Tropospheric methane and carbon dioxide over West Siberia: observation data analysis, surface flux inventories and transport modeling

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Contents:

- Atmospheric observation network
- Inverse modeling of the Siberian surface CO_2 fluxes
- Model – observation comparison for methane

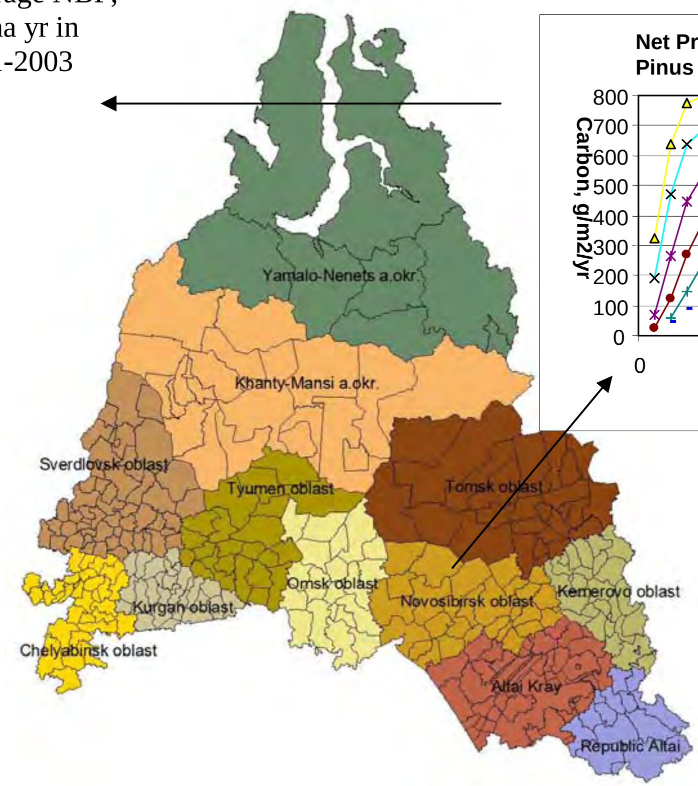
Bottom up. Empirical modeling of the forest carbon stock inventory and dynamics

Forest state account (FSA) based: provides observations of the wood stock and annual change in forest area by category (felling, fire, etc),

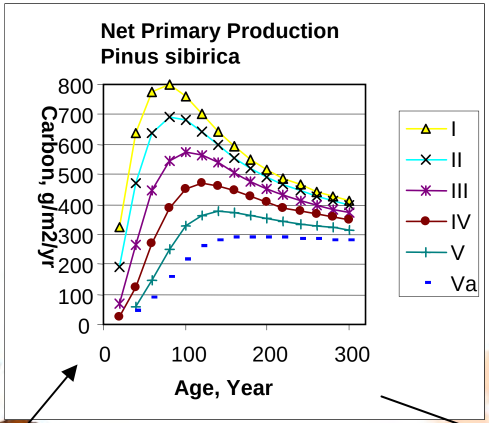
FSA data for each unit: wood stock, area - by species, age class

Region	Average NBP, t C/ha yr in 1961-2003
Alt Kray	0.54
Rep Altai	0.89
Kemerovo	0.43
Kurgan	0.92
Novosib	0.76
Omsk	0.72
Sverdlovsk	0.49
Tomsk	0.35
Tjumen	0.47
Khanty- Mansi	0.25
Jamalo-Nenetsk	0.18
Cheljabinsk	0.76

Shvidenko et al 2006

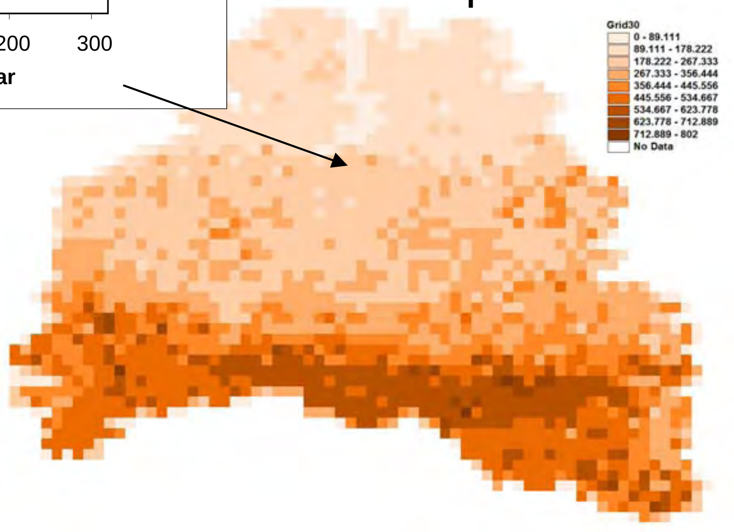


FSA: regions and enterprises



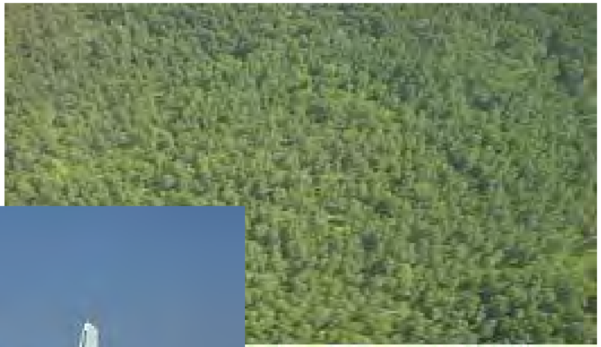
Empirical dynamic model

NPP map



1. Observations: airborne air sampling and analysis

Surgut
1993 –

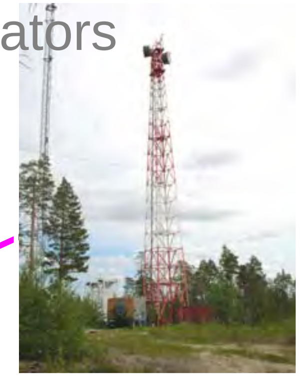


Novosibirsk

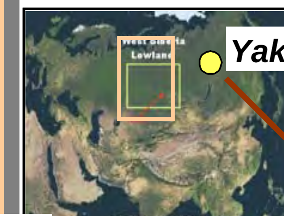
Yakutsk

Inverse modeling with dense regional networks: Siberia data by T. Machida (NIES) and collaborators

