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Carbon emission related to thermokarst processes in wetlands of NE European Tundra

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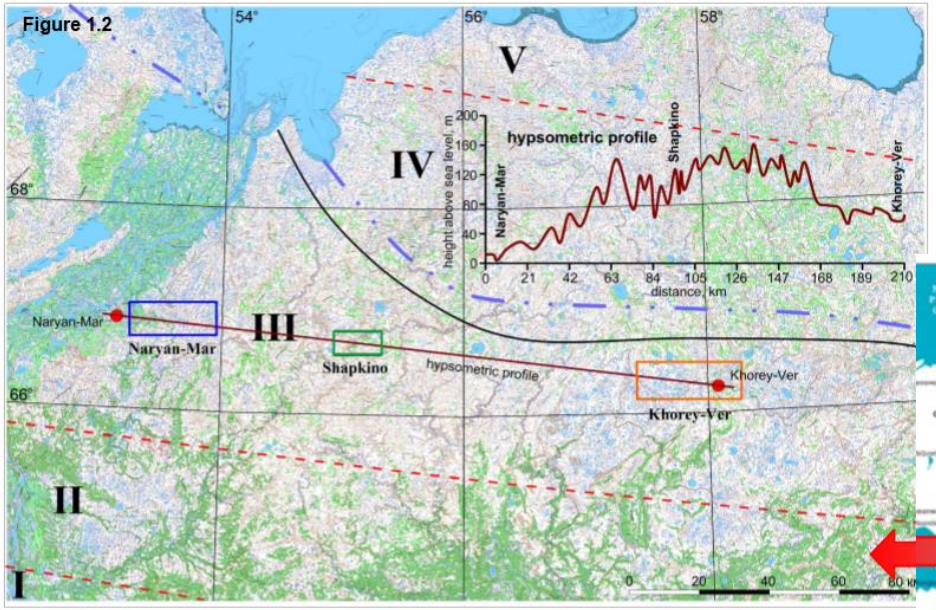
Introduction

Emission of greenhouse gases (GHG) from inland waters is recognized as highly important and understudied part of terrestrial carbon (C) biogeochemical cycle. These emissions are still poorly quantified in subarctic regions containing vast amount of surface C in permafrost peatlands. This is especially true for NE European peatlands, located within sporadic to discontinuous permafrost zone which is highly vulnerable to thaw.

Goal:

assessing the effect of waterbody size (over 5 orders of magnitude in surface area) and seasonality on C emissions and quantifying the overall emission flux of CO_2 and CH_4 from the lakes of BZT territory to the atmosphere.

Study site



I – rare permafrost (1-5% based on area); II - rare and sporadic permafrost (5-25% based on area);
III – sporadic permafrost (25-60% based on area); IV – mostly continuous permafrost (25-60% based on area)
V – mostly continuous permafrost (70-95% based on area)

100 m permafrost boundary — zone permafrost boundaries — mostly continuous permafrost boundarie

Bolshezemelskaya tundra (NE Europe) is the largest frozen peatland in Europe.
There is very limited information on GHG emission from inland waters of European Russian tundra.

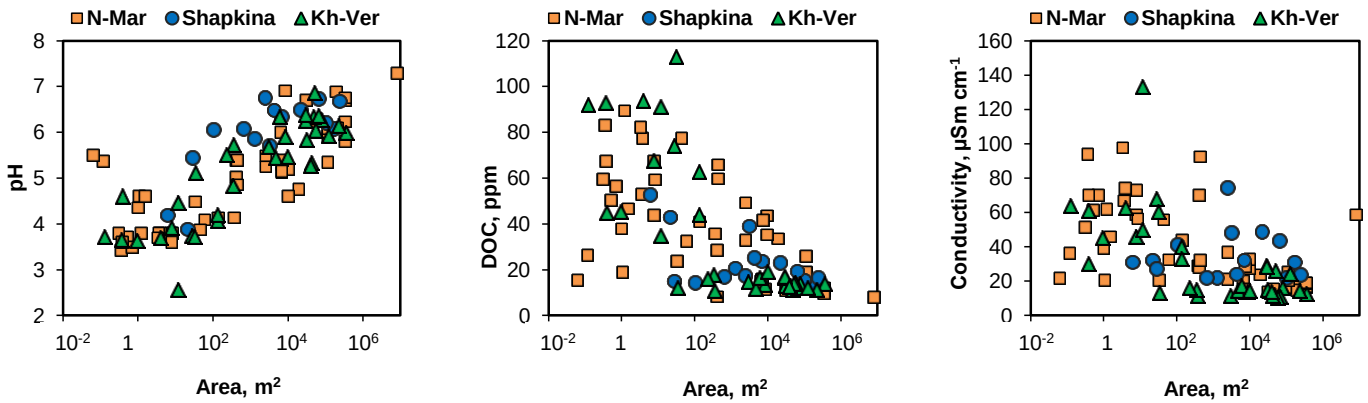
The areas of the sites Naryan-Mar, Shapkino, Khorey-Ver differ in altitude, the thickness of peat bogs and the type of underlying mineral component

