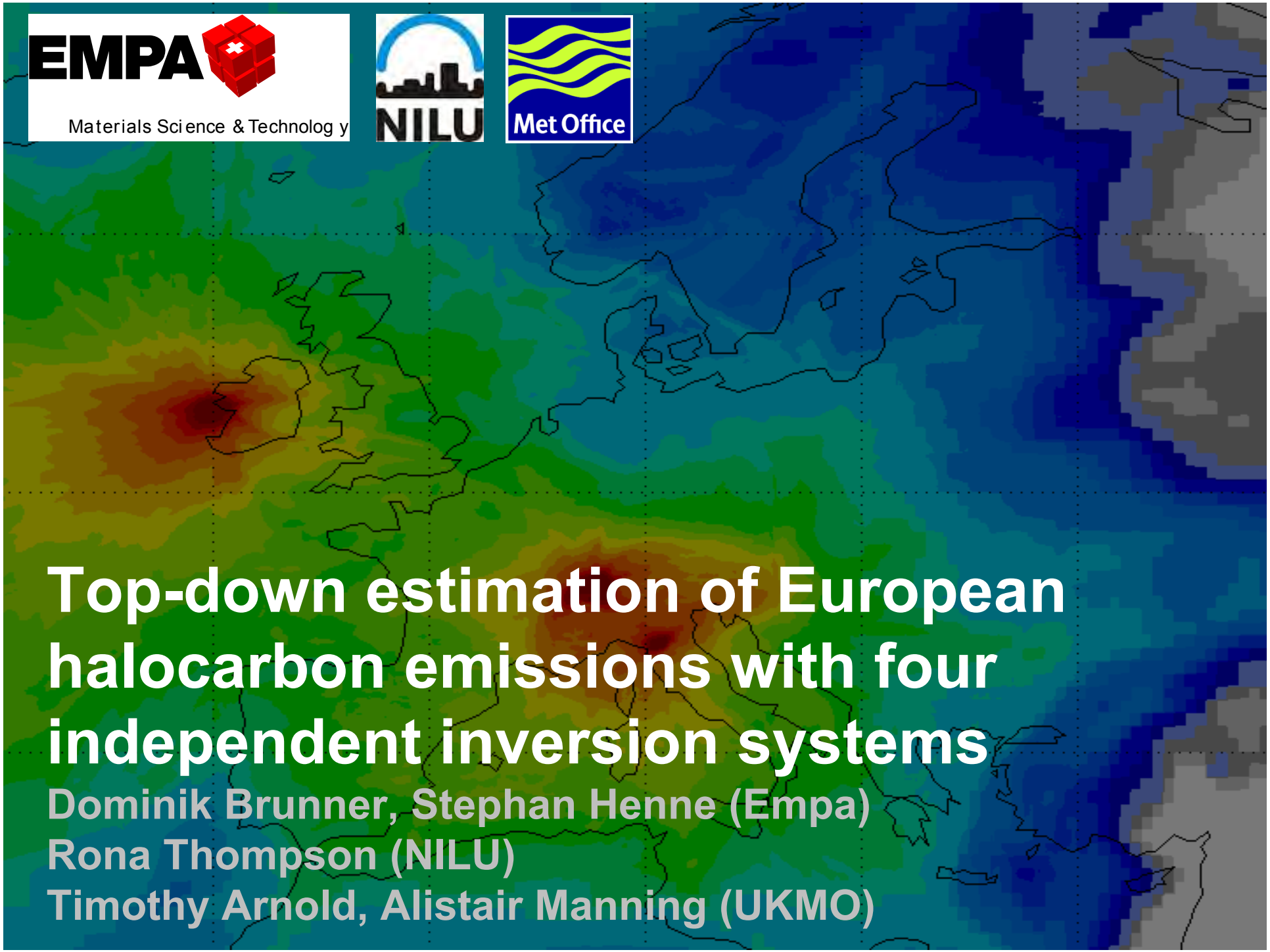
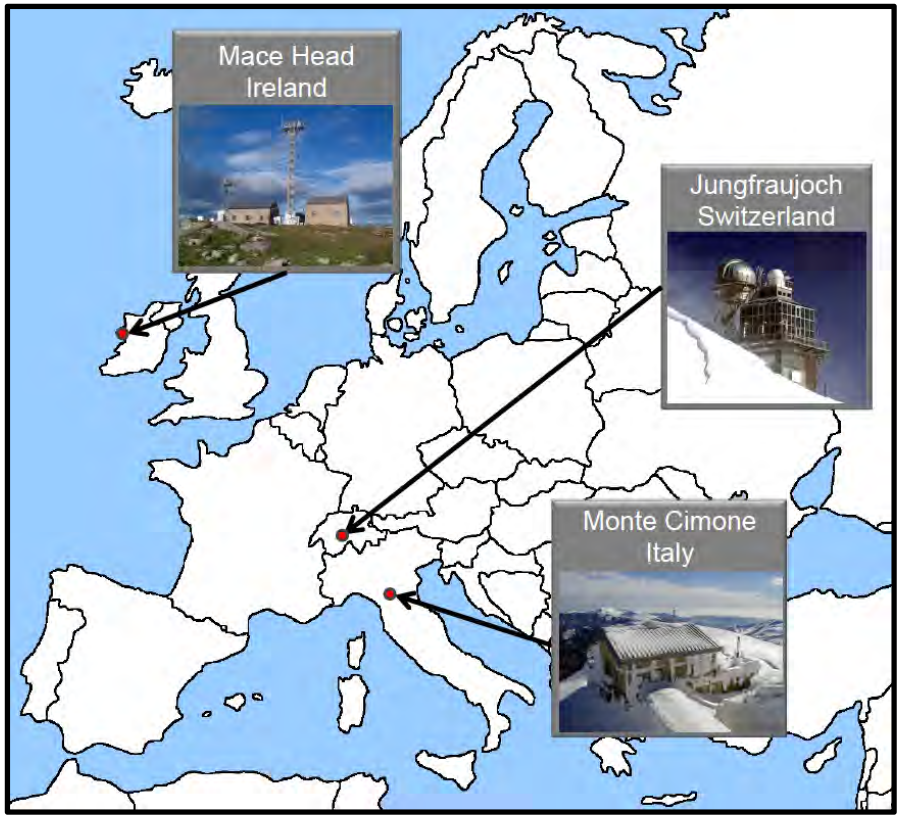


Top-down estimation of European halocarbon emissions with four independent inversion systems

Dominik Brunner, Stephan Henne (Empa)
Rona Thompson (NILU)
Timothy Arnold, Alistair Manning (UKMO)

Halocarbon measurements in Europe



Montreal Protocol Species

- CFCs: Chlorofluorocarbons
- Halones: (containing bromine)
- Halogenated solvents and CH_3Br
- HCFCs: Hydrochlorofluorocarbons

Kyoto Protocol Species

- HFCs: Hydrofluorocarbons
- PFCs: Perfluorocarbons
- SF_6

Others

$C_2 - C_7$ hydrocarbons

CH_3Cl	***CH_3I***	***$CHCl_3$***	***CH_2Cl_2***
CH_2Br_2	***$CHBrCl_2$***	***CH_2BrCl***	***$CHBr_3$***
SO_2F_2	*SF_5CF_3*	*COS*	
HFC-1234ze(E)		*HFC-1234yf*	

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Halocarbon and SF_6 inversions in INGOS

Objectives

- To provide improved top-down estimates of European halocarbon emissions
- To compare the results of four well established inversion systems
- To better quantify uncertainties beyond analytical (mathematical) uncertainties

Setup of model experiments

- Observations from Jungfraujoch, Mace Head & Monte Cimone
- Joint modeling protocol:
  - Common set of observations including uncertainty
  - Common a priori emissions
  - Common output: gridded output, country estimates, time series
- Not fixed: a priori and model-data uncertainties, background treatment

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Inverse modeling of halocarbons and SF_6

Lagrangian transport model based inversion systems:

Group	Model	Method	Meteorology	References
Empa	FLEXPART	extKF	ECMWF analyses 0.2° x 0.2°, 3hrly	*Brunner et al., 2012*
Empa2	FLEXPART	Bayesian	ECMWF analyses 0.2° x 0.2°, 3hrly	*Stohl et al. 2009; Vollmer et al. 2009*
NILU	FLEXPART	Bayesian	ECMWF analyses 0.2° x 0.2°, 3hrly	*Thompson et al., 2014*
UKMO	NAME	Bayesian	UKMO analyses 25 x 25 km^2, 3hrly	*Manning et al., 2011*

