



F-gas emissions monitoring through atmospheric observation

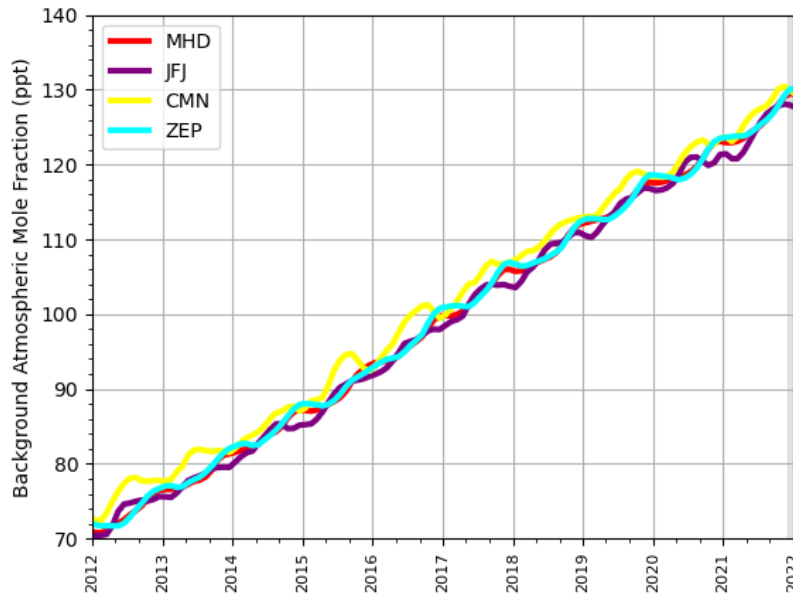
Observations: Jgor Arduini, Tim Arnold, Andreas Engel, Paul Fraser, Arnoud Frumau, Chris Harth, Paul Krummel, Michela Maione, Steve Montzka, Jens Mühle, Simon O'Doherty, Joe Pitt, Chris Rennick, Peter Salameh, Tanja Schuck, Gerry Spain, Kieran Stanley, Martin Vollmer, Ray Weiss, Angelina Wenger, Dickon Young

Modelling: Stephan Henne, Lei Hu, Alistair Manning, Alison Redington, Stefan Reimann, Cathy Trudinger

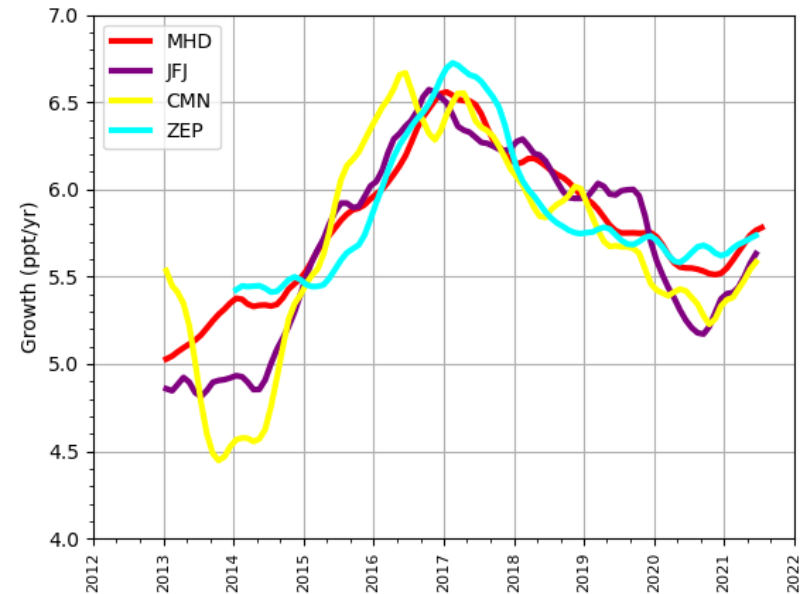
Outline

- Global F-gas concentrations are virtually all rising
- GHG inventory compilers need to estimate national emissions of a wide range of F-gases
- Atmospheric observations can significantly help inventory compilers understand emissions
 - Confirm magnitudes of emission
 - Identify significant emission sources
 - Give an early indication of national emissions

Global Concentration: HFC-134a (mobile air-conditioner)



(a) N.H. Baselines for HFC-134a 2012-2021



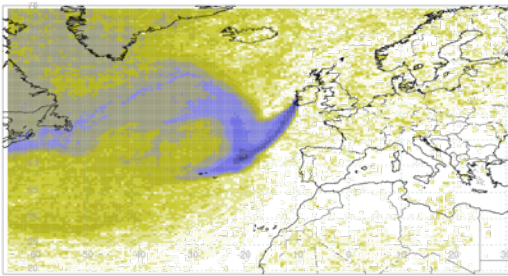
(b) N.H. Baseline Growth for HFC-134a 2012-2021

Consistently growing by more than 5 ppt per year

Inversion Systems

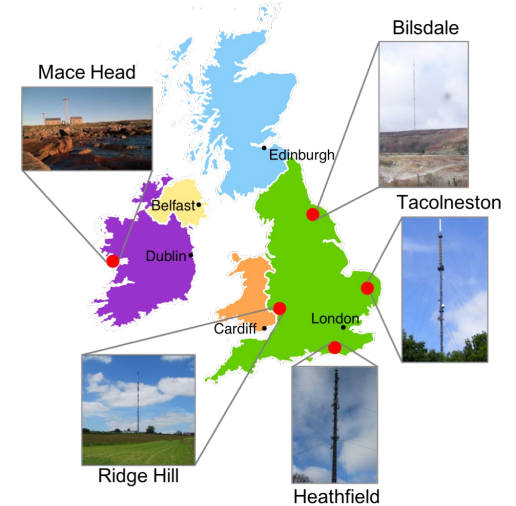
To understand the recent history of the air arriving at measurement stations