- The mean annual temperature is -3.1°C
- the mean annual precipitation is 503 mm
- the dominant vegetation of the tundra zone is mosses, lichens and dwarf shrubs.

CO_2 and CH_4 concentrations and fluxes to the atmosphere in 98 depressions, thaw ponds and thermokarst lakes were measured .

Methods

One key site (Naryan-Mar) was selected for seasonal and annual monitoring of lakes (~43 km SE from the town of Naryan-Mar) and two additional sites (Shapkino and Khorey-Ver) to account for spatial heterogeneity over summer season (July 2016). To reveal seasonal and annual variability of GHG concentrations and fluxes in BZT depressions, thaw ponds and thermokarst lakes, we visited the Naryan-Mar site in spring (16-17 June 2017), summer (17-23 July 2017) and autumn (02-04 October 2017). To account for inter-annual variability, three lakes of the Naryan-Mar site were sampled in July 2015, 2016, 2017 and 2018. The 4 sampled years were rather contrasting in mean monthly and annual temperature and precipitation.



Hydrochemical characteristics of thermokarst water bodies

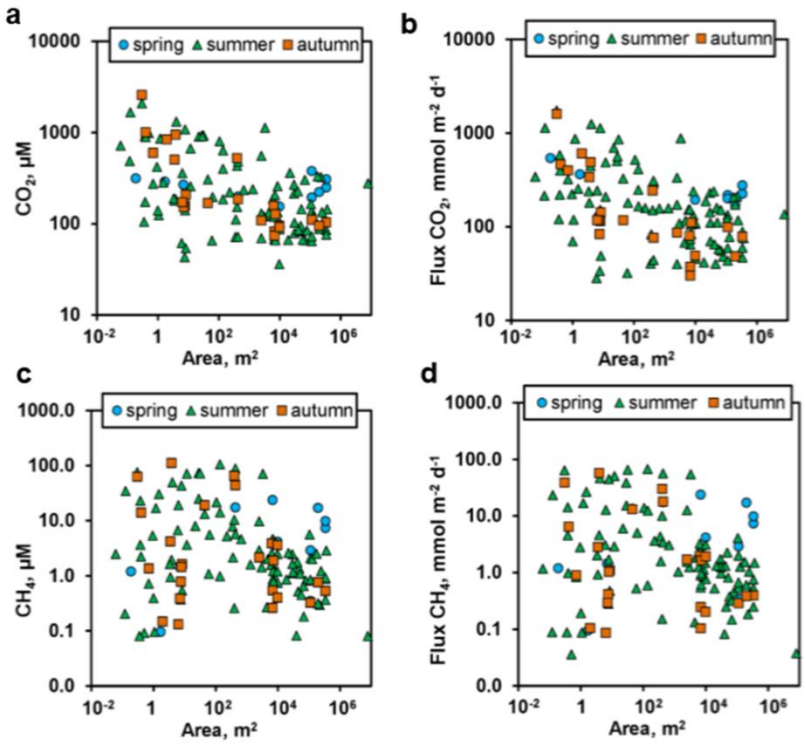
CO_2 and CH_4 concentration and flux measurements and calculations

- Surface water concentrations of methane and carbon dioxide were determined through gas chromatography
- CO_2 and CH_4 fluxes were calculated from wind speed and surface water gas concentrations (Repo et al. 2007). This technique is based on the two-layer model of Liss and Slater (1974). The gas transfer coefficient was taken from Cole and Caraco (1998).

