Оценка потока метана из почв Росии на основе простейших математических моделей

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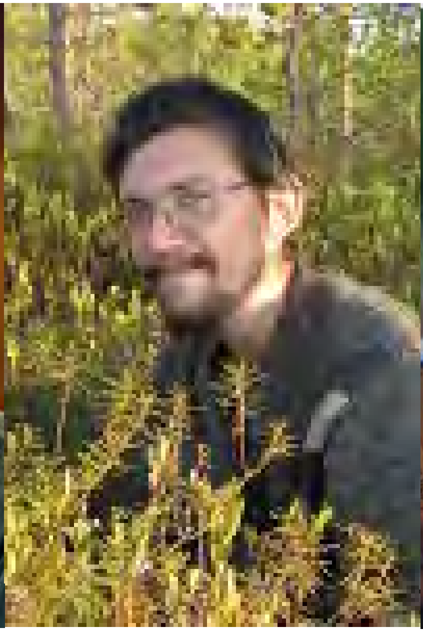
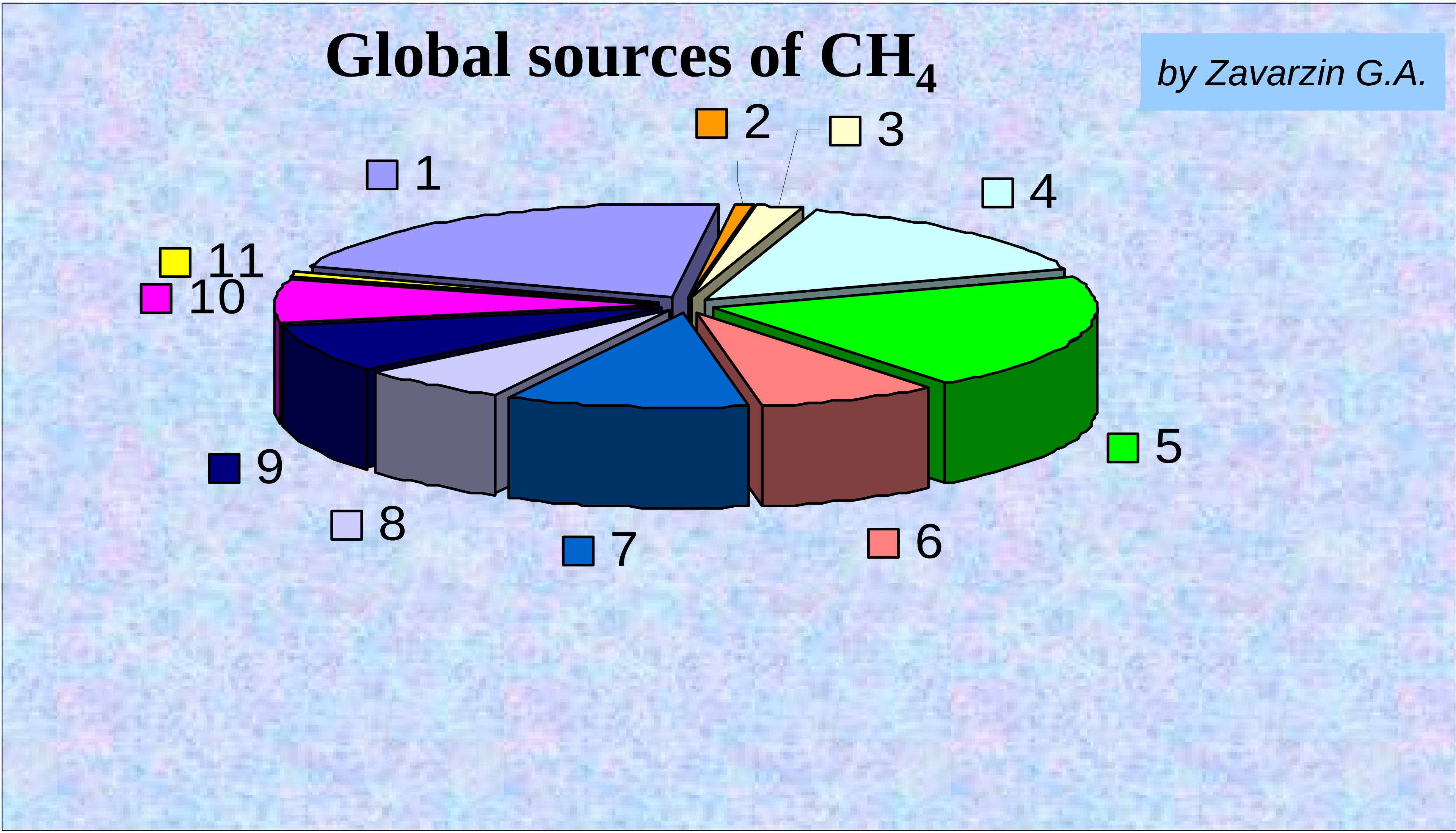


1- wetlands; 2 – gasehydrates; 3 - ocean; 4 – ruminant animals; 5 – rise fields; 6 - termites; 7 – biomass burning; 8 – coal mining; 9 – natural gas; 10 - landfills; 11 – freshwater bodies.

CH_4 flux measurements in Russia

Calculation of methane emission on the regional scale

$$F = \sum_{k}(S_k \cdot \mu_k \cdot q),$$

F – (gC·yr^{-1}) annual methane emission;

S_k – area of k-th sub-region (m^2);

μ_k – part, occupied by mires inside k-th area;

q – CH_4 flux (gC·m^{-2}·yr^{-1}).

For calculations of *q* we used several models:

Emission as a function of NPP [Taylor *et al*, 1991]:

$$q = c \cdot \text{NPP};$$ (MoTEA)

Miami-model for NPP [Lieth, 1975]:

$$q = b \cdot \min\{[1+\exp(1.315-0.119 \cdot T)]^{-1}, 1-\exp(-0.000664 \cdot P)\},$$ (MoTaM)

T – average annual temperature (°C),

P – annual precipitation (mm).

