University of BRISTOL

Evaluation of the UK’s methane emissions using atmospheric data: current capability and future directions

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NERC SCIENCE OF THE ENVIRONMENT

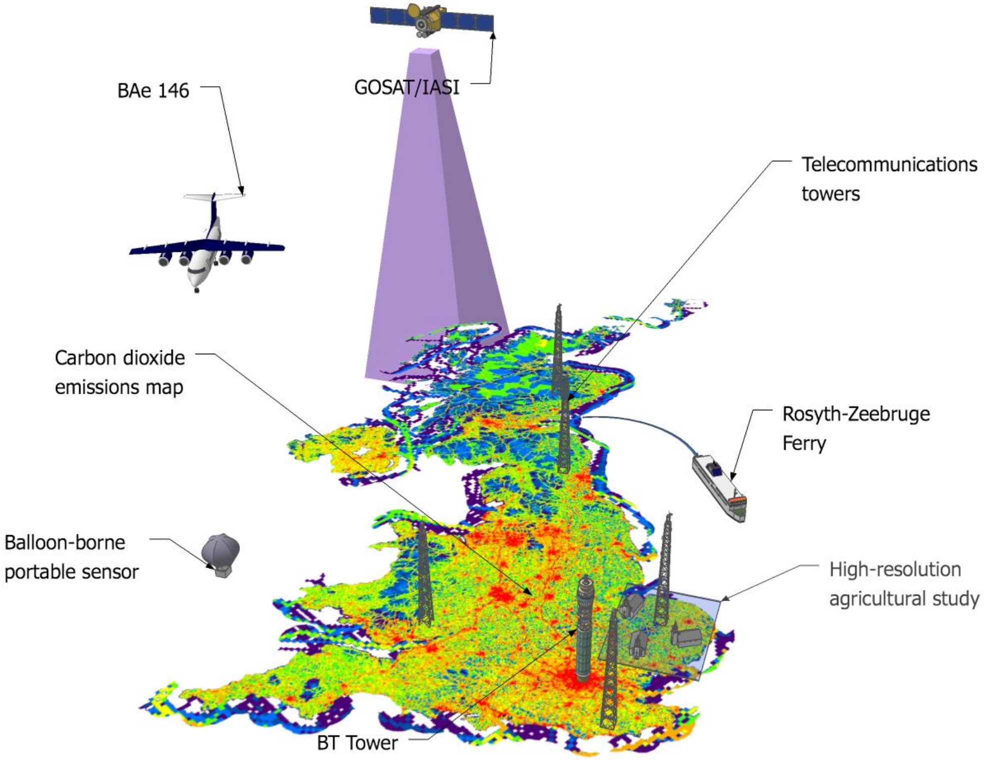
Outline

- Top-down and inventory trends from 1990-2022
- Recent methane measurements in the UK
- Evaluation of recent negative emissions trend
- Future directions: measurements and modelling for sector-level estimation

UK methane measurements

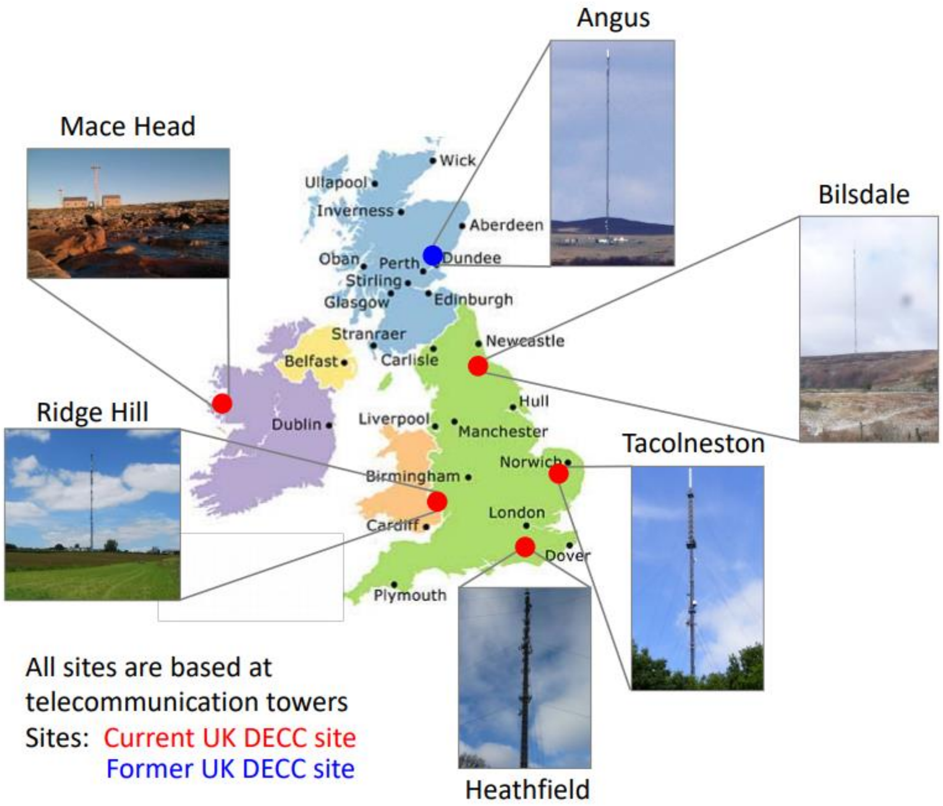
- Core “operational network”
- Research projects to push state-of-the-art

