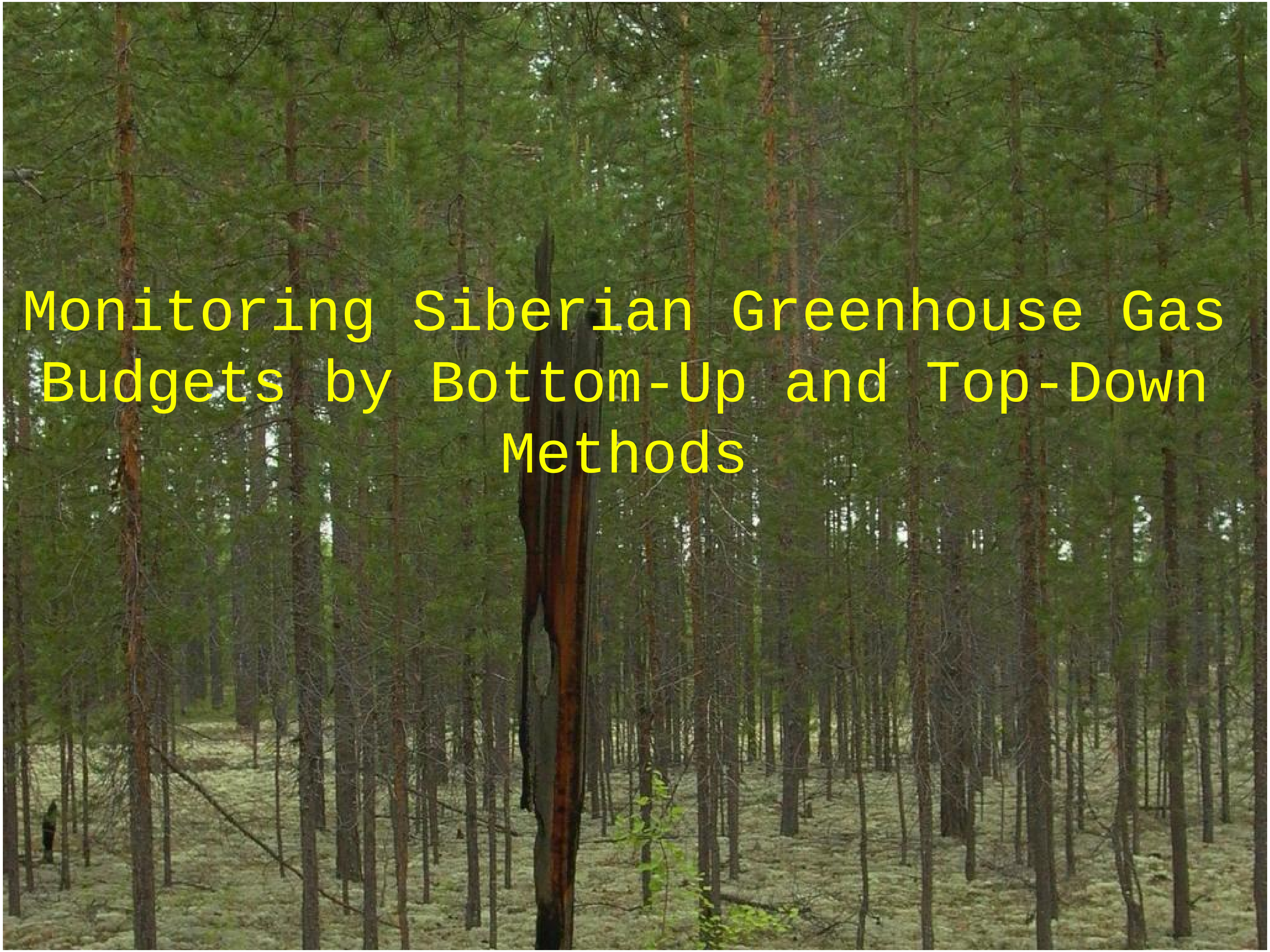
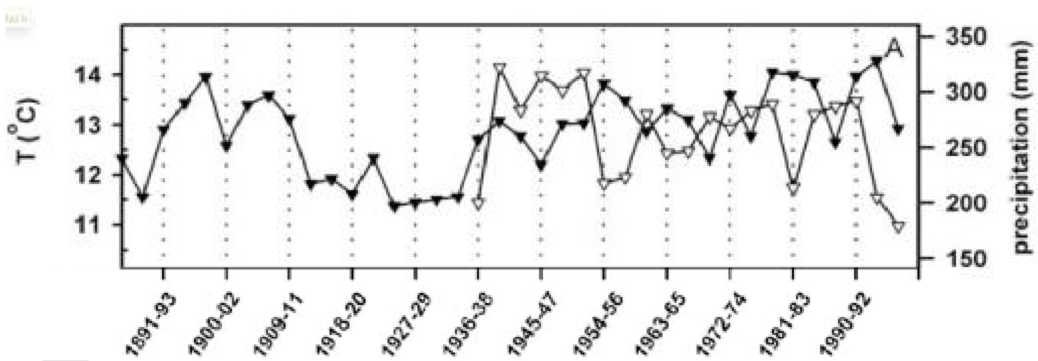


