Data
Models
Inventories

PARIS

Process Attribution of Regional Emissions

GA 101081430, RIA

Inverse estimates of European F-gases emissions derived for previous year

Milestone 11			
Delivery due date Annex I	16| April 2024		
Actual date of submission	22 | October 2024		
Lead beneficiary: GUF	Work package: 3	Nature: data	Dissemination level: Public
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Internal reviewers	S. Walter		
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Horizon Europe Cluster 5: Climate, energy and mobility

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1. Changes with respect to the DoA (Description of the Action)

The milestone was due in project month 16 (April 2024). However, due to the data review process, the final and quality controlled data for the inversions are only available by mid-year (July 2024) after the European AGAGE and the AGAGE data reviews. Final inversion runs could only be performed after these reviews. In alignment with inventory compilers and their annual meetings, which will be held between October to December each year, it was decided that groups are allowed to complete the inversions until September and preparing the milestone reports until the end of October.

The specified annual timeline will also apply for the milestones M11, M20, and M24. By this the inversion milestone dates align with the Annex deliverable dates.

2. Dissemination and uptake

This output and/or the methods developed leading to this output will be used in compiling the annexes to the upcoming National Inventory Reports (NIR). This output is used in WP2 for the reconciliation of top-down and bottom-up national level estimates, and in discussion with stakeholders and national inventory report compilers.

3. Short Summary of results

Close collaboration between the three modelling groups in the project, University of Bristol, Met Office and EMPA, has resulted in a standardized data format for the output of the inverse models. An intercomparison software tool has been developed across the groups, which allows detailed investigation of the different modelling systems to be conducted efficiently and in-depth.

It is possible to make comparisons between, for example, the different models' selection of observations, and the baselines calculated at each measurement site. The development of both this tool and the three models to output the required information, was carried out by modelling F-gases, which are measured at four previously existing European sites. This allowed us to gain an understanding of modelling differences and to make changes to the models, where necessary. This tool, and the inverse models, have been used to explore inverse modelling of 10 HFCs (HFC-23, HFC-32, HFC-125, HFC-134a, HFC-143a, HFC-152a, HFC-227ea, HFC-245fa, HFC-365mfc, HFC-4310mee), four PFCs (CF_4, PFC-116, PFC-218, PFC-318), and SF_6. Yearly results covering the period 2018–2023, have been completed using the three inversion systems: InTEM, ELRIS, and RHIME. Similarly, yearly SF_6 results have been obtained (but using nine stations) for the same period. An in-depth intercomparison of the results generated by the different models has been conducted. The data will become publicly available by linkage with the NIR annex as soon those are published.

4. Evidence of accomplishment

4.1 Introduction | Background of the deliverable | milestone

Inverse estimates of F-gases are made using atmospheric measurements of mole fractions. Use of atmospheric transport models is necessary to translate these atmospheric measurements into estimates of emissions from the surface. Multiple methods and analyses can be used to couple models with atmospheric data, which can vary significantly, for example through the data filtering methodologies, resolution of the transport model output, transport model setup, and execution of the statistical inversion technique.

Team members have each published their own independent methods and results on the use of their inversion systems in estimating F-gases emissions (e.g., Manning et al., 2021, Redington et al., 2023, Katharopoulos et al.,

2023). PARIS aims to understand the differences between setups, the effects of those differences, and harmonizing, where possible, the inputs and outputs to allow for robust comparability.

Throughout the project, F-gases emissions estimates will be derived for Europe across a matrix of transport models and inversion setups through this project, using new data also collected in the project.

- University of Bristol: NAME-RHIME, FLEXPART-RHIME
- Met Office: NAME-InTEM, FLEXPART-InTEM
- EMPA: NAME-ELRIS and FLEXPART-ELRIS

4.2 Scope of the deliverable | milestone

This milestone will provide inverse F-gases estimates to be used in compiling the annexes to the upcoming NIR. This document reports on the progress of inversion estimates of F-gases. These estimates will be made on a recurring basis across the course of the project. This milestone report shows the progress in delivery of the systems to make these estimates together with some of the first results. The results and methodologies will feed into the NIR annex work that is due later in the year. Current results are thus shown in comparison to the last available NIR (2023). In this report, we show results from measurements of F-gases using the previously existing measurements across Europe from the following configurations: Met Office (NAME-InTEM), the University of Bristol (NAME-RHIME), and EMPA (NAME-ELRIS).

