Republic of Rwanda

THE KIGALI AMENDMENT 2016–2026

UN environment programme ozone secretariat

Vienna Convention MONTREAL PROTOCOL

MOP38

2-6 NOVEMBER 2026 | KIGALI, RWANDA

THIRTY-EIGHTH MEETING OF THE PARTIES TO THE MONTREAL PROTOCOL

IMPROVING ESTIMATES OF EUROPEAN F-GAS EMISSIONS BY ATMOSPHERIC MONITORING

MONDAY
2 NOVEMBER 2026

13:00 - 15:00

AD12-B

IMPROVING ESTIMATES OF EUROPEAN F-GAS EMISSIONS BY ATMOSPHERIC MONITORING

WELCOME BY

ARNO KASCHL, DG CLIMA, EUROPEAN COMMISSION

SEBASTIAN SCHNATZ, BMUKN, GERMANY

INTRODUCTION – WHO WE ARE

- Barbara Gschrey – Oeko-Recherche, Frankfurt, Germany
- Anita Ganesan – University of Bristol, Bristol, U.K.
- Guus Velders, RIVM, Bilthoven, and Univ. Utrecht, the Netherlands
- Andreas Engel, University of Frankfurt, Frankfurt Germany






INTRODUCTION – EU FUNDED PROJECTS

- Recent EU funded projects relevant to the Montreal Protocol

  - PARIS: **P**rocess **A**ttribution of **R**egional Em**iss**ions
    https://horizoneurope-paris.eu/

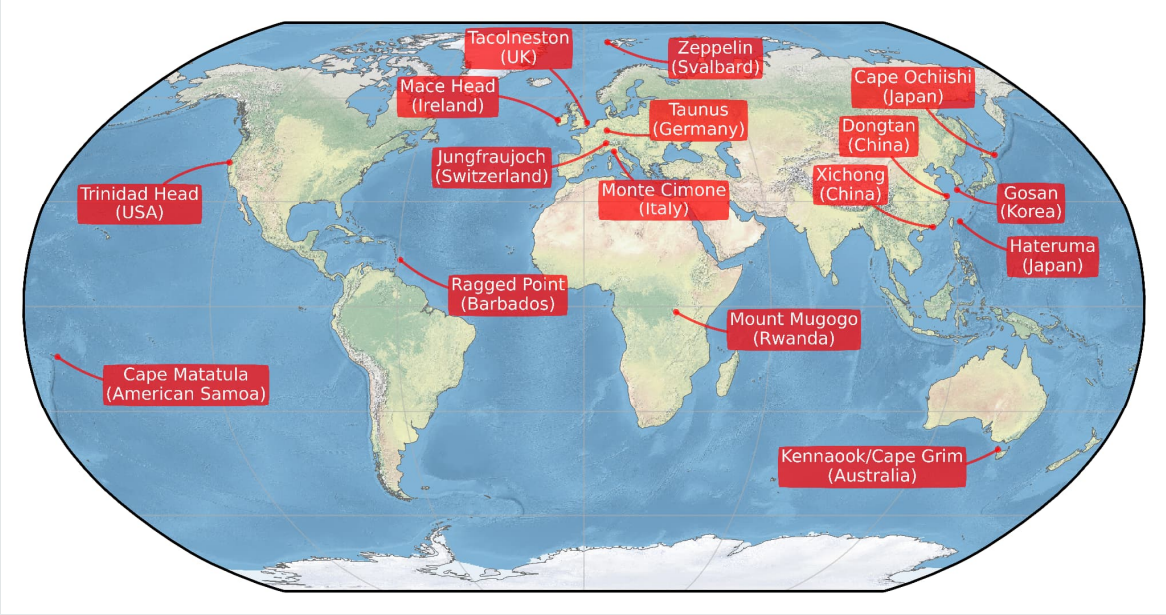
  - REIGN-MP: **R**esilient and **E**ffective **I**nternational **G**overnance and **N**etwork for monitoring gases relevant to the **M**ontreal **P**rotocol

REIGN-MP
GLOBAL NETWORKS SUPPORTING THE MONTREAL PROTOCOL

INTRODUCTION – THE AGAGE NETWORK

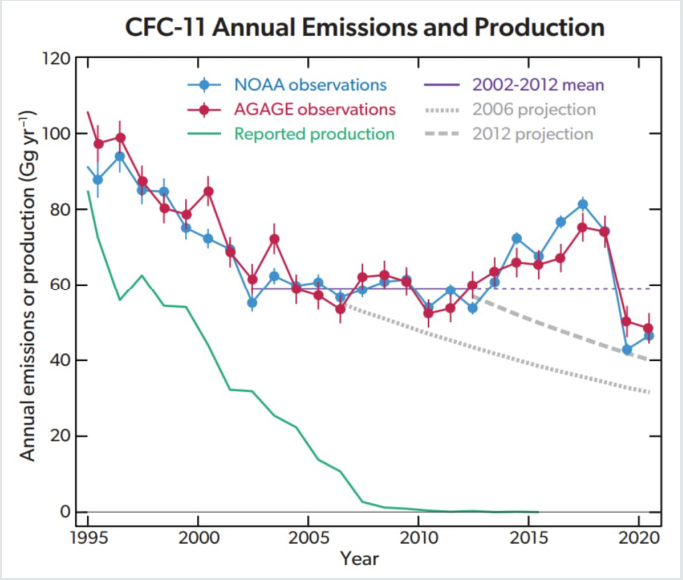
- Global Monitoring of Ozone depleting gases and F-gases related to the Montreal protocol:

The **A**dvanced **G**lobal **A**tmospheric **G**ases **E**xperiment: AGAGE

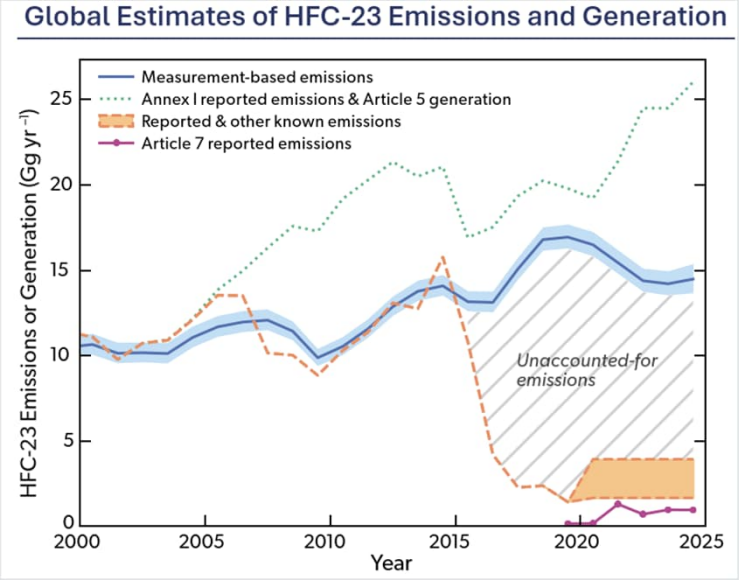


https://www-air.larc.nasa.gov/missions/agage/

UNEXPECTED EMISSIONS DETECTED BY OBSERVATIONS



WMO 2022,
First reported by Montzka et al., 2018



WMO Executive Summary, 2026,
First reported by Stanley et al., 2020

- Global measurements tell us **how much** is being emitted worldwide, but not **where** it comes from.
- Regional measurements are needed to see which countries/regions are responsible.

COMPILATION OF THE EU GHG INVENTORY

- To be submitted to the UNFCCC annually
- Based on GHG inventories of all EU Member States
- Member States apply different methodologies which might be based on
  - production and import statistics
  - stock models
  - combined approaches varying by sectors
- Common quality checks and review
  - Data consistency across Member States
  - Plausibility

https://www.eea.europa.eu/en/analysis/publications/annual-european-union-greenhouse-gas-inventory-2026