Atmospheric Transport Model



Prior Knowledge

Atmospheric Observations of GHG



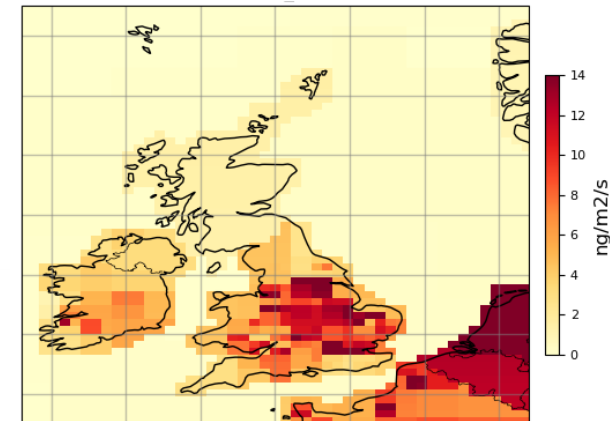
With Estimated Uncertainties

To estimate the surface emissions that best describe the observations

Inverse Modelling System

Estimate of surface emissions

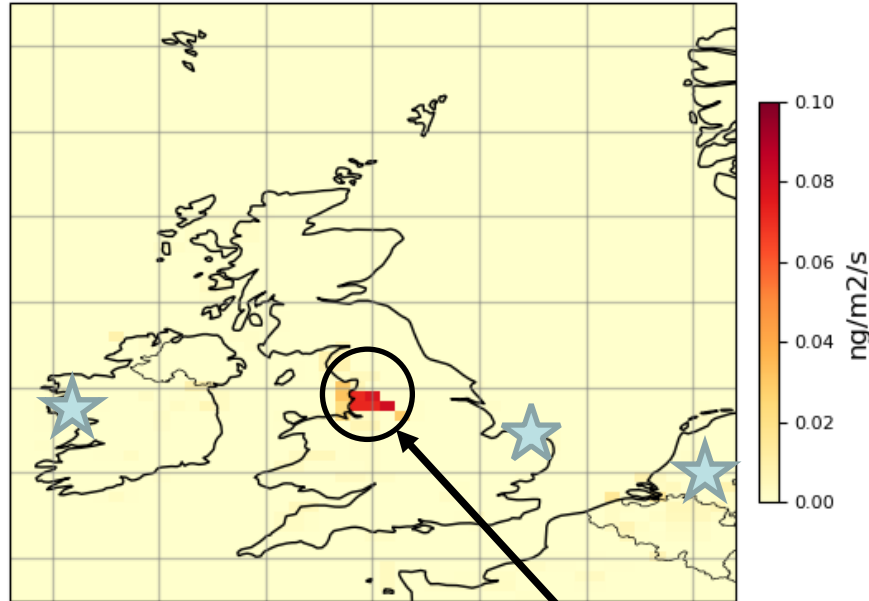
Uncertainties Estimated



Emission Distributions

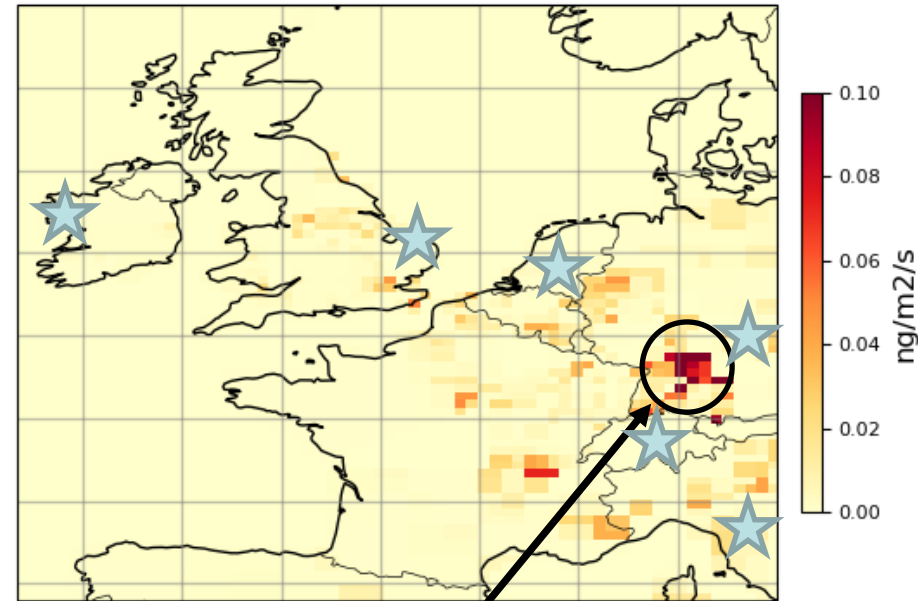
PFC-218

InTEM_2018-2021



SF₆

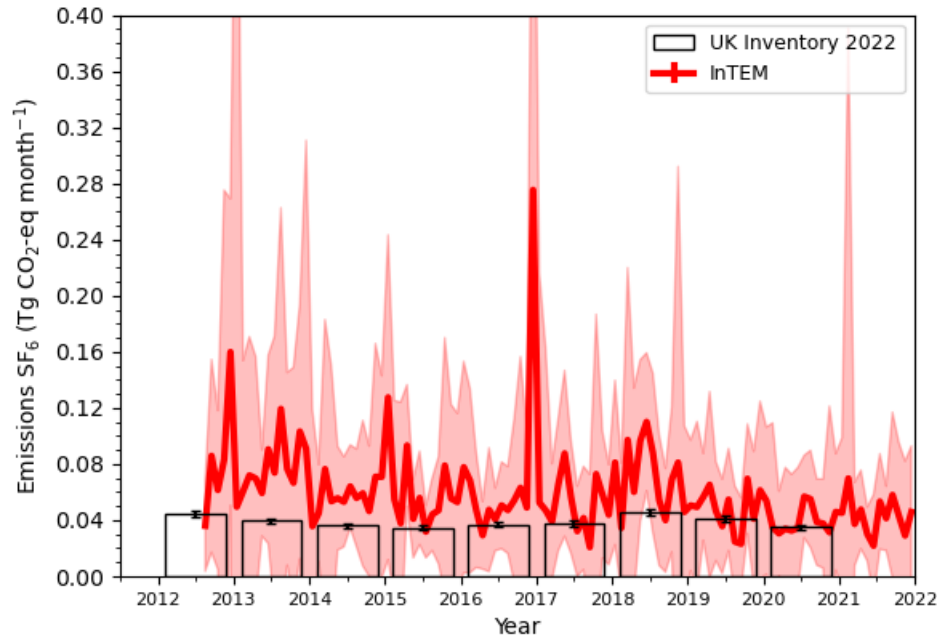
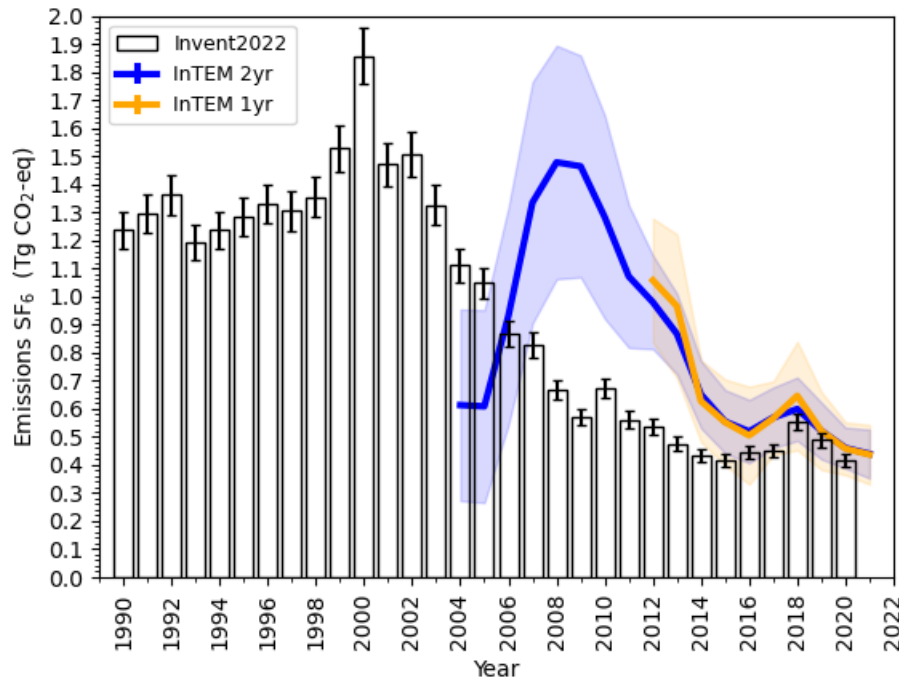
InTEM_2018-2021