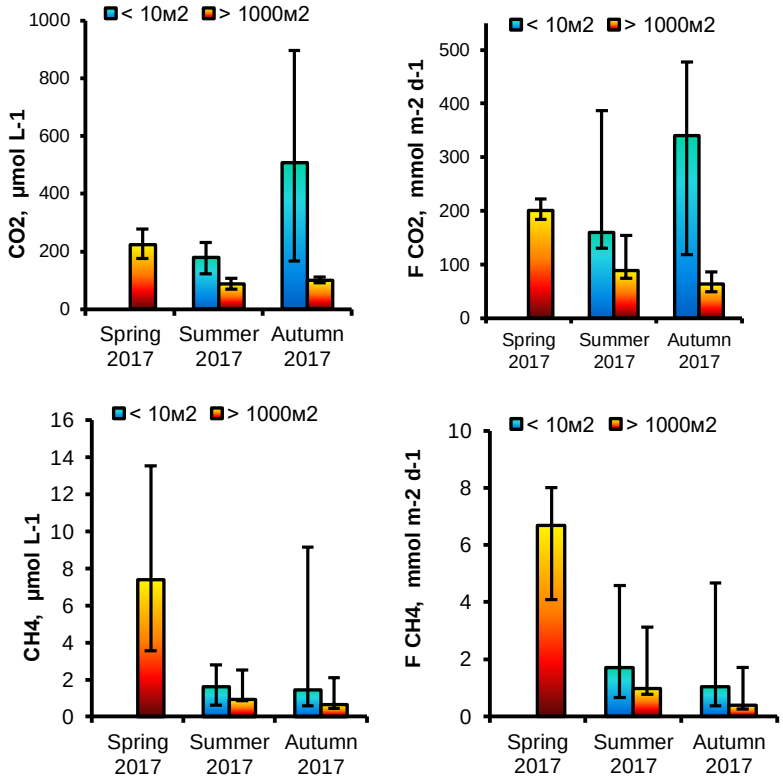
Lake size and area inventory using satellite imagery

- Satellite images of the Landsat-8 medium resolution (MR), along with the GeoEye-1 ultra-high resolution (UHR) images were used to map the distribution of lakes throughout the BZT territory affected by permafrost.
- For the entire territory of BZT we used a mosaic of 50 MR images. Images were processed using standard ArcGIS 10.3 software tools using the Fmask algorithm (see Polishchuk et al. 2014, 2017, 2018 for description of methodlogy).
- To calculate partial contributions of lakes of different size range to the overall emissions of CO_2 and CH_4 in lakes of Bolshezemelskaya Tundra, were used median concentrations and fluxes (averaged over all sites and all seasons) and lake size distribution from GeoEye-1 and Landsat data.

