Atmospheric methane variability over the largest Northern European industrial region (Saint-Petersburg area, Russia)

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Introduction

- Investigation of greenhouse gases content evolution is very important for understanding of climate variability formation mechanisms.
- Urban area of Saint-Petersburg, being one of the largest industrial areas in the Northern Europe, is used as an example for examining of methane budget formation.
- To estimate the interannual greenhouse content variability the real methane concentrations obtained for summer and winter conditions together with total methane content data are analyzed, the multiyear rows of observations are used, obtained by spectroscopic (1991-2001) and gas chromatographic methods (1995-2001), from sampling sites located in up- and downwind sides of Saint-Petersburg.
- 3D regional model for multiyear period is applied for modelling of atmospheric methane distribution.

Map of the Saint-Petersburg sity area with measurement sites

Spectroscopic measurements in Peterhof

(St.-Petersburg State University)

- Measurements are carried out 35 km away from the city centre to south-western direction (59.9^{o}N, 29.9^{o}E)
- The industrial zone of Saint-Petersburg extends in the angle range 40 - 130 degrees.
- The method applied for total content of atmospheric gases definition is based on direct solar IR spectra interpretation and provides ~ 1-3% errors for daily averaged data.
- Spectroscopic measurements of CH_4 were started in 1991

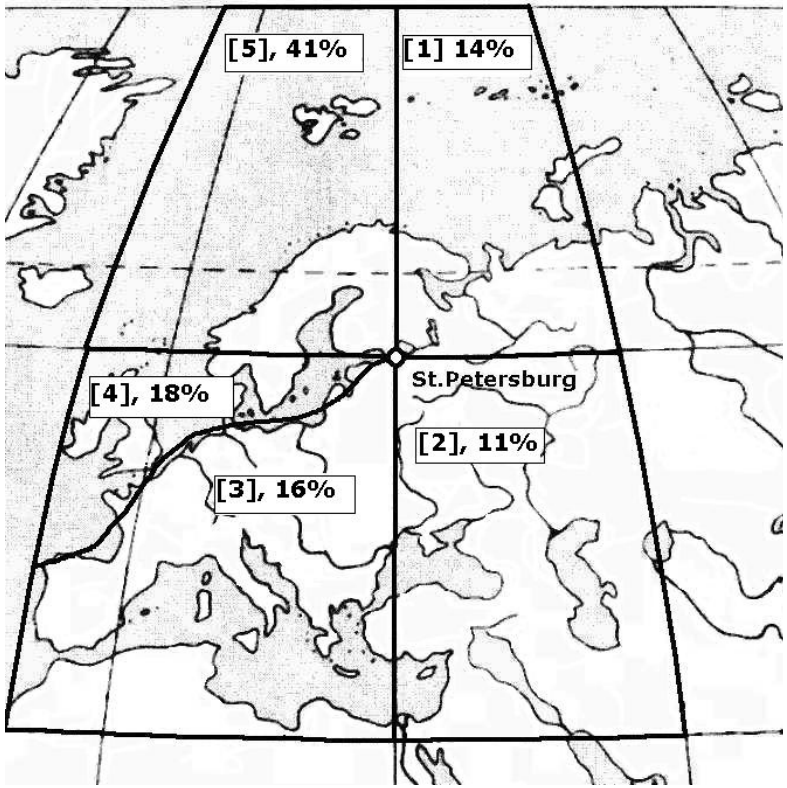
Gas chromatographic measurements

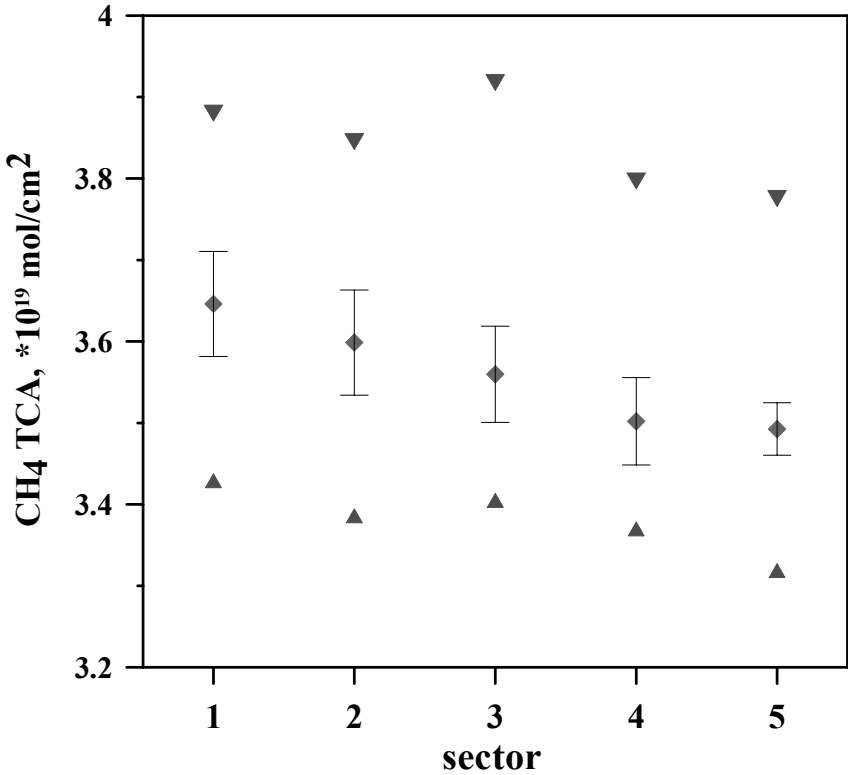
(RC RSA)

- Voeikovo (59^{o}57'N, 30^{o}42'E, 72 masl) is located east from St. Petersburg, 12 km away from its administrative frontier. vast lowland spreads about 20 km in the eastern direction towards the Ladozhskoye Lake coastline.
- The industrial zone of Saint-Petersburg extends in the angle range 200 - 310 degrees. The sector from zero to 200 degrees is relatively free of the industrial activity.
- Gas chromatographic measurements were started in 1995 and carried out with some gaps in time up to now.

