SPATIO-TEMPORAL VARIATION OF METHANE EMISSION FROM RESERVOIRS WITH THE DIFFERENT WATER RESIDENCE TIME*

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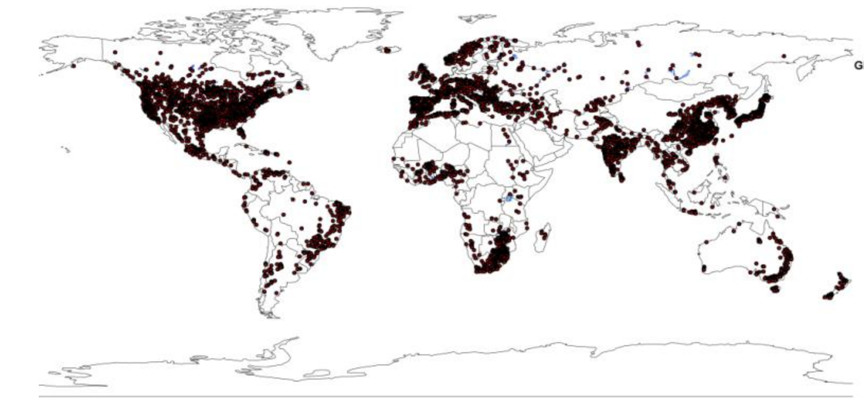
The relevance of the study

The previously obtained estimates of total emissions from water reservoirs have quite a large range of differences (fig. 1). The causes of such large discrepancies in the estimates of the specific methane flow may be associated with differences in water regime (flow) and trophic status. Therefore, it makes sense to make a more detailed division of water bodies into subgroups within each climat zone. Further, it is necessary to clarify the characteristic values of specific methane flow (annual averages) for water bodies from each group with the most thoroughly studied methane emission regime. In the absence of detailed inter-annual full-scale data, mathematical modeling should be used, having previously calibrated the model according to the available full-scale data. The large variation in methane flux values indicates that climate is not the dominant factor influencing specific flux values. Nevertheless, at lower latitudes, methane flux is larger than in temperate climate zone. Diffusion fluxes of methane in the shallow areas is much higher than in the deep [Roehm, Tremblay 2006, Goldenfun, 2010]. A similar pattern is discovered in the Mozhaiskoe reservoir [Grechushnikova, et al., 2017]. A significant seasonal and inter-annual variability of oxygen regime in low-flow reservoirs will determine the extent of spatial and temporal variability of methane emissions from their surface. For reservoirs with intensive water exchange, performing not short-term and seasonal flow regulation, the formation of anoxic conditions is not typical.



Reservoirs from GRanD (http://atlas.gwsp.org/atlas/img/map/grand_v1_1_wl.png).

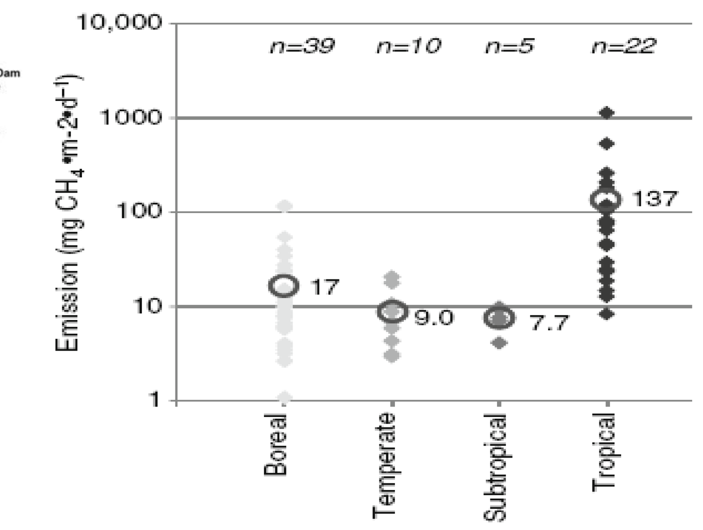
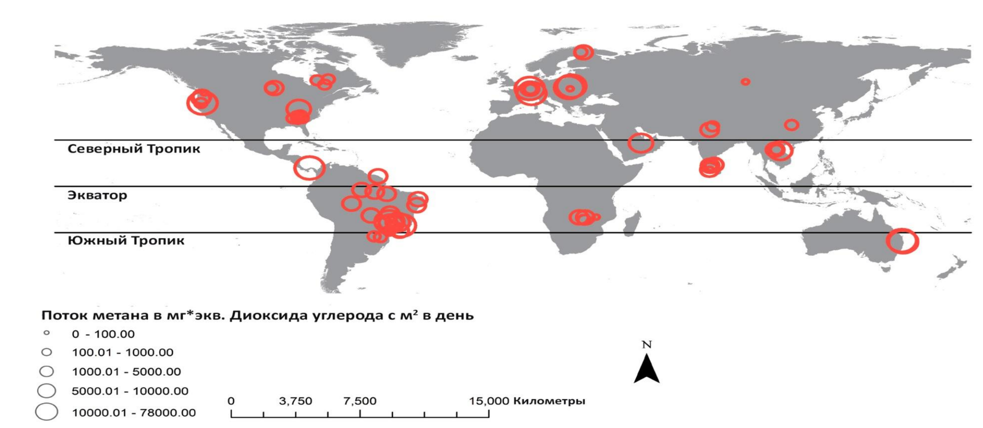