Identify significant hot spots of emission

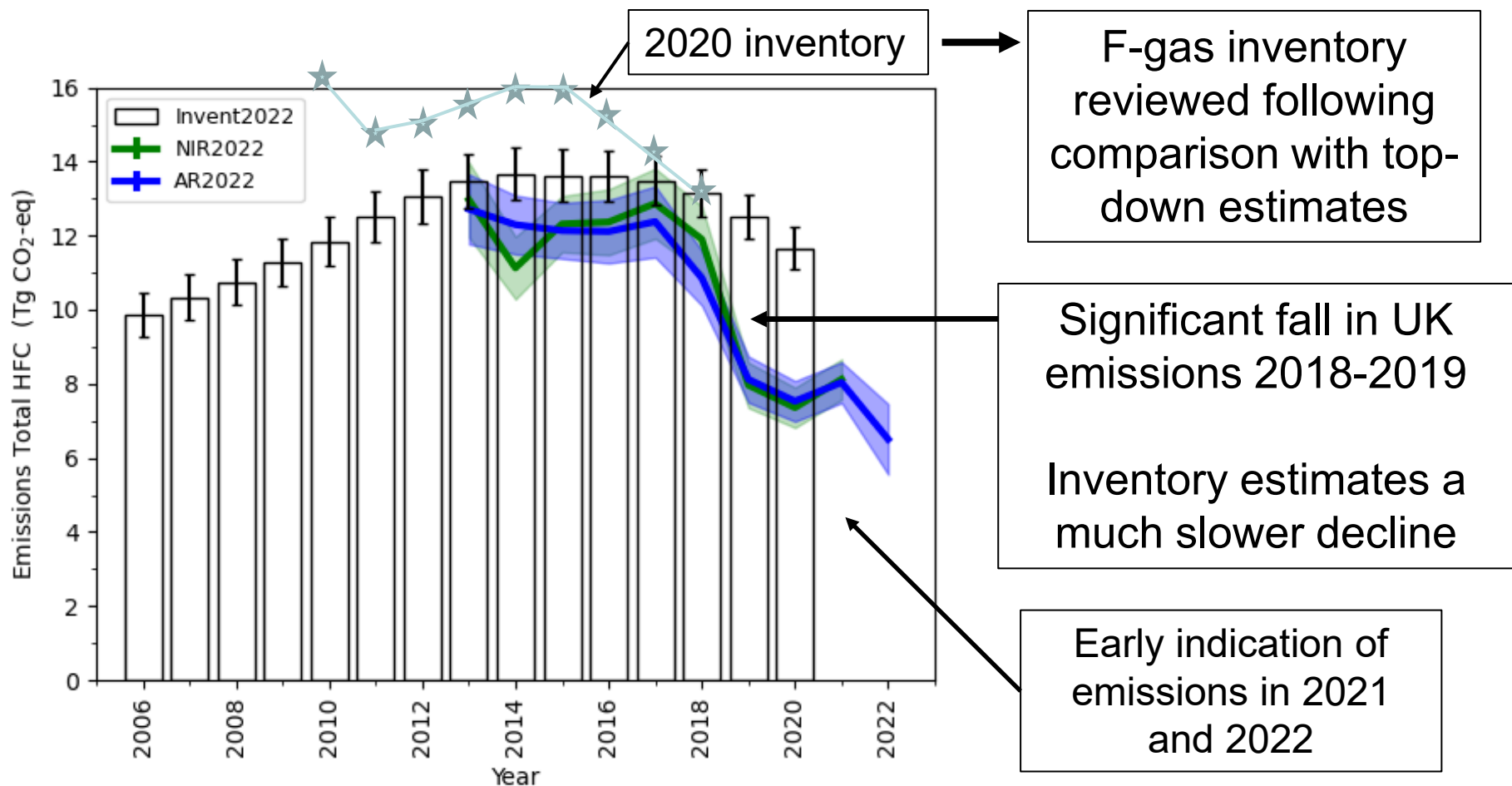
★ F-gas Observation Stations

UK SF₆ emissions



- Significant mis-matches identified
- Good agreement confirms inventory
- High temporal resolution helps understand emissions

Total UK HFC emissions

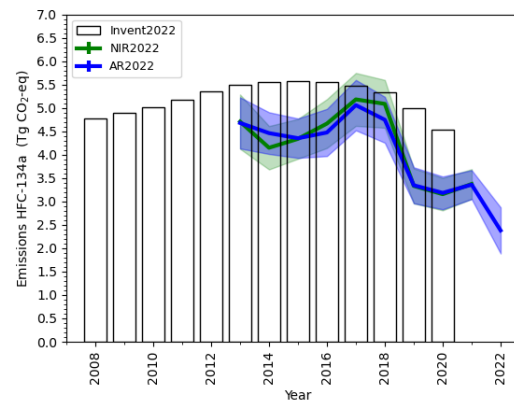


UK HFC emissions by gas

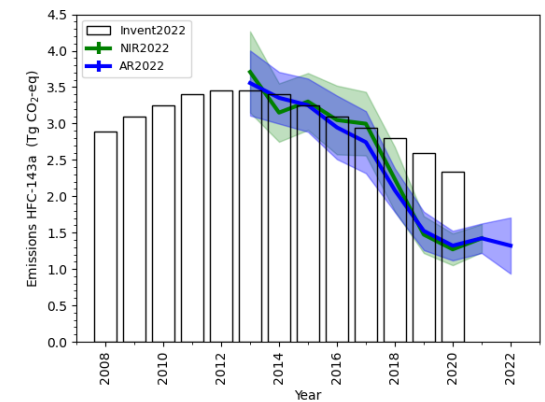
Most significant HFCs

Emissions in Tg CO₂-eq

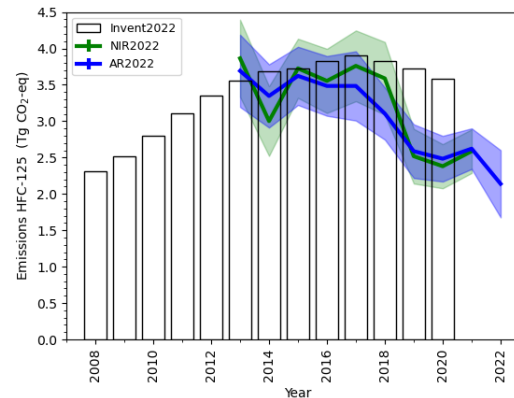
Observed fall in 2018-2019 much greater than reported in Inventory