Joint experiments:

ID	Trace gas	A priori inventory	Time period
H11v3	**HFC-125**	EDGARv4.2 2008	2011
H12v3	**HFC-134a**	EDGARv4.2 2008	2011
H13v3	**SF_6**	EDGARv4.2 2008	2011
H14v3	HFC-125	constant a priori	2011

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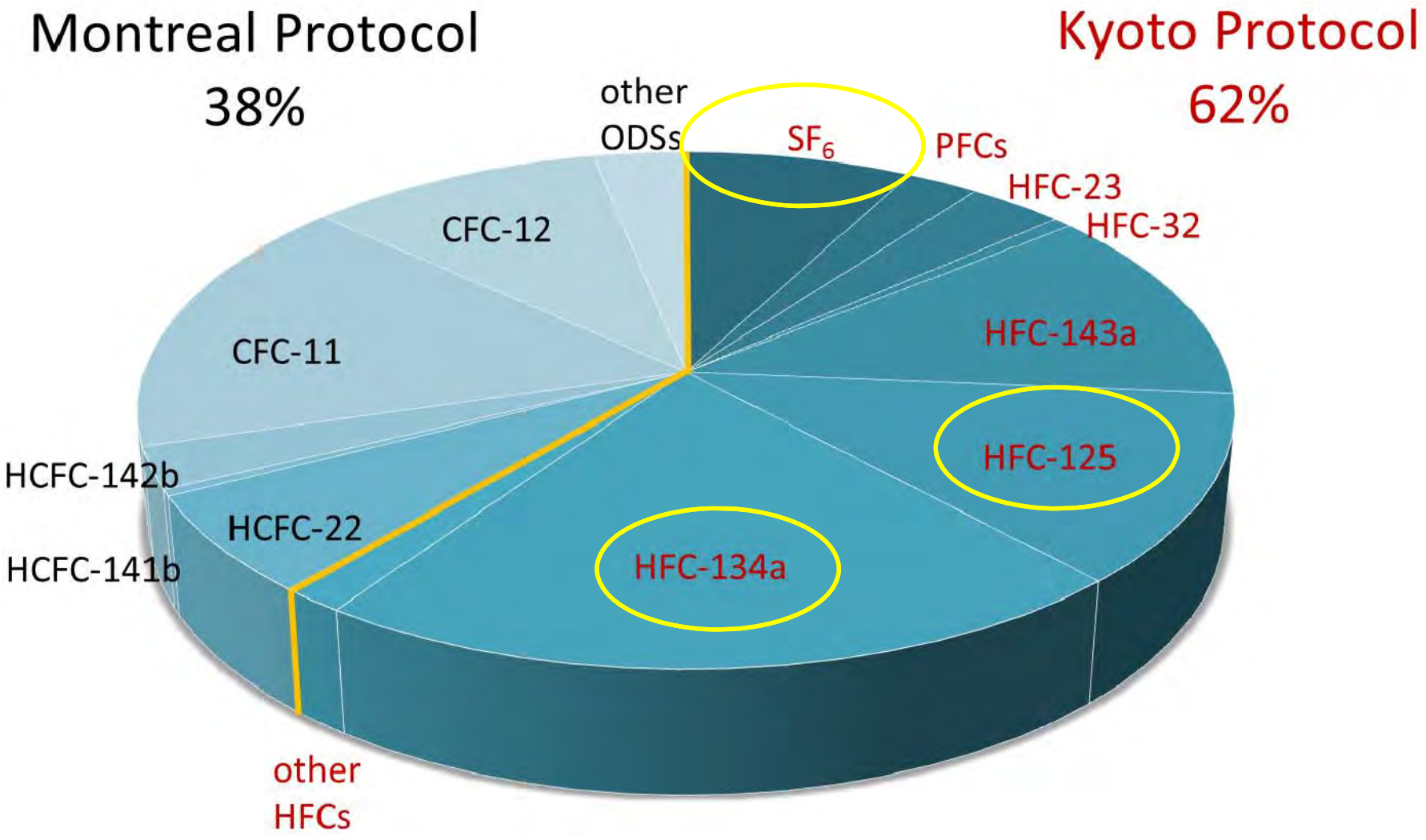
Emissions in Switzerland in CO_2-equivalents



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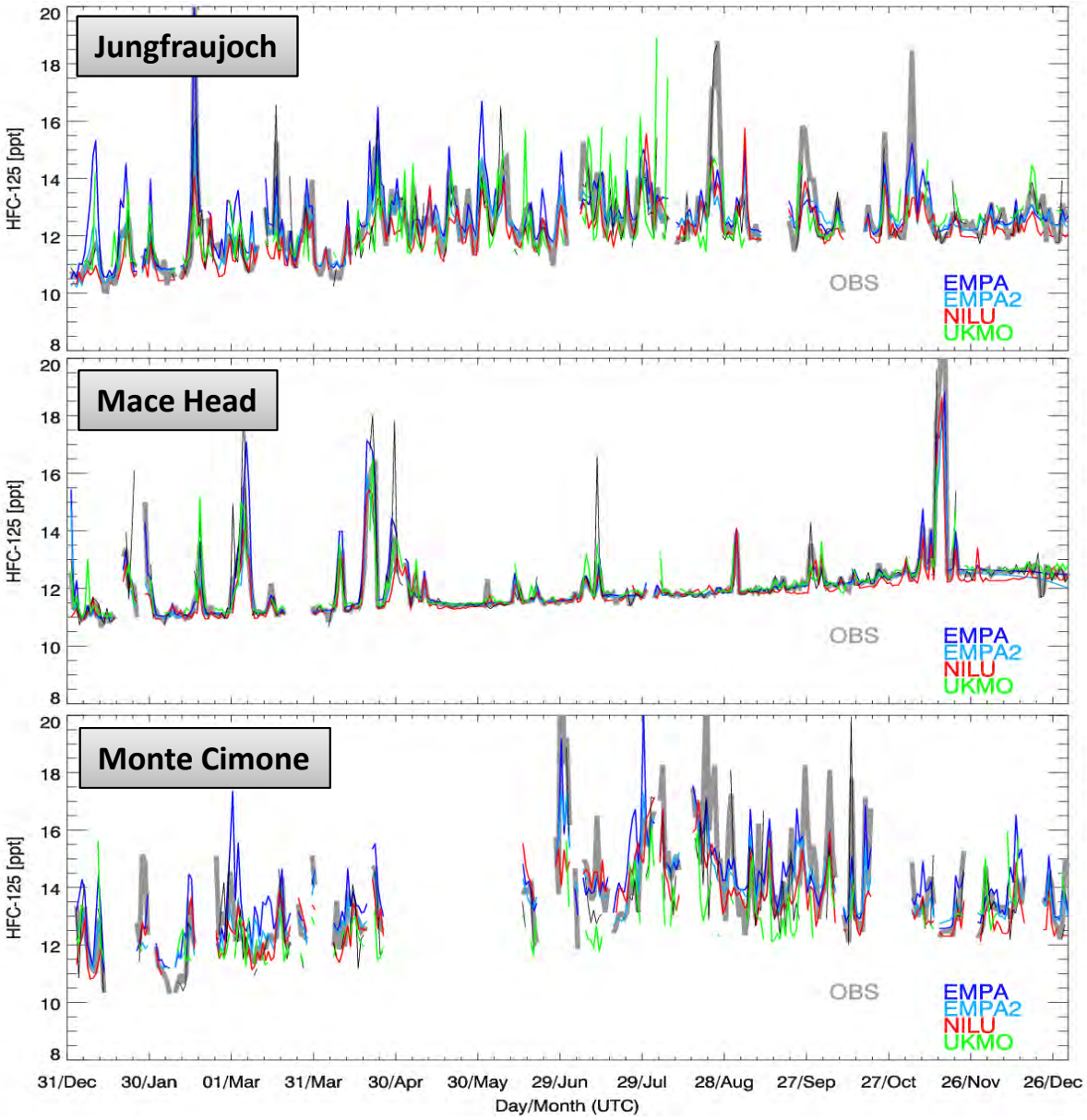
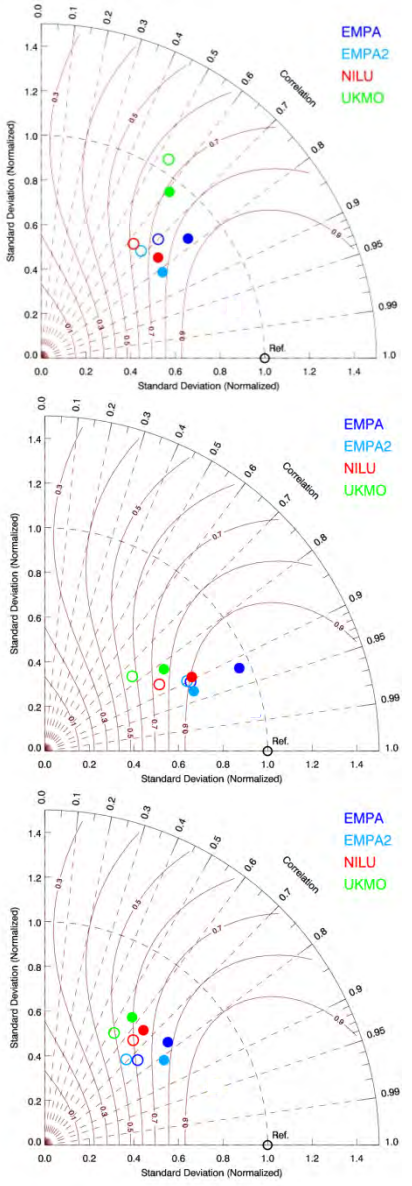
HFC-125: a posteriori time series