Model for NPP from [Puzachenko, 2010]: (MoTaP)

$$q = e \cdot \{76.76 \cdot T_K - 0.1323 \cdot T_K^2 - 530.9 \cdot \ln(P) + 65.51 \cdot [\ln(P)]^2 - 7.249 \cdot (T_K/P) + 0.0123 \cdot (T_K/P)^2 - 9958.25\}, \quad T_K = T + 273.15$$

Model for NPP from [Naumov, 2010]:

$$q = d\cdot(19.958 - 0.0328\cdot x - 0.003\cdot x^2) \qquad \text{(MoTaN)}$$

x - ° north latitude;

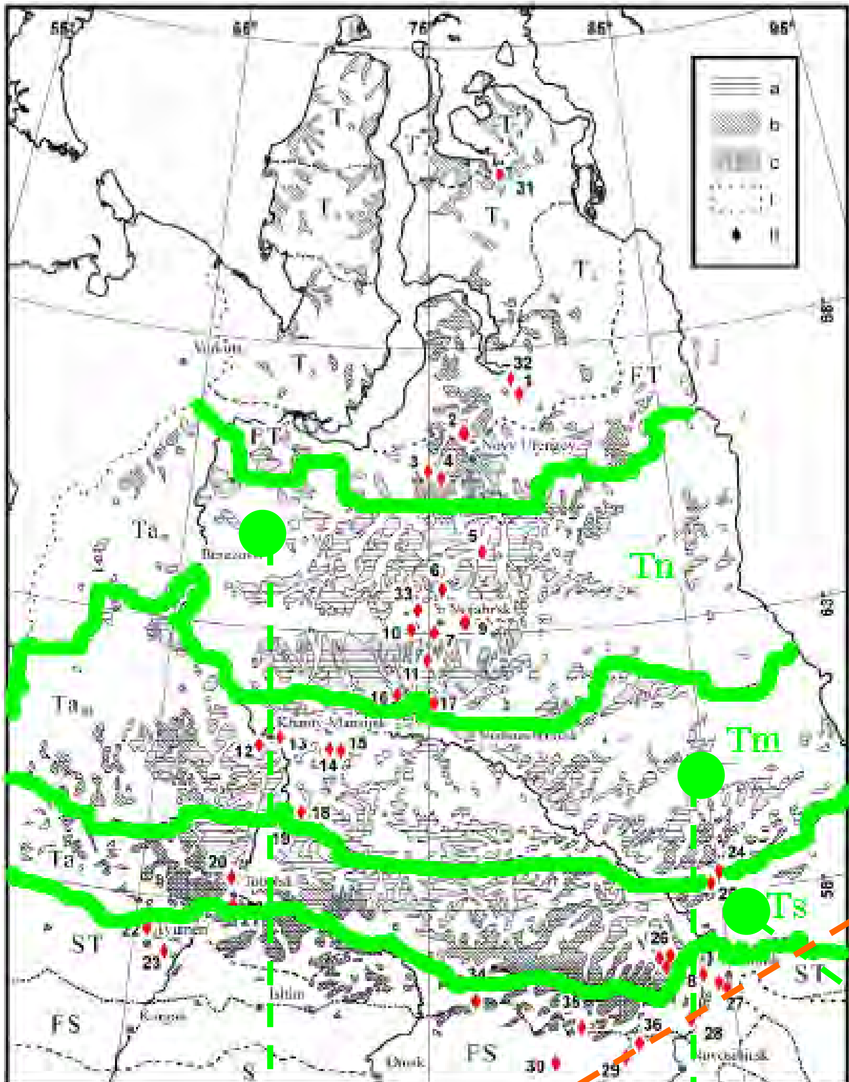
Model of dynamics of soil organic matter [Andronova and Karol, 1993]:

$$q = a\cdot(0.0253\cdot T_K - 6.531)\cdot(8.322\cdot T_K - 2054) \qquad \text{(MAK)}$$

Median model:

MoMed = median(MoTEA, MoTaM, MoTaP, MoTaN, MAK)

Identification of model parameters (a, b, c, d, e)

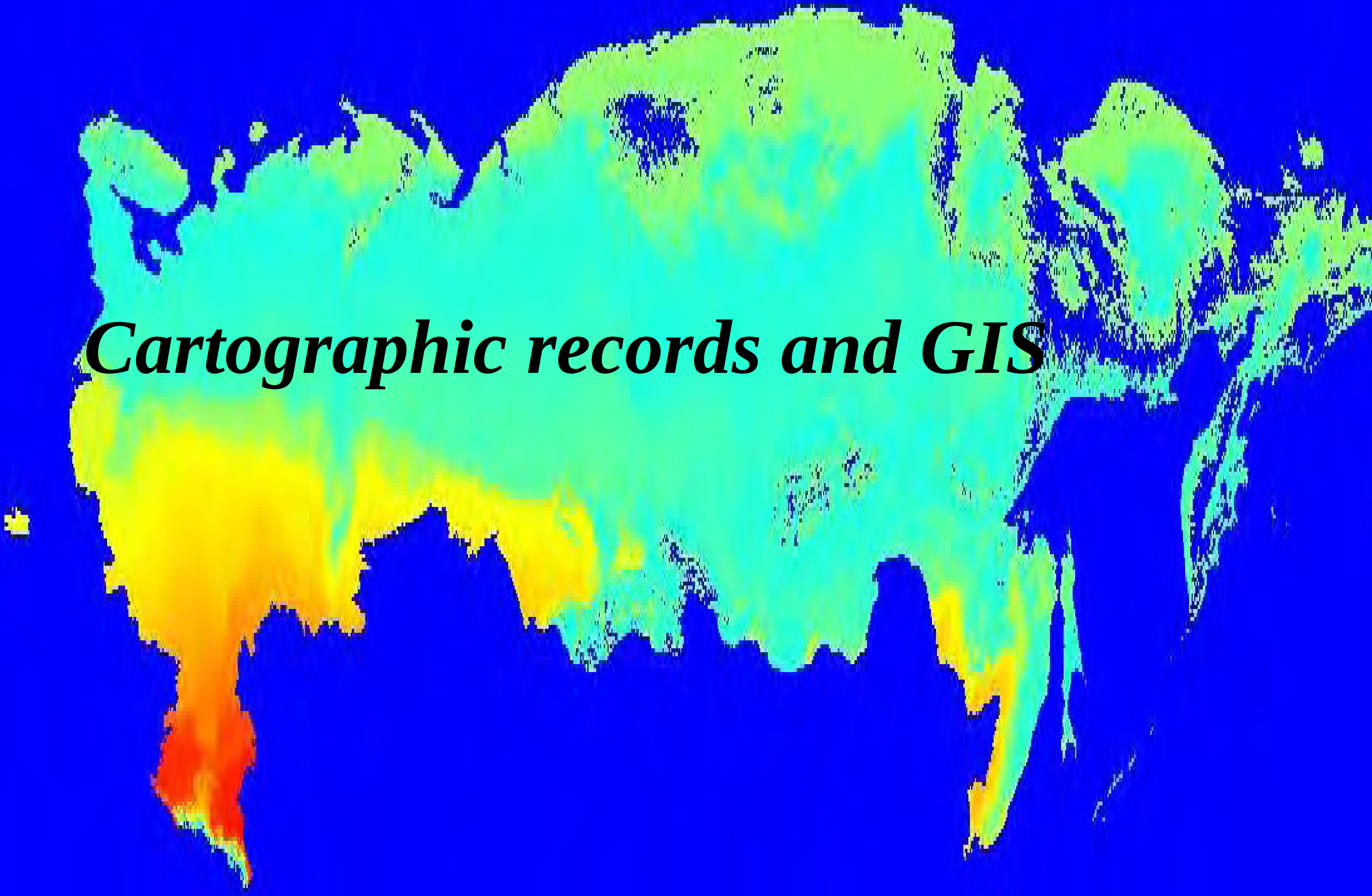


F_N; F_M; F_S

min (SS)