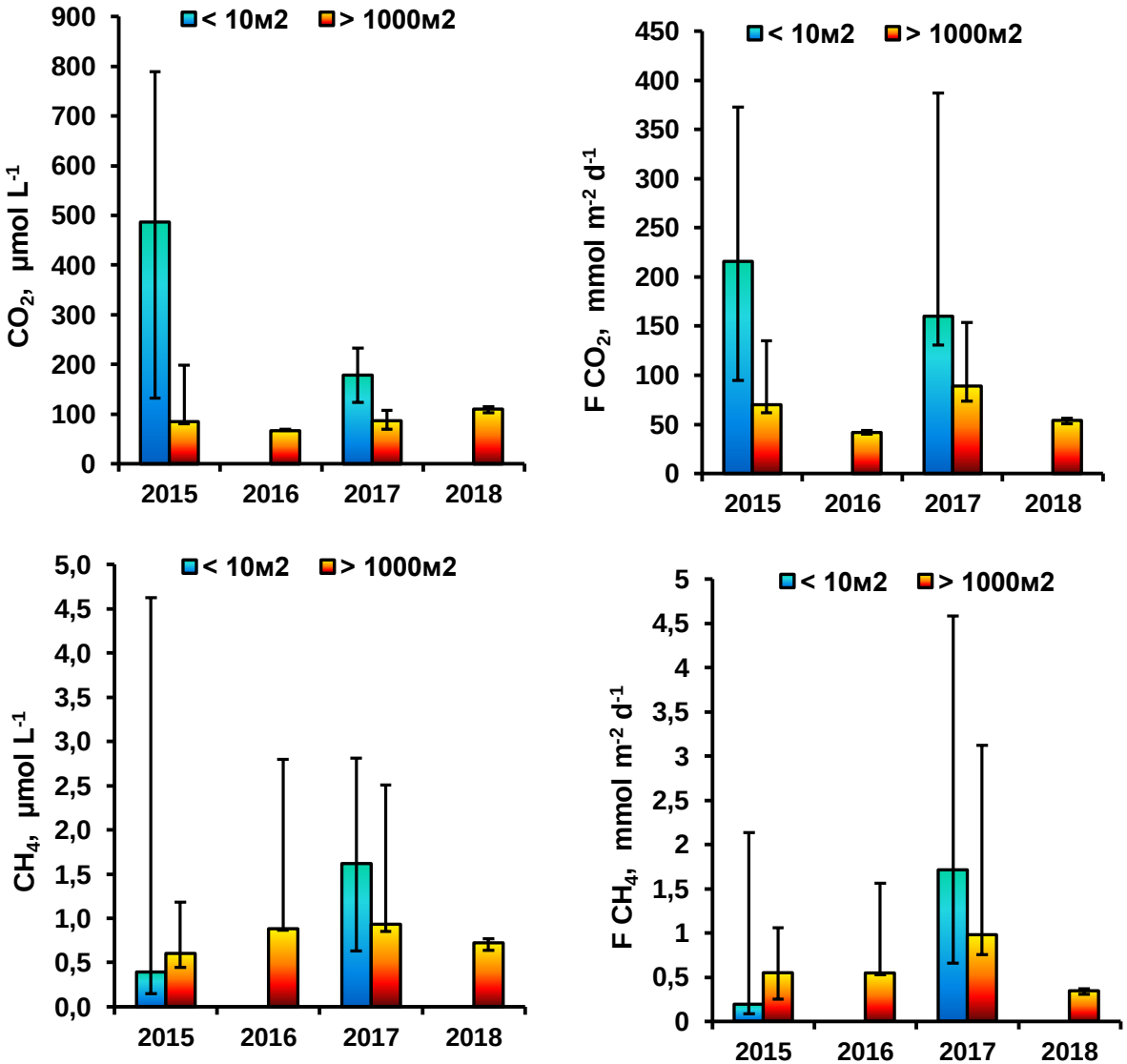
CO_2 and CH_4 concentrations and fluxes as a function of lake surface area in spring, summer and autumn at the Naryan-Mar site



Seasonal variations of median and interquartile CO_2 , CH_4 concentrations and emissions at the Naryan-Mar site in 2017

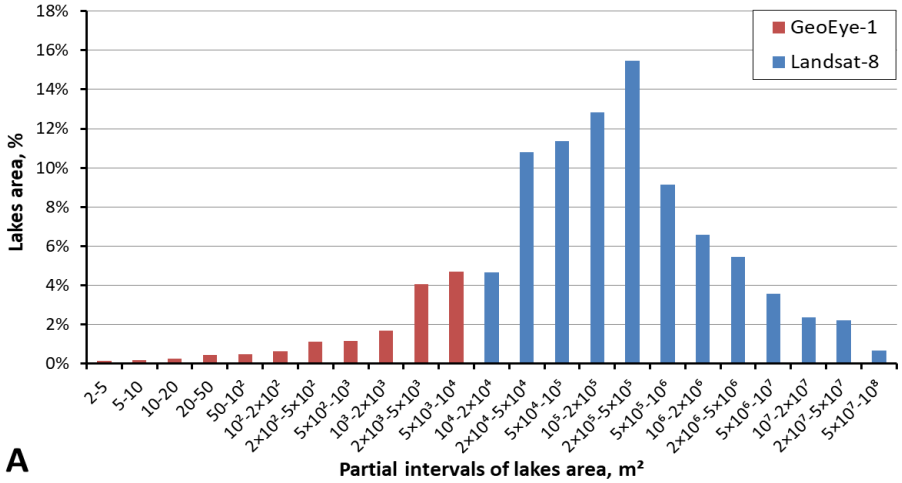


Inter-annual variations of median and interquartile CO_2 and CH_4 concentrations and CO_2, CH_4 emissions at the Naryan-Mar site in July, 2015-2018