RC RSA – Research Center of Remote Sensing of Atmosphere

Trajectory analysis for air masses coming to Saint-Petersburg

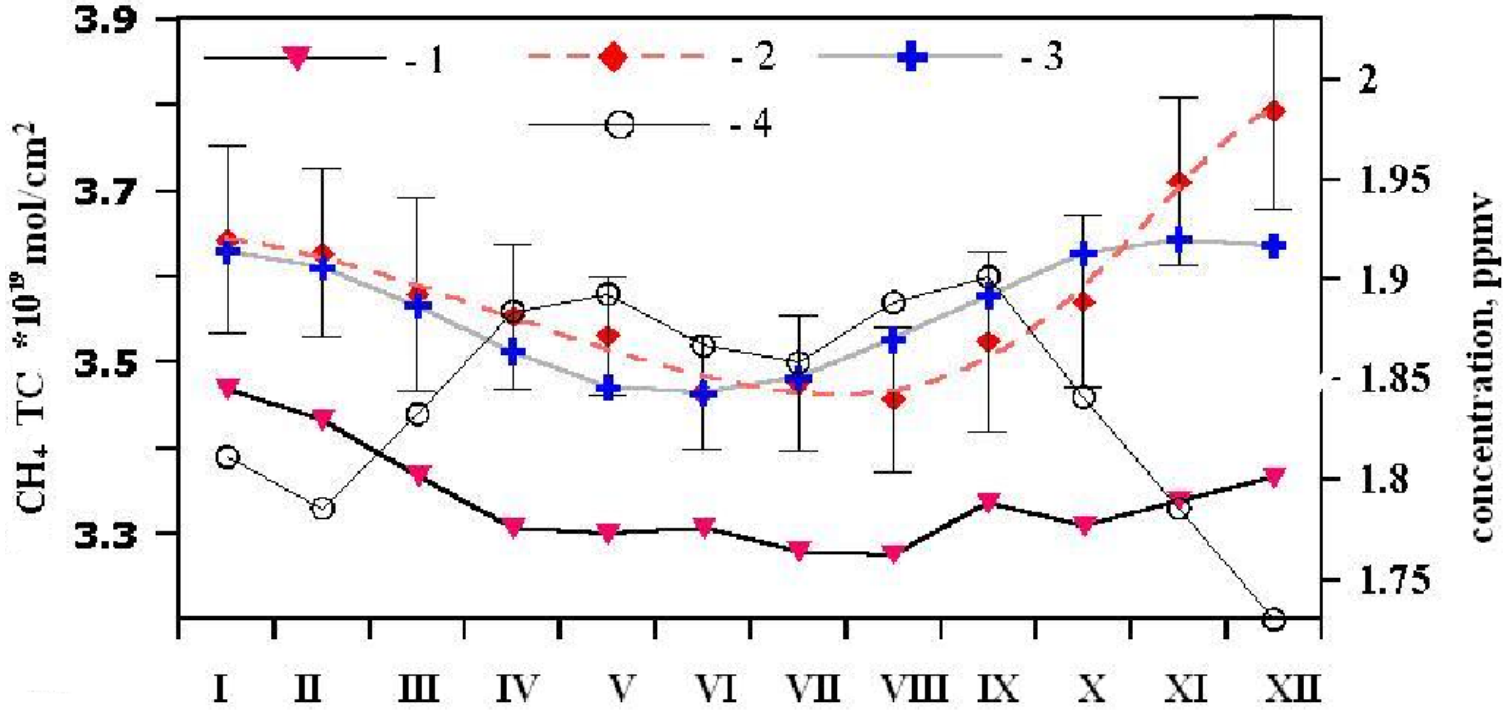




- Maximal values, observed usually in autumn-winter season are influenced by anthropogenic sources located along the air mass trajectories. Air masses with high methane concentrations come from continental part of Russia (sectors 1 and 2). Relatively clean air masses come from sectors 4 and 5, and air masses from Europe (sector 3) bring mean methane values. The difference between methane total column content of air masses coming from sectors 4,5 and 1,2 achieves ~ 4-5 %, which is compared with annual amplitude of methane column content for Saint-Petersburg

Makarova, Poberovskiy, Jagovkina et al., 2006

Annual course of methane total column and of surface concentration



1 – Annual course of CH_4 TC for 1999

2 – Averaged annual course of CH_4 TC for period 1991-2003

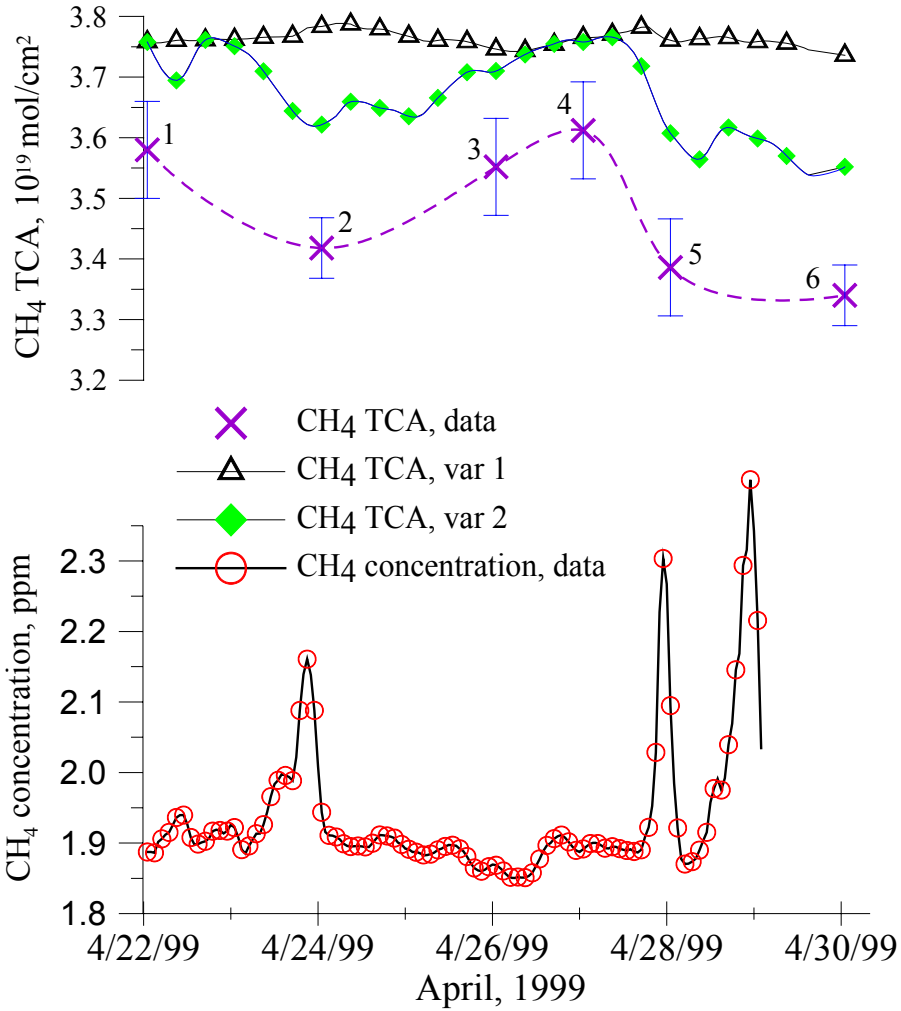
3 – Mean annual course of CH_4 surface concentration in Voeikovo, 1995-2000

4 – Averaged annual course of CH_4 TC in Ny-Alezund for1992-1995

Averaged seasonal course of methane total content in St.-Petersburg has **maximum** in November – December and **minimum** in June-August, with amplitude of ~ 4.5 %

