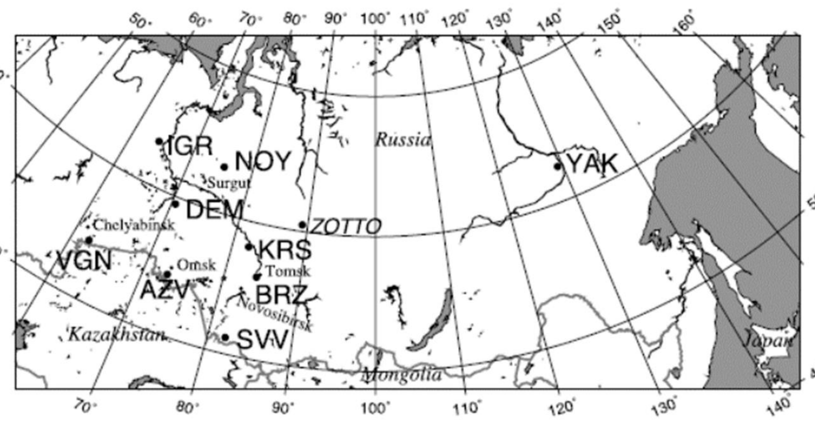
EGU2020-16416

Natural and anthropogenic methane emissions in West Siberia estimated using a wetland inventory, GOSAT and a regional tower network

Japanese-Russian tower network JR-STATION



Shamil Maksyutov[1], Motoki Sasakawa[1], Fenjuan Wang[1], Aki Tsuruta[2], Rajesh Janardanan[1], Irina Terentieva[3], Alexander Sabrekov[3], Mikhail Glagolev[4,5], Toshinobu Machida[1], Mikhail Arshinov[6],Denis Davydov[6], Oleg Krasnov[6], Boris Belan[6], Ed Dlugokencky[7], Jost V. Lavric[8], Akihiko Ito[1], Greet Janssens-Maenhout[9], Johannes Kaiser[10], Yukio Yoshida[1], and Tsuneo Matsunaga[1]

(1) National Institute for Environmental Studies, Tsukuba, JPN
(2) Finnish Meteorological Institute, Helsinki, FIN
(3) Yugra State University, Khanty-Mansyisk, RUS
(4) Moscow State University, Moscow, RUS
(5) Institute of Forest Science, Uspenskoe, RUS
(6) Institute of Atmospheric Optics, Tomsk, RUS
(7) ESRL/GMD, National Oceanic and Atmospheric Administration, USA
(8) MPI-BGC, Jena, GER
(9) European Commission, Joint Research Centre (JRC), Ispra, ITA
(10) DWD, Offenbach, GER

Outline. West Siberia contributes a large fraction of Russian methane emissions, with both natural emissions from peatlands and anthropogenic emissions by oil and gas industries. To quantify anthropogenic emissions with atmospheric observations and inventories, we must better understand the natural wetland emissions. We combine high-resolution wetland mapping based on Landsat data for whole West Siberian lowland with a database of in situ flux measurements to derive bottom up wetland emission estimates. We use a global high-resolution methane flux inversion based on a Lagrangian-Eulerian coupled tracer transport model to estimate methane emissions in West Siberia using atmospheric methane data collected at the Siberian GHG monitoring network JR-STATION, ZOTTO, data by the global in situ network and GOSAT satellite observations. High-resolution prior fluxes were prepared for anthropogenic emissions (EDGAR), biomass burning (GFAS), and wetlands (VISIT model combined with Global Lake and Wetlands Database (GLWD) wetland map). We estimate flux corrections to prior flux fields for 2008 to 2016. The inverse model optimizes corrections to two categories of fluxes: anthropogenic and natural (wetlands). Based on fitting the model simulations to the observations, the inverse model provides upward corrections to West Siberian anthropogenic emissions in winter and wetland emissions in summer. We estimate 15% higher anthropogenic emissions than EDGAR inventory for whole Russia, with most of the correction attributed to West Siberia and European part of Russia. Comparison of the inversion estimates with the bottom-up wetland emission inventory for West Siberia suggests a need to adjust the wetland emissions to match observed north-south gradient of emissions with higher emissions in the southhern taiga zone.