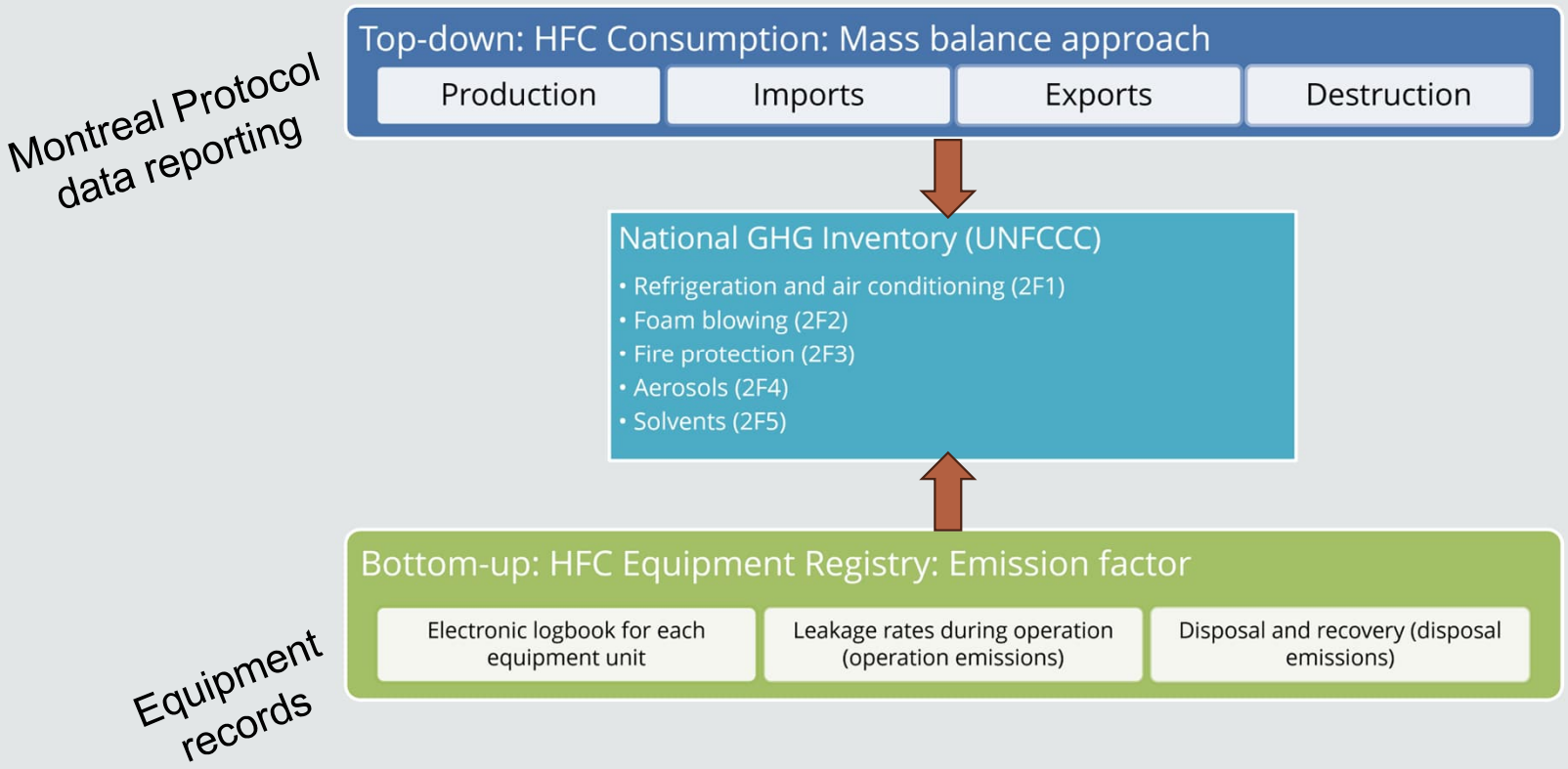


BOTTOM-UP ESTIMATES FOR GHG INVENTORIES

- UNFCCC emission reporting relies on the methodologies by the Intergovernmental Panel on Climate Change (IPCC) and include
  - **T**ransparency
  - **A**ccuracy
  - **C**onsistency
  - **C**ompleteness
  - **C**omparability

- Country-specific estimates are achieved by means of bottom-up and/or top-down activity data:
  - Mass balance approach
  - Emission factor approach
- Time series goes back to 1990/1995, data can be revised in later years when new information becomes available or methodologies change
- Currently no cross-checking with atmospheric measurements at national level

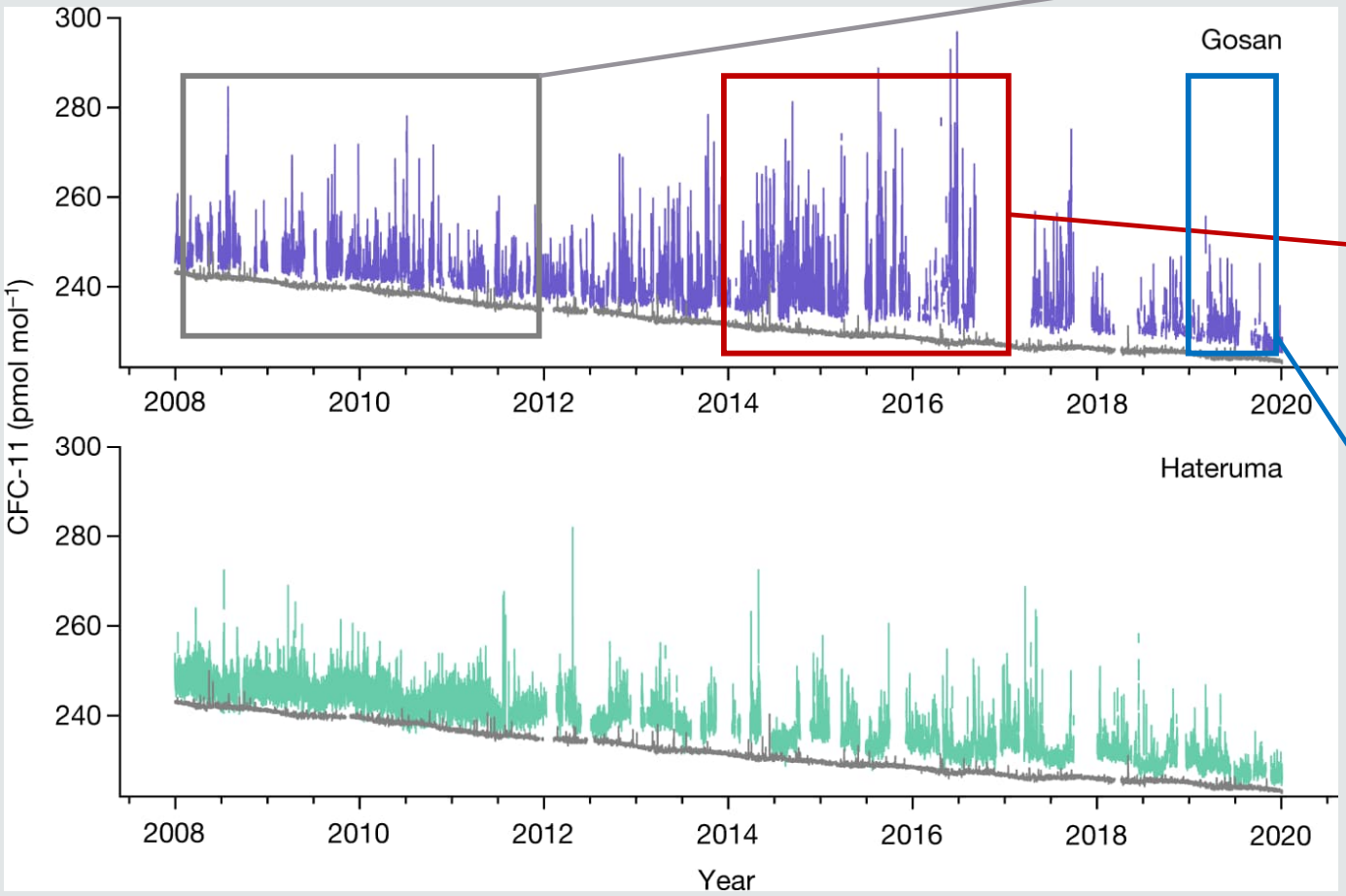
NATIONAL DATA SOURCES FOR GHG INVENTORIES

