Horizon 2020 Societal challenge 5:
Climate action, environment, resource efficiency and raw materials

VERIFY

Observation-based system for monitoring and verification of greenhouse gases

GA number 776810, RIA

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Internal reviewer:	Philippe Peylin (CEA)

1. Changes with respect to the DoA

None

2. Dissemination and uptake

The model results will be made available via the VERIFY project database and are currently available via a data server (in some cases registration will be necessary). These model results are used in the top-down (inverse) modelling approach for D4.7 and will be used in the synthesis product in WP5.

3. Short Summary of results

Natural CH_4 emissions are an important component of the global CH_4 budget, comprising approximately 40% of the total emissions. The largest source of natural emissions is from wetlands with a smaller, but very uncertain, contribution from inland water bodies. This deliverable provides estimates of natural emissions of CH_4 from wetlands and mineral soils, as well as from inland water bodies. Two modelling frameworks are used to estimate the emissions: 1) the combined model JSBACH-HIMMELI, which is used to estimate wetland and mineral soil emissions, and 2) an empirical model of inland water emissions. JSBACH-HIMMELI is a process-based model consisting of a land-surface model, JSBACH, which is used to drive a model of CH_4 emissions from wetlands, HIMMELI (see Section 2.1.1). The inland water bodies model is empirical and scales-up measurements of CH_4 emissions from lakes and reservoirs to the European scale relying on proxy data (see Section 2.2.1). Results are presented from both models as gridded maps at 0.1°×0.1° resolution (see Section 3).

4. Evidence of accomplishment

5. All the simulation results will be accessible through the dedicated data THREDDS server that is accessible from the VERIFY web site: http://verify.lsce.ipsl.fr/index.php/products

6. Note that some of these data may be password protected during a consolidation phase and thus only accessible to the VERIFY partners (accessible through the internal share-point platform).

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Version	Date	Description	Author (Organisation)
V0	23/07/2019	Creation/Writing	Rona Thompson (NILU)
V1	09/09/2019	Formatting/Delivery	Philippe Peylin (CEA)

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1. Introduction

This document describes the two modelling frameworks used to estimate natural emissions of CH_4. Natural emissions of CH_4 are primarily those from peatlands (and to a lesser extent mineral soils) and fresh water systems. While there is also a natural geological source of CH_4, this is not covered in VERIFY, and estimates for this source vary widely, from nearly negligible with a global total of 1-5 Tg/y to significant with a global total of approximately 50 Tg/y. The model framework, JSBACH-HIMMELI is used to estimate peatland and mineral soil emissions, and an empirical model is used to estimate the emissions from inland water bodies.

2. Descriptions of bottom-up models used to estimate natural emissions in WP4

2.1. JSBACH- HIMMELI

2.1.1. Model description

JSBACH-HIMMELI is a combination of two models, JSBACH, which is a land-surface model, and HIMMELI, which is a specific model for northern wetland emissions of CH_4. HIMMELI (HelsinkI Model of MEthane buiLd-up and emIssion for peatlands) has been developed especially for estimating CH_4 production and transport in northern wetlands and simulates both CH_4 and CO_2 fluxes in wetlands and can be easily used as a module within different modelling environments (Raivonen et al., 2017; Susiluoto et al., 2018). HIMMELI is driven with soil temperature, water table depth and the leaf area index and anoxic respiration. These parameters will be provided to HIMMELI from the land surface, JSBACH, which models hydrology, vegetation and soil carbon input (Reick et al 2013). CH4 emission and uptake of mineral soils were calculated following the method by Spahni et al. (2011).

2.1.2. Changes for next year

Over the next year, we will update the fluxes using high-resolution climate driver data provided by VERIFY WP3 and extending to year 2019. We will update the EU-CORINE-based land use map to improve the peatland distribution and compare to other existing wetland maps. Also the model domain will be slightly extended to better match the other model domains in use in VERIFY. We will develop and improve the calculation of mineral soil fluxes and consider overlaps with agricultural land emissions. We will engage multi-site flux measurements and other observations to further develop and calibrate the process model and validate the regional results.

2.1.3. References

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Susiluoto, J., Raivonen, M., Backman, L., Laine, M., Mäkelä, J., Peltola, O., Vesala, T., and Aalto, T.: Calibrating a wetland methane emission model with hierarchical modeling and adaptive MCMC, Geosci. Model Dev., 11, 1199–1228, https://doi.org/10.5194/gmd-11-1199-2018, 2018

2.2. Inland water bodies

2.2.1. Model description

This data set represents a climatology of average annual CH_4 emissions (sum of diffusive and ebullitive emissions) from lakes and reservoirs at the spatial resolution of 0.1°. The climatology is based on 5 alternative estimates, of which we report the mean and the standard deviation. The mean represents the “best estimate”, while the standard deviation represents a measure of uncertainty. All 5 alternative estimates are based on the HydroLAKES database (Messager et al., 2016).