- UK DECC network: 2012 –
- GAUGE: 2014 – 2017
- DARE-UK: 2019 –

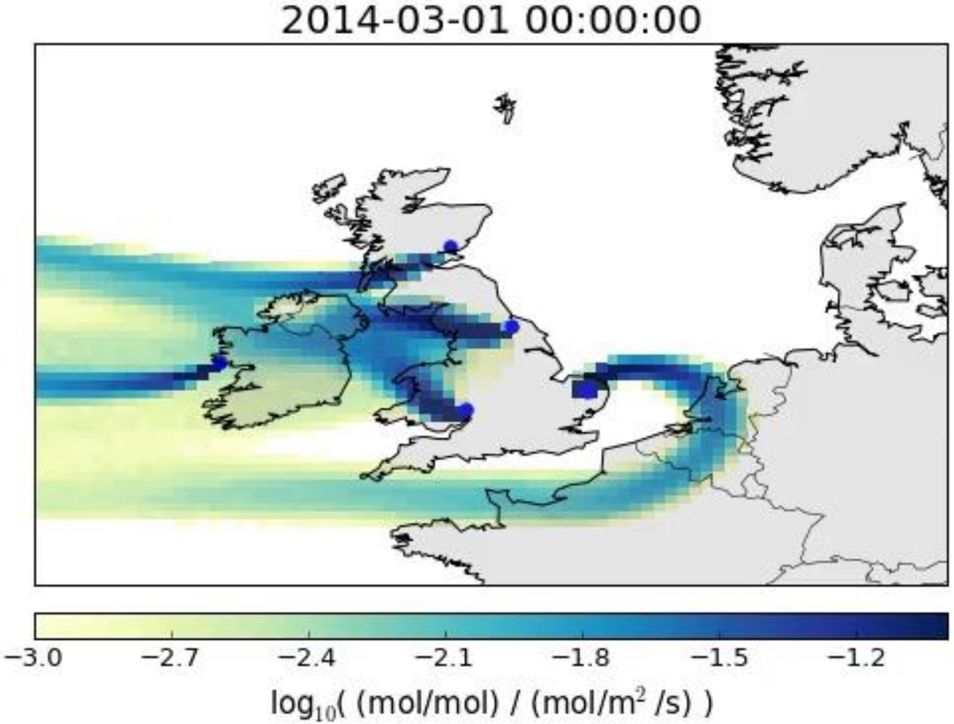


UK core DECC network

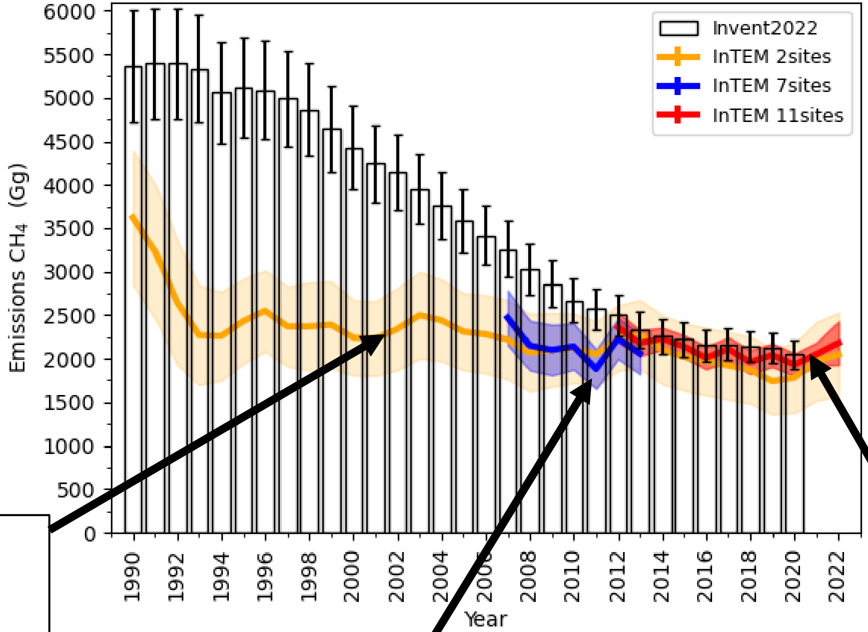
- Core network used for methane estimation for the UK UNFCCC NIR



Measurement footprints



UK top-down and inventory emissions



