

Quantifying CO₂ fluxes of boreal forests in Northern Eurasia

Integrated analyses of *in-situ* eddy flux tower,
remote sensing and biogeochemical model

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A stylized, low-poly mountain range graphic in shades of brown and tan, positioned at the bottom of the slide against a blue gradient background.

International collaborative project

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Boreal forest and global carbon cycle

Boreal forest distribution

Siberia of Russia:	600 million ha
Europe (including European Russia):	300 million ha
North America:	500 million ha

Carbon in boreal forest: ~50% of global carbon in vegetation and soils

There are large uncertainty in CO₂ fluxes of boreal forests

$$NEE = GPP - R_e$$

Eddy flux tower for CO₂, water and energy - Fluxnet

THE LAND COVER OF NORTHERN EURASIA FOR THE YEAR 2000



Tver flux sites

Yakutia flux sites

Krasnoyarsk flux sites


LEGEND / ЛЕГЕНДА		MAP INFORMATION		CONTACT DETAILS		
FORESTS / ЛЕСА	OTHER VEGETATION TYPES AND COMPLEXES / ДРУГИЕ ВИДЫ РАСТИТЕЛЬНОСТИ И КОМПЛЕКСЫ	MAP INFORMATION	CONTACT DETAILS			
European Mixed Forest	Forest Park	Scale: 1:200,000	Dr. Sergey A. Bartalev			
European Broadleaf Forest	Forest Park	Projection: Albers Equal-Area Conic, Spheroid: Spheroid, Central Meridian: 90° E, Reference Latitude: 42° N, Standard Parallel 1: 30° N, Standard Parallel 2: 50° N	Alex. Alexander S. Isakov, Dr. Dmitry V. Yershov			
European Broadleaf Forest	Forest Park	Map projection: Albers Equal-Area Conic, Spheroid: Spheroid, Central Meridian: 90° E, Reference Latitude: 42° N, Standard Parallel 1: 30° N, Standard Parallel 2: 50° N	The Russian Academy of Sciences Space Research Institute 64/3 Profsovetov St. 125080 Moscow, Russia Fax: 007 505 913 20 40 bartalev@ssu.ru			
European Broadleaf Forest	Forest Park	Map projection: Albers Equal-Area Conic, Spheroid: Spheroid, Central Meridian: 90° E, Reference Latitude: 42° N, Standard Parallel 1: 30° N, Standard Parallel 2: 50° N	Dr. Alan S. Belward			
European Broadleaf Forest	Forest Park	Map projection: Albers Equal-Area Conic, Spheroid: Spheroid, Central Meridian: 90° E, Reference Latitude: 42° N, Standard Parallel 1: 30° N, Standard Parallel 2: 50° N	The European Commission Joint Research Center Institute for Environment and Sustainability Global Vegetation Monitoring Unit 43102 Ispra (VA), Italy Fax: +39 0332 789812 alan.belward@ec.europa.eu			
European Broadleaf Forest	Forest Park	Map projection: Albers Equal-Area Conic, Spheroid: Spheroid, Central Meridian: 90° E, Reference Latitude: 42° N, Standard Parallel 1: 30° N, Standard Parallel 2: 50° N				

Scientific questions to be addressed:

(1) What factors control the seasonal and interannual variations of NEE, GPP and R_e at individual flux tower sites in northern Eurasia?

(2) What factors control the spatial variations of NEE, GPP and R_e across the flux tower sites in northern Eurasia?

(3) What are the impacts of disturbance and land use change on carbon fluxes in Siberia since 1998?



Project Objectives

- (1) Developing a prototype tool by integrating CO₂ flux tower measurements, remote sensing analysis and biogeochemical models to interpret the observed CO₂ flux data across the tower sites in northern Eurasia;
- (2) Quantifying temporal dynamics and spatial patterns of CO₂ fluxes from boreal forests in Russia over the period of 1998 – 2005.



Research approach and methods

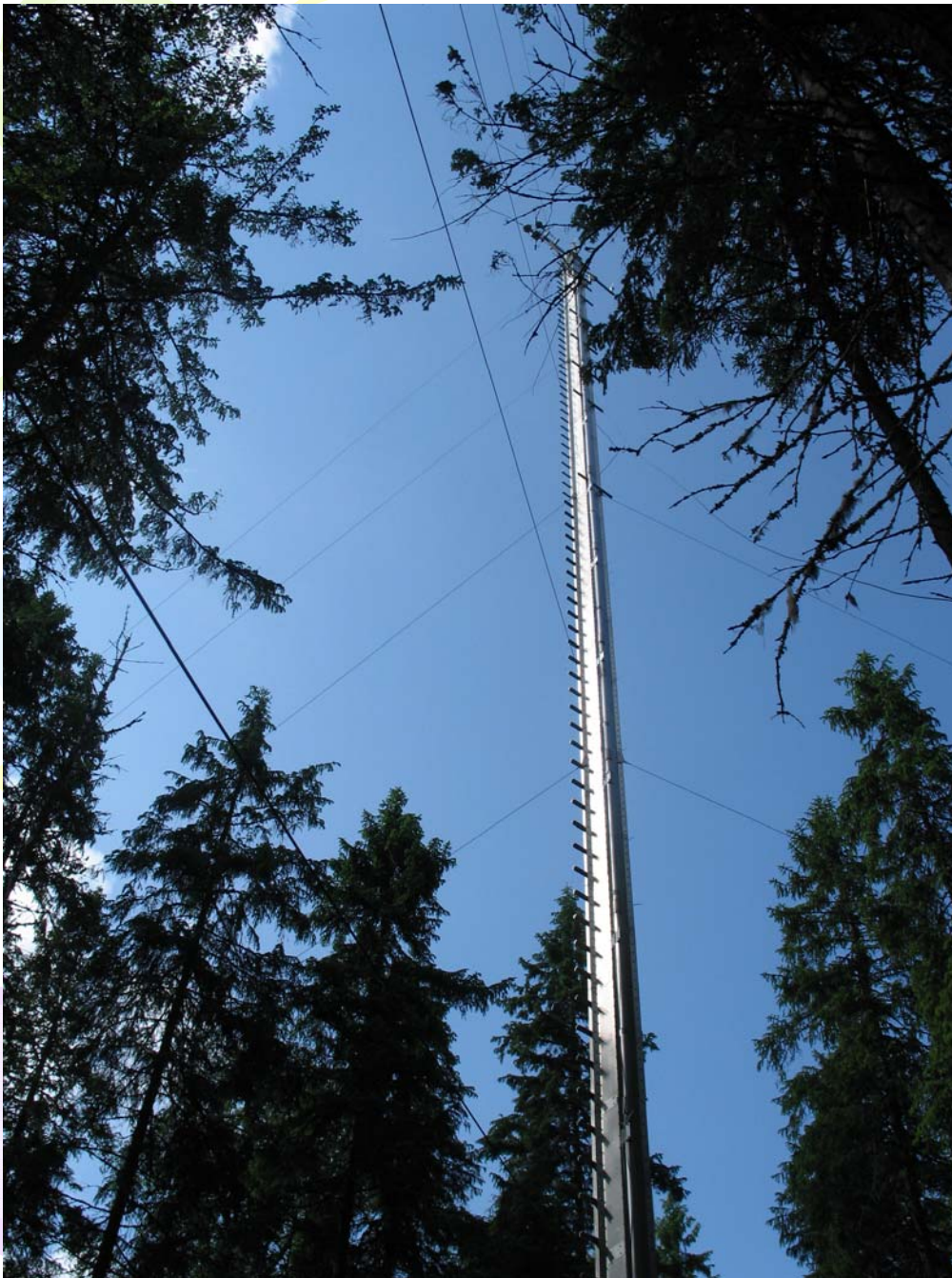
	leaf	canopy	ecosystem	landscape	region
field/lab work	chlorophyll nitrogen	LAI	species, soils	land cover	
eddy flux tower			NEE, GPP, R_e		
radiative transfer model	chlorophyll $FPAR_{chl}$	LAI			
Landsat				land cover	
MODIS				$FPAR_{chl}$	$FPAR_{chl}$
VPM			GPP	GPP	GPP
DNDC			NEE, R_e	NEE, R_e	NEE, R_e