The first estimate is based on direct upscaling from observed CH_4 emission rates (155 lakes and reservoirs), which we have classified into rates reported for small lakes (<0.3 km^2), larger (>0.3 km^2) lakes, and reservoirs. In addition, we applied a coarse regionalization distinguishing the Boreal (>54°N) from the Temperate to Sub-Tropical (<54°N) zone. The other four estimates are based on predictions of CH_4 emission rates from nutrient (phosphorous and nitrogen) concentrations in lakes and reservoirs. The nutrient concentrations are modelled values taken from the studies of Maavara et al. (2019) and Lauerwald et al. (in revision). The four estimates represent all possible combinations of two empirical equations relating CH_4 emissions to chlorophyll-a concentrations (Deemer et al., 2016; DelSontro et al., 2018) and two equations relating chlorophyll-a concentrations to nutrient concentrations (both from McCauley et al., 1989).

2.2.2. Changes for next year

Over the next two years, we will develop a more process-based model approach with which it will be possible to assess the seasonality in lake CH_4 emissions.

2.2.3. References

Deemer, B. R., Harrison, J. A., Li, S., Beaulieu, J. J., DelSontro, T., Barros, N., Bezerra-Neto, J. F., Powers, S. M., dos Santos, M. A. and Vonk, J. A.: Greenhouse Gas Emissions from Reservoir

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Messager, M. L., Lehner, B., Grill, G., Nedeva, I. and Schmitt, O.: Estimating the volume and age of water stored in global lakes using a geo-statistical approach, Nat. Commun., 7, 13603, doi:10.1038/ncomms13603, 2016.

3. Model results

3.1. JSBACH- HIMMELI

Simulations using JSBACH-HIMMELI for peatland and mineral soil fluxes of CH_4 have been completed for Europe at 0.1°×0.1° covering the period 1981-2017. An overview of mean annual European methane fluxes is given in Table 1 for year 2005-2017. Mineral soil fluxes are a composition of wet soil emission and dry soil uptake, calculated following approach by Spahni et al., 2011 and utilizing soil moisture, temperature and respiration input from JSBACH model. The wet mineral land fluxes are rather large, and there is room for improvement related to e.g. estimation of soil moisture and the moisture limit where the soil uptake turns to emission, as well as methane conversion factors. The uncertainty of the European methane emissions is very large due to uncertainty in the mineral land fluxes. However, the estimated peatland fluxes agree with the local wetland flux measurements.

Table **1**. Methane emissions from JSBACH-HIMMELI (TgCH4/yr) for 34.5° to 73.5°N and 10.5°W to 33.0°E.

Year	Peatland emission	Wet mineral soil emission	Dry mineral soil uptake
2005	2.650	12.366	-2.100
2006	2.793	13.146	-2.119
2007	2.562	13.858	-2.179
2008	2.445	13.041	-2.176
2009	2.539	13.768	-2.149

2010	2.496	14.317	-2.083
2011	2.665	12.309	-2.134
2012	2.375	13.241	-2.116
2013	2.789	12.414	-2.124
2014	2.825	14.304	-2.206
2015	2.396	10.506	-2.155
2016	2.521	13.724	-2.176
2017	2.366	12.808	-2.160

3.1.1. Peatlands

The European peatland methane fluxes are shown in Figure 1. The distribution of the emissions follows the peatland map newly created based on EU-CORINE land use map with national specifications and information on river and lake distributions. The magnitude of the emissions is sensitive to e.g. simulated peat water table depth, temperature profile and dynamically changing fresh substrate input from peatland vegetation.

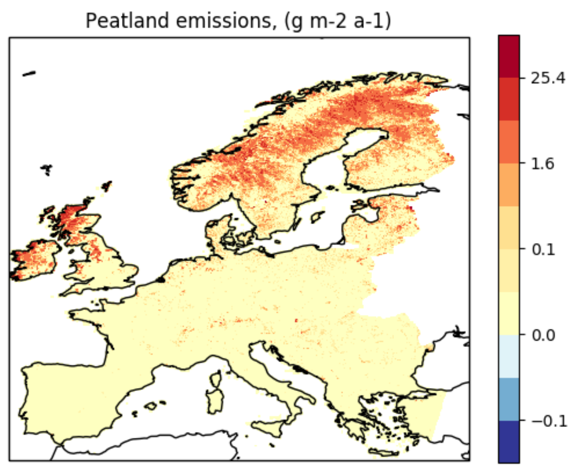

Figure 1. Peatland emissions from JSBACH-HIMMELI. Average over years 2005-2017.

