Quantifying oil and gas methane emissions from the US Gulf Coast and Appalachian basins using aircraft observations of ethane and methane

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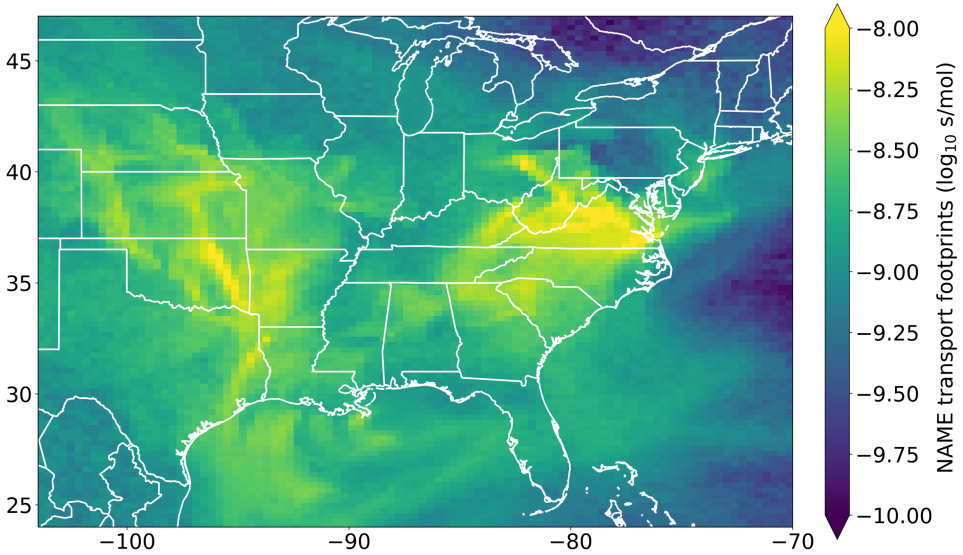

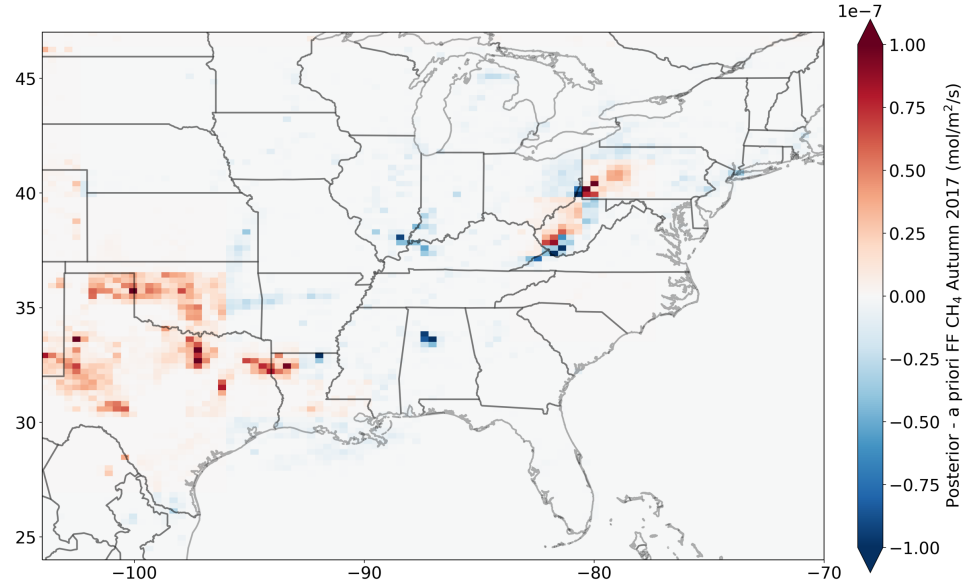

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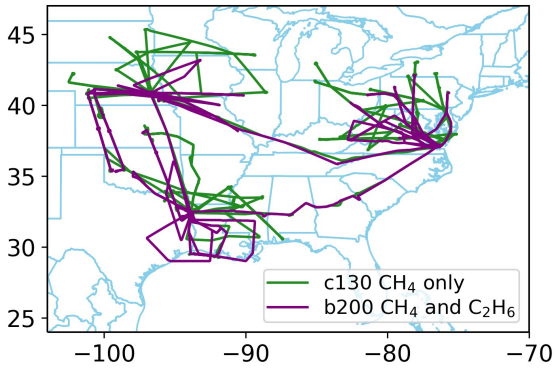
Inverse modelling using variable emission ratios