2-sites MHD+CBW
2-year inversions
Large uncertainty
Large mis-match in 1990 early 2000s

7-sites (1 in UK)
2-mth inversions
Reduced uncertainty
Lower than inventory

MHD, CBW, TTA, JFJ, CMN, LUT, TRN

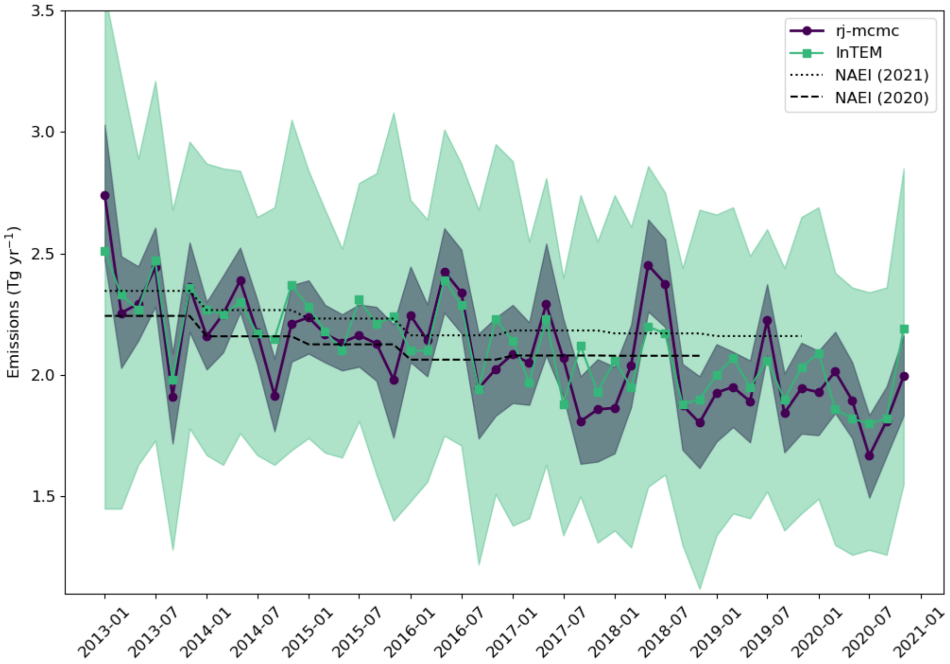
11-sites (6 in UK)
1-mth inversions
Small uncertainty
Agrees inventory 2012+

