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Using atmospheric inverse modeling to estimate national methane emissions from Finland

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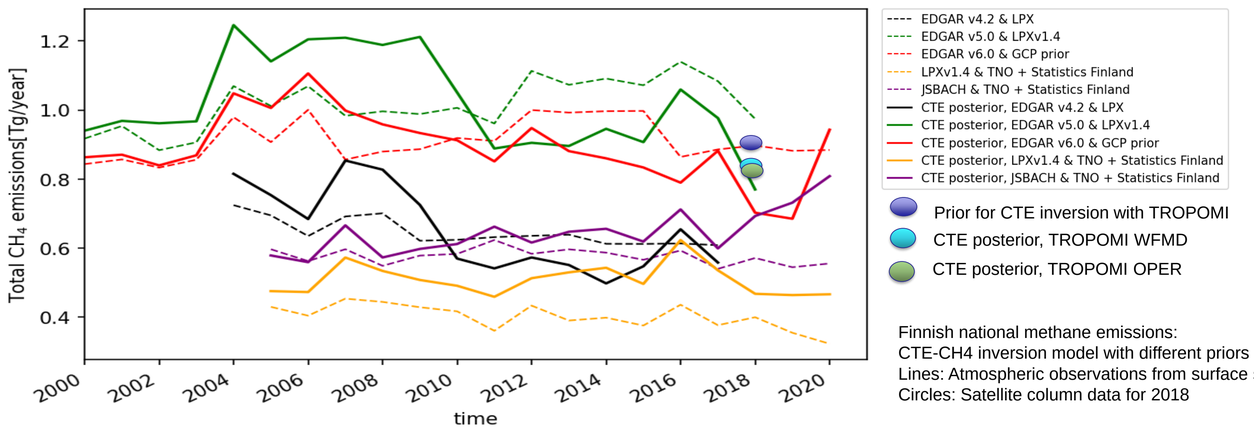
Introduction

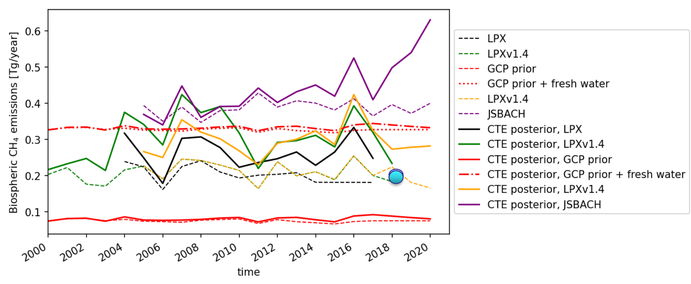
Requirements of accurate and timely quantification of greenhouse gas budgets, and verification of national greenhouse gas inventories, calls for GHG atmospheric inversion estimates in resolutions that are utilisable in country level, and demands assimilation of satellite obsevations in addition to surface observations. High intensity data might enable separation of the emissions to different categories that are used in national inventory reporting. Here we study methane emissions from Finland using several inversion set-ups and possibilities to assign fluxes to different land cover categories.

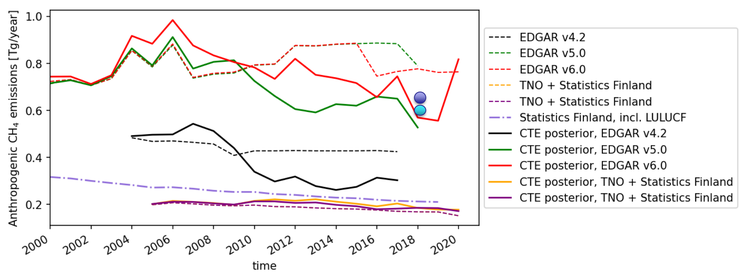
Materials and methods

- Atmospheric inversion model Carbon Tracker Europe – CH4 (CTE-CH4, Tsuruta et al., 2017): global biospheric and anthropogenic methane emissions with 1 x 1 degree resolution over Finland and neighbouring regions. Several set-ups with different priors, including EDGAR versions 4.2, 5 and 6 (Crippa et al., 2020), TNO emissions (Kuenen et al., 2014) redistributed using agricultural data from Statistics Finland, LPX-Bern ecosystem model (Lienert et al.,2018), JSBACH ecosystem model (Petrescu et al., 2020) and mean of Global Carbon Project models (Saunois et al., 2020)
- Methane observations at surface sites (FMI, Obspack v 3.0: Kenneth et al., 2021) and satellite data from TROPOMI (OPER: Hu et al., 2016, WFMD: Schneising et al., 2019)
- Finnish Corine land cover (Härmä et al., 2019)
- Copernicus Water & Wetness v. 2.0 Expert Product (https://land.copernicus.eu/pan-european/high-resolution-layers/water-wetness)