Monitoring Siberian Greenhouse Gas Budgets by Bottom-Up and Top-Down Methods

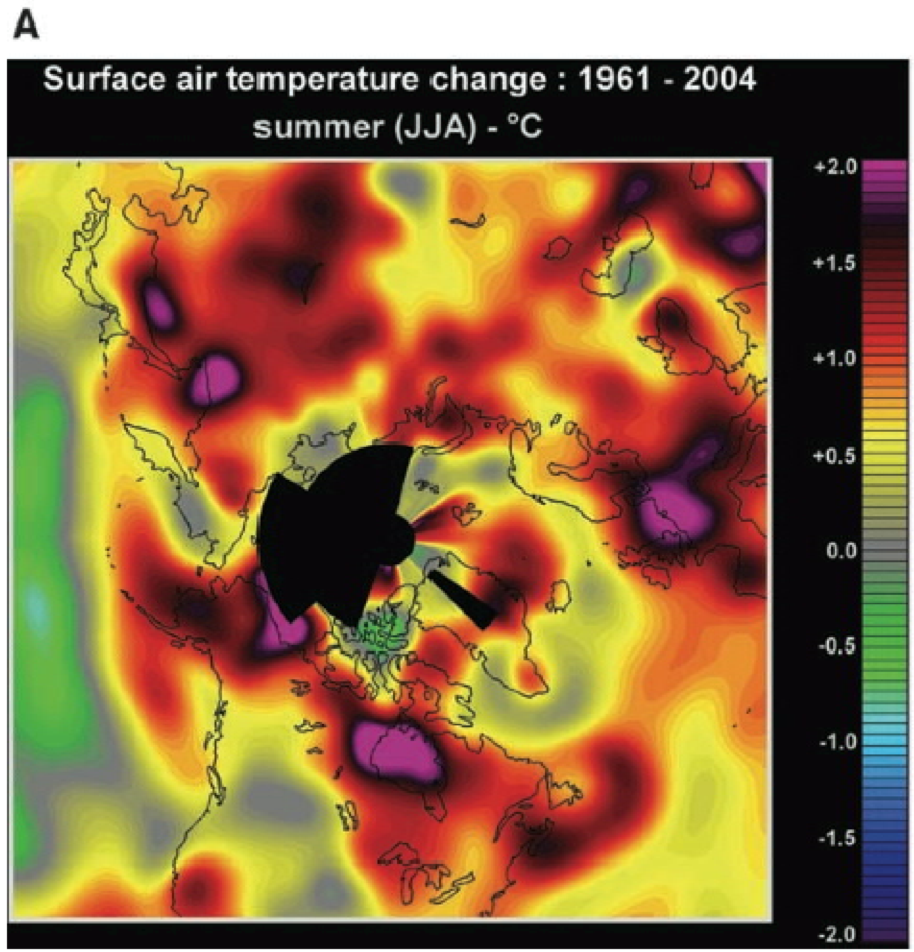
Motivation

Summertime Warming and Variability in Boreal and Arctic Regions

Growing Season Temperature and Precipitation, Bor, 61.6°N, 90.2°E, 3yr means



Arneth et al., 2002, Tellus



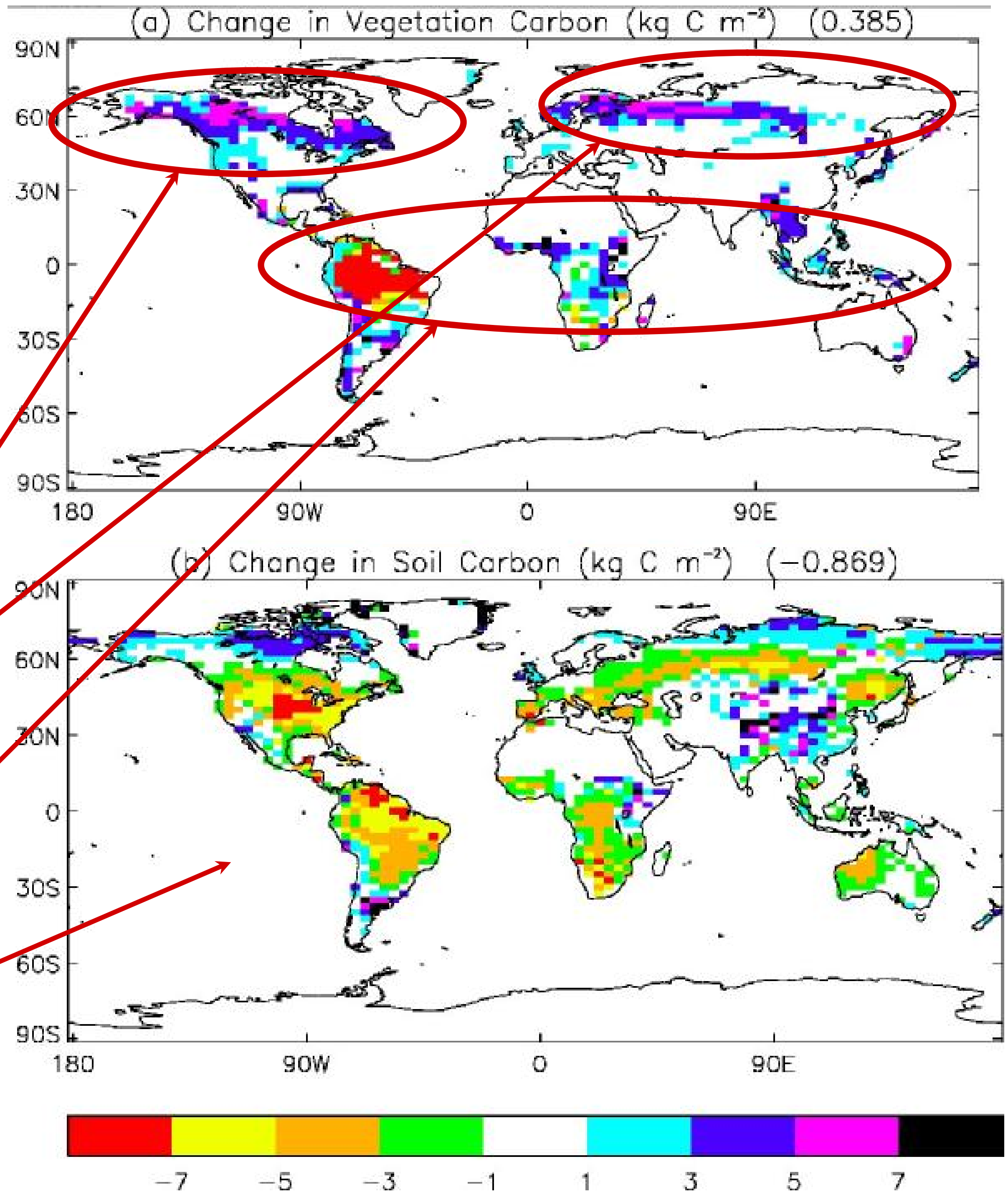
Chapin et al., 2005, Science

Simulated Changes in Carbon Storage Hadley Center Model 1860-2100

Carbon Cycle "Hotspots":

Boreal Forests, Tundra (Permafrost) Tropical Ecosystems

Soils



Why Siberia?

- Siberian boreal forest is a significant component of the global carbon cycle:
  - ~ 10% of global terrestrial carbon (vegetation+soils)
  - ~ 5-10% of global terrestrial productivity
  - ~ 65% of Siberian forests contain permafrost
- Relatively homogenous ecosystem/landscape
- Modest anthropogenic impacts
- Expected large climate change impacts
- Large interannual climate variability
- Fire a crucial disturbance factor
- Permafrost carbon:
  400PgC, vulnerability: 5PgC (20yr), 100PgC (100yr)

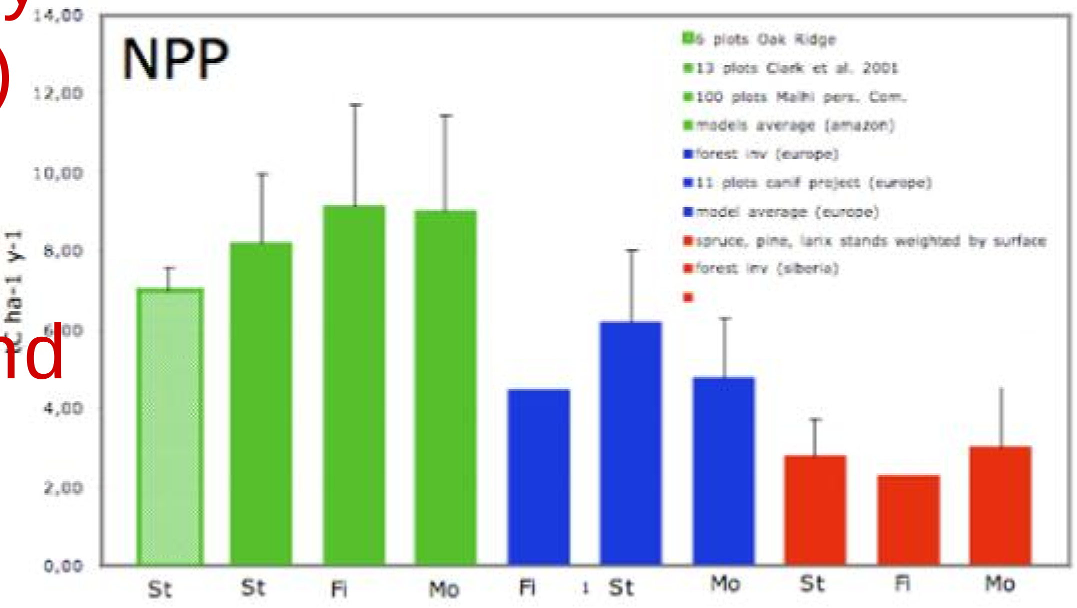
Anticipated high-latitude changes and unknowns

- Changes in snow cover, sea ice, atmospheric circulation reflected for example in precipitation changes
- Changes in land cover (fires, steppe/agriculture, forest logging, ecosystem migrations)
- Permafrost: deepening of active layer, possible catastrophic destruction of frozen soil C stores
-

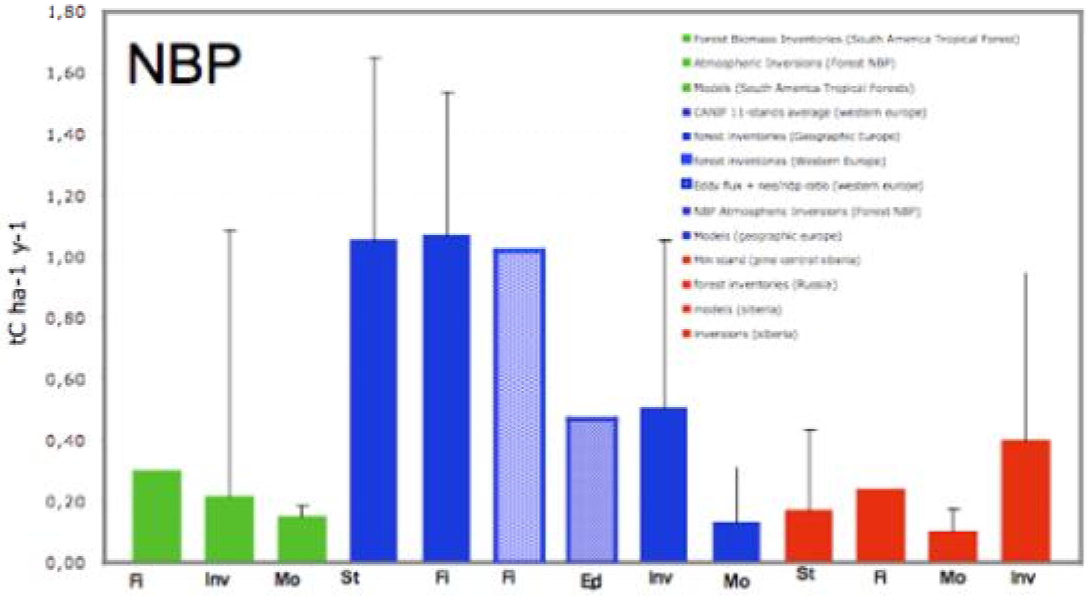
è Ecosystem changes

è Atmospheric composition changes

Decadal Net Primary Productivity (NPP) and Net Biome Productivity in Amazonia, Europe and Siberia