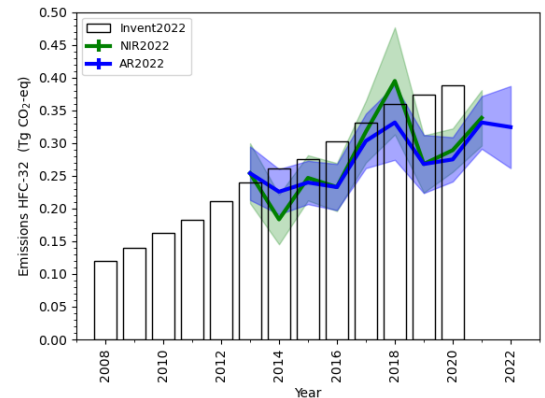
(a) HFC-134a



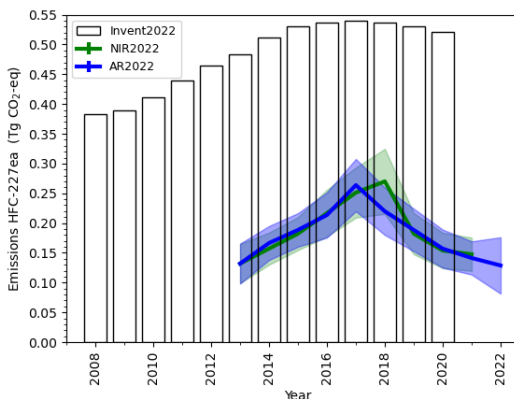
(b) HFC-143a



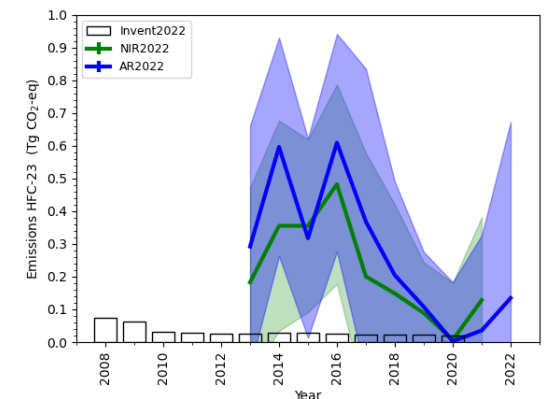
(c) HFC-125



(d) HFC-32

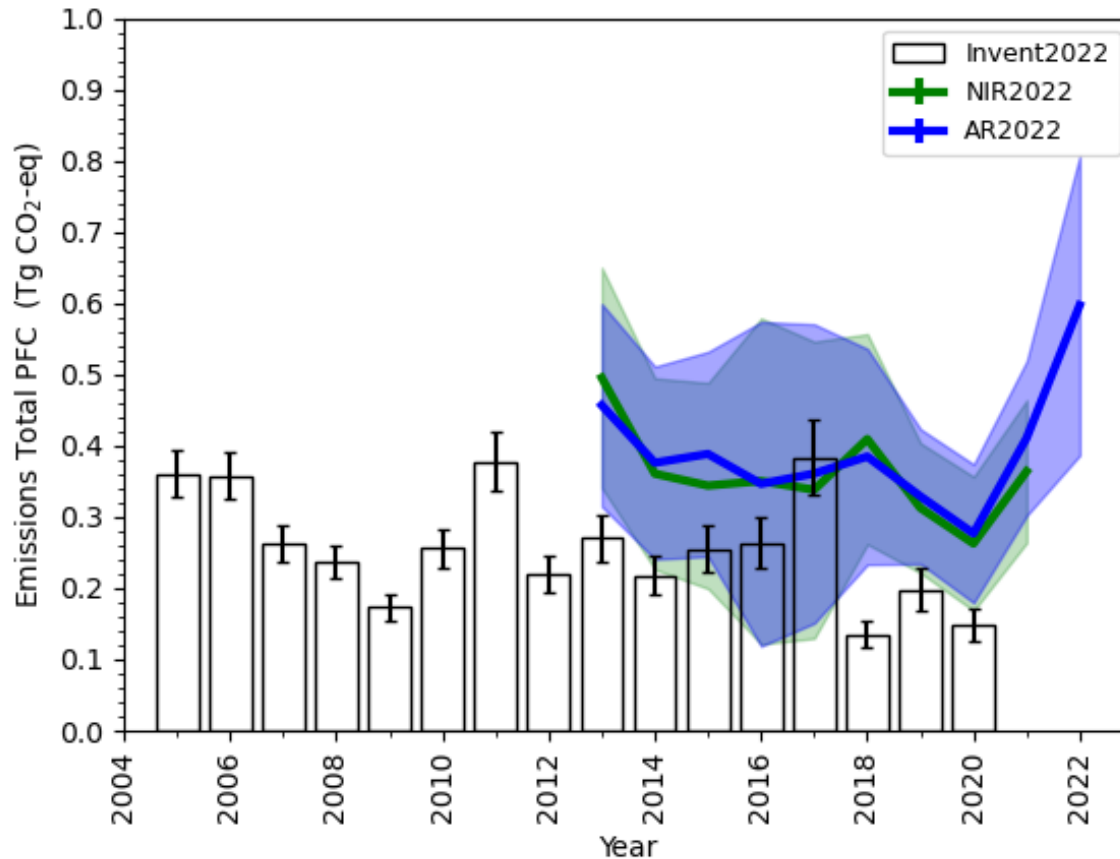


(e) HFC-227ea



(f) HFC-23

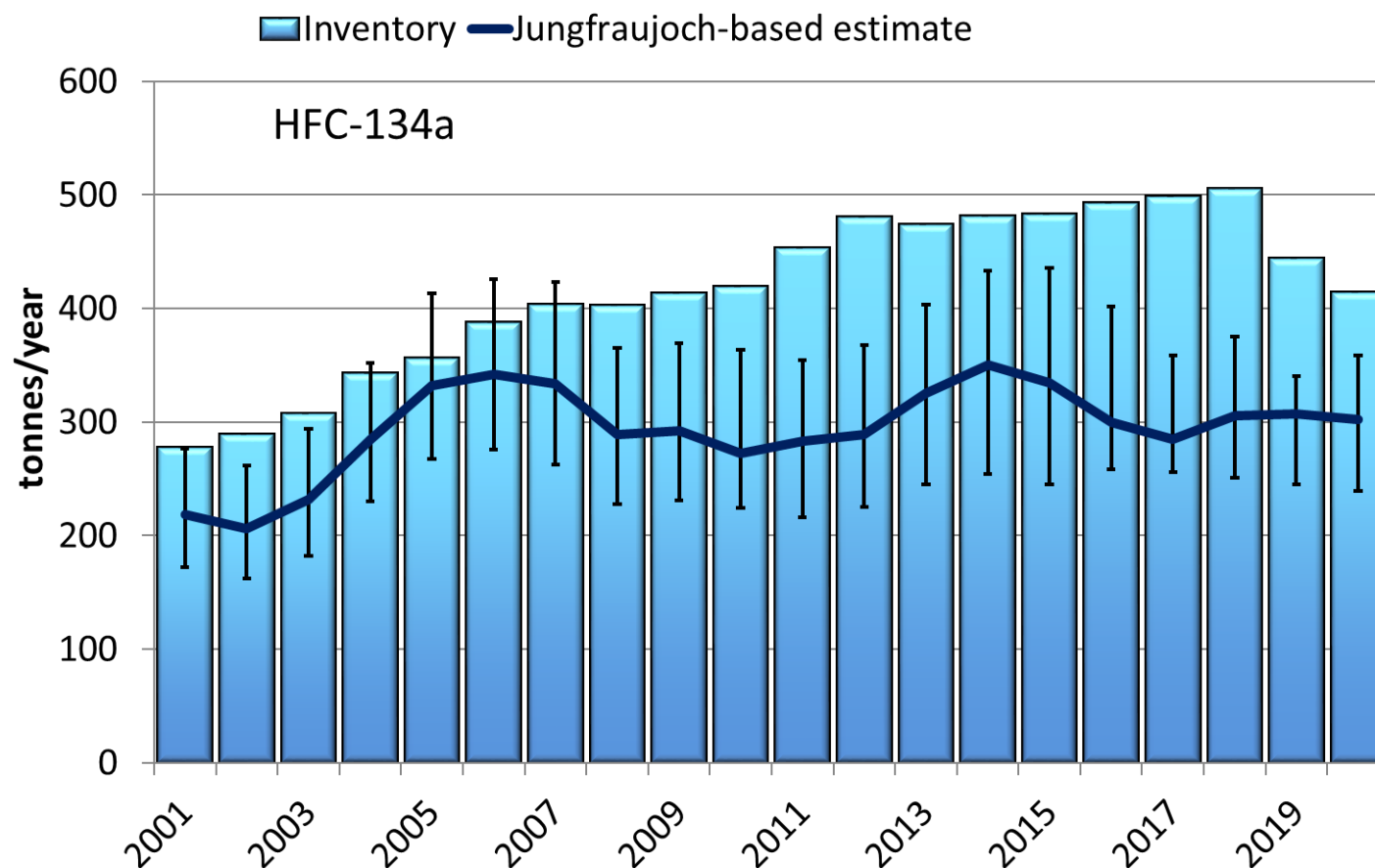
Total UK PFC emissions



Inventory mostly lower than InTEM estimates but uncertainties overlap

Potential sharp rise in 2021 and 2022

