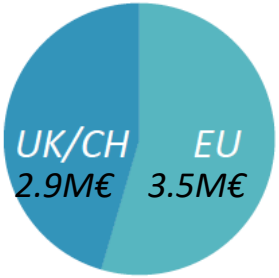
Process **A**ttribution of **R**egional Em**IS**sions

PARIS

Horizon Europe: Verification and reconciliation of estimates of climate forcers

17 participants from 9 countries, 2023-2026

Thomas Röckmann & Anita Ganesan, PARIS



University of Bristol · Utrecht University · Empa Materials Science and Technology · KIT Karlsruhe Institute of Technology · Met Office · The University of Edinburgh · Goethe Universität Frankfurt am Main · MTA Atomki Debrecen · Wageningen University & Research · 1506 Università degli Studi di Urbino Carlo Bo · Öko-Recherche Büro für Umweltforschung und -beratung GmbH · Agroscope · Ollscoil na Gaillimhe University of Galway · NILU · Deutscher Wetterdienst Wetter und Klima aus einer Hand · DWD · University of East Anglia · university of groningen

Objectives of PARIS

1) **Quantify emissions from 8 European countries** of all major GHGs reported under UNFCCC (CO_2, CH_4, N_2O, F-gases) and black carbon aerosol (BC)*

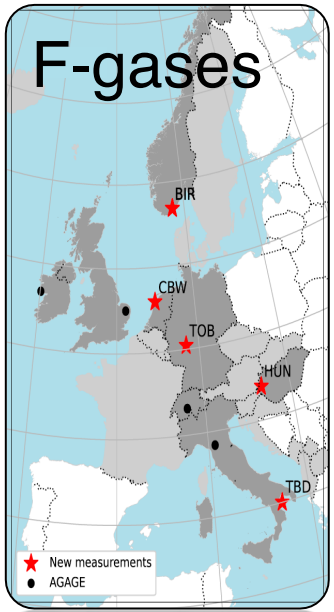
2) Quantify the contribution of **major source sectors** of GHG and BC emissions and organic matter aerosol (OM) abundance
   - ➢ implementation of **innovative measurement and analysis technologies**

3) Derive **time- and space-resolved flux estimates** for GHGs with complex or uncertain source distributions

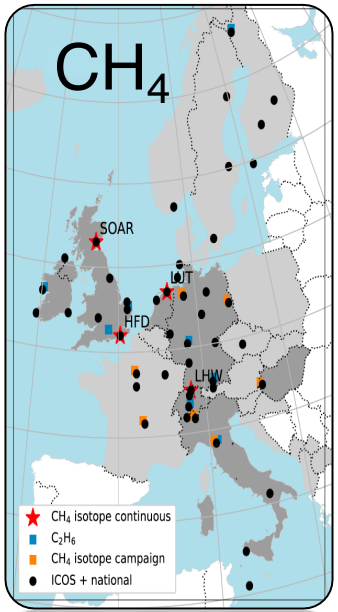
4) Produce **draft Annexes to the annual National Inventory Reports (NIRs)** for a selection of 'focus' countries.

*reported under CLRTAP (Convention on Long-range Transboundary Air Pollution)