Expected results

1. Validation of satellite-based Vegetation Photosynthesis Model (VPM)
2. Validation of process-based DNDC model
3. Evaluating radiative transfer model (PROSAIL2)
4. A multi-scale satellite image database for the flux tower sites in northern Eurasia, and its analysis
5. Regional datasets of GPP of boreal forests in Siberia for 1998-2005 from the VPM model
6. Regional datasets of NEE of boreal forests for 1998-2005 from coupled VPM-DNDC models

Activities and results in Year 1

1. Project meeting in Moscow, June 2005
 2. Continuous operation of eddy flux towers in CFBR sites
 3. Field sampling and survey in CFBR sites
 4. Evaluating improved radiative transfer model
 5. Evaluating VPM model
 6. Evaluating DNDC model
 7. Analysis of Landsat images
 8. Analysis of MODIS and VEGETATION images
- 



Eddy flux tower at CFBR

NEE of CO₂

Water flux

Energy flux





Leaf sampling at CFBR sites

chlorophyll

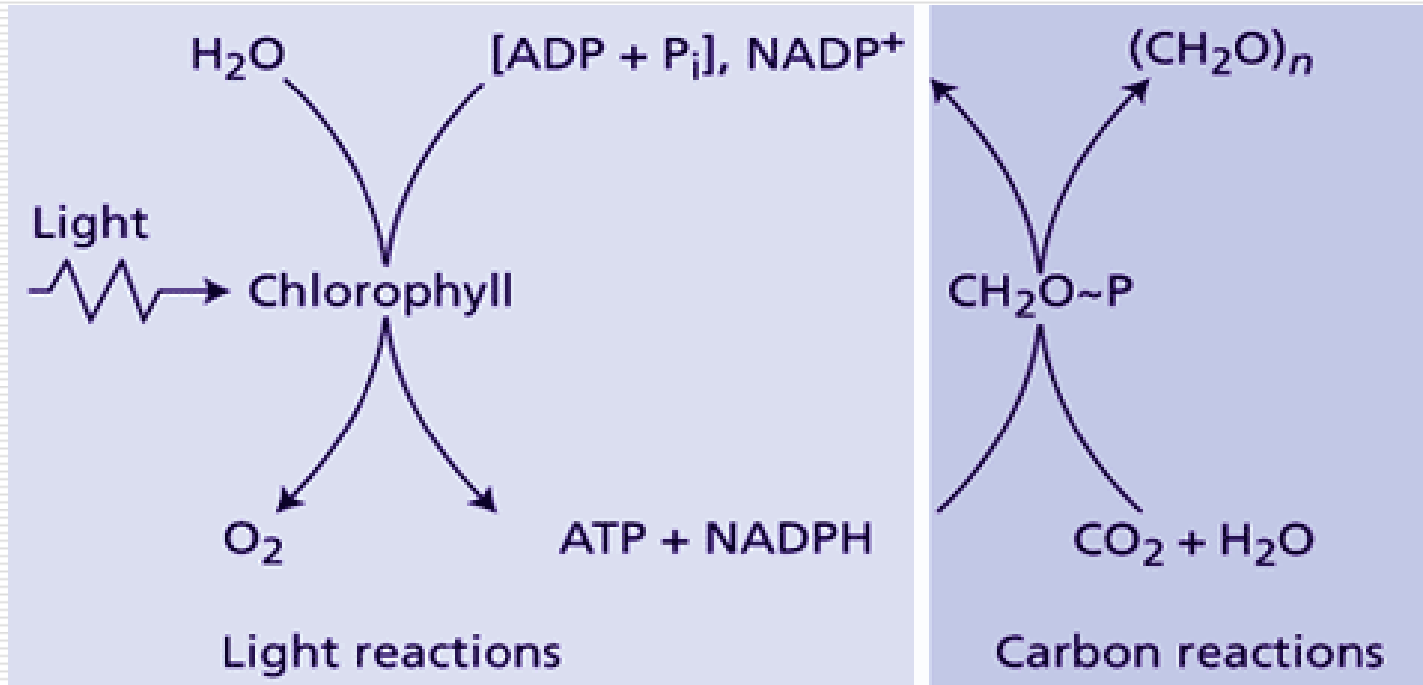
nitrogen

leaf water content

leaf specific weight



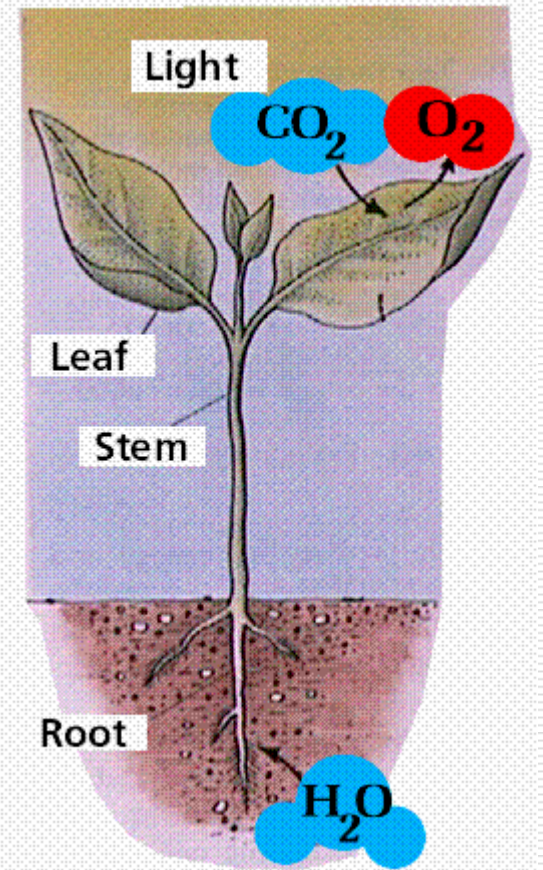
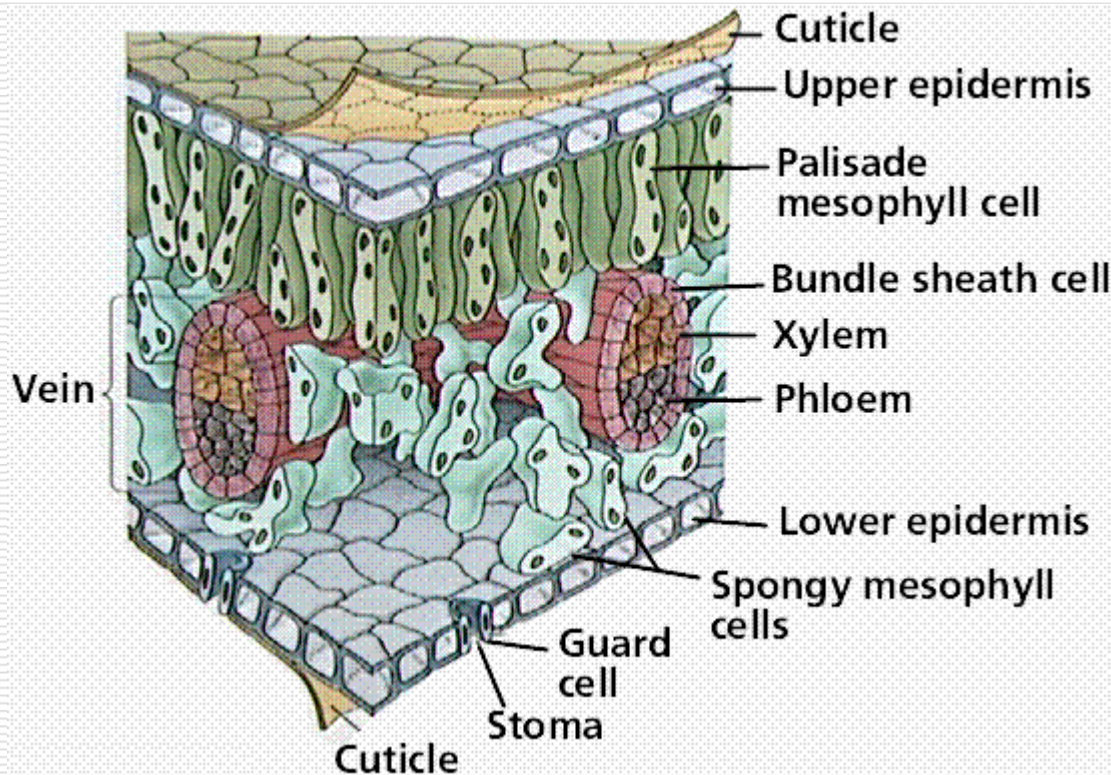
Plant Photosynthesis or GPP



Leaf chlorophyll content and light absorption by chlorophyll are the fundamental controlling factors of GPP

Scaling-up of light absorption from chlorophyll to leaf and canopy

non-photosynthetic vegetation (NPV)



Partition light absorption at chlorophyll, leaf and canopy levels

Leaf level

canopy = green leaf + NPV (stem, branch)