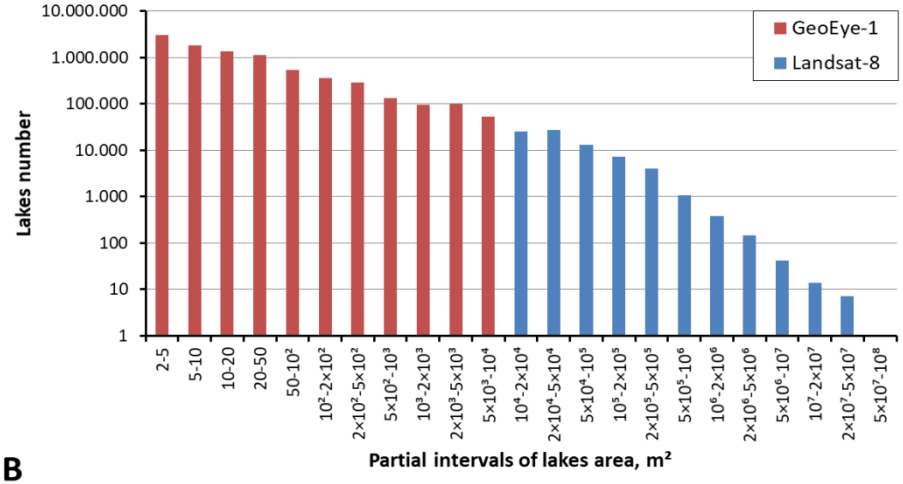


The summer of 2015 was cold (-4.8°C below normal in July), and the summers of 2016, 2017 and 2018 were warm (+5.0, +4.0 and +2.5°C above normal in July). The summers of 2016 and 2018 were dry (31 and 36% of normal in July), where as the precipitation in 2015 and 2017 was 83 and 56% of normal.

The distribution of total lake number (A) and relative contribution of different size of lakes into the total lake areas (B)

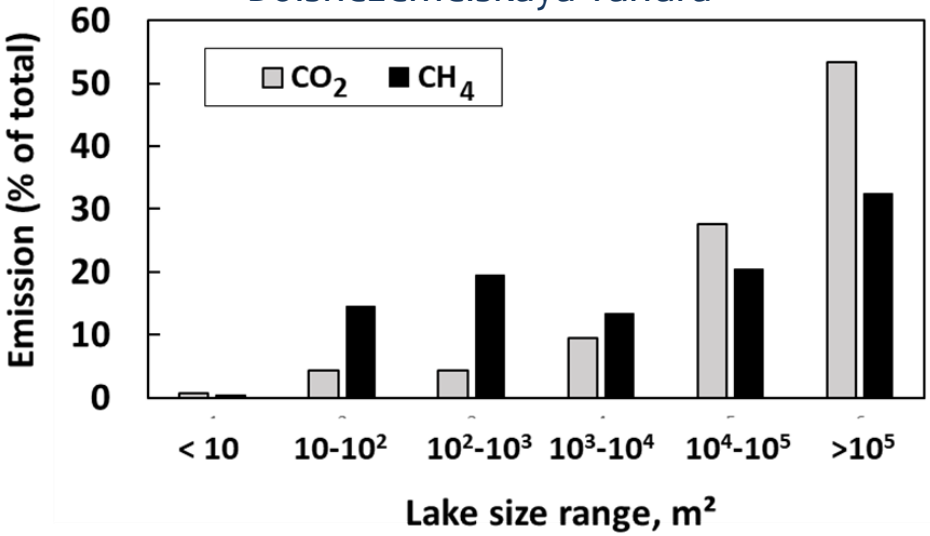


A



B

Partial contributions of lakes of different size range to the overall emissions of CO_2 and CH_4 in lakes of Bolshezemelskaya Tundra