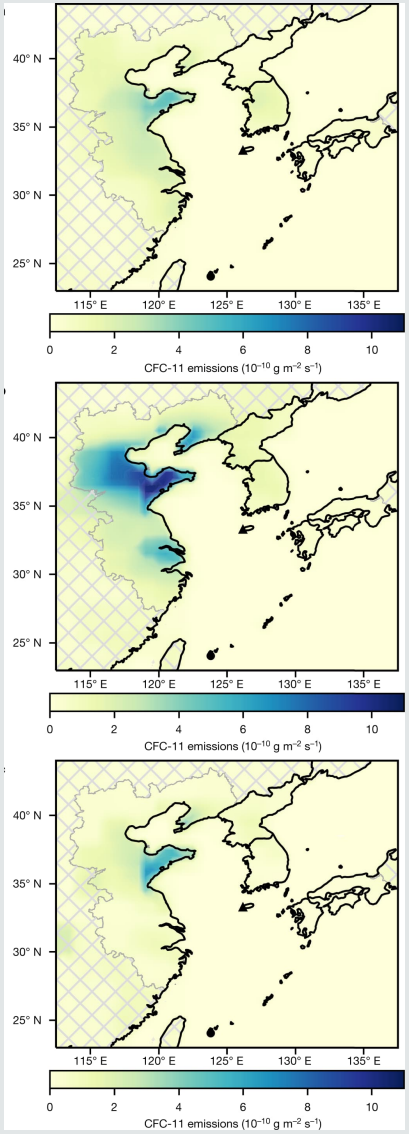


TOP-DOWN REGIONAL CONCEPT: AN INTERACTIVE VIEW

- https://acrg-bristol.github.io/acrg-inversions-docs/examples/hfc134a-europe/

DETECTING REGIONAL EMISSIONS





2008-2012

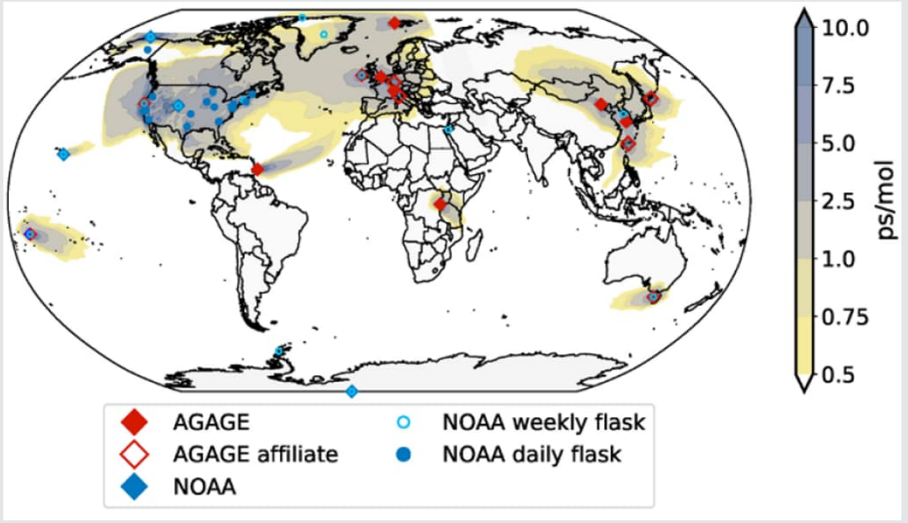
2014-2017

2019

Rigby et al., 2019 and Park et al., 2021

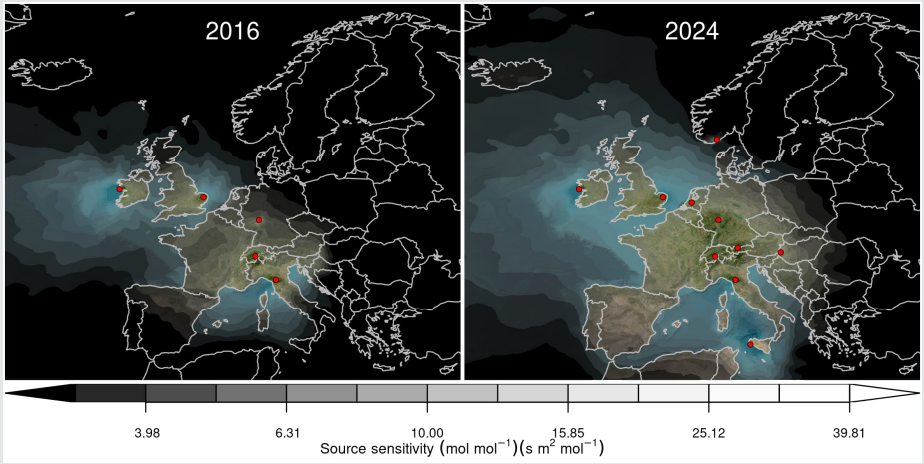
THE GLOBAL NETWORK FOR HALOGENATED GASES

- Large Gaps in Global Network



WMO, 2022

The European Network



De Longueville et al., 2026, https://doi.org/10.5194/acp-26-7647-2026.

- Growing network in Europe over the last decade

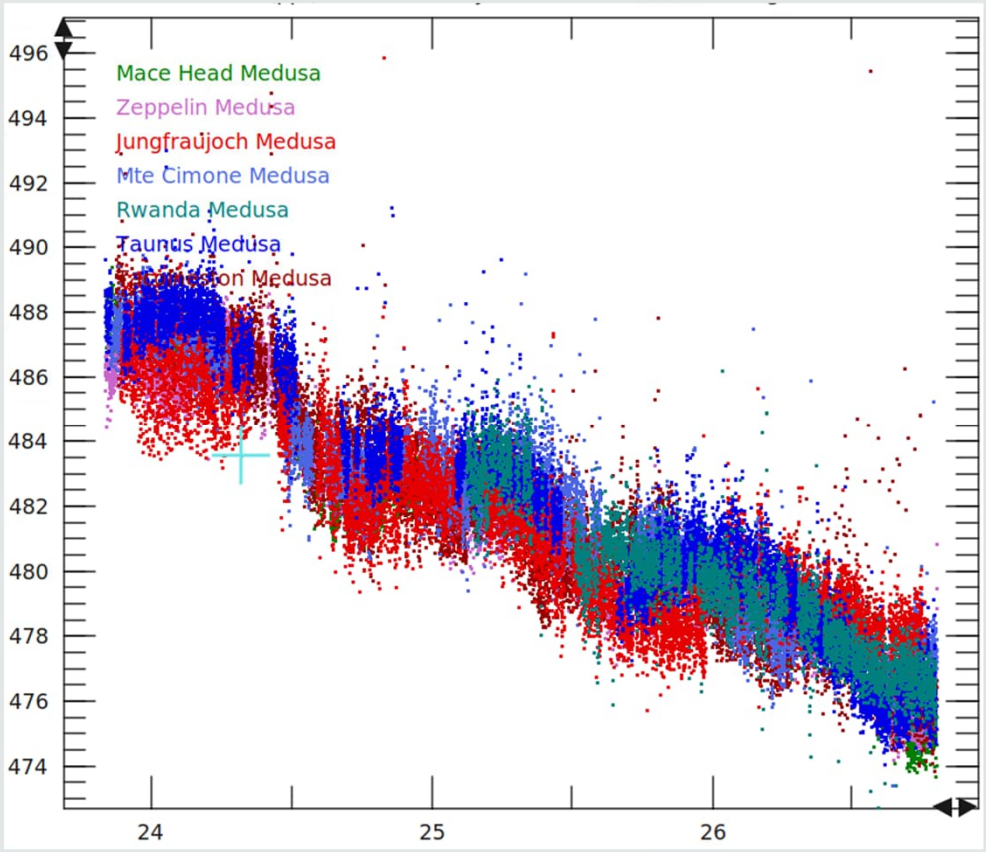
WHAT IS REQUIRED TO RUN A STATION

- **Reliable measurements need long-term investment in people and infrastructure:**

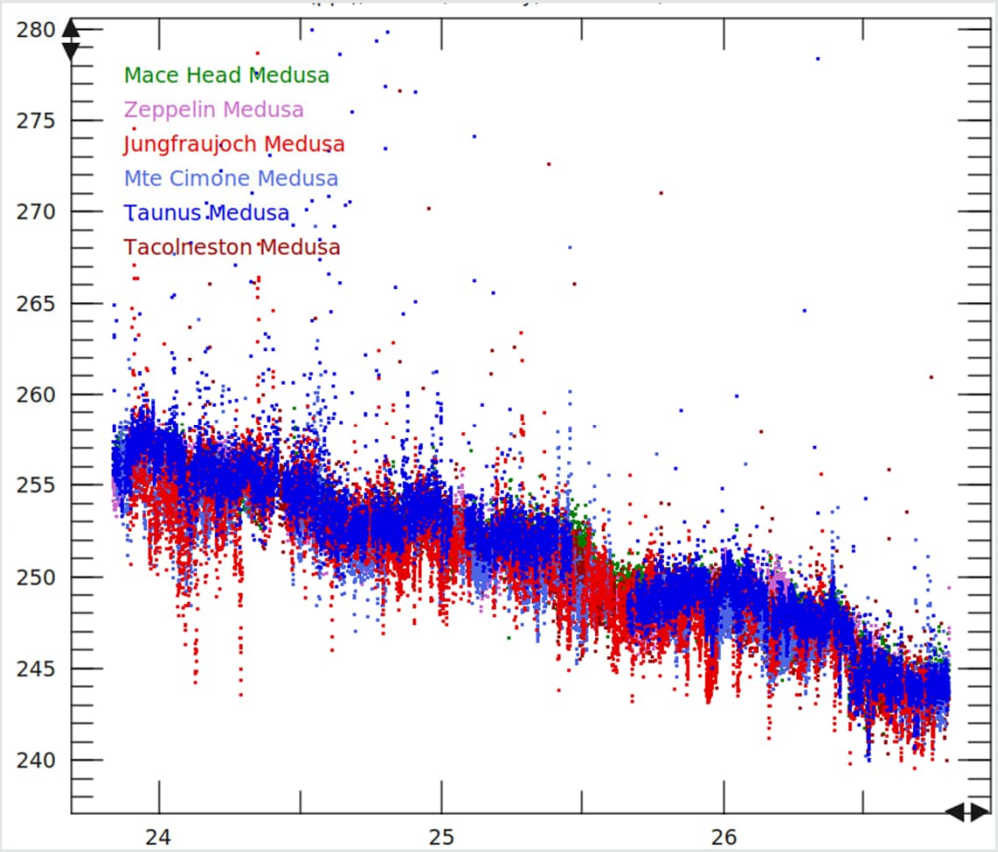
  - **Equipment:** about €500,000 per station for specialist instruments (gas chromatography–mass spectrometry).
  - **People:** 1.5–2 full-time experts per station, covering both running the measurements and interpreting the science.
  - **Ongoing quality checks:** weekly checks at each station, a shared calibration standard, and network-wide reviews twice a year.
  - **New stations:** extensive initial support, especially to calibrate against the existing network and ensure high data quality