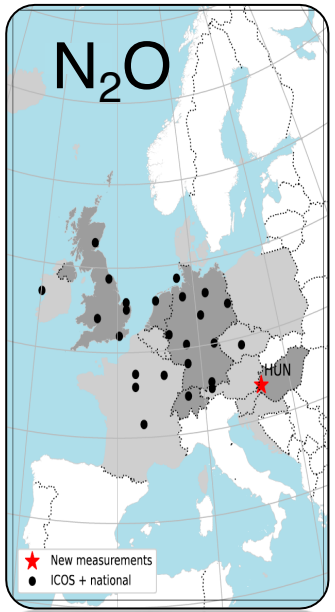
Novel measurement components in PARIS



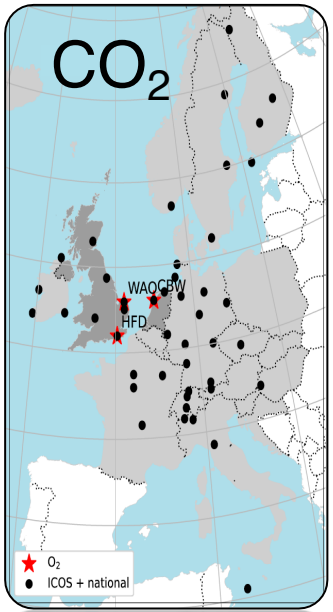
Extended F-gas measurements



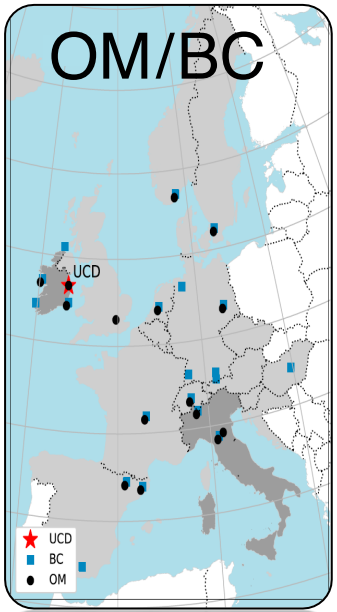
Continuous CH_4 isotope observations



Additional measurements & isotope studies



Atmospheric Potential Oxygen measurements

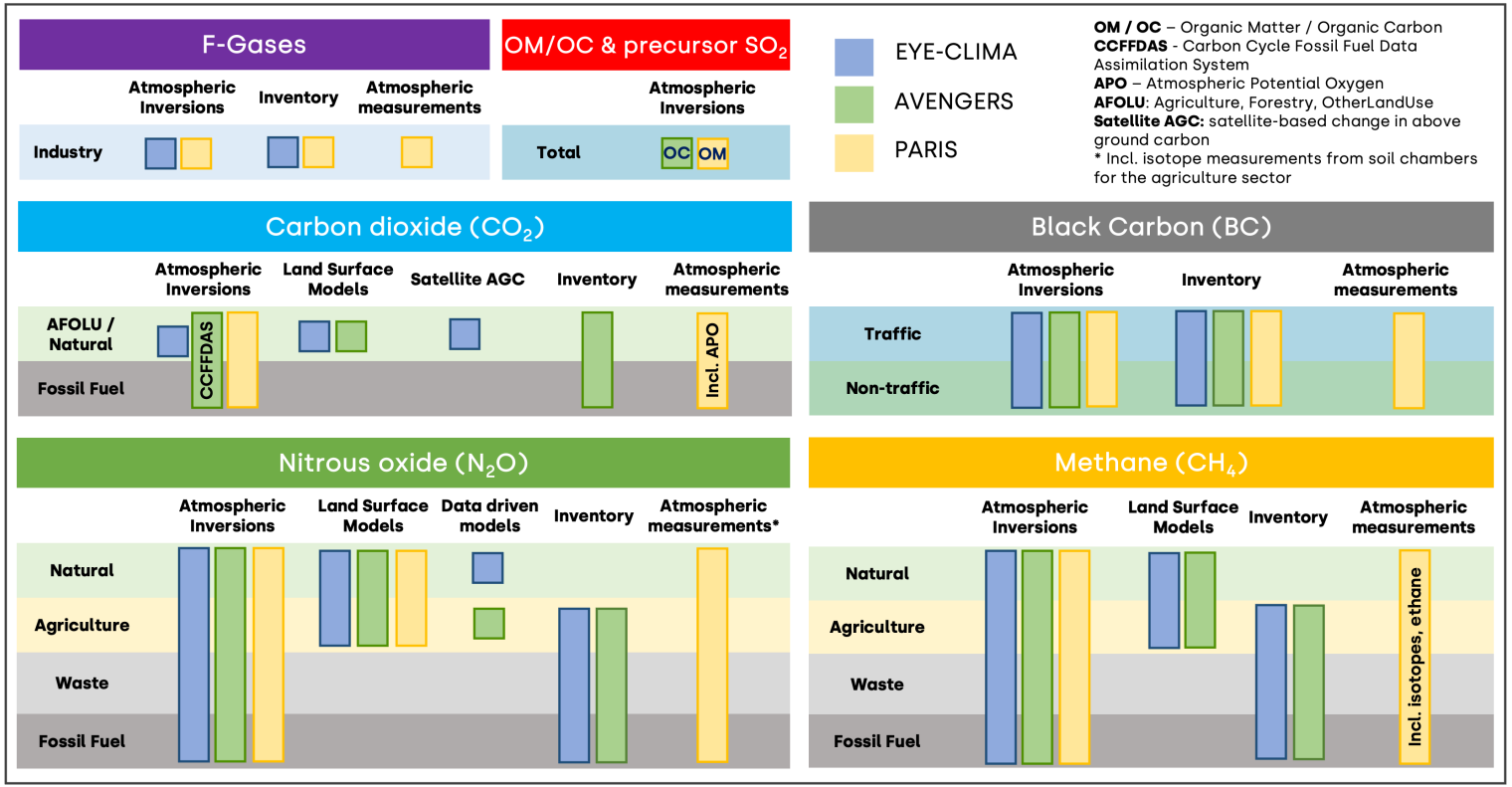


New OM and BC measurements

Focus countries

8 Focus Countries

PARIS - AVENGERS – EYE-Clima



Common stakeholder engagement strategy

Splinter meeting at EGU - 'Verification and reconciliation of estimates of climate forcers'

30th April 2025, 12:45-13:45 CEST, Room: 2.96, Convener: Rona Thompson I Co-convener: Thomas Röckmann

Draft Annexes to National Greenhouse gas inventories

UK Greenhouse Gas Inventory, 1990 to 2021

Annual Report for Submission under the Framework Convention on Climate Change

Main authors Brown P, Cardenas L, Del Vento S, Karagianni E, MacCarthy J, Mullen P, Passant N, Richmond B, Thistlethwaite G, Thomson A, Wakeling D, Willis D

With contributions from Anthony S, Aston C, Broomfield M, Buys G, Carnell E, Clilverd H, Dragosits U, Gibbs, M, Gilhespy S, Glendining M, Gluckman R, Gorji S, Hampshire K, Henshall P, Hobson M, Kelsall A, King K, Lambert N, Levy P, Malcolm H, Manning A, Matthews R, Milne A, Misra A, Misselbrook T, Murrells T, Nickerson R, O'Doherty S, Pang Y, Pearson B, Pitt J, Quinn P, Raine B, Redington A, Richardson J, Sandars D, Skirvin D, Stanley K, Stewart R, Szanto C, Thornton A, Tomlinson S, Walker C, Watterson J, Williams A, Wong J, Young D, Young H

Verification **A6**

ANNEX 6: Comparison of Inventory and Emissions Estimated using Atmospheric Observations

This Annex describes the verification of the reported UK emissions through comparison with UK emissions estimated through the use of atmospheric observations and modelling.

A 6.1 MODELLING APPROACH USED FOR COMPARISON WITH THE UK GHGI

Comparison of the UK GHGI (Greenhouse Gas Inventory) with emission estimates calculated using atmospheric observations is considered to be best practice by the UNFCCC as it allows for an independent assessment of the GHG emissions from the UK using a comprehensively different approach. Significant differences in the emissions estimated using the two methods are a means of identifying areas worthy of further investigation, for example as occurred with a re-assessment of the emissions of HFCs for refrigeration.

In order to provide a comparison to the UK GHGI, BEIS (UK government department of Business, Energy and Industrial Strategy) supported the establishment and maintenance of a high-quality remote observation station at **Mace Head (MHD)** on the west coast of Ireland as part of the Advanced Global Atmospheric Gases Experiment (AGAGE) (Prinn et al., 2018). The station reports high-frequency concentrations of the key greenhouse gases and is under the supervision of Prof. Simon O'Doherty of the University of Bristol (O'Doherty et al. 2004, 2014, Stanley et al. 2018, Stavert et al. 2019).