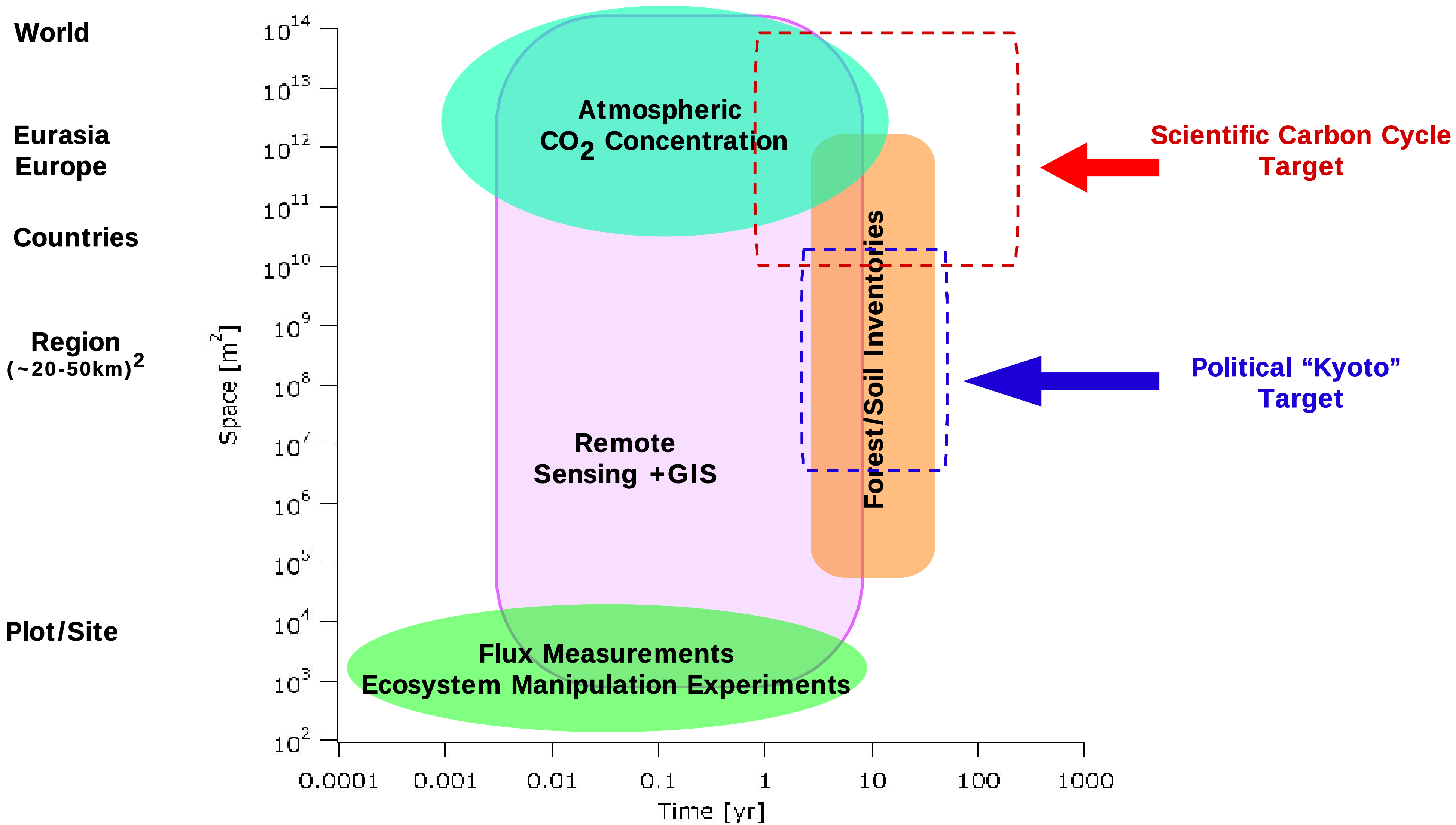


Estimations with different methods

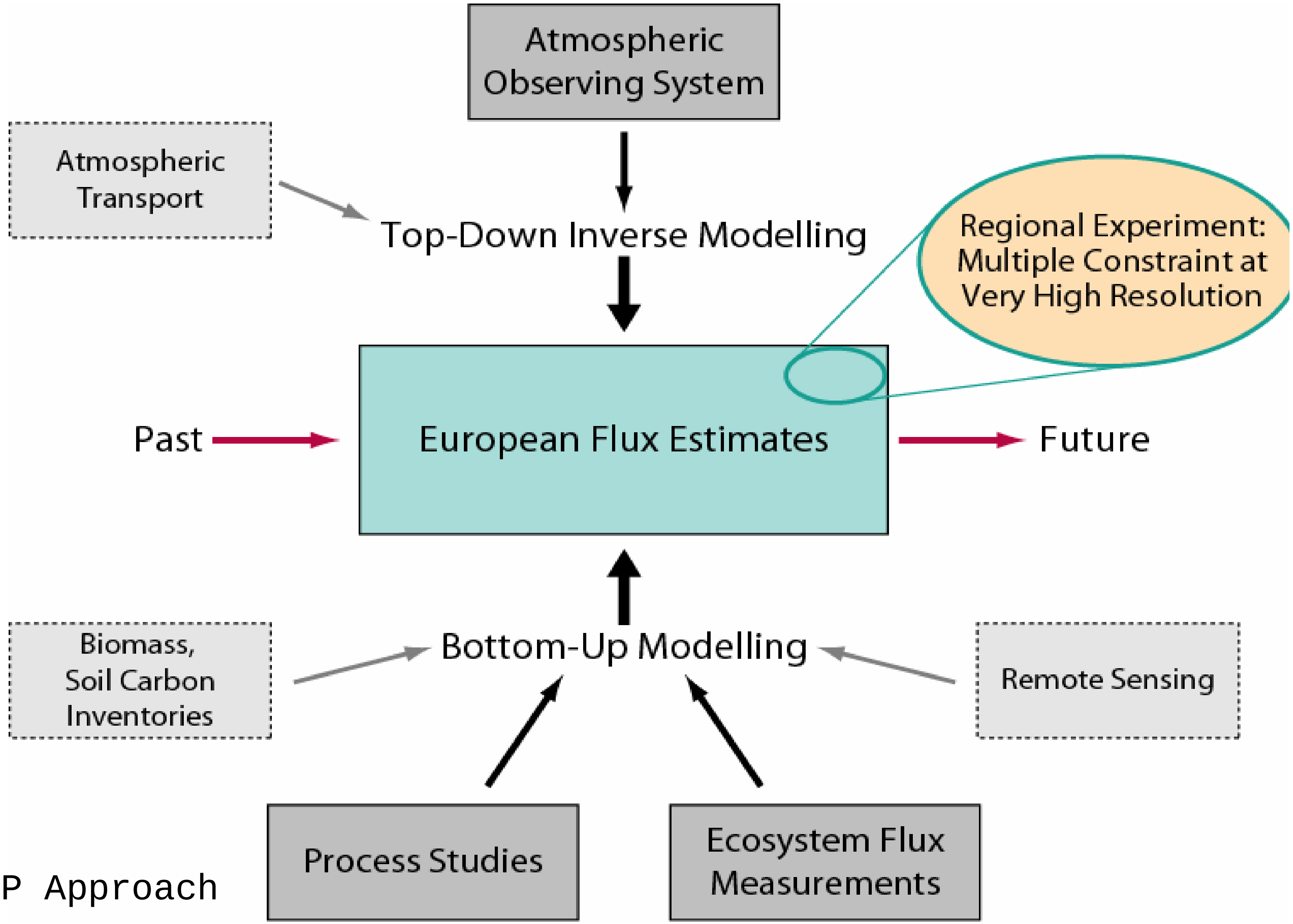


Ciais et al., 2004

Carbon Cycle Observing Systems: Spatio-Temporal Characteristics



Estimating Reginal Carbon Balances: Top-Down vs Bottom-Up Approach



:arboEurope-IP Approach

Observational Programs

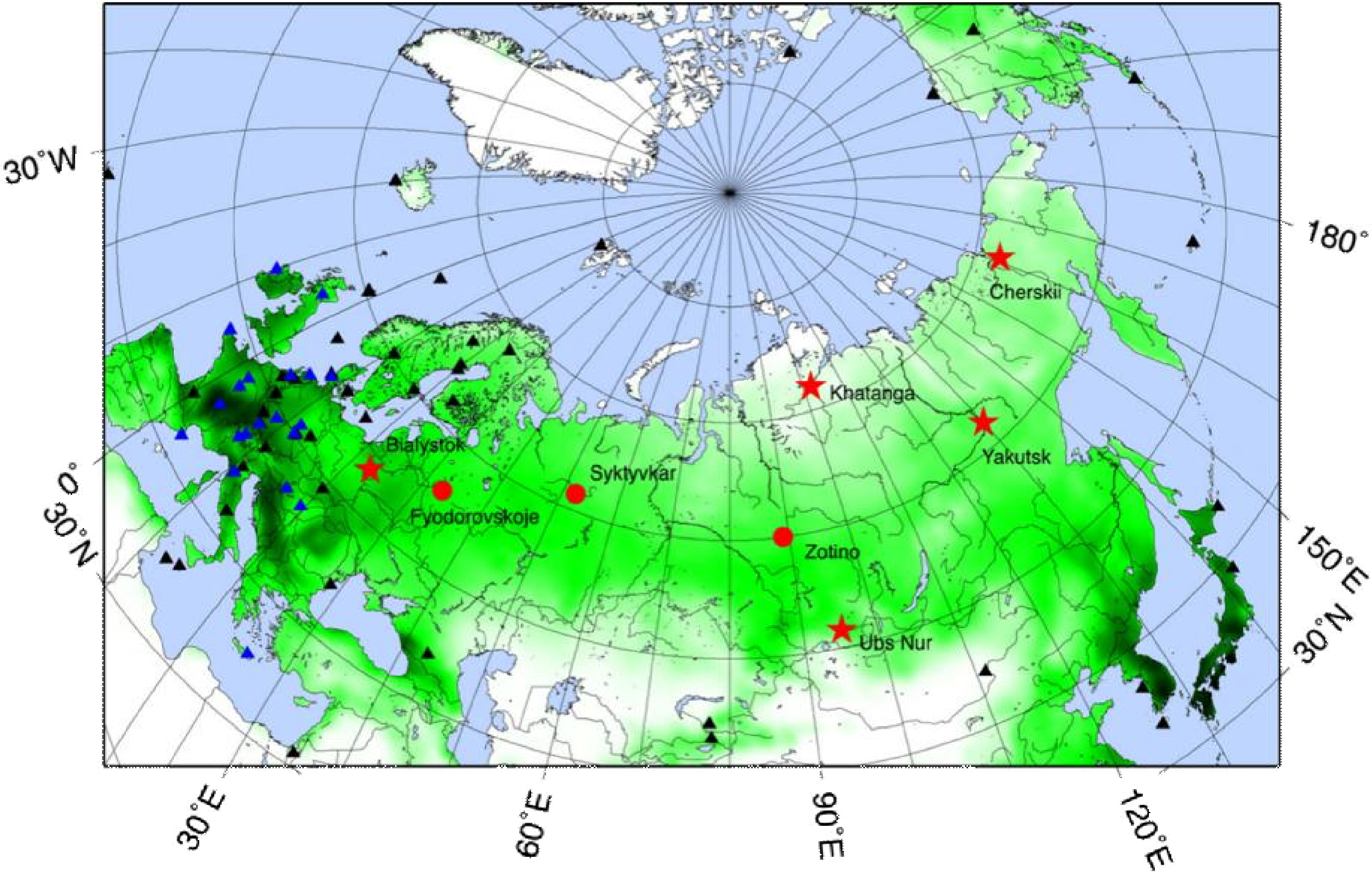
Siberian carbon observational projects with substantial european support

- Terrestrial Carbon Observing Project - Siberia
  (TCOS-Siberia) 2002-2005:
  Network of surface flux measurements and atmosphere monitoring sites
- AEROSIB-YAK (F-D-RU) 2006-????:
  Long-distance transects by chartered aircraft
- Zotino Tall Tower Observatory (ZOTTO):
  300m tall observation tower near Zotino
  (~60°N, ~90°E)

TCOS-Siberia: Principal Investigators

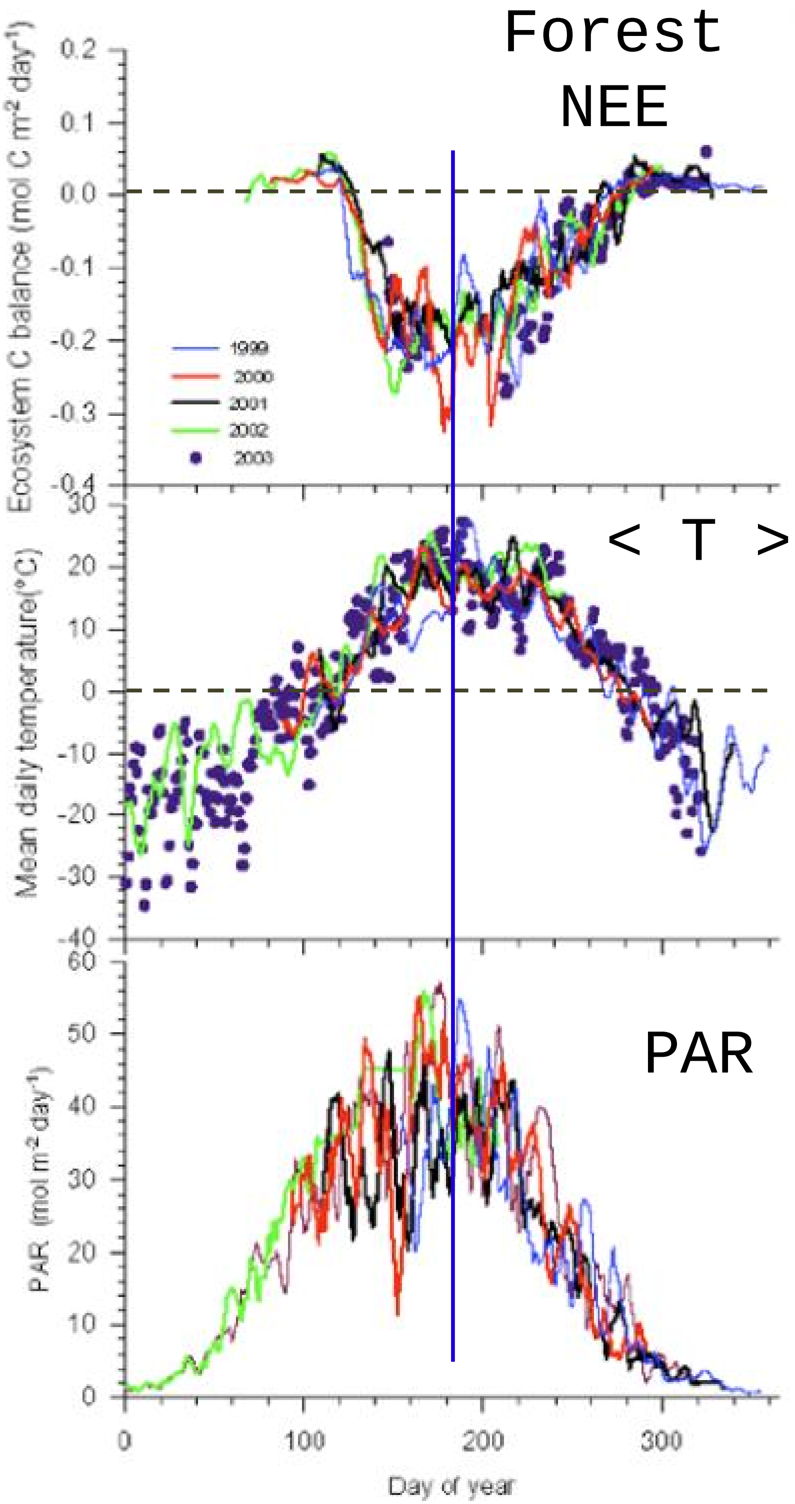
