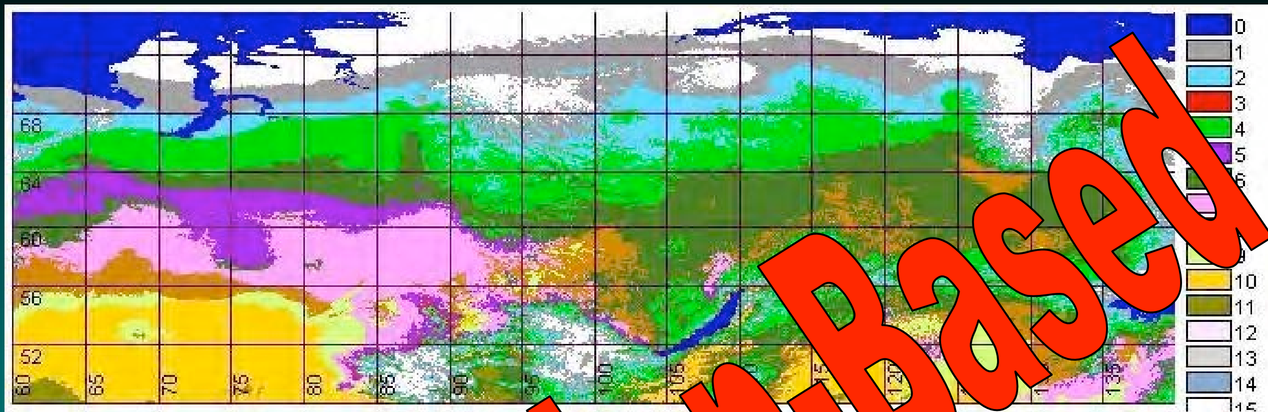
2090



Potential and actual (in brackets) distributions (%) of main tree species in current and 2090 climates

Tree species	Current climate	Future climate
Pinus sylvestris	68 (38)	87 (62)
Larix sibirica	58 (26)	71 (28)
Larix dahurica	60 (33)	38 (24)
Larix sukaczewii	12 (12)	26 (23)

Correlation-Based

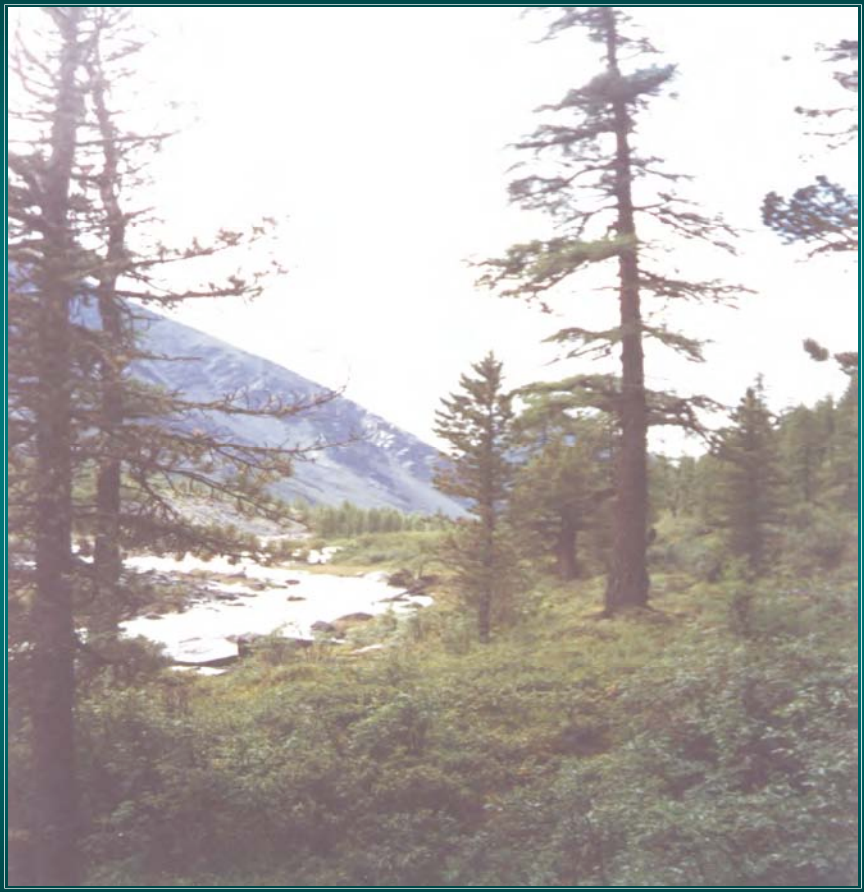


Current distribution of Siberian vegetation

Future (2100) estimate of Siberian vegetation based on climate change

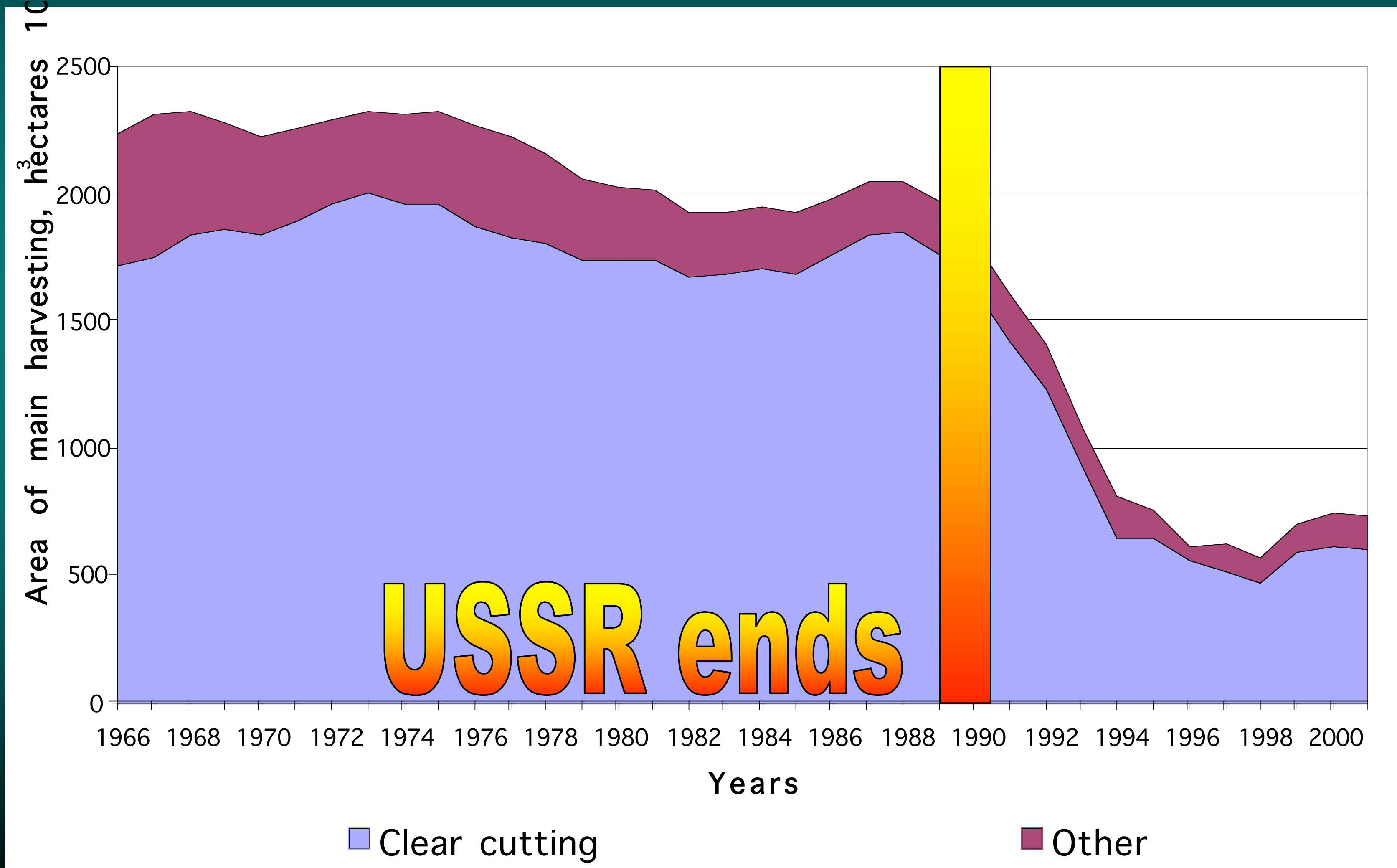
Water (0)
Tundra (1)
Forest-tundra (2)
Northern dark taiga (3)
Light taiga (4)
Middle dark taiga (5)
Light taiga (6)
Southern dark taiga (7)
Light taiga (8)
Forest-steppe (9)
Steppe (10)
Semi-desert (11)
Broadleaved (12)
Temperate forest-steppe (13)
Temperate steppe (14)

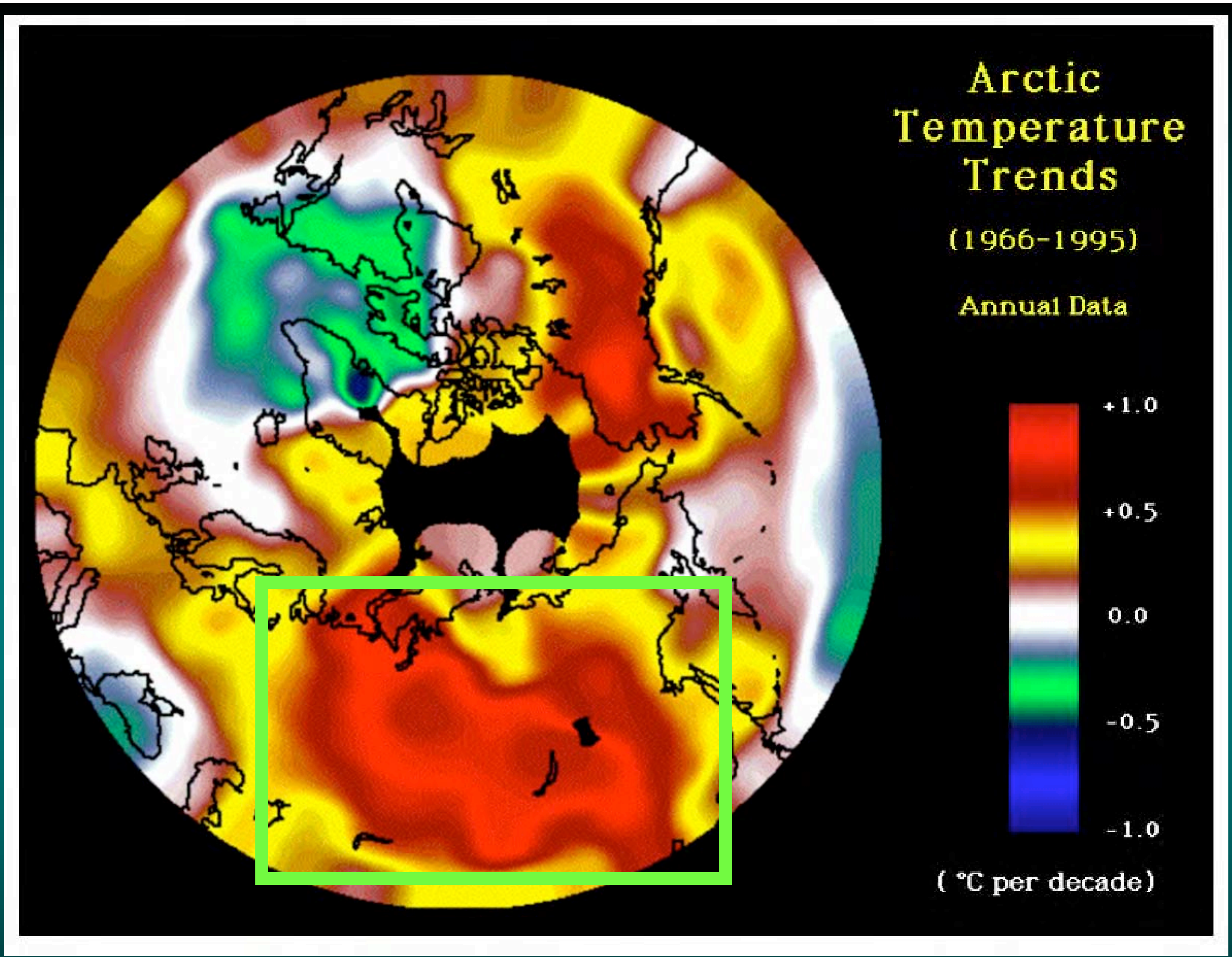
Tchebakova, N., and E. Parfenova (2004), Possible vegetation changes in Arctic and Boreal regions due to climate warming, in *Feasibility Workshop for Circumpolar LIDAR Mapping for Biomass Carbon Assessment and Vegetation Change Monitoring*, pp. in press, Waseda University, Tokyo.



If we see large changes from a static evaluation of climate altering the vegetation potentials, what are the results from dynamic studies?

Dynamics of the Principal Areas of Forest Harvest for Russia





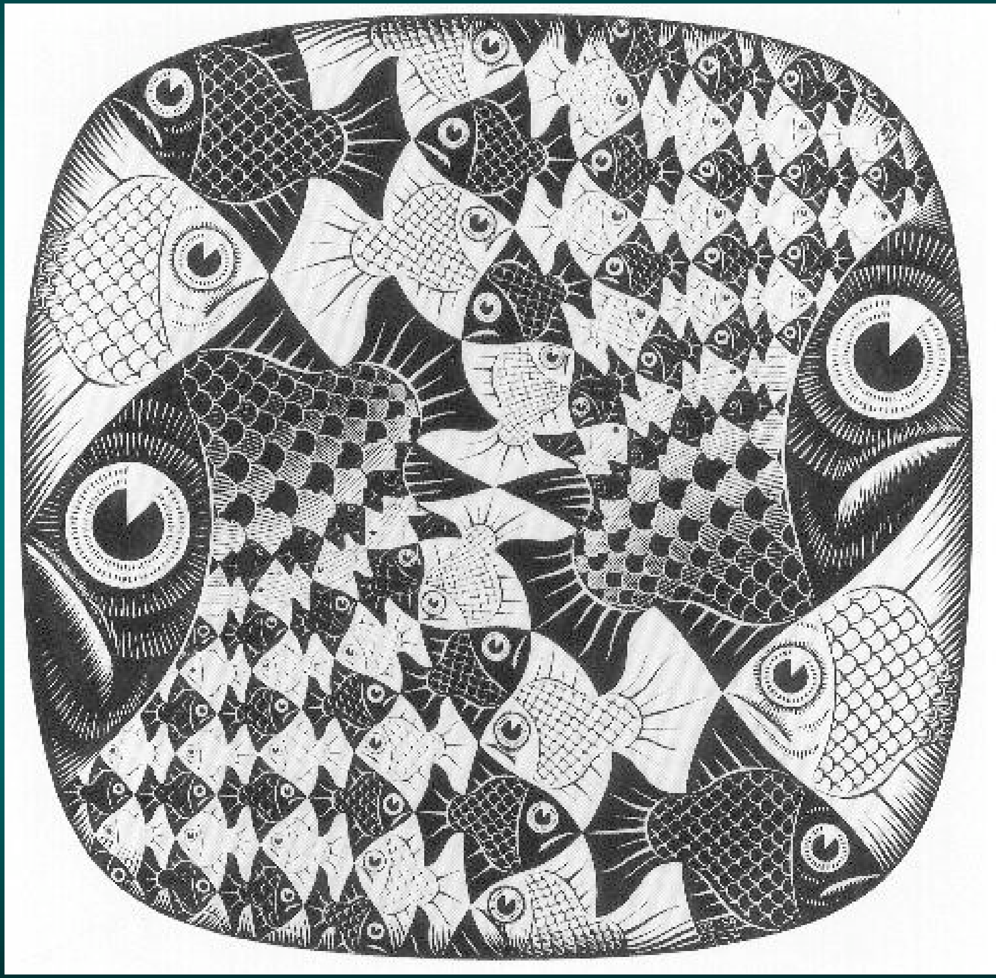
Observed Warming Trend From: Serreze, MC, et al. 2000. Observational Evidence of Recent Change in the Northern High-latitude Environment. Climatic Change 46:159-207.