Makarova, Poberovskiy, Jagovkina et al., 2006

Measured and modeled methane total column content and measured surface methane concentrations



Var 1 - upper (h>2 km) boundary concentration is prescribed as 1.72 ppm
Var 2 - upper (h>2 km) western boundary concentration is prescribed as1.66 ppm (air mass transport from marine sector)

Model estimation of different factors input into atmospheric methane column

Parameter	Atmospheric layer	The range of parameter variability	Change of CH_4 total column relative mean value (%)
Vertical profile of CH_4 mixing ratio (for surface pressure 1000 hPa)	0-1 km	2.8->1.8 ppm	~1.8
	0-2 km	2.8->1.8 ppm	~3
	1-11 km	1.6 ppm -> 1.8 ppm	~7
Methane content	> 11 km	7.1-7.8 10^{18} mol*cm^{-2} (seasonal variability)	<2
Tropopause height		8 - 12 km	~1.5
Surface pressure	0 km –upper boundary of atmosphere	1000 hPa – 1030 hPa	2.5

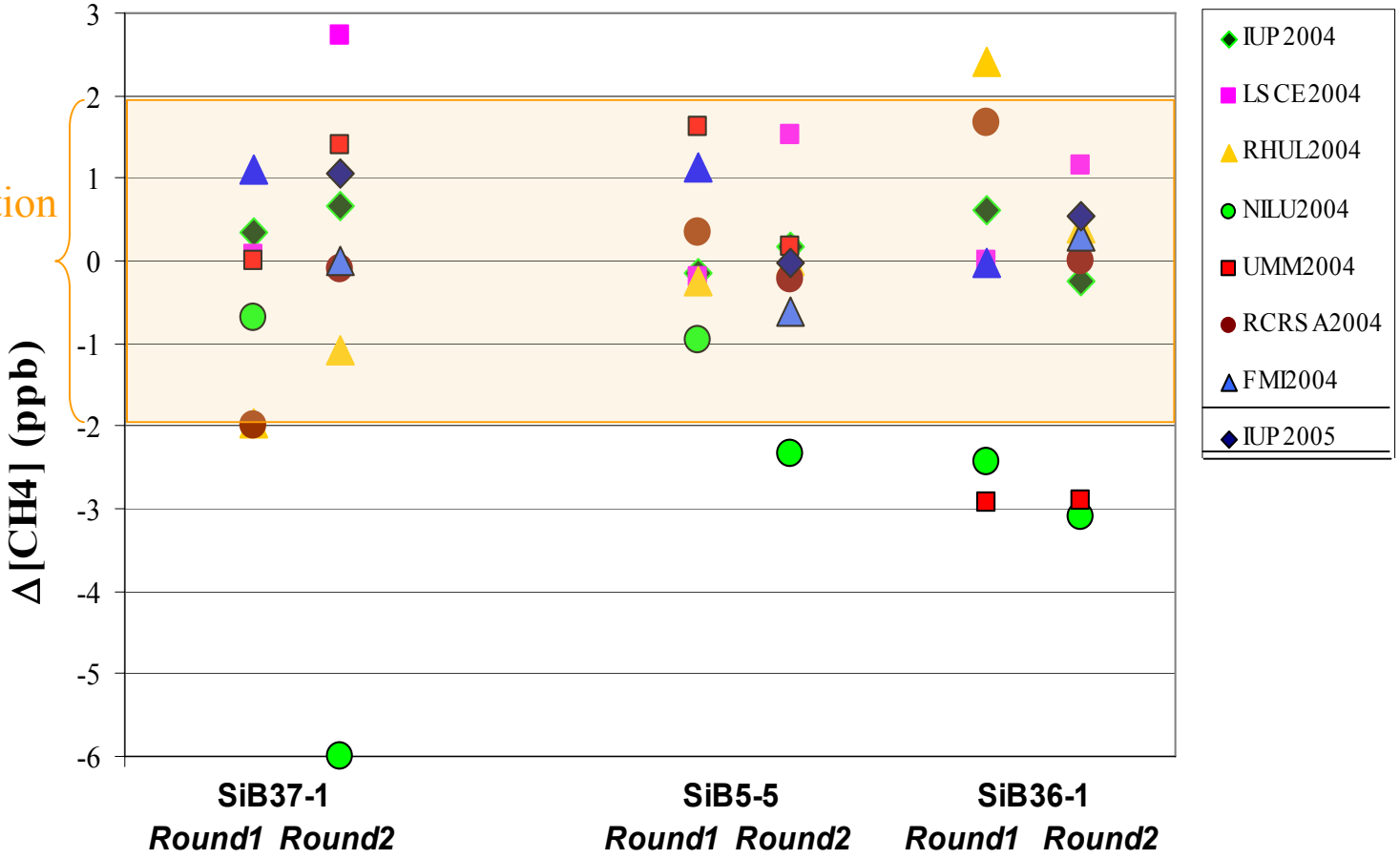
Gas chromatographic measurements in Voeikovo (RC RSA)

- An automated Russian-made gas chromatograph (GC) system (TZVET 500M) is used for CH_4 concentration measurement. The GC is equipped with flame ionization detector. The retention time for CH_4 is less than one minute. The routine measurement cycle takes 4 minutes including one standard and one ambient air record.
- Calibration of the GC system has been performed against the reference gas (dry air with the CH_4 concentration of 2025 ppb) provided by he Institute for Umweltphysik (IUP), Heidelberg, Germany.
- The high precision of the measurement techniques was confirmed by inter-comparison with 7 European laboratories in the frame of EC GMES MethMonitEUr Project (http://www.gl.rhul.ac.uk/METH/ MonitEUr).