4.3 Content of the deliverable | milestone

Significant work has been undertaken to prepare for the first national inventory comparison in autumn 2024. Intense exchange between three modelling groups (University of Bristol, Met Office, and EMPA) has resulted in standardized data formats for inverse modelling enabling the rapid interchange of atmospheric transport model (NAME, FLEXPART) and the three inverse modelling systems (RHIME, InTEM, ELRIS).

Comprehensive inter-comparison software has been co-developed across the groups. This new tool enables detailed investigation of the different modelling systems to be conducted efficiently and in depth.

For HFCs and PFCs, yearly results covering the period 2018–2023 have been completed with each model, using four stations across Europe (Mace Head, Ireland; Jungfraujoch Switzerland; Monte Cimone, Italy; Tacolneston, United Kingdom) and NAME footprints. Fig. 1 shows the yearly posterior flux estimates for North-West Europe for total HFC (left panel) and total PFC (right panel). Total HFC sums the CO_2-eq emissions of 10 HFCs: HFC-23, HFC-32, HFC-125, HFC-134a, HFC-143a, HFC-152a, HFC-227ea, HFC-245fa, HFC-365mfc, HFC-4310mee. Total PFC sums the CO_2-eq emissions of four PFCs: CF_4, PFC-116, PFC-218, PFC-318.

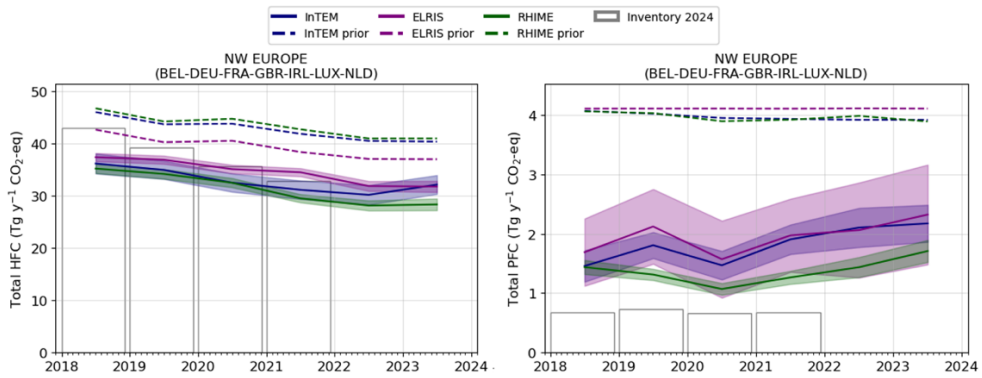

Fig. 1: Trends in total HFC and PFC flux estimates (Tg y^{-1} CO_2-eq) for the North-West Europe region from 2018 to 2023 Posterior flux estimates (solid lines) from InTEM (dark blue), ELRIS (purple), and RHIME (green), are compared to their prior flux estimates (dashed lines) and inventory flux estimates as reported to the UNFCCC (black bars) in 2023.

The flux estimates of four major HFCs are shown in Fig. 2: HFC-134a (panel (a)), HFC-125 (panel (b)), HFC-143a (panel (c)), HFC-32 (panel (d)) for North-West Europe. Those fluxes were also estimated per country, as shown in Fig. 3 where examples of HFC-134a flux estimates are given for the UK, Germany, France, and Italy.

Fig. 4 shows example output for the station Mace Head, using the inter-comparison software which facilitates easy plotting of observational data against posterior model mole fractions (with associated uncertainties) at any of the observation sites, to assess both individual model performance and differences between models.

Fig. 5 shows the HFC-134a emission flux maps from each model, which result from averaging the yearly inversions throughout the 2018–2023 period. Observation sites are marked as black circles. For SF_6, yearly results covering the period 2018–2023 have been completed with each model, using nine stations across Europe. Fig. 6 shows the yearly posterior SF_6 flux estimates for Germany, North-West Europe, France, and Benelux. Fig. 7 shows the SF_6 emission flux maps from InTEM, RHIME, and ELRIS, which result from averaging the yearly inversions throughout the 2018–2023 period.

Empa have set up and completed atmospheric transport simulations (FLEXPART driven by ECMWF inputs) for inverse modelling for several sites across Europe and the period 2018-2023. Hourly footprints (source sensitivities) were produced using the same output grid definition as applied by the Met Office for the NAME model. HFC-143a, HFC-32, and PFC-218, inversions based on these FLEXPART transport simulations have been calculated using ELRIS, RHIME and InTEM.