Contemporary Biosphere and Carbon Cycle Changes in Northern Eurasia

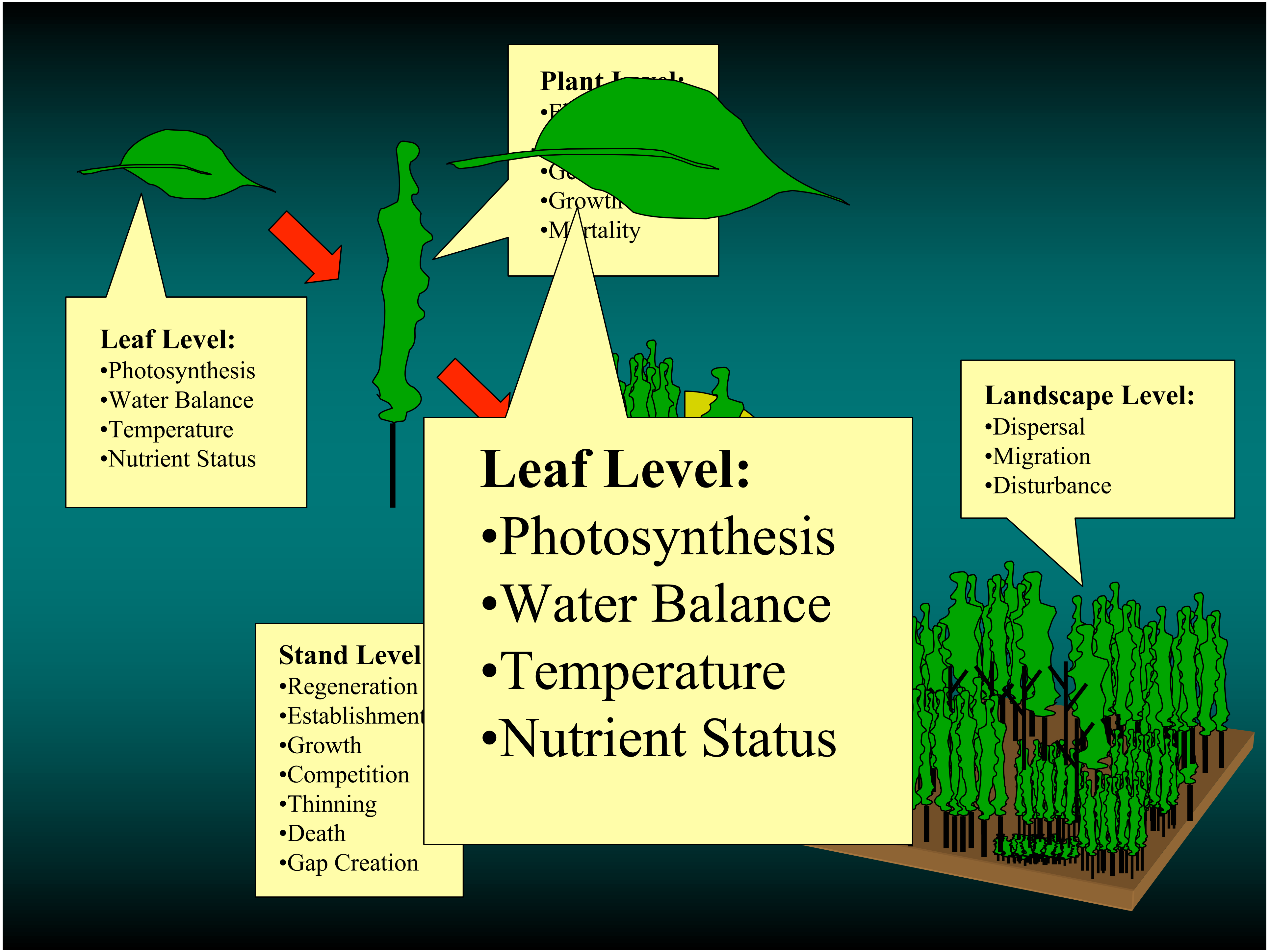
H.H. Shugart
Department of Environmental Sciences
University of Virginia

With Much Appreciated Help from Many Colleagues

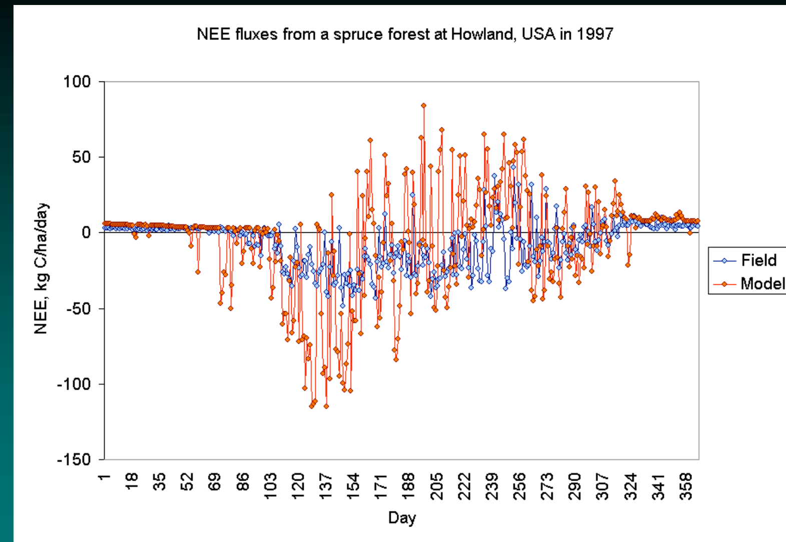
Central to the Understanding of Dynamics is an Appreciation of Scale

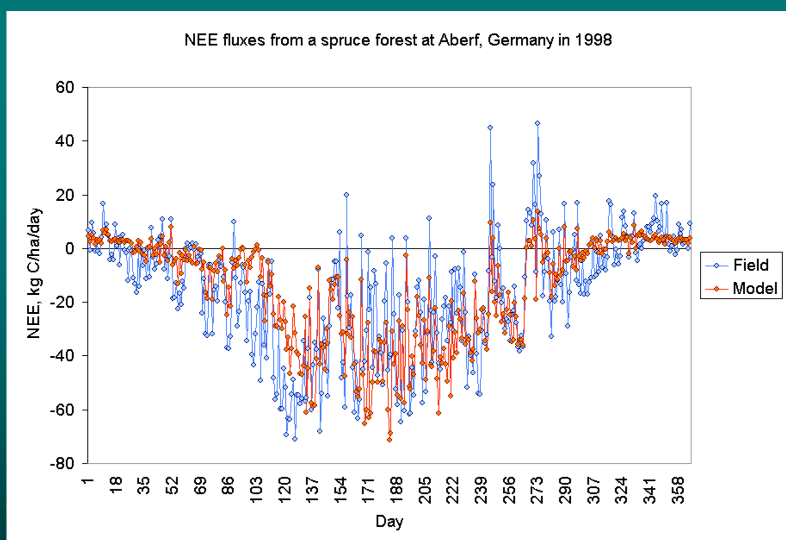


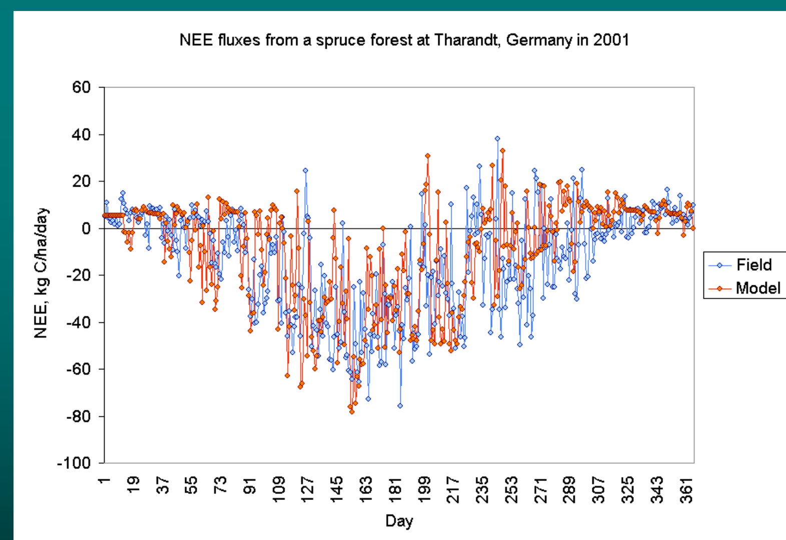
Fish whose scales are fish at another scale (M.C. Escher)


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

Testing of Forest-DNDC against observed NEE fluxes

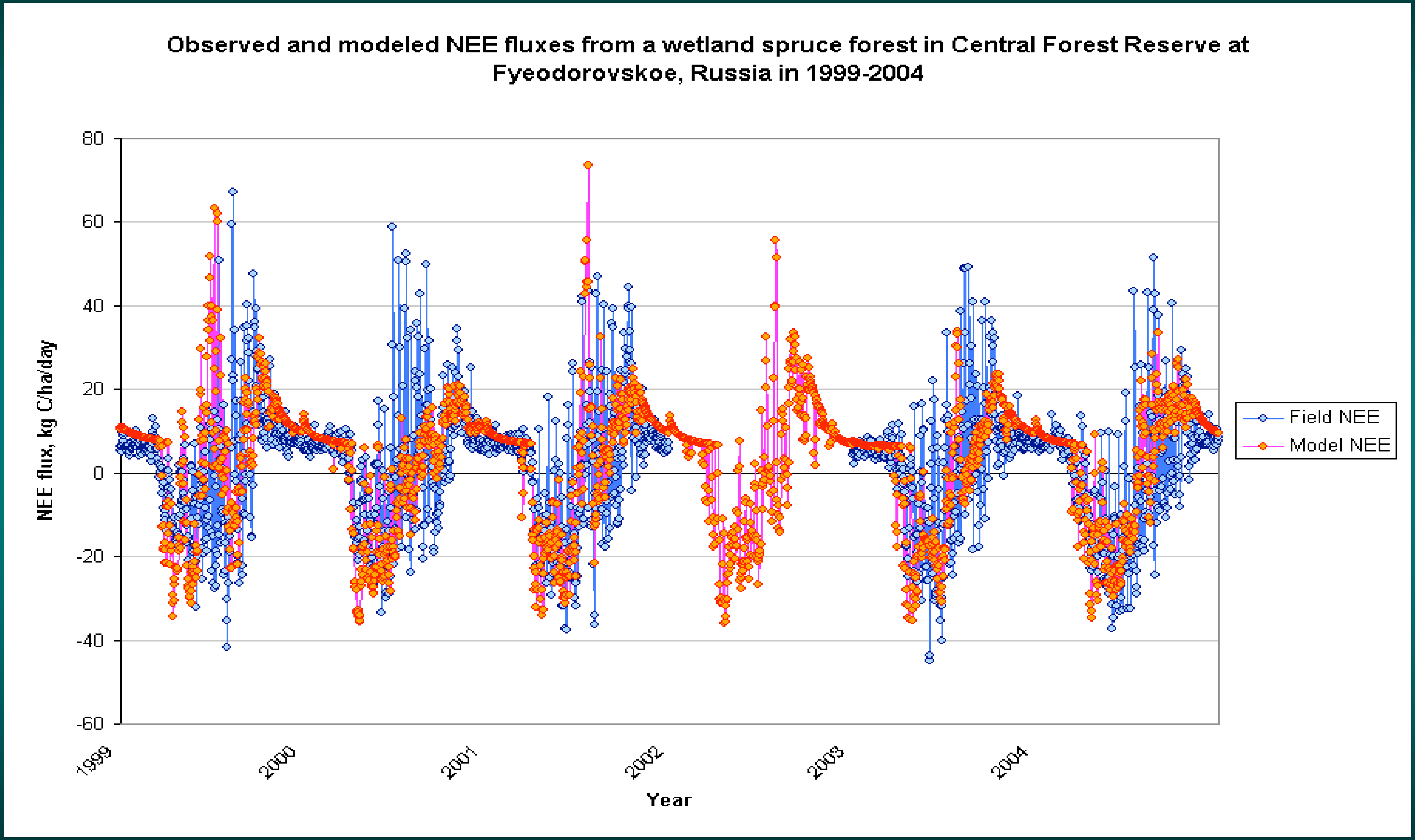






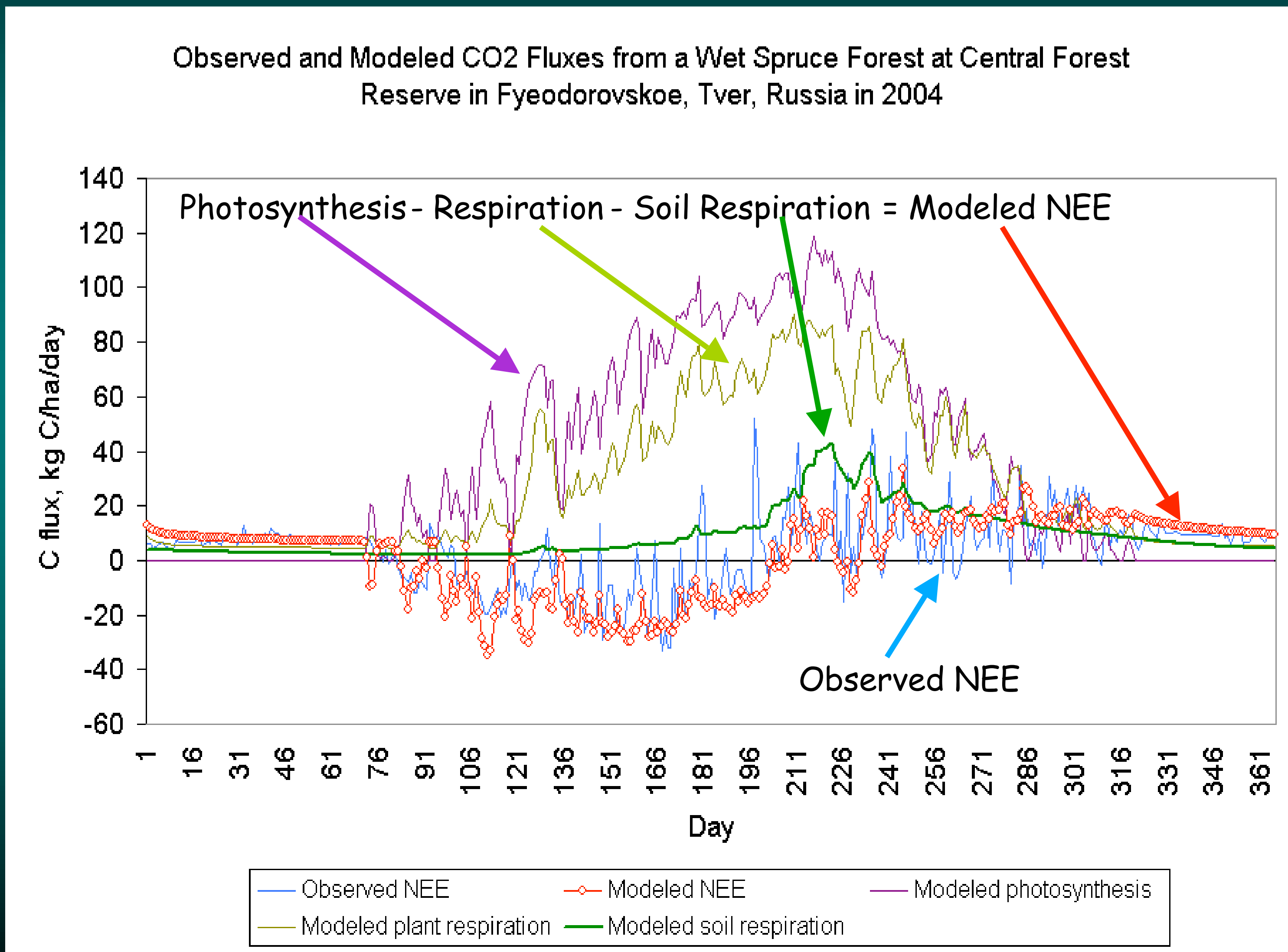
Comparison between observed and Forest-DNDC modeled NEE fluxes.