CH_4 concentration intercomparison

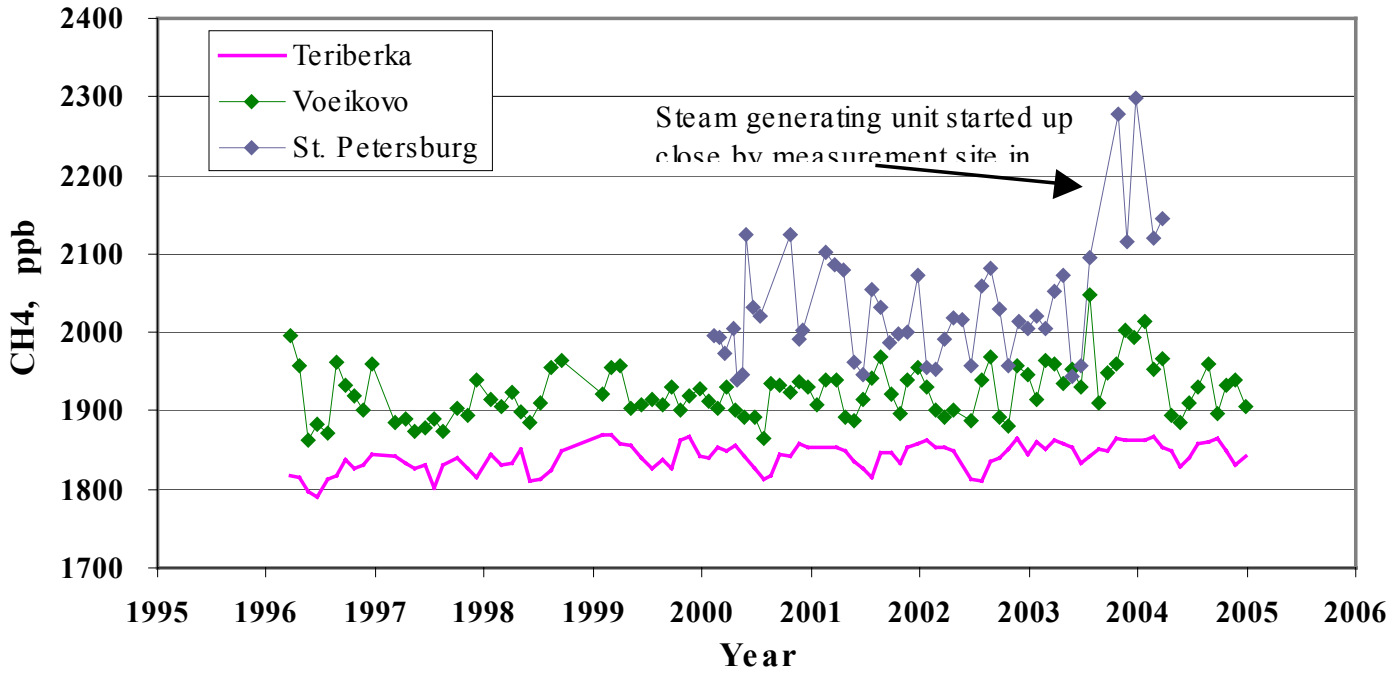
Difference from Median

WMO recommendation

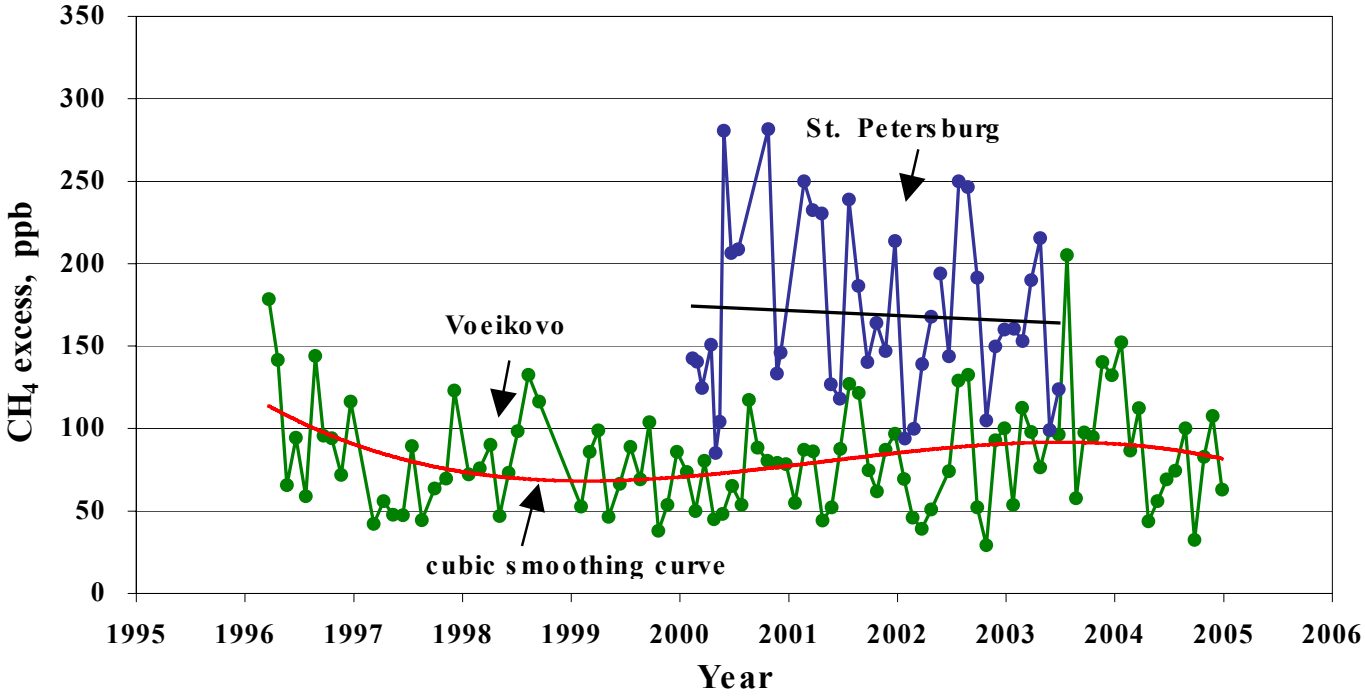


Round 1:	median=	1768.40ppb	1865.57ppb	1928.53ppb
Round 2:	median=	1767.30ppb	1865.63ppb	1929.30ppb

Monthly mean concentration in ambient air in Voeikovo and Saint-Petersburg with data from the Arctic coastal station Teriberka (GAW station)

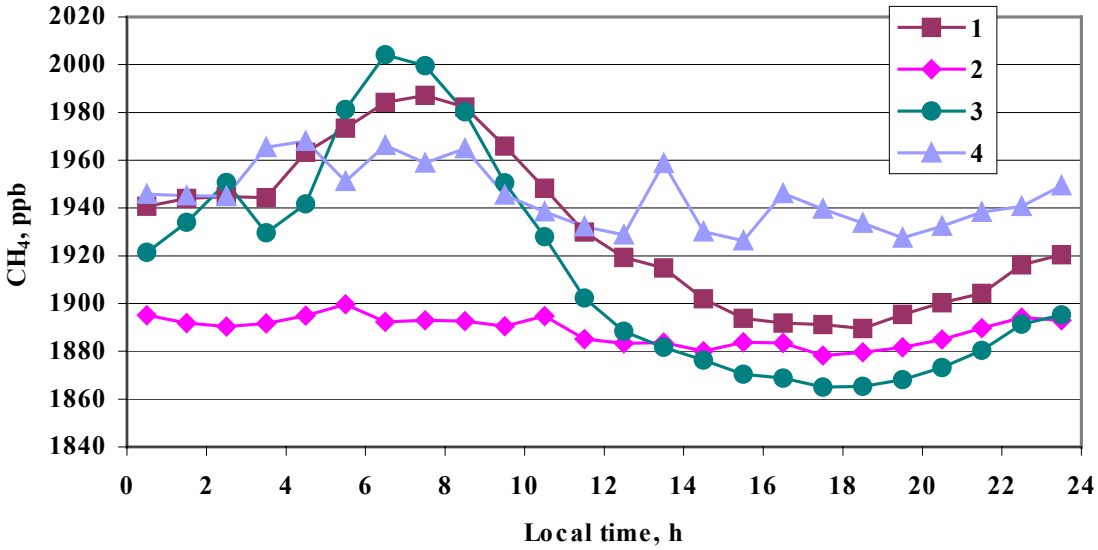


CH_4 excess in Voeikovo and Saint-Petersburg relative to the Teriberka background level