Igrim (IGR)
(63°12'N, 64°24'E)
47m, 24m



Noyabrsk (NOY)
(63°26'N, 76°46'E)
43m, 21m



Before 2006
From 2006-2007
Max Plank

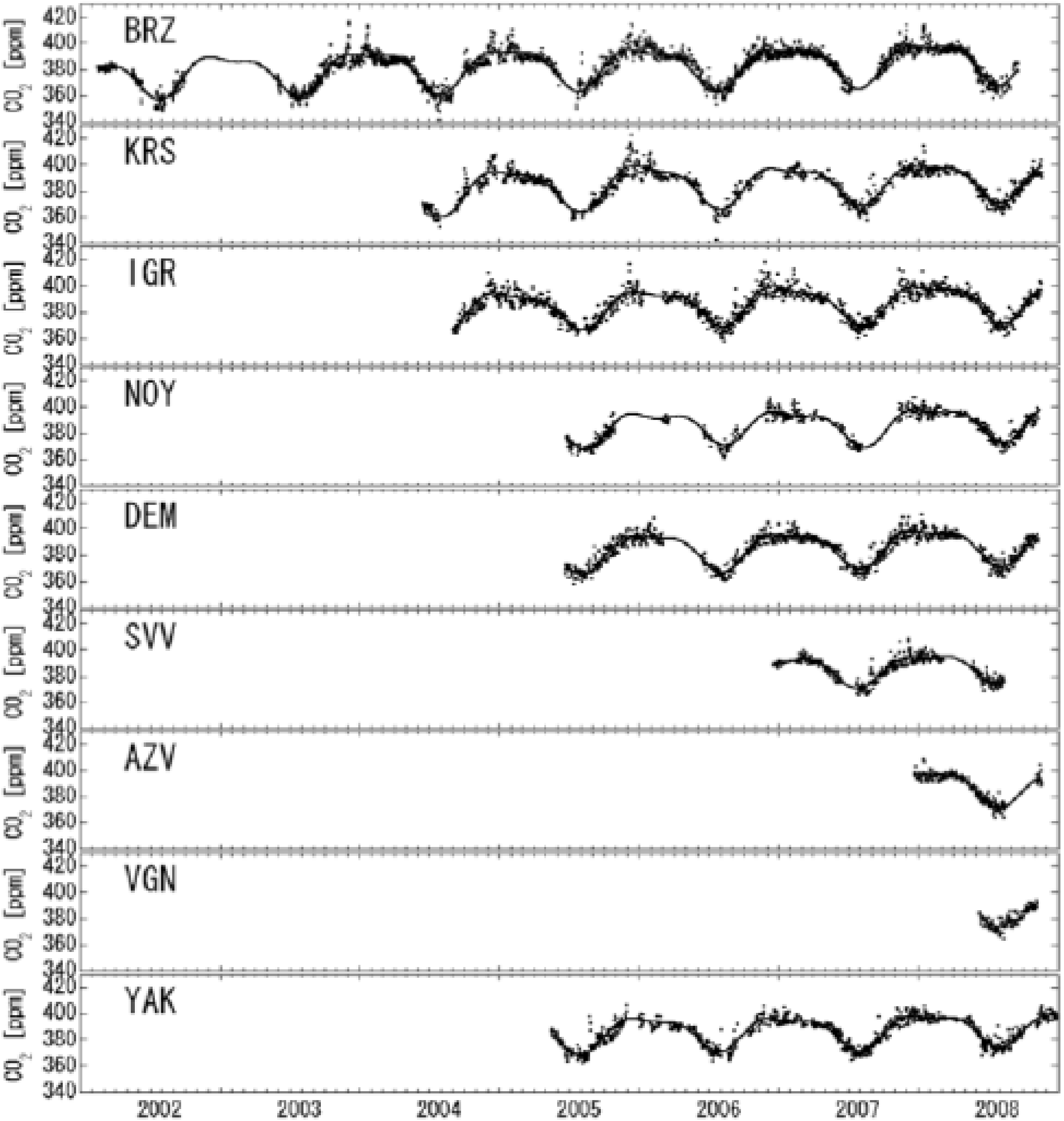
Demyanskoe (DEM)
(59°47'N, 70°52'E)
63m, 45m

Yakutsk (YAK)
(62°50'N, 129°21'E)
70m, 11m

Parabel (PRB)
(58°15'N, 82°24'E)
67m, 35m

Berezorechka (BRZ)
(56°09'N, 84°20'E)
80m, 40m, 20m, 5m

Top-down approach to estimation of the regional carbon budget in West Siberia



CO_2 observations, day-time hourly data

Method: Inverse model of the atmospheric CO2 transport is applied to constrain surface CO2 fluxes by the observed patterns of the atmospheric CO2 (with seasonal cycles)

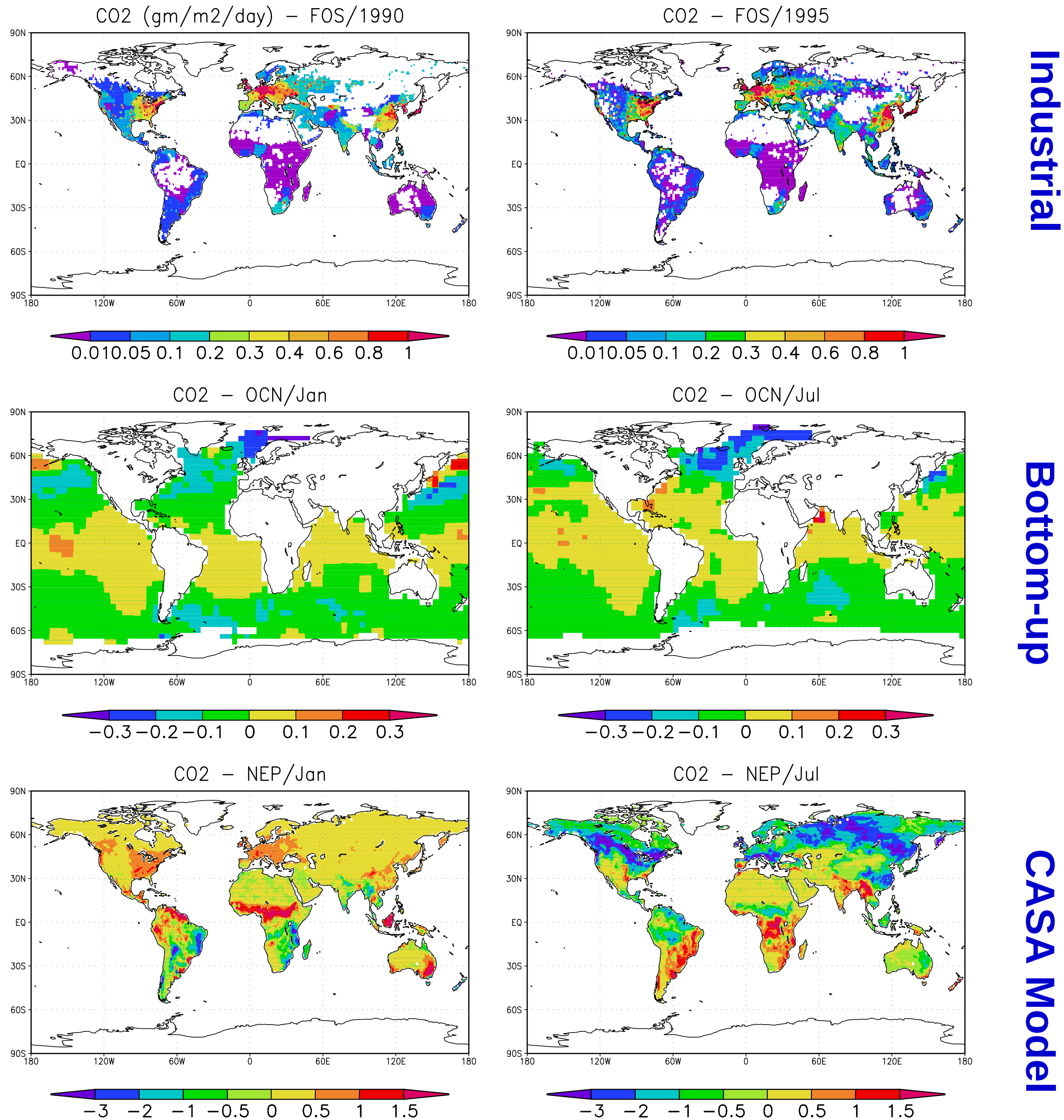
Components:

1. Forward models: terrestrial ecosystem flux model (hourly to seasonal scale): coupled to atmospheric transport model.

2. Inverse model of atmospheric transport, finding optimal corrections to the surface fluxes

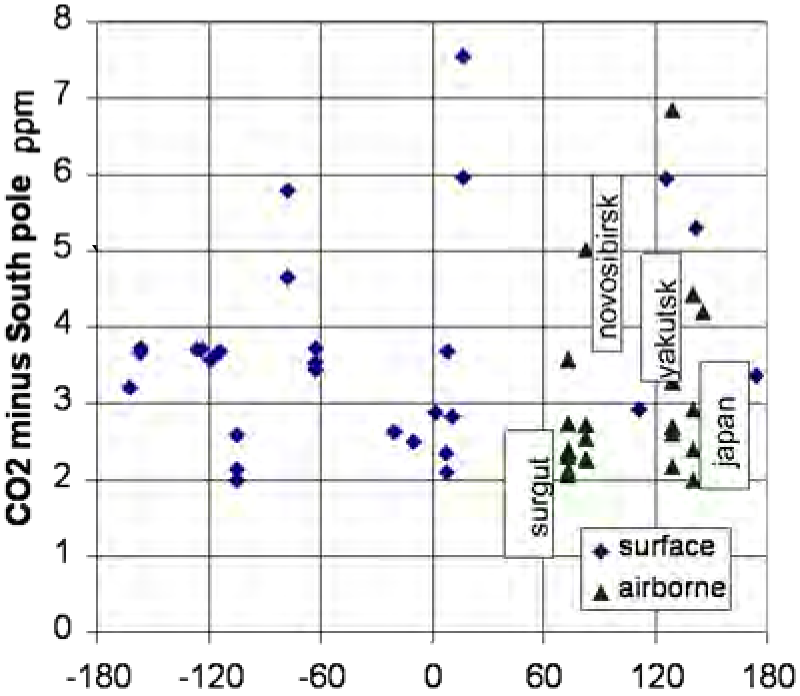
Known distributions of CO2 sources/sinks:

From
fossil fuel burning
(annual, upper),
ocean exchange
(monthly, middle),
terrestrial ecosystem
(monthly, lower)



Inverse modeling of regional CO2 fluxes with annual mean observations.

Observations (North of 30N)



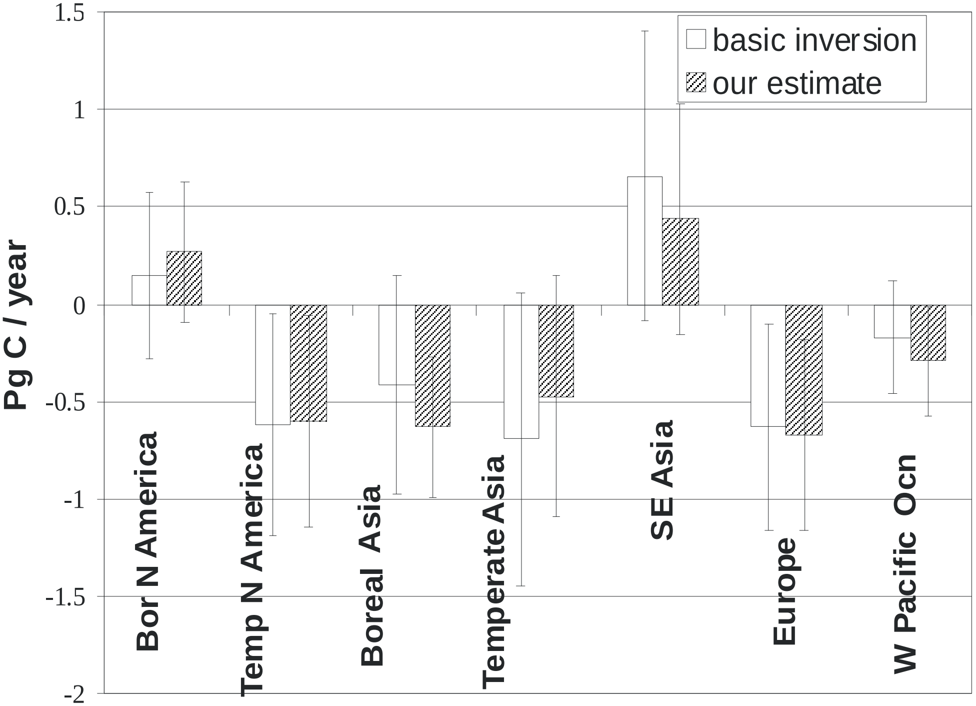
Coarse resolution inverse model, with annual mean observation used to constrain annual mean fluxes.