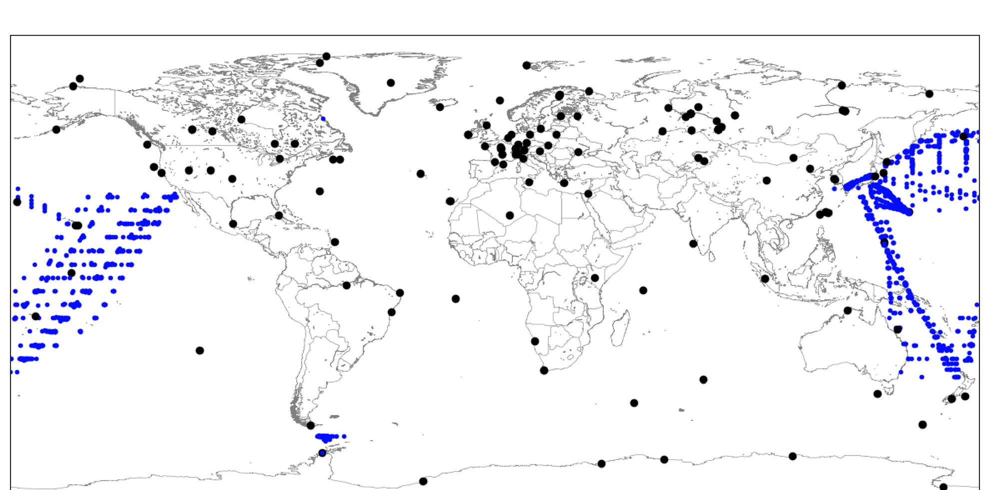
For simulation of GHG transport in the atmosphere we use a coupled Eulerian-Lagrangian model NIES-TM – Flexpart, which combines NIES TM v08.1i (resolutions of 2.5 degree and 32 vertical levels), with Flexpart model (Stohl, 2005), with surface flux resolution of 0.1, degree. For application to grid based inversion, a manually developed adjoint of the NIES TM v08.1i was completed. Transpose of the receptor sensitivity matrixes simulated by Flexpart serves as adjoint of Lagrangian component. See Wang et al 2019, Janardanan et al 2020, Maksyutov et al 2020 for details of inverse model. Observational data for Siberia and rest of the world, including GOSAT v02.72 data are same as used in inversion submitted GCP-CH4 project (Saunois et al 2019)

-Configuration of NIES-TM (Maksyutov et al. 2020)
resolution (2.5 degree),
reduced grid, larger longitudinal grid size near poles mass conserving meteorology,
mass fluxes on hybrid isentropic vertical coordinates interpolated from JCDAS
hand-coded adjoint with same CPU cost in forward and adjoint modes

Configuration of Flexpart
-JCDAS meteorology (1.25 deg, 40 model levels, 6 hourly)
-flux footprints estimated on 0.1x0.1 deg grid, hourly time step
-time window 2 to 3 days (for coupling to NIES-TM at 0 GMT)
-for coupling to NIES-TM, concentration footprints at coupling time estimated on isentropic vertical grid at 2.5 deg horizontal resolution

Prior fluxes, sinks:
1. EDGAR 4.3.2 anthropogenic: fossil/industrial, coal, oil and gas, municipal and agriculture
2. VISIT - wetland and soil sink
3. GFAS fire (daily)
4. Termites, ocean, geological as in Transcom-CH4
5. 3D monthly OH, O1D, Cl as in Transcom-CH4
VISIT wetland fluxes remapped from original 0.5 deg to 0.1 degree using maps of wetland area (GLWD 1km)
Flux corrections estimated for 2 flux categories
Anthropogenic, uncertainty 0.3 of EDGAR, monthly (use year 2010)
Wetlands, uncertainty 0.5 of VISIT (Cao), monthly climatology

-Observational data: WDCGG, GCP-CH4 dataset, global.
-Analysis period, 2008 – 2016.
-Optimization problem: reconstruct fluxes and uncertainties at weekly time step at resolution 0.1 deg