Fig. 1 Greenhouse Gas Emissions from Reservoirs [Olli Varis et al., 2012]



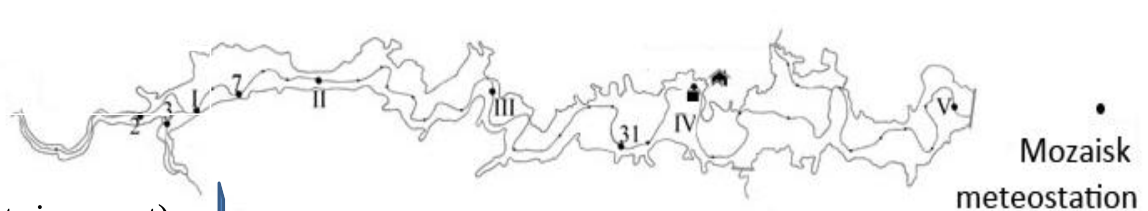
Estimations of net methane emission from reservoirs:

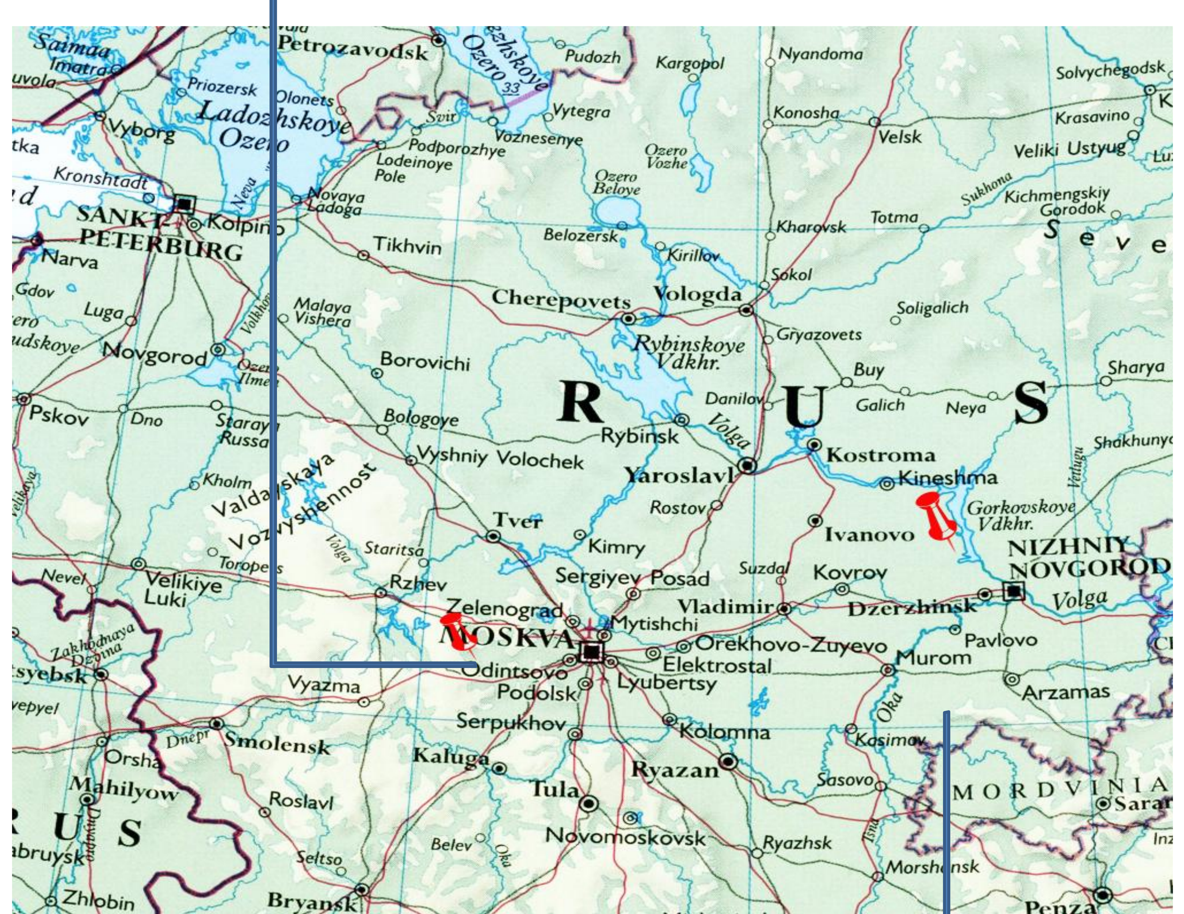
69 Tg CH_4/year [St Louis et. al. 2000],
95-122 Tg CH_4/year [Giles J., 2006],
2-4 Tg CH_4/year [Lima I. et. al., 2008],
4,8 Tg CH_4/year [Varis O. et. al., 2012],
17,9 Tg CH_4/year [Deemer et.al., 2017]