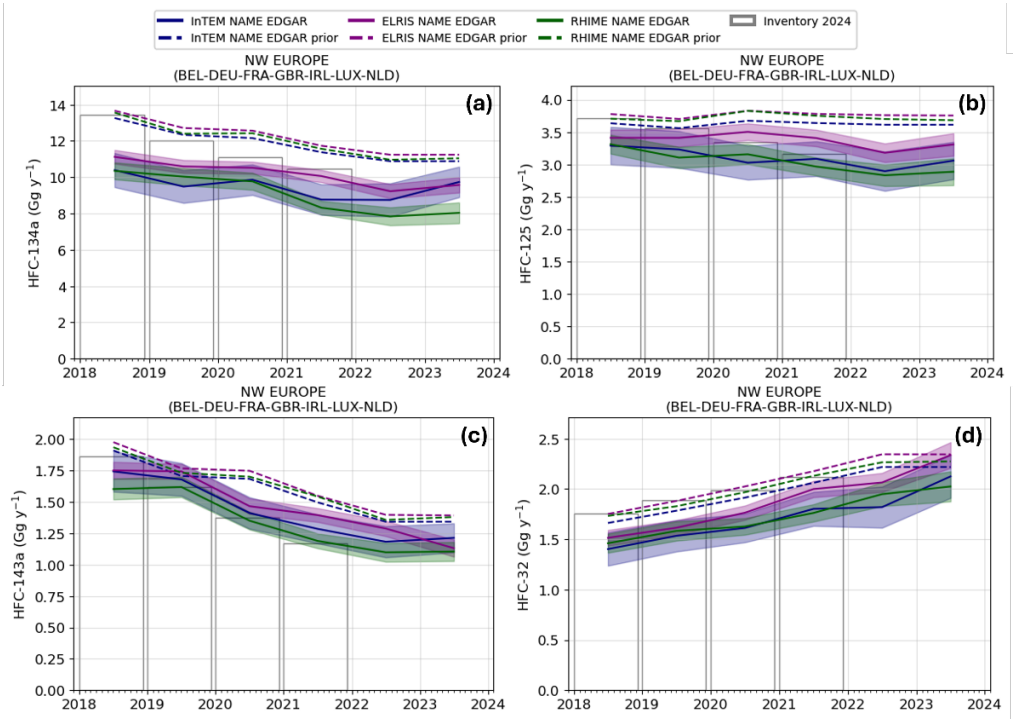

Fig. 2: Trends in HFC-134a, HFC-125, HFC-143a, and HFC-32 flux estimates (Gg y^{-1}) for the North-West Europe region from 2018 to 2023. Posterior flux estimates (solid lines) from InTEM (dark blue), ELRIS (purple), and RHIME (green), are compared to their prior flux estimates (dashed lines) and inventory flux estimates as reported to the UNFCCC (black bars) in 2023.