DECLINING ATMOSPHERIC LEVELS

CFC-12

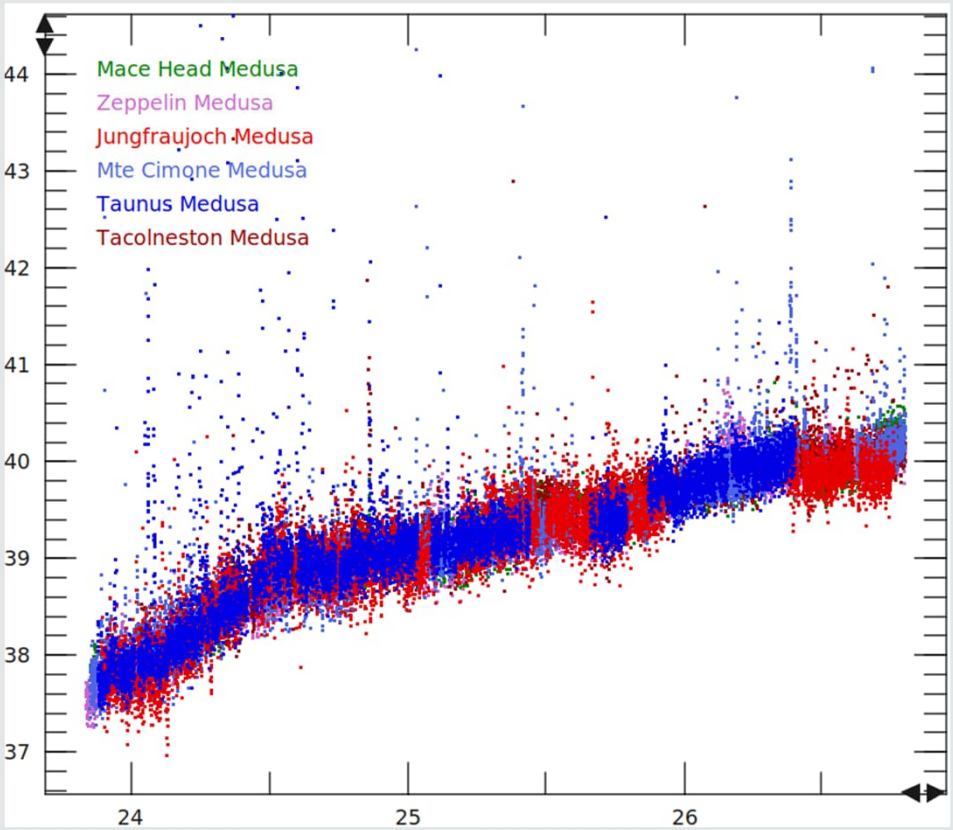


HCFC-22

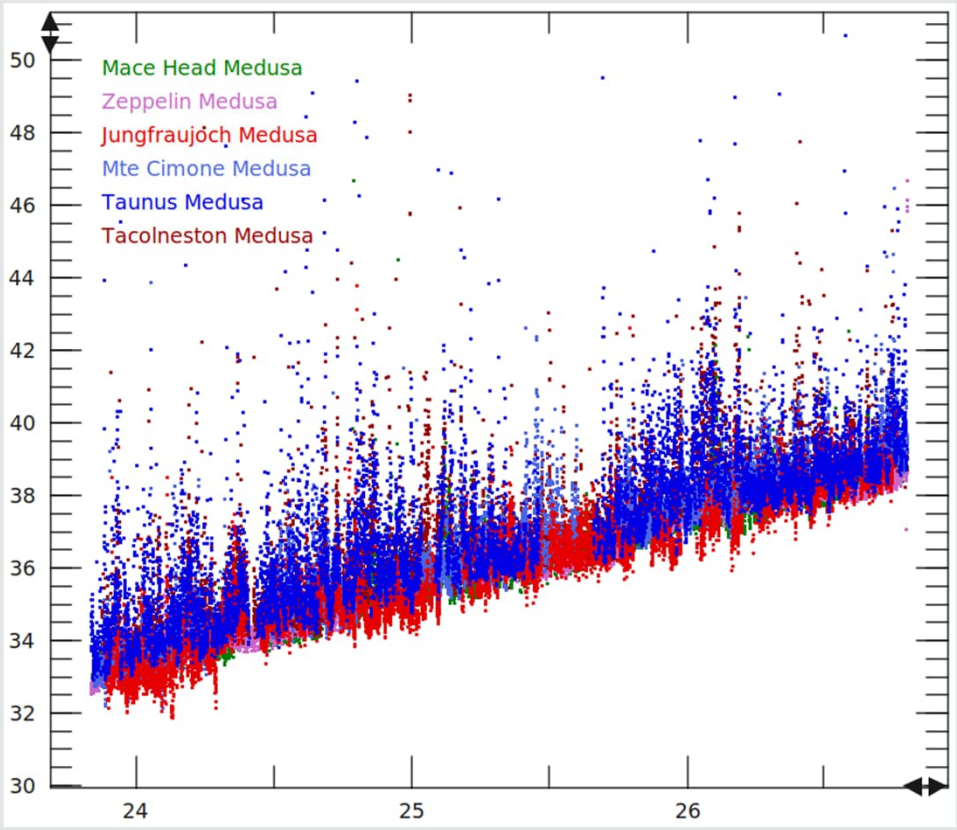


INCREASING ATMOSPHERIC LEVELS

HFC-23



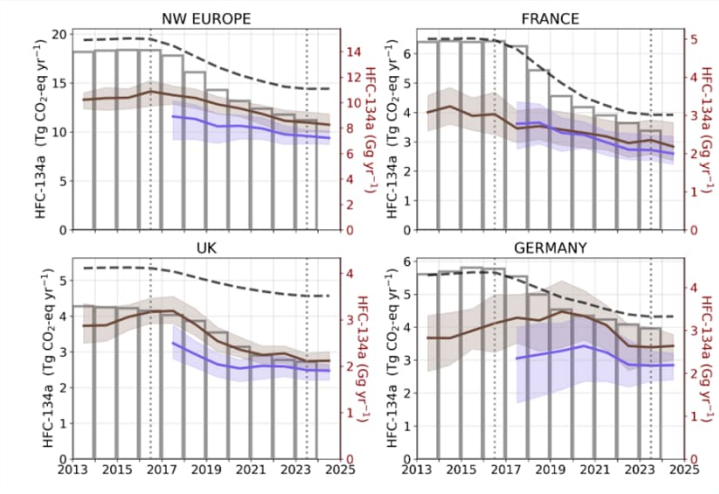
HFC-134a



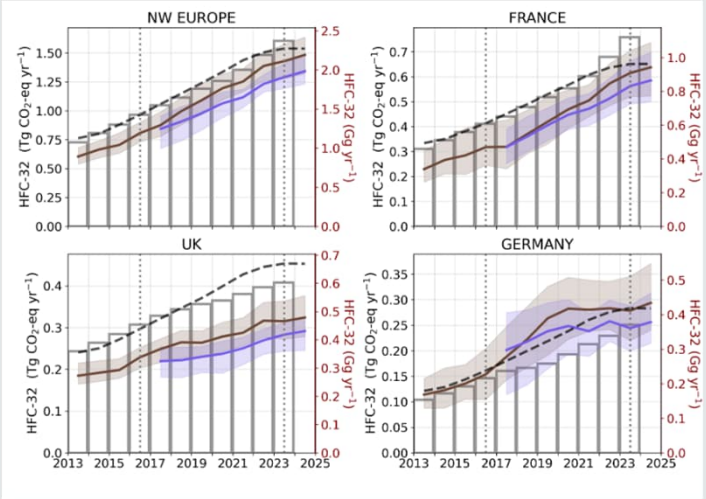
EUROPEAN HFC EMISSION TRENDS

- HFCs emissions targeted by European F-gas regulation
- Emissions reported under UNFCCC
- Phase-down depending on GWP