BEIS extended the measurement programme in 2012 with three new tall tower stations across the UK, collectively called the UK DECC (Deriving Emissions linked to Climate Change) network: **Tacolneston (TAC)** near Norwich; **Ridge Hill (RGL)** near Hereford; and **Tall Tower Angus (TTA)** near Dundee, Scotland (decommissioned in 2015). Two additional stations, **Heathfield (HFD)** in Southern England and **Bilsdale (BSD)** in North Yorkshire, were established through the NERC GAUGE (Greenhouse gAs UK and Global Emissions) programme. BSD replaced TTA in 2015 in the UK DECC network and is funded by DESNZ (formerly BEIS). A fire at BSD in August 2021 destroyed the tower and measurements have therefore been discontinued until a replacement tower is available. HFD is supported by the National Physical Laboratory (NPL).

Switzerland's Greenhouse Gas Inventory 1990–2021

National Inventory Document

Submission of April 2023
under the United Nations Framework Convention on Climate Change

Annex 6 Additional information on verification activities

A6.1 Independent verification of the National Greenhouse Gas Inventory for F-gases

Introduction

Since 2000, the Swiss Federal Laboratories for Materials Science and Technology (Empa) performs continuous measurements of halogenated greenhouse gases at the high-Alpine site of Jungfraujoch (3'580 m a.s.l.). These measurements are used for estimating emissions of fluorinated greenhouse gases (HFCs, SF_6) from Switzerland and neighbouring countries. The information can be used for an independent assessment of Swiss inventory data of these greenhouse gases. The independent emission estimate is not used directly for deriving data for the inventory. Data is used, however, to identify either consistency in support of the inventory or discrepancies, which could lead to a reassessment for identifying sources for disagreement and options for improvements.

For the independent assessment of fluorinated greenhouse gas emissions from Switzerland the so-called tracer-ratio method is applied, where Swiss pollution events of HFCs and SF_6, arriving at Jungfraujoch, are scaled to concurrent pollution events of carbon monoxide (CO) and then multiplied by the Swiss CO emission inventory (see Figure A – 2 for a graphical illustration of the method). Similar approaches are also used for the independent verification of greenhouse gas emissions in the United Kingdom (UK MetOffice – using atmospheric observations from Mace Head (Ireland) combined with atmospheric transport models), in Australia (CSIRO – using the tracer-ratio method with measurements from Cape Grim, Tasmania) and in the US (NOAA – using a combination of airborne and ground-based samples).

Method description

PARIS Data Models Inventories

D2.1 – Draft Annexes to the National Inventory Reports

Table of content

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Method description

Greenhouse gas emissions in the Netherlands 1990-2023

National Inventory Document 2025

RIVM report 2025-0005

Annex 8 Verification activities of greenhouse gas emissions using atmospheric observations

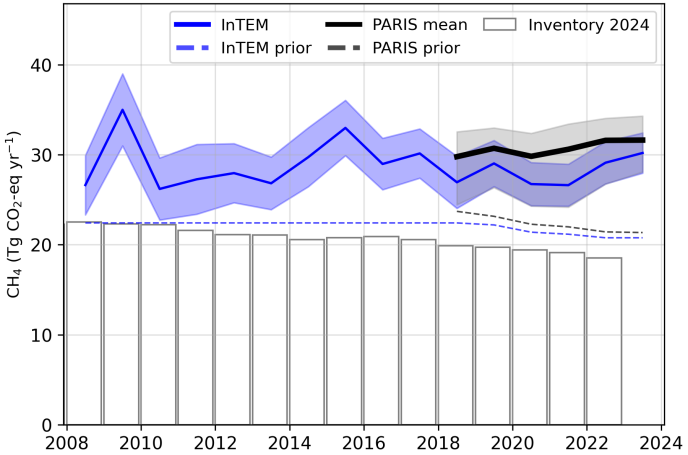
In this annex, reported Dutch greenhouse gas emissions are compared with emission data derived from atmospheric observations. This comparison not only allows to verify the reported emissions against an independent data source, but also contributes to validation of emission estimates from atmospheric observations. Emission estimates from atmospheric observations for this submission were provided by the Horizon 2020 Europe project PARIS (https://horizoneurope-paris.eu/).

This annex is a first attempt at such a comparison for the Netherlands and not all observations can yet be fully explained. It covers the greenhouse gases methane, nitrous oxide and hydrofluorocarbons from 2018 until 2023. Going forward, the aim is to answer the questions raised by this first analysis and to expand it to more gases and more inversion systems. These verification activities are planned to take place on a yearly basis as part of the overall verification system for the NIR, with significant differences between inventory emission and atmospheric observations pointing to areas that might be deserving of further investigation.

A8.1 Summary

Emission estimates derived from atmospheric observations were compared to reported emissions for methane, nitrous oxide and hydrofluorocarbons. It should be noted that these are both emission estimates relying on assumptions without one being closer to the true

Results for the Netherlands

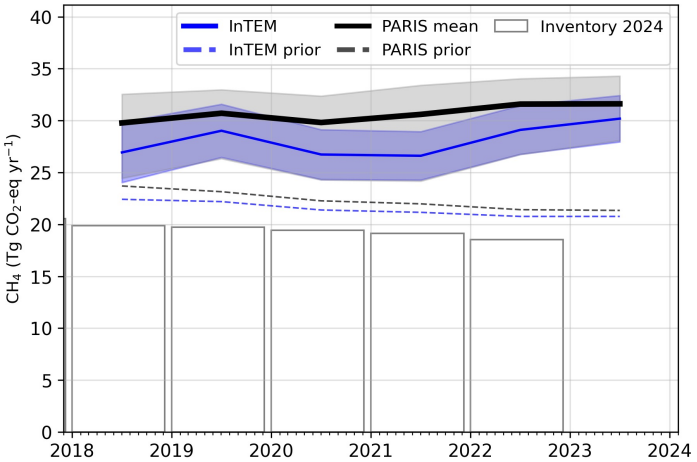


Emissions from all three models >> National Inventory
Different trends in past years