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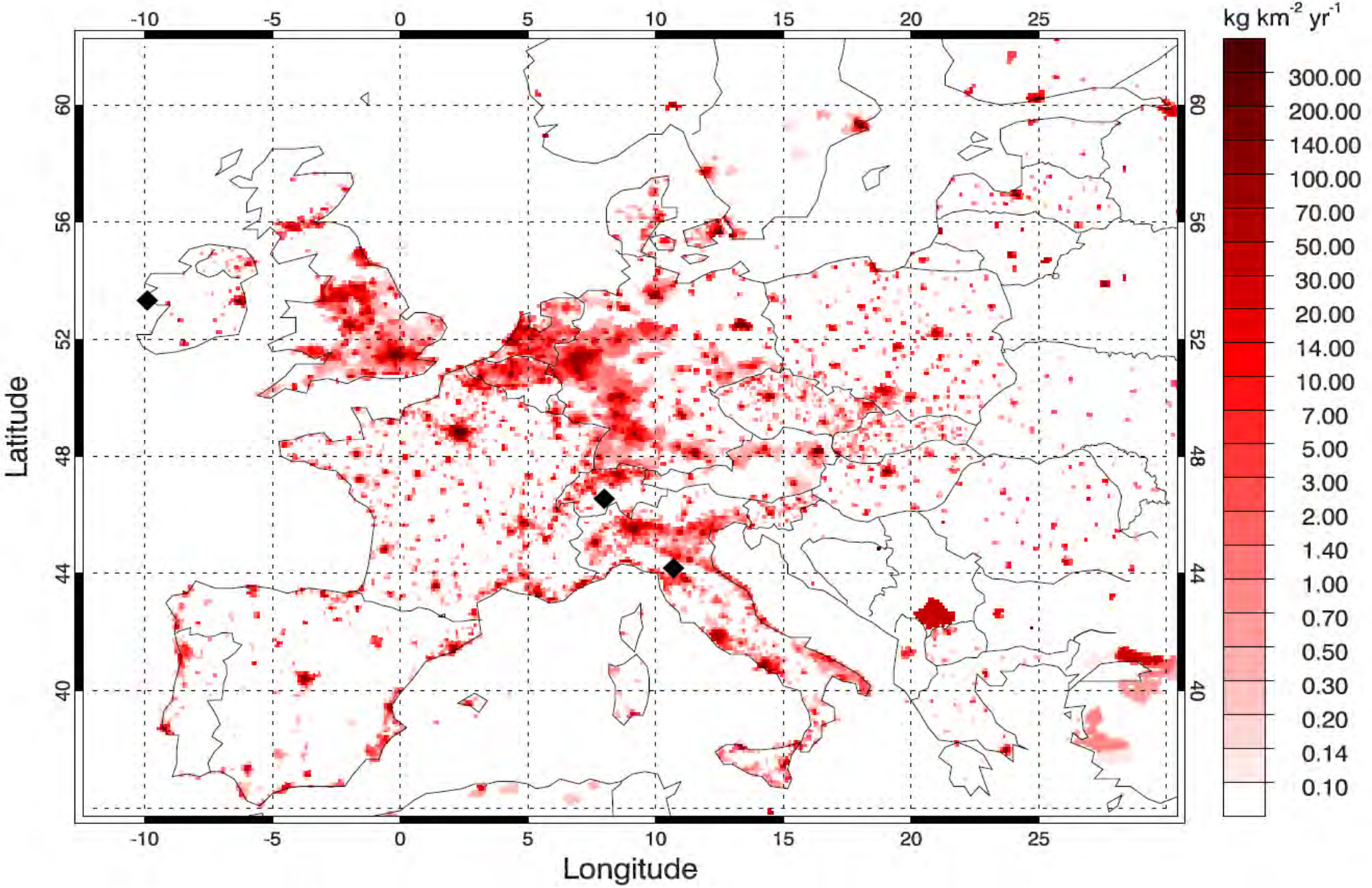
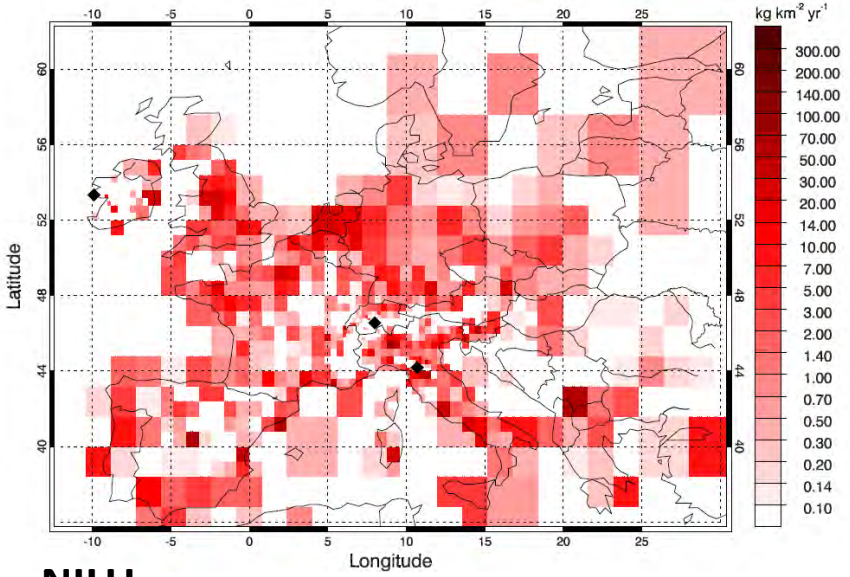
HFC-125: A priori emissions (EDGAR v42)