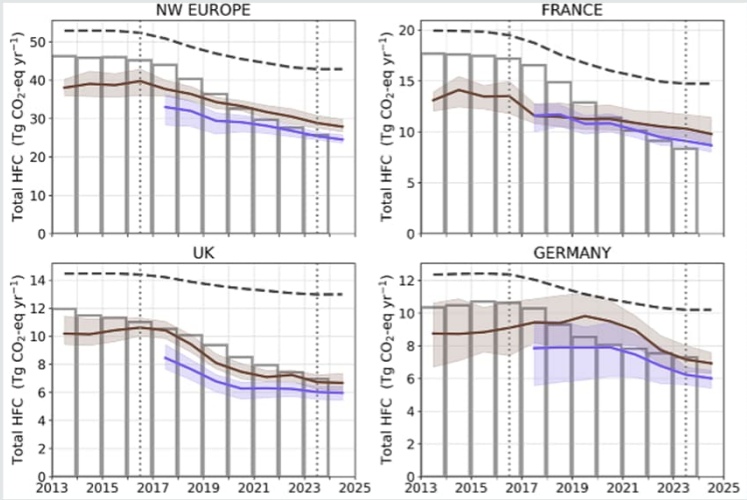
HFC-134a; GWP_{100}: 1430



HFC-32; GWP_{100}: 675

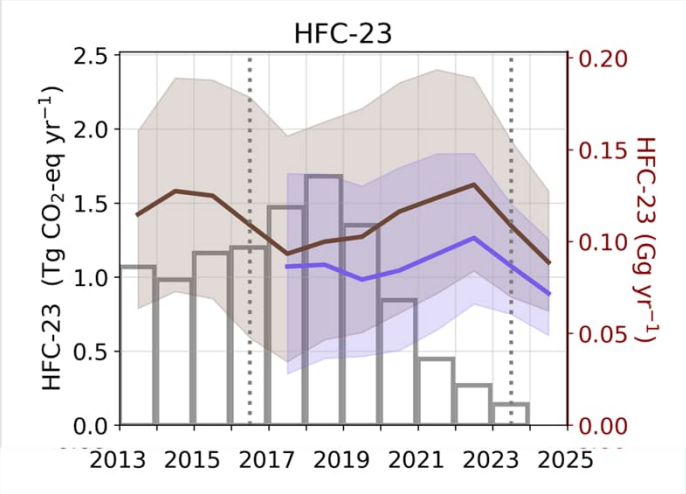


Total HFC ; GWP_{100} weighted



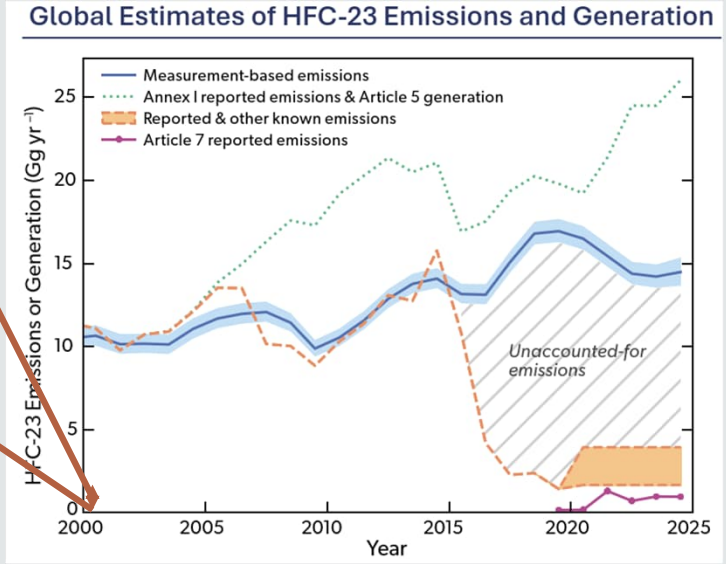
De Longueville et al., 2026, https://doi.org/10.5194/acp-26-7647-2026.

HFC-23 EMISSIONS ARE SMALL BUT STILL OBSERVED



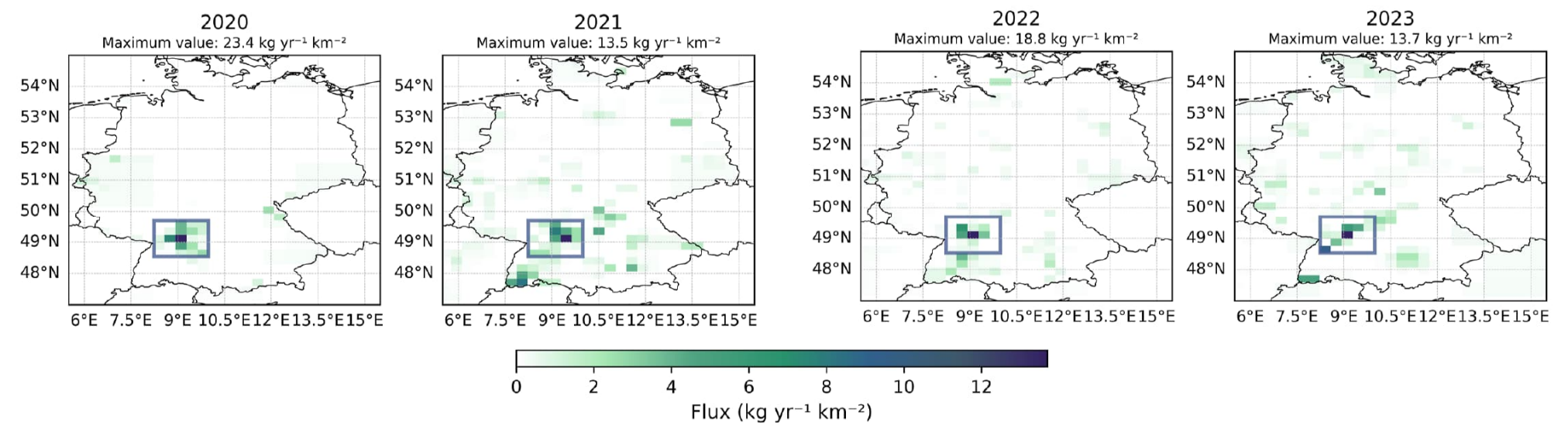
De Longueville et al., 2026, https://doi.org/10.5194/acp-26-7647-2026.

- HFC-23 emissions from North-West Europe based on top-down estimates **significantly** higher than reported emissions by a factor of about 5-7
- Higher relative uncertainty compared to other gases due to point source emissions.
- NW Europe emissions small compared to global



WMO Executive Summary, 2026,
First reported by Stanley et al., 2020

EMISSION HOT SPOT OF SF_6 IN GERMANY

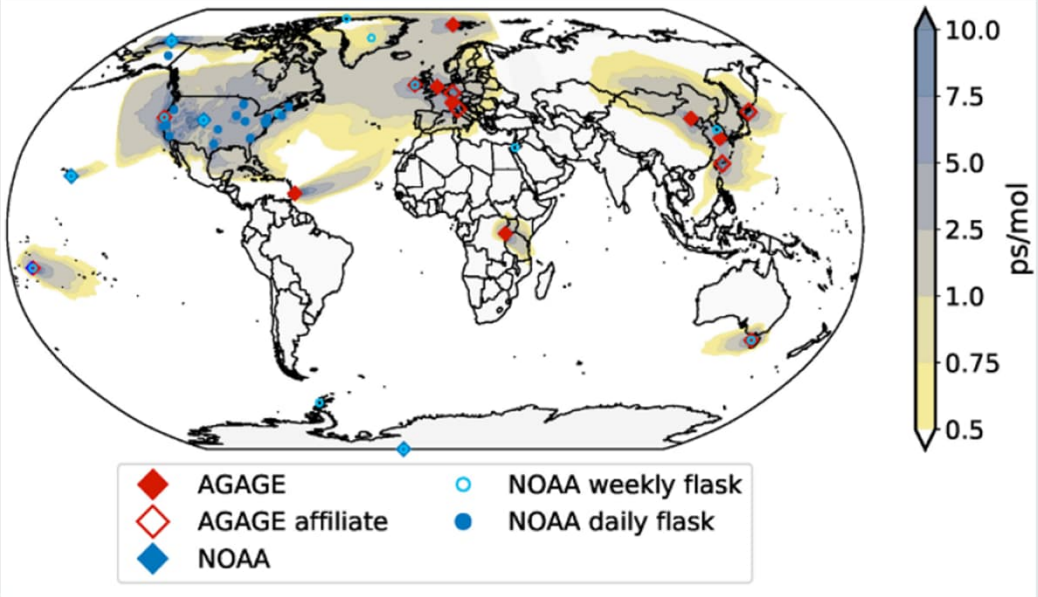


Focus region (blue box, southwest Germany): on average **Rougly 1/3rd** of German SF_6 emissions, 2020–2023.

Europe's only plant producing and recycling SF_6 lies inside the focus region.

Meixner et al. (2025), ACS ES&T Air 2, 2889–2899

EUROPE IN THE WIDER LANDSCAPE



- Europe is working on a denser network of atmospheric measurement stations to verify emission estimates.
- What do we need to expand networks globally?