MHD, CBW, TTA, RGL, TAC, HFD, BSD, WAO, JFJ, CMN, ZEP

UK National Inventory Report, 2022

Quantification of uncertainties

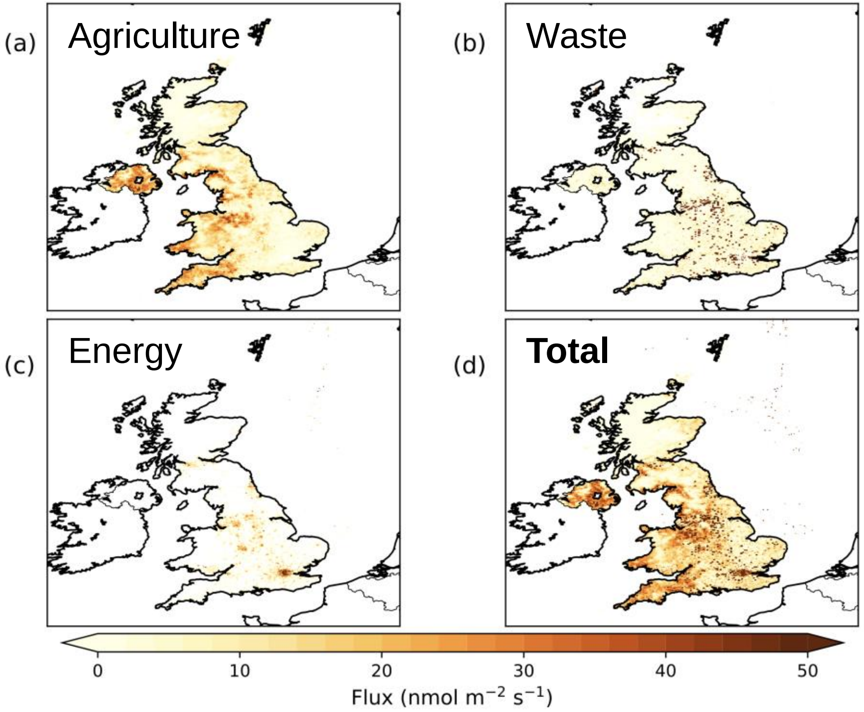
- NAME-based inversion frameworks
  - InTEM Bayesian inversion
  - Hierarchical Bayesian MCMC
- Aspiration to have multiple model frameworks and LPDMs
- Key goal is to understand uncertainties in different approaches
- Clear communication of uncertainties to inventory compilers is vital



Lunt, et al. Atmospheric observations consistent with reported decline in the UK's methane emissions, 2013 – 2020, *ACP*, 2021

Inventory emissions

- UK National Atmospheric Emissions Inventory (NAEI)
- 1 km resolution with high uncertainty at this resolution
- Next goal is to constrain sectors with atmospheric observations



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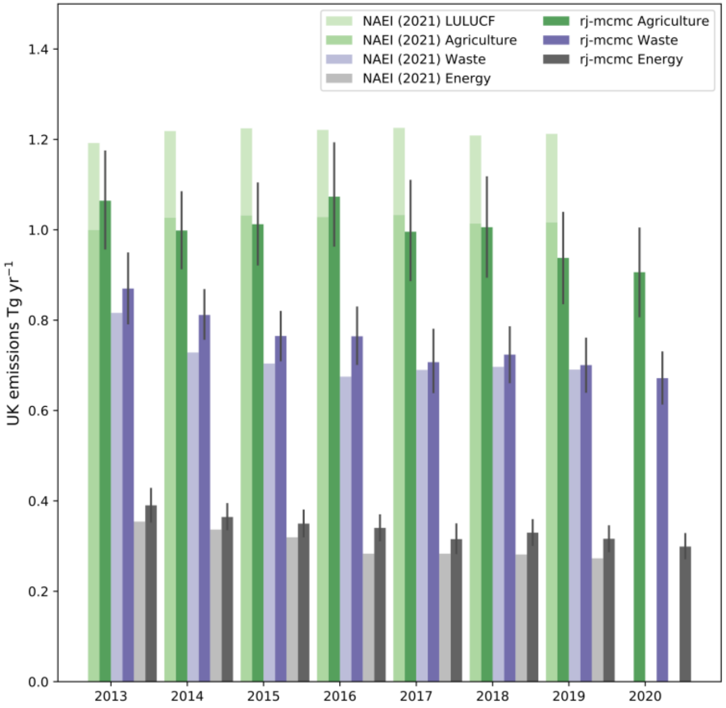
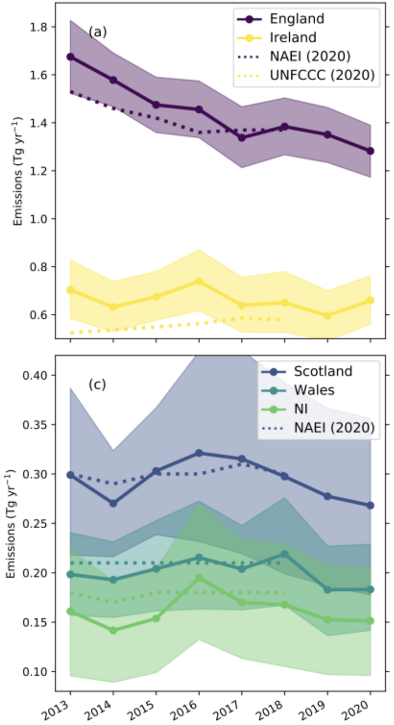
Sector and sub-national emissions