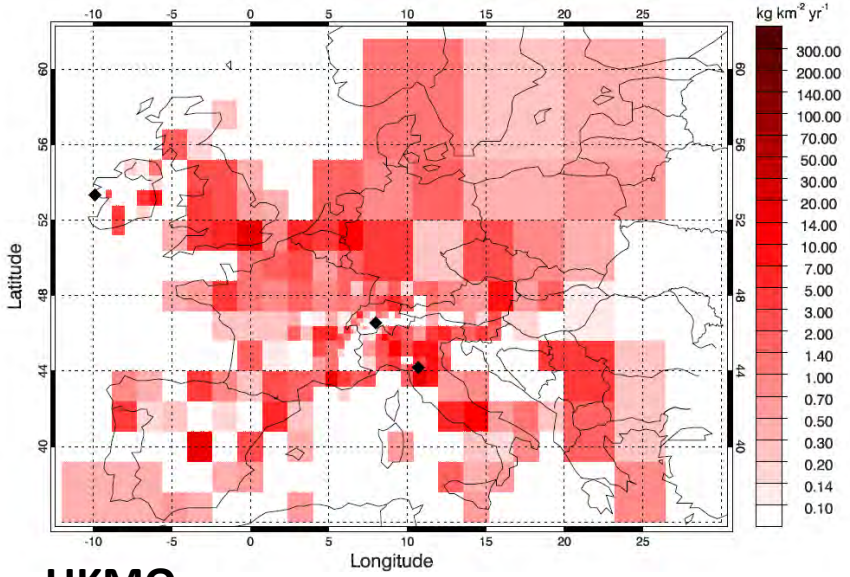


HFC-125: A posteriori emissions

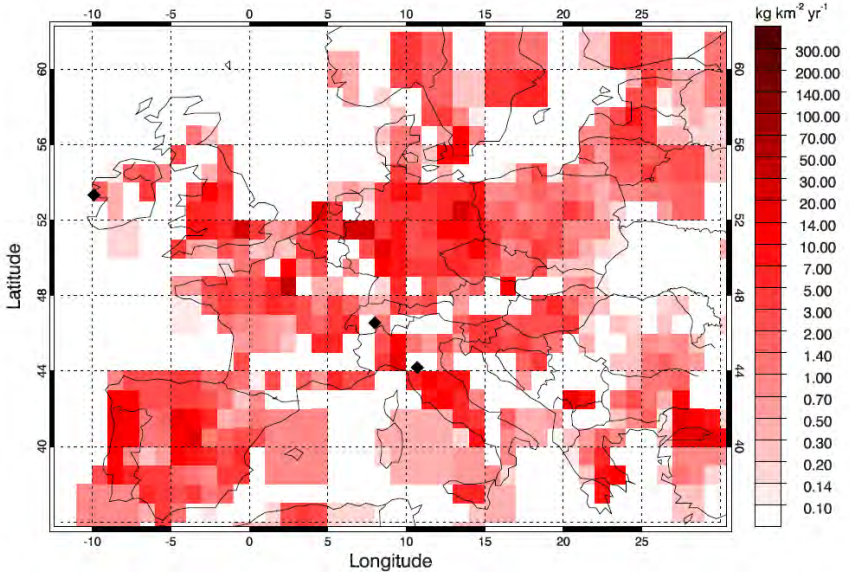
Empa



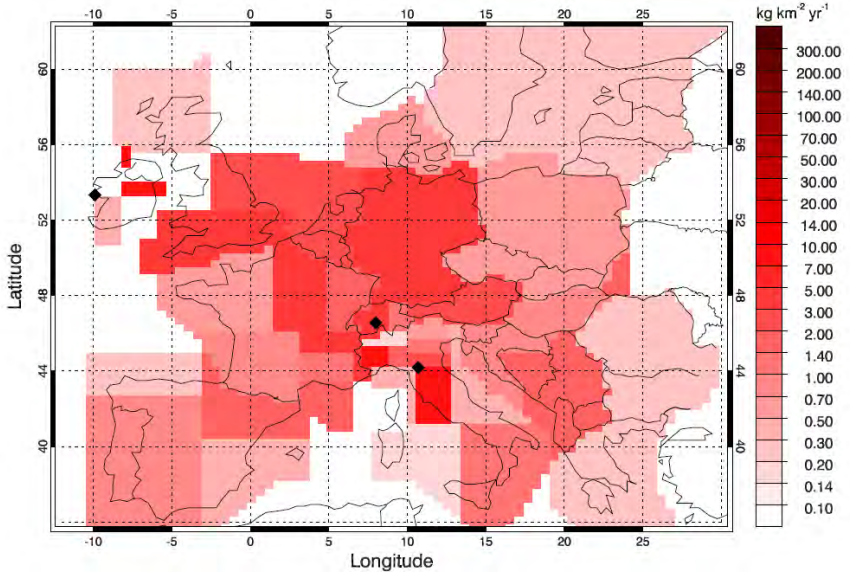
Empa2



NILU

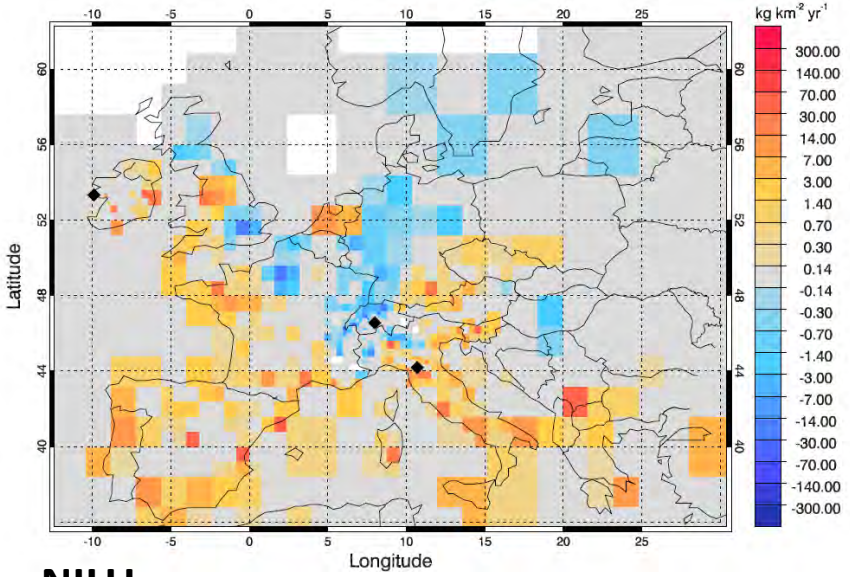


UKMO

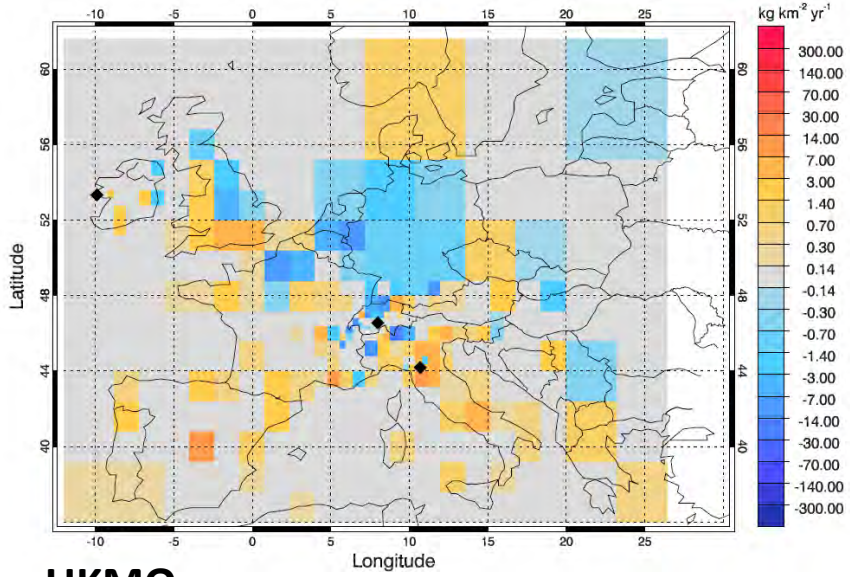


HFC-125: Difference a posteriori – a priori

Empa



Empa2



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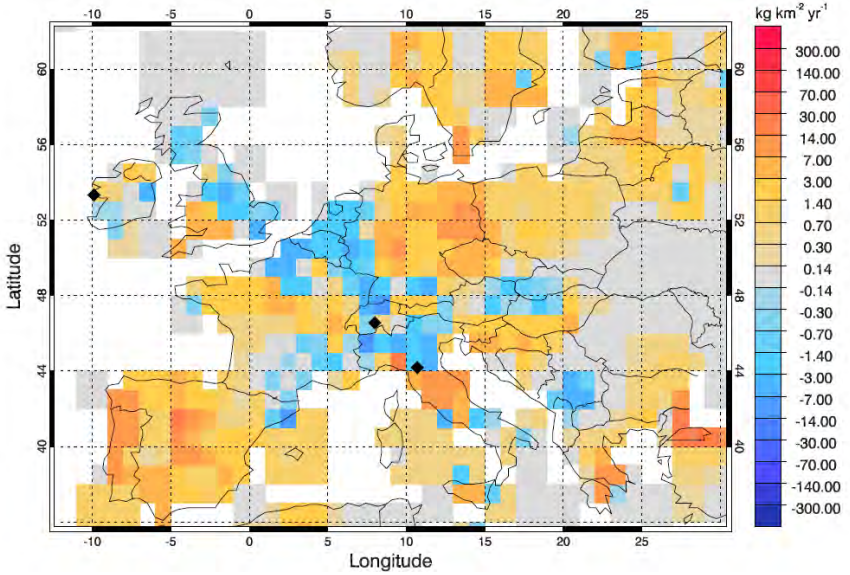