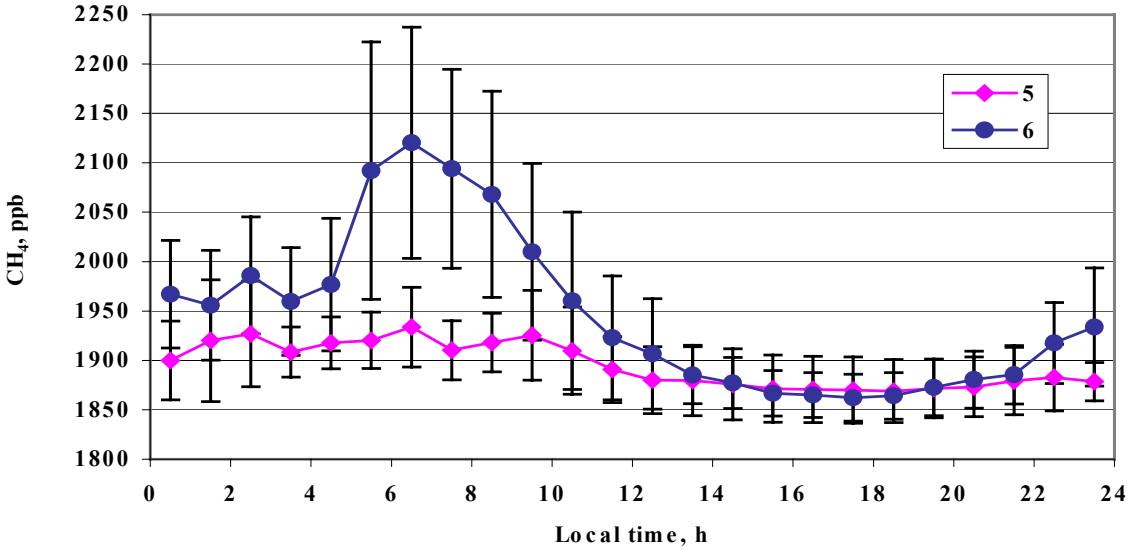


Mean CH_4 excess at Voeikovo (1996-2004) is 83 ± 33 ppb
Mean CH_4 excess at St. Petersburg (2000-July 2003) is 170 ± 53ppb
CH_4 excess at Voeikovo have downward trend from 1996 to 1999 and upward trend from 2000 to 2004.
For 1996-1999 linear correlation coefficient is -7.8 ± 4.4 (5 % significance level)
For 2000-2004 linear correlation coefficient is 5.0 ± 2.9 (5 % significance level).
Linear correlation coefficient for St. Petersburg CH_4 excess is not statistically significant.

Averaged diurnal cycle for different samples from Voeikovo data array

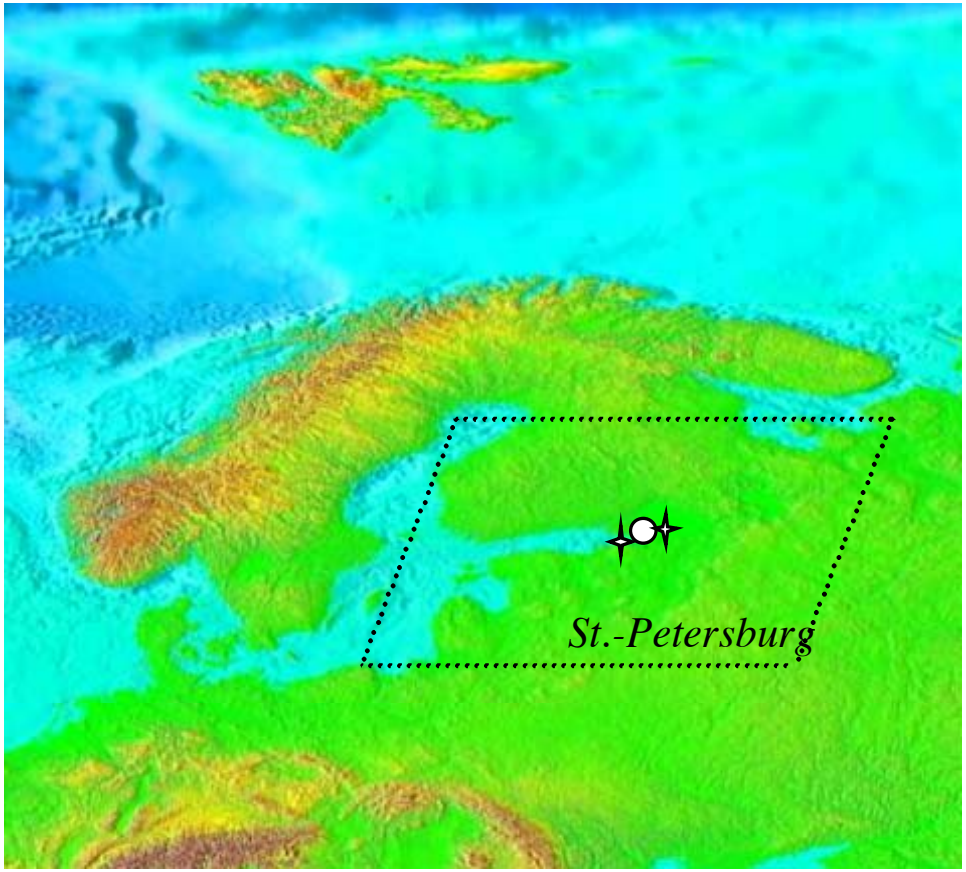


1 - wind speed < 3m/s ;
2 - wind speed > 3m/s
3 - t > 10° C;
4 - t < 10° C



5- t > 10° C, wind is from clean sector (0-175°)
6 - t > 10° C, wind is from urban sector (200-300°)