- MPI BGC Jena, Germany (Heimann, coordination, PI, Schulze PI, Lloyd PI, Zimmermann, project manager)
- LSCE, Saclay, France (Ciais, PI)
- IUP, University of Heidelberg, Germany (Levin, PI)
- RUG, Groningen, Netherlands (Meijer, PI)
- UNITUS, Viterbo, Italy (Valentini, PI)
- Vrije Universiteit Amsterdam, The Netherlands (Dolman, PI)
- IPEE, Moscow, Russia (Varlagin, PI)
- IFOR-RAS, Krasnojarsk, Russia (Shibistova, PI)
- IBPC-RAS, Yakutsk, Russia (Maximov, PI)
- PIG-RAS, Cherskii, Russia (Zimov, PI)
- UNI.BIAL, Bialystok, Poland (Chilmonczyk, PI)
- UNI.FB.FBS, Ceske Budejovice, Czech Republic (Santruckova, PI)

TCOS-Siberia Study Sites



In Situ Flux Measurements and Process Studies

Flux Measurements near Zotino, 60.75°N, 89.38°E (Eddy Covariance Method) [Shibistova et al., 2004]



Large interannual variability of in situ carbon flux measurements

(Varlagin et al, EUROSIBERIAN CARBONFLUX, TCOS-Siberia data)