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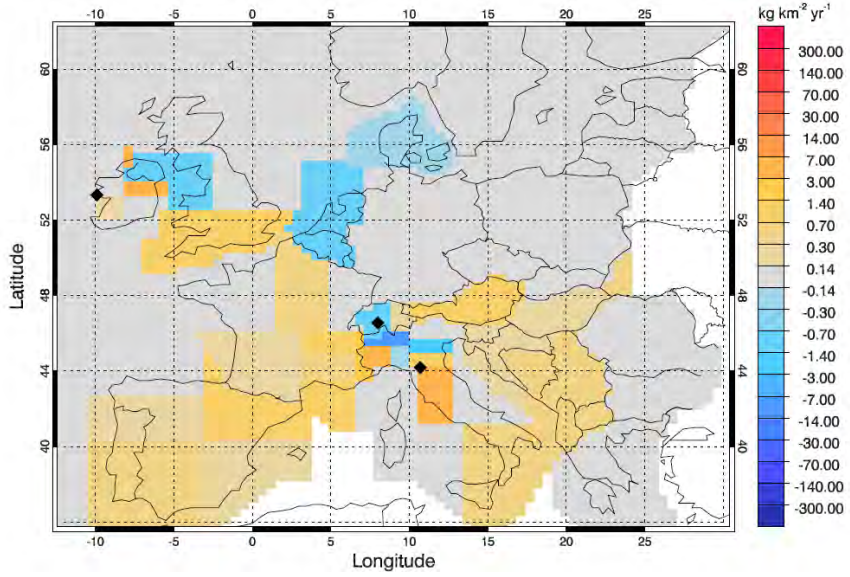
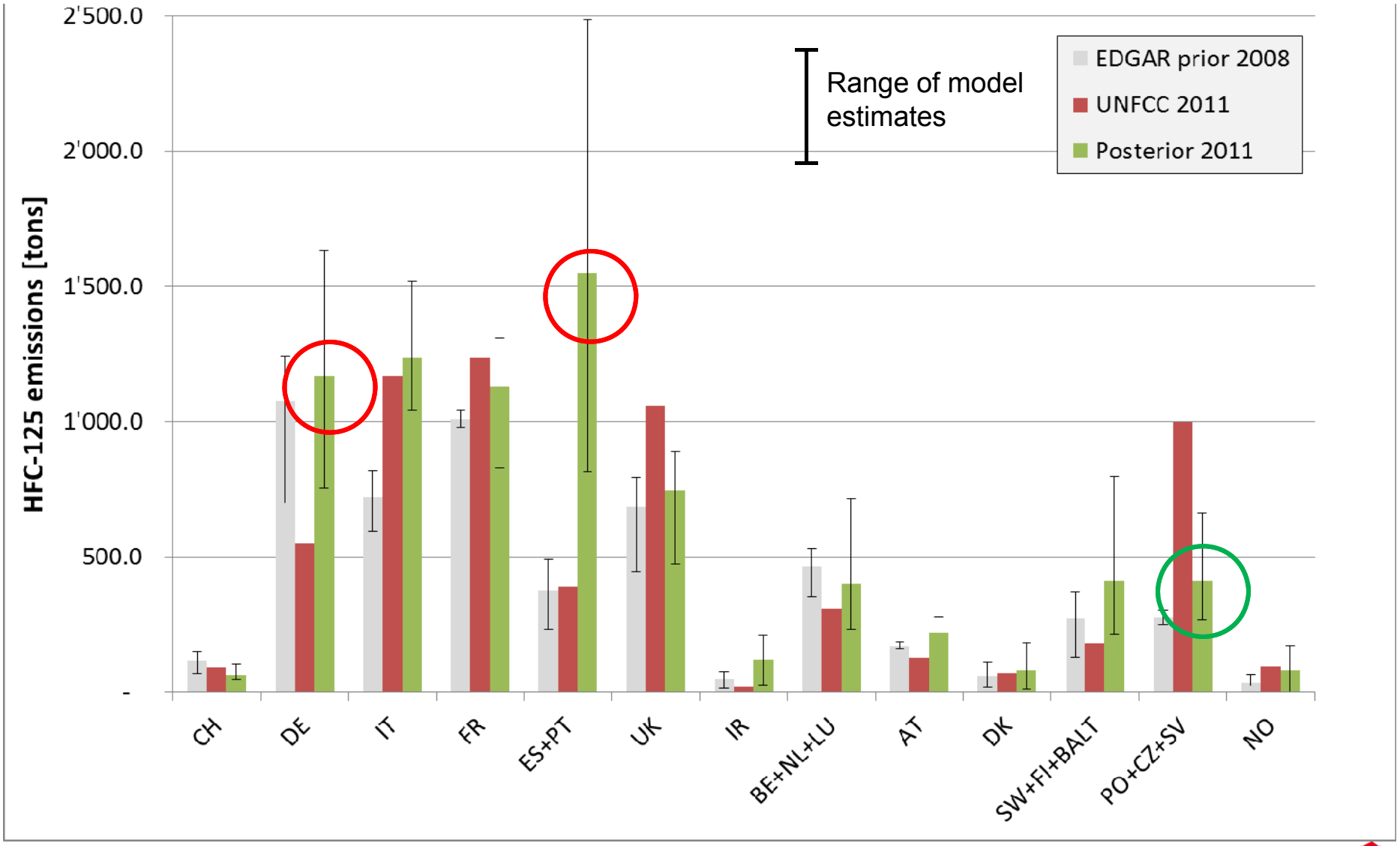


HFC-125 emissions per country



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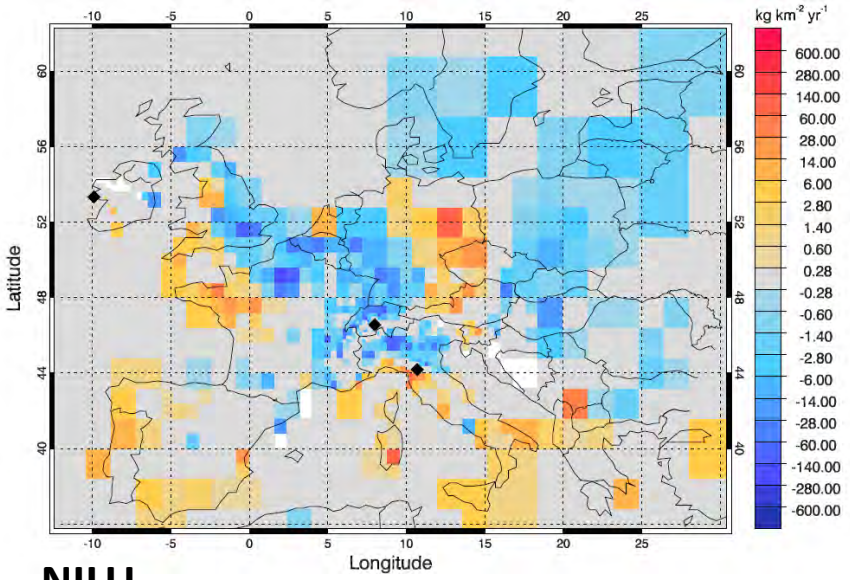
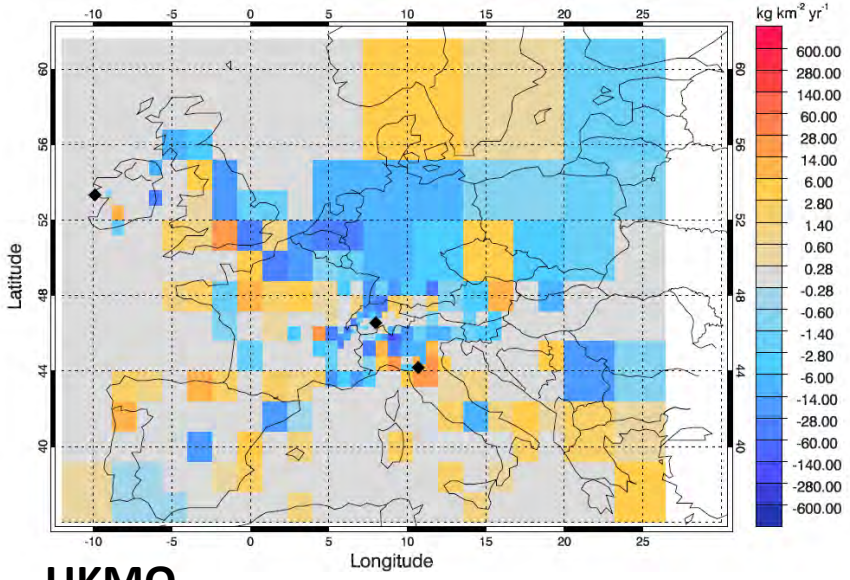
HFC-134a difference a posteriori – a priori