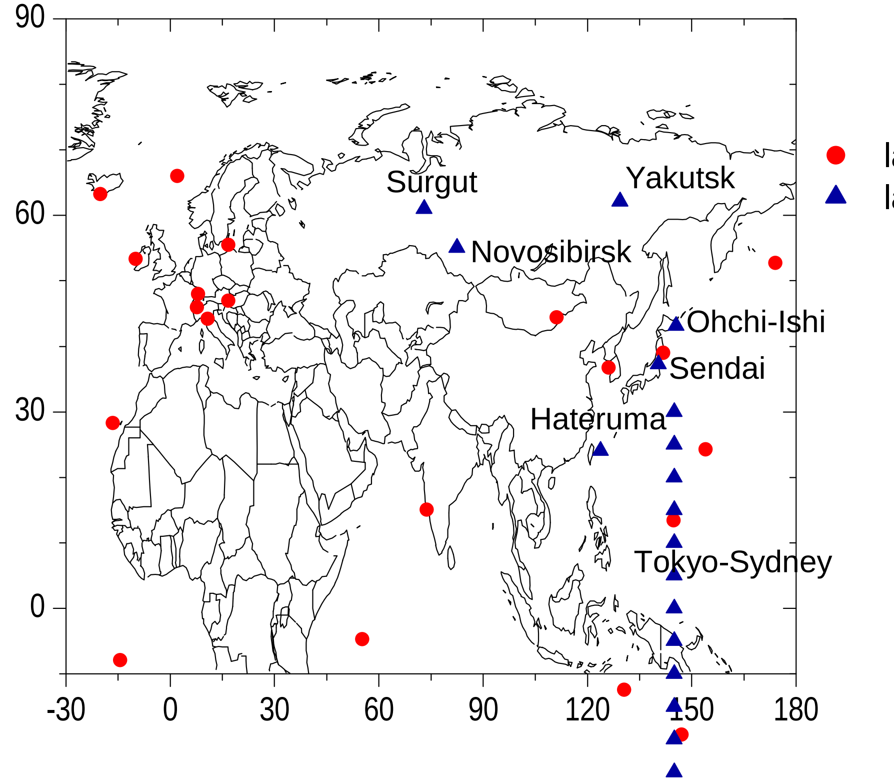
Gurney et al Nature 2002

West ----- Longitude ------ East

Higher CO2 over emitting regions: N.America, Europe, East Asia

Asian flux estimates, improved by recent observations.



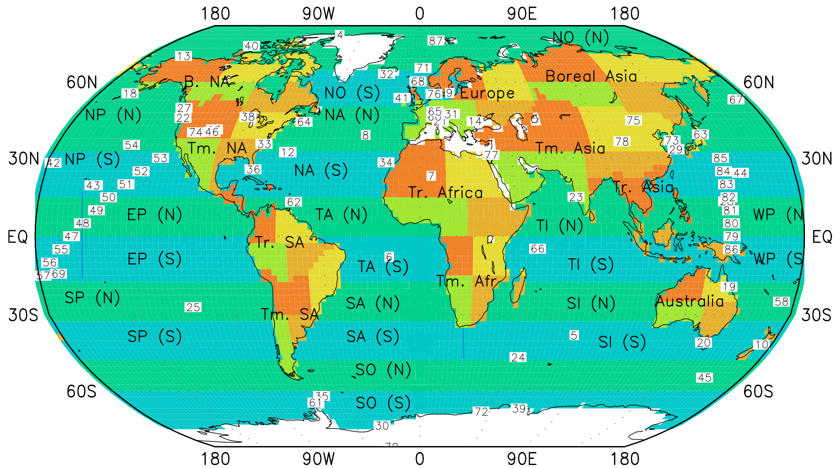


Changes in estimated annual mean fluxes (left) due to adding the observations (right)

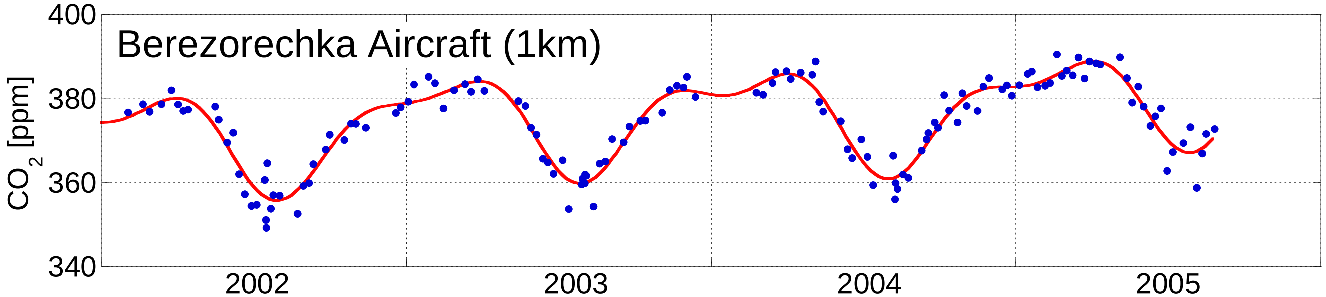
Maksyutov et al., Tellus, 2003

Top down: atmospheric transport and inverse modeling

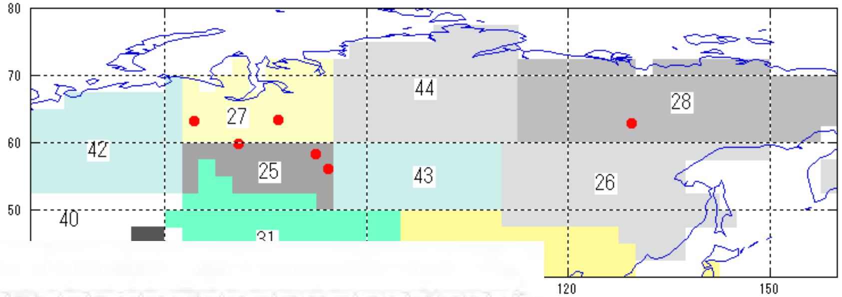
Region based inversion 64 regions monthly
global 2.5deg transport, monthly fluxes