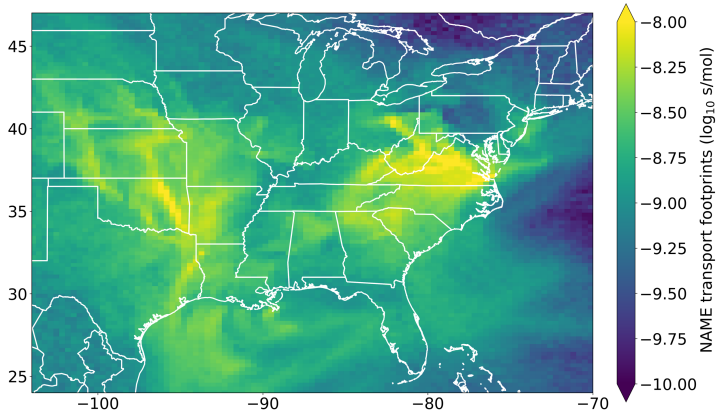
A Bayesian inverse model combines atmospheric transport footprints, aircraft observations of CH_4 and C_2H_6 and prior estimates of emissions and ratios.

Observations:
CH_4 and C_2H_6 from 4 seasonal ACT-America flight campaigns.



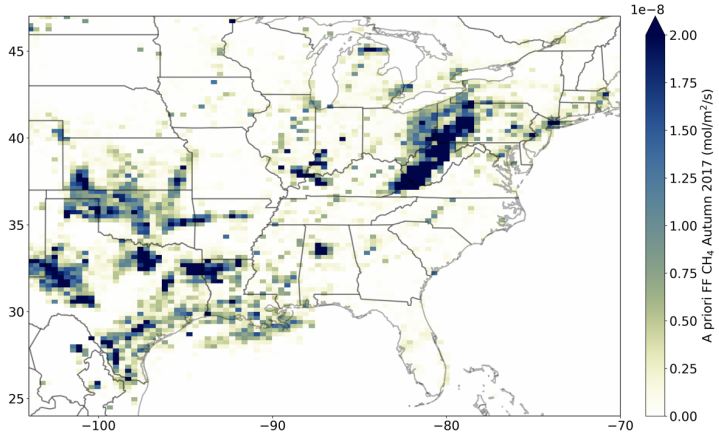
Flight paths
Autumn 2017

Transport model:
UK Met Office NAME



Transport model

A priori CH_4 flux estimates:
Fossil fuel: Global Fuel Exploitation Inventory (Scarpelli, 2020)
Non-fossil fuel: EDGAR and WetCHARTs



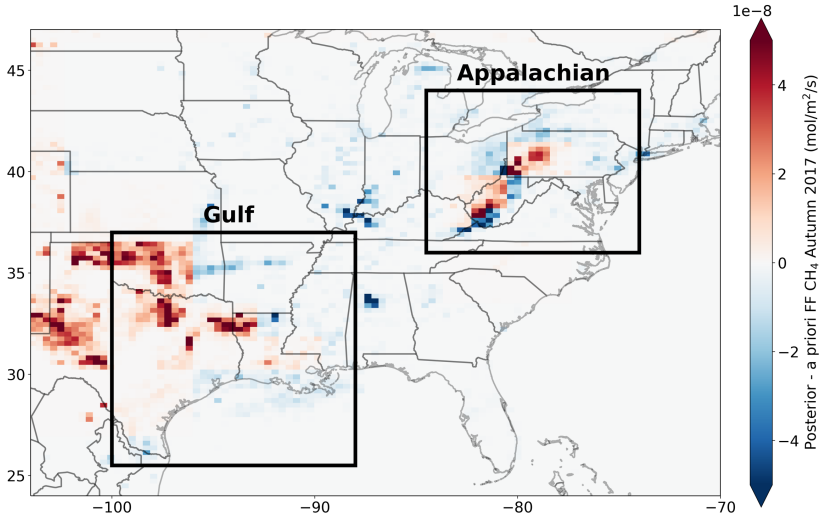
A priori FF fluxes

Scarpelli T. et al. (2020) *A global gridded (0.1◦ × 0.1◦) inventory of methane emissions from oil, gas, and coal exploitation based on national reports to the United Nations Framework Convention on Climate Change,* Earth Syst. Sci. Data.