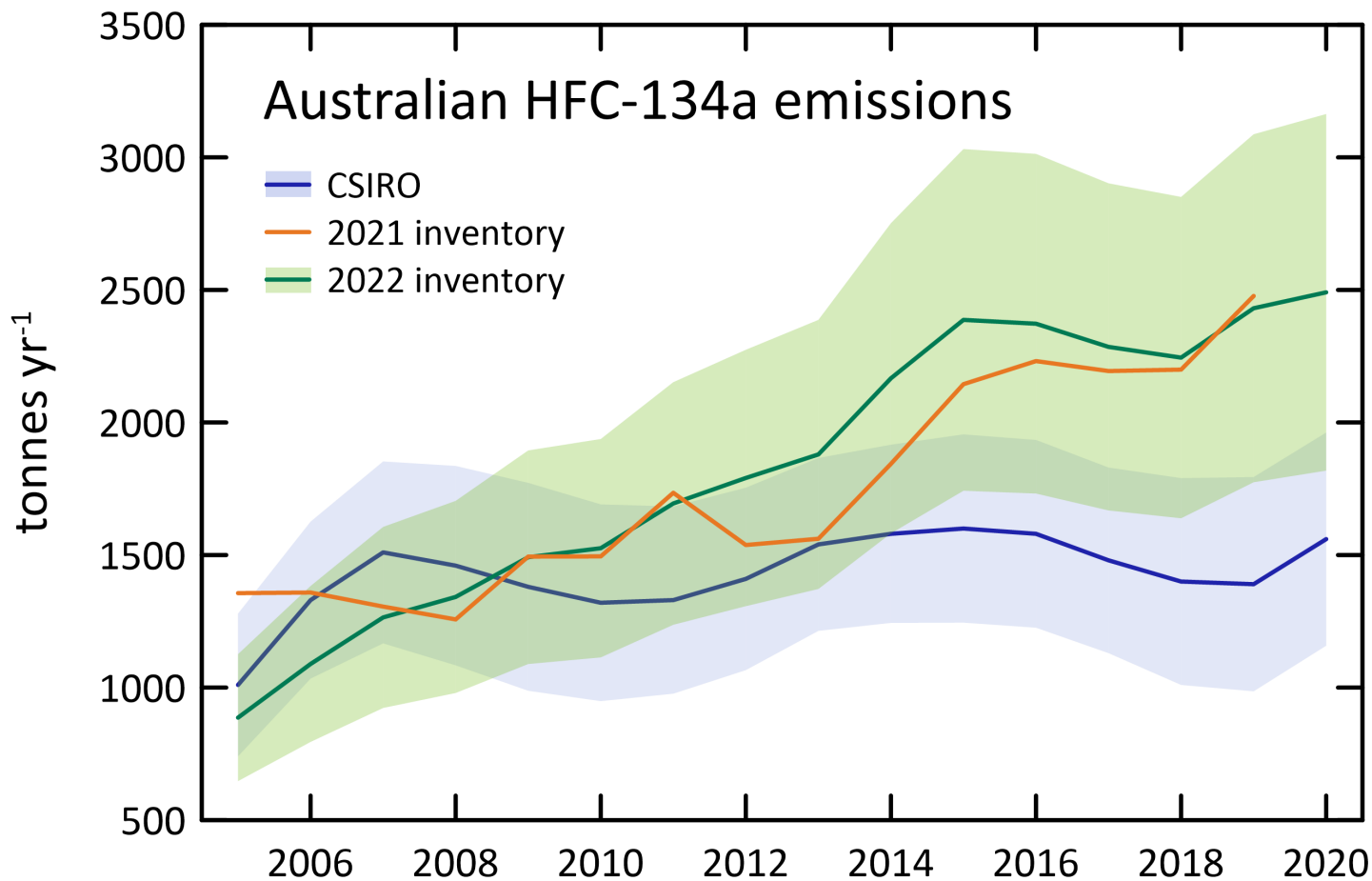
Swiss NIR – HFC-134a example



Empa

Inventory
higher
than top-
down
estimate

Australian NIR – HFC-134a example



CSIRO

Inventory
higher
than top-
down
estimate

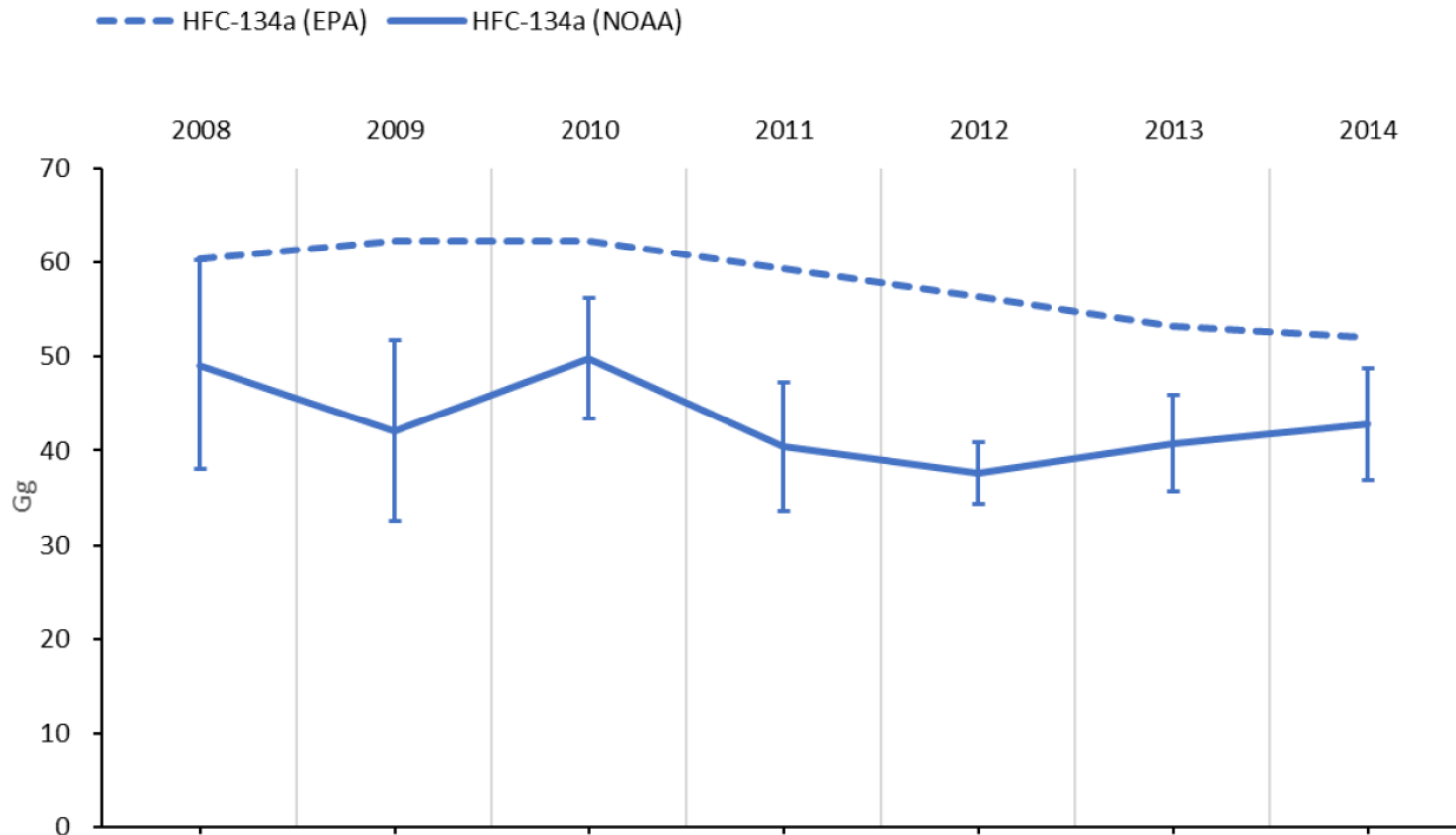


University of
BRISTOL



Met Office

USA NIR – HFC-134a example



NOAA

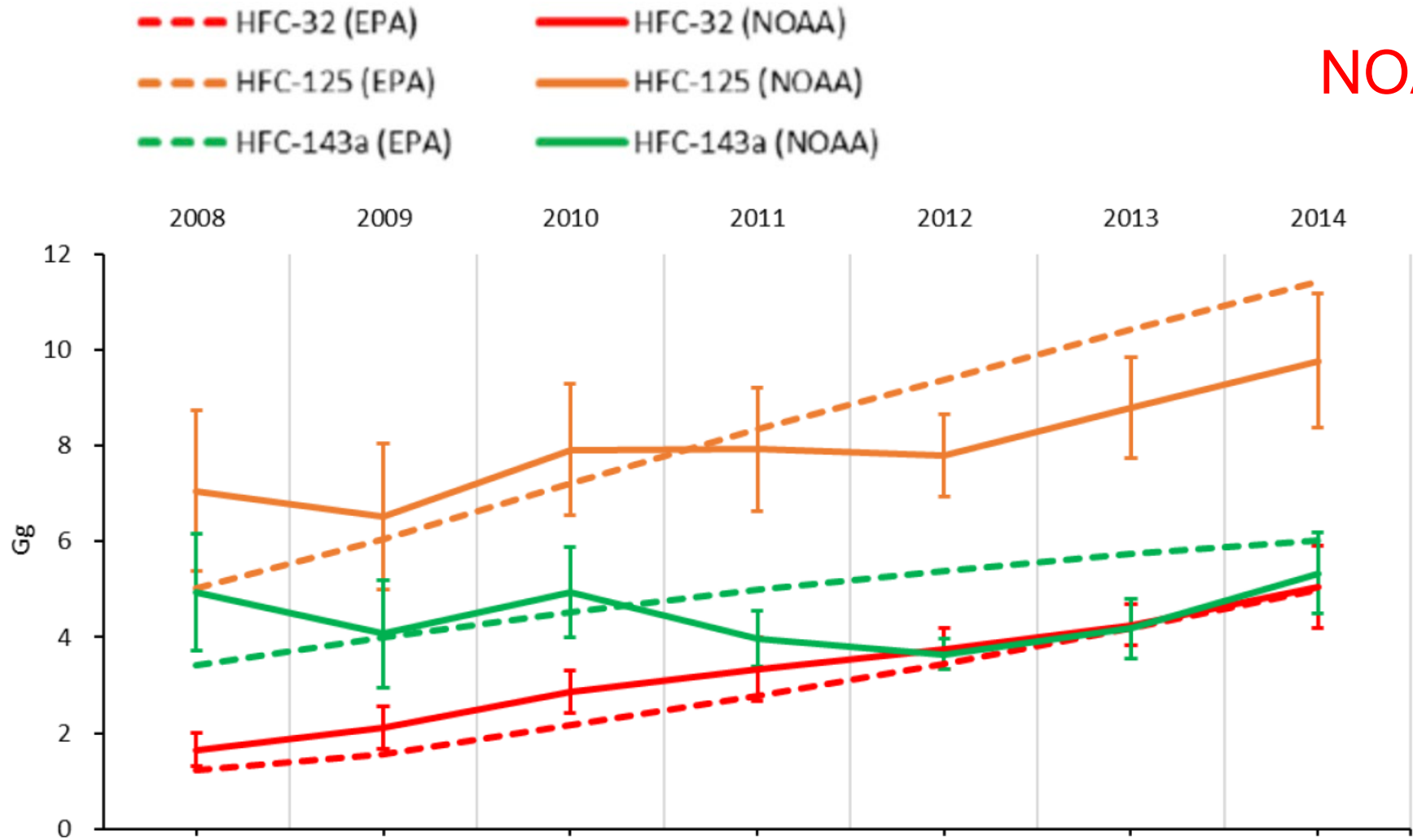
Inventory
higher
than top-
down
estimate

Conclusions

- Global F-gas concentrations are virtually all rising
- Atmospheric observations can significantly help inventory compilers understand emissions
 - Confirm magnitudes of emission
 - Identify significant emission sources
 - Give an early indication of national emissions
- 4 countries currently include 'top-down' inversion estimates from atmospheric observations in their NIRs – others are planning to do so
- New EU project PARIS has major focus on F-gases