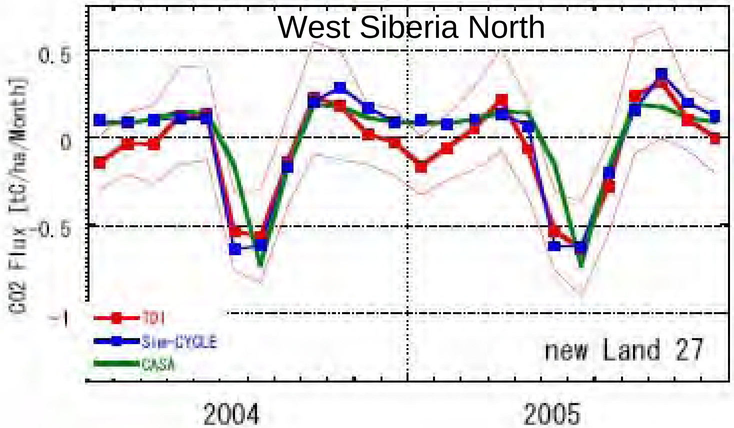


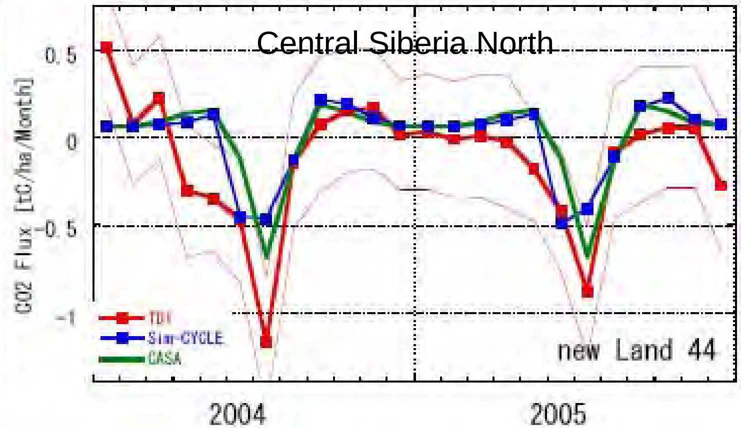
Monthly flux pulses from each region are
used to fit monthly average observations



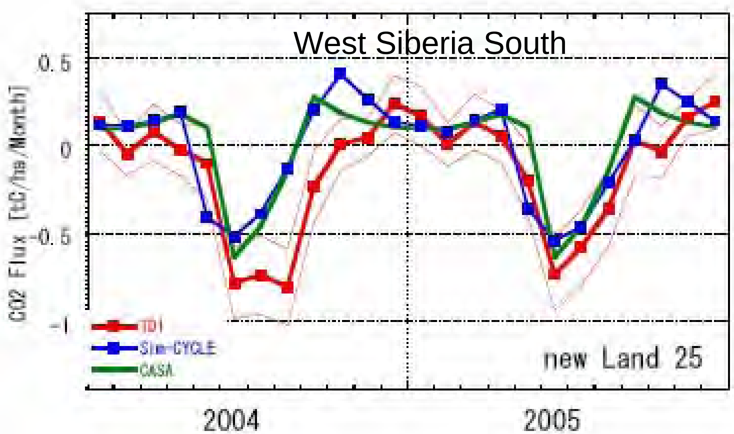
Siberian inverse model fluxes with 66 region inversion

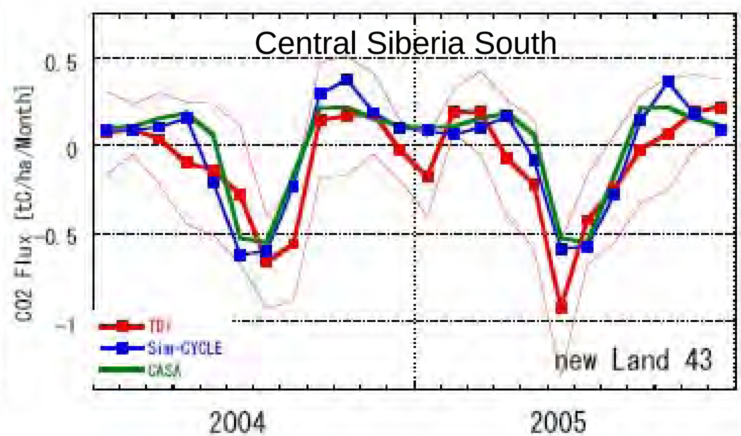






Several sites ↔ No observations





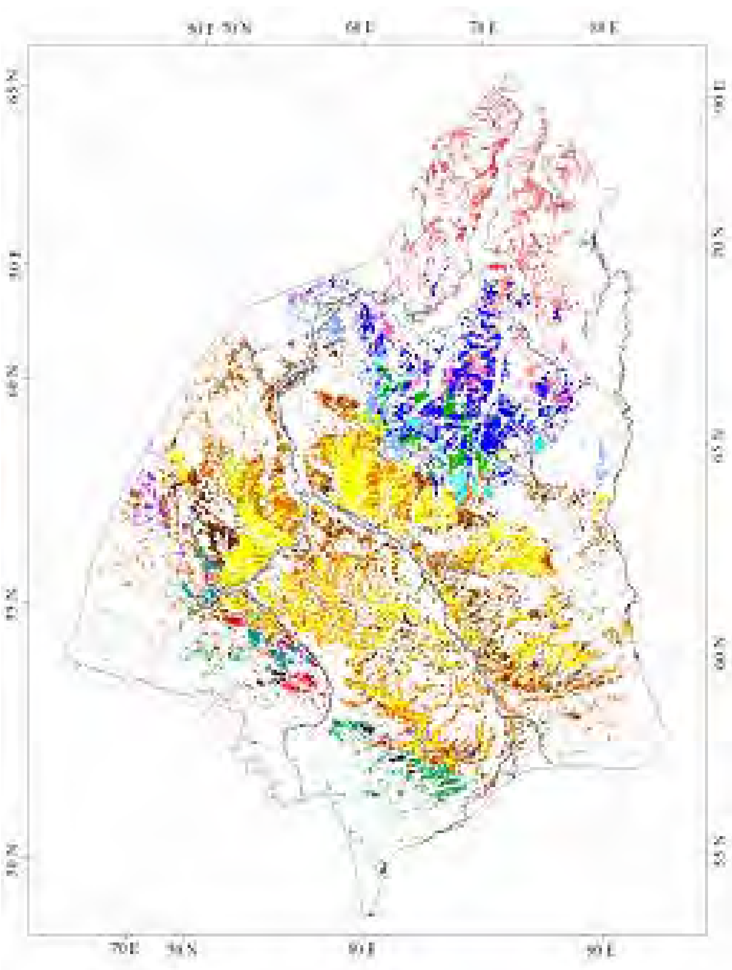
Red - inverse model, green – CASA, blue – Sim-Cycle
Inverse model 2004 – spin-up, 2005 - use actual data