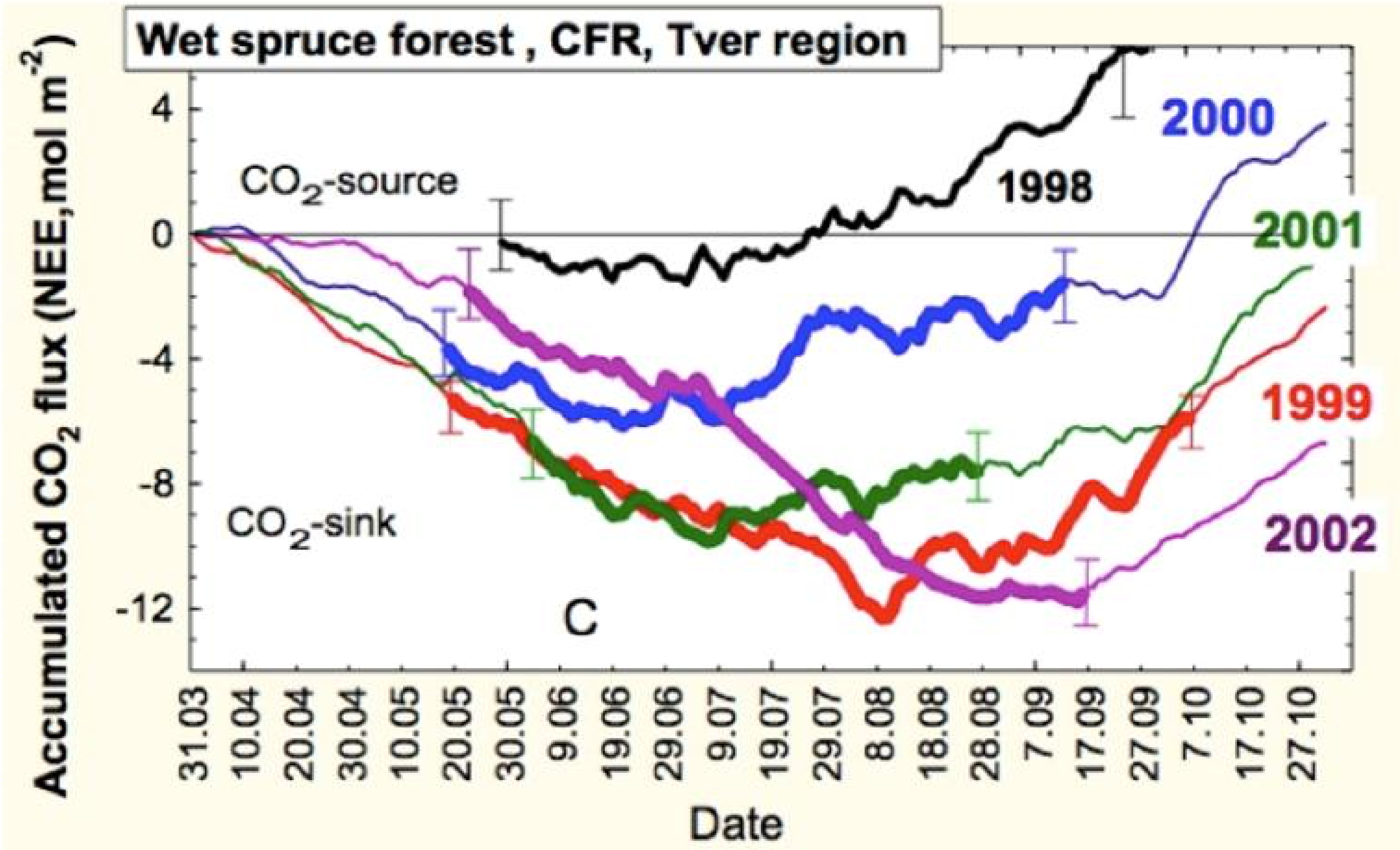
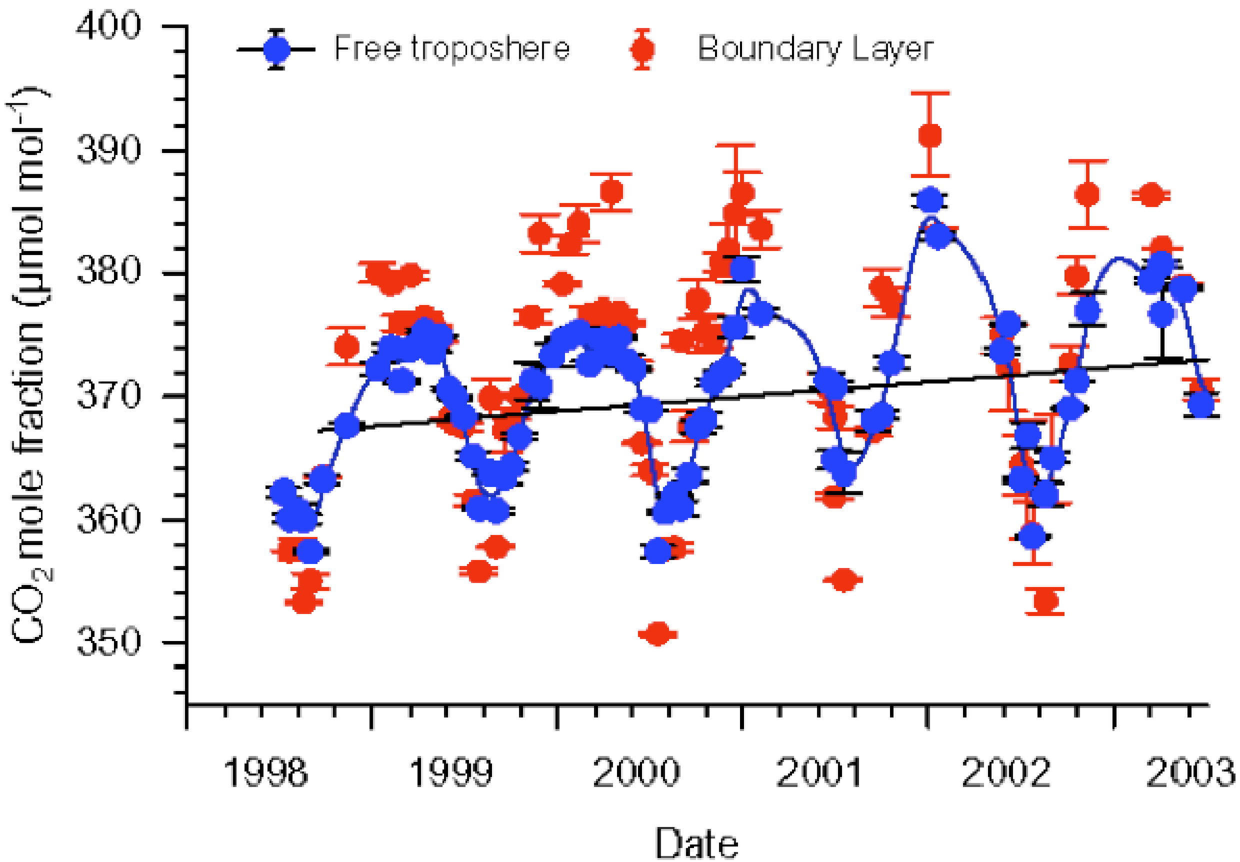


Figure 2: Accumulated Net Ecosystem Exchange observed by eddy covariance over a wet spruce forest at the Fedorovskoje site near Tver in Western Russia.

Aircraft Measurements

Aircraft Measurements: Zotino
(~60°N, ~90°E, 0-3000m)



Simulated Atmospheric CO_2 Mixing Ratio over Eurasia

"Free troposphere"
(3000m)

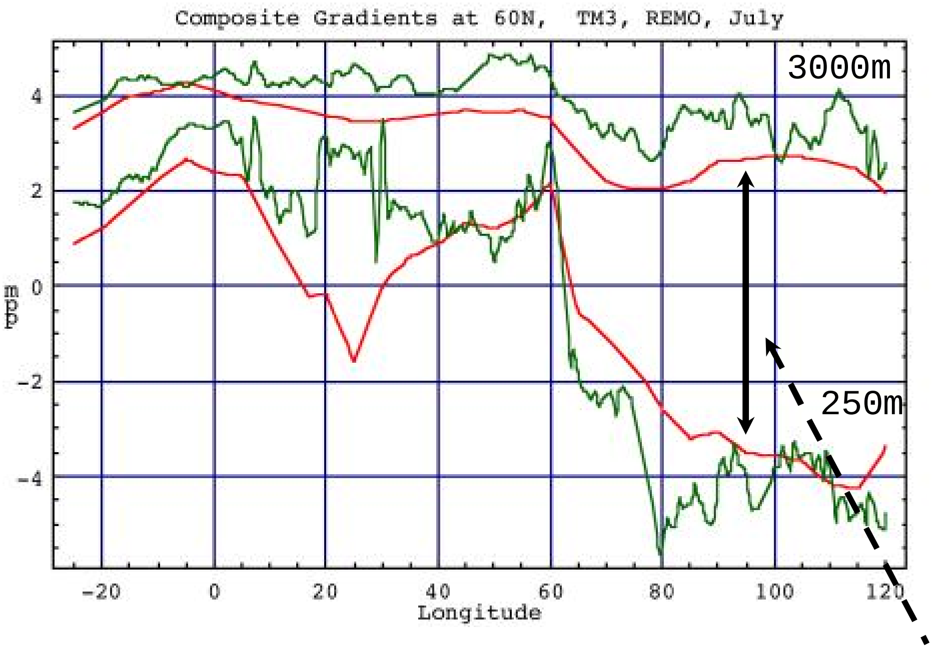
QuickTime™ and a
GIF decompressor
are needed to see this picture.