$$FPAR_{\text{canopy}} = FPAR_{\text{leaf}} + FPAR_{\text{NPV}}$$

Chlorophyll level

Leaf/canopy = Chlorophyll + NPV (veins, cell wall)

$$FPAR_{\text{canopy}} = FPAR_{\text{chl}} + FPAR_{\text{NPV}}$$

NPV = non-photosynthetic vegetation

Radiative transfer model (PROSAIL2)

Coupled leaf- (PROSPECT) and canopy-level (SAIL2) model

Retrieve both leaf- and canopy-level variables, and

Calculate $FPAR_{canopy}$, $FPAR_{leaf}$ and $FPAR_{chl}$

Zhang et al., 2005, RSE; Zhang et al., 2006a,b

A comparison between the PROSAIL2 model [Zhang, et al., 2005] and the radiative transfer model used for MODIS standard LAI/FPAR products (MOD15) [Myneni, et al., 2002]

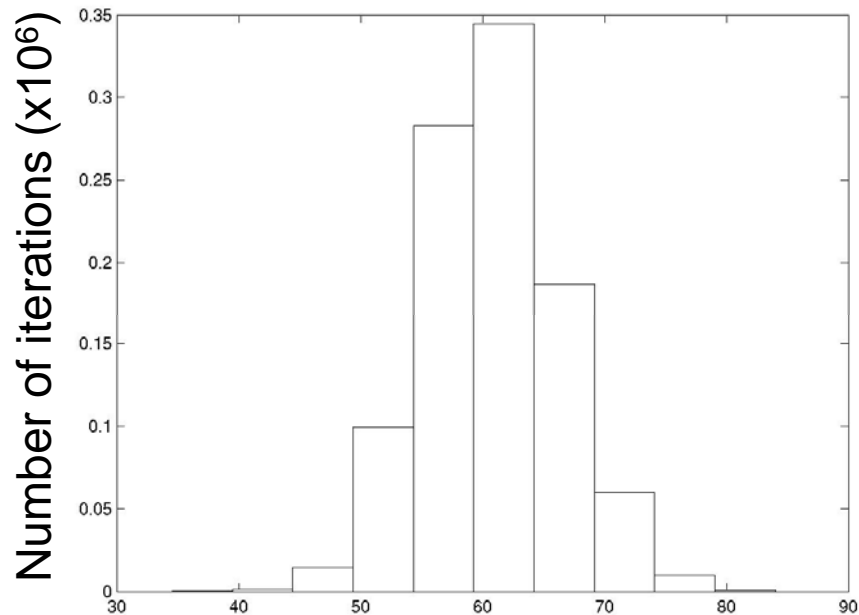
	Name	Description	Unit	PROSAIL2	MOD15
MODIS bands				Green, Red, NIR ₁ , NIR ₂ , SWIR ₁	Red, NIR ₁
MODIS		Spatial resolution		500-m	1-km
Inversion		Inversion algorithm		MCMC	Look-up table
Structure				1-D	3-D
Leaf-level	C _{ab}	Leaf chlorophyll (a+b)	μg/cm ²	Retrieved,	Fixed
	C _{brown}	Other pigments in leaf		Retrieved,	Not included
	C _m	Leaf dry matter	g/cm ²	Retrieved,	Fixed
	C _w	Leaf equivalent water thickness	cm/cm ²	Retrieved,	Fixed
	N	Leaf internal structure		Retrieved,	Fixed
Canopy-level	LAI	Leaf area index	m ² /m ²	Retrieved,	Retrieved
	SAI	Stem area index	%	Retrieved,	Not included
	CF	Cover fraction	%	Retrieved,	Retrieved
FPAR		Fraction of PAR absorption		FPAR _{canopy} , FPAR _{leaf} , FPAR _{chlorophyll}	FPAR _{canopy}