Summary

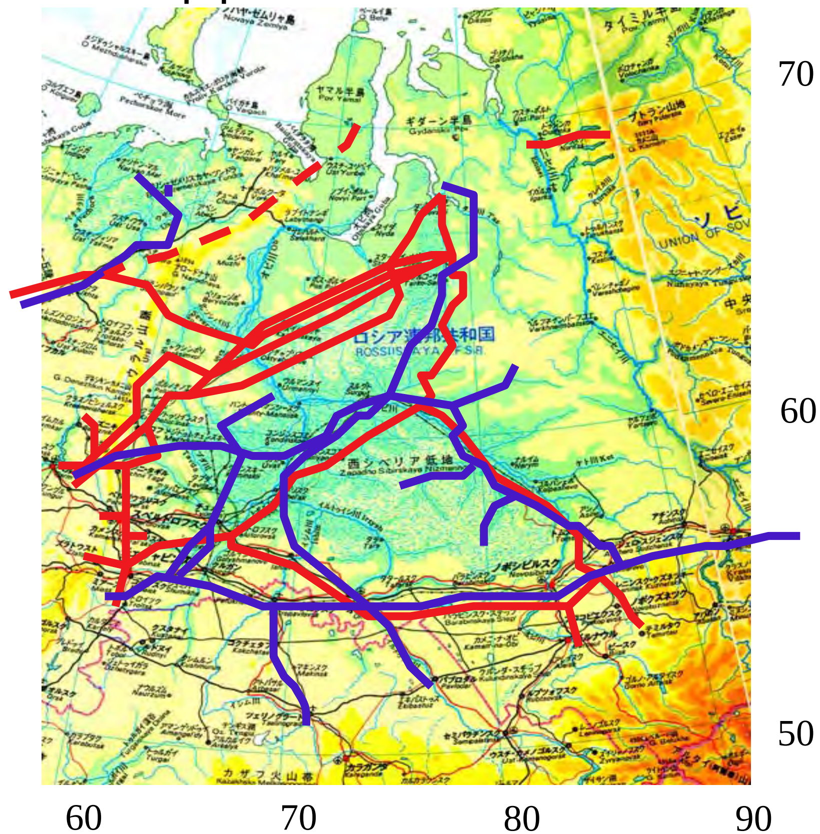
Inverse model study of seasonal flux variability suggests the observational data are useful for estimating the regional CO2 flux seasonality, provided there are enough observations, adjusting and validating large scale flux simulations with biogeochemical models at monthly and daily time scale. The annual mean flux estimation requires more accurate analysis and is relatively less robust.

Using the tower observations we confirmed that earlier flux drawdown simulated by Sim-Cycle model in northern West Siberia is fitting the observed CO2 better than with CASA model. Amplitude-wise both models agree with inversion within model uncertainty range during warm season.

Why observe methane over west Siberia? Two major emission sources with large uncertainties: (a) wetlands, (b) gas, oil fields and pipelines