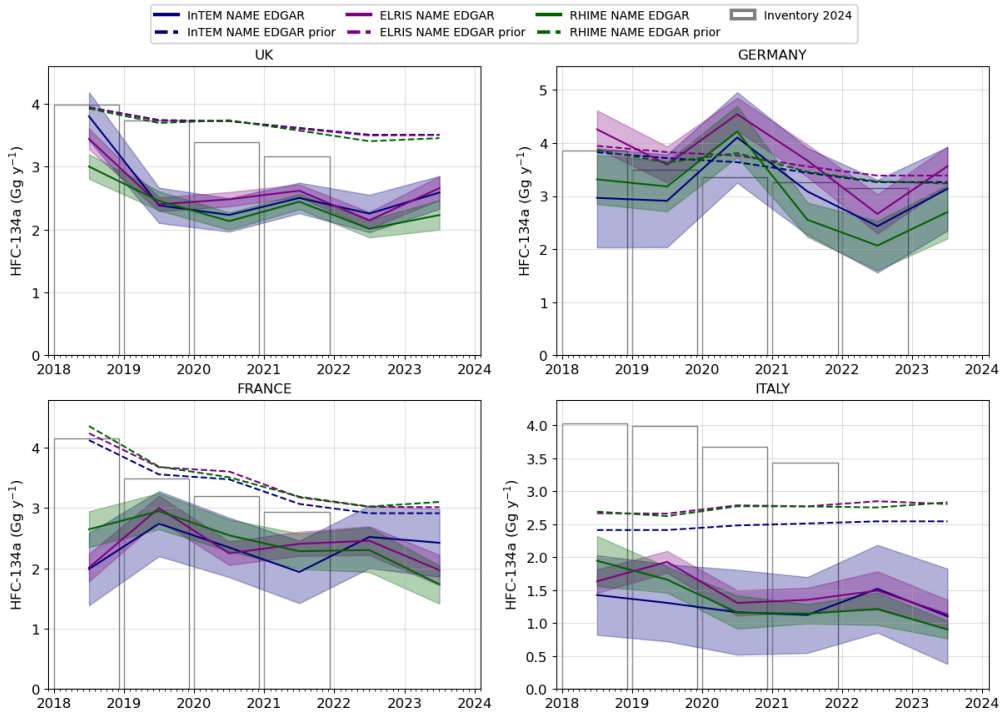

Fig. 3: Trends in HFC-134a flux estimates (Gg y^{-1}) from 2018 to 2023, given for four countries: the United Kingdom, Germany, France, and Italy. Posterior flux estimates (solid lines) from InTEM (dark blue), ELRIS (purple), and RHIME (green), are compared to their prior flux estimates (dashed lines) and inventory flux estimates as reported to the UNFCCC (black bars) in 2023.

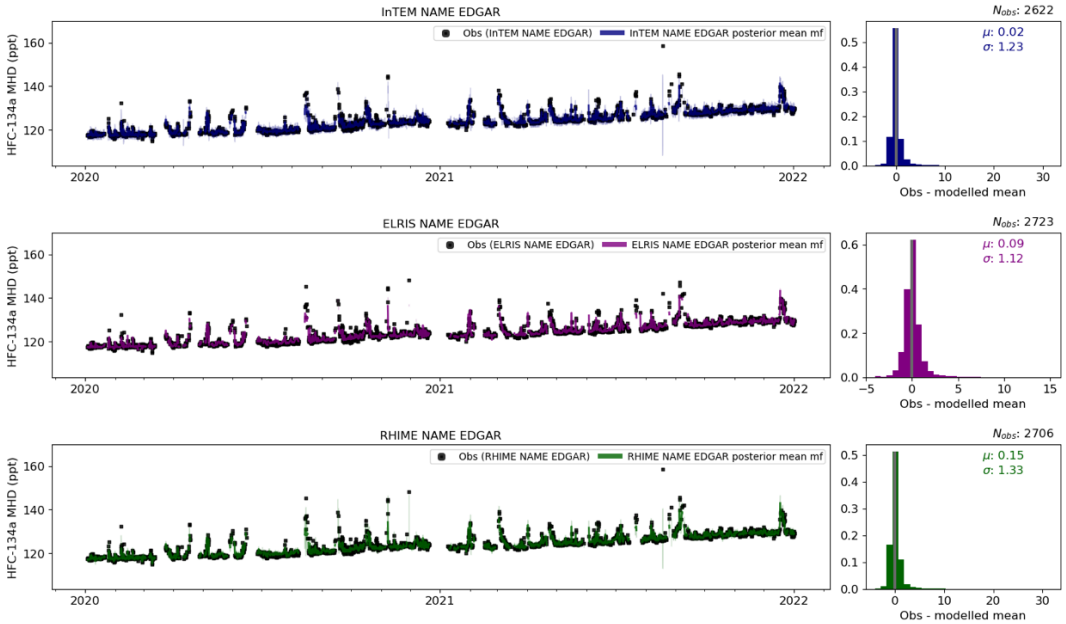

Fig. 4: Two years of observed (black squares) and posterior modelled (circles and shading; dark blue: InTEM, purple: ELRIS, green: RHIME) HFC-134a mole fractions from the example site Mace Head (MHD). Statistics representing the modelled mole fractions' fit to observations over this period are given in the histogram plots.