3D modeling

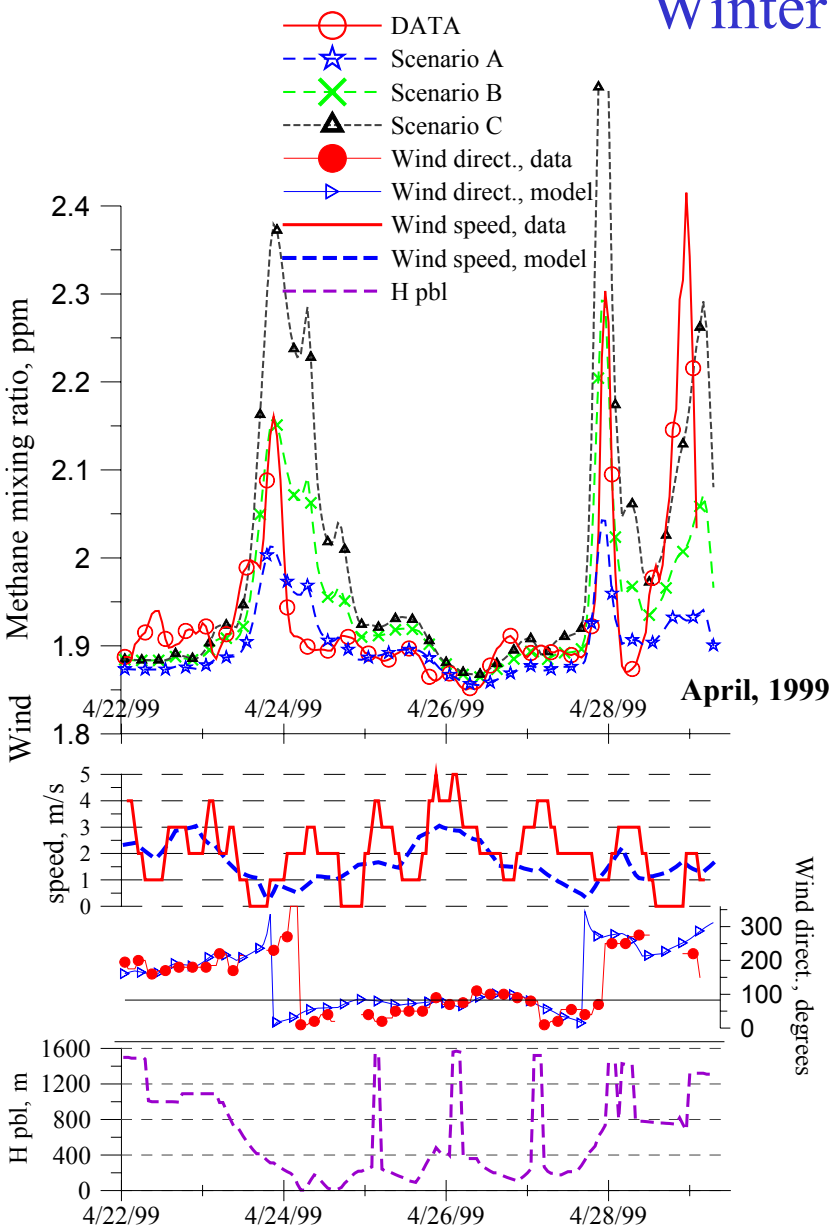


Modeling area:
horizontal resolution:
55-65^0 N x 20-40^{0}E
0.5^0 long x 0.25^0 lat
vertical resolution: 0-11 km
10 layers up to 1 km
10 layers with step of 1 km
time step = 5 min

Meteorological data base:
ERA-40

Modeling periods:
1997 (winter, summer), 1998 (summer),
1999 (winter), 2000 (summer)

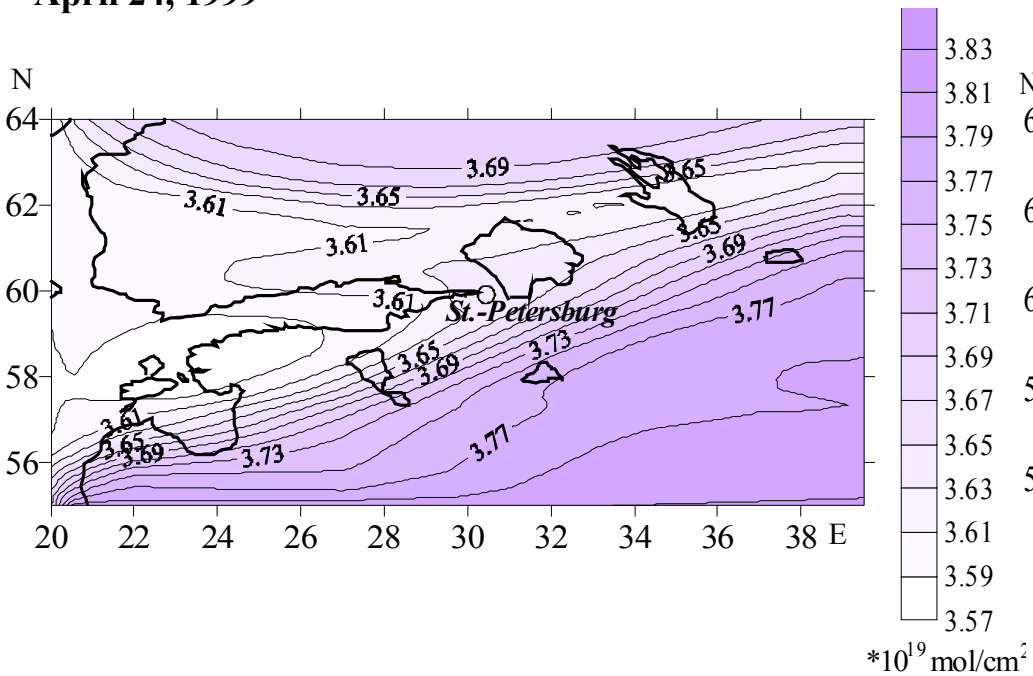
Estimation of methane emission in St. Petersburg region
Winter season



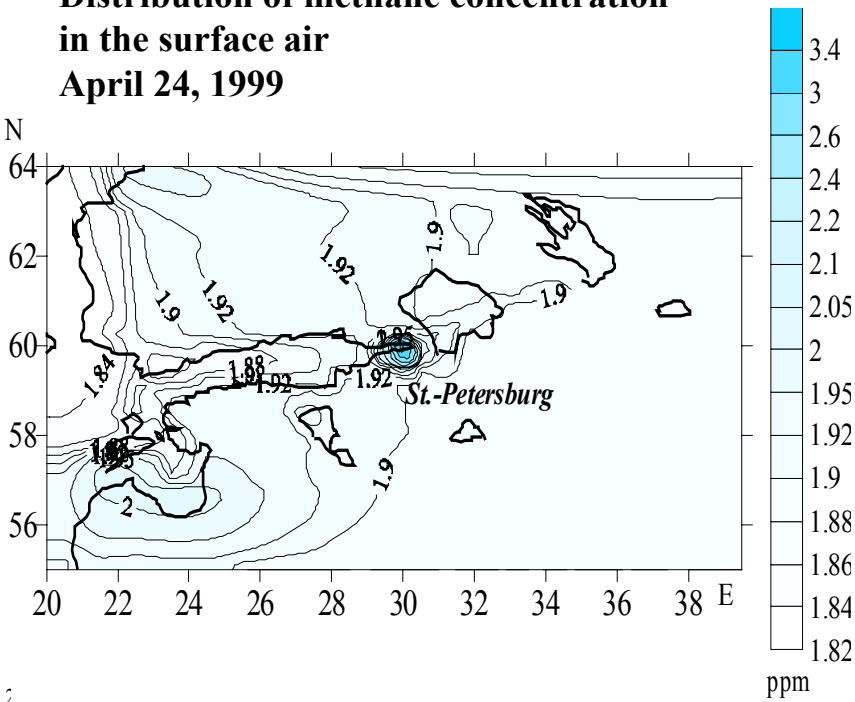
Scenario A	**130 mg/(m² day)**	**45 kT / year**
Scenario B	**300 mg/(m² day)**	**100 kT / year**
Scenario C	**600 mg/(m² day)**	**200 kT/year**