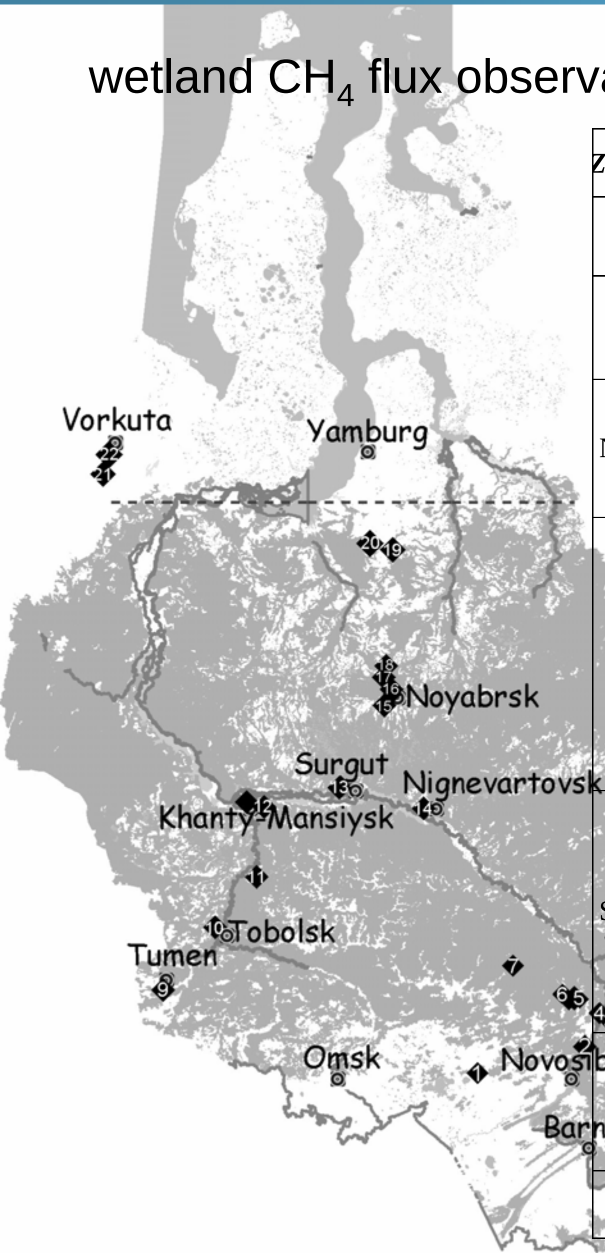


Wetlands: 25-50% of the area



Pipelines: red – gas, blue - oil

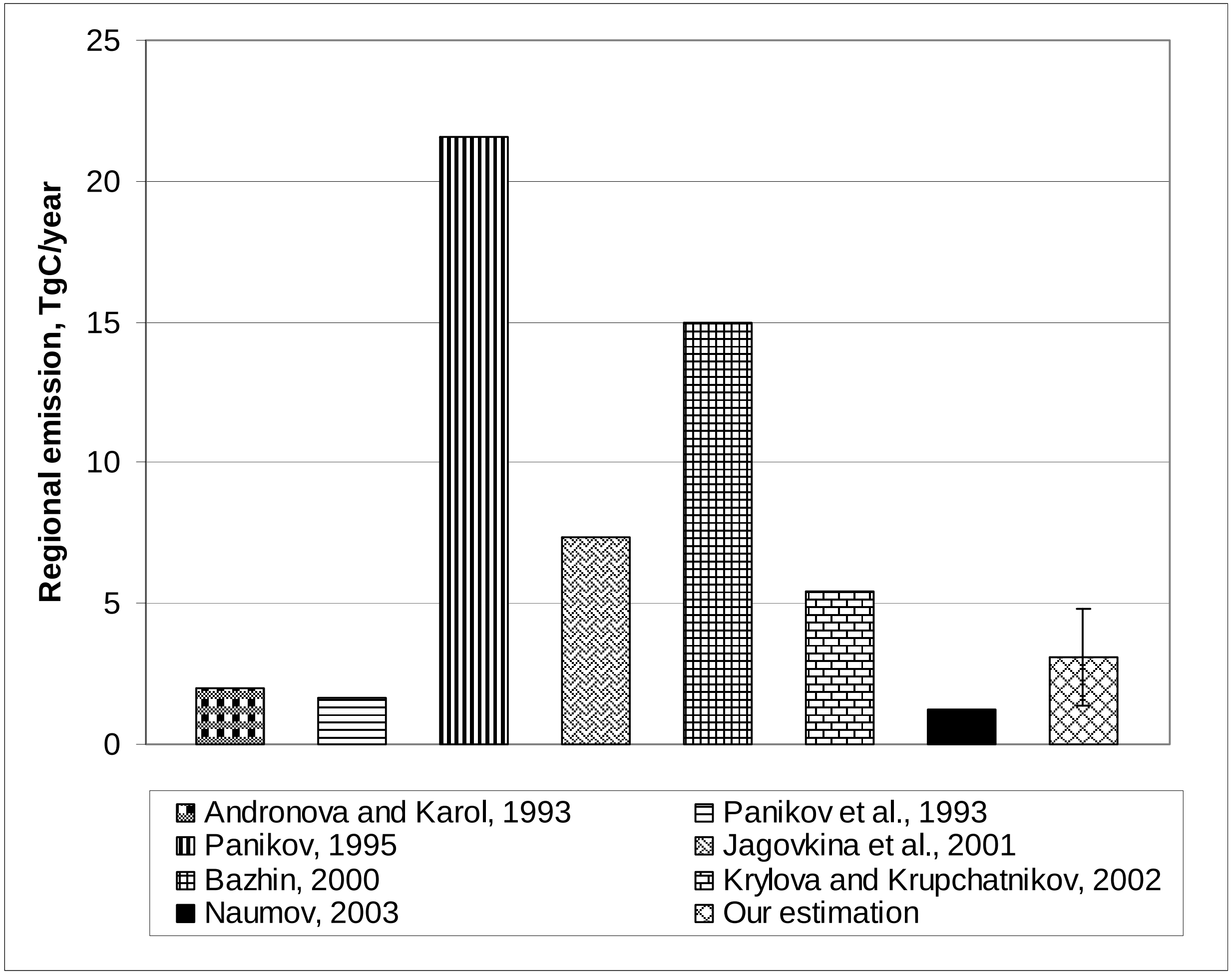
wetland CH_4 flux observations database



Average fluxes by climate zone

Zone or subzone	*Ecosystem*[1)]	*Flux*[2)], $mgC\cdot m^{-2}\cdot h^{-1}$	*Error*[3)], $mgC\cdot m^{-2}\cdot h^{-1}$	*Source of information*
Tundra	Palsa	-0.06 (3)	-0.17/-0.03[κ]	[Slobodkin et al., 1992] and own data (2003)
	Hollow	1.61 (9)	0.59/1.98[κ]	
Forest Tundra	Palsa	0.22 (31)	0.04/0.36[κ]	[Naumov et al., 2007], own data (2003, 2007)
	Hollow	1.21 (36)	0.77/1.41[κ]	
	Lake	0.19[a] (4)	0.09[σ]	[Naumov et al., 2007]
Northern Taiga	Palsa	0.00 (10)	-0.13/0.01[κ]	[Naumov, 2001]
	Unforested bog	0.62, 0.62[a] (9)	0.42/0.83[κ], 0.35[σ]	
	Hollow of RHC	0.86 (11)	0.58/1.05[κ]	[Naumov, 2001] and own data (2007)
	Ridge of RHC	0.00 (8)	0.00/0.27[κ]	
Middle Taiga	Fen	3.58, 3.59[a] (43)	2.03/5.25[κ], 2.12[σ]	[Naumov et al., 2007], own data (2006-2007)
	Hollow of RHC	1.83 (60)	0.78/7.25[κ]	
	Ridge of RHC	0.45, 0.40[d] (8)	0.23/0.65[κ], 0.27[Σ]	Own data (2006-2007)
	Ryam	0.31 (34)	0.09/0.87[κ]	[Tohjima et al., 1995; Naumov et al., 2007], own data (2006-2007)
	Pond	1.28[a] (6)	1.28[σ]	[Naumov et al., 2007]
	Lake	0.25[a] (7)	0.28[σ]	
Southern Taiga	Eutrophic hollow	3.55 (84)	2.46/6.35[κ]	[Sergeeva and Zadorozhnaya, 2006] and own data (2003-2006)
	Fen	4.16 (180)	2.59/7.91[κ]	
	Hollow of RHC	2.74 (47)	1.01/4.44[κ]	
	Ridge of RHC	1.70 (37)	1.05/2.77[κ]	
	Ryam	1.26 (109)	0.28/2.94[κ]	
	Lake	3.10 (11)	0.06/17.94[κ]	
	Waterlogged Forest	0.21 (7)	0.05/0.61[κ]	
Subtaiga	Eutrophic hollow	15.80 (21)	8.82/18.10[κ]	Own data (2003-2007)
	Hollow of RHC	3.40 (3)	2.68/3.51[κ]	Own data (2006)
	Ridge of RHC	0.57 (3)	0.54/1.12[κ]	
	Ryam	0.21, 0.66[a] (23)	1.37[σ]	[Panikov, 1994]
Forested steppe	Ryam	0.26, 0.26[d] (4)	-0.11/0.42[κ],0.17[Σ]	Own data (2007)

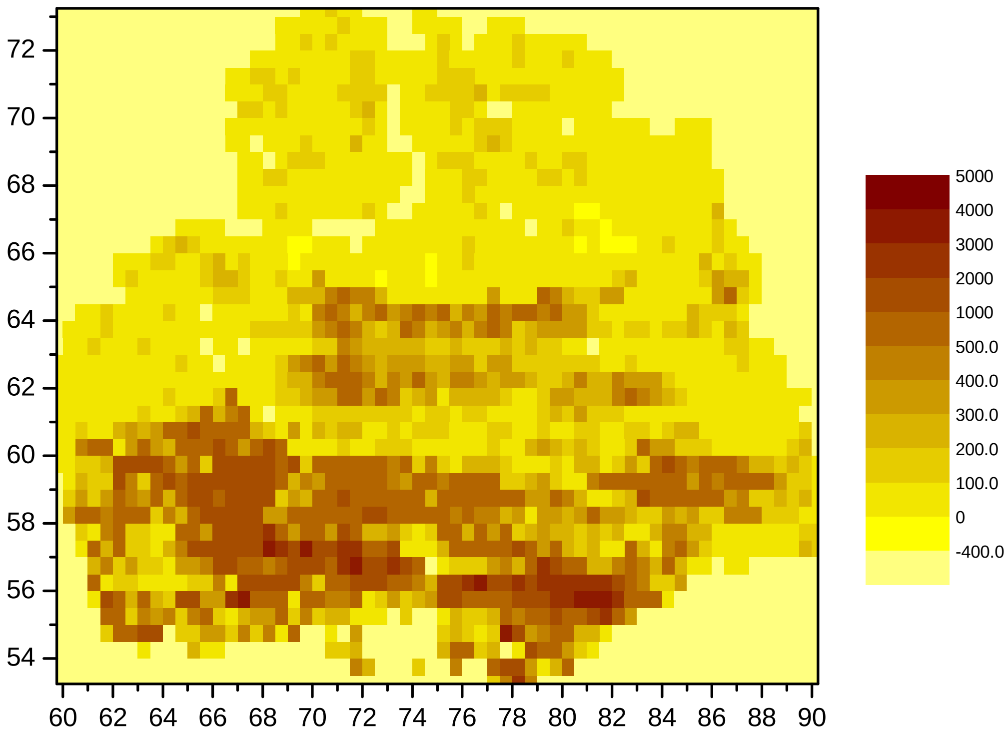
Wetland methane emission estimates. Annual mean. (Compiled by M. Glagolev 2007)