Radiative transfer model

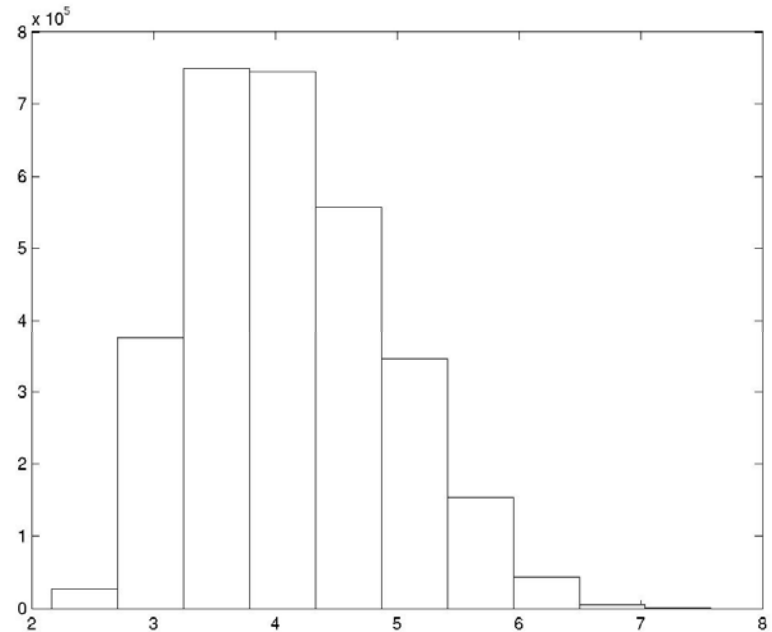
coupled leaf- (PROSPECT) and canopy (SAIL2) model

daily MODIS data (500-m spatial resolution)

Retrieve leaf- and canopy variables at CFBR sites



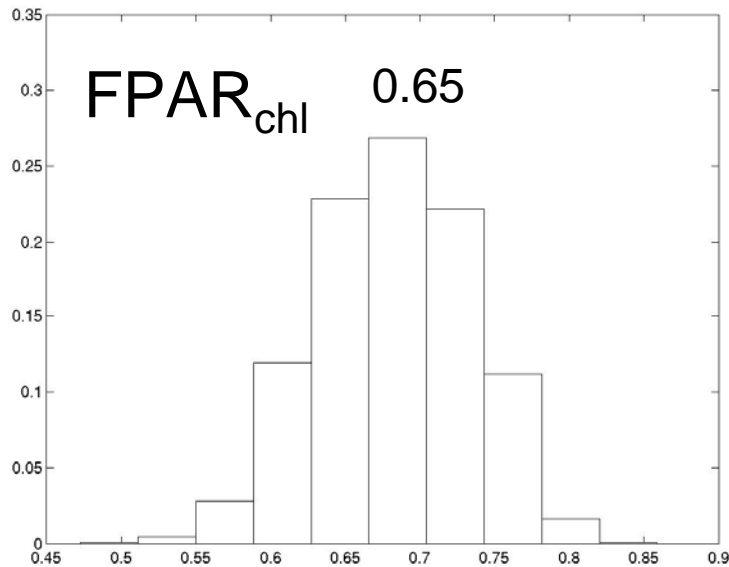
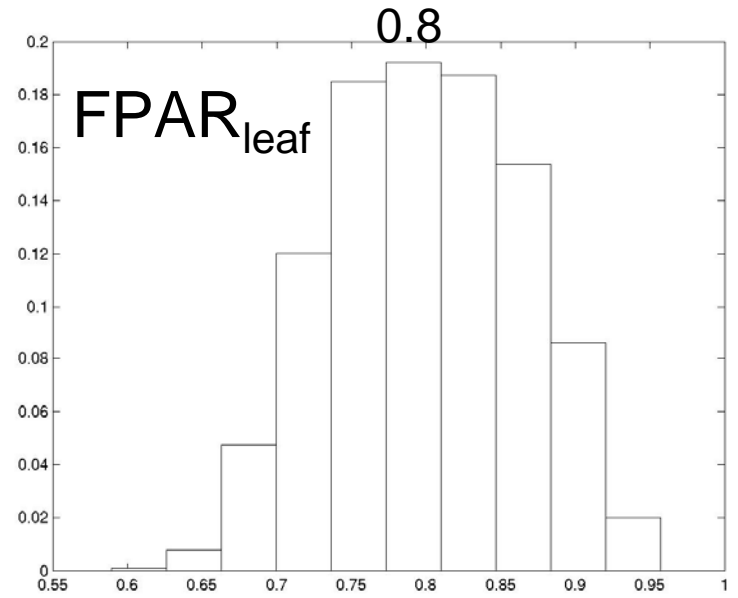
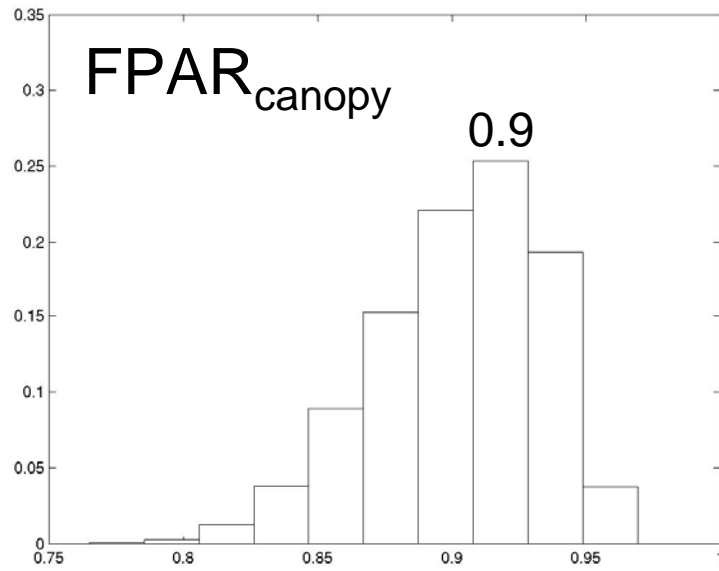
Leaf chlorophyll content (µg/cm²)



Leaf area index (m²/m²)

Daily MODIS data from June 1 -16, 2004 were used for inversion of PROSAIL2

Number of model iterations ($\times 10^6$)



Radiative transfer model

coupled leaf- (PROSPECT)
and canopy (SAIL2) model

daily MODIS data (500-m
spatial resolution)

Retrieve leaf- and canopy
variables at CFBR sites

Daily MODIS data from June 1 - 16, 2004

Uncertainty in estimating GPP

model variable/process and parameters

~~absorption of PAR~~

Structural perspective

PAR absorbed by canopy (PSN, GLO-PEM)