- Trend in sectors is less clear but inventory suggests waste and energy





Lunt, et al. Atmospheric observations consistent with reported decline in the UK's methane emissions, 2013 – 2020, *ACP*, 2021

Co-emitted tracers for FF and non-FF

- Can co-emitted tracers be used to effectively constrain sectors?
- Hierarchical Bayesian inversion using CH_4 and C_2H_6
- Key aspect is that emission ratio uncertainty included

$$\rho(\mathbf{x}, \mathbf{R}, \boldsymbol{\epsilon}_y | \mathbf{y}) \propto \rho(\mathbf{y} | \mathbf{x}, \mathbf{R}, \boldsymbol{\epsilon}_y) \cdot \rho(\mathbf{x}) \cdot \rho(\mathbf{R}) \cdot \rho(\boldsymbol{\epsilon}_y)$$

- High-frequency and high-precision C_2H_6 data from two sites

Mace Head Tacolneston

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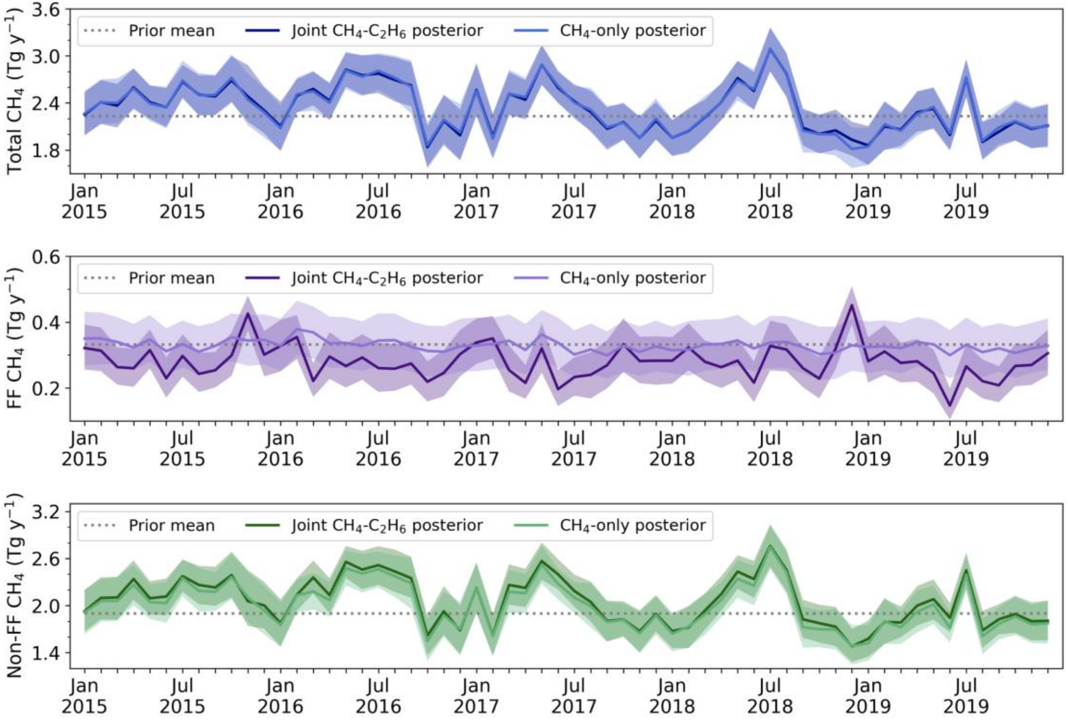
Ramsden et al., Quantifying fossil fuel methane emissions using observations of atmospheric ethane and an uncertain emission ratio, *ACP*, 2022