Testing of Forest-DNDC against observed NEE fluxes

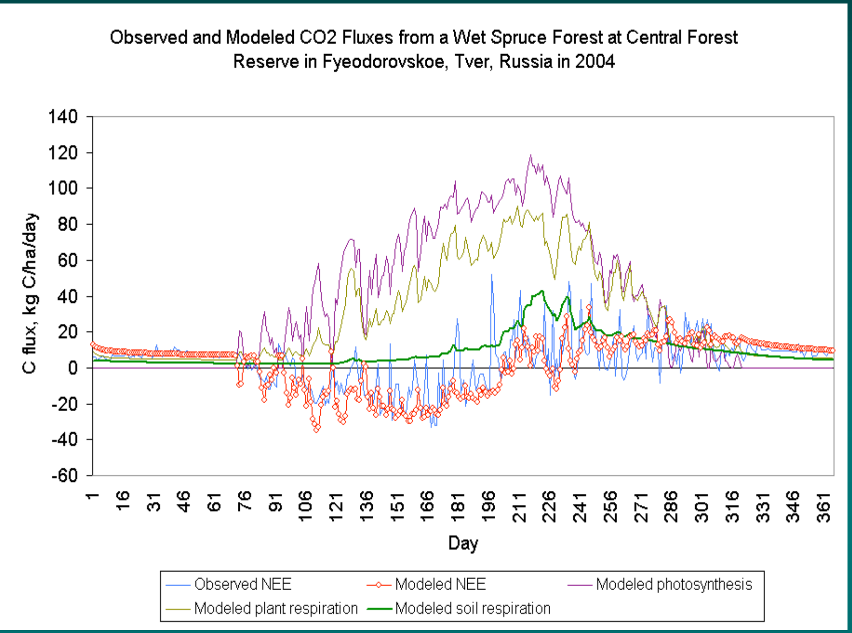


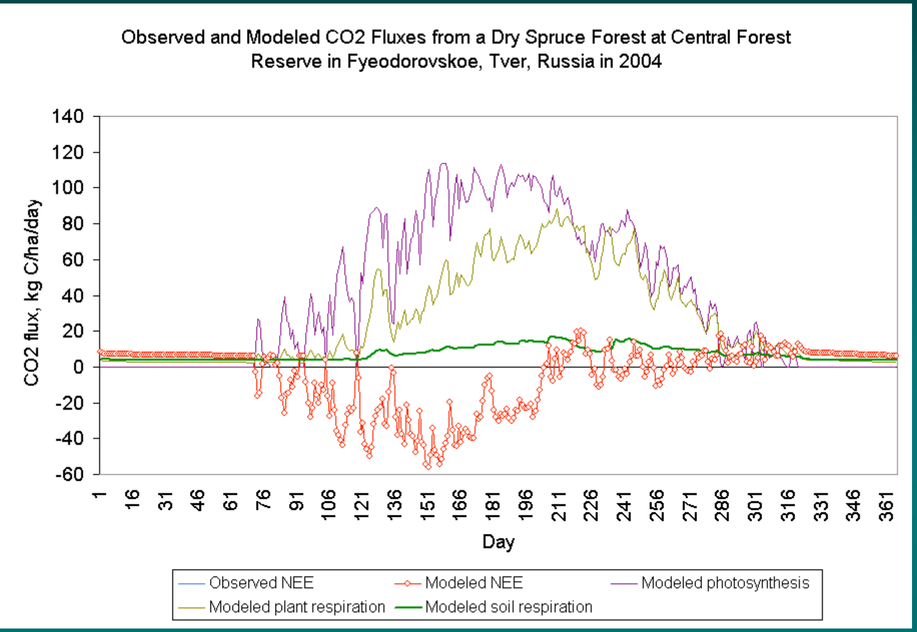
Comparison between observed and Forest-DNDC modeled NEE fluxes.

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



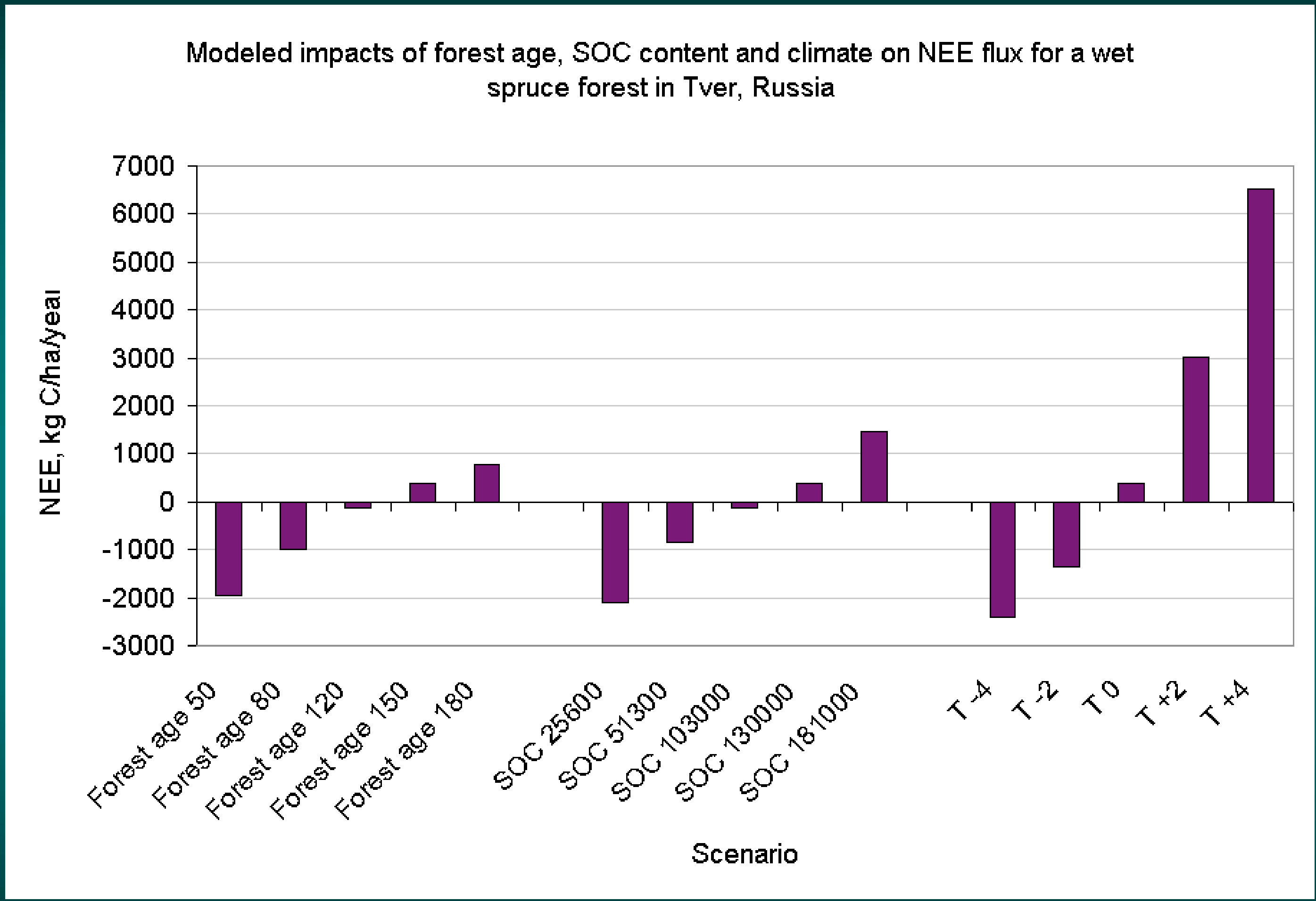
Modeled C fluxes composing NEE: Soil is a key factor determining sink or source





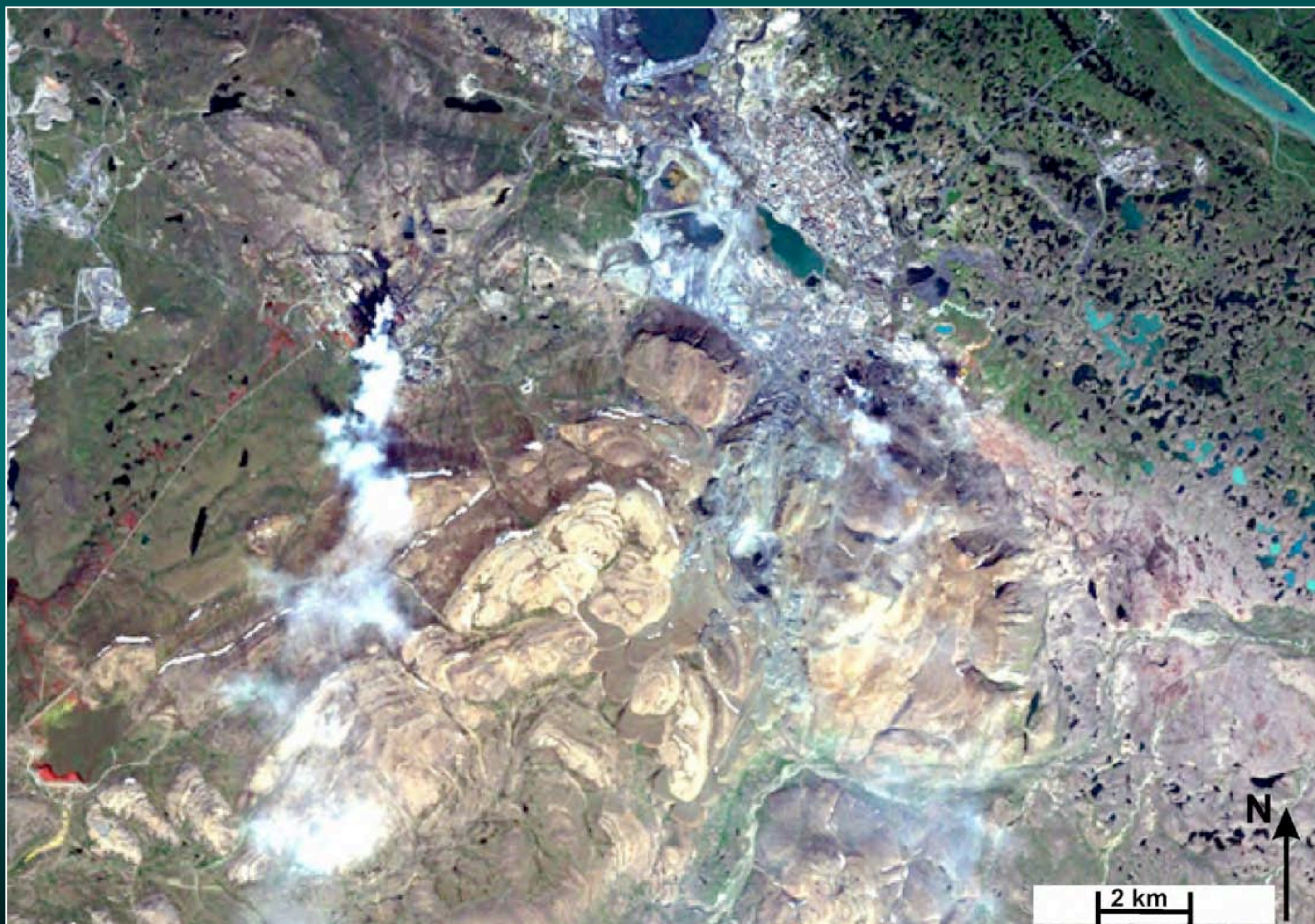
Stand	Photosynthesis kgC ha^{-1} yr^{-1}	Plant respiration kgC ha^{-1} yr^{-1}	Soil respiration kgC ha^{-1} yr^{-1}	GPP kgC ha^{-1} yr^{-1}	NEE kgC ha^{-1} yr^{-1}
WSF	13132	10361	3481	2771	711
DSF	14162	9616	2683	4546	-1863

Impact of forest age, SOC and temperature on C dynamics

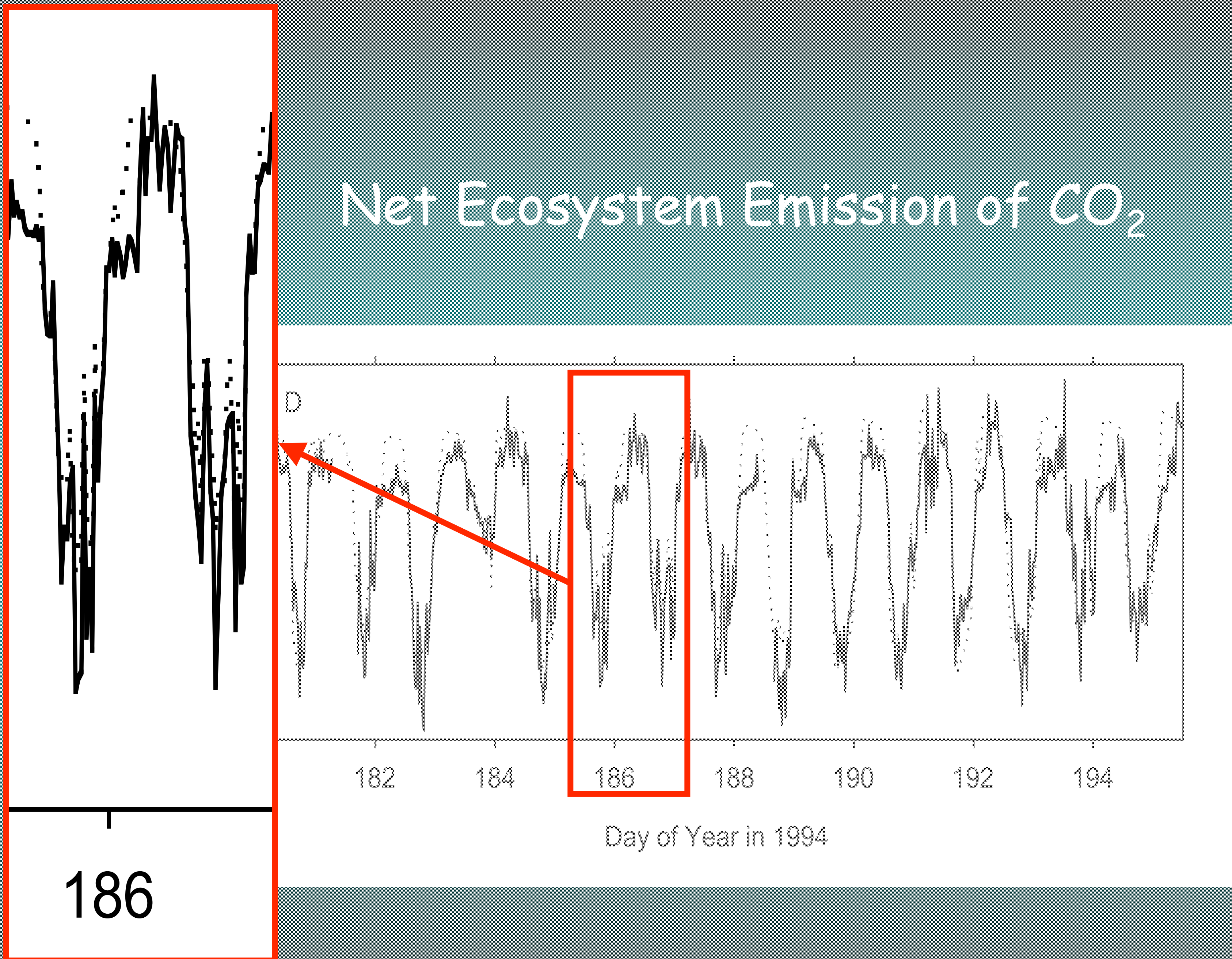


NEE was sensitive to forest age, SOC content and temperature. Along with increase in