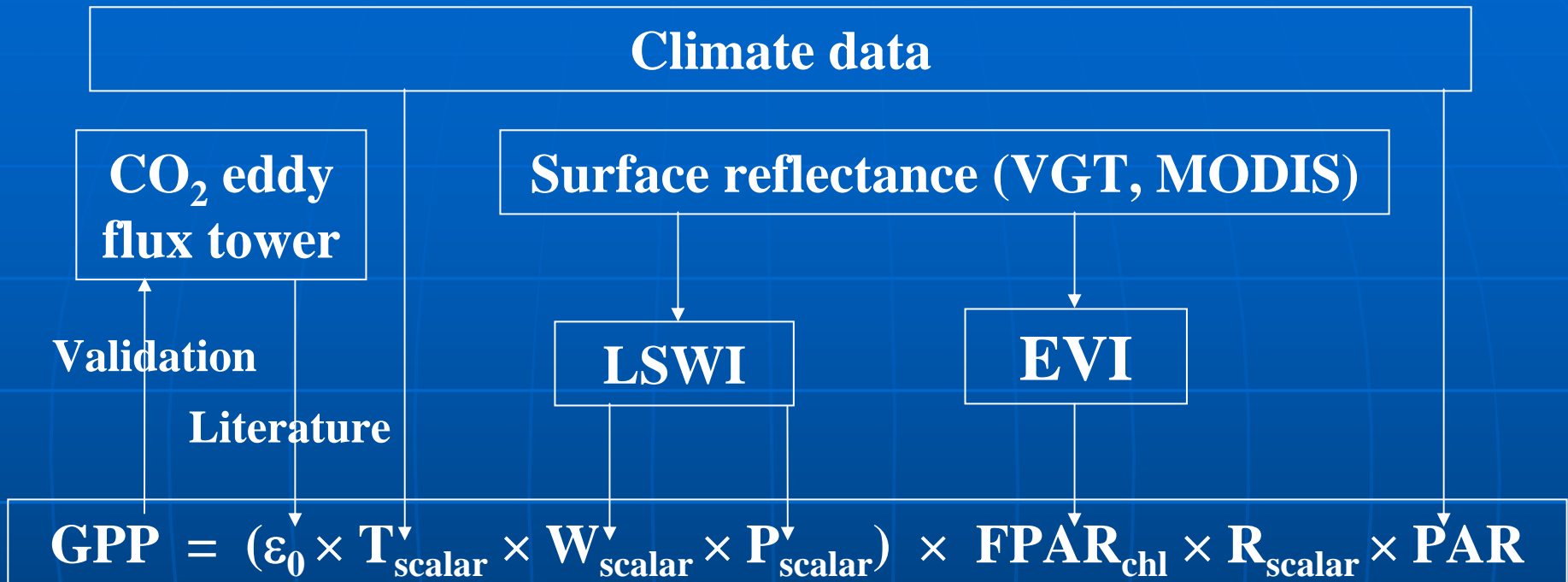
$$\text{GPP} = \varepsilon_g \times \text{FPAR}_{\text{canopy}} \times \text{PAR}$$

Biochemical perspective

PAR absorbed by chlorophyll (VPM)

$$\text{GPP} = \varepsilon_g \times \text{FPAR}_{\text{chl}} \times \text{PAR}$$

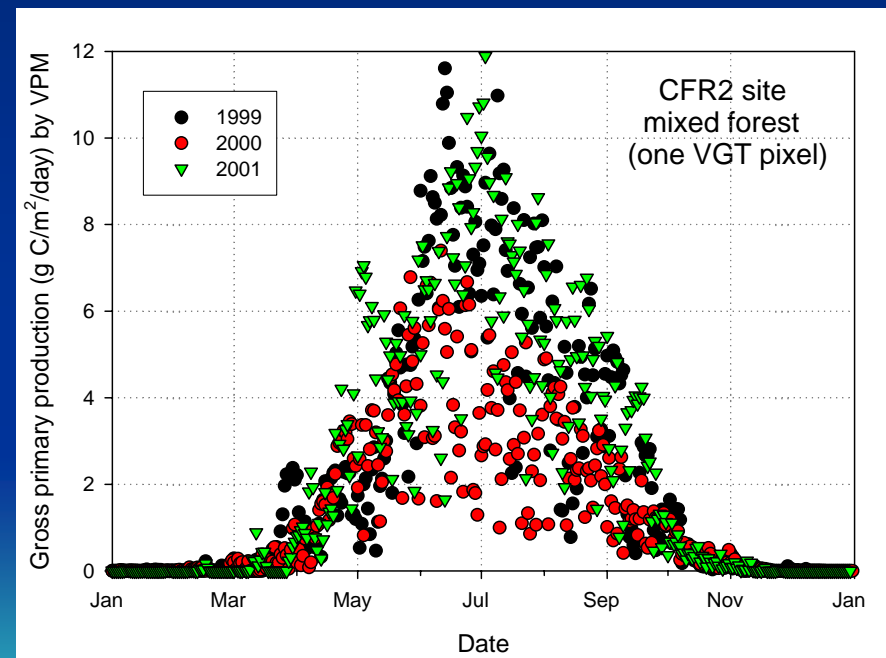
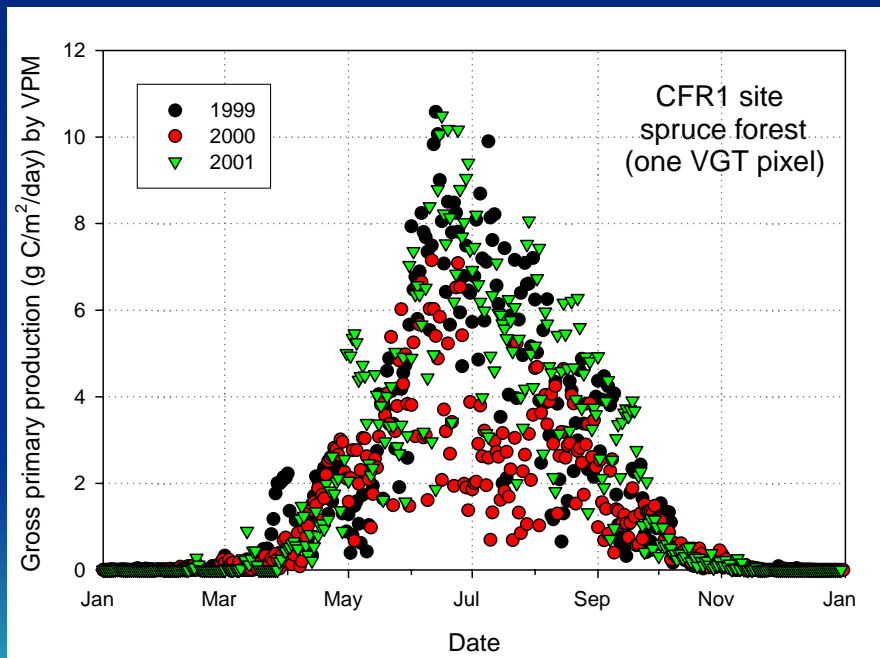
Satellite-based Vegetation Photosynthesis Model (VPM)