3.1.2. Mineral soils

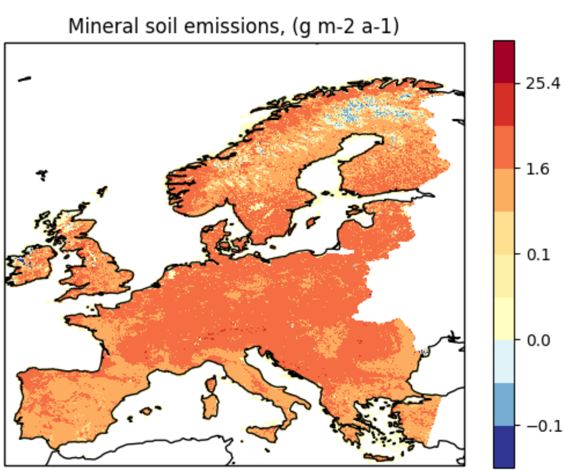

Figure 2. Mineral soil fluxes from JSBACH-HIMMELI (g m-2 a-1). Average over years 2005 – 2017.

The European mineral soil methane fluxes are shown in Figure 2, showing the net flux of the wet mineral soil emissions and dry mineral soil uptake. Soil moisture is an important factor regulating the fluxes. Already as such soil moisture is challenging to simulate, and adding that there is limited information on the moisture level where the soil turns from methane sink to methane source, the total mineral land methane fluxes are very uncertain. In the current simulations the wet mineral soil methane emissions were closely connected to precipitation events and the magnitude of the emission was large during the events. Dry soil sink was more evenly distributed with larger sink in the south.

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3.2. Inland water bodies

Our model results give the average annual CH_4 emission from lakes (including reservoirs) for the period 1990 to the present day. The model outputs at the spatial resolution of 0.1°×0.1° are represented in Figure 3 below. For the area covered by the NUTS 2016 regions (EU membership countries, + EU candidates and EFTA countries), we estimate an annual emission (± standard error) of 2.2±1.0 Tg CH_4-C yr^{-1}.

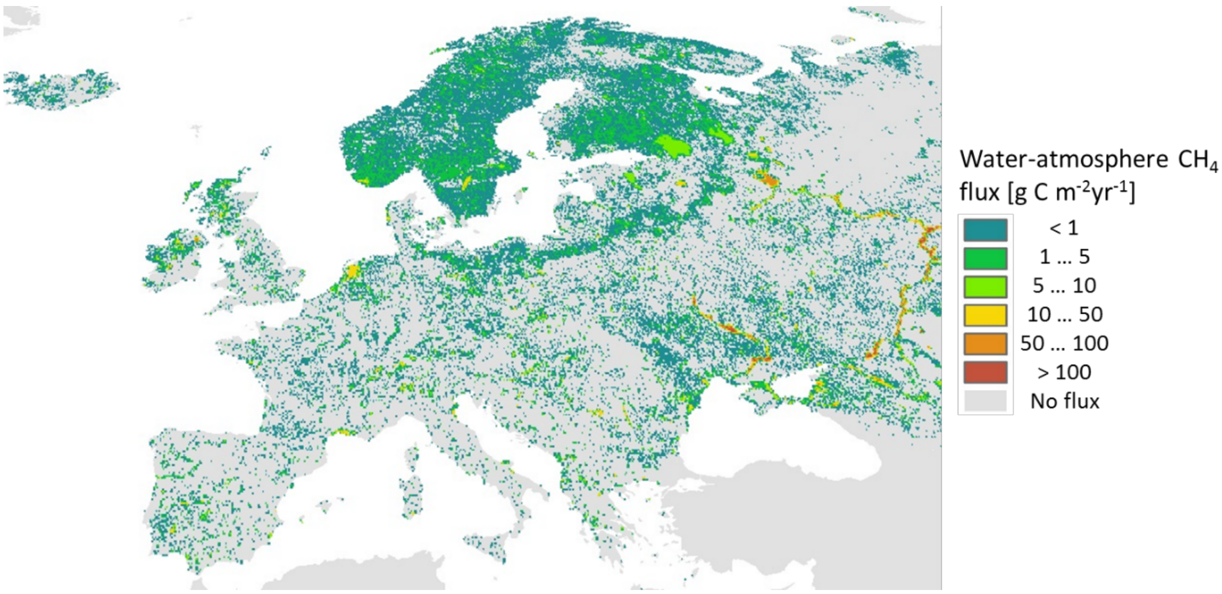

Figure 3. Estimated CH_4 emission from lakes and reservoirs. Flux rates refer to total continental area.

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