Finnish national methane emissions:
CTE-CH4 inversion model with different priors
Lines: Atmospheric observations from surface sites.
Circles: Satellite column data for 2018





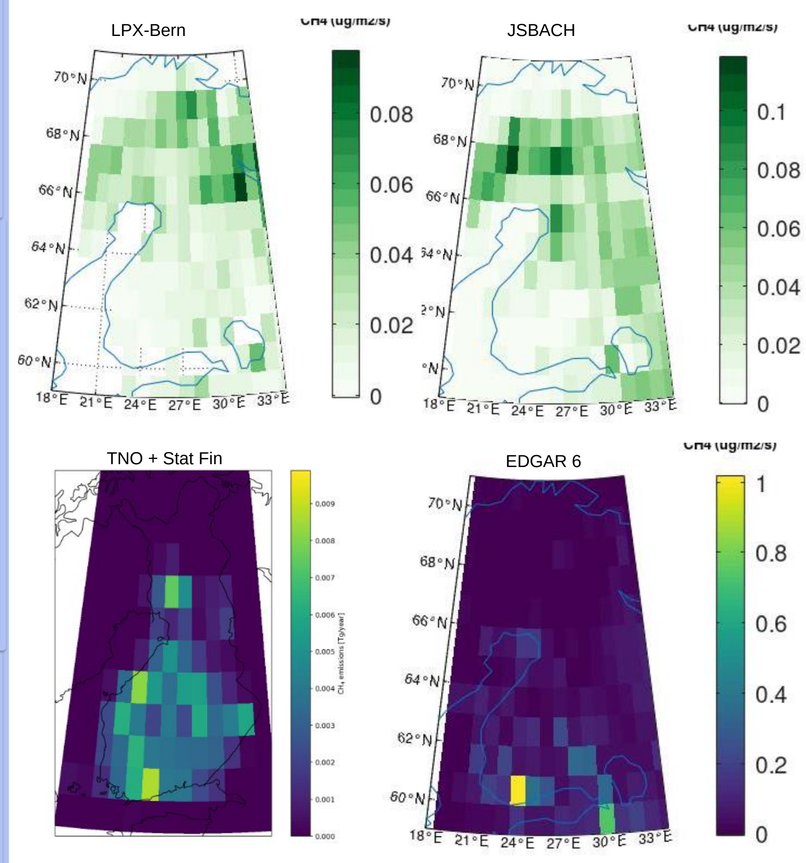
Results

- Anthropogenic (agriculture, waste, energy) emissions dominate in southern Finland.
- For the national total, prior TNO emissions are smaller than EDGAR emissions and follow those reported in national inventory. In the posterior, inversion increases the lowest anthropogenic priors and decreases largest priors. The decrease is observed also in the TROPOMI inversion.
- Biospheric (all land) emissions are dominant in northern Finland, where also Copernicus WAW data shows highest occurrences of permanently wet land.
-The highest emissions occur in grid cells where open bog cover fraction is largest. Notable correlations are also found for forest and transitional woodland on peat, however they are often co-located in open bog grid cells. The forested peatland might act as a source of methane during wet periods or if the drainage is not working properly.
- Inversions almost always increase the annual biospheric emissions

Conclusions

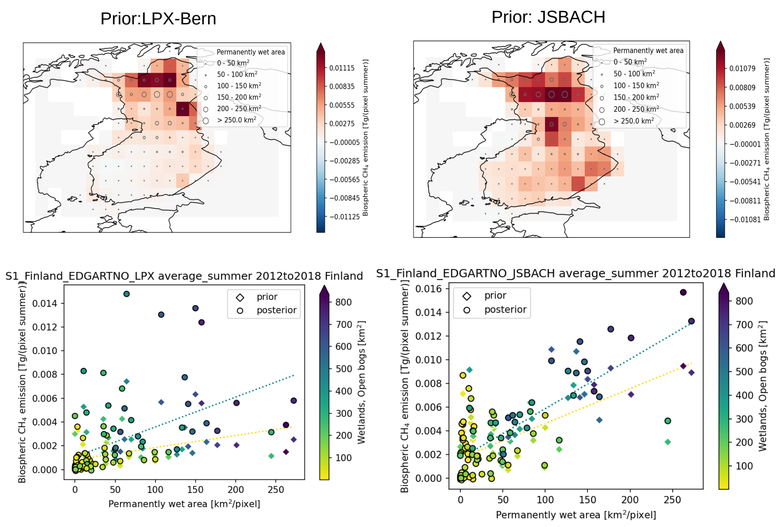
The national emissions for Finland vary significantly depending on inversion set-up. Despite of several representative surface stations, the number of observation sites could be increased due to diversity of the emissions and their spatial distribution. High resolution satellite observations like those from TROPOMI may provide a better constraint on emissions. However the possible problems like biases still need to be tackled (see poster by Aki Tsuruta).