$$SS = [(Q_N - F_N)/Q_N]^2 + [(Q_M - F_M)/Q_M]^2 + [(Q_S - F_S)/Q_S]^2$$

Cartographic records and GIS

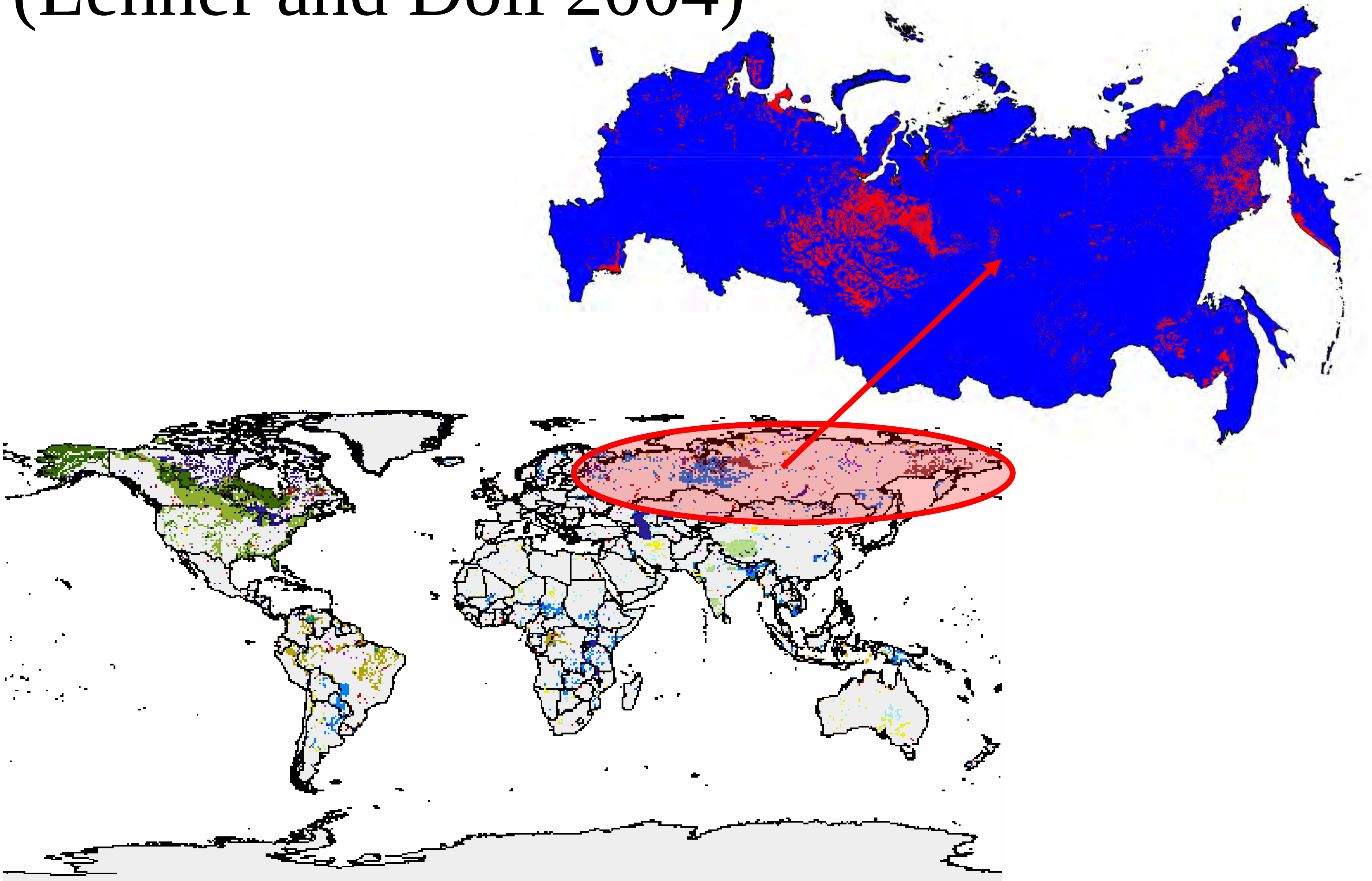


Layer of border constituents of Russian Federation

(http://gis-lab.info/qa/rusbounds-rosreestr.html)

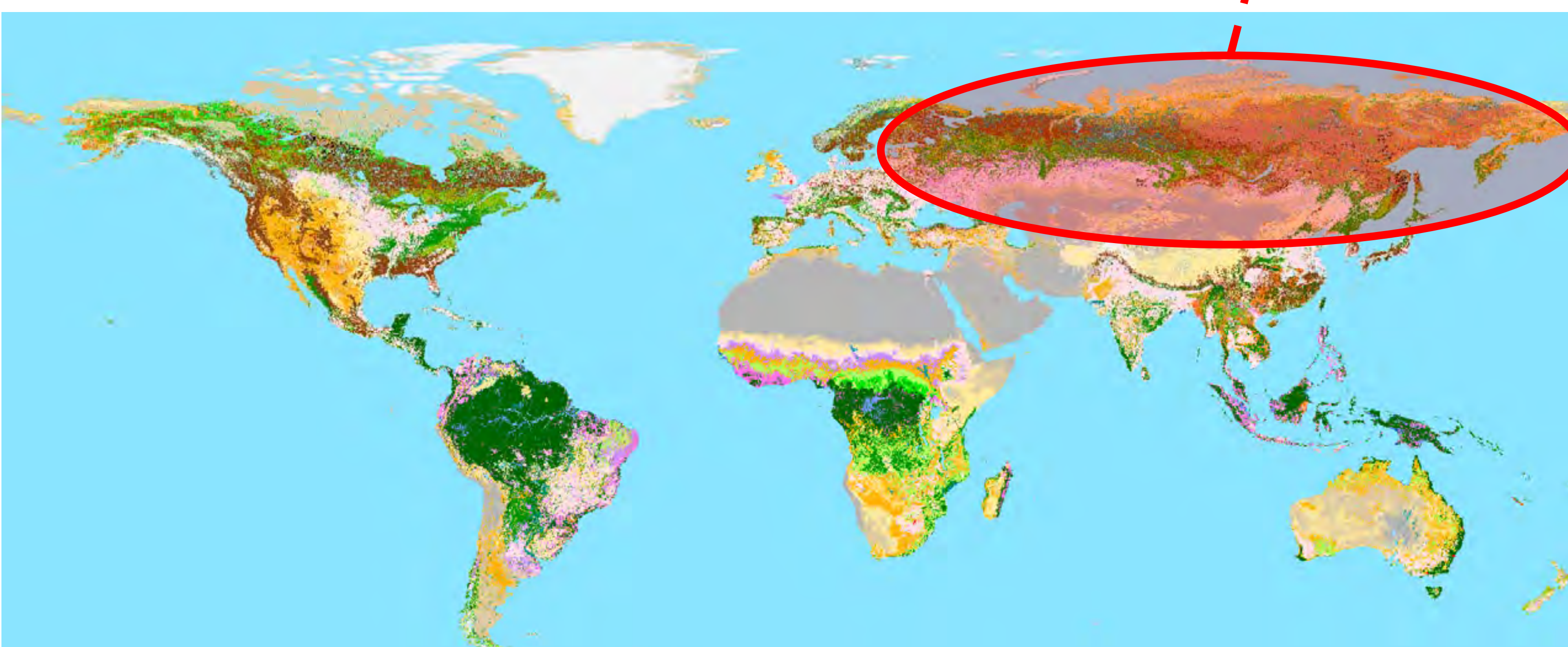
Mire mask from GLWD3 data set

(Lehner and Döll 2004)