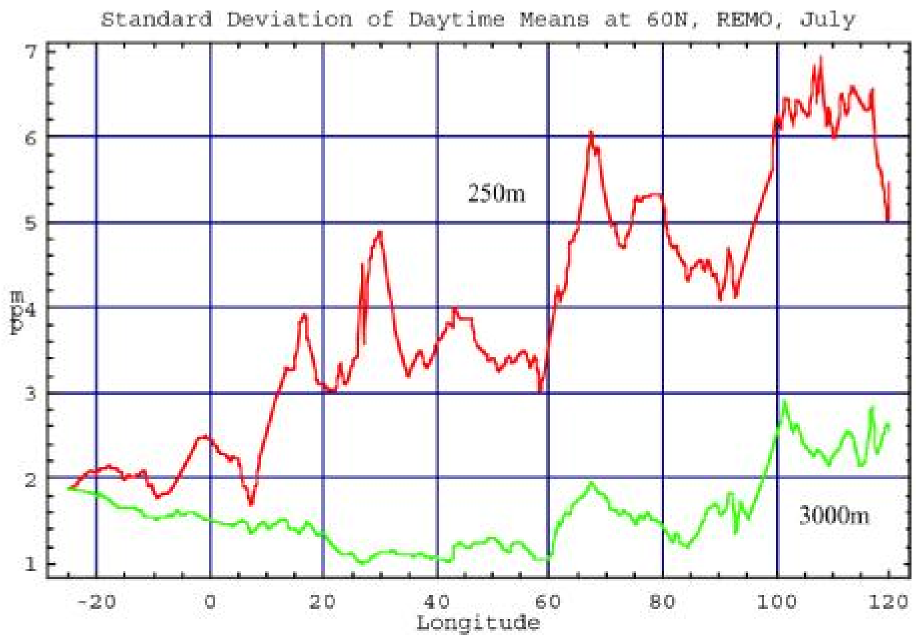
ppm

PBL
(300m)

MO Simulation, U. Karstens, MPI-BGC

Model Simulation
West-East CO_2 Concentration Gradients at 60N, Monthly Mean and Standard Deviation, July 2002

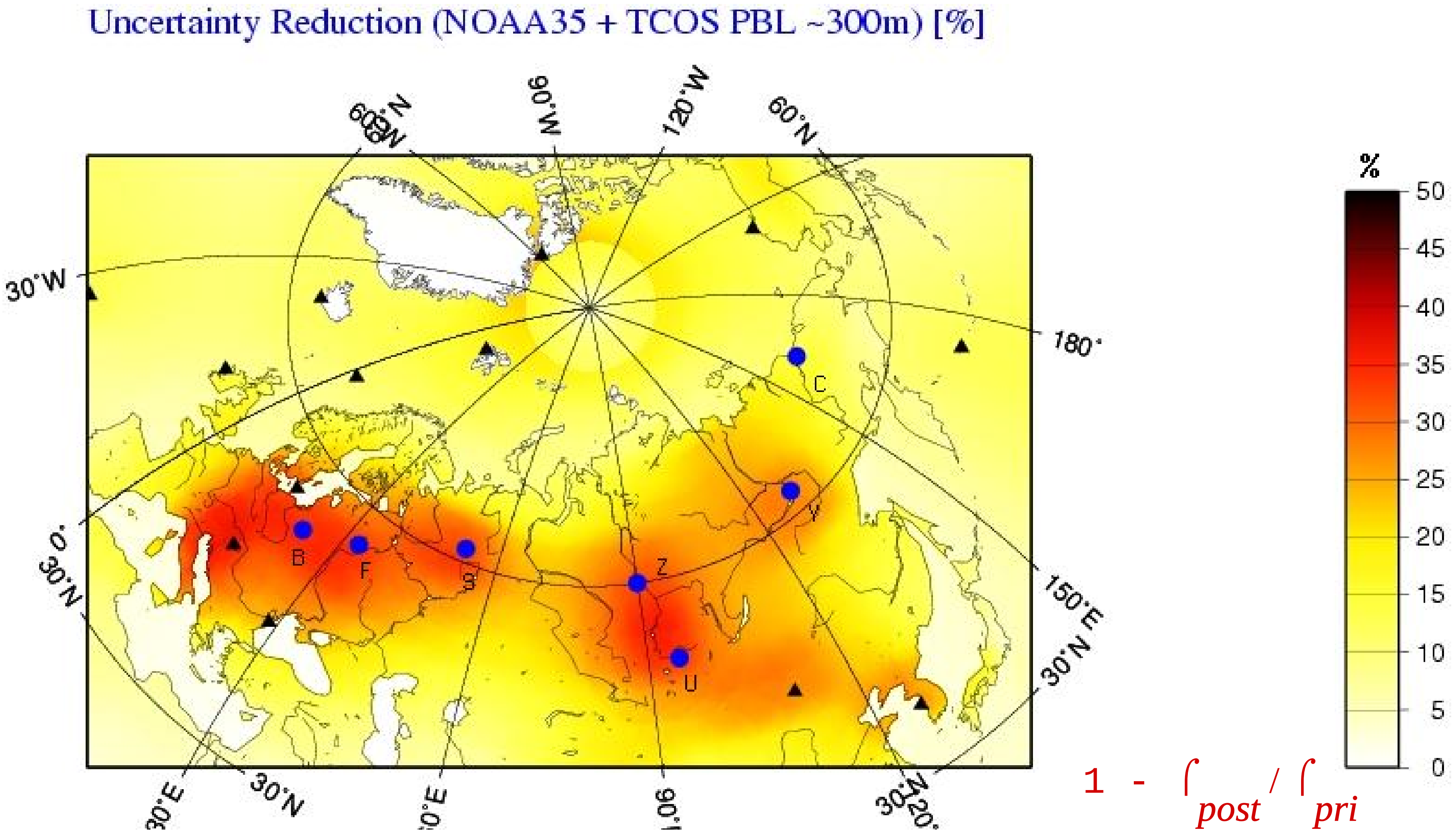




Atmospheric “signal” of boreal forest biosp

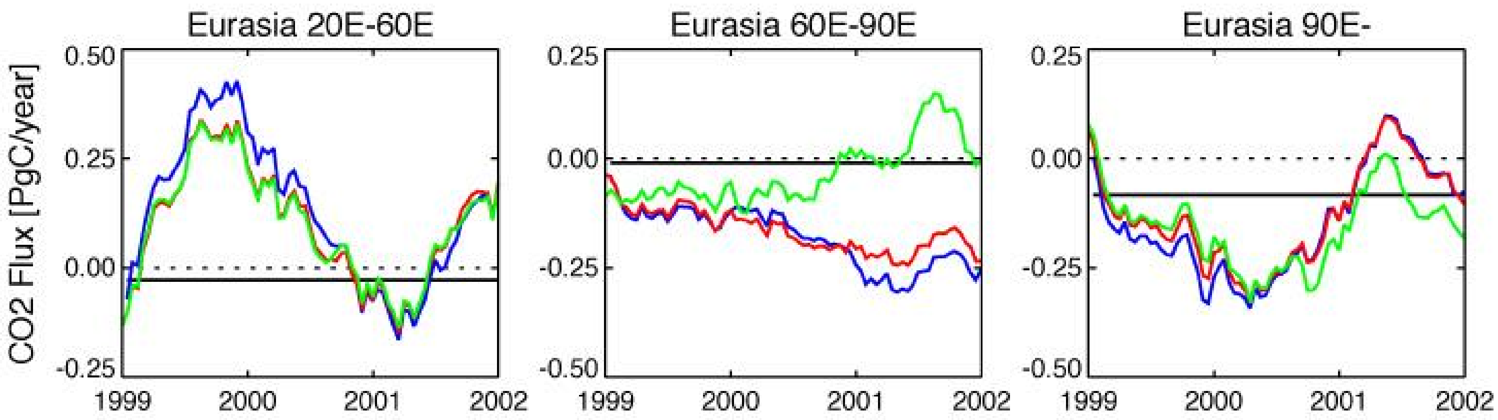
Simulation, Karstens et al.]