Empa



Empa2



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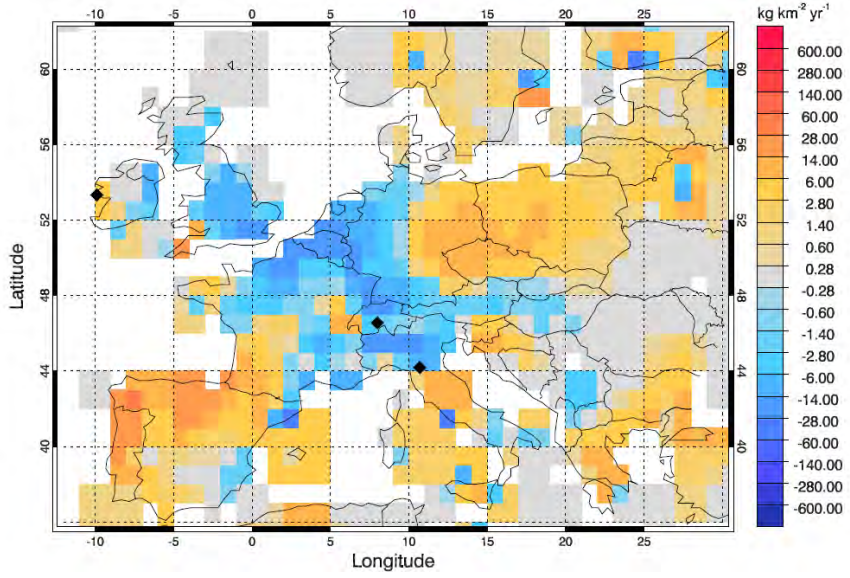

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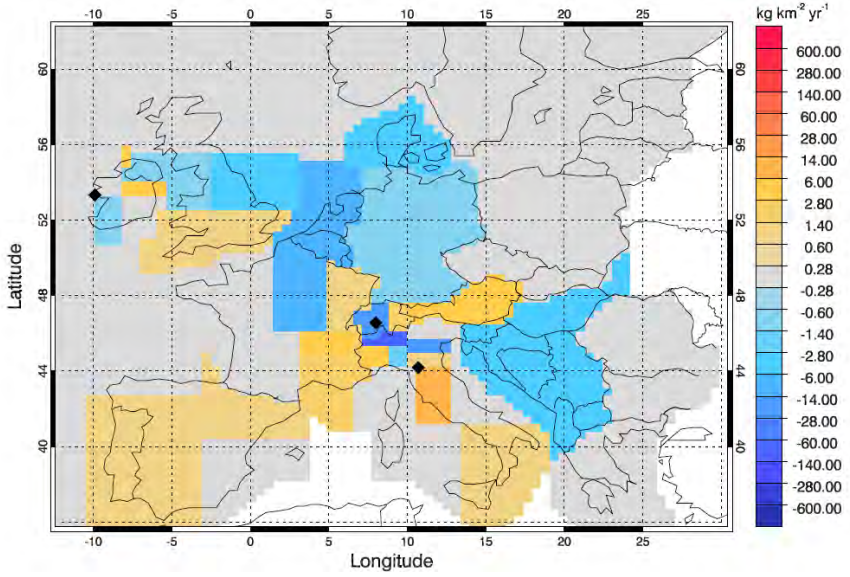
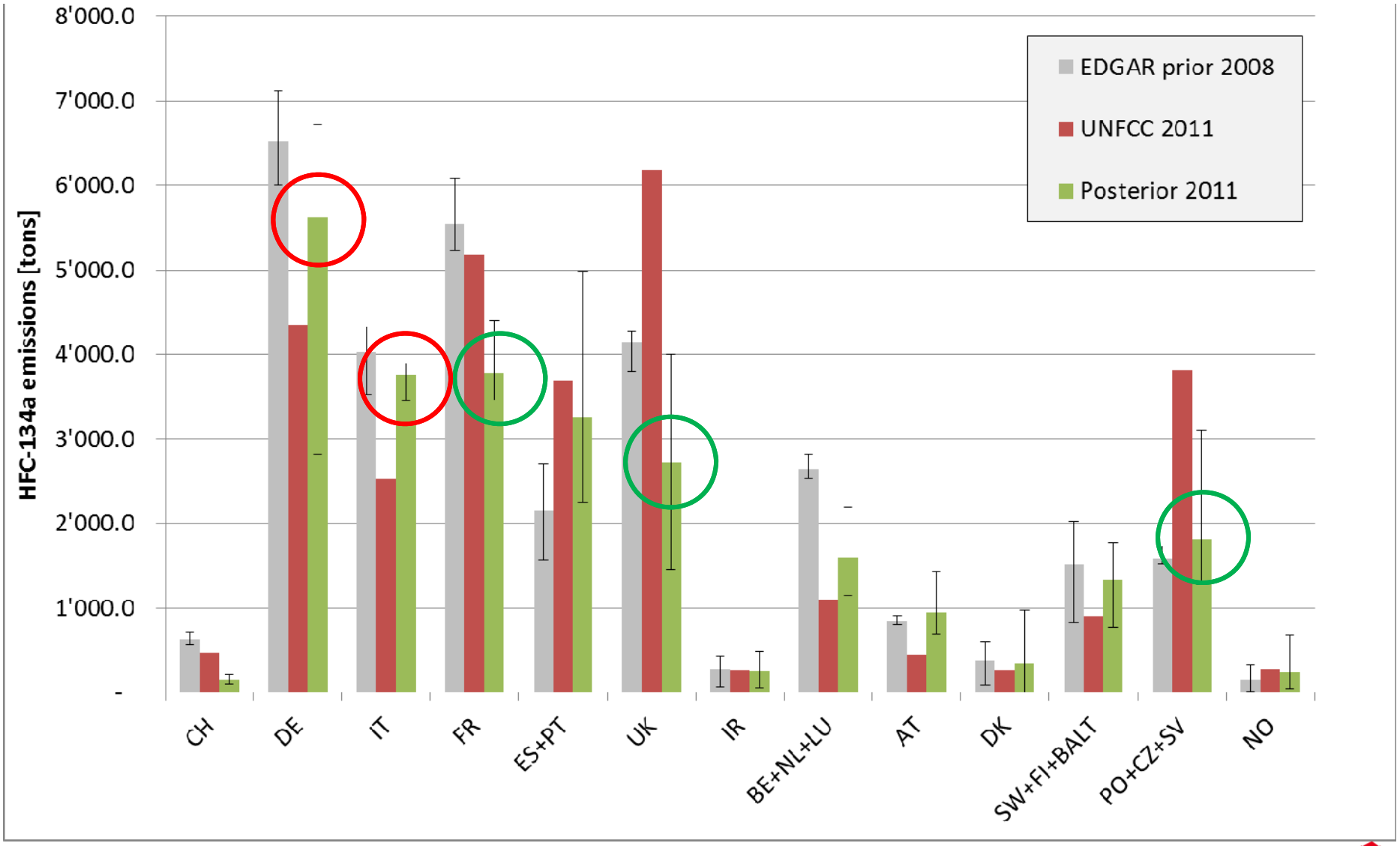