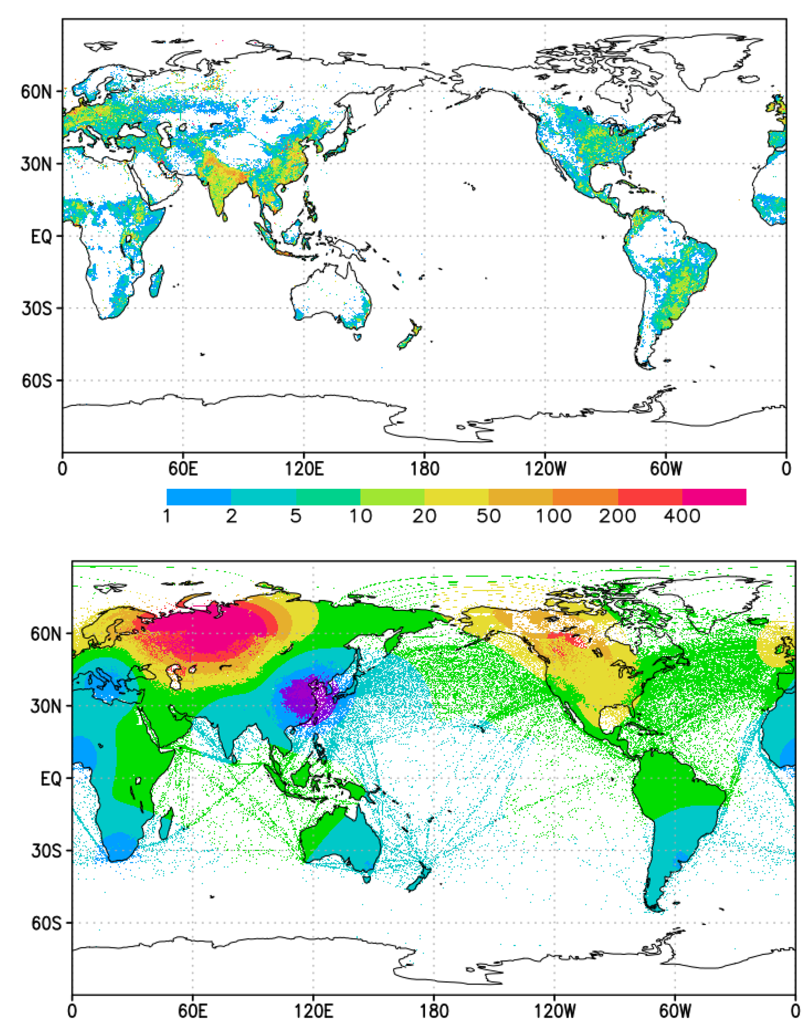
Inverse problem $y = H \cdot (x_p + x)$

y – CO_2 observations by GOSAT, H – transport model, x_p – prior flux
x – grid-resolving flux correction field
As the problem is ill-constrained in case of large dimension of x, regularization is applied by optimizing cost function

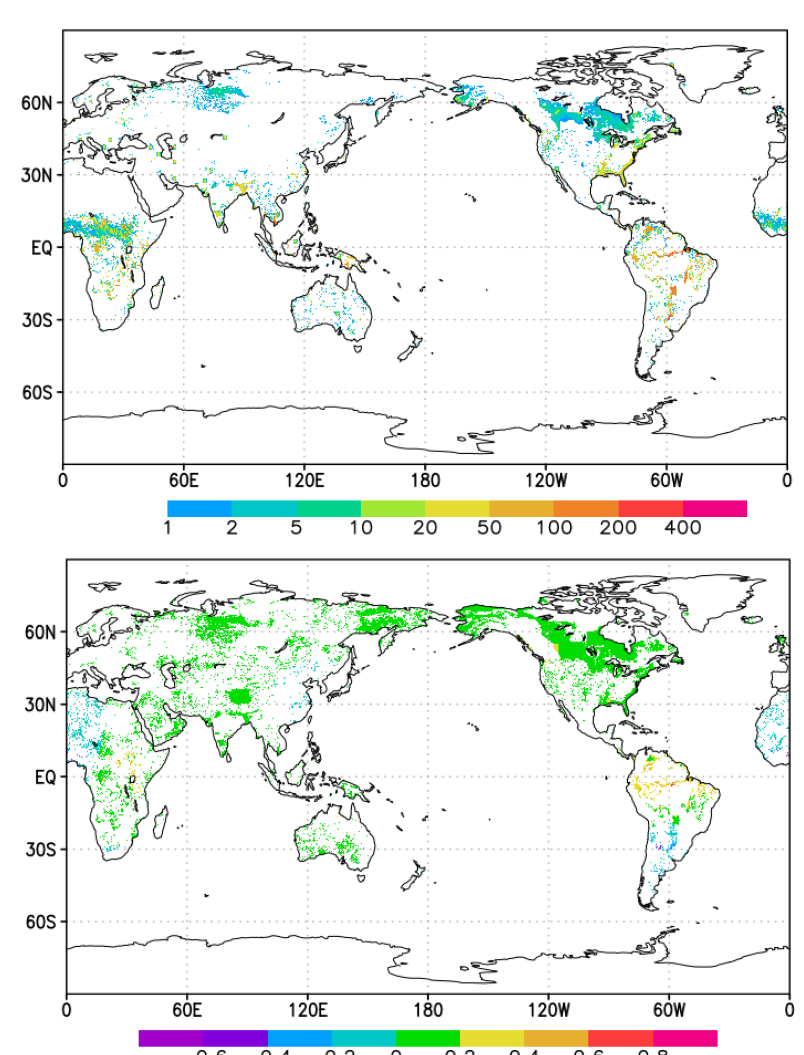
$$J = \frac{1}{2}(r - H \cdot x)^T R^{-1} (r - H \cdot x) + \frac{1}{2} x^T B^{-1} x$$