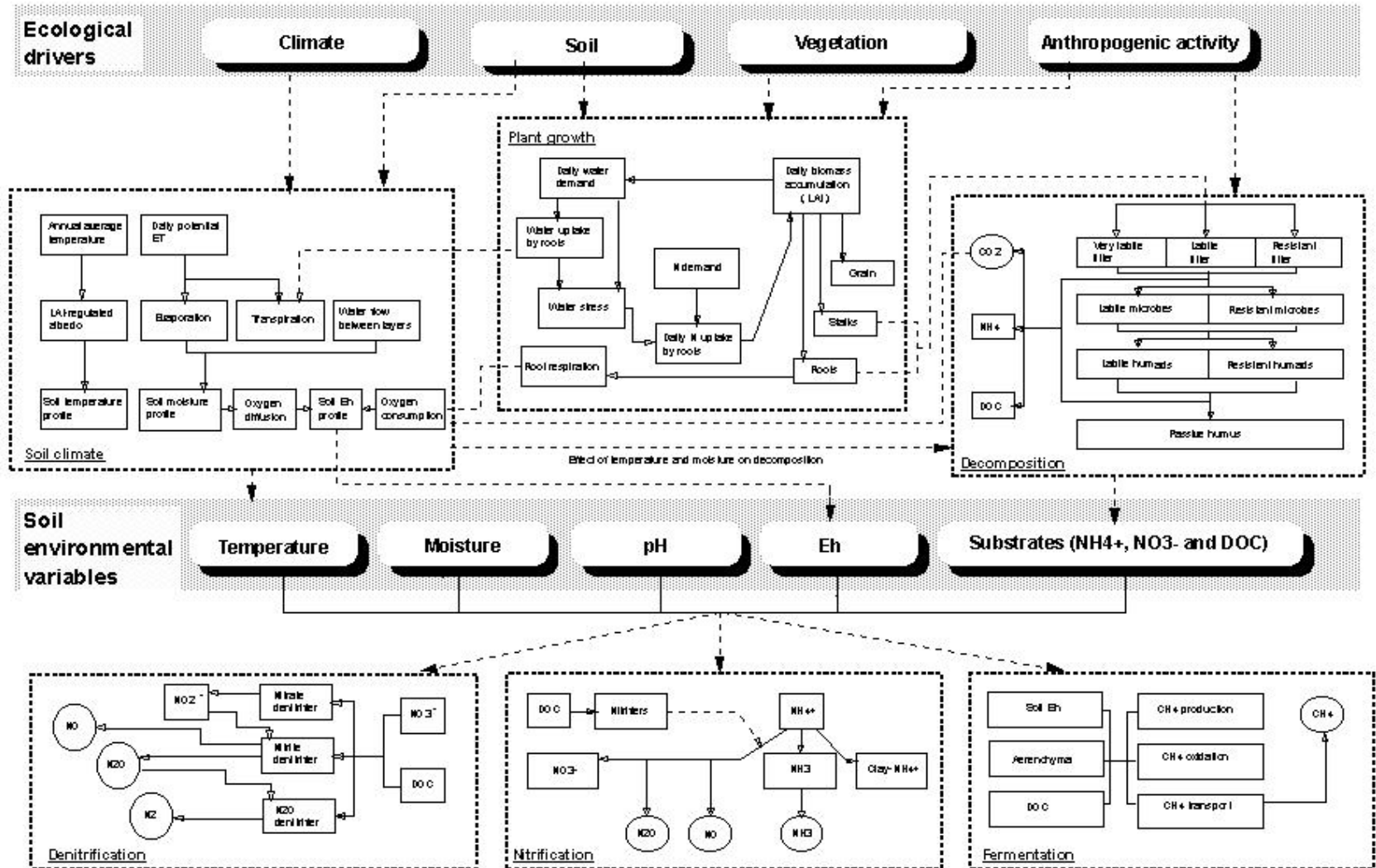
T_{scalar} , W_{scalar} , P_{scalar} , R_{scalar} – downward regulation scalars for air temperature, leaf water content, leaf phenology and non-linear light response

VPM is evaluated at ~40 eddy flux tower sites of AmeriFlux, EuroFlux, and ChinaFlux

Gross primary production predicted by VPM model wet spruce forest and mixed forest sites

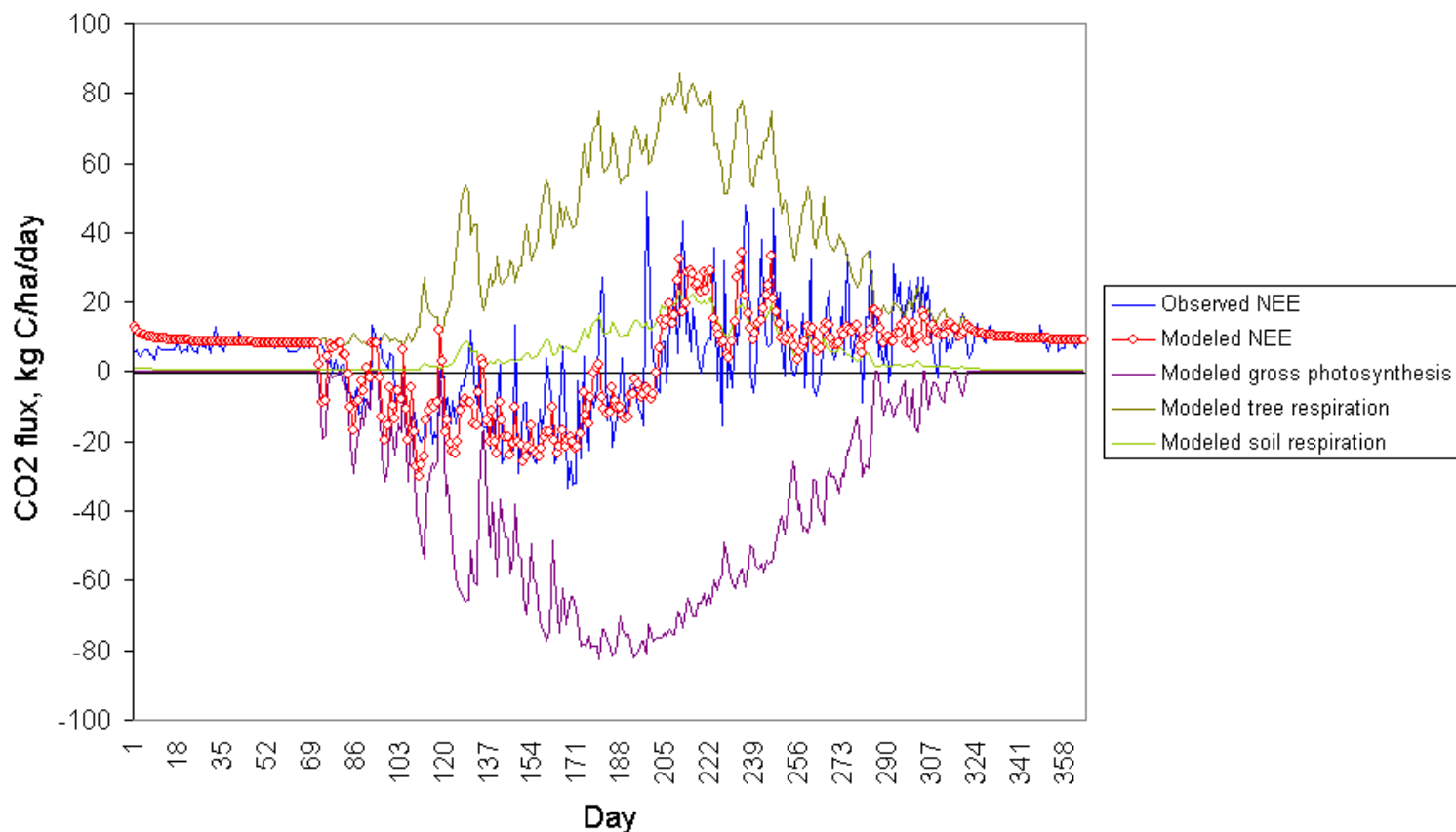


Structure of Forest-DNDC



DNDC-predicted photosynthesis, tree respiration and soil respiration for a wetland spruce forest at CFBR in 2004