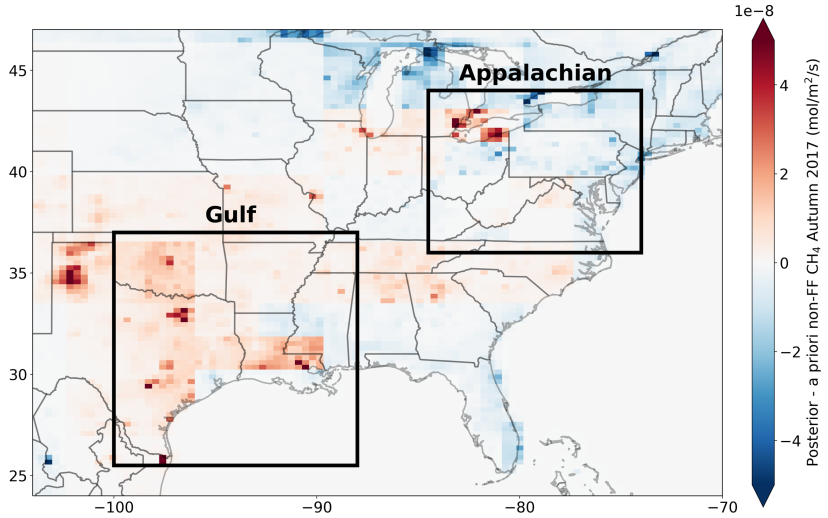
Inverse modelling using variable emission ratios

CH_4 emissions from two sectors (fossil fuel and non-fossil fuel) are optimised by the inverse model, along with C_2H_6:CH_4 emission ratios from the fossil fuel sector.

Seasonal fossil fuel and non-fossil fuel CH_4 emissions are estimated for two basin areas in the USA. In this document, we present results for Autumn 2017.



Posterior fossil CH_4 fluxes relative to the prior.



Posterior non-fossil CH_4 fluxes relative to the prior.

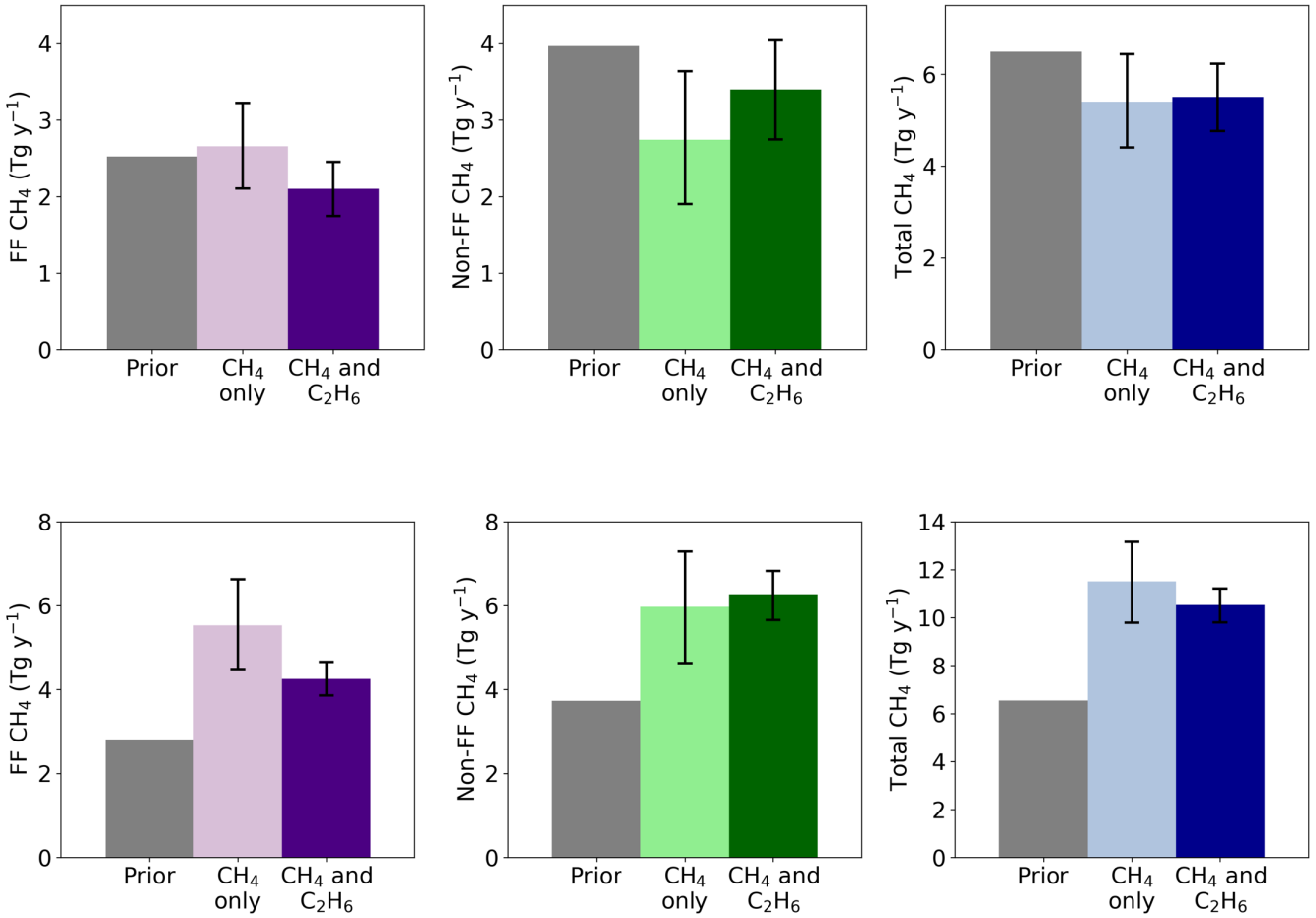
Appalachian and Gulf basin fluxes - Autumn 2017