$r = y - H \cdot x_p$ is residual misfit of forward simulation
B provides smoothing constraint on x, (flux uncertainty)
R is covariance for data-model mismatch (data uncertainty)

Posterior anthropogenic methane emissions (top) and the scaling factors (bottom, mean for 2010-2012, unit mg CH_4 m^{-2} d^{-1}).

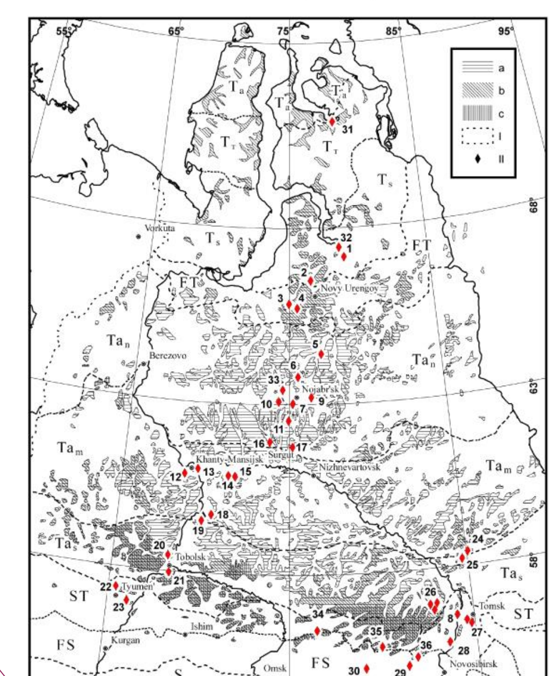


Posterior natural methane fluxes (top) and the scaling factors (bottom) 2010-2012 average, unit mg CH_4 m^{-2} d^{-1}.

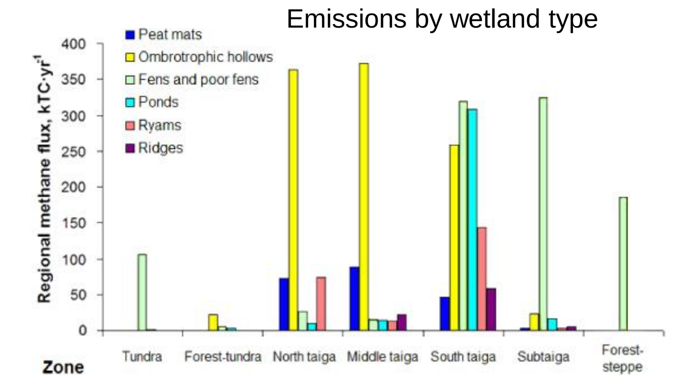


Wetland emission inventory – field observations and early mapping effort. Methane emissions from mires in all climate–vegetation zones of West Siberia (forest steppe, subtaiga, south taiga, middle taiga, north taiga, forest tundra and tundra) were measured using a static chamber method (Glagolev et al, 2011). The observed fluxes varied considerably from small negative values in forested bogs and palsa to tens of mgC m^{-2} h^{-1} in ponds and wet hollows. Observed data were consolidated in the form of the representative values of methane emissions for micro landscape types. The model is based on medians of CH4 flux distributions of eight different micro-landscape types depending on their location and estimated duration of methane emission period within the climate–vegetation zone. The estimates of methane flux from West Siberia mires by (Glagolev et al, 2011) give 2.9 ± 0.9 TgC CH4/yr, using multiscale mapping of WS wetlands by (Peregon et al 2009).