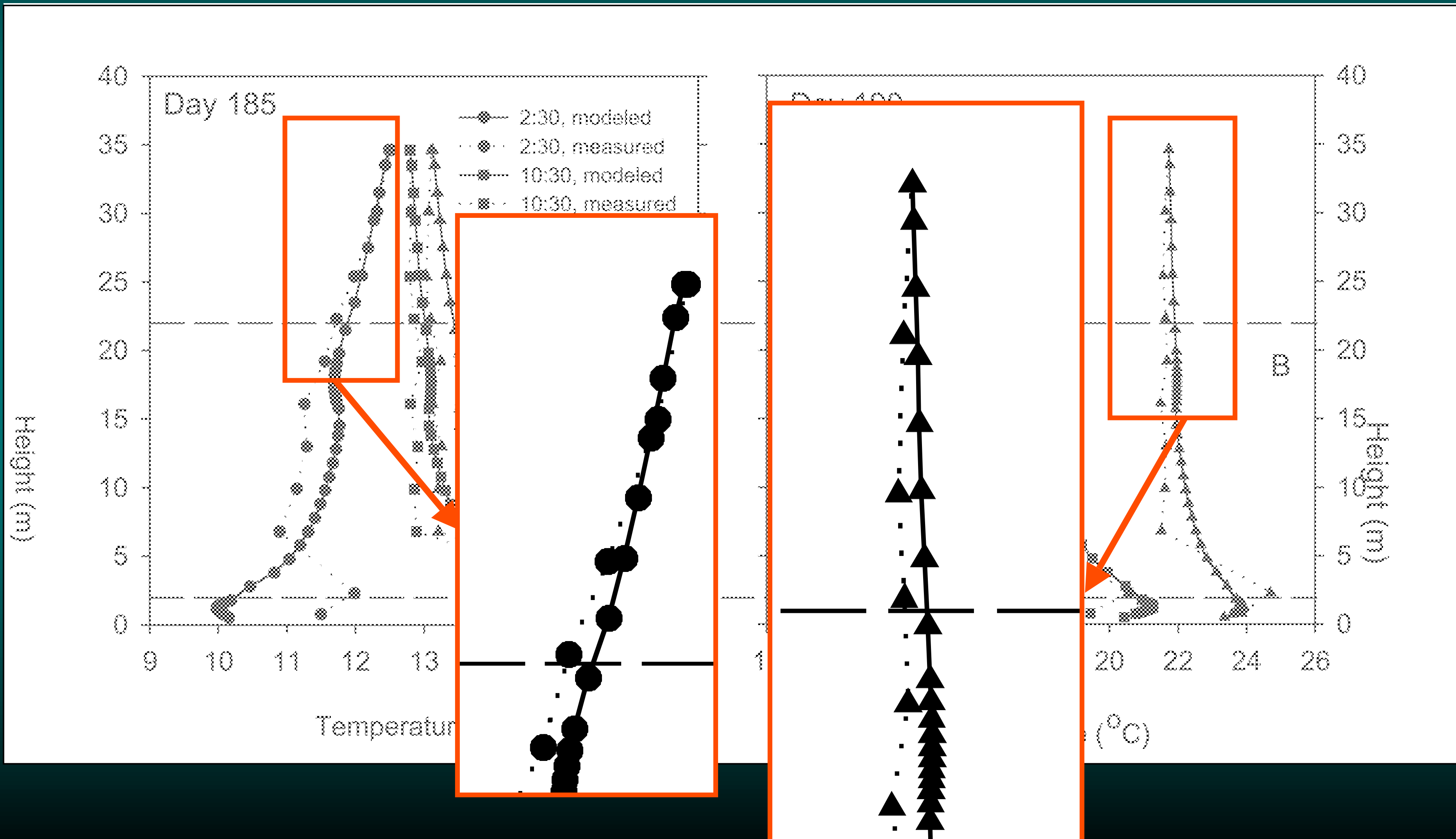
Norilsk Industrial Region

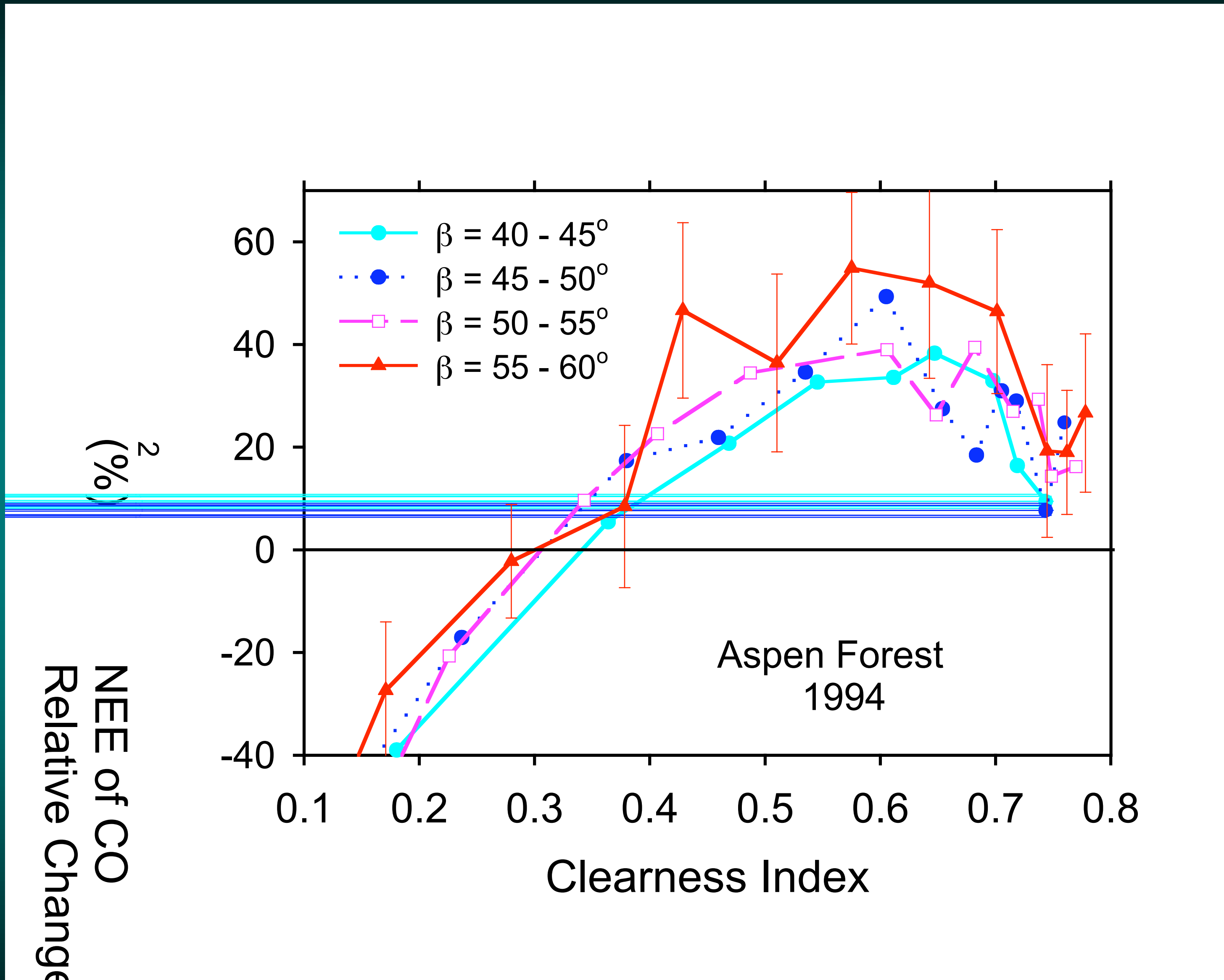


Net Ecosystem Emission of CO_2

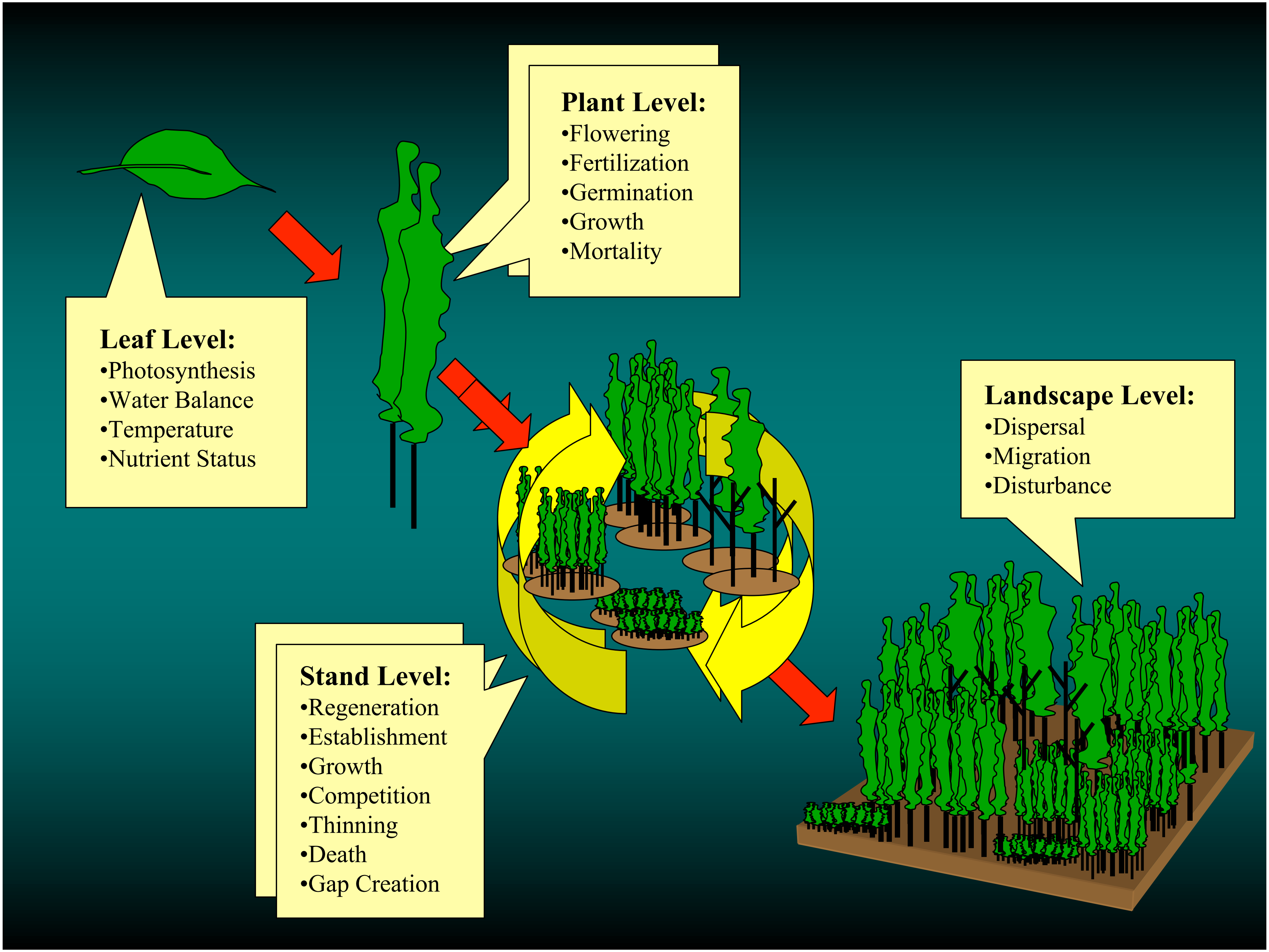


Prediction of Temperature Profiles at Different Elevations on Different Days.





β = 40 - 45°
β = 45 - 50°
β = 50 - 55°
β = 55 - 60°
60
40
20
0
-20
-40
Aspen Forest
1994
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Clearness Index
NEE of CO2 (%)
Relative Change


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

FAREAST: A Boreal Forest Simulator

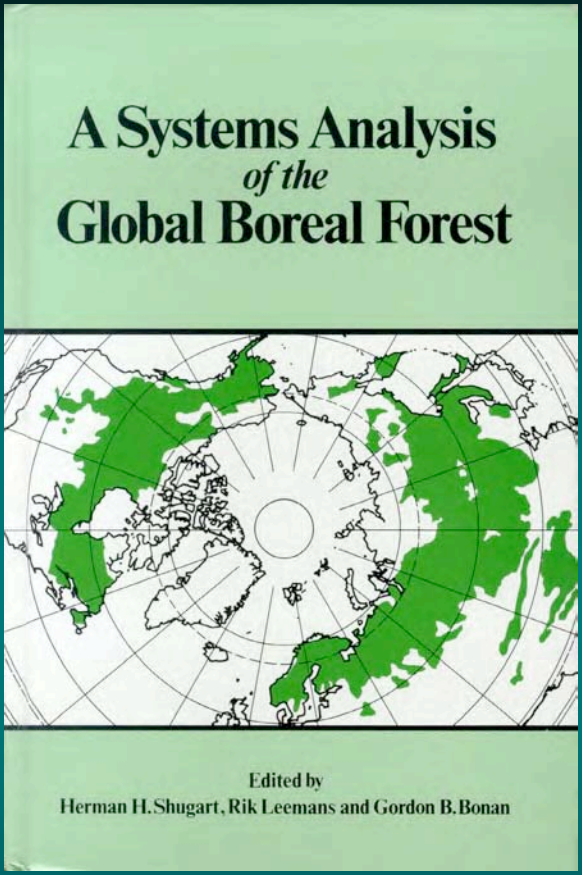
Growth:
- Available Light
- Soil Moisture
- Site Quality
- Growing-Degree Days
- Depth of Thaw
- Diameter
- Age
- Height

Mortality:
- Stress
- Fire
- Insects
- Age

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

Data Needs:

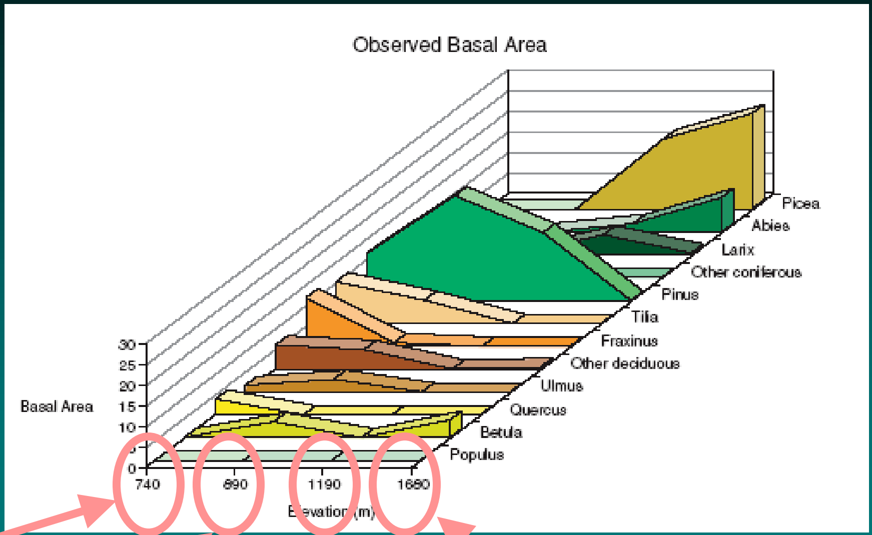
Process information on the silvicultural features of the boreal tree species, allometric equations, light extinction coefficients, and other biological, biophysical and physical aspects of stand dynamics.

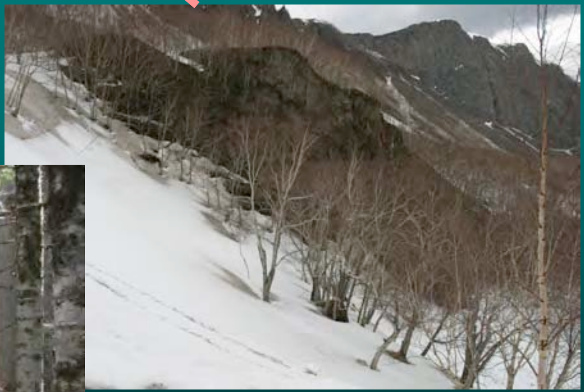


Much of this has been derived from earlier synthesis activities but there remains a need for a characterization of the fundamental processes, particularly thermal fluxes and ice-related processes.

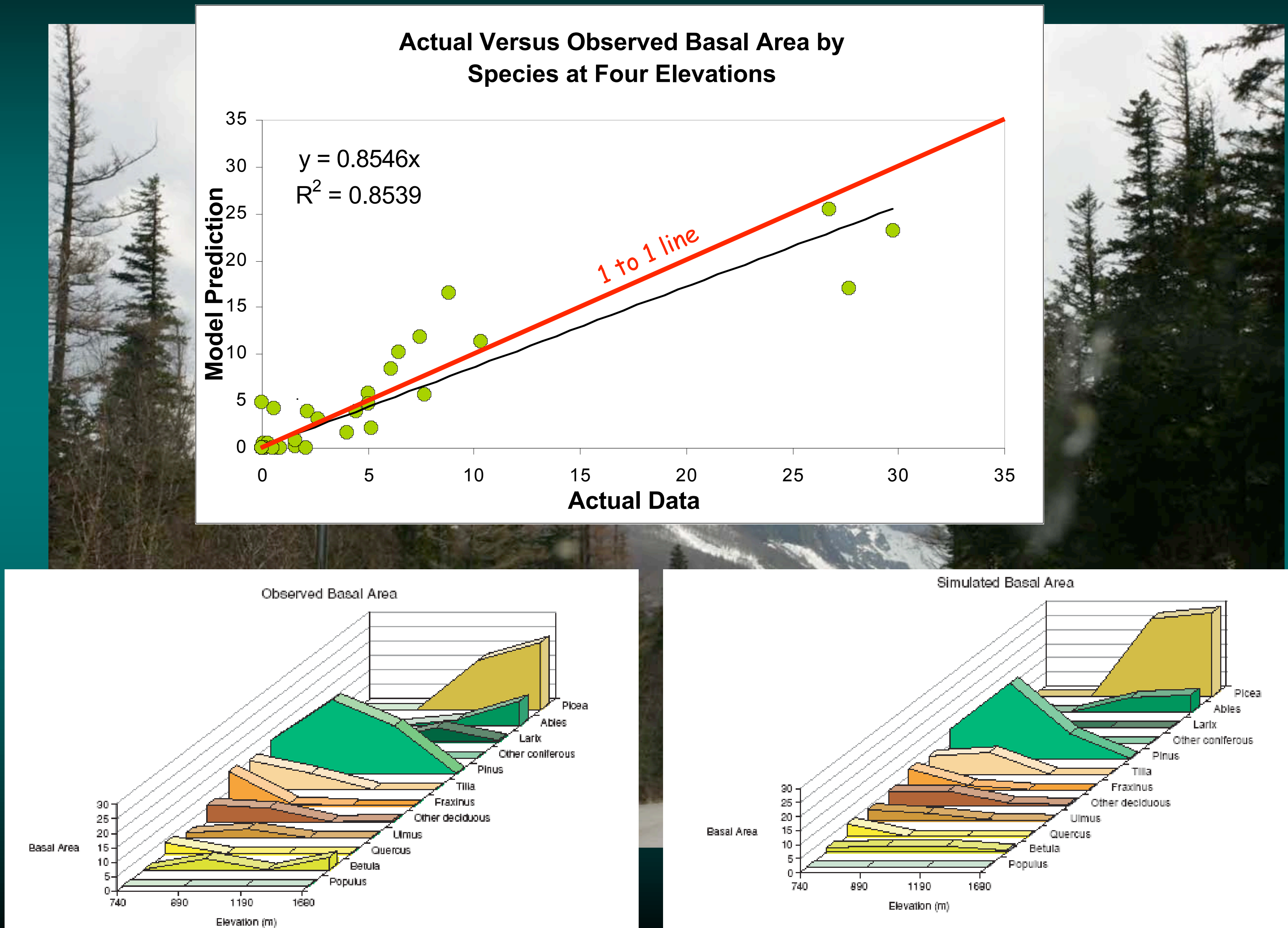
Testing Individual-based Models of the Boreal Forest