"Footprint" of Atmospheric Measurements: Uncertainty Reduction of Time-Averaged (monthly) Source Estimates by TCOS-Siberia Aircraft Measurements - Bi-Weekly Observations



$1 - \sigma_{post} / \sigma_{pri}$

Interannual Variability of Ecosystem Carbon Fluxes



Fluxes determined by inverse atmospheric modeling including observations from TCOS-Siberia project

Some Results

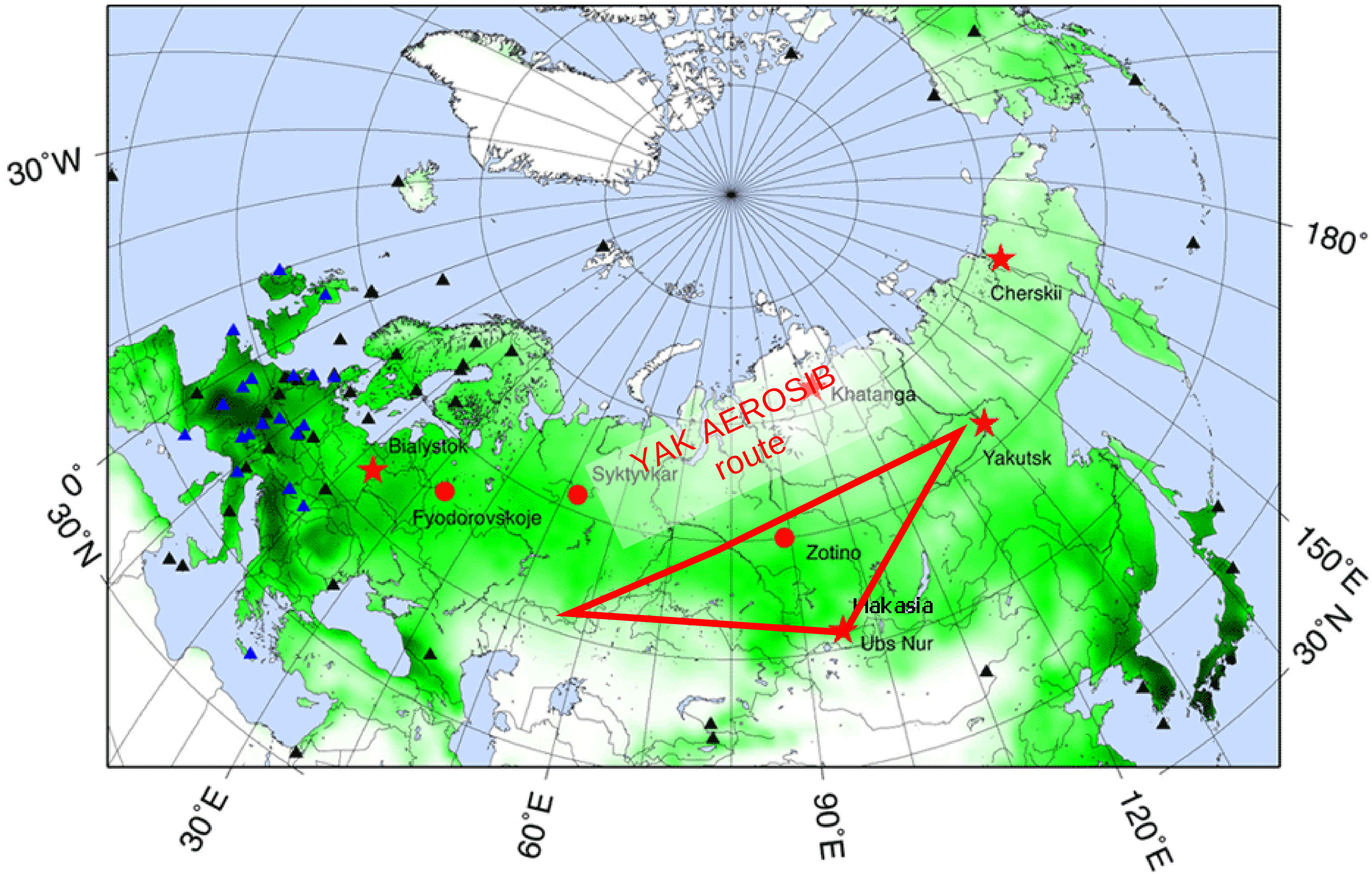
- TCOS-Siberia has demonstrated the feasibility of operating elements of a biogeochemical monitoring system in Siberia.
- Siberia smaller sink than generally assumed: < 20% of fossil emissions from Russian Federation (~0.4 PgC/yr)
- Expected high interannual variability of terrestrial carbon fluxes, driven by the large variability of climate variability and fires
- Comparative studies show increases in carbon uptake with higher temperatures
- Abandoned agriculture in southern grasslands region leads to substantial carbon uptake
- Siberia a longer-term (decadal) source or sink of carbon? Need longer term measurements!

AEROSIB-YAK

Transiberian Airborne Greenhouse Gases Observations

P. Ciais[1], G. Golitsyn [2], M. Heimann[3], C. Gerbig[3], B. Belan[4], M. Ramonet[1] C. Carouge[1], C. Camy-Peyret[5], D. Mondelain[5], J. Chappelaz[6], P. Nedelec[7], D. Hauglustaine[1], K. Law[8]

[1] LSCE (F) [2] IFA (Ru) [3] MPI-BGC (D) [4] IOA (Ru)
[5] LPMA (F) [6] LGGE (F) [7] LA (F) [8] SA (F)


30°W
180°
0°
30°N
150°E
30°N
30°E
60°E
90°E
120°E
YAK AEROSIB
route
Khatanga
Cherskii
Yakutsk
Bialystok
Syktyvkar
Fyodorovskoje
Zotino
Hakasia
Ubs Nur

Observations and models

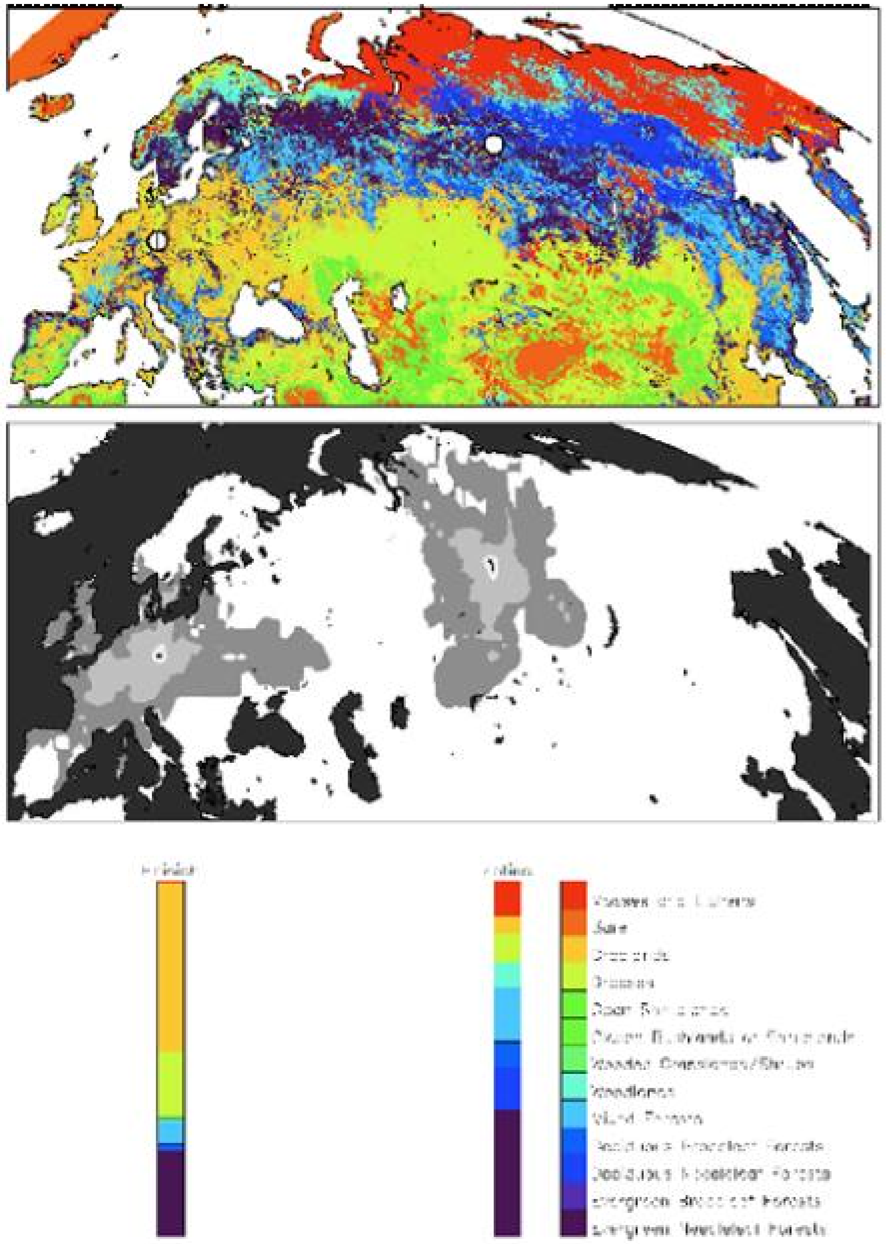
- 2006 : Measurement of suite of tracers:
  - in situ : CO_2, CO, O_3 , $CH_{4,}$, [aerosols]
  - In flasks : CO_2, CH_4 with their ^{13}C isotopes, $CO^{18}O$, APO
  - SF_6 , N_2O, CO, H_2
- Meteorological parameters
- After 2006
- in-situ : 13C using specifically developed laser diode
- in flasks : isotopes in CH_4, 15N and 18O in N_2O
- Use of high resolution atmospheric transport/chem models
- Use of remote sensing to infer ecosystem fluxes and fires

The Zotino Tall Tower Observation Facility (ZOTTO)