WMO Ozone assessment, Ch. 1., 2022

PARIS

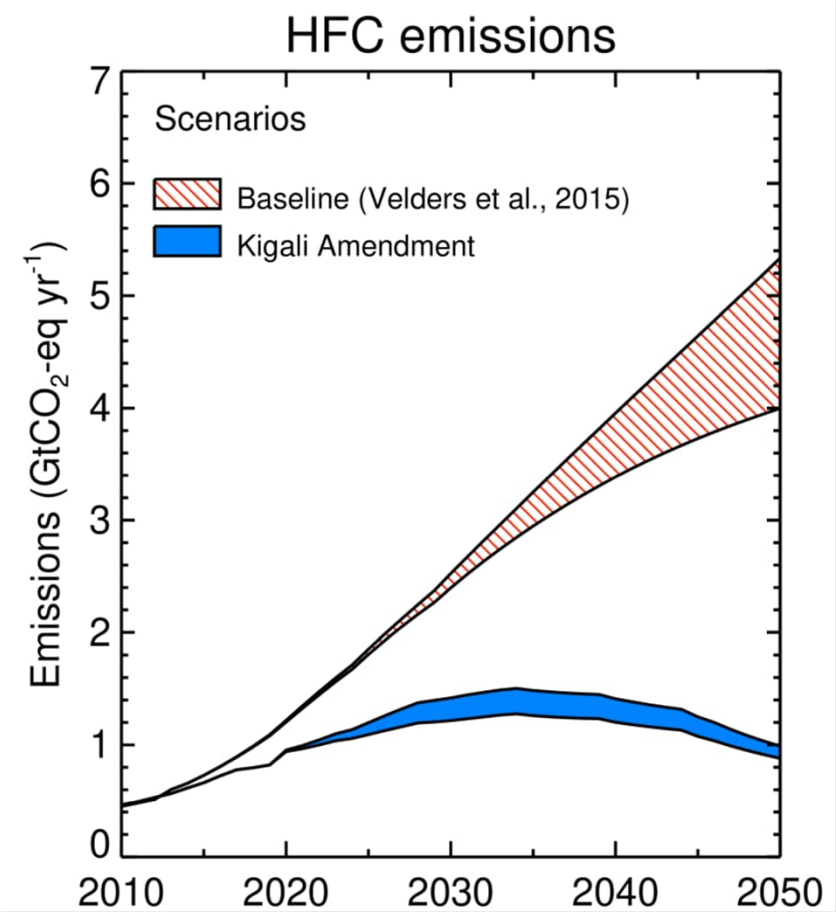
REIGN-MP
GLOBAL NETWORKS SUPPORTING THE MONTREAL PROTOCOL

HFC SCENARIOS/FUTURE

Ingredients for HFC scenarios

- Consumption data reported to UNEP (all countries)
- Emissions/stocks reported to UNFCCC
  => Consumption estimates
- Projections for the future use of HFCs
  => Per sector, region

- Observations in the atmosphere
  => Emissions estimate

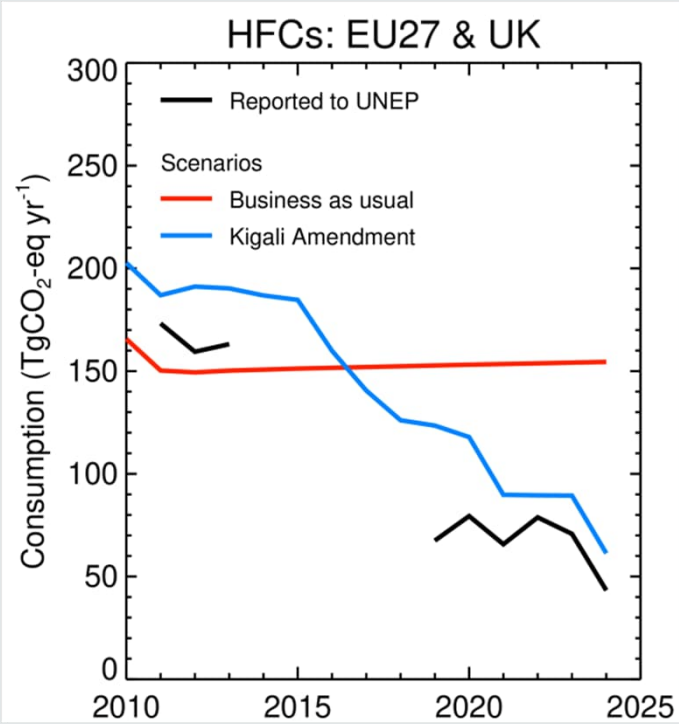


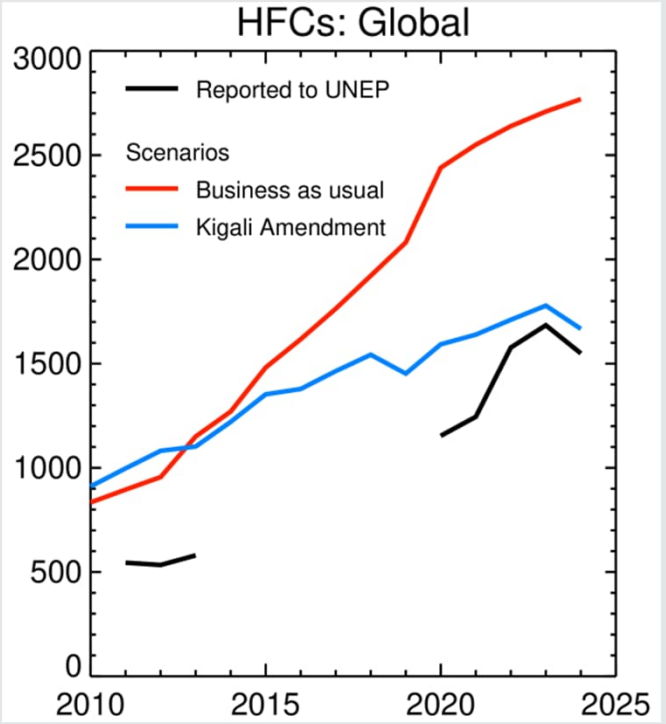
Adapted from Velders et al., 2022)

UNEP CONSUMPTION DATA

- Data reported to UNEP

- Consumption below Baseline scenario (without any controls)
- In line with Kigali Amendment scenario





Velders et al., in prep)

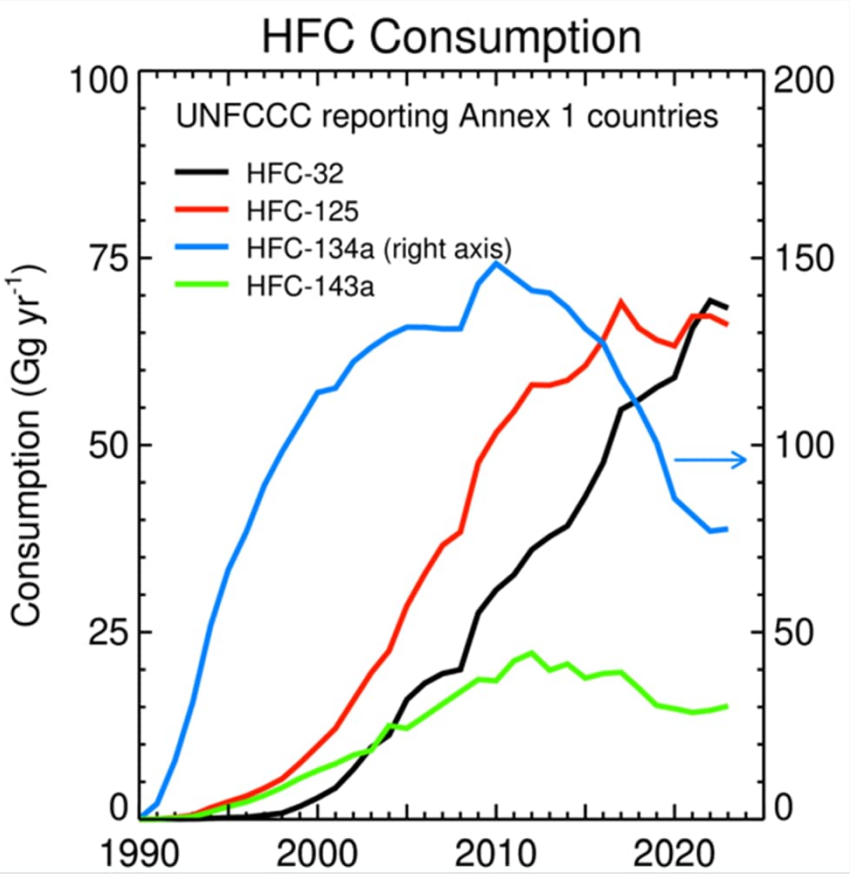
CONSUMPTION ESTIMATED FROM UNFCCC

Developed countries report:

- Emissions of HFCs
- Amounts in stock
- Per sector, per species
- Developed countries, plus few developing countries

➔ Estimate of consumption per sector, species

- Large decrease HFC-134a: Mobile AC, other uses
- Large increase in HFC-32: Stationary AC
- Leveling off HFC-125/143a: Stationary AC, Refr.