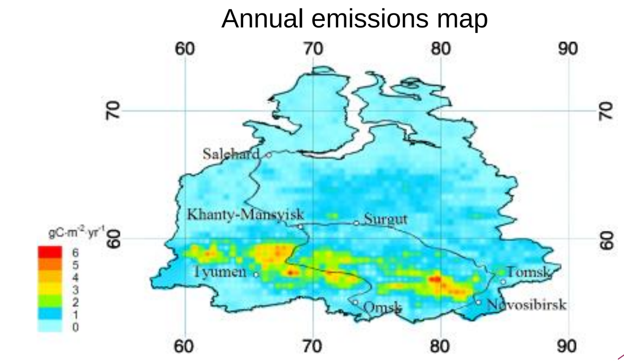
Flux observations sites by Glagolev et al 2011



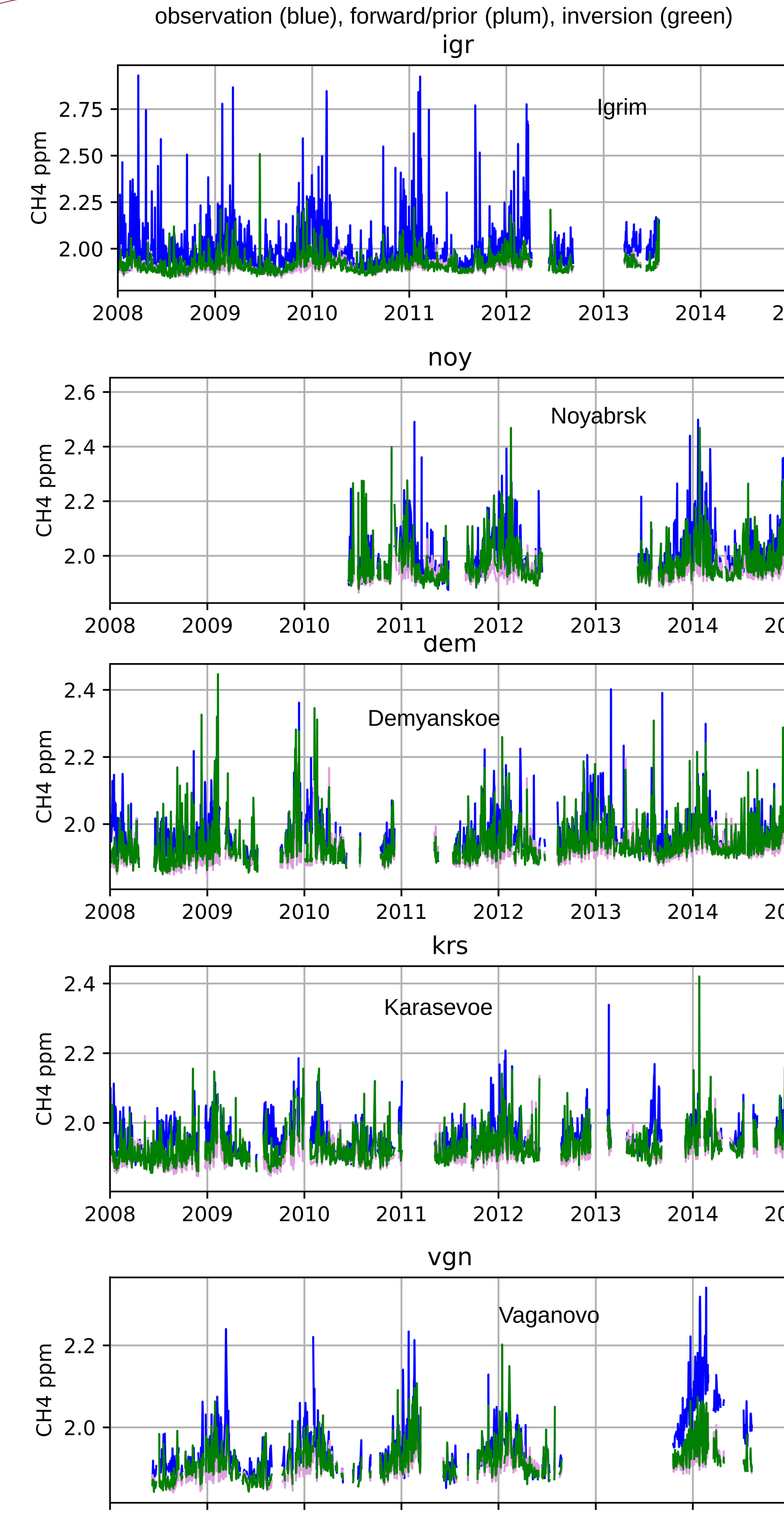
Emissions by wetland type