Appalachian basin:

- Posterior fluxes are typically lower than the a priori flux estimate from the combined inventories.
- Both the CH_4-only and joint CH_4-C_2H_6 models suggest that this is mainly due to an overestimation of non-fossil emissions.

Gulf basin:

- Posterior fossil and non-fossil fluxes from the Gulf region are both higher than the a priori inventory estimate.
- The joint CH_4-C_2H_6 model finds substantially lower fossil CH_4 fluxes than the CH_4-only model.



Variable emission ratios

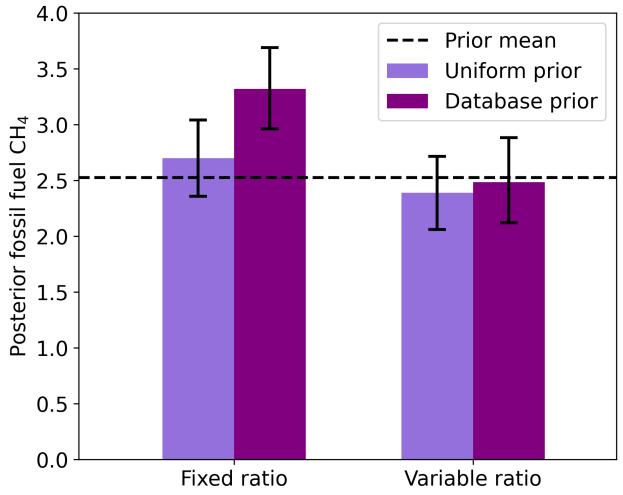
To test the use of variable emission ratios, we ran the model with two different a priori estimates of C_2H_6:CH_4 emission ratios:

1. A uniform value of 0.056 across the study domain.
2. Spatially varying ratios from the Global Inventory of Gas Geochemistry Database (Sherwood, 2017).

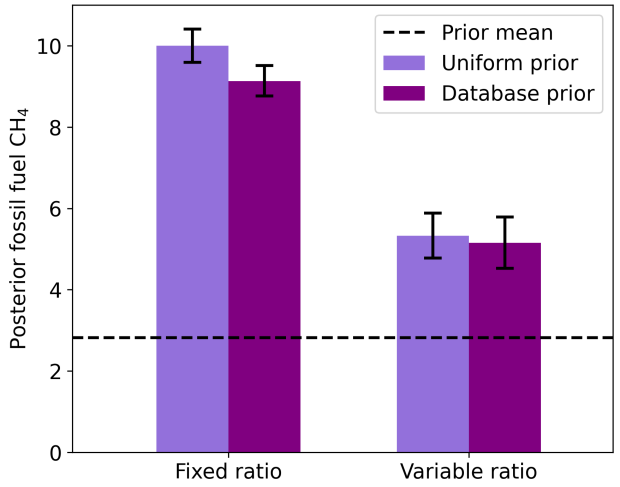
! When emission ratios are fixed, posterior flux estimates are biased by the a priori emission ratios.

☑ When the emission ratios are optimised along with emissions, this bias is removed and uncertainty in the emission ratios are carried forward into the posterior flux estimates.

Appalachian basin



Gulf basin



Sherwood O. et al. (2017) *Global Inventory of Gas Geochemistry Data from Fossil Fuel, Microbial and Burning Sources,* Earth Syst. Sci. Data.

Conclusions

Using a fixed C_2H_6:CH_4 ratio with this inverse model could potentially introduce error or bias into posterior flux estimates.

We solve this issue by using variable emission ratios that are optimised on the same temporal and spatial scale as emissions.

Using variable C_2H_6:CH_4 emission ratios also reduces uncertainty when estimating sector-level CH_4 emissions.

We find that inventory estimates of CH_4 emissions may be underestimating Gulf emissions and overestimating Appalachian emissions.

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Method: Ramsden A, et al. (2022) *Quantifying fossil fuel methane emissions using observations of atmospheric ethane and an uncertain emission ratio,* Atmos. Chem. Phys.

Data: David, K.J. et al. (2018) *ACT-America: L3 Merged In Situ Atmospheric Trace Gases and Flask Data, Eastern USA*. ORNL DAAC, Oak Ridge, Tennessee, USA.

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