Observed and Modeled CO₂ Fluxes from a Wetland Spruce Forest at Central Forest Reserve in Fyeodorovskoe near Moscow, Russia in 2004



Landscape-scale study

field surveys in CFBR

land cover types

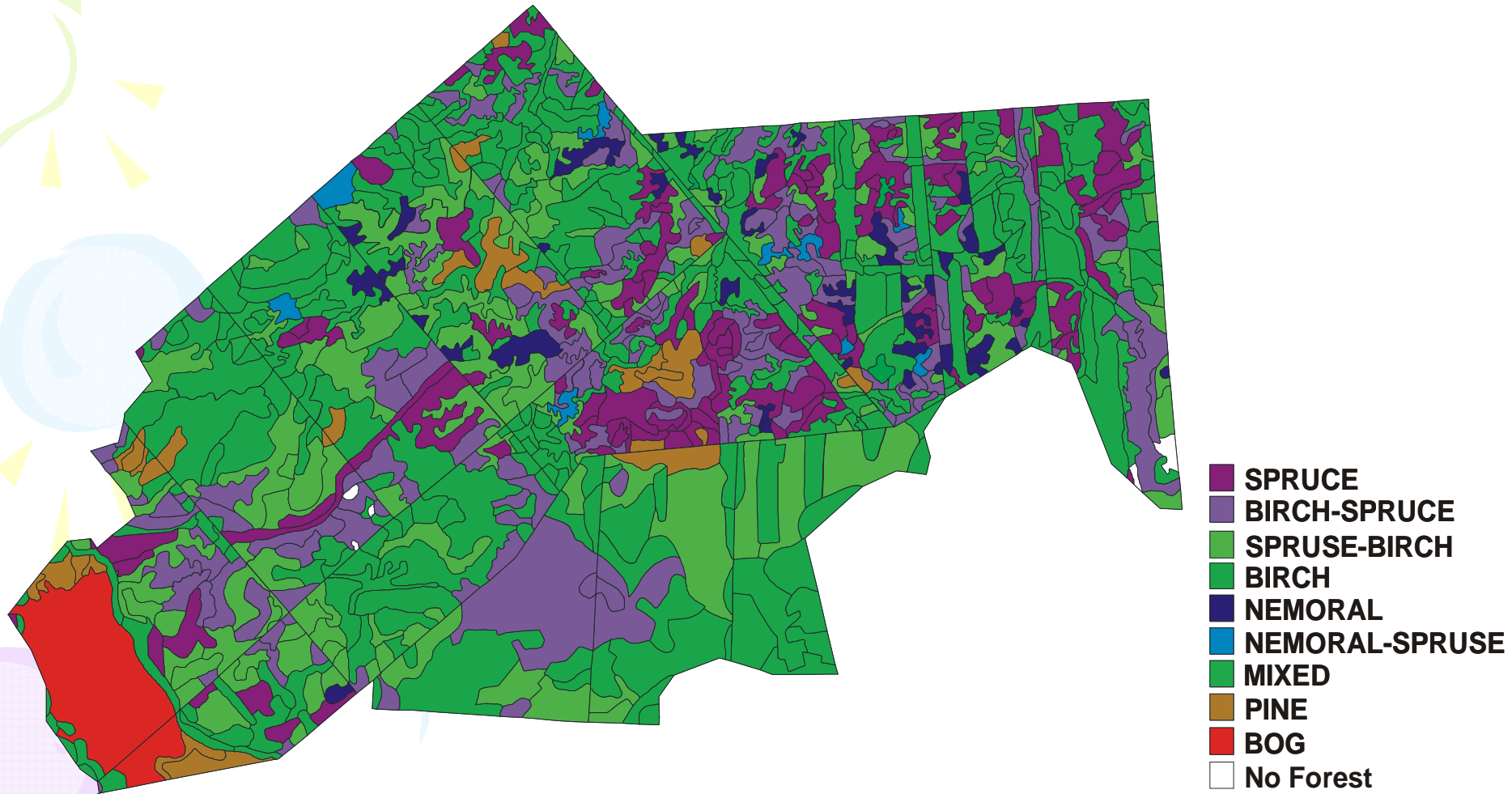
tree species

soils



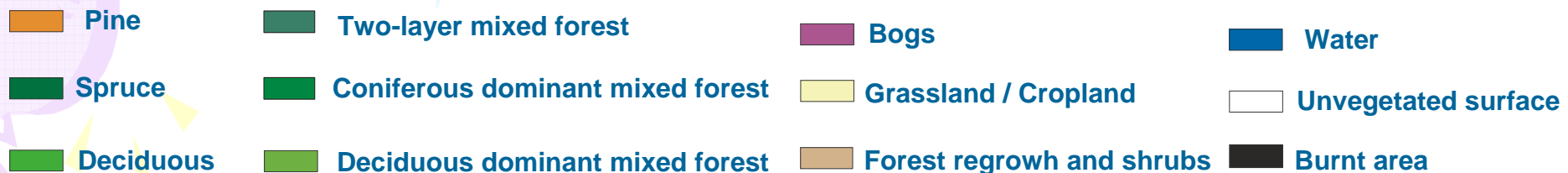
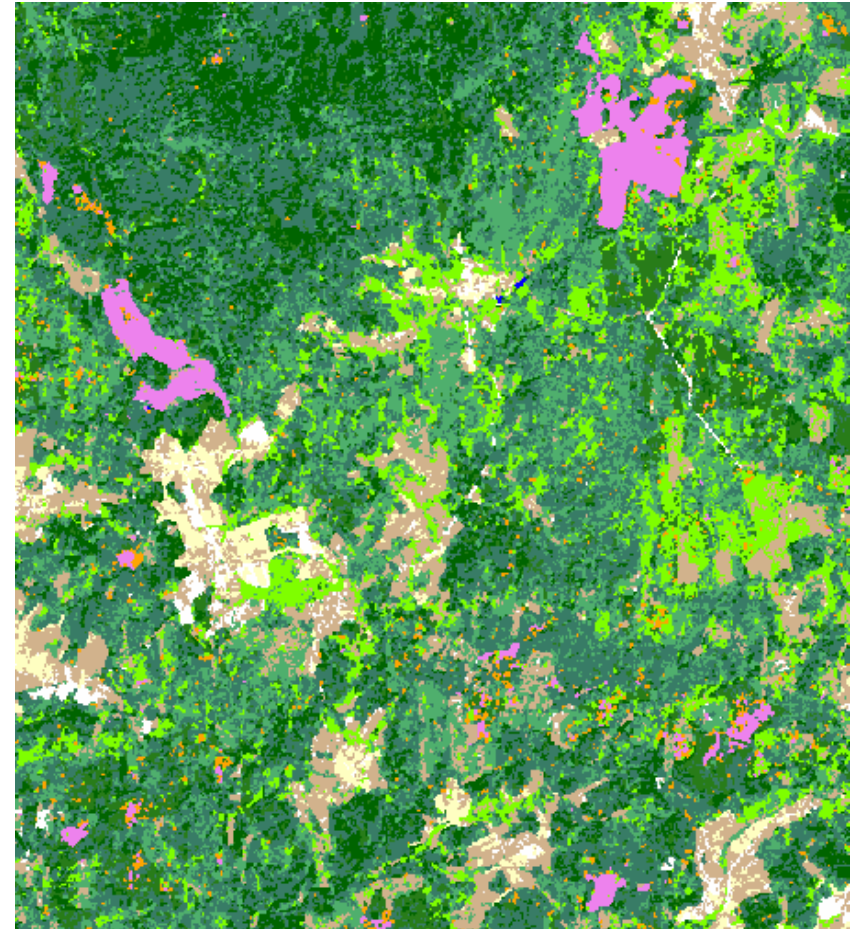
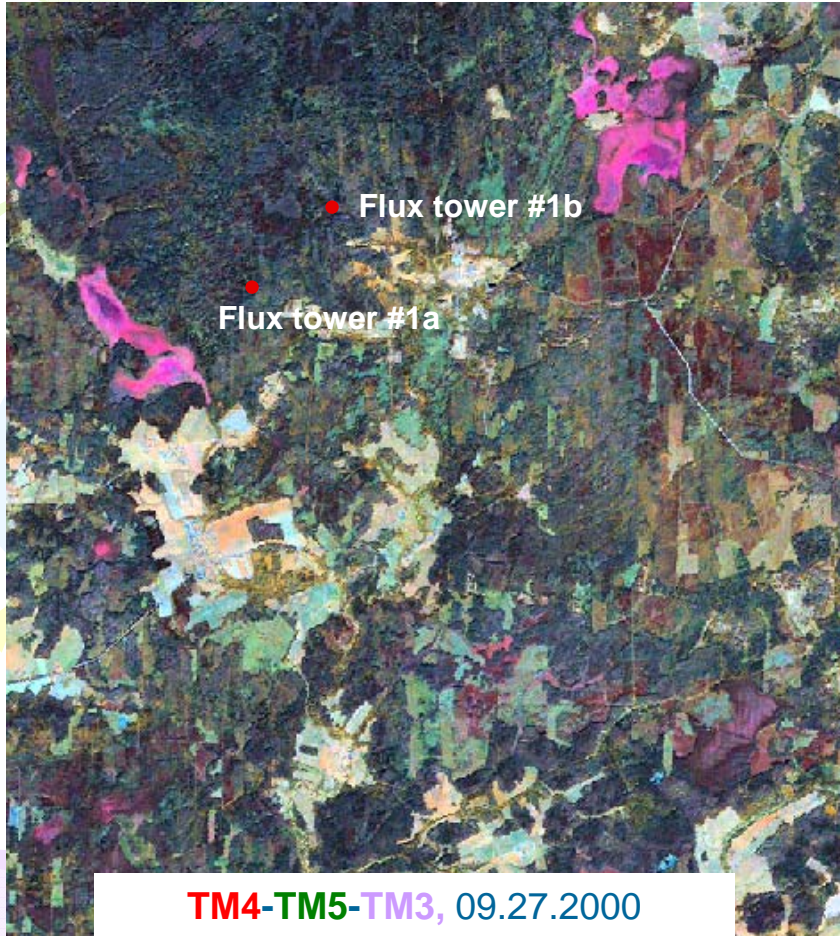
Landscape-scale analysis

Collection of ground truth data for the test sites



GIS database for Central Forest Natural Biosphere reserve,
test site in Tver region

Land cover map of CFBR site (right) derived from Landsat-ETM+ image (left)



Regional-scale study

Develop <http://remotesensing.unh.edu> website

Image data

MODIS data from 2000 – present