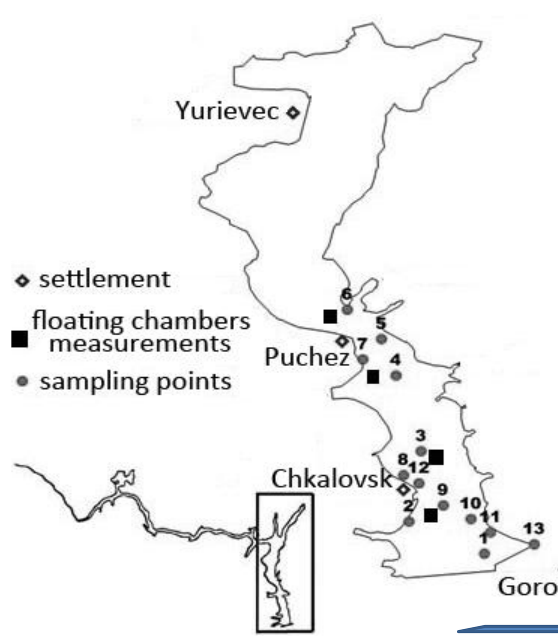
The purpose and objects of study:

to compare changes in water column the content and methane specific flows in two different types of reservoirs by the example of Mozhaisk and Gorky reservoirs

Characteristic	Mozhaiskoe	Gorkovskoe
Normal retaining level, m abs	183	84
Surface area, km²	30,7	1 591 (full) 1008 (without river part)
Maximum depth, m	23	22
Mean depth, m	7	5,5
Full volume, km³	0,235	8,82
Useful volume, km³	0,221	2,78
Water exchange koeff., 1/год	1,15	6







Observation results

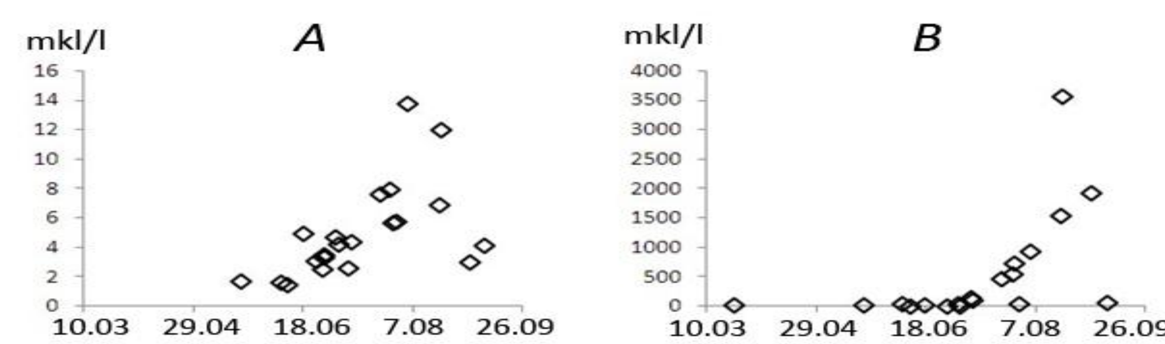


Fig. 2. Methane concentration in surface (A) and bottom (B) layer on st. IV in Mozaiskoe reservoir in 2017

Detailed seasonal measurements on the Mozhaiskoe reservoir have revealed a large inter-seasonal variability of methane in surface and bottom layers of this mesotrophic-eutrophic reservoir associated with the development of anoxic conditions in the small flowage. The highest content of methane in the surface and bottom layers on the example of 2017 is noted in August before the destruction of the stratification (fig. 2).