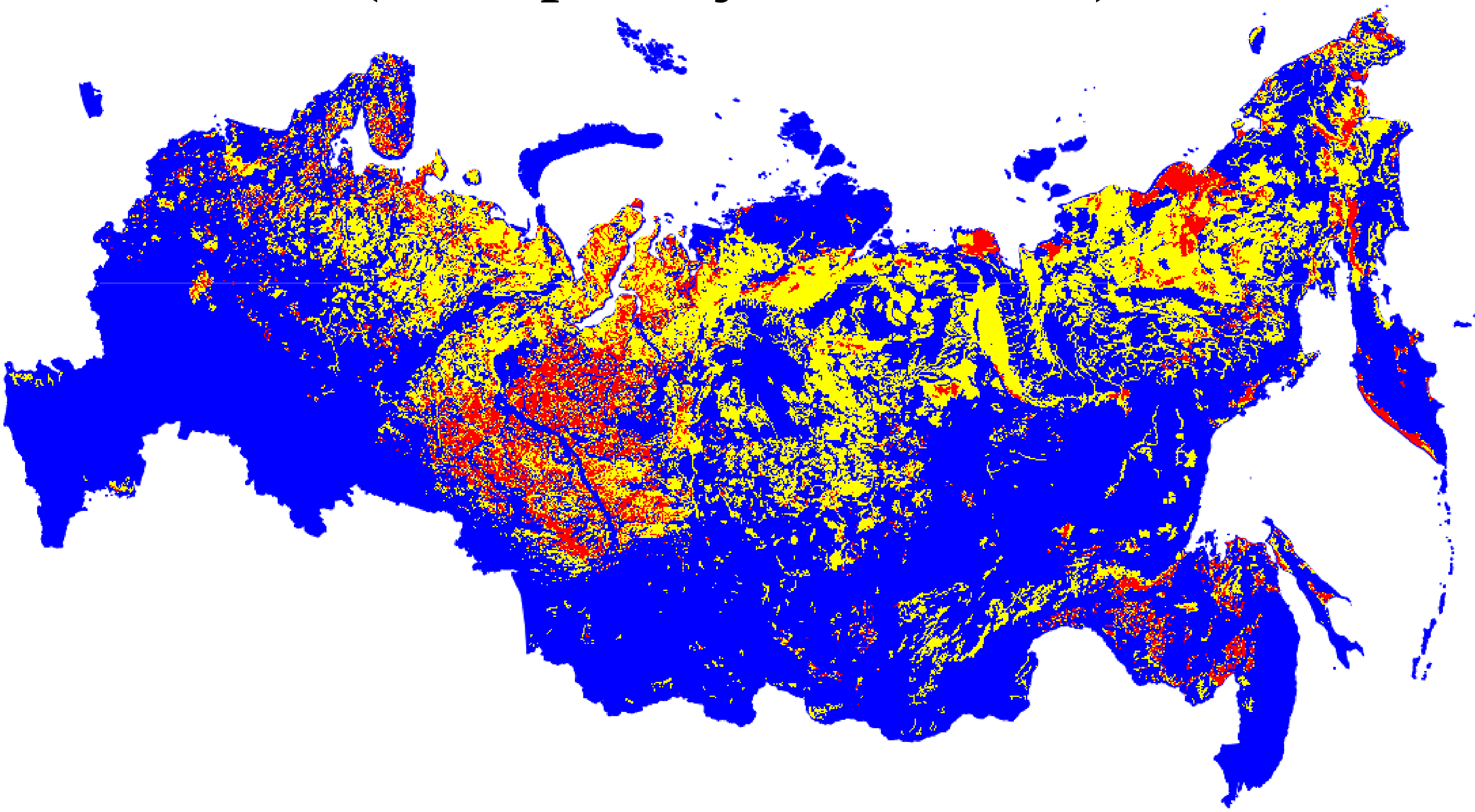
Mire mask from GlobCover v. 2.3 data set

(Bontemps *et al* 2011)