USA NIR – HFC examples

NOAA

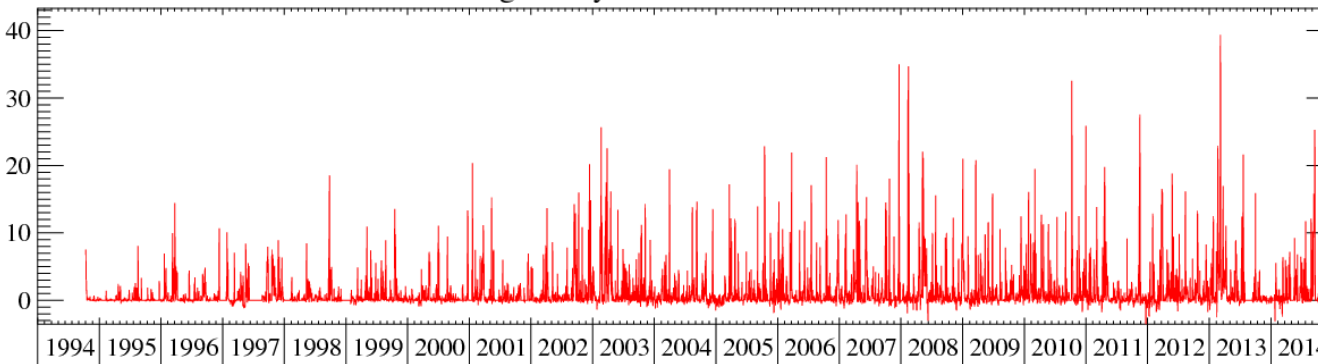


Estimating emissions using Atmospheric Observations

InTEM

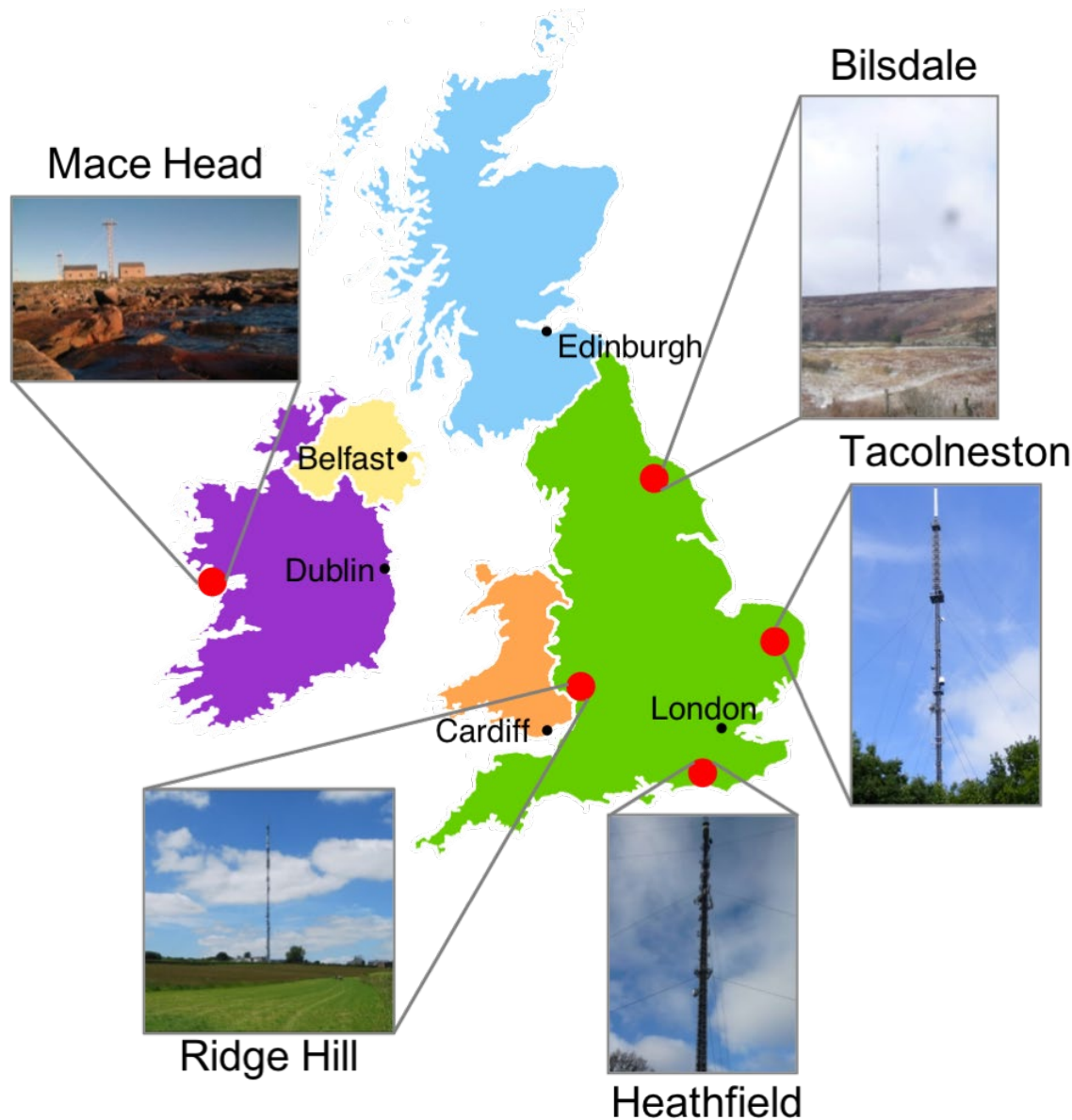
Inversion Technique for Emission Modelling

Average Daily Excursion above Baseline



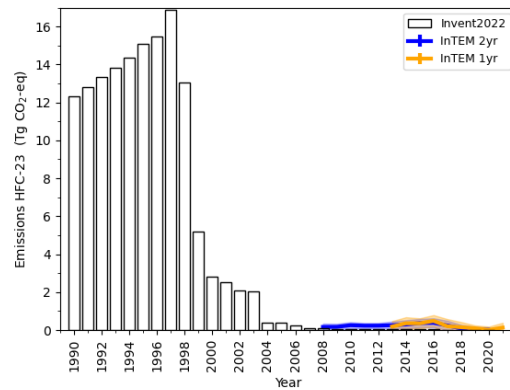
**Generate regional
emission estimates
from 'polluted' (above
baseline) observations.**