In the upper flow and in the middle part (st. III) methane concentration near surface can grow up to 60 mkl/l in the mixing periods due to weather conditions. In the deepest part near the dam (st. V) methane concentration during summer stratification does not grow more than 10-12 mkl/l because the water column can`t be mixed to the bottom (fig. 3).
The typical pattern during the summer is the increase of the difference between diffuse and total methane flux, which characterizes the intensity of the methane bubble flux, increasing by the time of stratification destruction, up to 90% of the total flow.

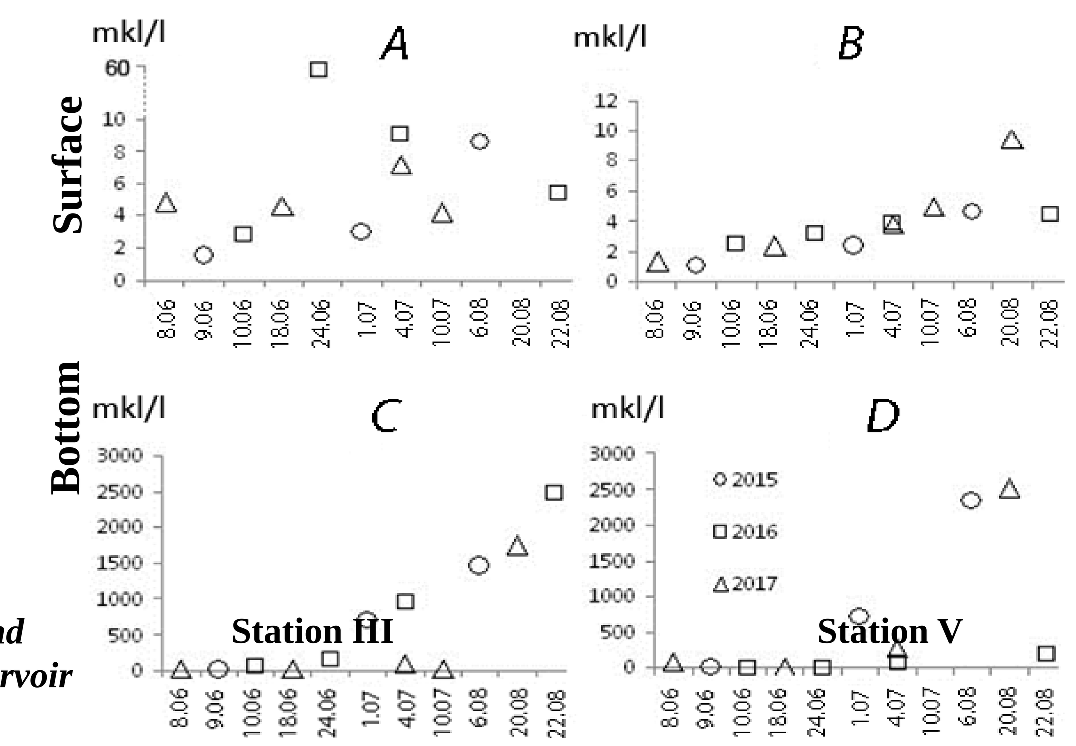


Fig. 3. Methane concentration in surface (A, B) and bottom (C, D) layer on st. III and V in Mozaiskoe reservoir in 2015-2017

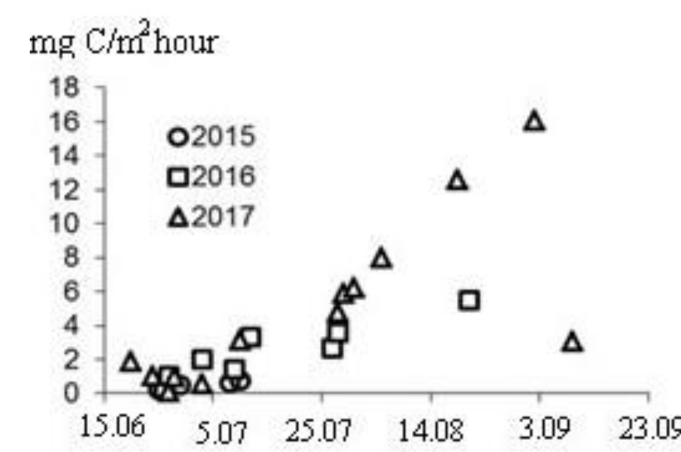


Fig. 4. Specific methane flux defined by floating chambers on st. IV .

