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Solving Methane Fluxes at Northern Latitudes using Atmospheric and Soil Earth Observations Data

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Atmospheric methane in the Arctic and boreal regions – Introduction

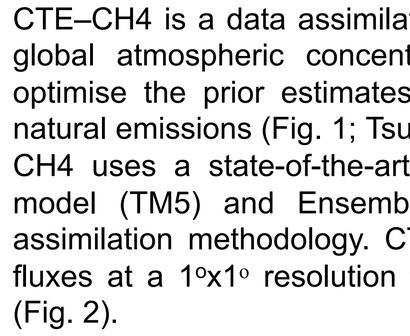
Atmospheric methane concentration has globally increased by about 150% since 1750. Methane is the second most important greenhouse gas in terms of its direct radiative forcing. Methane has a high global warming potential, which means that changes in the CH_4 fluxes are crucial for climate and, therefore, essential to be accurately quantified and continuously monitored. Natural emissions of CH_4 originate mainly from wetlands. The boreal and Arctic regions contribute to the global methane budget through the wetlands, permafrost and lakes (Global Methane Budget, 2016). The sources and sinks of CH_4 can be quantified using inverse modelling. The model is informed by data assimilation using in-situ and ground-based measurements, and Earth observations. The wetland CH_4 emissions are highly dependent on the ground conditions and properties. In this newly-funded ESA Science for Society project, we seek to improve CH_4 modelling in the boreal and Arctic regions by incorporating synergetic, novel EO datasets for atmospheric CH_4 columns and soil freezing.

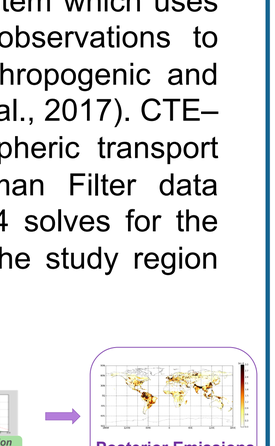
Space-based methane observations from GOSAT and Sentinel-5P TROPOMI

Primary data source:

- Retrievals of column-averaged methane (XCH_4) from the Greenhouse Gases Observing Satellite (GOSAT), launched in 2009 by JAXA and NIES.

Retrievals of XCH_4 from TROPOMI (launched in October, 2017, by ESA) will be included in the analysis.



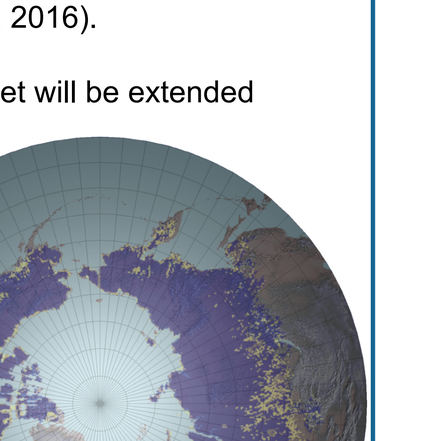


Methane column observations on the ground and in-situ measurements

Data sources:

- Ground-based retrievals of XCH_4 from FTIR
- In-situ CH_4 concentrations (see Fig. 2)
- In-situ CH_4 fluxes
- Atmospheric CH_4 profiles

These data will be used in CTE–CH4 data assimilation and partly to evaluate the satellite CH_4 retrievals.



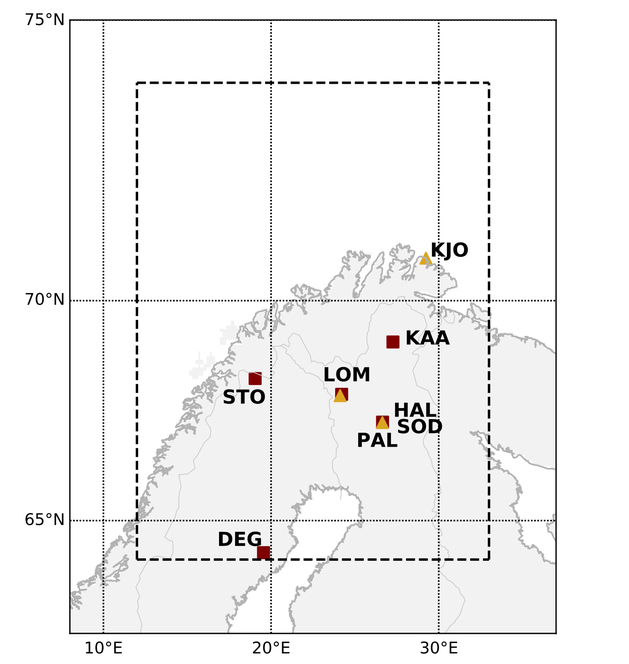


Fig. 2. The study region of specific focus during this project. The locations of the in-situ sites are shown.