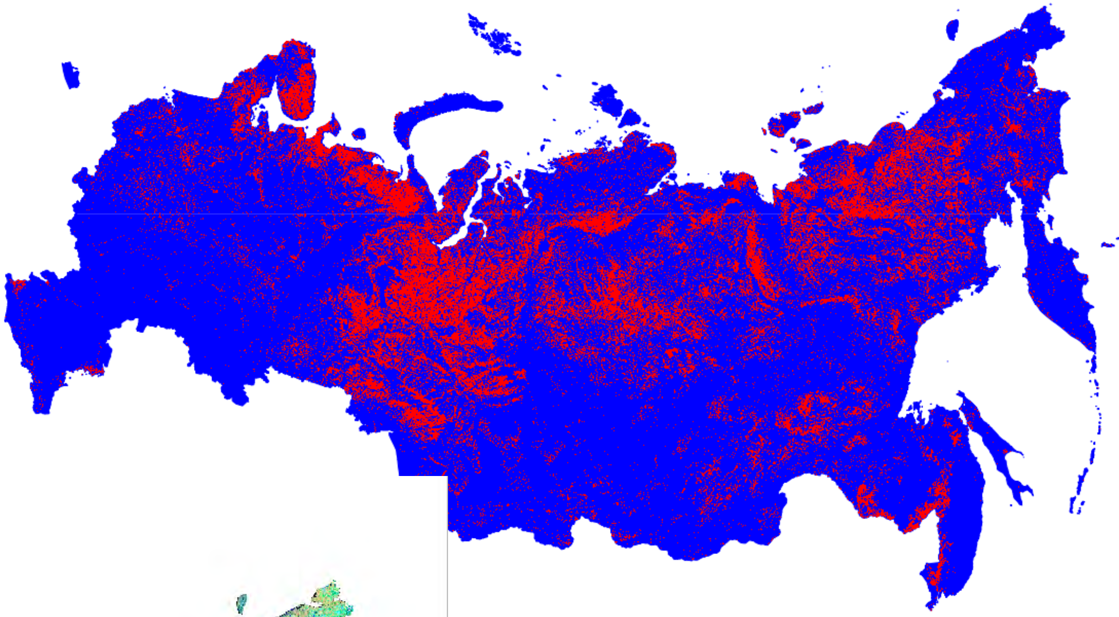


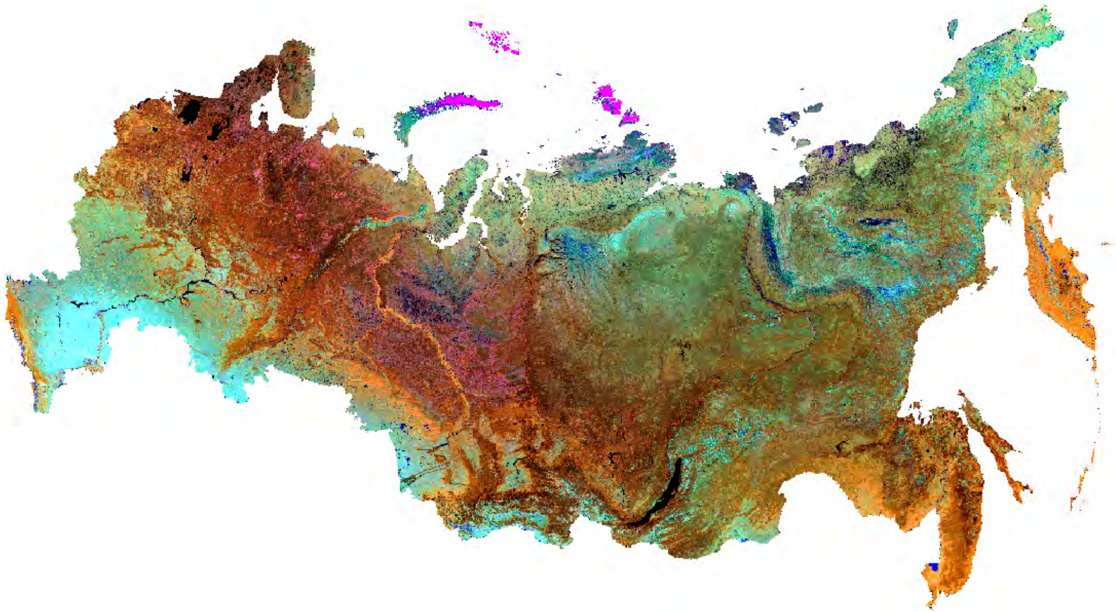
Data set “Peatland Ecosystems of Russia”

(Vompersky *et al* 2011)



PeatMap1





MODIS MCD43A4 land surface reflectance product. The recording period of space images was between 2000 and 2012. The recording range was between 12th and 20th of August.

Creation principles of Filippov’s wetland map “PeatMap1”

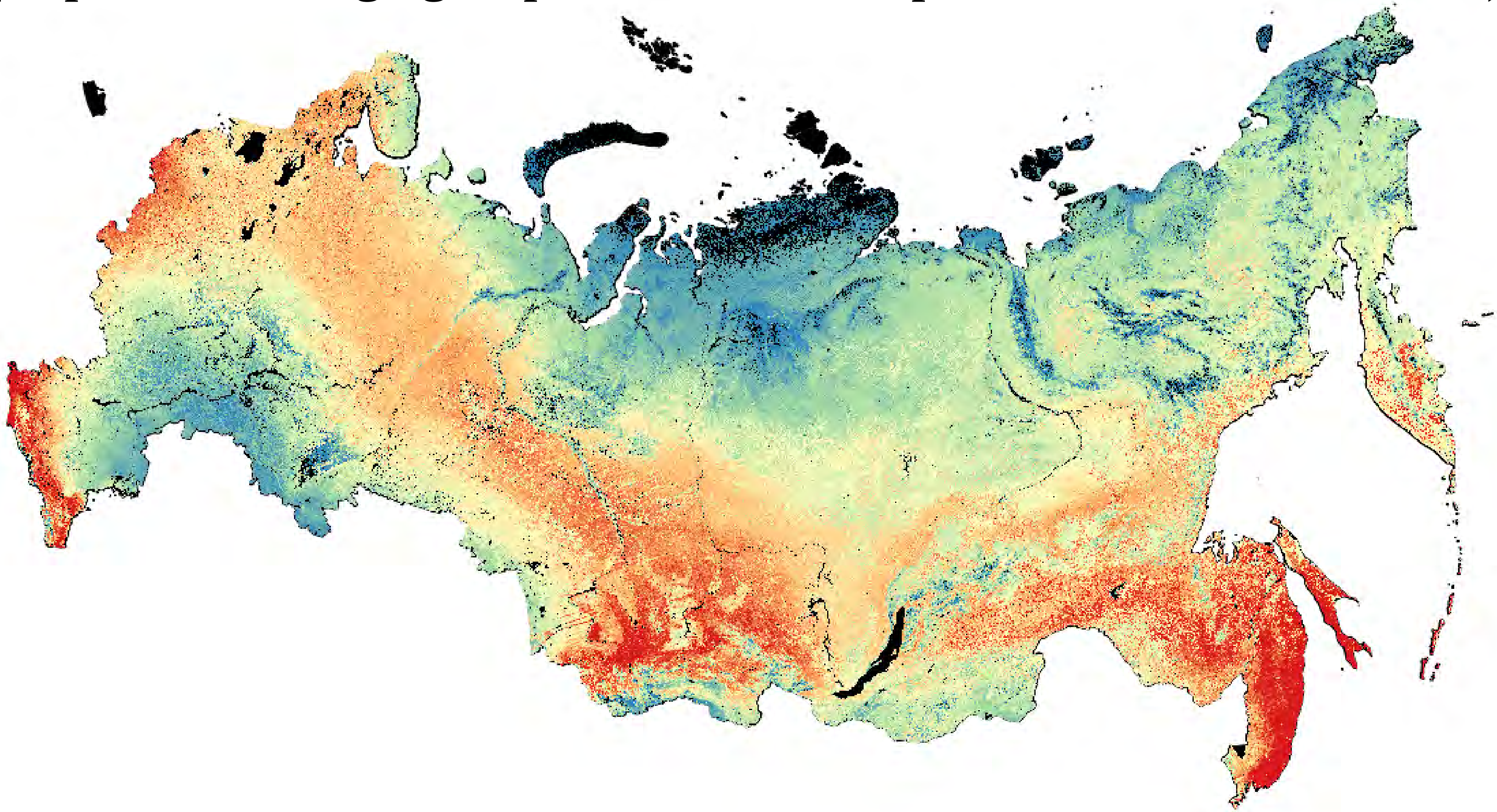
- 500-meter MODIS MCD43A4 land surface reflectance product was used (channels 2:6:1):

https://lpdaac.usgs.gov/products/modis_products_table/mcd43a4

- A interval of years: 2000-2012;
- Time period: 12-20 August;
- Median filter was applied;
- 2 methods of classification: Random Forest and i.smap for GRASS GIS.