Floating chamber measurements revealed a significant increase in the specific methane flux by the end of the summer stratification period in August, when the oxygen-free zone reaches the largest volume and the gradient of water temperature in the water column decreases. At the beginning of the autumn convection period, the specific methane flux determined by the floating chamber method decreases by an order of magnitude (fig.4).

An increase in the specific methane flux during the summer period for all areas of the reservoir with medium depth was revealed; there was a tendency to reduce the diffusive methane flux from the upper area to the dam. When calculating the integral emission from the surface of reservoirs, it is necessary to take into account spatiotemporal changes in the specific methane flow, which differ in the reservoirs of the valley type.

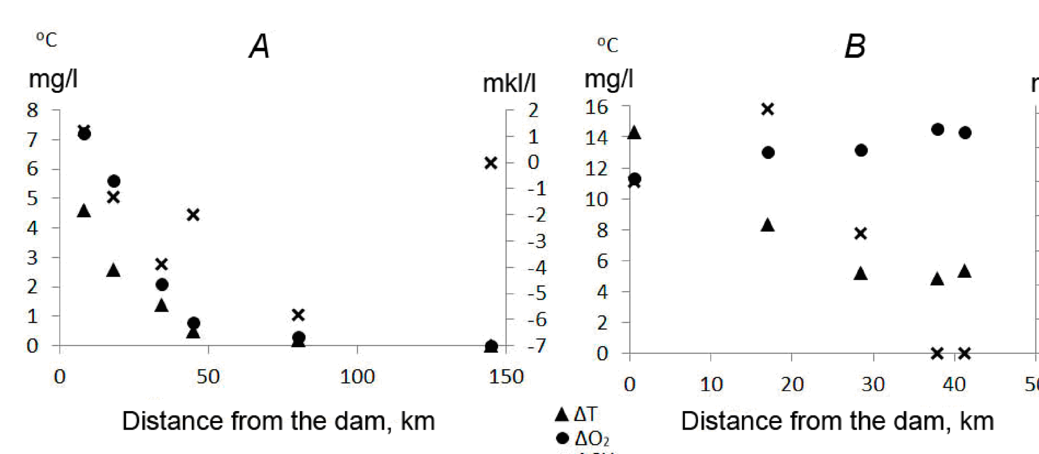


Fig. 5.
Longitudinal change in the difference between water temperature, dissolved oxygen (mg/l) and methane content (µl/l) in the surface and bottom layer:
A - Gorkovskoe reservoir 13-15.08.2017;
B-Mozhaiskoe reservoir 20.08.2017

According to the results of the floating chambers measurements, the spatial difference of the specific methane flux in the lake part of the Gorkovskoe reservoir was not detected during the period of expedition observations, and its values vary from 0.2 to 1.6 mgC/m² h, which is significantly less than the specific methane flux in August at the Mozhaisk reservoir (more than 10 mgC/m² h).
the low-flow reservoir is characterized by high values of the diffusive specific flow of methane due to the significant difference in the regime and intensity of the in-water processes affecting its formation, accumulation and emission.

Conclusion

- **The results of field observations revealed significant variations in the content and specific flow of methane in reservoirs with different flow rates.**
- **Significant spatial-temporal changes of methane content in the reservoir with a small water exchange are detected.**
- **This circumstance does not allow to use the results of occasional expedition observations on low-flow reservoirs to estimate characteristic emission values by averaging.**
- **The numerous diversity of reservoirs, the combination of their flow and trophic status with few full-scale data on the values of the specific methane flux, raise the question of a more detailed full-scale study of reservoirs and the involvement of mathematical modeling of greenhouse gas emissions. In particular, the developed model for the calculation of gaze exchange in lakes [Stepanenko et al., 2016] can be used to estimate emissions from deep zones of low-flow reservoirs.**