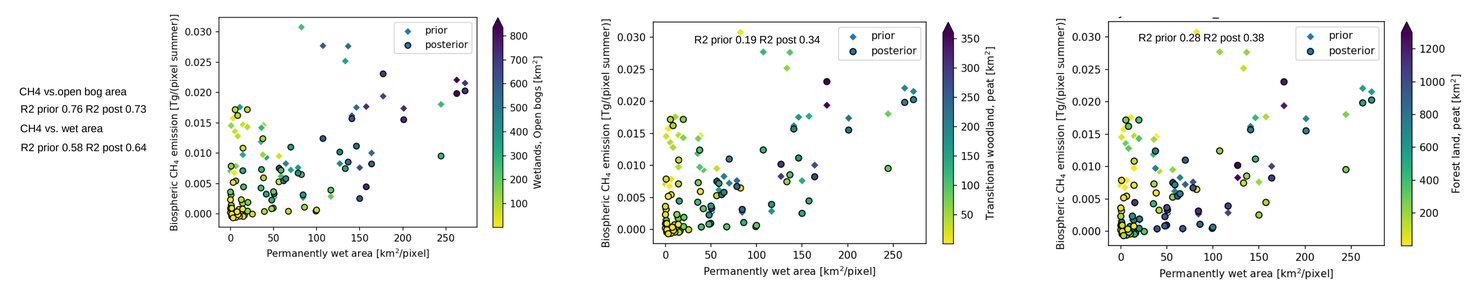
With current resolution it is challenging to detect fluxes from the detailedly specified land cover classes in Finnish Corine. However, the results are promising in terms of detecting the most significant emission categories especially when multiple data sets and approaches are used together, and in preparation to higher resolution inversions.



Prior methane fluxes from ecosystem models and anthropogenic emission databases.

CTE-CH4 emissions vs Copernicus WAW permanently wet area
Colour scale in lower figures according to area in open bog land cover class
Mean fluxes, summer 2012 - 2018





CTE-CH4 emissions in summer 2018 vs permanently wet area, coloured according to area in different land use classes (open bog, transitional woodland on peat, forest land on peat)

References

Crippa, M. et al. High resolution temporal profiles in the Emissions Database for Global Atmospheric Research. Scientific Data 7, 121 (2020).
Hu, H. et al. The operational methane retrieval algorithm for TROPOMI. Atmospheric Measurement Techniques 9, 5423–5440 (2016).
Härmä et al.,Final report on Copernicus Land Monitoring 2014 – 2020 in the framework of Regulation (EU) No 377/2014 of the European Parliament (2019)
Kenneth N. et al. Multi-laboratory compilation of atmospheric methane data for the period 1983-2020; obspack_ch4_1_GLOBALVIEWplus_v3.0_2021-05-07; NOAA Earth System Research Laboratory, Global Monitoring Laboratory. http://doi.org/10.25925/20210401. (2021)
Kuenen, J. J. P., Visschedijk, A. J. H., Jozwicka, M., and Denier van der Gon, H. A. C.: TNO-MACC_II emission inventory; a multi-year (2003–2009) consistent high-resolution European emission inventory for air quality modelling, Atmos. Chem. Phys., 14, 10963–10976, https://doi.org/10.5194/acp-14-10963-2014, 2014.
Lienert, S. & Joos, F. A Bayesian ensemble data assimilation to constrain model parameters and land-use carbon emissions. Biogeosciences 15, 2909–2930 (2018).
Petrescu, A.M.R., et al. The consolidated European synthesis of CH42$O emissions for EU27 and UK: 1990–2018. Earth System Science Data Discussions 1–78. https://doi.org/10.5194/essd-2020-367 (2020)
Saunois, M,et al. The Global Methane Budget 2000–2017. Earth System Science Data 12, 1561–1623. https://doi.org/10.5194/essd-12-1561-2020 (2020)
Schneising, O. et al. A scientific algorithm to simultaneously retrieve carbon monoxide and methane from TROPOMI onboard Sentinel-5 Precursor. Atmospheric Measurement Techniques 12, 6771–6802 (2019).
Tsuruta, A. et al. Global methane emission estimates for 2000–2012 from CarbonTracker Europe-CH4 v1.0. GMD 10, 1261–1289 (2017).

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