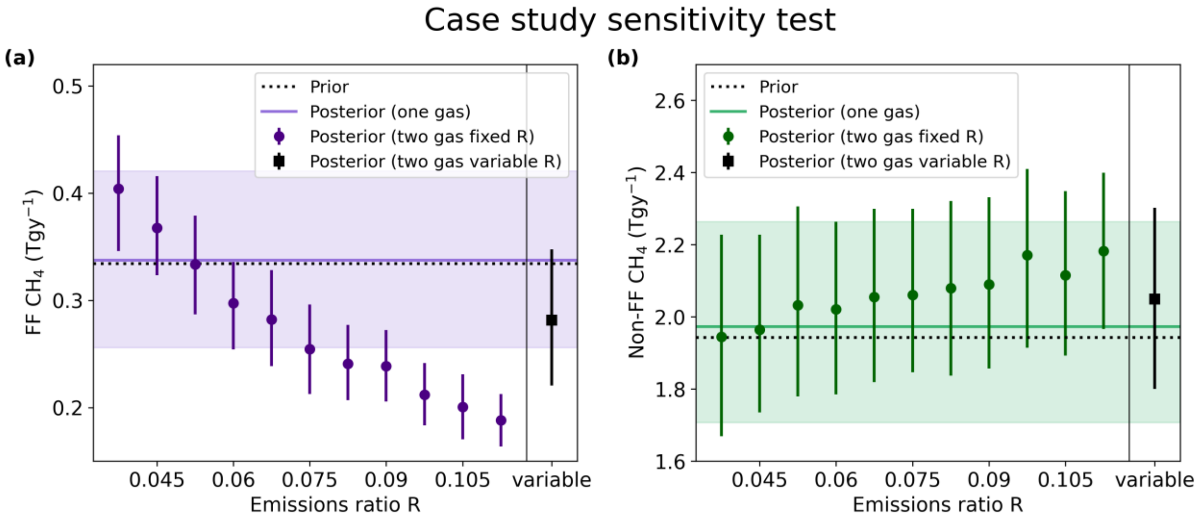
Co-emitted tracers



- Total CH_4 remains same with or without C_2H_6
- FF emissions are 15% lower than NAEI when using C_2H_6 to constrain sector

Ramsden et al., Quantifying fossil fuel methane emissions using observations of atmospheric ethane and an uncertain emission ratio, *ACP*, 2022

Co-emitted tracers



- Incorrectly specified ERs strongly impact results
- This could have different messages for policy makers
- Important to capture the true uncertainty characteristics of the system

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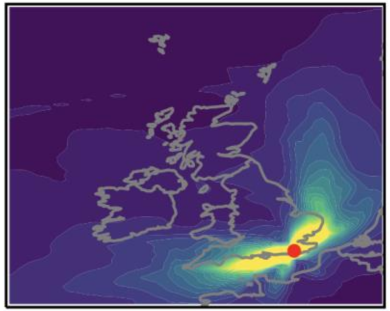
Ramsden et al., Quantifying fossil fuel methane emissions using observations of atmospheric ethane and an uncertain emission ratio, *ACP*, 2022