HFC-134a emissions per country



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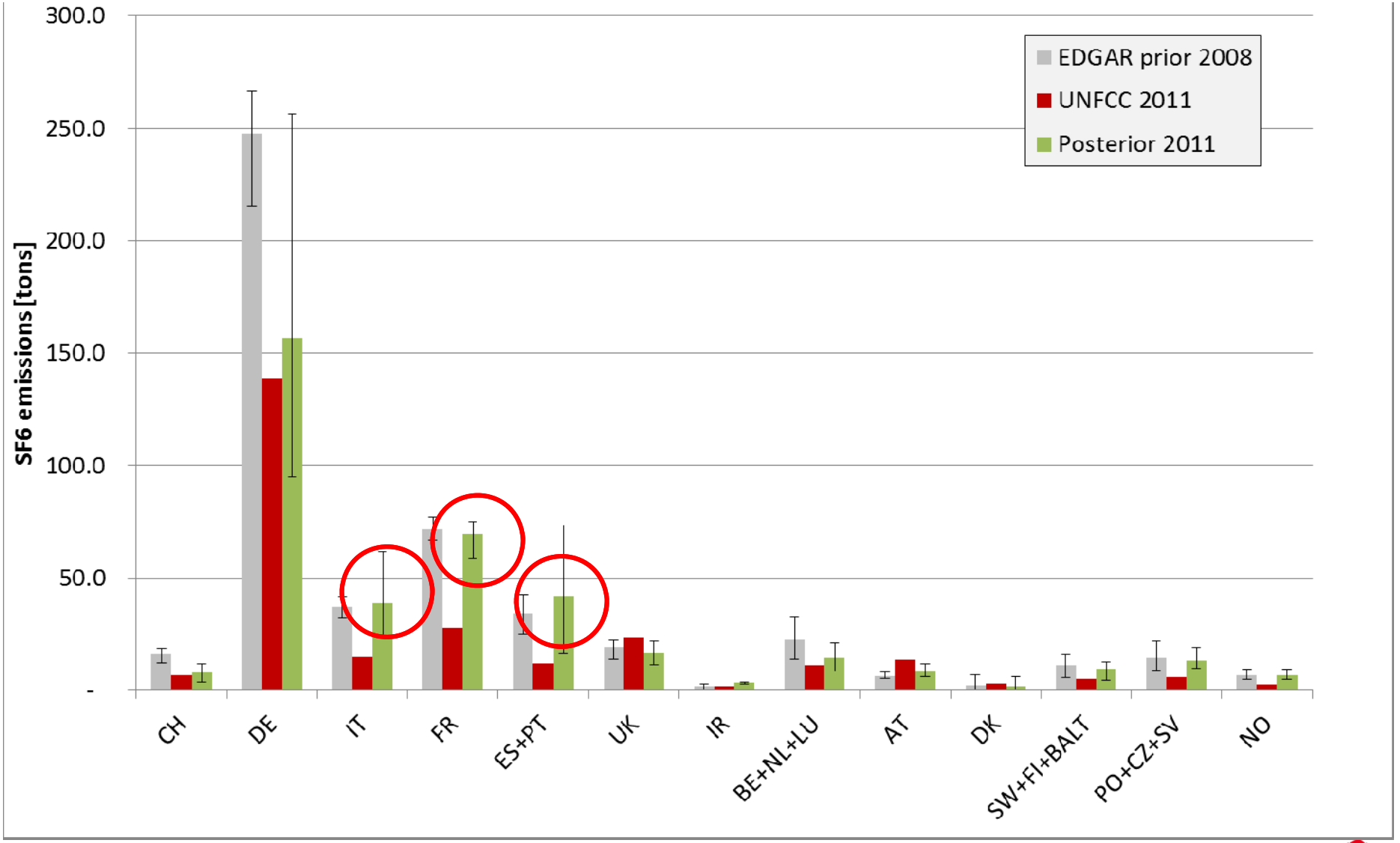
SF_6 emissions per country



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Conclusions

- First comprehensive intercomparison of regional-scale halocarbon inversions
- Significant differences in setup
  - inversion schemes: extKF vs. Bayesian, error covariances, baseline treatment
  - different reduced/irregular inversion grids
  - transport models: FLEXPART vs. NAME
- Emission amplitudes well constrained by 3 sites at large scales
- … but spatial pattern of emissions only weakly constrained.
  Network not dense enough!
- Mountain sites still difficult to simulate, potential for systematic errors
- Nevertheless, inversions show potential for country-scale estimates, especially for large countries not too distant from measurement sites
- Total emissions (sum over 22 countries considered):

	EDGAR v42 (2008)	UNFCCC (2011)	Mean Models (2011)	Range
HFC-125	5316	6300	7608	6450 - 8926
HFC-134a	30406	29482	25820	22755 - 28602
SF_6	492	267	390	319 - 540

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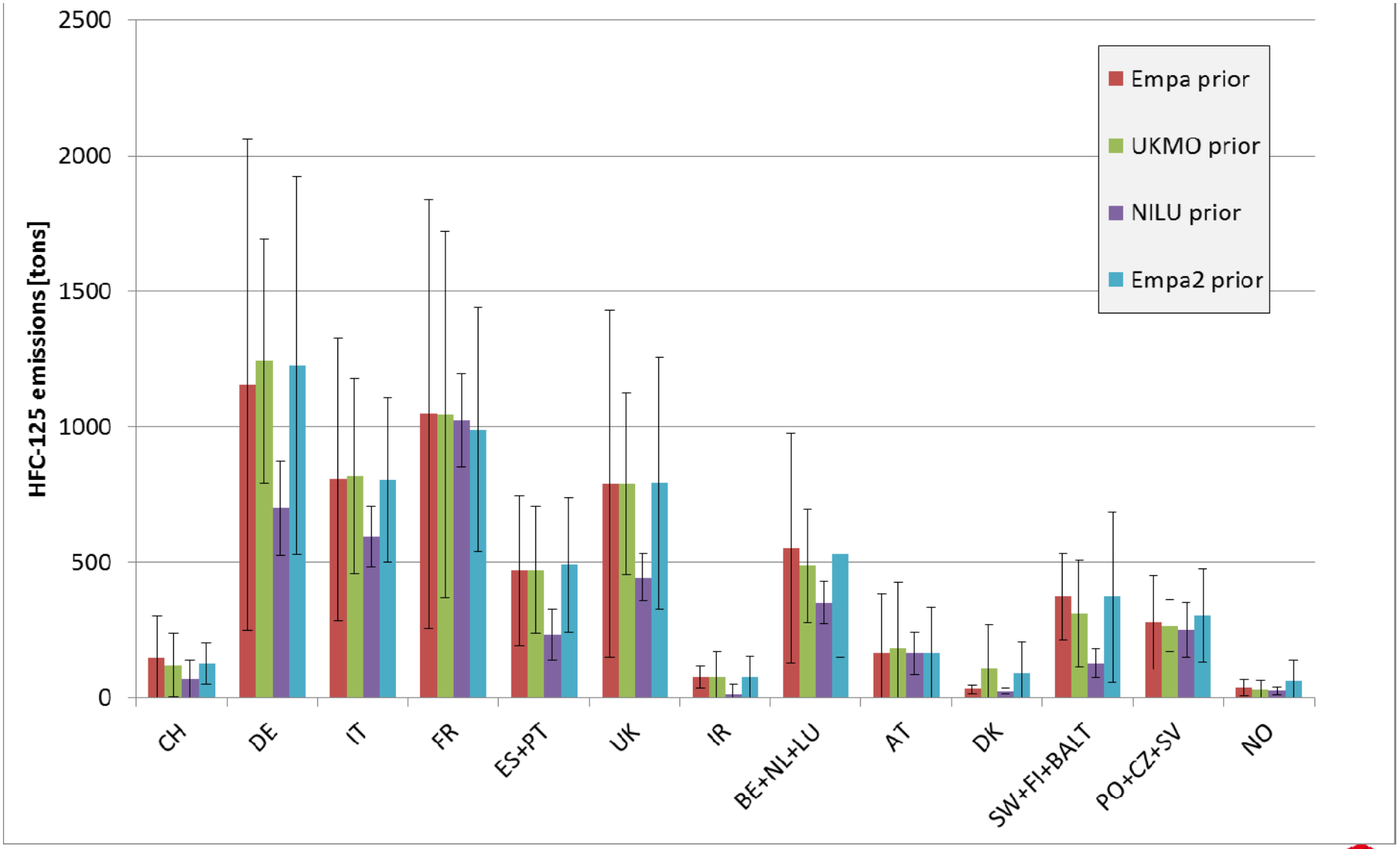
HFC-125 emissions per country: A priori



