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The monitoring and modeling framework for assessment of methane and carbon dioxide sinks and sources in the regional climate system of Western Siberia

Vasili Bogomolov (1), Victor Stepanenko (2), Igor Okladnikov (1), Alla Yurova (3), Eugeni Gordov (1), Vasilii Lykosov (4,2)

(1) Siberian center for Environmental Research and Training, Institute of Monitoring of Climate and Ecological Systems, Russia, 634055, Tomsk, Akademicheski ave., 10/3, (office@scert.ru), (2) Moscow State University, Research Computing Center, Faculty of Geography, Russia, Moscow, GSP-1, 119991, Leninskie Gory, building 4 (vstepanenkomeister@gmail.com), (3) Hydrometeorological Research Centre of Russian Federation (Hydrometcentre of Russia), Russia, 123242, Moscow, B. Predtechensky per., 11-13, (alla.yurova@gmail.com), (4) Institute of Numerical Mathematics, RAS, Russia, 119333, Moscow, Gubkin str., 8 (lykossov@yandex.ru)

Carbon dioxide and methane are major greenhouse gases in the atmosphere and hence their dynamics is crucial to be accurately represented in climate models. In future climate projections the most uncertainty on these gases' concentrations in the atmosphere is attributed to uncertainty of their sinks and sources at the land surface. The intensity of sinks and sources is connected with feedbacks between climate and land ecosystems. In this context the feedbacks between climate and permafrost are of particular importance. The climate warming during last several decades in high latitudes is characterized by the largest magnitude over the globe and it causes significant permafrost degradation. Permafrost degradation is accompanied by wetland spreading and enhancing of thermokarst processes. This is likely to cause higher methane emissions from permafrost regions further increasing the atmospheric greenhouse effect. This positive feedback was qualitatively understood long ago but is still poorly quantified. In situ observation data on methane emissions are sparse in space and episodic in time, and regional emission estimates basing on them obtained by different authors differ significantly. Satellite-based retrievals of atmospheric CH4 and CO2 concentrations (AIRS, SCIAMACHY, GOSAT) provide integral amounts of these gases in the atmospheric column and vertical profiles globally at a regular grid but the accuracy of these products remains questionable, especially in the vicinity of Earth surface. There are attempts to use satellite data to solve inverse atmospheric tracer transport problem to calculate surface fluxes of methane and carbon dioxide, however, contradictions have been reported between inverse modeling estimates and in situ measurements. On the other hand, numerical models of soil, vegetation, wetlands and lakes that are currently used in land surface schemes of climate models do not represent all crucial biogeochemical feedback mechanisms between atmosphere and land ecosystems. For instance, to the knowledge of authors emissions of methane by thermokarst lakes that are abundant in permafrost area are still not parameterized in any climate model.

This report presents a short overview of methane and carbon dioxide sinks and sources estimates for Western Siberia based on observations and modeling studies and suggests a new framework for these estimates involving satellite observations and regional atmospheric modeling of high resolution. The goal of this study is to produce a new estimation of methane and carbon dioxide fluxes at the surface of Western Siberia basing on coupled atmosphere-land surface modeling of high resolution (up to several kilometers) for current climate conditions and to develop relevant physical and biogeochemical models minimizing the discrepancy between modeled atmospheric greenhouse gases (GG) concentrations and those retrieved from satellite data. The regional scale non-hydrostatic three-dimensional atmospheric model NH3D_MPI of high resolution (up to 1 km) is coupled with land surface model including along with heat and moisture transfer in plants and soil parameterizations for CO2 – related surface processes such as photosynthesis, plants' respiration and emission due to organics decomposition in soil; methane emission from bogs is calculated by B.Walter and M.Heimann model, methane production and emission from thermokarst lakes are explicitly simulated by a one-dimensional lake model. Initial, boundary conditions and reference state variables for this model will be extracted from regional reanalysis for Western Siberia, produced by atmospheric model WRF.