Modeling of methane distribution over St. Petersburg region
Winter season

Distribution of methane content over St.-Petersburg area
April 24, 1999

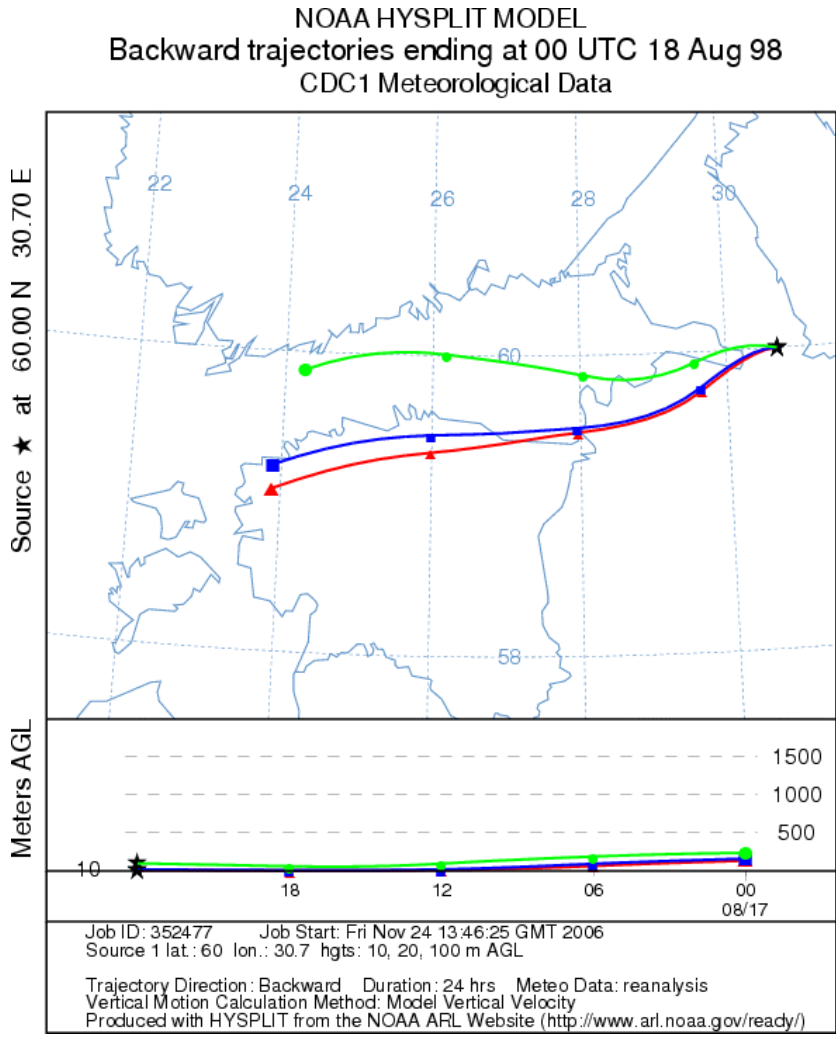


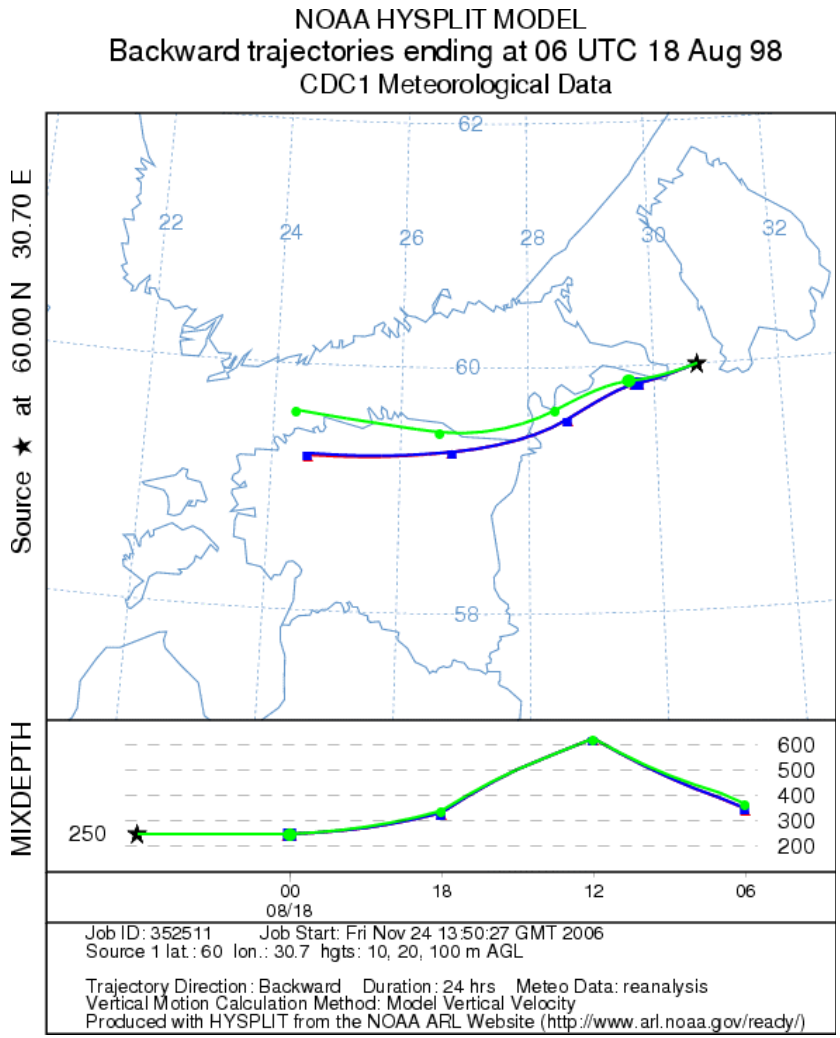
Distribution of methane concentration
in the surface air
April 24, 1999