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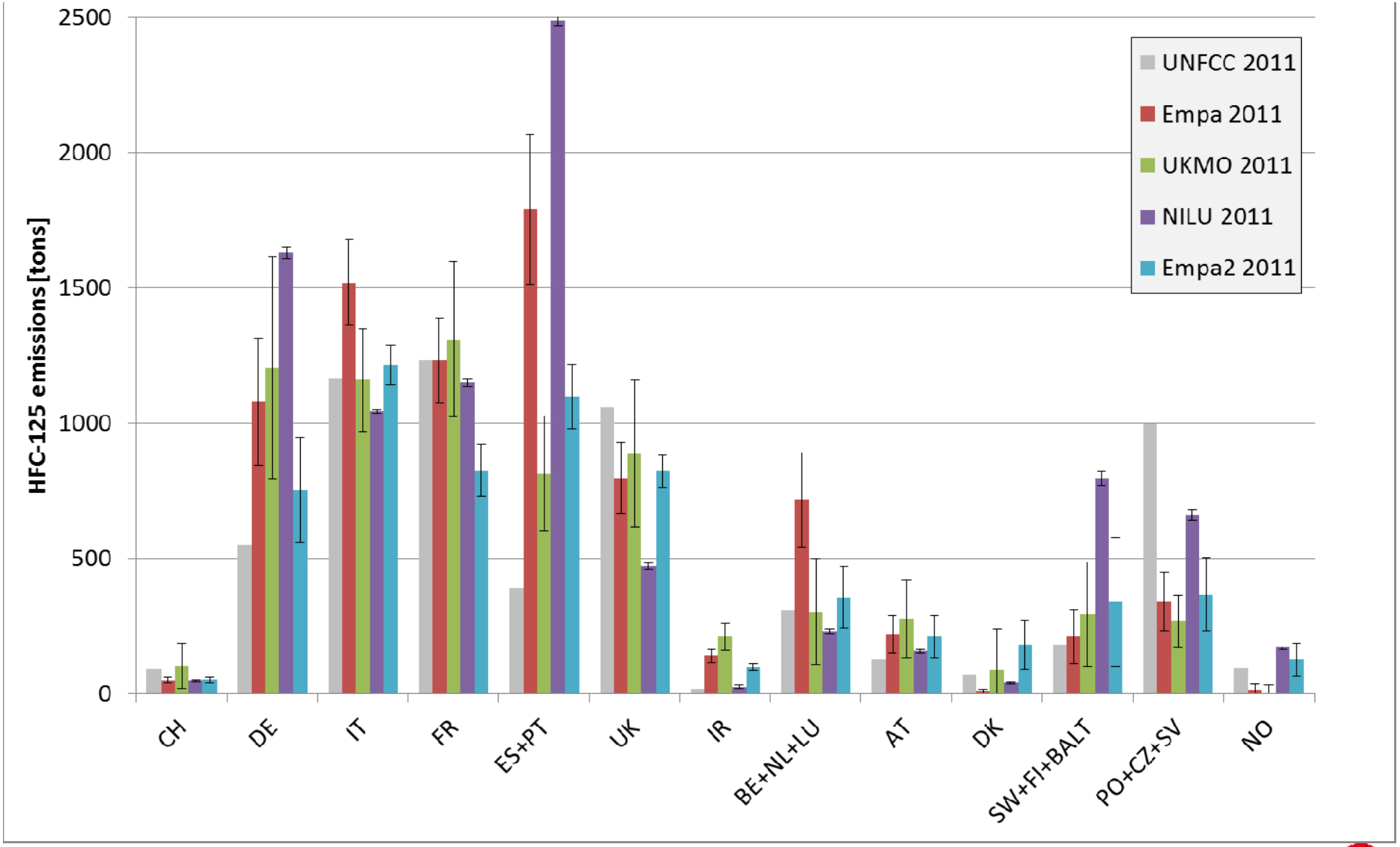
HFC-125 emissions per country: A posteriori



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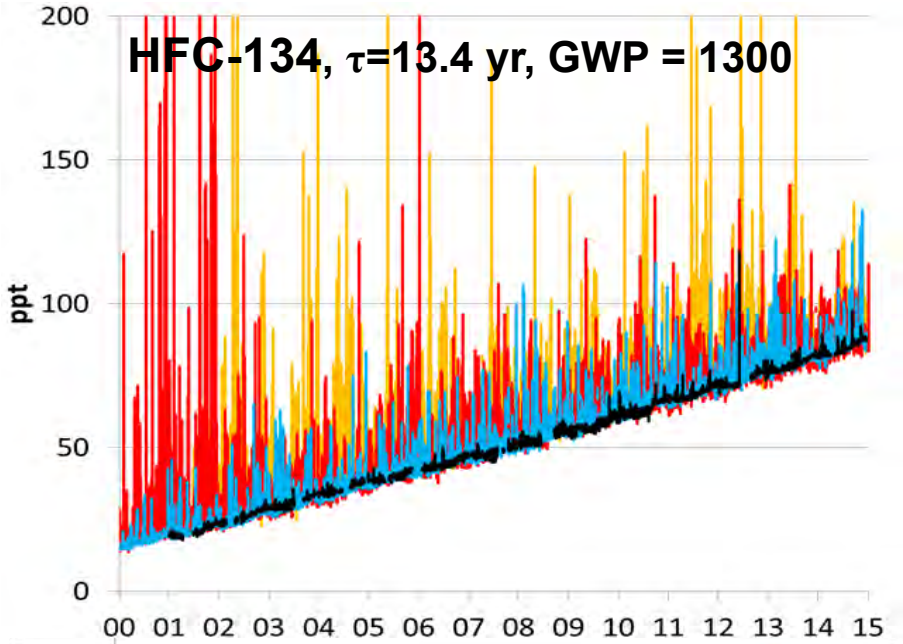
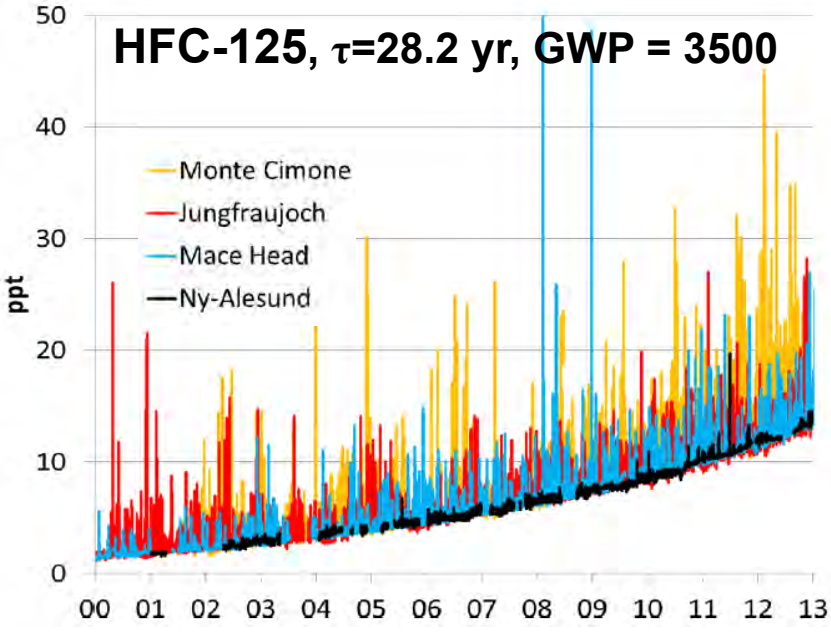
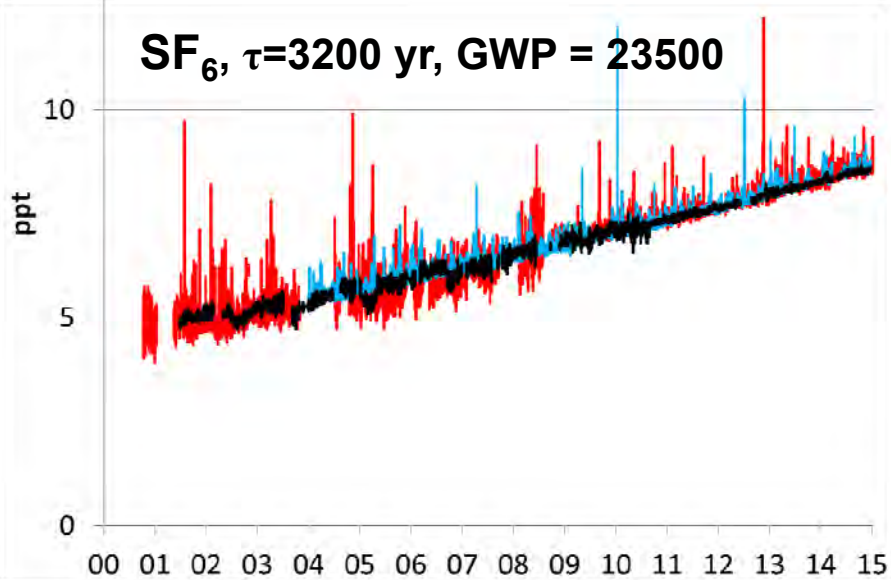
HFC-125, HFC-134a and SF_6







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