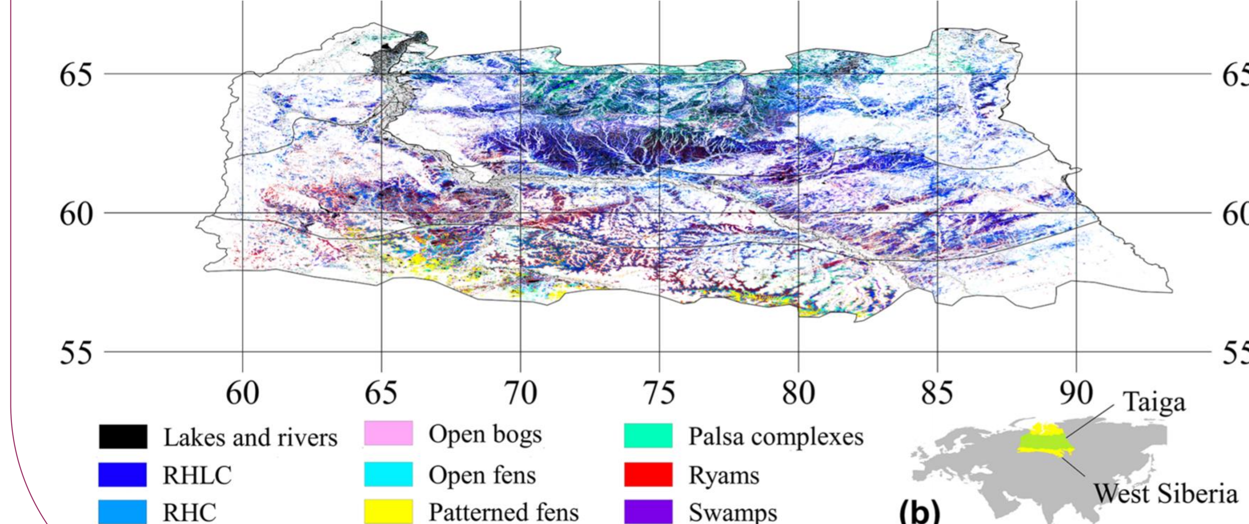
Annual emissions map



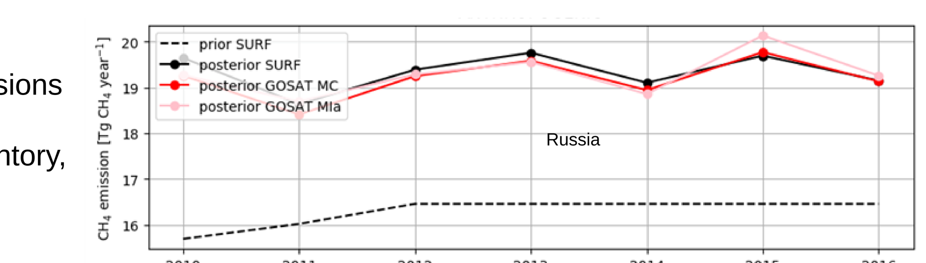
observation (blue), forward/prior (plum), inversion (green)