UK DECC (Deriving Emissions related to Climate Change) Network of observations

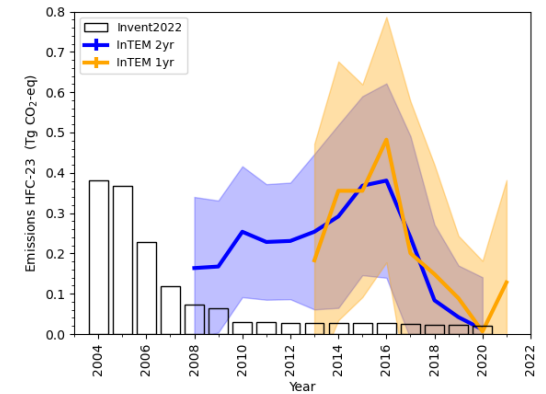


MHD from 1987
TAC & RGL from 2012
HFD & BSD from 2014

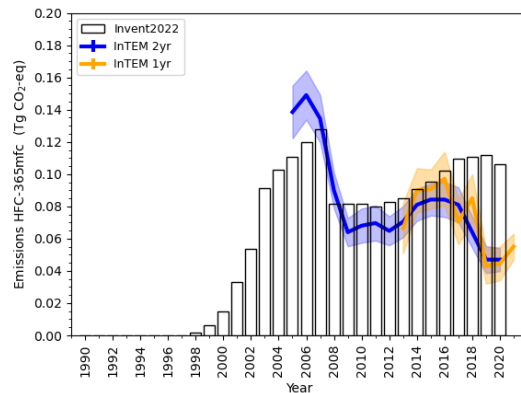
UK HFC emissions



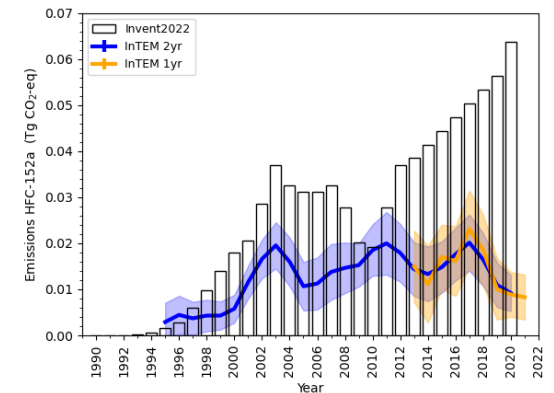
(a) HFC-23



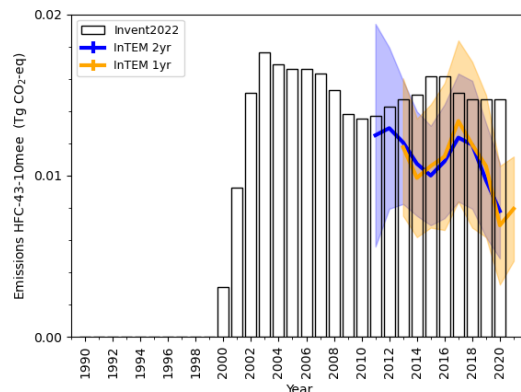
(b) HFC-23



(c) HFC-365mfc



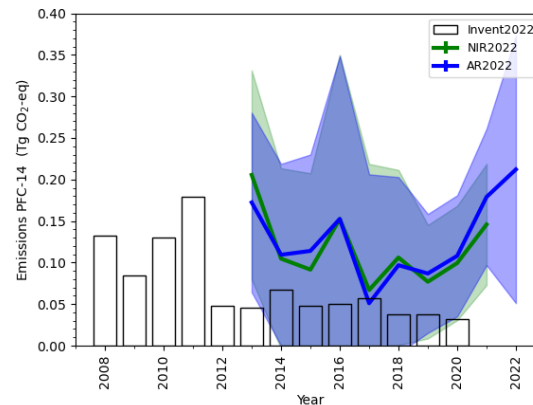
(d) HFC-152a



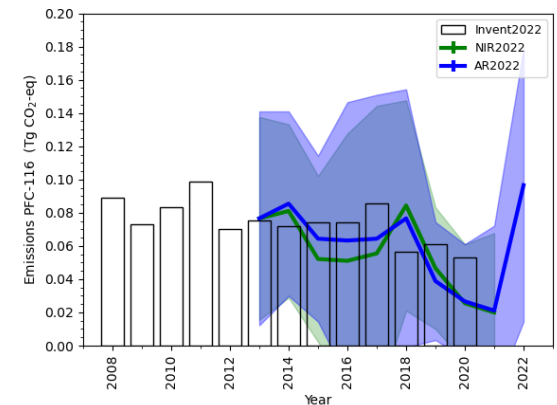
(e) HFC-43-10mee

UK PFC emissions by gas

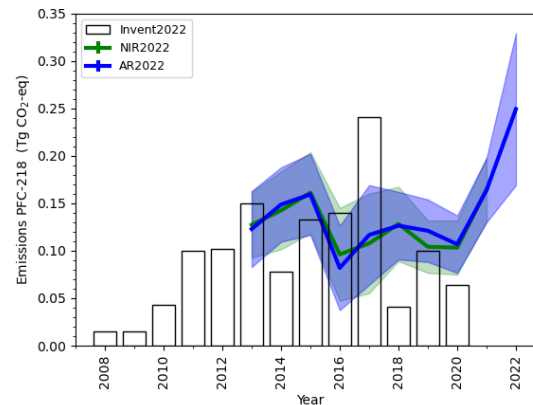
Emissions in Tg CO₂-eq



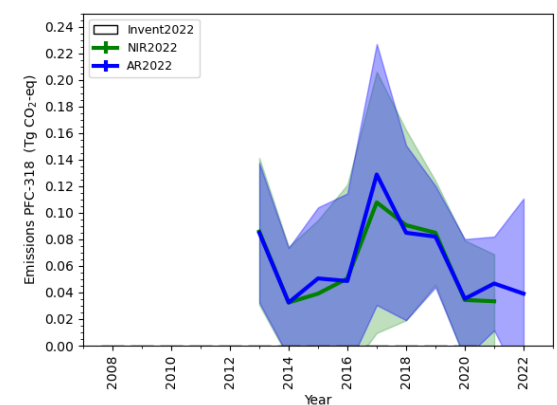
(a) PFC-14



(b) PFC-116



(c) PFC-218



(d) PFC-318

InTEM (Inversion Technique for Emission Modelling)

Uncertainty Matrices

$$C = (M'e' - y)^T R^{-1} (M'e' - y) + (e' - e'_p)^T B^{-1} (e' - e'_p)$$

$$M' = M [t \times n] \mid P [t \times p] \mid F [t \times f]$$

M = Dilution matrix
P = Baseline Adj + Outer Region
F = Location Bias

$$e' = e [n] \mid b [p] \mid q [f]$$

e = Surface Emissions

$$y [t]$$

Times series observations

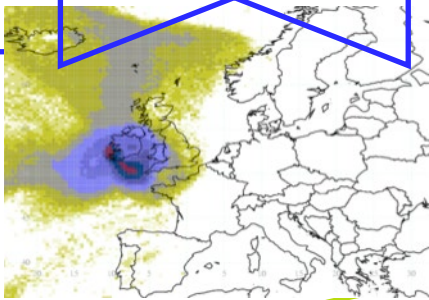
$$e'_p = e_p \mid b_p \mid q_p$$

e_p = Prior Emission

Assume UK prior
Very uncertain

B [n' x n'] : Prior uncertainty

R [t x t] : Model-Obs uncertainty



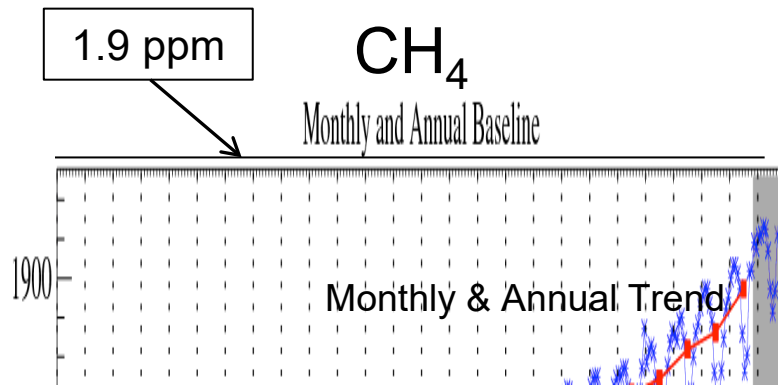
- Air history maps from transport model
- Time-series of relative contributions of each surface source to each observation

Uncertainty Analysis Matrix

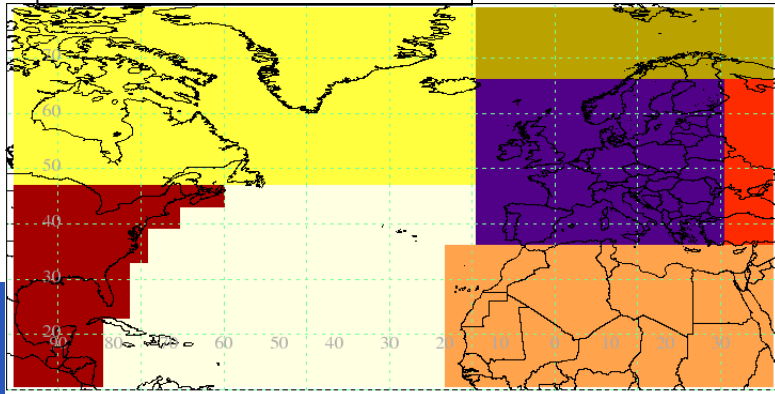
$$A = (M'^T R^{-1} M' + B^{-1})^{-1}$$

Baseline Prior adjusted within InTEM

- Depending on where air enters regional domain
- Each station has unique baseline



Now also solve for
6 Outer Regions



Baseline
modified
based on
where the
air comes
from