VGT data from 1998 – present

Vegetation indices

LSWI, EVI, NDVI, ...

Phenology

Regional-scale study

Geospatial databases for VPM-DNDC simulations

Climate

NCEP/NCAR global climate reanalysis

Soil

Land Resources of Russia (IIASA)

Vegetation

Land Resources of Russia (IIASA)

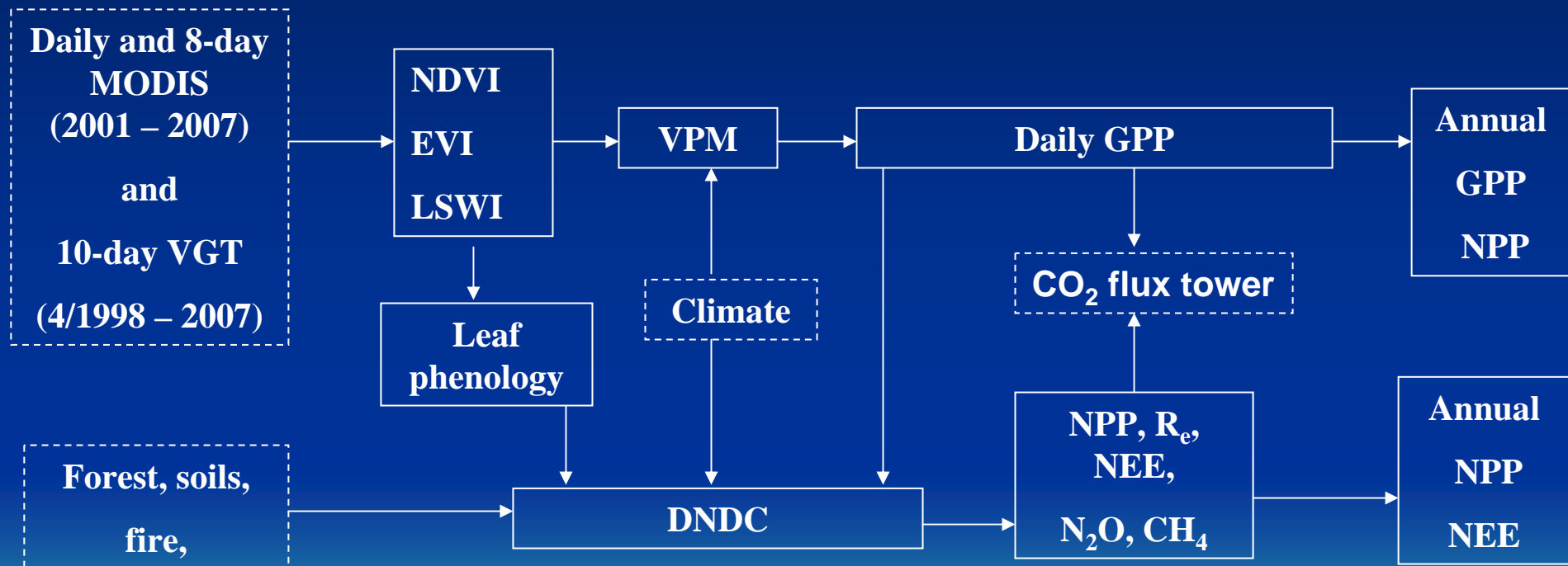
Plan for Year 2

- 1. Continue the field work in CFBR**
 - 2. Evaluate VPM/DNDC/PROSAIL2 models for flux tower sites in central Siberia**
 - 3. Couple VPM/DNDC models**
 - 4. Conduct landscape-scale analysis**
 - 5. Initiate regional analysis**
-

Thank you



A data-model assimilation system coupled VPM – DNDC models



Flowchart of a data-model assimilation system for quantifying carbon fluxes and trace gases emissions.