Product MOD17A3 of MODIS space survey

(https://ldaac.usgs.gov/products/modis_products_table/mod17a3)



STATISTICS

Map accuracy calculation: Method

- Simple random sampling [Stehman, 1999];
- 1000 points [Congalton, 1991];
- 500 x 500 m area around each point;
- Visual checking with Google Map:

  point = “wetland” if >50% of area are wetlands;

  point = “non-wetland” otherwise;
- Visual checking at 1 : 200 000 topographic map (if necessary);
- Standard way of map accuracy calculation: [Congalton, 1991; Stehman and Czaplewski, 1998].

“Conditional kappa” calculation [Næsset, 1996]

		Классы в реальности							
		1	2	...	j	...	k		
Ре-зуль-таты де-шиф-риро-ва-ния	1	N_{11} $P_{11} = N_{11}/N$	N_{12} $P_{12} = N_{12}/N$	...	N_{1j} $P_{1j} = N_{1j}/N$	...	N_{1k} $P_{1k} = N_{1k}/N$	$N_{1+} = \sum_{j=1}^{k} N_{1j}$	$P_{1+} = N_{1+}/N$
	2	N_{21} $P_{21} = N_{21}/N$	N_{22} $P_{22} = N_{22}/N$	...	N_{2j} $P_{2j} = N_{2j}/N$	...	N_{2k} $P_{2k} = N_{2k}/N$	$N_{2+} = \sum_{j=1}^{k} N_{2j}$	$P_{2+} = N_{2+}/N$
	...	...	...	...	...	...	...	...	...
	i	N_{i1} $P_{i1} = N_{i1}/N$	N_{i2} $P_{i2} = N_{i2}/N$	...	N_{ij} $P_{ij} = N_{ij}/N$	...	N_{ik} $P_{ik} = N_{ik}/N$	$N_{j+} = \sum_{j=1}^{k} N_{ij}$	$P_{j+} = N_{j+}/N$
	...	...	...	...	...	...	...	...	...
	k	N_{k1} $P_{k1} = N_{k1}/N$	N_{k2} $P_{k2} = N_{k2}/N$	...	N_{kj} $P_{kj} = N_{kj}/N$	...	N_{kk} $P_{kk} = N_{kk}/N$	$N_{k+} = \sum_{j=1}^{k} N_{kj}$	$P_{k+} = N_{k+}/N$
		$N_{+1} = \sum_{i=1}^{k} N_{i1}$	$N_{+2} = \sum_{i=1}^{k} N_{i2}$	...	$N_{+j} = \sum_{i=1}^{k} N_{ij}$	...	$N_{+k} = \sum_{i=1}^{k} N_{ik}$	$N = \sum_{i,\, j=1}^{k} N_{ij}$	
		$P_{+1} = N_{+1}/N$	$P_{+2} = N_{+2}/N$	...	$P_{+j} = N_{+j}/N$	...	$P_{+k} = N_{+k}/N$		
		$P_{o(+1)}=P_{11}/P_{+1}$	$P_{o(+2)}=P_{22}/P_{+2}$	...	$P_{o(+j)}=P_{jj}/P_{+j}$	...	$P_{o(+k)}=P_{kk}/P_{+k}$		
		$K_{+j} = (P_{o(+j)} - P_{j+})/(1 - P_{j+})$							

Relative error of emission (S) is expressed by formula: $S = |(E - E_m)/E| \cdot 100\%$

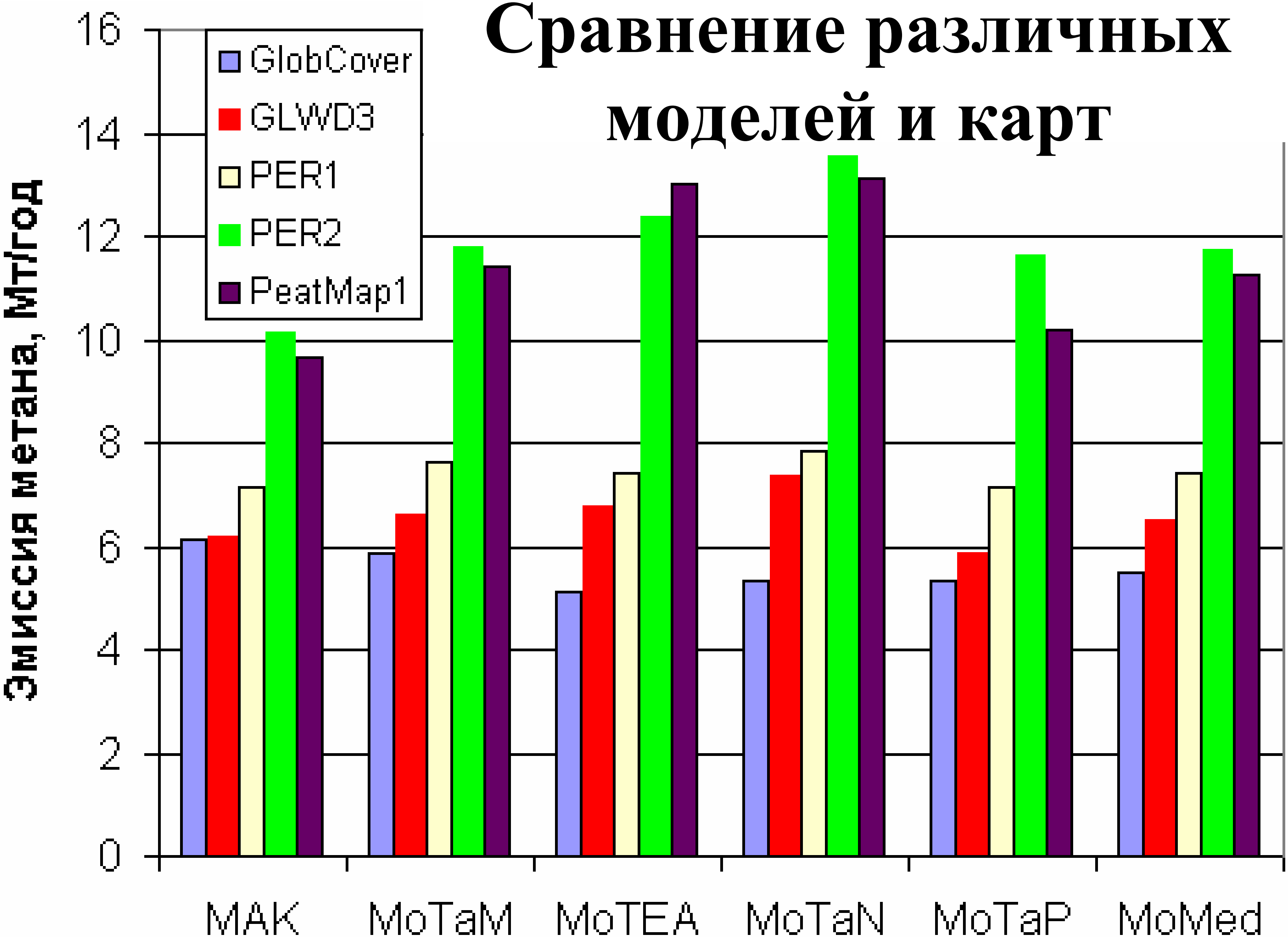
- E - emission from all “test areas” (TA) of the mires proper (эмиссия со всех “проверочных площадок”, действительно относящихся к болотам);
- E_m – emission from all TA which are attributed to mires on the tested map (эмиссия со всех “проверочных площадок”, которые отнесены к болотным по проверяемой карте);