Wetland emission inventory – high resolution mapping with Landsat. In order to reduce uncertainties at the related to mapping of the wetland types, Terentieva et al (2016) mapped wetlands and water bodies in the taiga zone of The West Siberia Lowland (WSL) on a scene-by-scene basis using a supervised classification of Landsat imagery. Training data consist of high-resolution images and extensive field data collected at 28 test areas. The classification scheme aims at supporting methane inventory applications and includes seven wetland ecosystem types comprising nine wetland complexes distinguishable at the Landsat resolution. To merge typologies, mean relative areas of wetland ecosystems within each wetland complex type were estimated using high-resolution images. Ridge-hollow complexes prevail in WSL's taiga zone accounting for 33 % of the total wetland area, followed by pine bogs or "ryams" (23 %), ridge-hollow-lake complexes (16 %), open fens (8 %), palsa complexes (7 %), open bogs (5 %), patterned fens (4 %), and swamps (4 %). Various oligotrophic environments are dominant among wetland ecosystems, while poor fens cover only 14 % of the area. Because of the significant change in the wetland ecosystem coverage in comparison to previous studies, total CH4 emissions from the taiga zone is estimated to be more than 30% higher than by Glagolev et al (2011). Comparison of the bottom-up wetland emission inventory for West Siberia with VISIT ecosystem model and inversion estimates suggests a need to adjust the wetland emissions to match observed north-south gradient of emissions with higher emissions in the southern taiga zone.



Russia total: annual anthropogenic emissions are estimated to be higher than the inventory, but no significant increasing trend



SUMMARY
We used global high-resolution methane flux inversion based on the Lagrangian-Eulerian coupled tracer transport model to estimate methane emissions in Russia using atmospheric methane data collected at the Siberian station network JR-STATION, GOSAT and data by the global in-situ network.
We estimate higher anthropogenic emissions (19 Tg/y) than EDGAR inventory (16.5 TG/y) for Russia, by 15%. Correction attributed to West Siberia, European part of Russia.
Russian national inventory (2019 version) reports similar value to EDGAR inventory, inverse model difference with inventory is within model uncertainty range.
Comparison of the inversion estimates with the bottom-up wetland emission inventory for West Siberia suggests a need to adjust the wetland emissions to match observed north-south gradient of emissions with higher emissions in the southern taiga zone.

Acknowledgements. Authors acknowledge contribution by Environment and Climate Change Canada, Huilin Chen, Emilio Cuevas, Juha Hatakka, Petri Keronen, Elena Kozlova, Paul Krummel, Jost Lavric, Tuomas Laurila, Zoe Loh, Ivan Mammarella, Nikolaos Mihalopoulos, Simon O'Doherty, Michel Ramonet, Yasunori Tohjima, Ray Wang and other data contributors making the methane data available for the Global Carbon Project and WDCGG

References

Glagolev M., Kleptsova I., Filippov I., Maksyutov S., Machida T. Regional methane emission from West Siberia mire landscapes. ERL, 6, 045214, 2011.
Janardanan, R., Maksyutov, S., Tsuruta, A., Wang, F. et al.: Country Scale Analysis of Methane Emissions with a High-Resolution Inverse Model Using GOSAT and Surface Observations, Remote Sensing, 12, 375, 2020.
Maksyutov, S., Oda, T., Saito, M., Janardanan, R., et al.: Technical note: A high-resolution inverse modelling technique for estimating surface CO2 fluxes based on the NIES-TM – FLEXPART coupled transport model and its adjoint, Atmos. Chem. Phys. Discuss., 2020.
Peregon A., Maksyutov S, Yamagata Y., An image-based inventory of the spatial structure of West Siberian wetlands Environ. Res. Lett. 4 045014, 2009
Saunois, M., Stavert, A. R., Poulter, B., Bousquet P. et al. The Global Methane Budget 2000–2017, Earth Syst. Sci. Data Discuss., in review, 2019.
Stohl, A., C. Forster, A. Frank, P. Seibert et al: Atmos. Chem. Phys. 5, 2461-2474, 2005
Terentieva, I., Glagolev, M., Lapshina, E., Sabrekov, A., Maksyutov, S.: Mapping of West Siberian taiga wetland complexes using Landsat imagery: implications for methane emissions, Biogeosciences, 13, 4615–4626, 2016.
Wang, F, Maksyutov, S., Tsuruta, A., Janardanan, R. et al. Methane Emission Estimates by the Global High-Resolution Inverse Model Using National Inventories. Remote Sens. 2019, 11, 2489.