Chang Bai Shan Vegetation Gradient

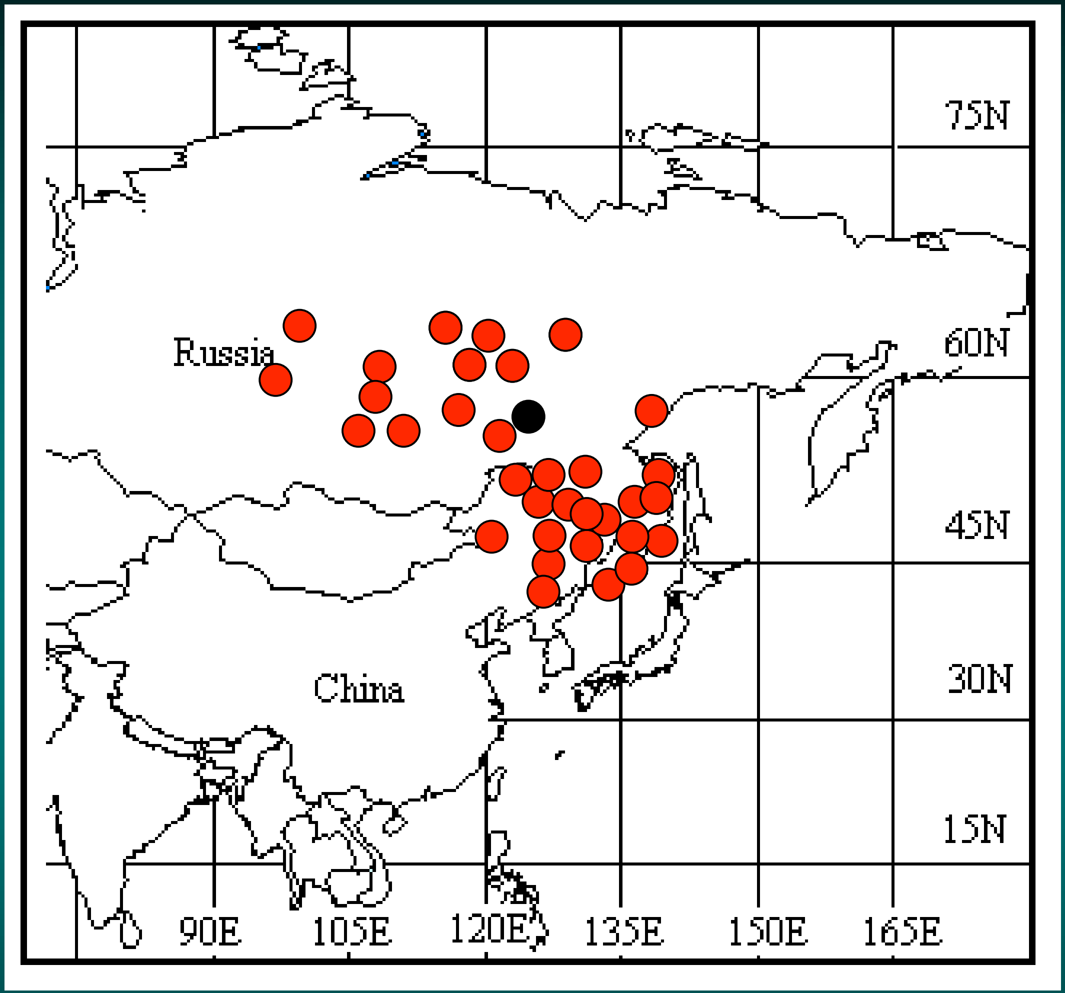




Tests of the FAREAST Model on Mountain Gradients



Test sites in China and Russia

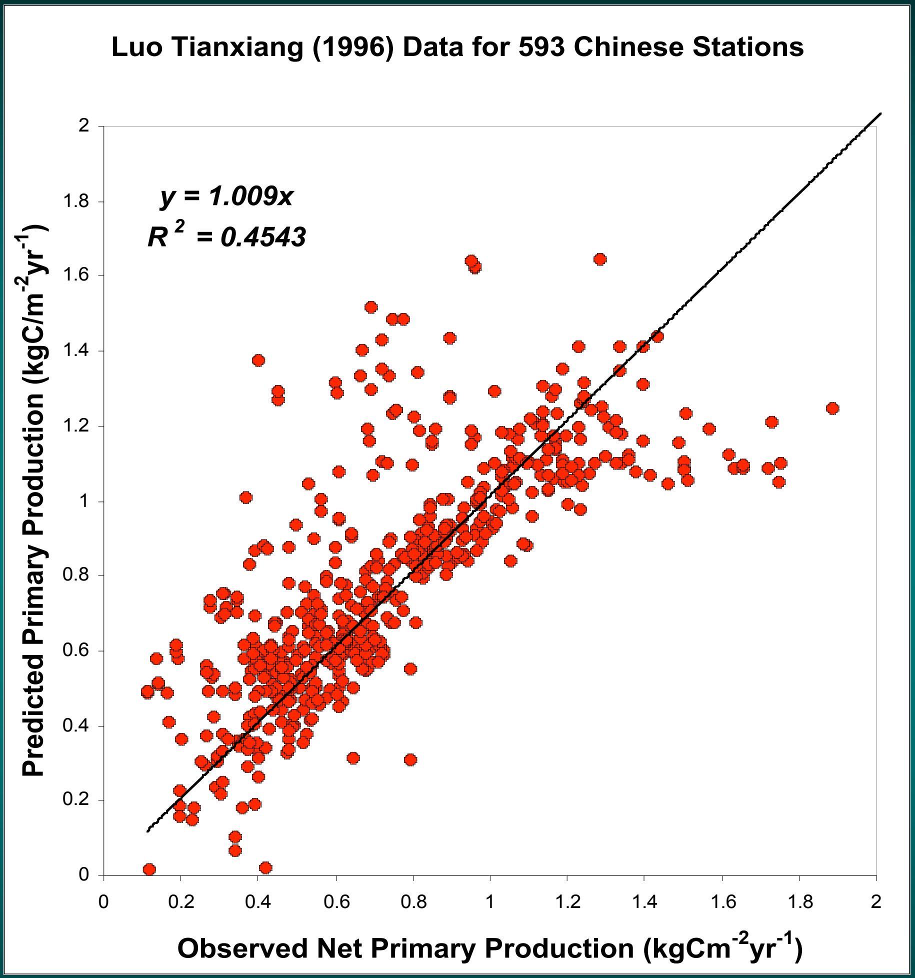


85% Correct (Validation Mode)
95% Correct (Verification Mode)

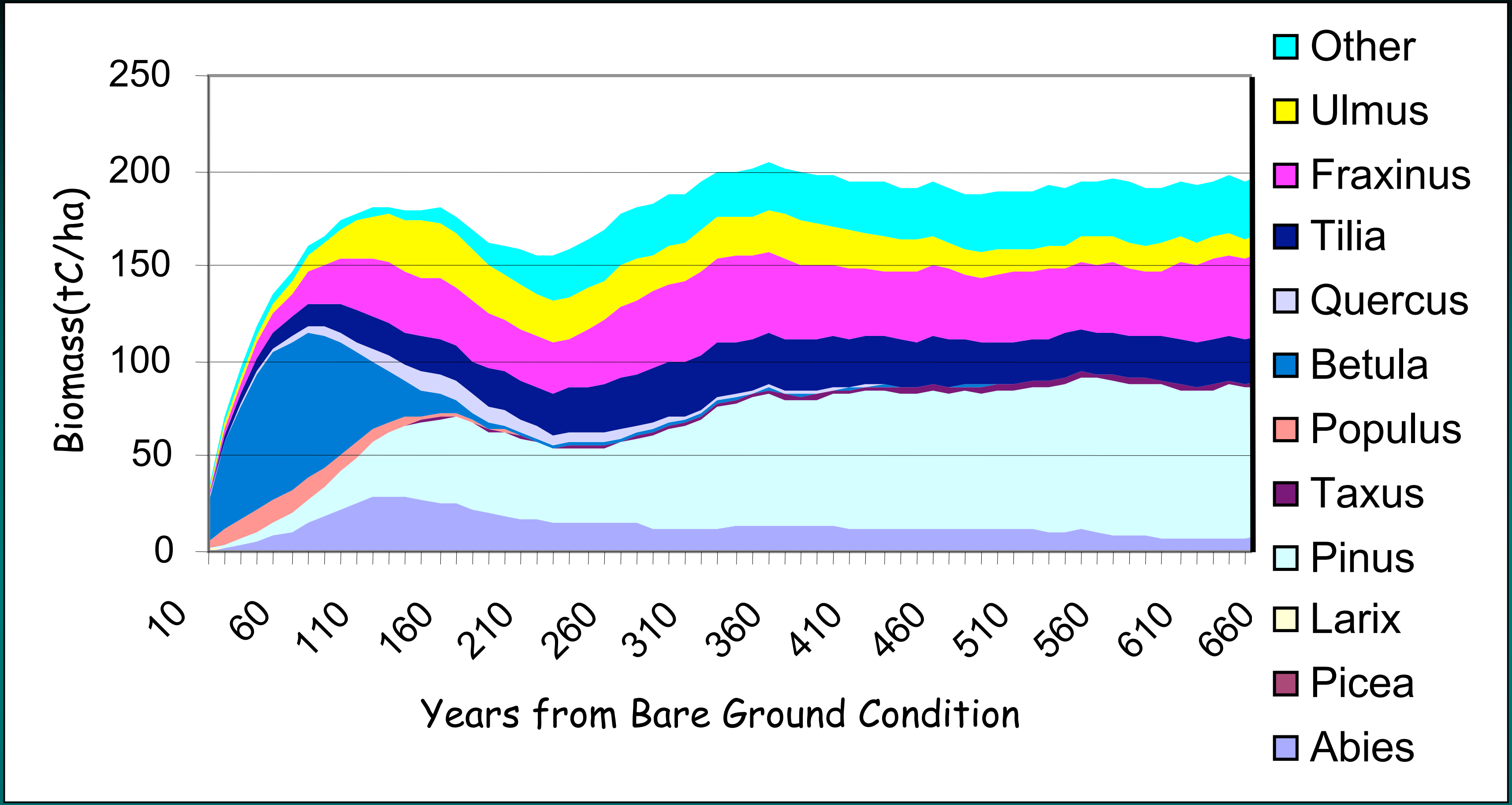
Gap Models Simulate Cover Dynamics and Carbon Dynamics.

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).



Simulated Forest Species Composition for Biomass (tC/Ha) for Vladivostok, Russia

Simulation Sites Across Russia

Climate data from: Razuvayev V.N., Apasova E.G., Martuganov R.A., Steurer P., Vose R., (1993) Daily Temperature and Precipitation Data for 223 U.S.S.R. Stations. ORNL/CDIAC, Numerical data package – 040, Oak Ridge National laboratory, Oak Ridge, Tennessee, USA

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.

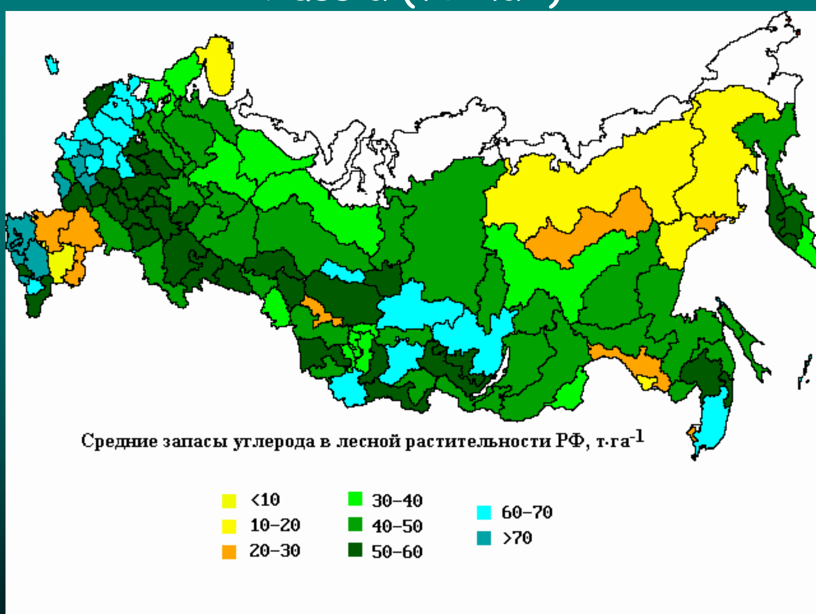
By running the FAREAST model (200 simulated plots for 700 years starting with an open plot) for 234 weather stations in the NEESPI region, one obtains both the expected successional dynamics and mature forest condition.

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

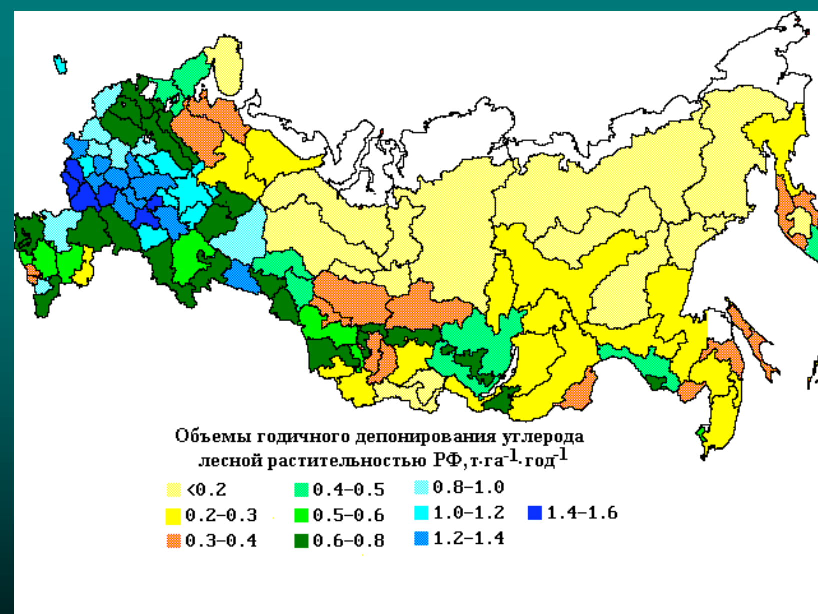
How does one know the reliability these predictions?
How does one determine the highest priorities for additional model development?