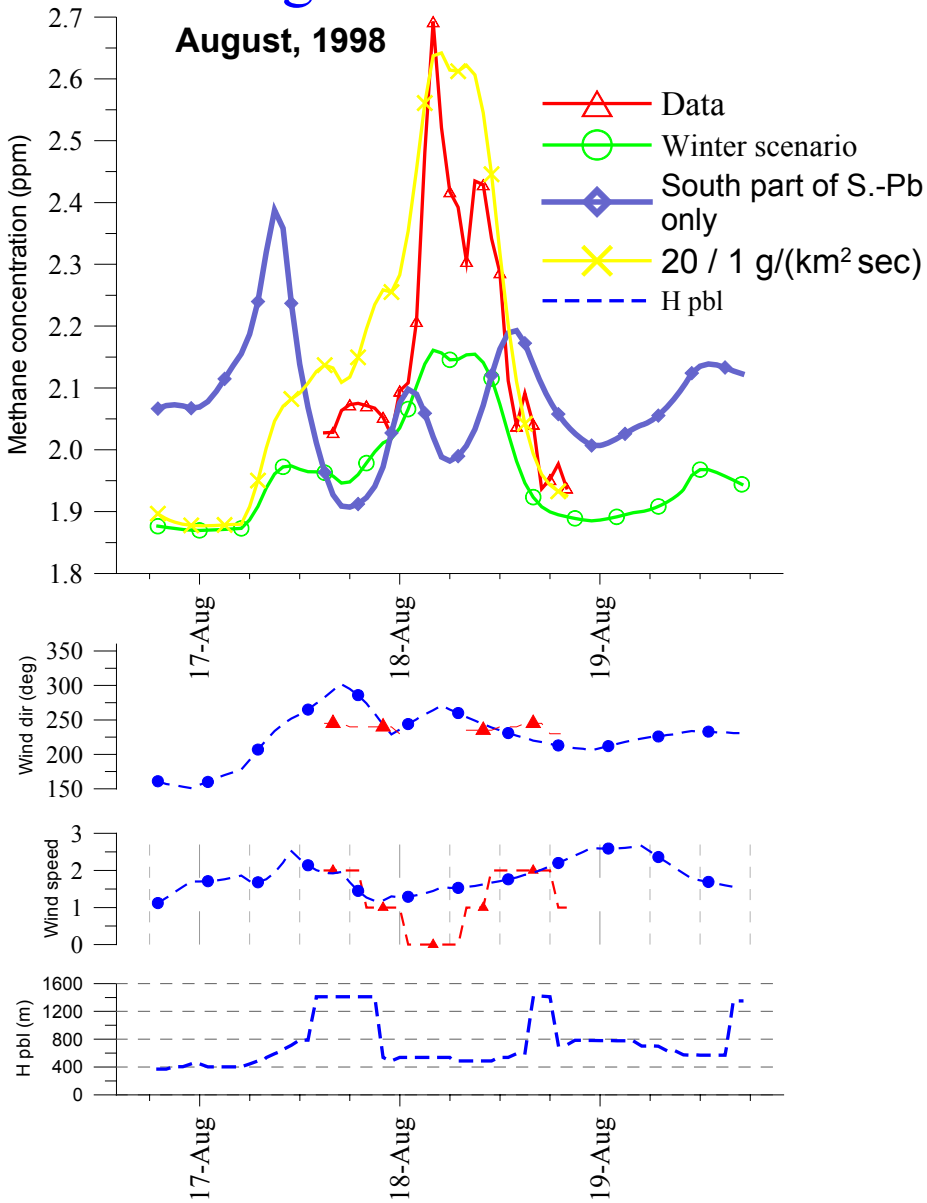
Estimation of methane emission in Saint-Petersburg region
Summer season

Backward trajectories for 18 August, 1998





3D regional modeling of surface air methane concentration

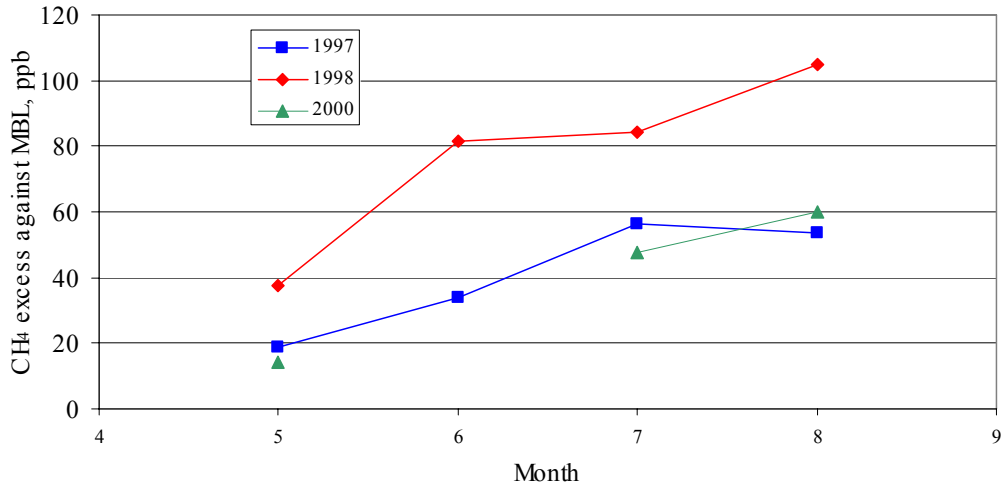


Some results of Saint-Petersburg area methane emission estimations

Winter season		Summer season	
Period	Emission from North/South part of St.Petersburg (g/km^2 sec)	Period	Emission from North/South part of St.Petersburg (g/km^2 sec)
February, 1997	2 / 1	July-Aug, 1997	1.5 / 0.78
April, 1999	3.5 / 0.78	May-June, 1998	8-10 / 2
		July, 1998	2 / 1
February, 2000	3.5 / 0.78	August, 1998	20 / 1
		August, 2000	10 / 0.78

1 $g/(km^2$ sec) = 86.4 $mg/(m^2$ day)

Voeikovo methane concentrations excess relative to concentrations in Marine boundary layer (MBL) for the same latitude



Description and explanation of methane distribution and estimates of methane fluxes in the St.-Petersburg area for 1998 need a special consideration

Conclusions

- Input of the city emission into methane total column does not exceed 2 %. Observed variability of total methane content is defined by the origin of air masses coming to the area of Saint-Petersburg. Air masses travelling over West and East continental parts of Europe have about 4 % excess of methane total content, as well as surface methane concentrations in comparison with air masses coming from North-Western sector.
- Main factor being responsible for the variability of surface methane concentrations in the area of St.-Petersburg is methane emission from the city. This emission increases the surface methane concentration more than 50 % for stable stratification in comparison with conditions of intensive atmospheric layer mixing.
- There is no statistical trend in methane concentrations in St.-Petersburg area
- 3D regional model is applied for estimation of integral emission from the city using surface methane concentration data

Results of this presentation were obtained in the frames of Projects:
Meth-MonitEUr EVK2-2002-000576 , RFBR 02-05-64711, and partly RFBR 05-05-64760

Thank you for your attention !