- *Natural emissions (NIR only includes anthropogenic)*
- *Uncertainties in inversion models?*
- *Underestimate in NIR for one or multiple large sectors?*
- *Low resolution: Emissions from neighbouring countries?*
- *Possible sum of multiple factors*

From Dutch NIR

Results for the Netherlands



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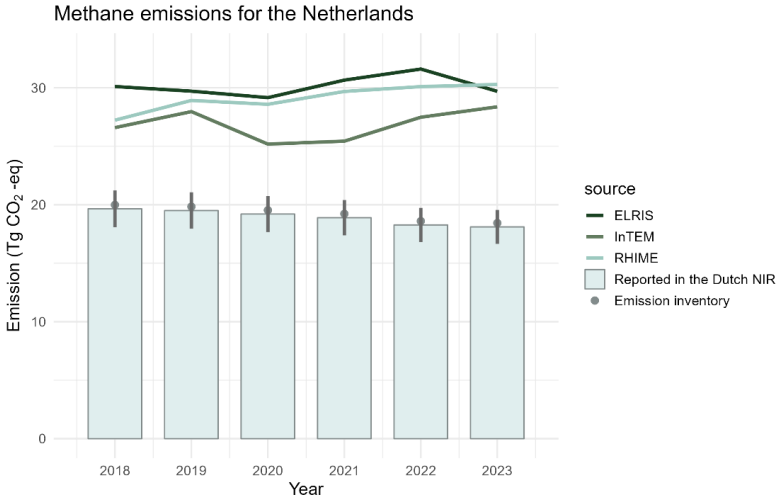

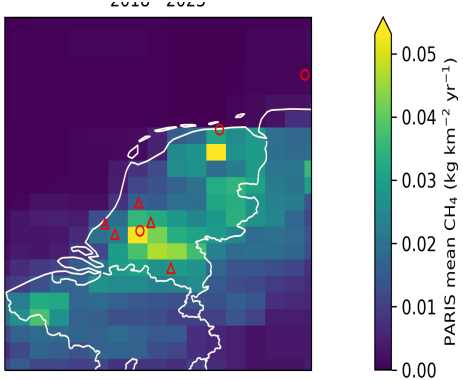

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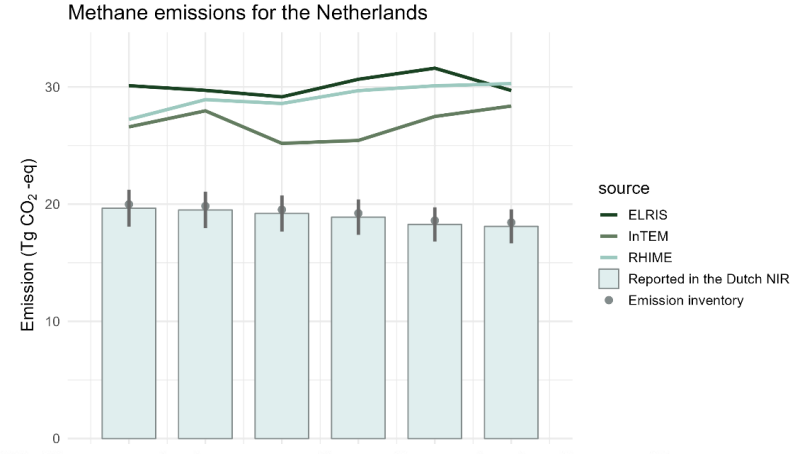
Results for the Netherlands



Emissions from all three models >> National Inventory
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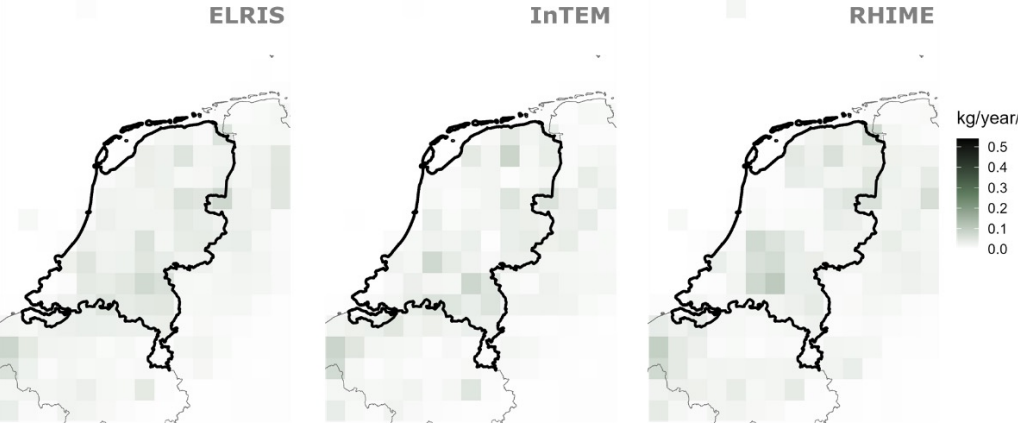
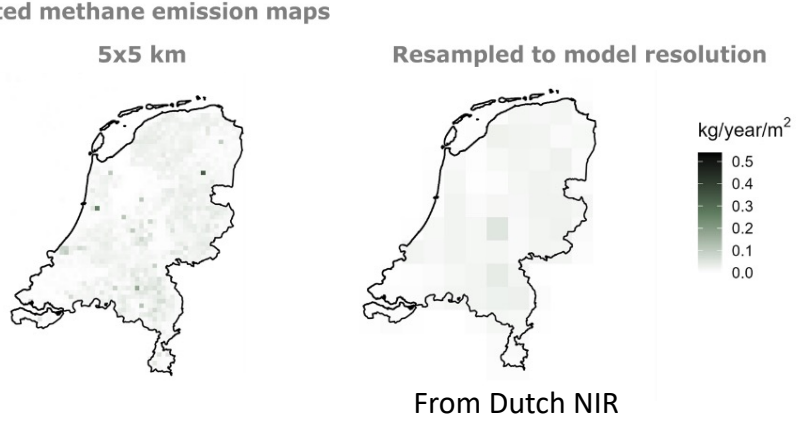
- *Underestimate in NIR for one or multiple large sectors?*
- *Low resolution: Emissions from neighbouring countries?*
- *Possible sum of multiple factors*