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

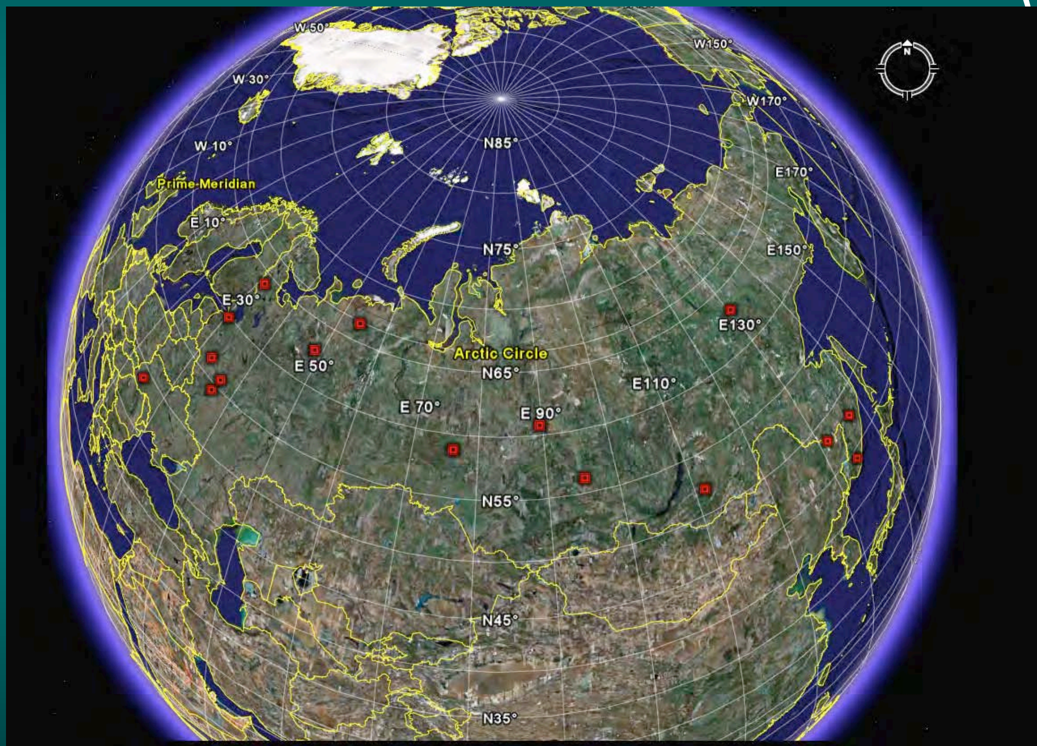
Carbon Store in Forest Lands of Russia (tC ha^{-1})



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 (____________

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_____________ _

__________ _____

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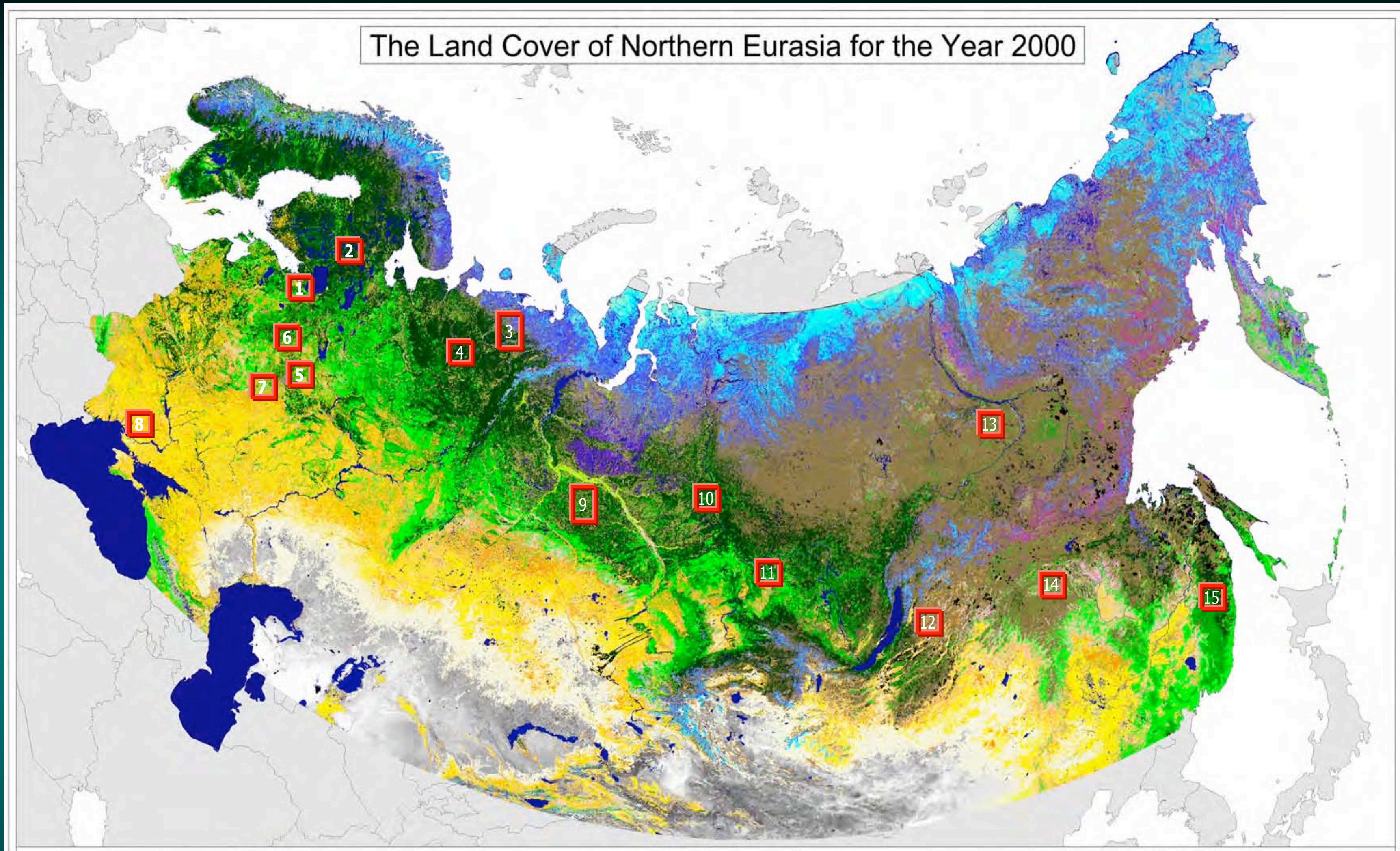
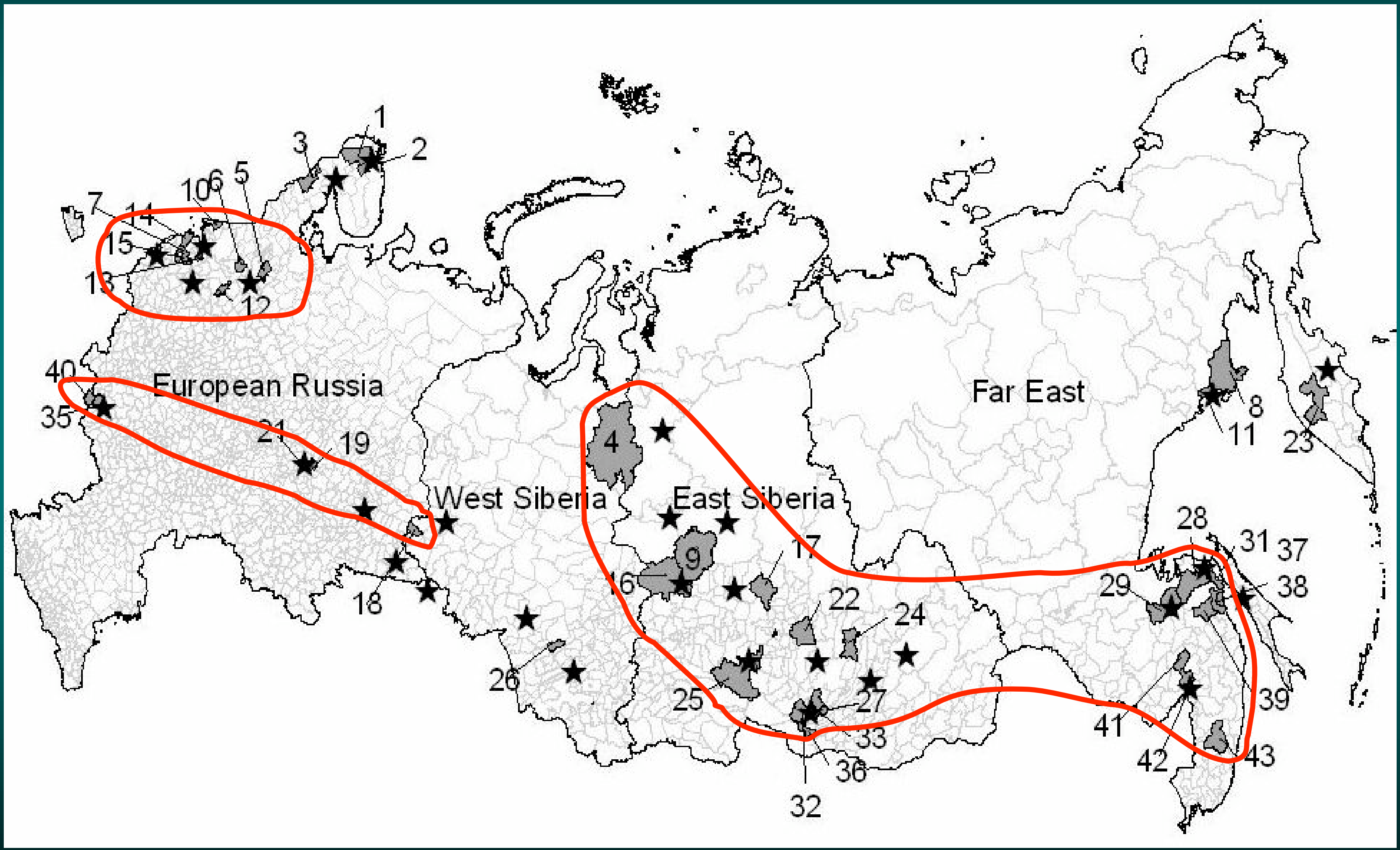
________ _ ____

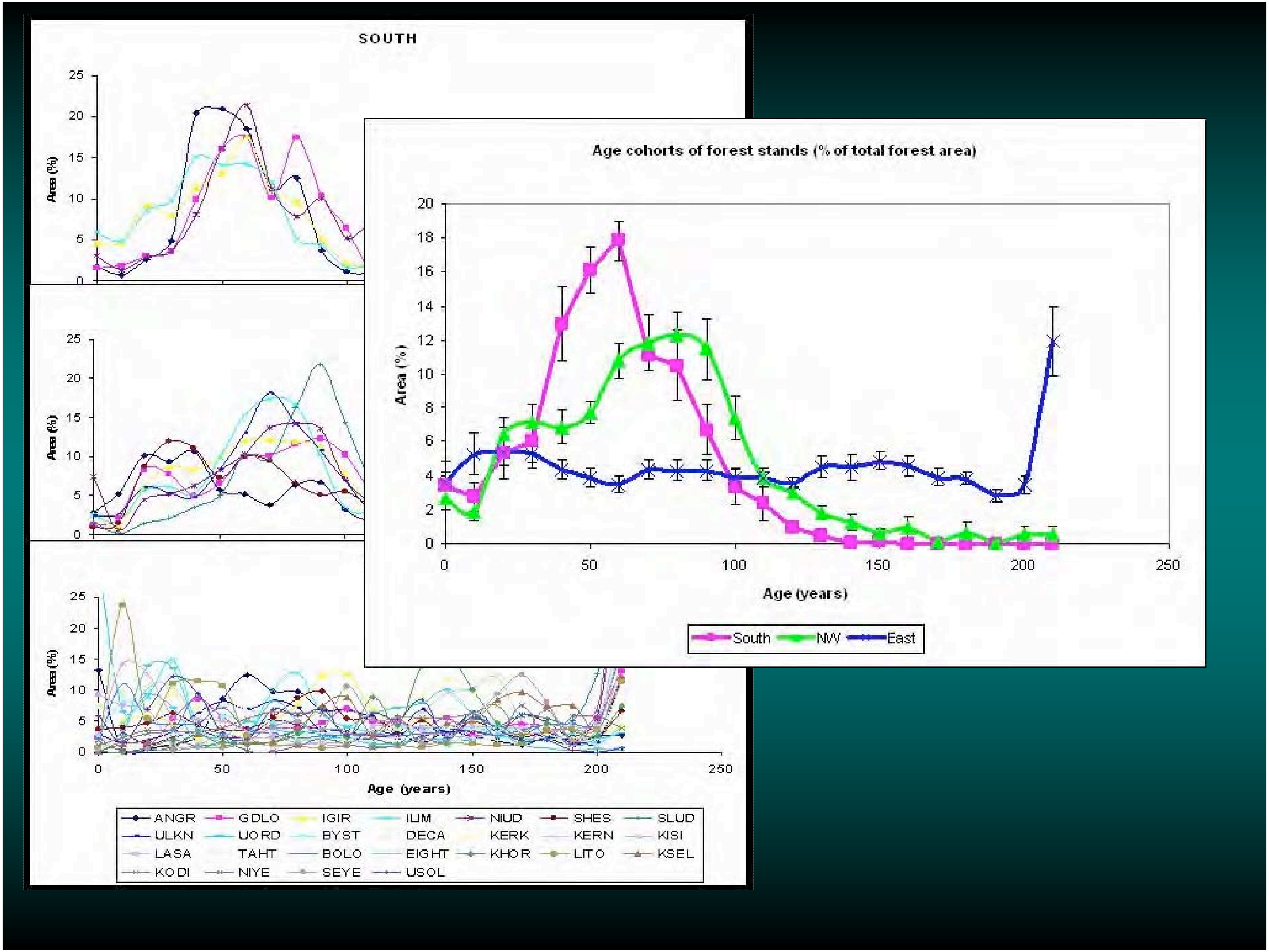
__________)

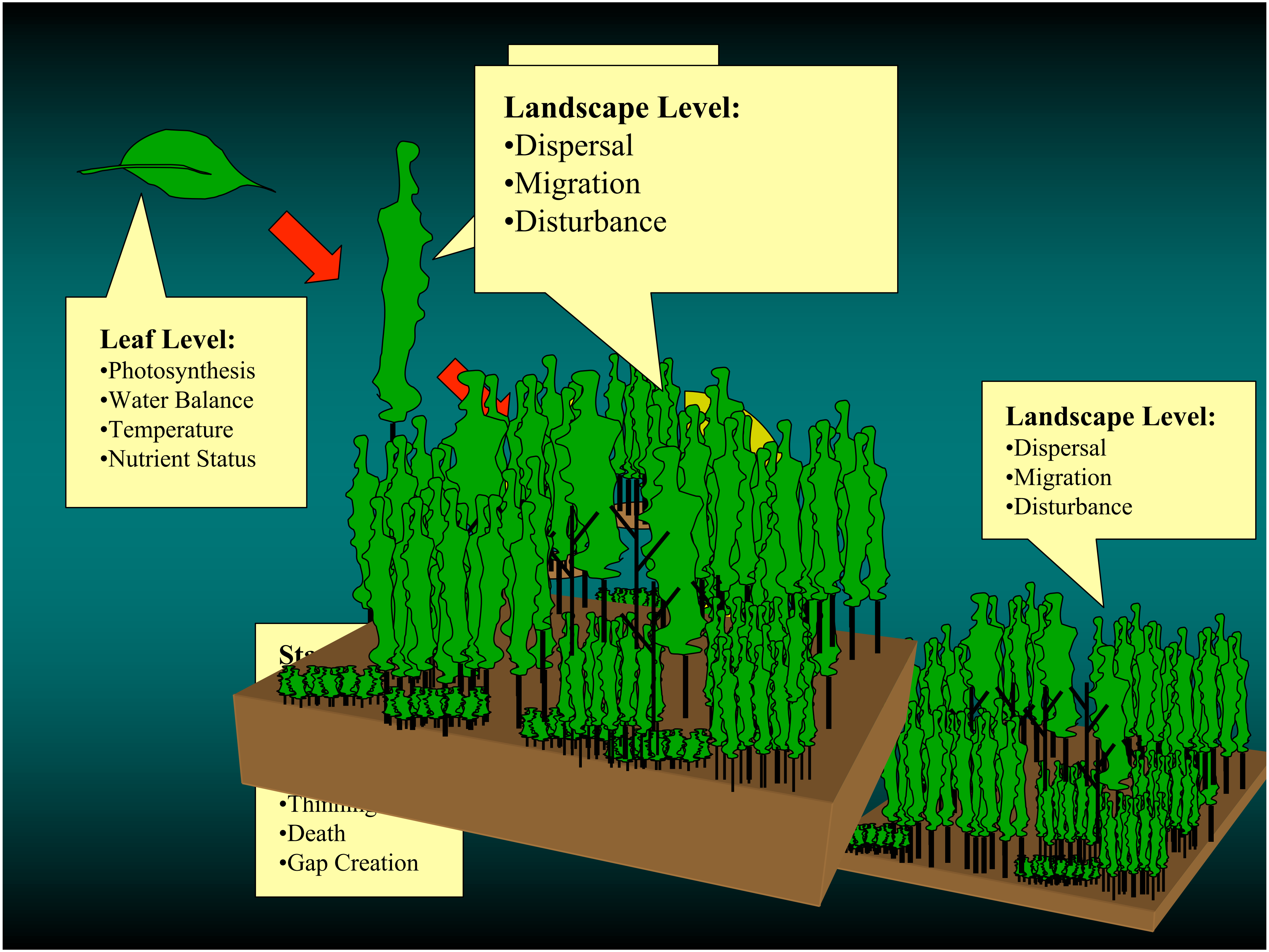


Location of NELDA test sites (Map was created at EC JRC as part of GLC 2000 project, Bartalev *et al.* 2003)