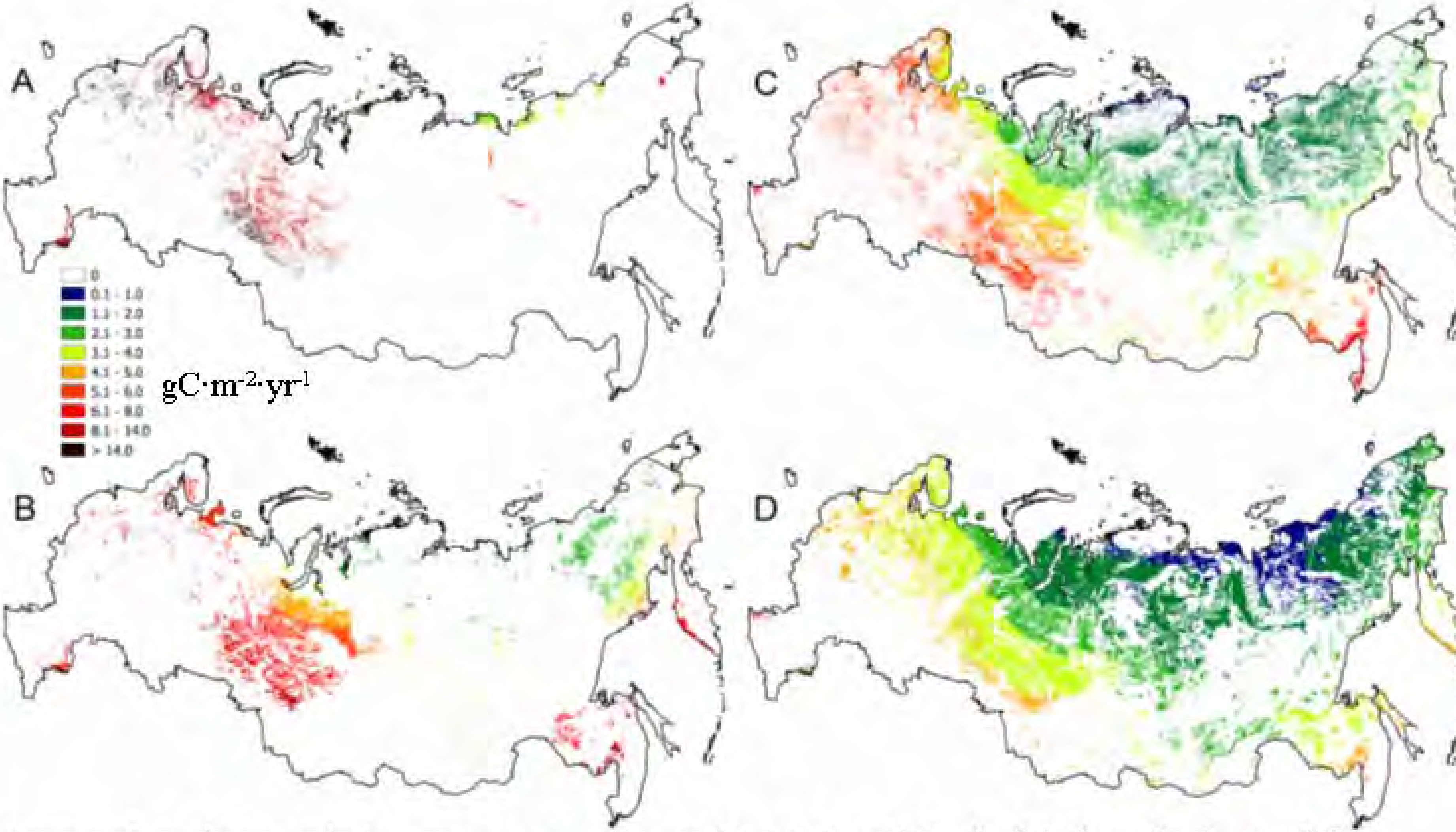

Results

Accuracy of the maps and methane flux from the Russian territory

Map	***Peatland area, km^2***	***Kappa***	***Error of CH_4 flux, %***
GlobCover	$0.472 \cdot 10^6$	0.11	77
GLWD3	$1.203 \cdot 10^6$	0.15	52
PER1	$1.204 \cdot 10^6$	0.01	63
PER2	$3.690 \cdot 10^6$	0.40	49
PeatMap1	$3.483 \cdot 10^6$	0.41	13