Forward model of methane isotopic ratios



Source Signatures
Menoud *et al* 2022
Sherwood *et al* 2017

EDGAR,
GFED,
WetCHARTS

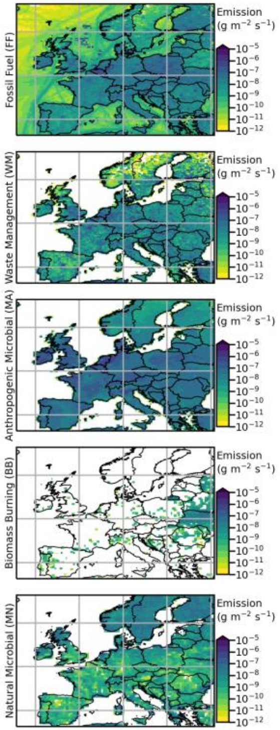
$\delta\,^{13}C$ = -40.0‰
δ D = -175.0‰

$\delta\,^{13}C$ = -55.0‰
δ D = -293.0‰

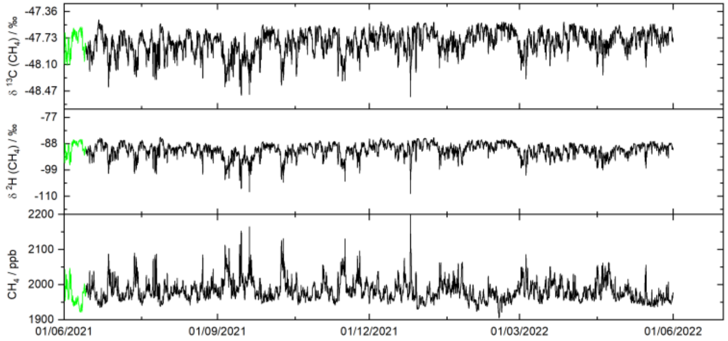
$\delta\,^{13}C$ = -68.0‰
δ D = -319.0‰

$\delta\,^{13}C$ = -26.2‰
δ D = -211.0‰

$\delta\,^{13}C$ = -69.2‰
δ D = -335.0‰



Calculated isotopic timeseries



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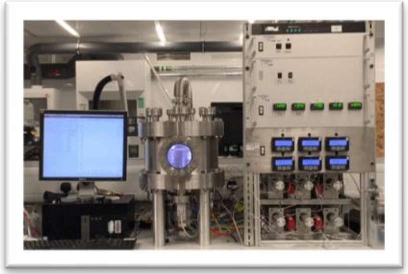
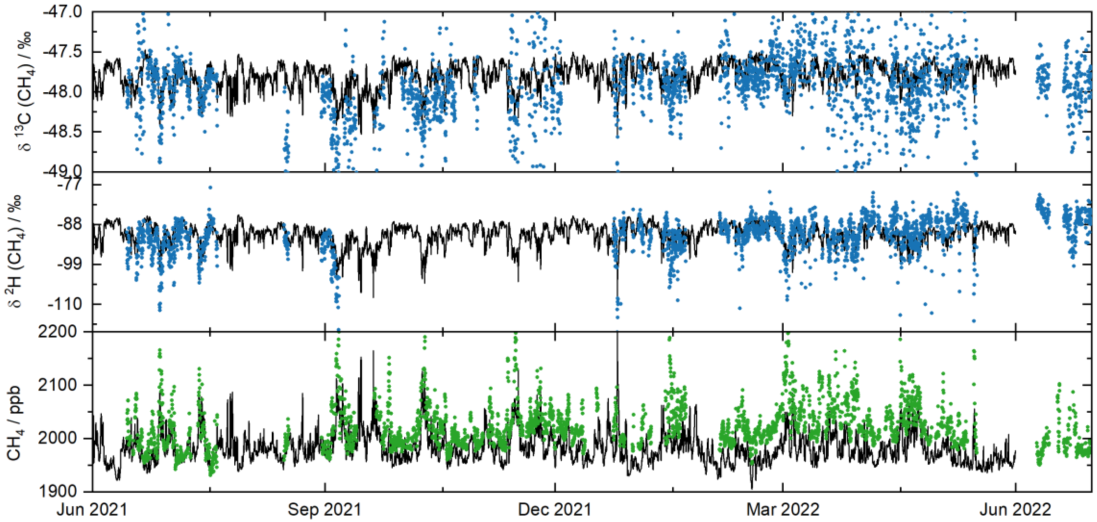
CH_4 isotopologue measurements

- High-frequency, high-precision $\delta^{13}C(CH_4)$ and $\delta D(CH_4)$ using optical instrument
- Heathfield, UK