Velders et al., in prep)

CONSUMPTION ESTIMATED FROM UNFCCC

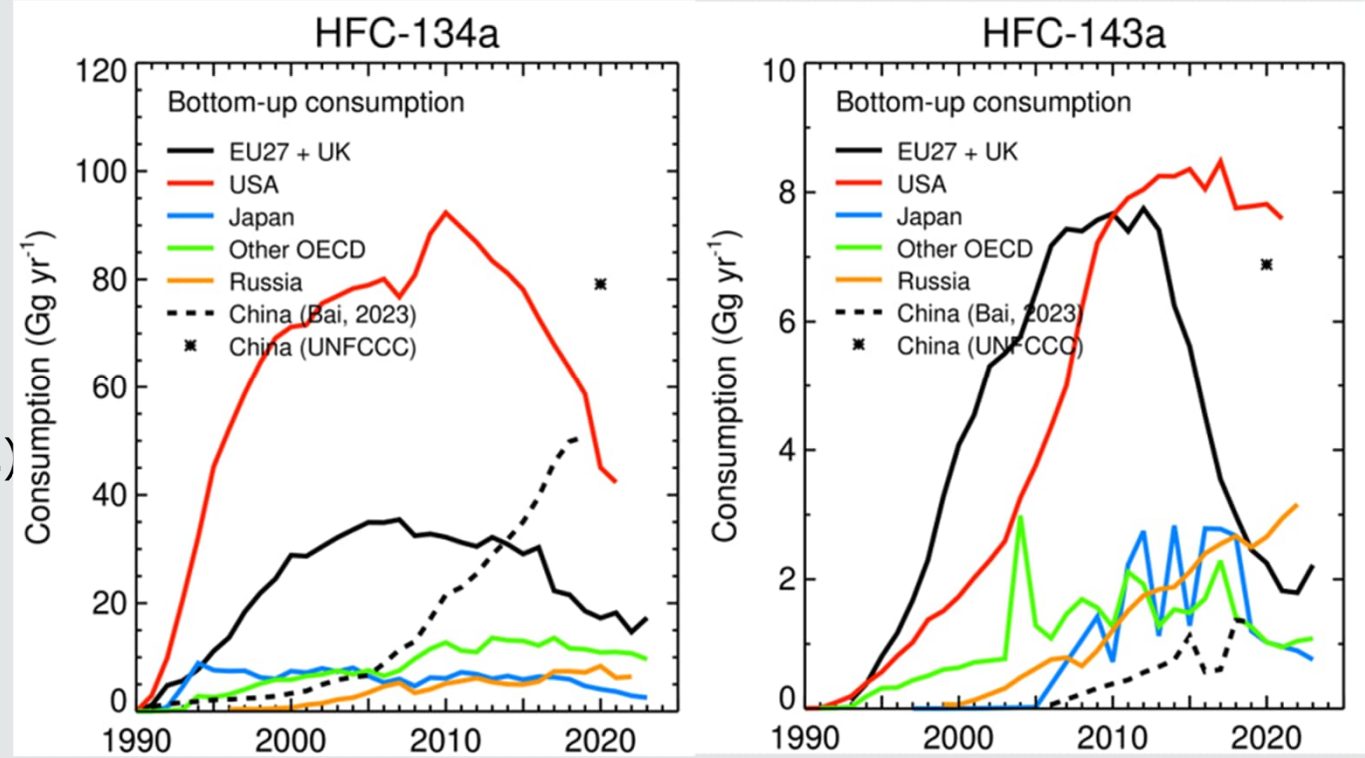
Focus on **Refrigeration**

HFC-134a:

- Decreasing is most countries
- Large increases in China

HFC-143a:

- Large decrease in EU (F-gas reg.)
- Constant in USA



Velders et al., in prep)

CONSUMPTION ESTIMATED FROM UNFCCC

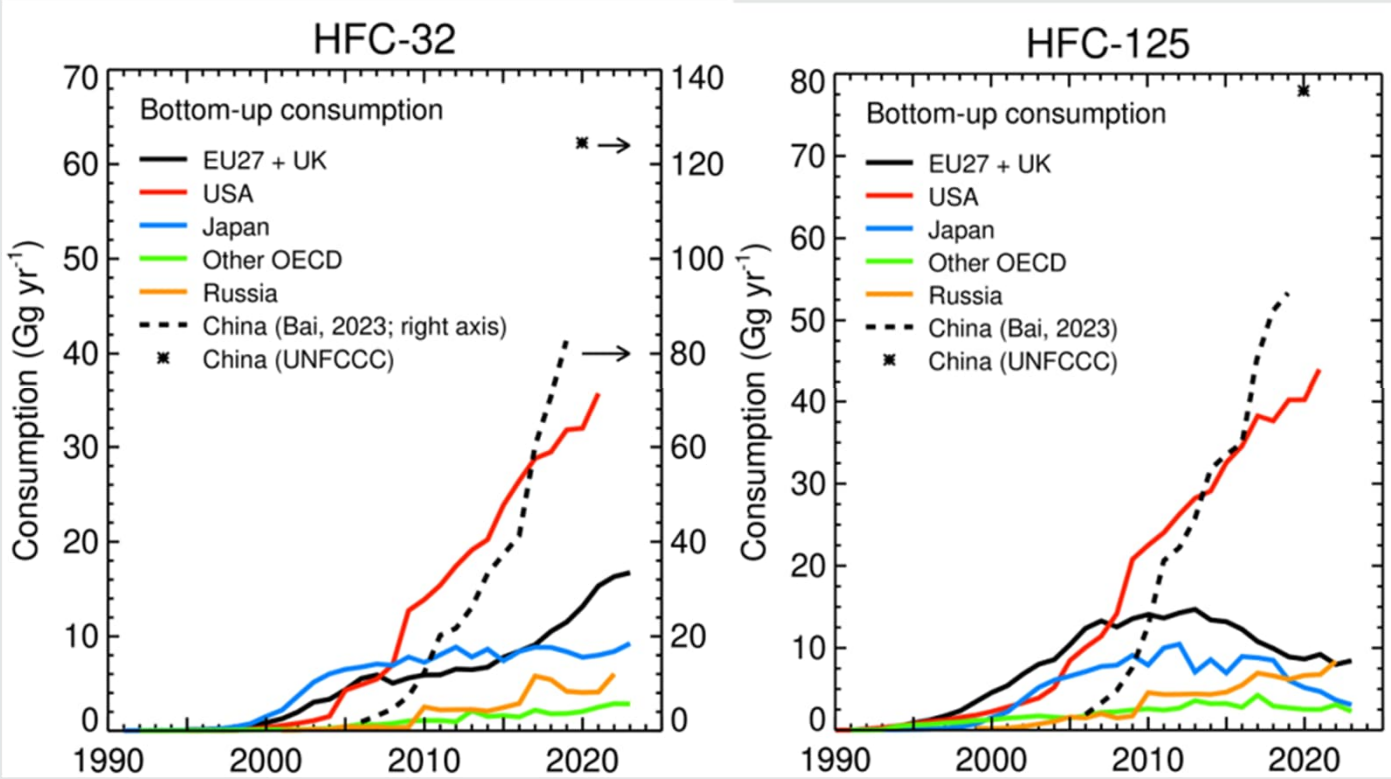
Focus on **Air conditioning**

HFC-32:

- Increases in all countries

HFC-125:

- Increases
- Decreases in EU and Japan



Velders et al., in prep)