Methane emission maps from atmospheric observations



Reported methane emission maps

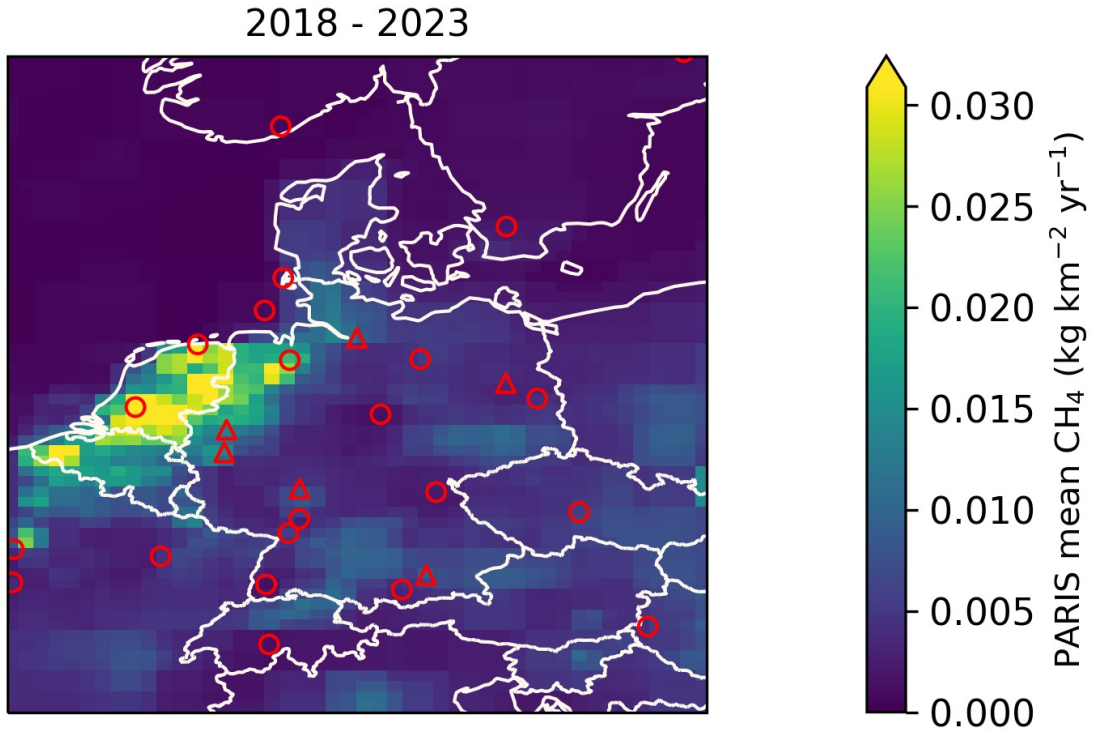


From Dutch NIR

Results for Germany

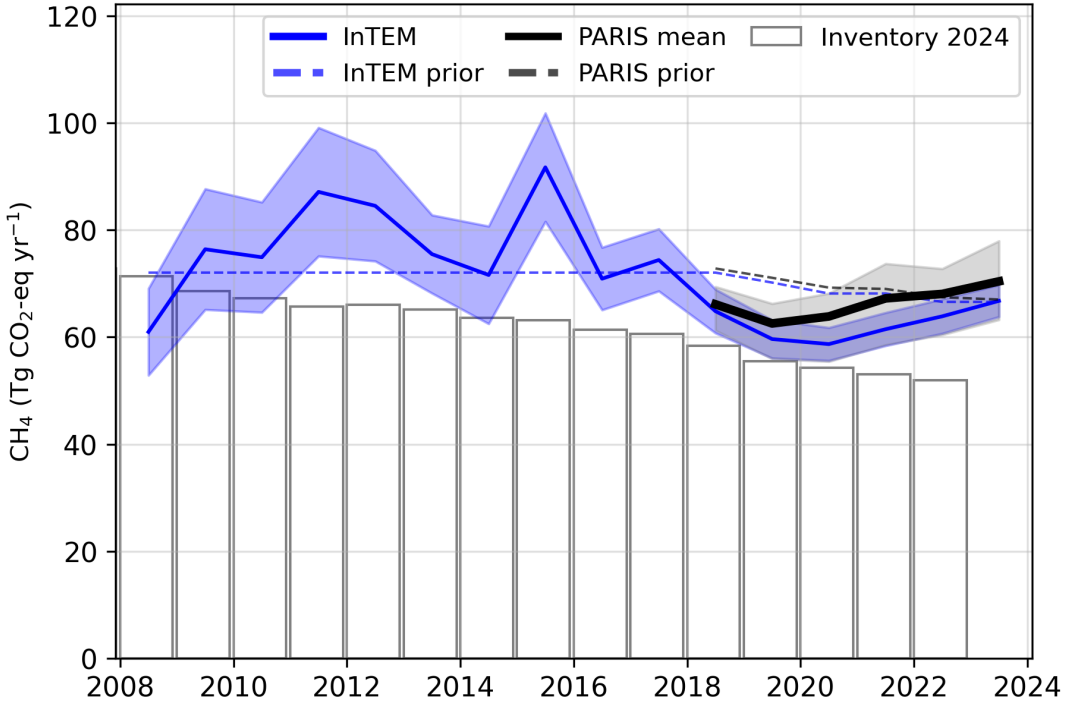
Top-down emissions maximum in northwest (intense agriculture)