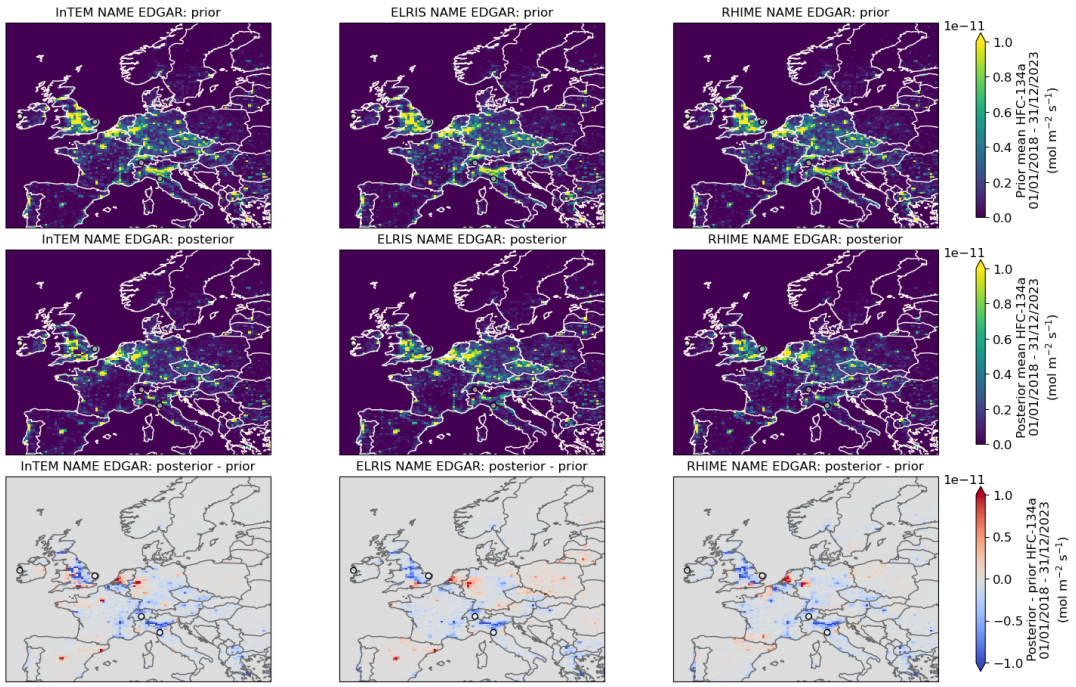

Fig. 5: Mean prior (first row) and posterior (second row) HFC-134a flux across Western Europe, averaged from yearly inversions between 2018 and 2023. The third row shows the difference maps of posterior minus prior flux. Observation site locations are shown in black circles.