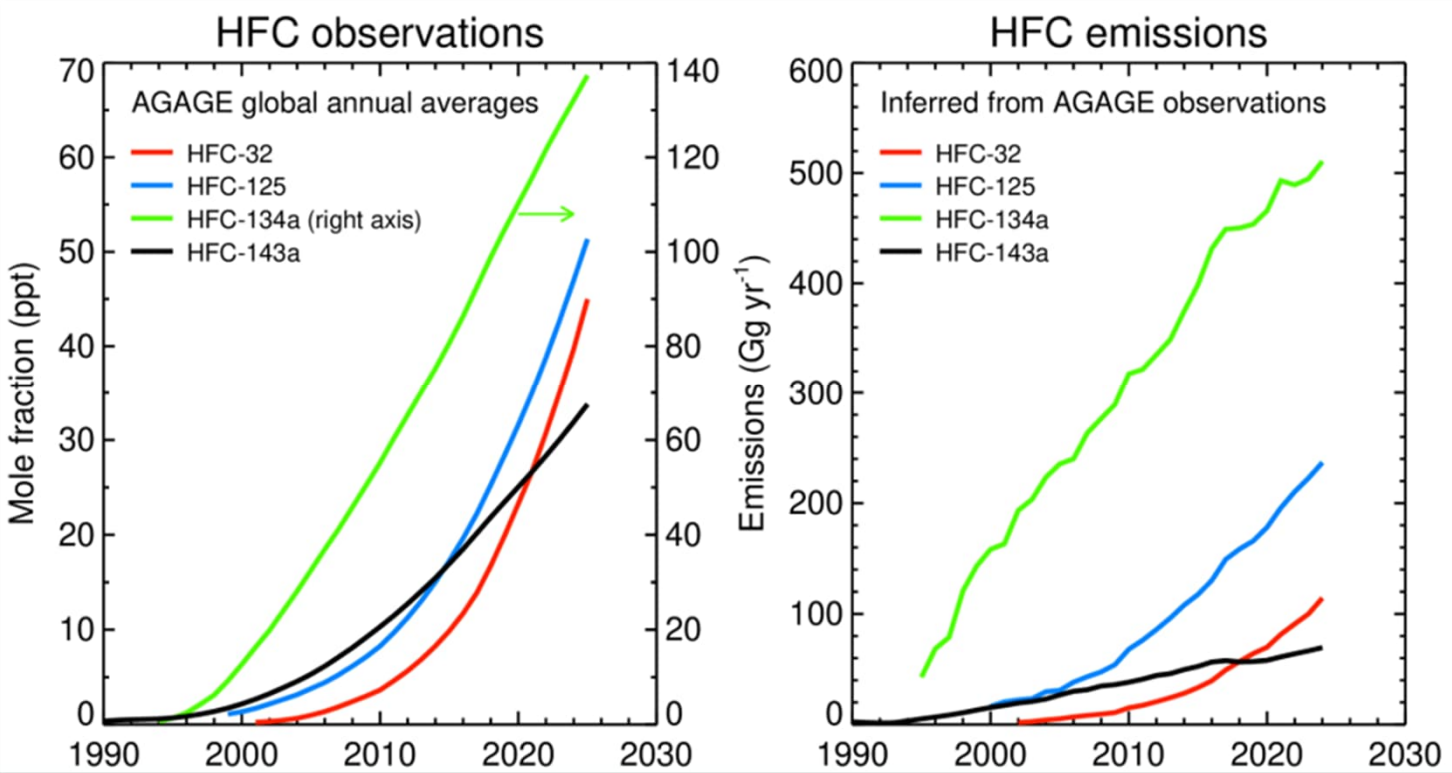
EMISSIONS AS FOUNDATION

Emissions inferred from observations

- Global averages (here =>)
- Regional emissions

Vital for:

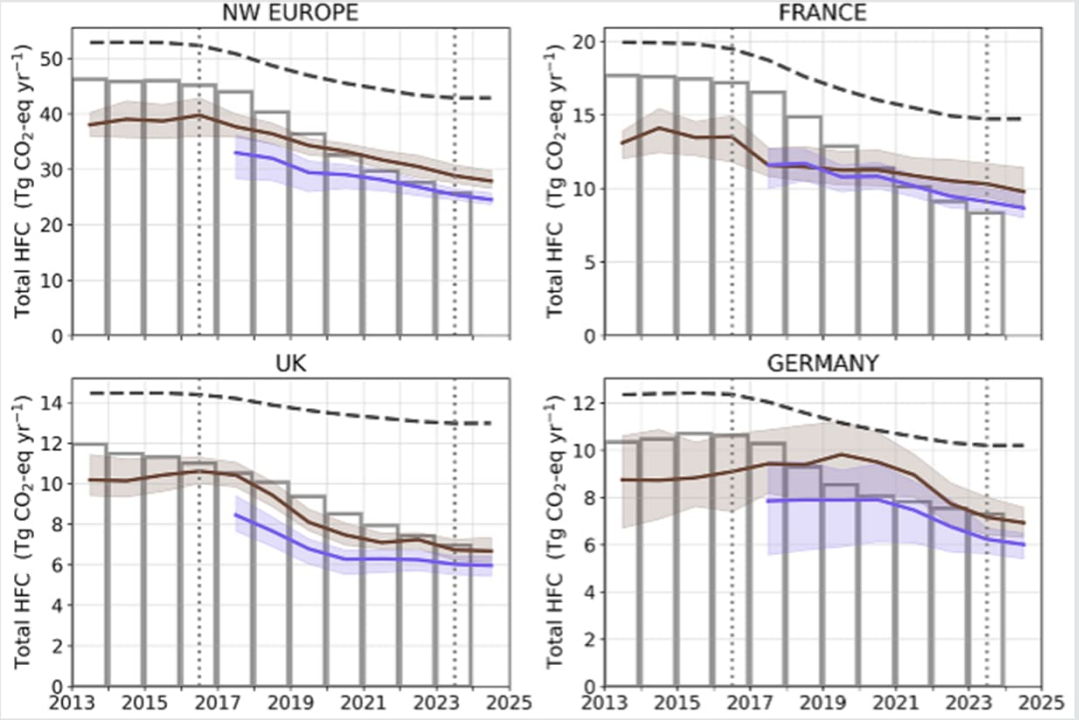
- Verification of historical data
- Constraining projections



AGAGE website (Luke Western, Jens Muhle)

SOME CONCLUSIONS

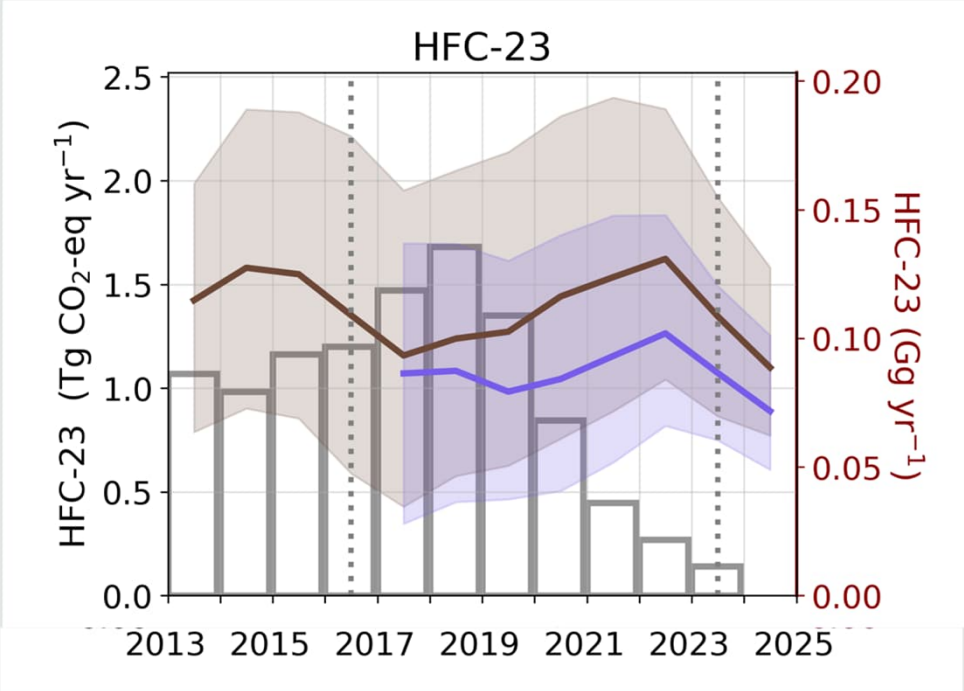
- Regional attribution of emissions requires regional observations
- Europe is working on further expanding its observational network and inverse modelling capabilities.
- Strong collaboration between bottom-up and top-down experts and modelling and experimental groups throughout Europe (and the rest of the world).
- European emissions of high GWP HFCs are declining based on both bottom-up and top-down estimates, showing the success of European F-gas legislation.



De Longueville et al., 2026, https://doi.org/10.5194/acp-26-7647-2026.

SOME CONCLUSIONS

- European emissions of HFC-23 are declining (but not zero).
- A thorough knowledge on past and current emissions (on a regional scale) is vital in improving estimates of future emissions.
- **European scientists are happy to cooperate with colleagues world-wide to share the knowledge and increase capacities.**



De Longueville et al., 2026, https://doi.org/10.5194/acp-26-7647-2026.

LINKS AND CONTACT

- More information on the AGAGE network: https://www-air.larc.nasa.gov/missions/agage/
- More information on EU Project PARIS:: https://horizoneurope-paris.eu/
- More information on EU Project REIGN-MP: contact Anita Ganesan (web page will become available soon)

- Contacts:
- On the observational side: an.engel@iau.uni-Frankfurt.de
- On the top-down modelling: anita.ganesan@bristol.ac.uk
- On the bottom-up inventories: b.gschrey@oekorecherche.de
- On the future scenarios: guus.velders@rivm.nl