High emissions in neighbouring countries



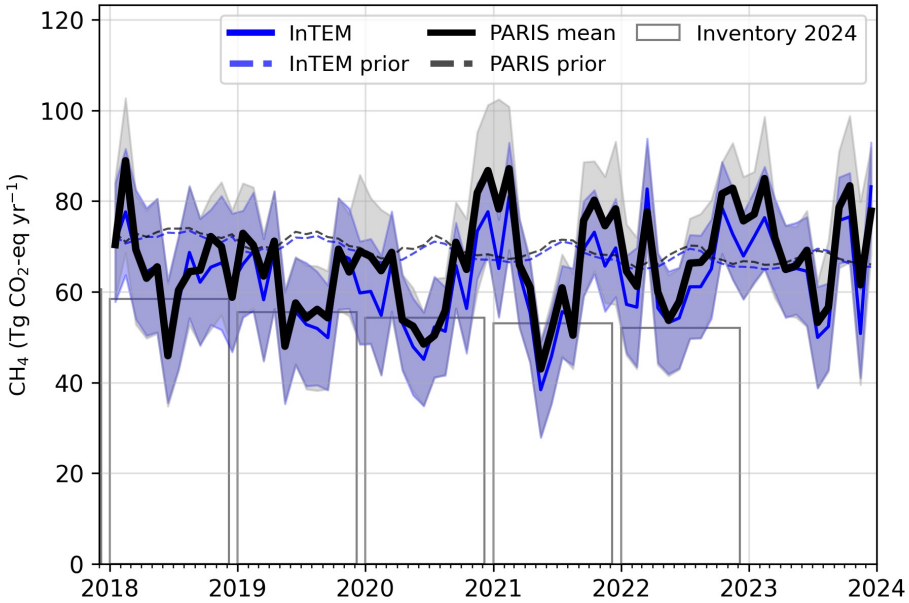
Results for Germany

Overall,15-30% higher emissions compared to inventory.
No decreasing trend in the inversions.