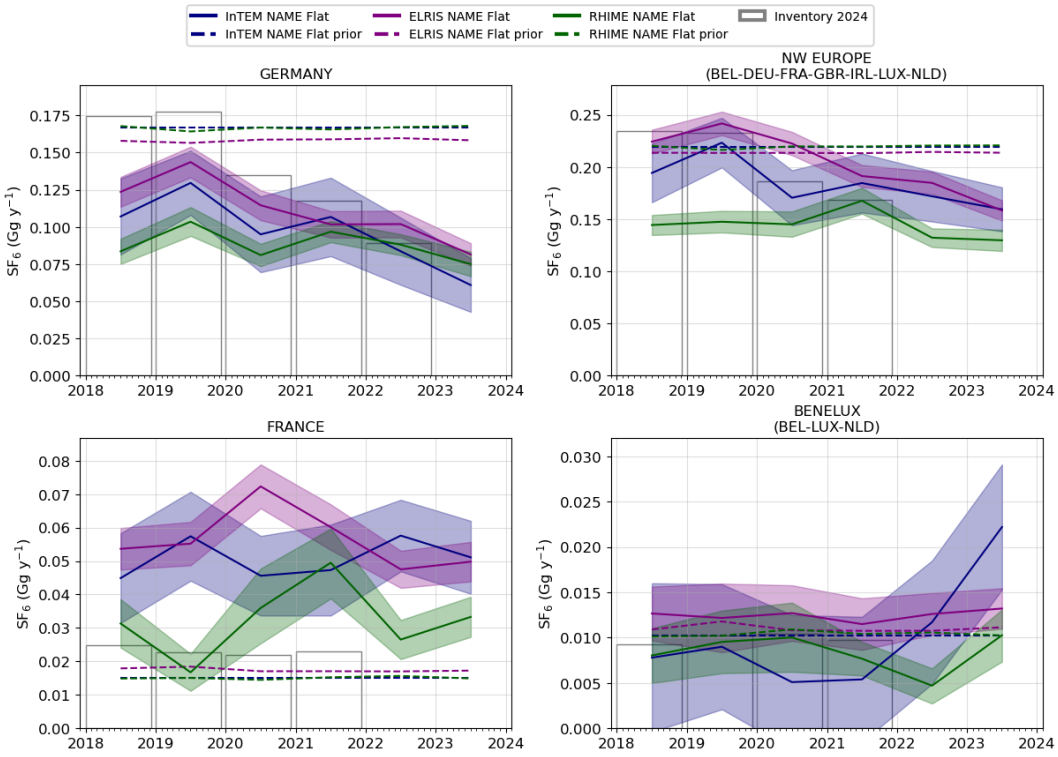

Fig. 6: Trends in SF_6 flux estimates (Gg y^{-1}) from 2018 to 2023 given for different regions: Germany, NW Europe, France, and Benelux. Posterior flux estimates (solid lines) from InTEM (dark blue), ELRIS (purple), and RHIME (green), are compared to their prior flux estimates (dashed lines) and inventory flux estimates as reported to the UNFCCC (black bars) in 2023.

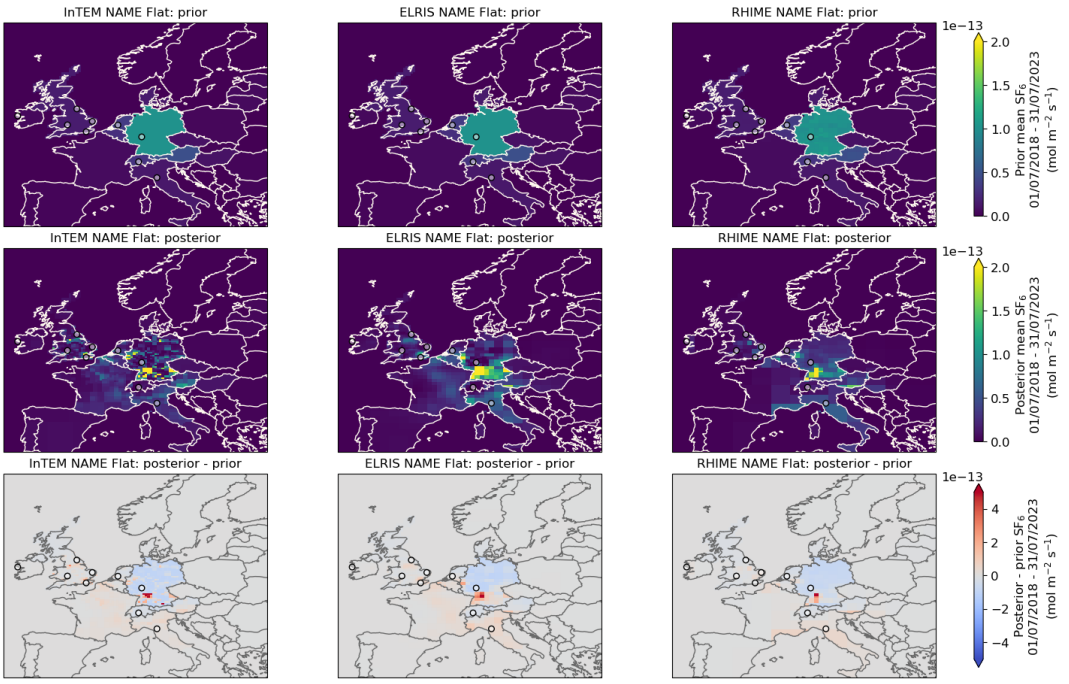

Fig. 7: Mean prior (first row) and posterior (second row) SF_6 flux across Western Europe, averaged from yearly inversions between 2018 and 2023. The third row shows the difference maps of posterior minus prior flux. Observation site locations are shown in black circles.

4.4 Conclusion and possible impact

The initial set up for the operational systems for inverse estimates of F-gases for Europe across the groups in this consortium is ready and results have been shown from InTEM, ELRIS, and RHIME, in preparation for later reporting under the NIR annexes. For this first reporting period, a rigorous comparison between model and inversion setups have been made.

4.5 References

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5. History of the document

Version	Author(s)	Date	Changes
1	H. De Longueville	4 Oct 2024	Set up
	A. Engel, A. Ganesan	10 Oct 2024	feedback
	S. Walter	11 Oct 2024	Finalised and submitted