Age cohorts of forest stands as a footprint of past disturbance



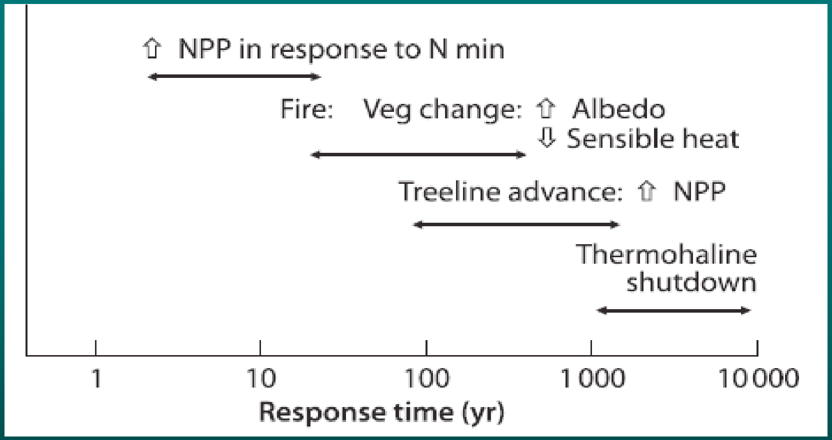

SOUTH
Area (%)
Age (years)
ANGR
GDLO
IGIR
ILIM
NIUD
SHES
SLUD
ULKN
UORD
BYST
DECA
KERK
KERN
KISI
LASA
TAHT
BOLO
EIGHT
KHOR
LITO
KSEL
KODI
NIYE
SEYE
USOL
Age cohorts of forest stands (% of total forest area)
Area (%)
Age (years)
South
NW
East



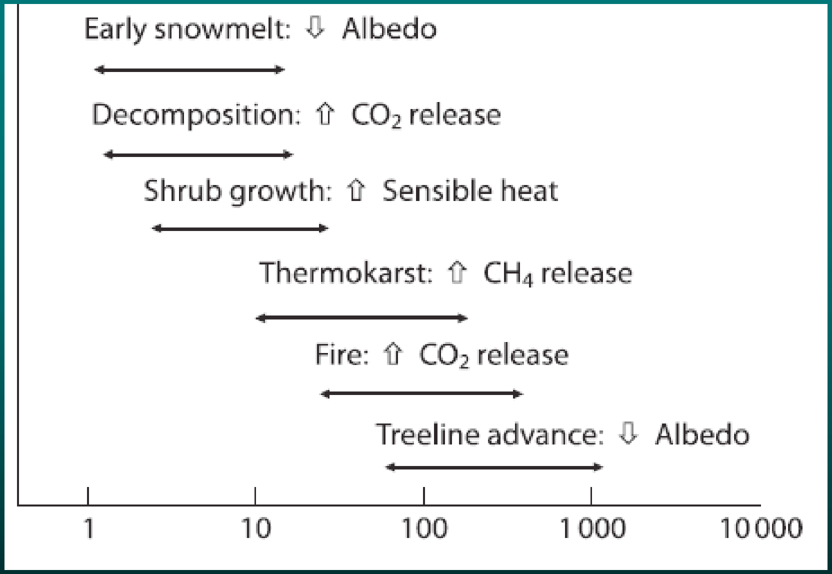
Leaf Level:
•Photosynthesis
•Water Balance
•Temperature
•Nutrient Status
Landscape Level:
•Dispersal
•Migration
•Disturbance
•Death
•Gap Creation
Landscape Level:
•Dispersal
•Migration
•Disturbance

The net effect of changes will enhance or mitigate warming. Responses of water, energy, and trace gas exchange may result in either positive or negative feedbacks to both regional and global warming.

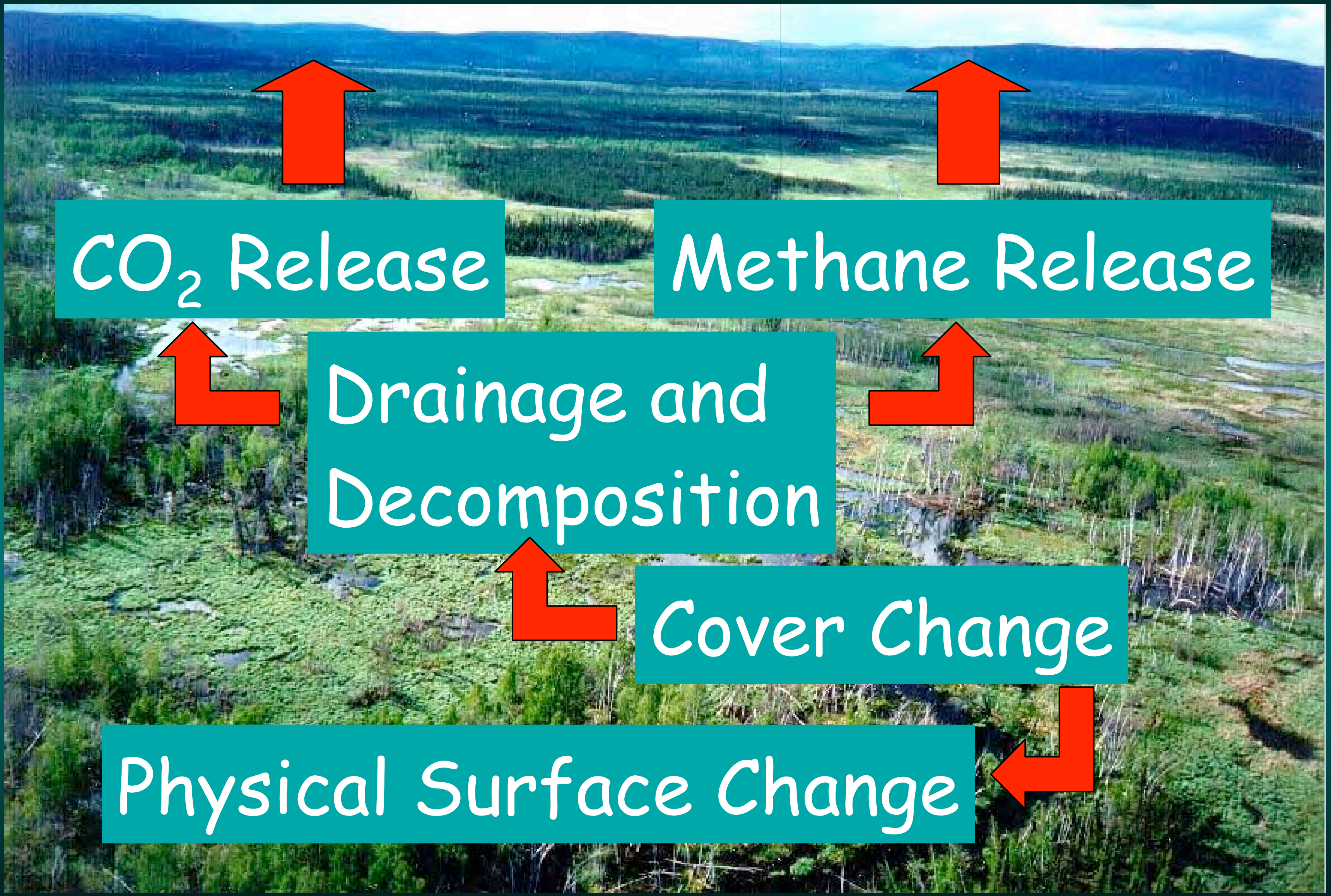
Negative Feedbacks to Warming



Positive Feedbacks to Warming

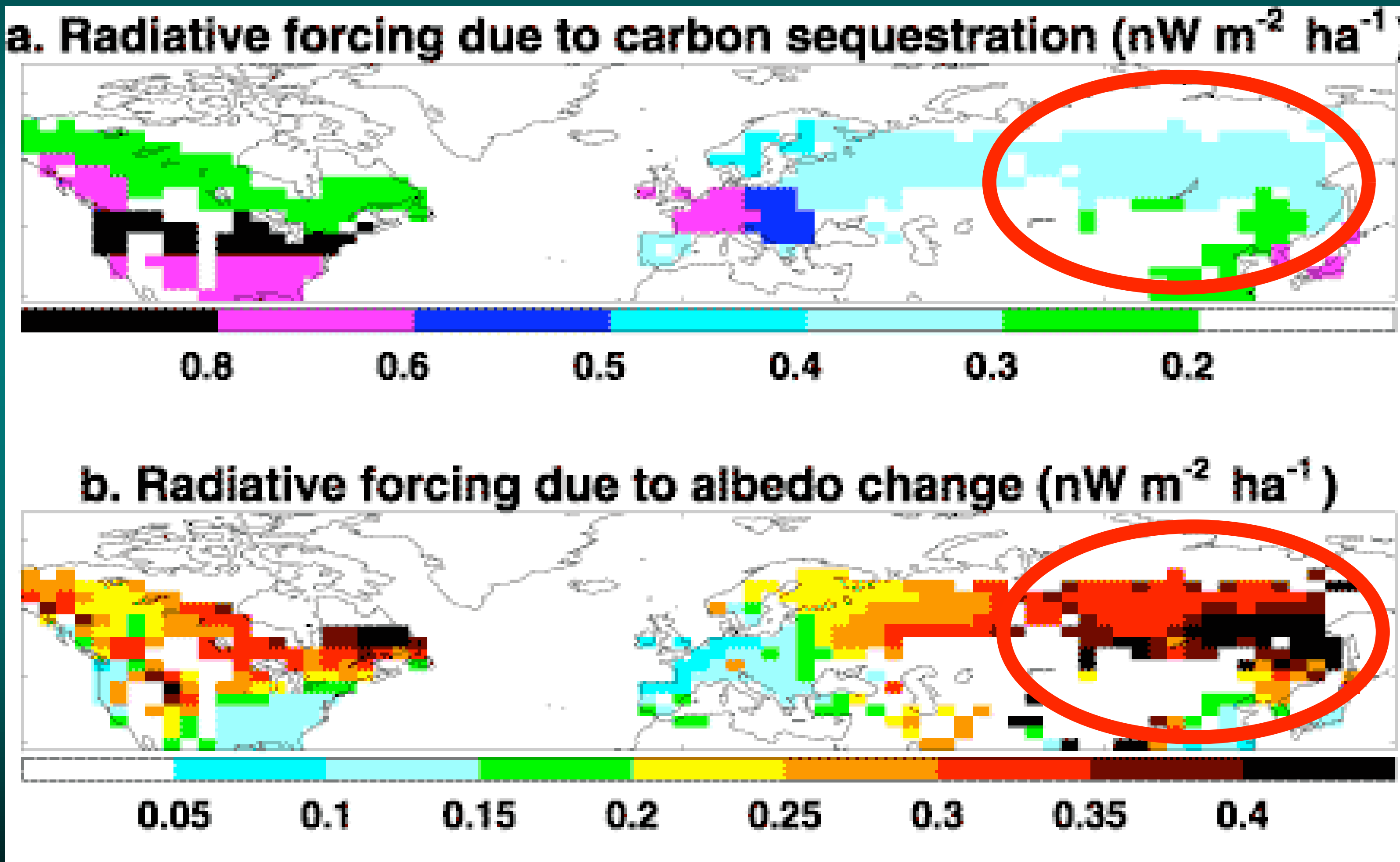


Implications of Change:



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

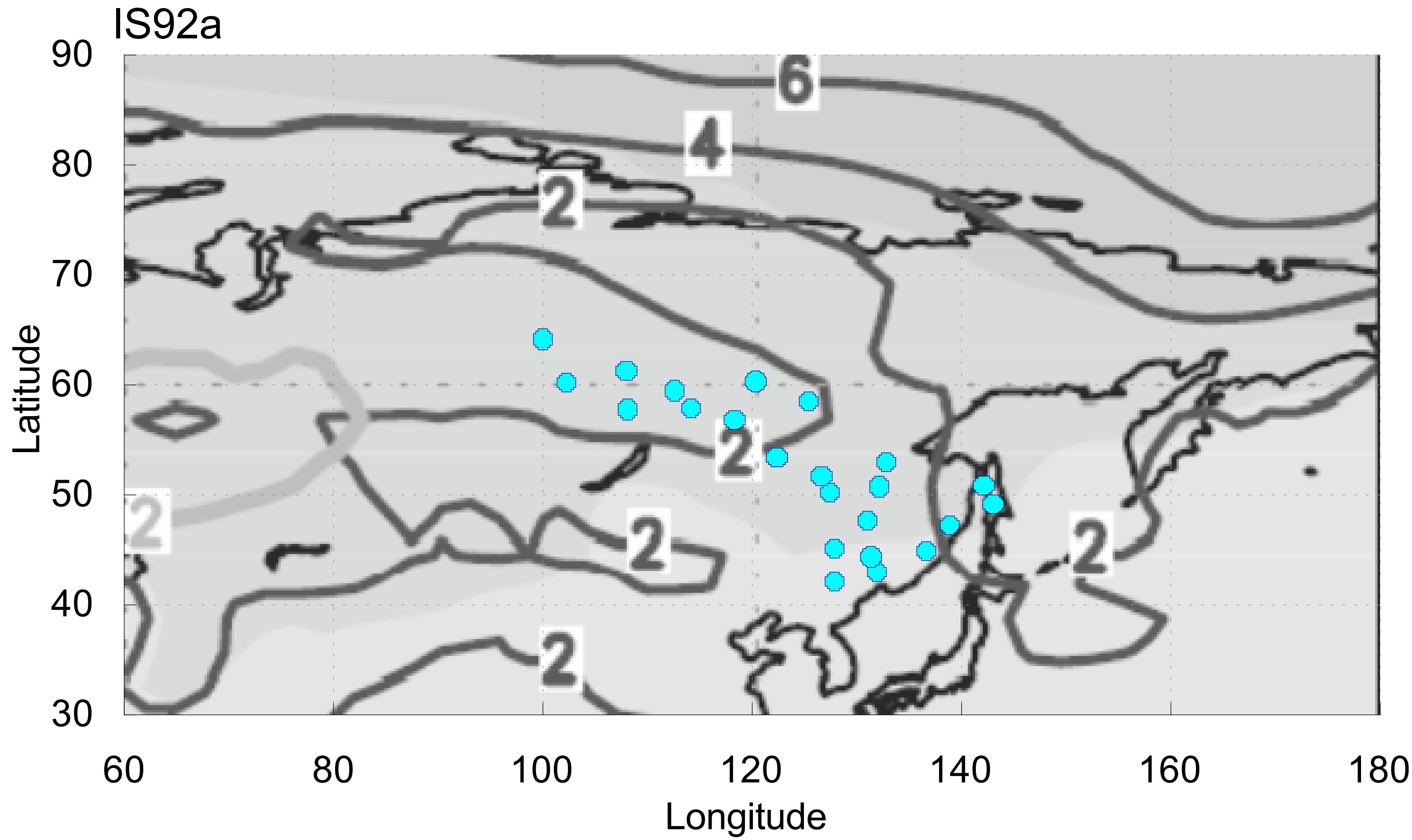
"… in large parts of the temperate and boreal forest areas, the decrease in surface albedo by forestation is as important as carbon sequestration in its forcing of climate. As a result, forest carbon sinks in these regions could exert a much smaller cooling influence than expected, or even exert an overall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



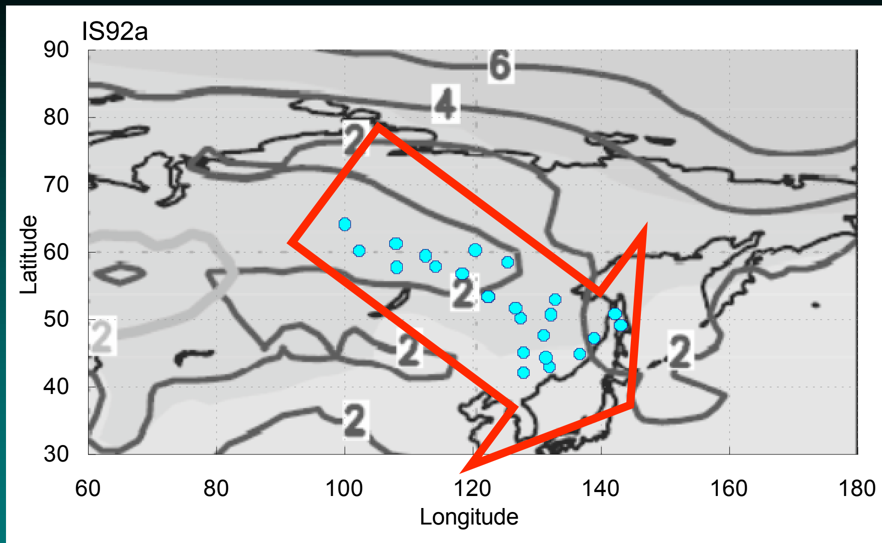
From: Richard A. Betts. 2000. Offset of the potential carbon sink from boreal forestation by decreases in surface albedo. Nature 408:187-190.