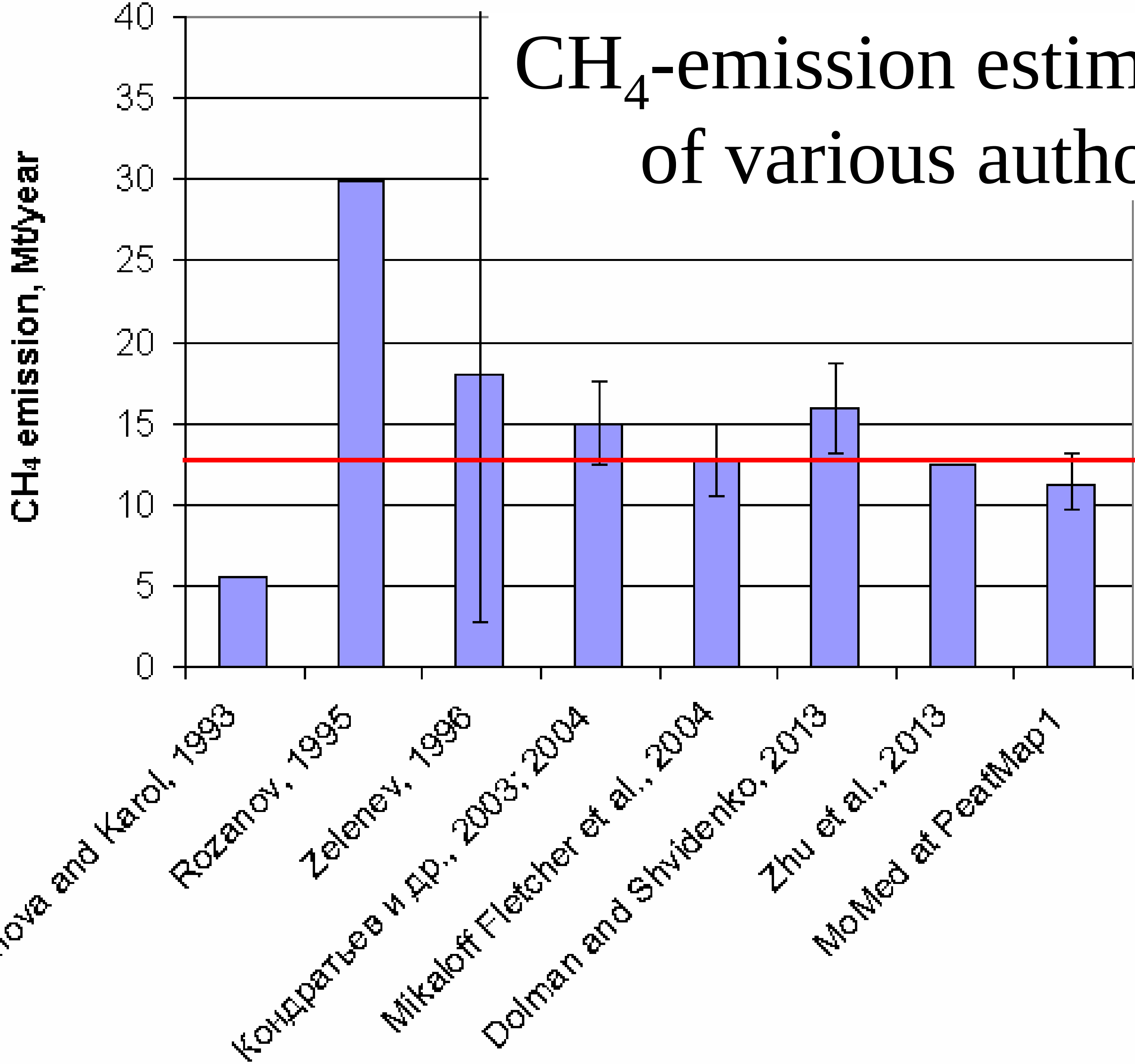
Сравнение различных моделей и карт



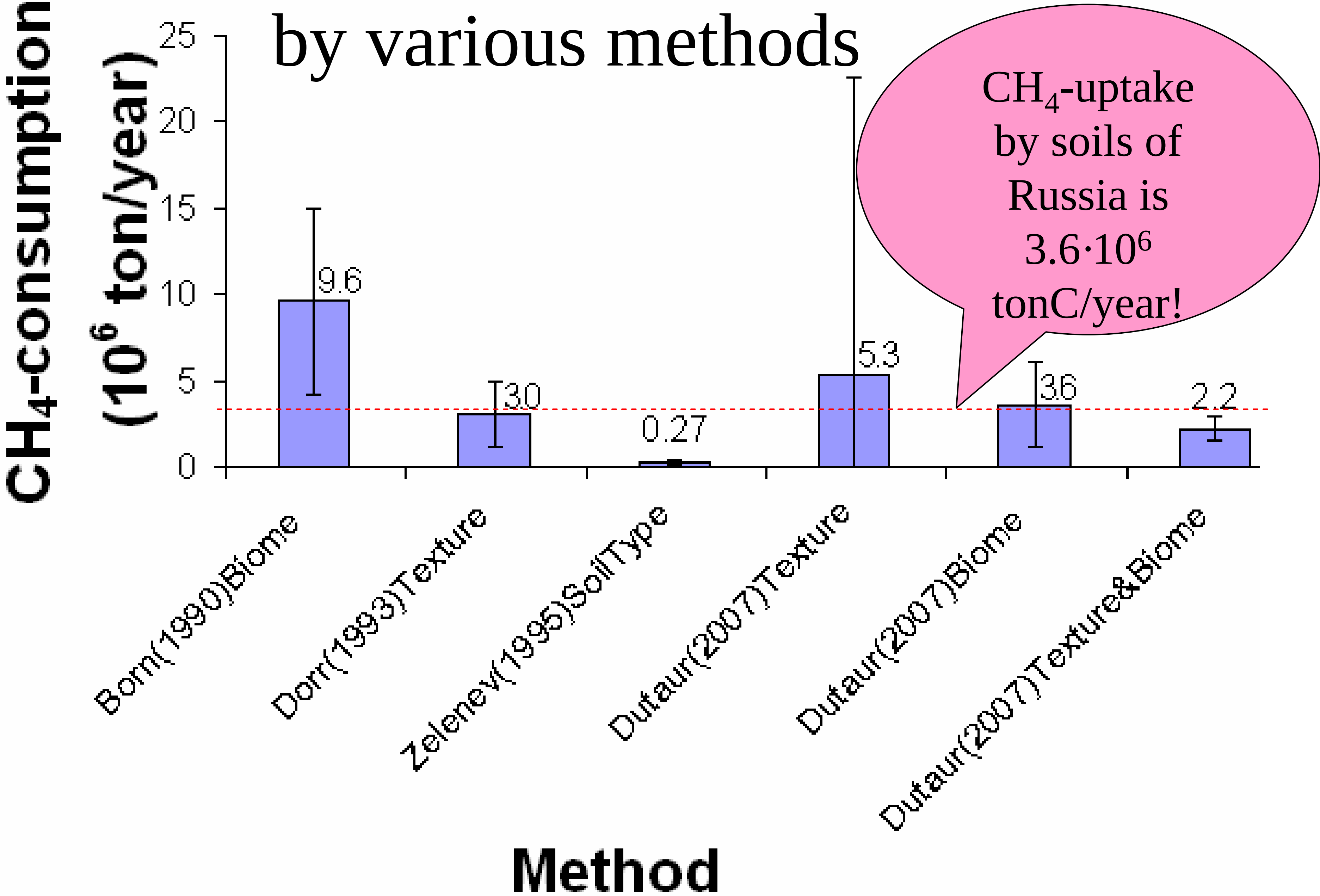


Averaged methane emission rate as according to MoMed model calculated on the base of the following maps of mires' distribution: A) GlobCover, B) GLWD3, C) PeatMap1, D) PER2

CH_4-emission estimations of various authors



CH_4-consumption estimations by various methods



CONCLUSIONS: Methane balance of Russian soils (our results)

- Methane emission (by averaging of 5 models at PeatMap1) = $11.6 \cdot 10^6$ tonC/year;
- Methane consumption (most probable from 5 inventories) = $3.6 \cdot 10^6$ tonC/year.
- NET METHANE EMISSION = $8 \cdot 10^6$ tonC/year.

Спасибо за внимание!