End-product objectives

- Identification of the magnitude of CH_4 sources in the Northern Hemisphere.
- Trend analysis on the methane emissions and their correlation with the soil freeze/thaw data.
- Identification of possible changes in the annual cycle of CH_4 sources.

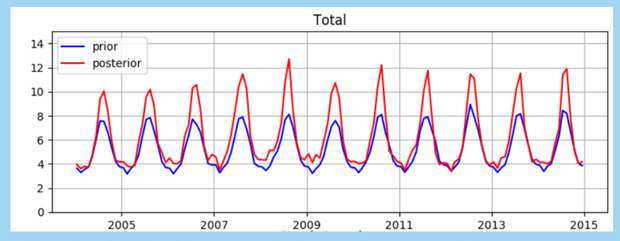


Fig. 3. CTE–CH4 model results: monthly methane flux estimates in Tg CH_4 for the Northern latitudes above 50°N for 11 years.

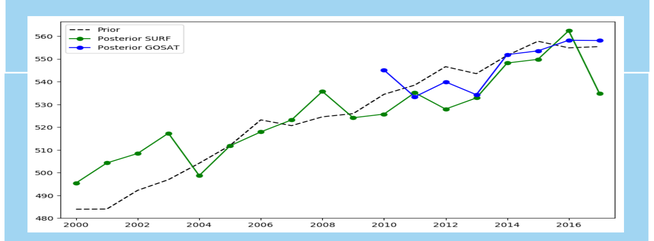


Fig. 4. Global total annual CH_4 emissions from CTE-CH4 model, assimilating in situ surface concentrations or satellite (GOSAT) columns

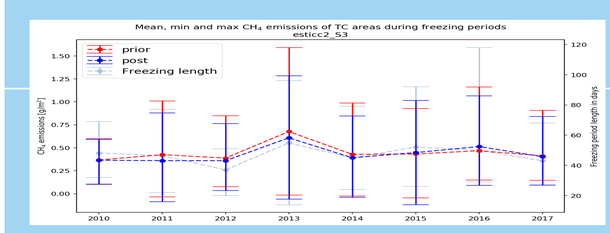


Fig. 5. Northern latitude CH_4 emissions during soil freezing period from CTE-CH4 model and number of soil freezing period days in the northern latitudes above 50°N

Atmospheric inversion model: CarbonTracker Europe – CH4 (CTE–CH4)

CTE–CH4 is a data assimilation system which uses global atmospheric concentration observations to optimise the prior estimates of anthropogenic and natural emissions (Fig. 1; Tsuruta et al., 2017). CTE–CH4 uses a state-of-the-art atmospheric transport model (TM5) and Ensemble Kalman Filter data assimilation methodology. CTE–CH4 solves for the fluxes at a 1°x1° resolution within the study region (Fig. 2).

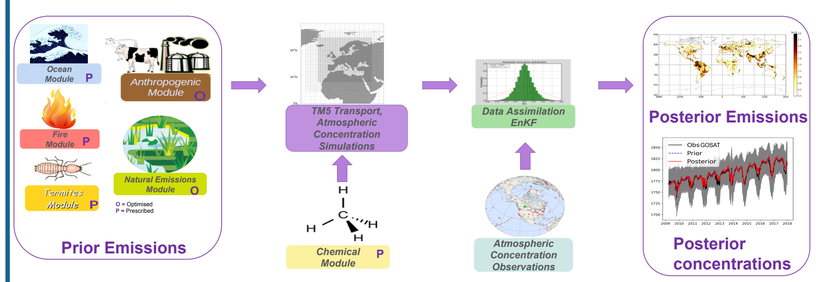


Fig. 1. CarbonTracker CH4 modelling scheme illustrated from prior emissions to posterior flux estimates.

Global soil freezing information from the SMOS satellite

Primary data source:

- Global soil freeze/thaw (F/T) data estimated from the ESA Soil Moisture and Ocean Salinity (SMOS) mission (Rautiainen et al., 2016).

During the project, this dataset will be extended historically using other satellite-based F/T data.

Further information on the product can be found from the SMOS service portal: http://nsdc.fmi.fi/services/SMOS Service/

References:
The Global Methane Budget 2000-2012, by M. Saunois and co-authors (2016), Earth System Science Data, DOI:10.5194/essd-8-697-2016.
Rautiainen et al., SMOS prototype algorithm for detecting autumn soil freezing, Remote Sens. Environ. 147, 206–218, 2016,
Tsuruta et al., Global methane emission estimates for 2000-2012 from CarbonTracker Europe-CH4 v1.0, Geosci. Model Dev. 10, 2785-2800, 2017.

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