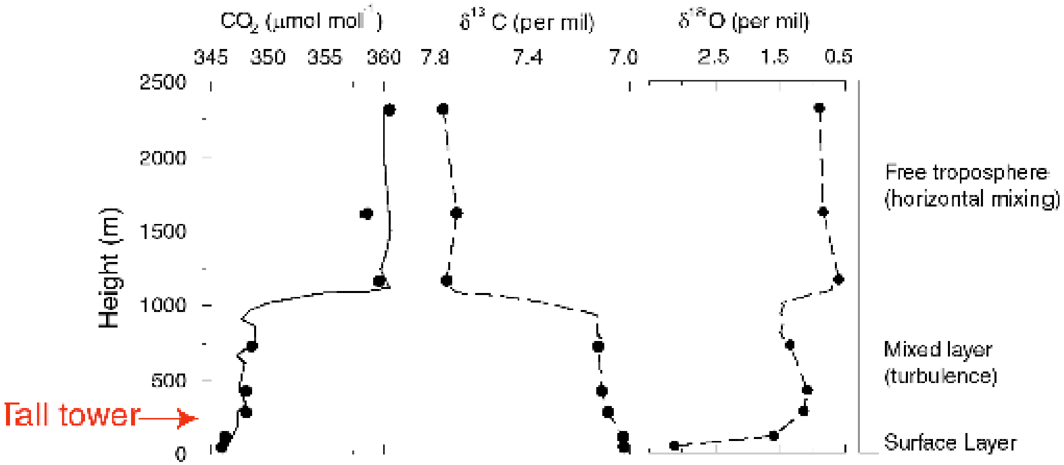
A Scientific Platform in the Center of Siberia for Observing and Understanding Biogeochemical Changes in Northern Eurasia

Footprint Analysis

Why 300m?



Typical aircraft profiles over Zotino



loyd et al., 2002, Tellus

Tall Tower in Siberia

- Funding by German Max-Planck-Society: ~ 3.0 MEuro/5yr,
- (Installation: ~1 MEuro, running costs: ~ 400k Euro/yr)
- Funding administration through ISTC
- Core partners:
  - Max-Planck-Institute for Biogeochemistry, Jena
  - Institute of Forest, Krasnojarsk
  - Max-Planck-Institute for Chemistry, Mainz
- Status: Construction in 2004/6, fully operational by October 1, 2006
- Beyond 2010: to become an international observatory with a life time of more than 30 yr

Scheduled Measurement Programme Status of 2005

MPI-BGC

- Continuous measurements of long-lived, primarily biogeochemical gases:
  - CO_2 (NDIR CO_2 analyzer)
  - O_2/N_2 (Paramagnetic O_2-analyzer)
  - CH_4 (GC-FID)
  - CO (GC-FID)
  - N_2O (GC-ECD)
  - SF_6 (GC-ECD)

  Heights: 5m, 50m, 150m, 300m
- Regular flask sampling for lab analyses (a.o. C-isotopes)
- Continuous meteorology
  - Temperature, humidity
  - Windspeed, -direction
  - Pressure
- Continuous flux measurements of CO_2, sensible and latent heat by the eddy correlation method (at various heights on the tower).

IFOR-RAS

- Update of forest inventory in ZOTTO "footprint" area.
- Monitoring with satellite images
- Analysis of spatial heterogeneity of ecosystems in footprint area

MPI-CHEM

- Continuous CO
- Sun photometer (for aerosols)
- CO isotopes on flasks (Brenninkmeijer)
- Campaign mode:
  - OH
  - Sodar (for boundary layer height determination)

ITP

- Continuous:
  - Nephelometer (aerosol light scattering coefficient)
  - SMPS (aerosol size spectrum 0.015-0.9 mum)
  - PSAP (aerosol light absorption coefficient)
- Campaign:
  - Aerosol sample collection for chemical analysis

IAP-RAS

- ISTC #2773 (TROICA – Extension, PI: N. Elansky)
  - Extension of TROICA project
  - Plan for Jenissey campaign with short-term measurements at Zotino (at surface only)
  - Flask analyses (CH_4, CO isotopes) at MPI-CHEM (Brenninkmeijer)
- ISTC #2770 (PI: A. Skorochod)
  - Continuous measurements
    - O_3 (0, 30m, 50m)
    - NOx (NO, NO_2, at surface only)
  - Campaign (jointly with TROICA) at Zotino
    - "reactive" gases: O_3, NO, NO_2, CO, CO_2, SO_2, CH_4, THC
    - meteorology
    - solar radiation
    - O_3 turbulent fluxes
    - integral content of CO, CH_4, H_2O
    - aerosols in situ size distributions
    - VOC
    - aerosols size fractionated chemical composition
- Zotino campaigns: 2 in winter, 2 in summer, first in Feb 2005

+ NIES, Tsukuba

Construction in Progress - Winter 2005/6: Height of ~53m

Measurement Bunker

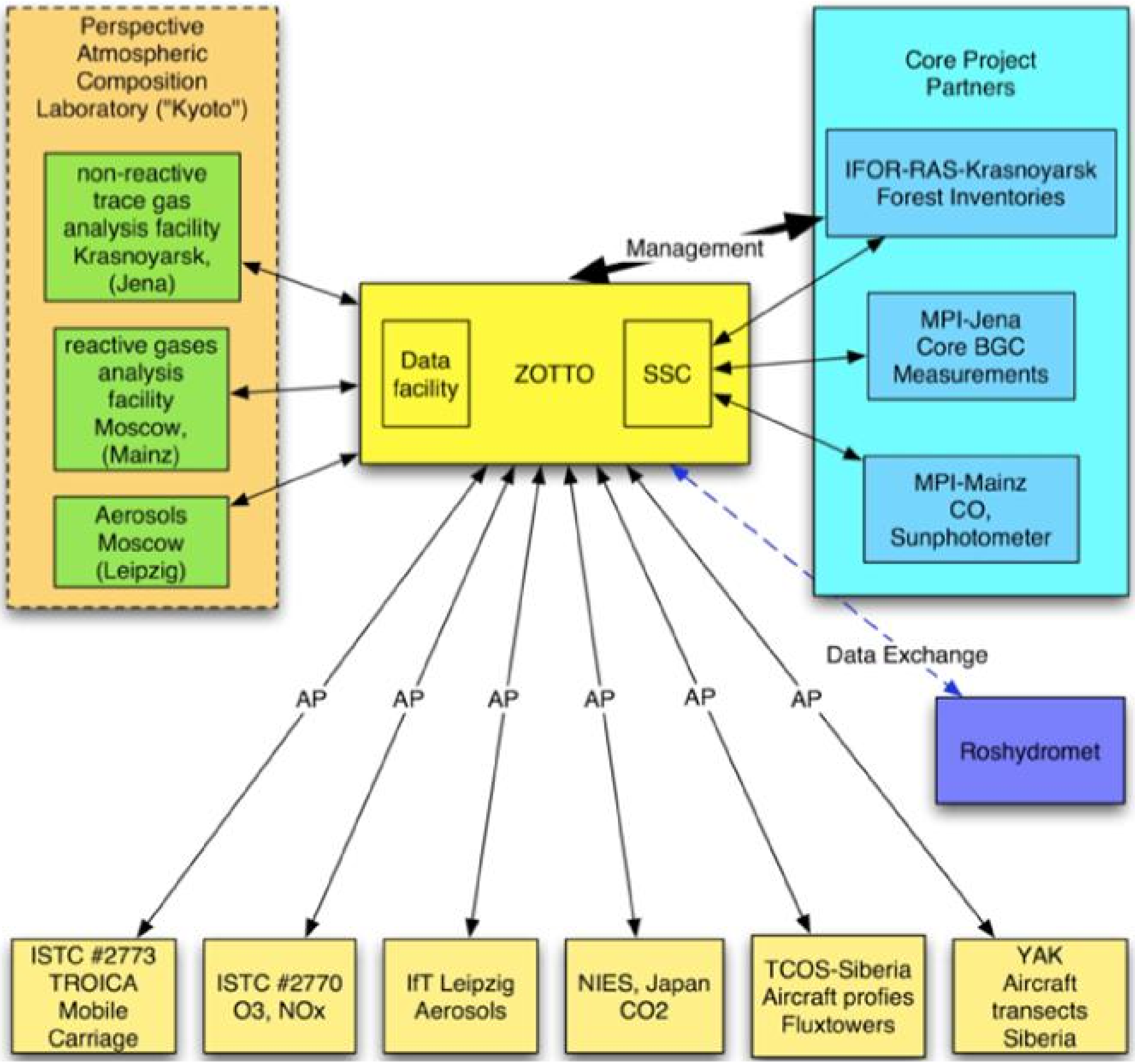
Pergola shelter between house and bunker

Scientis ts house

Generato rs

Tower Construction - June 2006: Height ~ 120m

ZOTTO Organization



Key Siberian ecosystems and processes necessitating improved monitoring and analysis

- Forest:
  - Photosynthesis + respiration
  - Disturbances (fire, harvest, insects)
  - Soil accumulation and lateral export by water
- Permafrost:
  - Large vulnerable carbon pool
  - CO_2 vs CH_4 emissions
- Bogs:
  - Large vulnerable carbon pool
  - Effects of water table changes (climate change, river rerouting)
- Grasslands:
  - Land use and management effects (recovery from agricultural use, cattle grazing)