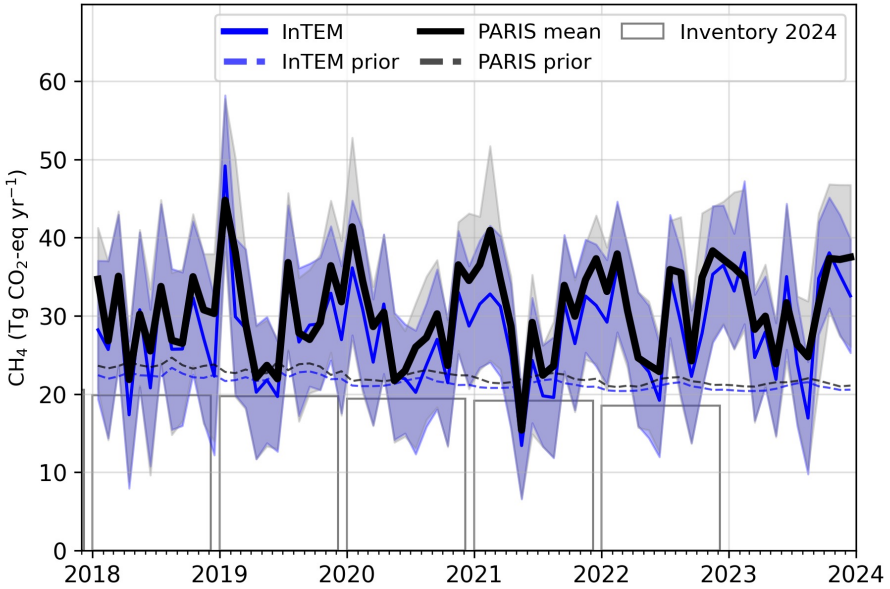


Seasonality: generally higher emissions in winter

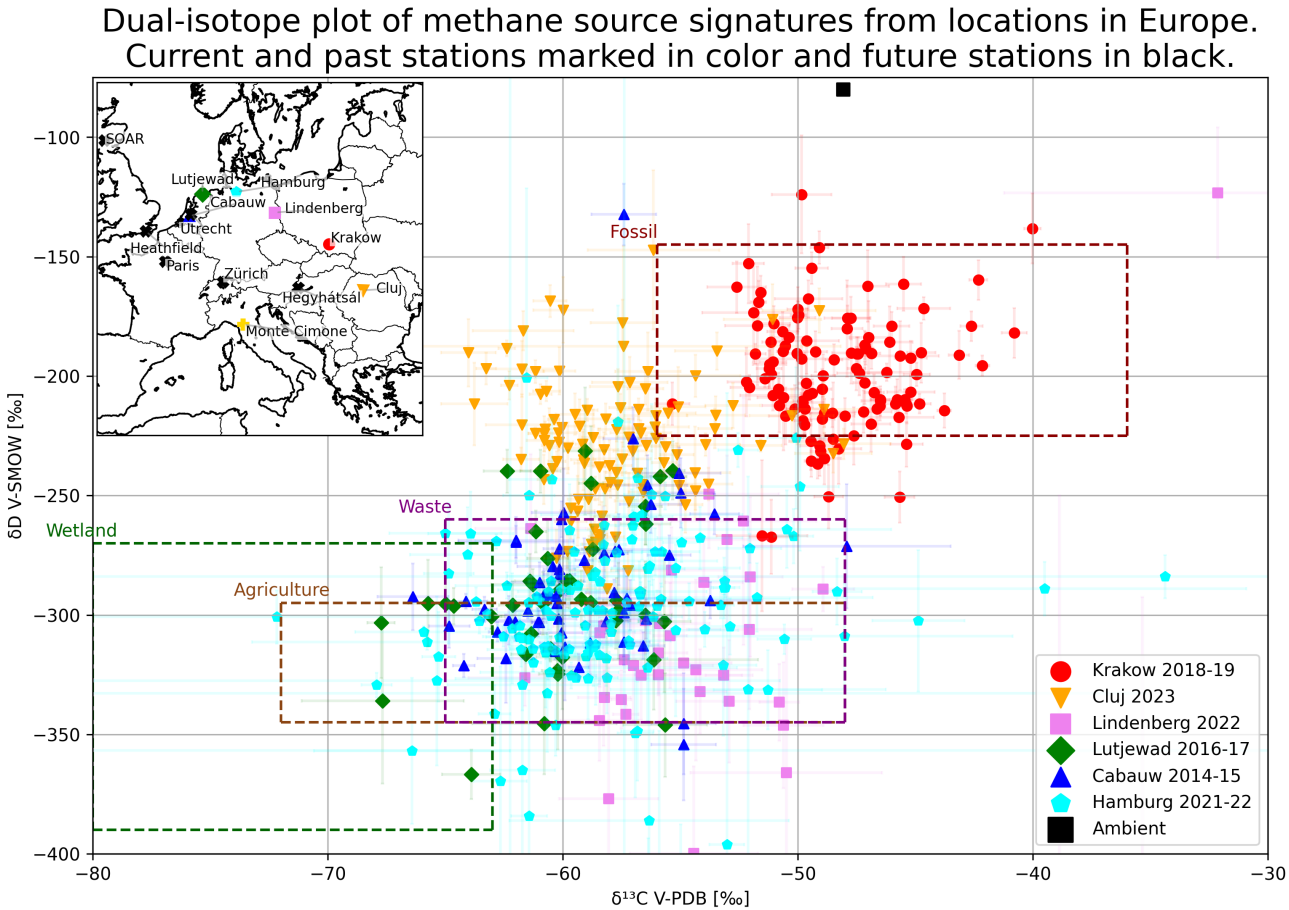
Germany



Netherlands



Next goal: Include isotope information



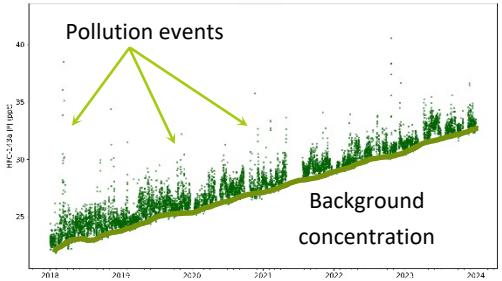
…for sector specific emission estimates

Thanks to the PARIS DATA MODELS INVENTORIES team

Inverse Modelling Frameworks

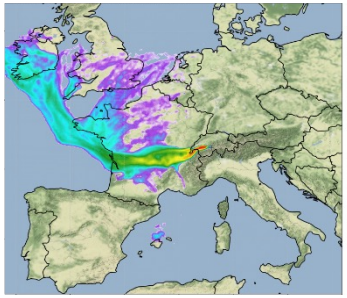
PARIS DATA MODELS INVENTORIES

Observations



Timeseries of HFC-143a concentrations measured at Jungfraujoch over the period 2018-2023.

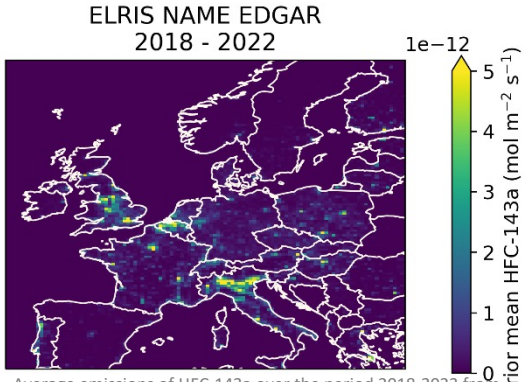
Lagrangian models



Example of source sensitivities distribution obtained with FLEXPART for Jungfraujoch for a given time interval.

Concentrations = Source sensitivities x Emissions

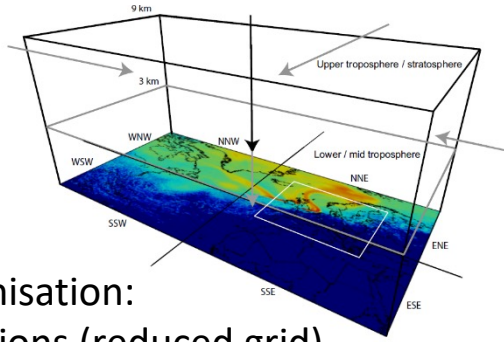
Prior inventories



Average emissions of HFC-143a over the period 2018-2023 from the EDGAR inventory.

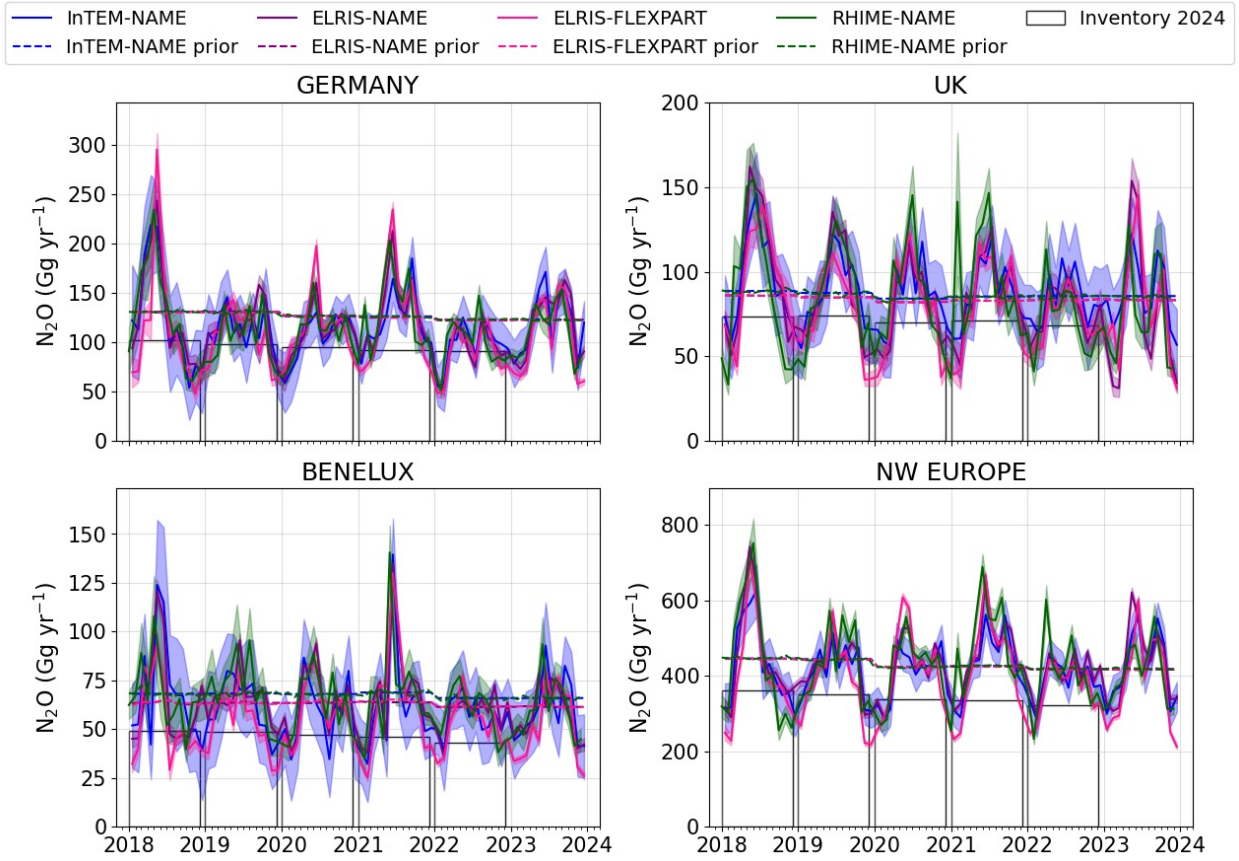
NAME (Met Office)	UK Unified Model (Jones et al., 2007)
FLEXPART (Empa)	ECMWF IFS-HRES (Stohl et al., 2005)