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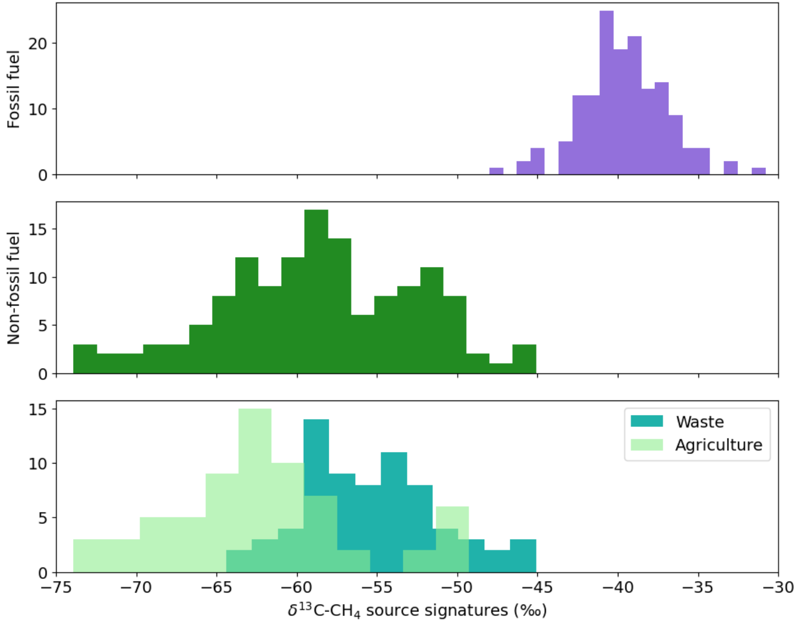
Rennick, et al., Boreas: A Sample Preparation-Coupled Laser Spectrometer System for Simultaneous High-Precision In Situ Analysis of $\delta^{13}C$ and $\delta^{2}H$ from Ambient Air Methane, *Anal. Chem.*, 2020

Capturing uncertainties in source signatures

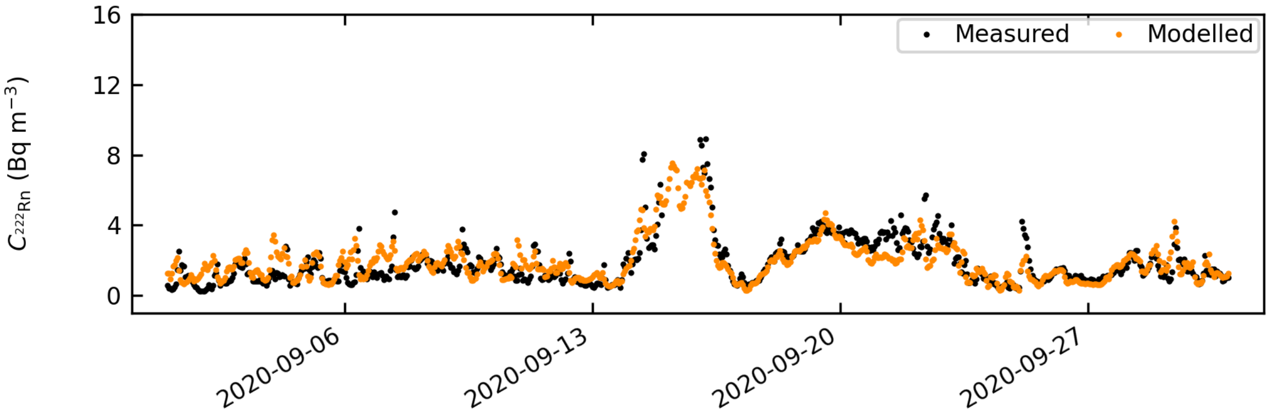
- Based on work from Royal Holloway and MEMO2 projects
- Distribution of source signatures in the UK

$$\rho(\mathbf{x}, \mathbf{R}, \boldsymbol{\epsilon}_y | \mathbf{y}) \propto \rho(\mathbf{y} | \mathbf{x}, \mathbf{R}, \boldsymbol{\epsilon}_y) \cdot \rho(\mathbf{x}) \cdot \rho(\mathbf{R}) \cdot \rho(\boldsymbol{\epsilon}_y)$$



Uncertainties in transport model: radon

- Looking for methods to quantify uncertainty in transport model
- Radon is potentially useful but still an area of active refinement
- Simulate the decay of 222Rn in footprints using the half-life
- Next steps: can this approach be used to correct for transport model errors? TBD.



Summary

- Atmospheric measurements valuable for evaluating national inventory:
  - Supports recent methane emissions decline (2013 – 2020)
  - Decline during 1990s and 2000s still not well understood
- New technologies for sector-level evaluation
  - Emissions estimation using co-emitted tracers
  - Methane:ethane ratios
  - High-frequency $\delta^{13}C(CH_4)$ and $\delta D(CH_4)$
  - Key research is in capturing emission ratio/source signature uncertainty