Matthews and Fung 1987 – around 5 Tg

Methane emissions map

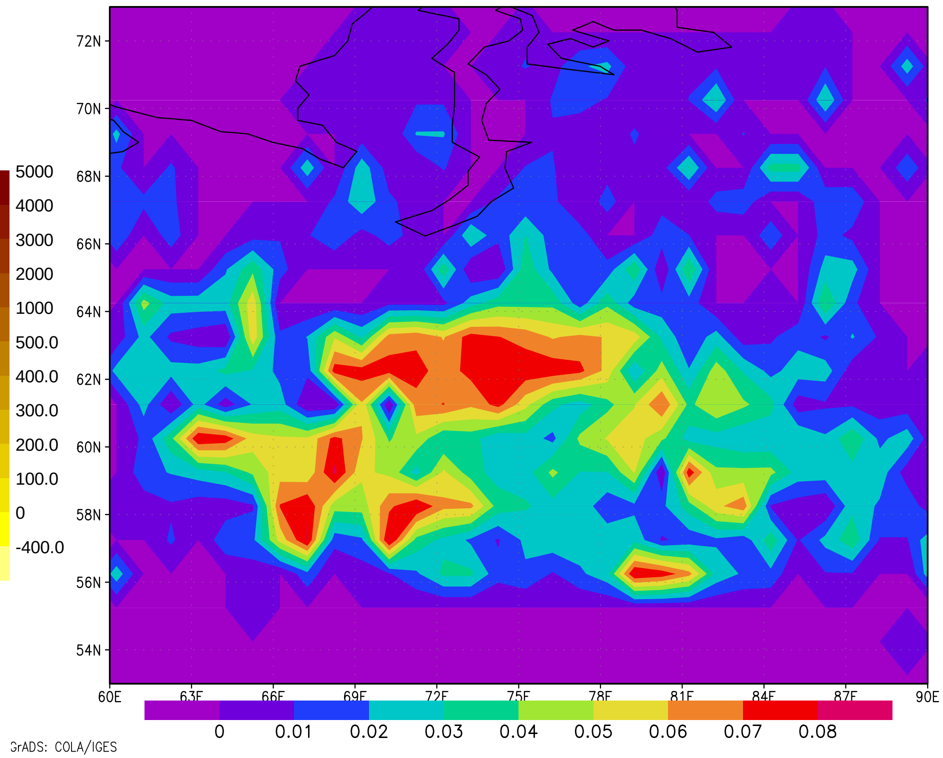
Our estimate (Glagolev et al, 2008, 2009)



Units: kgC/hour/grid cell (0.5x0.5 deg)

1000 kg/grid=0.16 mg/m2

Matthews & Fung, 1987



Units: gCH4/m2/day

Wetland classification by Matthews too simple: bogs, emissions biased towards north of 60 N, due to larger wetland area

Summary

Vertical profile observations point to significance of regional emissions both in winter (gas leak) and in summer (gas leak plus wetlands)

Models of emissions and transport are reasonable in reproducing vertical gradients given the uncertainty incorporated in the emissions and transport model errors.

Seasonality of both emission models and transport can be tuned more.

Atmospheric observations support fluxes should be corrected in southern part (southern taiga wetland contribution as a candidate)

Acknowledgements

Establishment of the research/monitoring program

G. Inoue (NIES/now RIHN, Kyoto), T. Nakazawa (Tohoku Univ, Sendai)

Observations operated by

M. Arshinov, B. Belan (IAO, Tomsk), N.Vinnichenko (CAO, Moscow Reg.)

Contents

- Why observe methane in Siberia
- Surface fluxes: observations and mapping
- Vertical CH_4 profiles
- Models: transport and emissions
- Seasonal cycle: comparison with observations

Flux table (2008)

Zone or subzone	***Microlandscape***[1)]	***CH_4 flux, $mgC \cdot m^{-2} \cdot h^{-1}$***		***Source of information***
		F[2)]	***Err***[3)]	
Northern Taiga	Palsa	0.00^{m} (10)	$-0.13/0.01^{\kappa}$	[Naumov, 2001]
	Unforested bog	0.62^{m}, 0.62^{a} (9)	$0.42/0.83^{\kappa}$, 0.35^{σ}	
	Hollow of RHC	0.86^{m} (11)	$0.58/1.05^{\kappa}$	[Naumov, 2001] and own data (2007)
	Ridge of RHC	0.00^{m} (8)	$0.00/0.27^{\kappa}$	
Middle Taiga	Fen	3.58^{m}, 3.59^{a} (43)	$2.03/5.25^{\kappa}$, 2.12^{σ}	[Naumov et al., 2007], own data (2006-2007)
	Hollow of RHC	1.83^{m} (60)	$0.78/7.25^{\kappa}$	
	Ridge of RHC	0.45^{m}, 0.40^{d} (8)	$0.23/0.65^{\kappa}$, 0.27^{Σ}	Own data (2006-2007)
	Ryam	0.31^{m} (34)	$0.09/0.87^{\kappa}$	[Tohjima et al., 1995; Naumov et al., 2007], own data (2006-2008)
	Pond	1.28^{a} (6)	1.28^{σ}	[Naumov et al., 2007]
	Lake	0.25^{a} (7)	0.28^{σ}	
Southern Taiga	Eutrophic hollow	3.55^{m}(84)	$2.46/6.35^{\kappa}$	[Sergeeva and Zadorozhnaya, 2006] and own data (2003-2007)
	Fen	4.16^{m} (180)	$2.59/7.91^{\kappa}$	
	Hollow of RHC	2.74^{m}(47)	$1.01/4.44^{\kappa}$	
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	Lake	3.1^{m} (11)	$0.06/17.94^{\kappa}$	
	Waterlogged Forest	0.21^{m} (7)	$0.05/0.61^{\kappa}$	