Summary

- The CO2 fluxes decreased by an order of magnitude when lake size increased by > 3 orders of magnitude, while CH4 fluxes showed large variability that were not related to lake size
- The external spatial and temporal factors exhibited the following order of control on GHG parameters: lake size > season > year.
- By using a combination of Landsat-8 and GeoEye-1 images we found that lakes cover 4% of BZT, and calculated the overall C emission (CO2+CH4) from the lakes of the territory to 3.8 Tg C y^{-1} (99% C-CO2, 1% C-CH4). Note that similar to previous works in other Arctic lakes, the GHG flux numbers represent a minimum estimate for the total annual CO_2 and CH_4 fluxes from Eastern European tundra thaw lakes because we did not include CH_4 ebullition (i.e., Sabrekov et al. 2017; Elder et al. 2018) and potential spring release of CO_2 and CH_4 accumulated under ice (Karlsson et al. 2013).
- Large lakes (> 10,000 m^2) dominated GHG emissions whereas small thaw ponds (< 1000 m^2) had a minor contribution to overall lake surface area (< 2%) and GHG emission (< 5 % of CO_2; < 20% of CH_4).
- The results suggest that, if permafrost thaw in NE Europe leads to disappearance of large thermokarst lakes and formation of new small thaw ponds and depressions, this will decrease GHG emission from lentic waters of this region.
- However, due to temporal and spatial variations of C fluxes, the uncertainties on areal GHG emission are at least one order of magnitude in small thaw ponds and a factor of 3 to 5 in thermokarst lakes.

References

Cole, J. J. and Caraco, N. F. 1998. Atmospheric exchange of carbon dioxide in a low-wind oligotrophic lake measured by the addition of SF6. *Limnol. Oceanogr.* 43, 647–656.

Elder, C. D., and others. 2018. Greenhouse gas emissions from diverse Arctic Alaskan lakes are dominated by young carbon. Nature Climate Change 8: 166-171 doi: 10.1038/s41558-017-0066-9

Karlsson, J., R. Giesler, J. Persson, and E. J. Lundin. 2013. High emission of carbon dioxide and methane during ice thaw in high latitude lakes. Geophys. Res. Lett. 40: 1–5. https://doi.org/10.1002/grl.50152

Liss, P. S. and Slater, P. G. 1974. Flux of gases across the air-sea interface. Nature **247**: 181–184.

Polishchuk, Y. M., A. N. Bogdanov, V. Y. Polischuk, R. M. Manasypov, L. S. Shirokova, S. N. Kirpotin and O. S. Pokrovsky. 2017. Size-distribution, surface coverage, water, carbon and metal storage of thermokarst lakes (> 0.5 ha) in permafrost zone of the Western Siberia Lowland. Water 9: 228. doi:10.3390/w9030228

Polishchuk, Y. M., A. N. Bogdanov, I. N. Muratov, V. Y. Polishchuk, A. Lim, R. M. Manasypov, L. S. Shirokova, and O. S. Pokrovsky. 2018. Minor contribution of small thaw ponds to the pools of carbon and methane in the inland waters of the permafrost-affected part of the Western Siberian Lowland. Environ. Res. Lett. 13: 04500. https://doi.org/10.1088/1748-9326/aab046

Polishchuk, Y., S. Kirpotin, and N. Bryksina. 2014. Remote study of thermokarst lakes dynamics in West-Siberian permafrost, p. 173-204. In O.S. Pokrovsky [ed], Permafrost: Distribution, Composition and Impacts on Infrastructure and Ecosystems. NY. Nova Science Publishers.

Repo, M. E., J.T. Huttunen, A.V. Naumov, A.V. Chichulin, E.D. Lapshina, W. Bleuten, and P.J. Martikainen. 2007. Release of CO_2 and CH_4 from small wetland lakes in western Siberia. Tellus Ser. B: Chem. Phys. Meteorol. **59**: 788–796. doi: 10.1111/j.1600-0889.2007.00301.x

Sabrekov, A F, B. R. K. Runkle, M. V. Glagolev, I. E. Terentieva, V. M. Stepanenko, O. R. Kotsyurbenko, S. S. Maksyutov, and O. S. Pokrovsky. 2017. Variability in methane emissions from West Siberia's shallow boreal lakes. Biogeosciences 14: 3715-3742. https://doi.org/10.5194/bg-14-3715-2017