InTEM (Met Office)	Analytical Bayesian (Manning et al., 2021)
ELRIS (Empa)	Analytical Bayesian (Henne et al., 2016)
RHIME (U. Bristol)	Bayesian MCMC (Ganesan et al., 2014)



Optimisation:
Emissions (reduced grid)
Background conditions

N_2O: Seasonal Variability



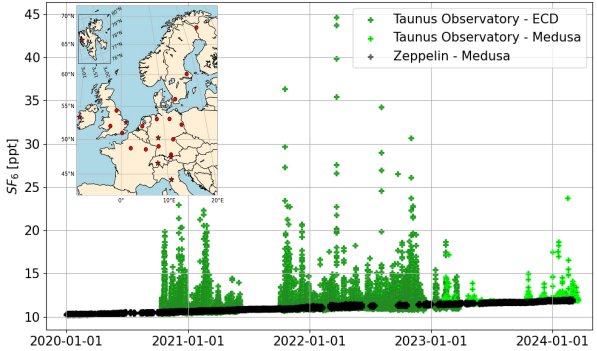
- Consistent variability across inversion systems
- No seasonality in prior
- Broad summer emission peak
- Year-to-year variability

NW Europe:
Belgium, Denmark, France, Germany, Ireland, Luxembourg, Netherlands, United Kingdom

From Stephan Henne, EMPA

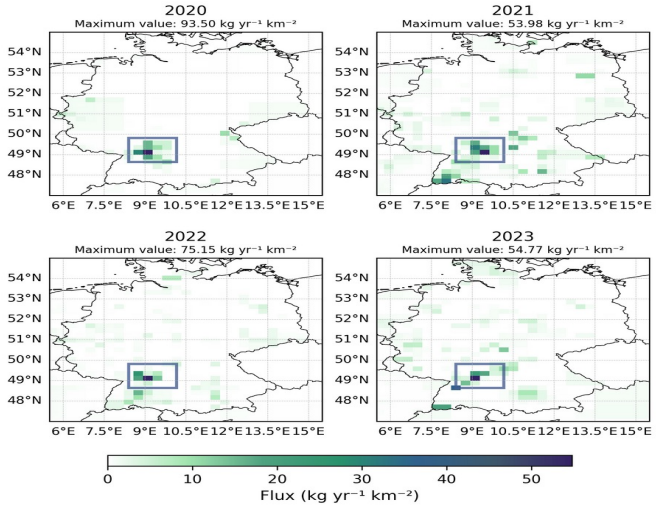
SF_6 emissions in Germany

Measurements at Taunus Observatory



Strong and frequent enhancements

NAME / InTEM inversions

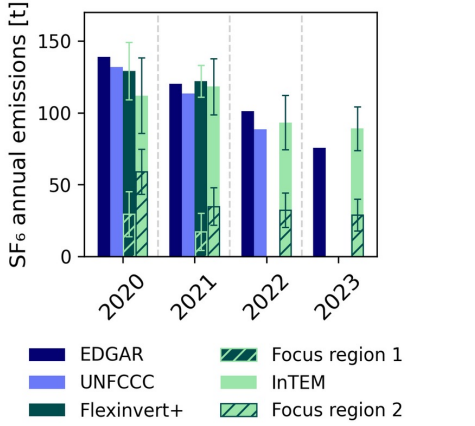


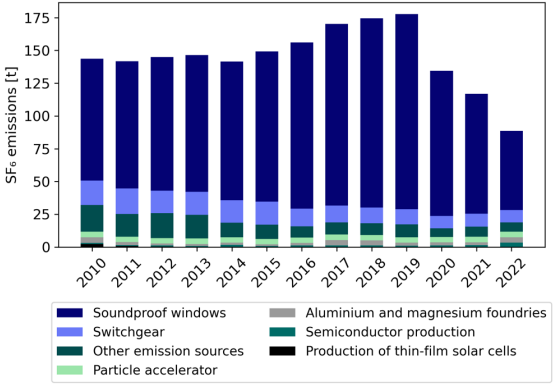
Strong point source in SW Germany

Similar results (independent) from Eye-Clima project

From Katharina Meixner, Univ. Frankfurt

Total emissions consistent with NIR





No strong point source in Inventory