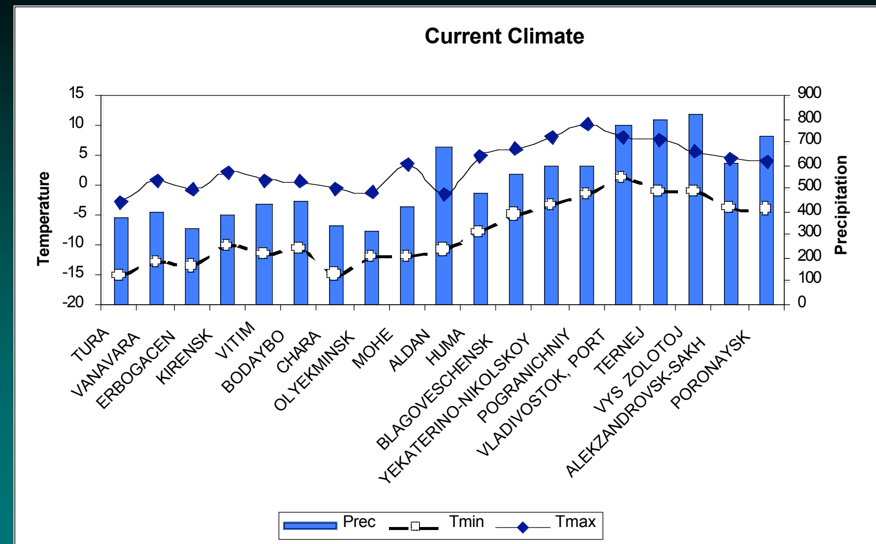
Replacing Larch with Evergreen Conifers has an effect on albedo in winter that is analogous to growing trees.

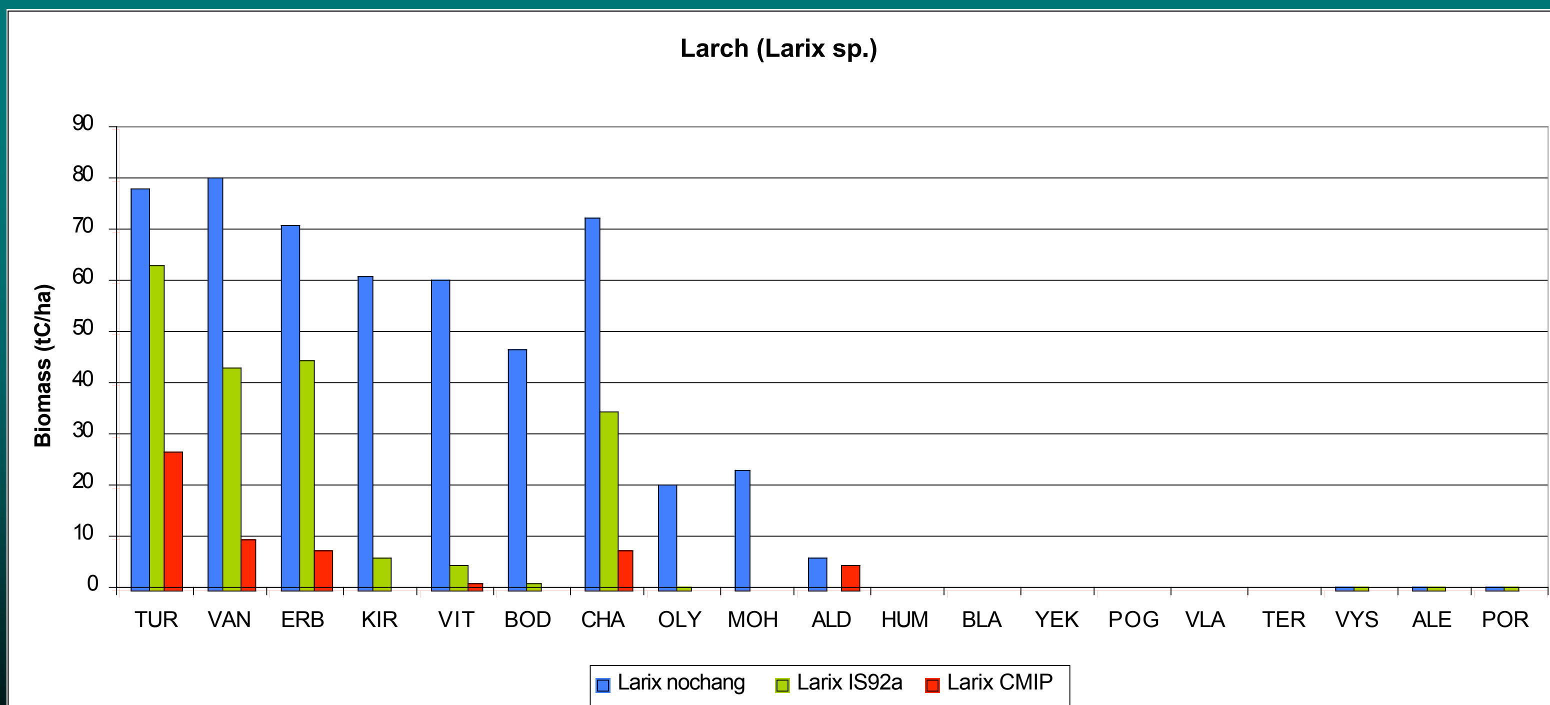
Siberian pine regeneration under a Larch canopy



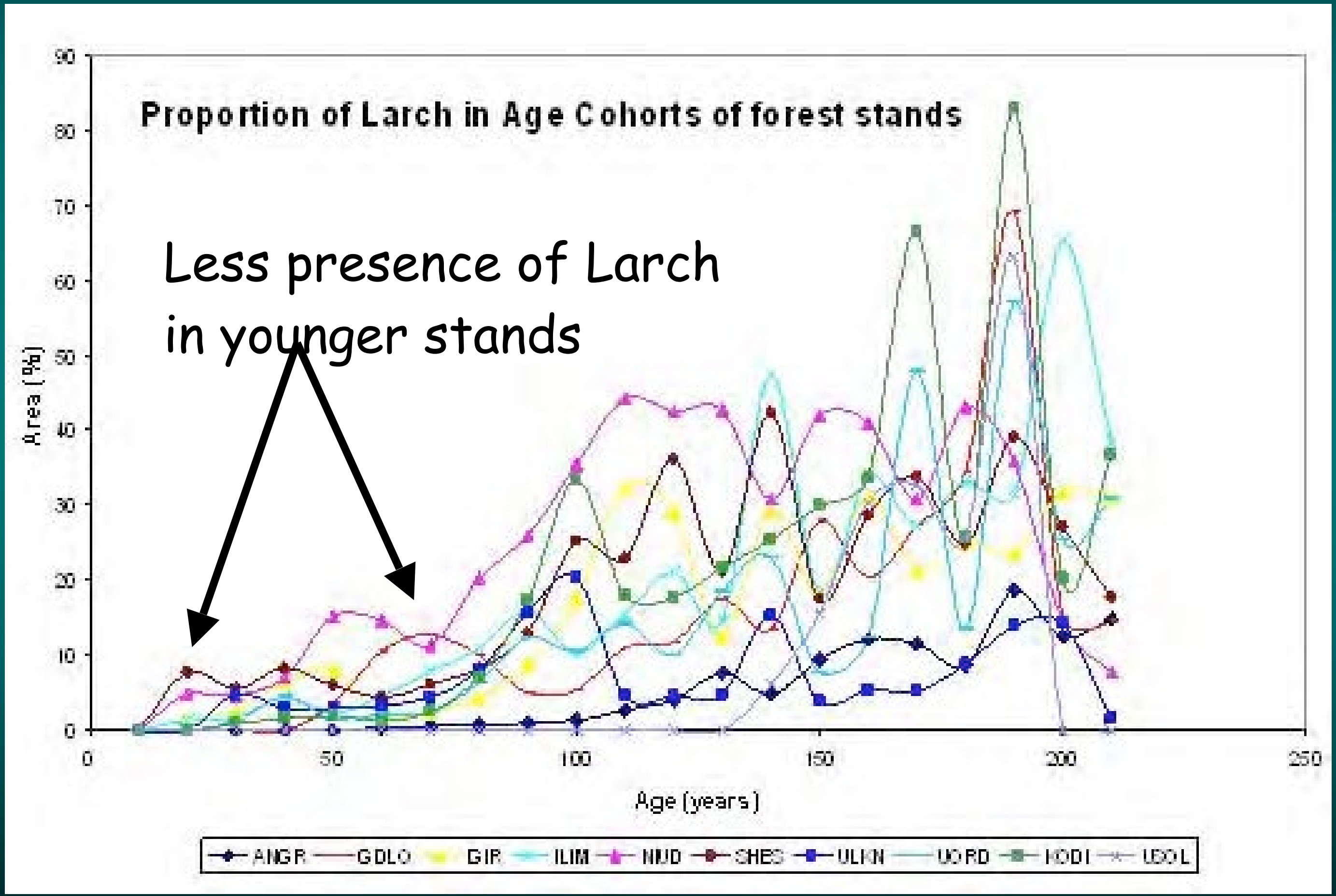
Multi-model-ensemble annual-mean change of the temperature (Gray shading), its range (Unit:°Ĉ)mean change divided by the multi-model standard deviation for the IPCC-DDC scenario IS92a (GS: greenhouse gases and Sulphate aerosols) for the year 2021 to 2050 relative the period 1961 to 1990.


IS92a
Latitude
Longitude
90
80
70
60
50
40
30
60
80
100
120
140
160
180
6
4
2

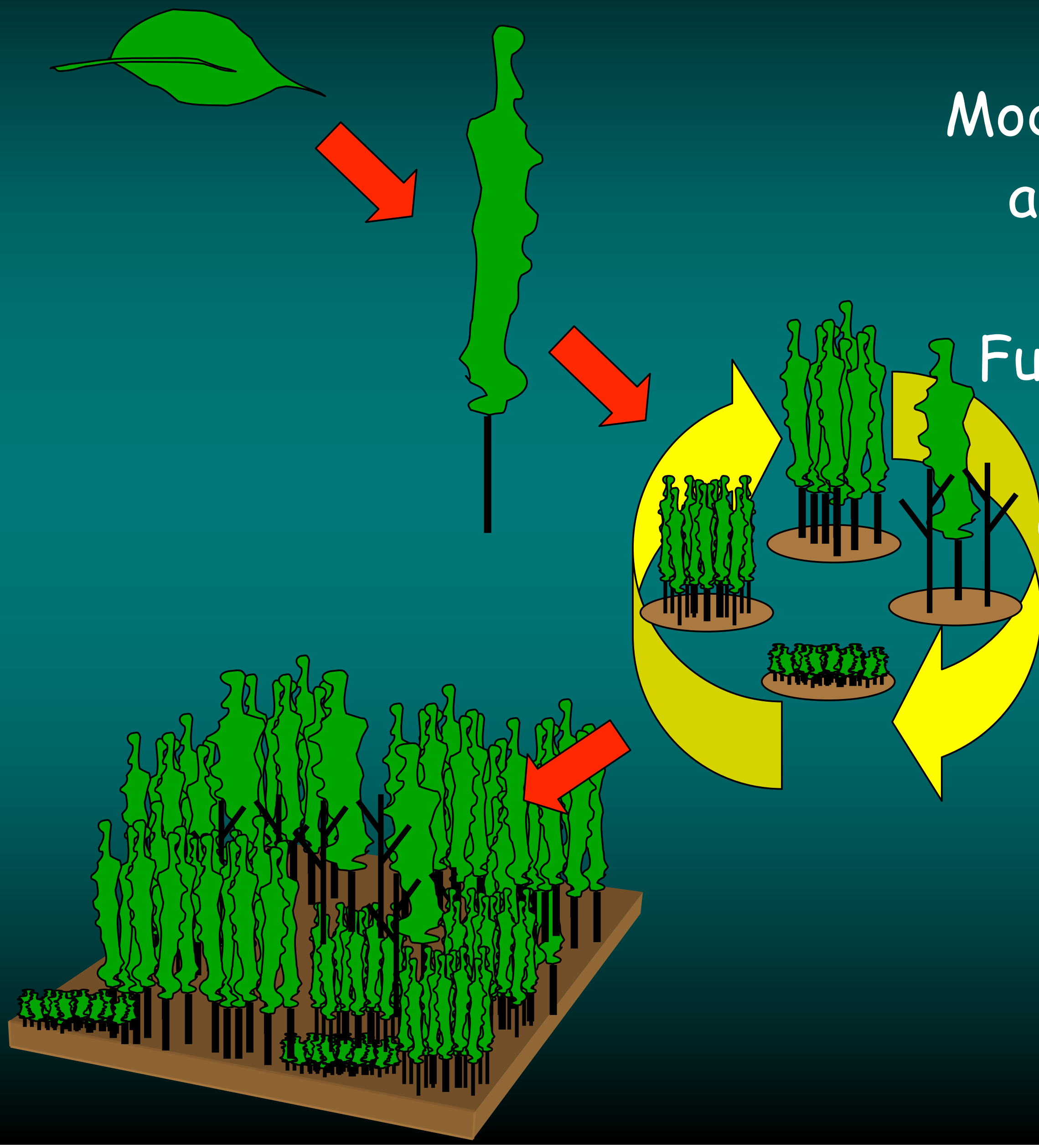

Current Climate
Temperature
Precipitation
15
10
5
0
-5
-10
-15
-20
900
800
700
600
500
400
300
200
100
0
TURA
VANAVARA
ERBOGACEN
KIRENSK
VITIM
BODAYBO
CHARA
OLYEKMINSK
MOHE
ALDAN
HUMA
BLAGOVESCHENSK
YEKATERINO-NIKOLSKOY
POGRANICHNIY
VLADIVOSTOK, PORT
TERNEJ
VYS ZOLOTOJ
ALEKZANDROVSK-SAKH
PORONAYSK
Prec
Tmin
Tmax


Larch (Larix sp.)
Biomass (tC/ha)
90
80
70
60
50
40
30
20
10
0
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



Where do we stand?



Models and observations across multiple scales.

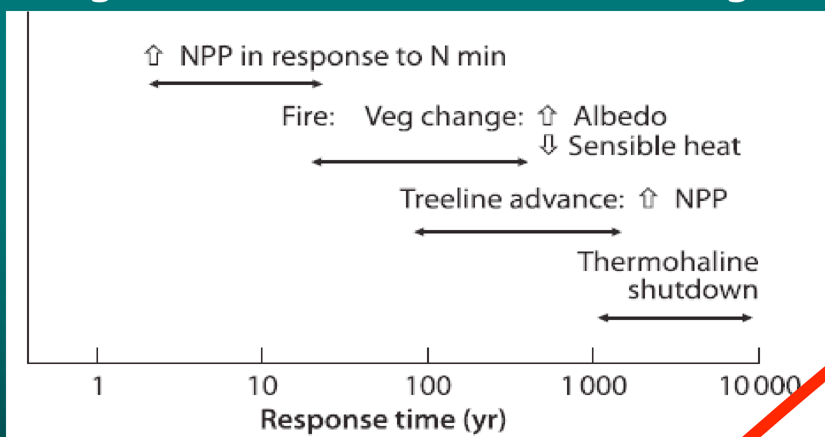
Fusion among different sensors with different resolutions and capabilities.

Development of an increased capability to represent land dynamics as an essential part of the

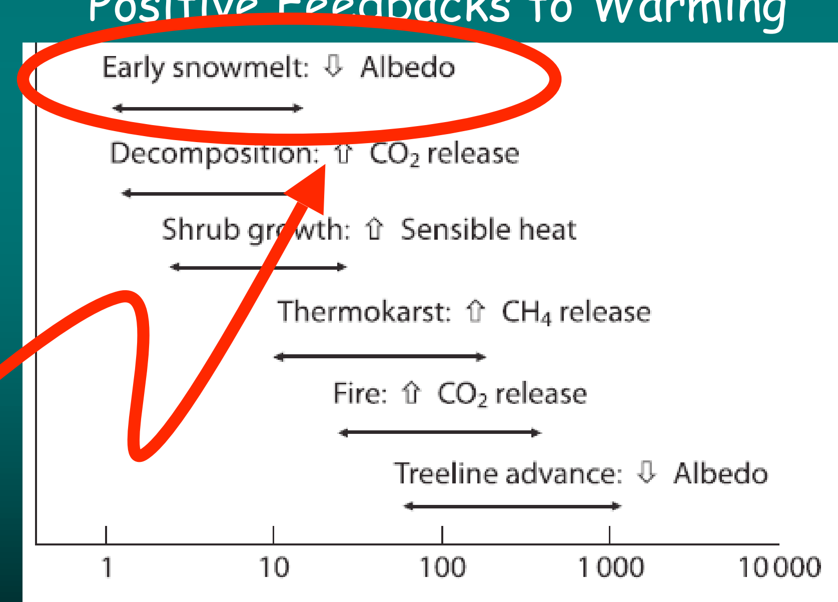

THE END

The net effect of changes will enhance or mitigate warming. Responses of water, energy, and trace gas exchange may result in either positive or negative feedbacks to both regional and global warming.

Negative Feedbacks to Warming



Positive Feedbacks to Warming



An Example

Spatial distribution of changes in snow cover (days $year^{-1}$) for:

- Changes in snowmelt (b) plus
- Changes in snow return (d) equals
- Changes in total length of snow cover duration (f).