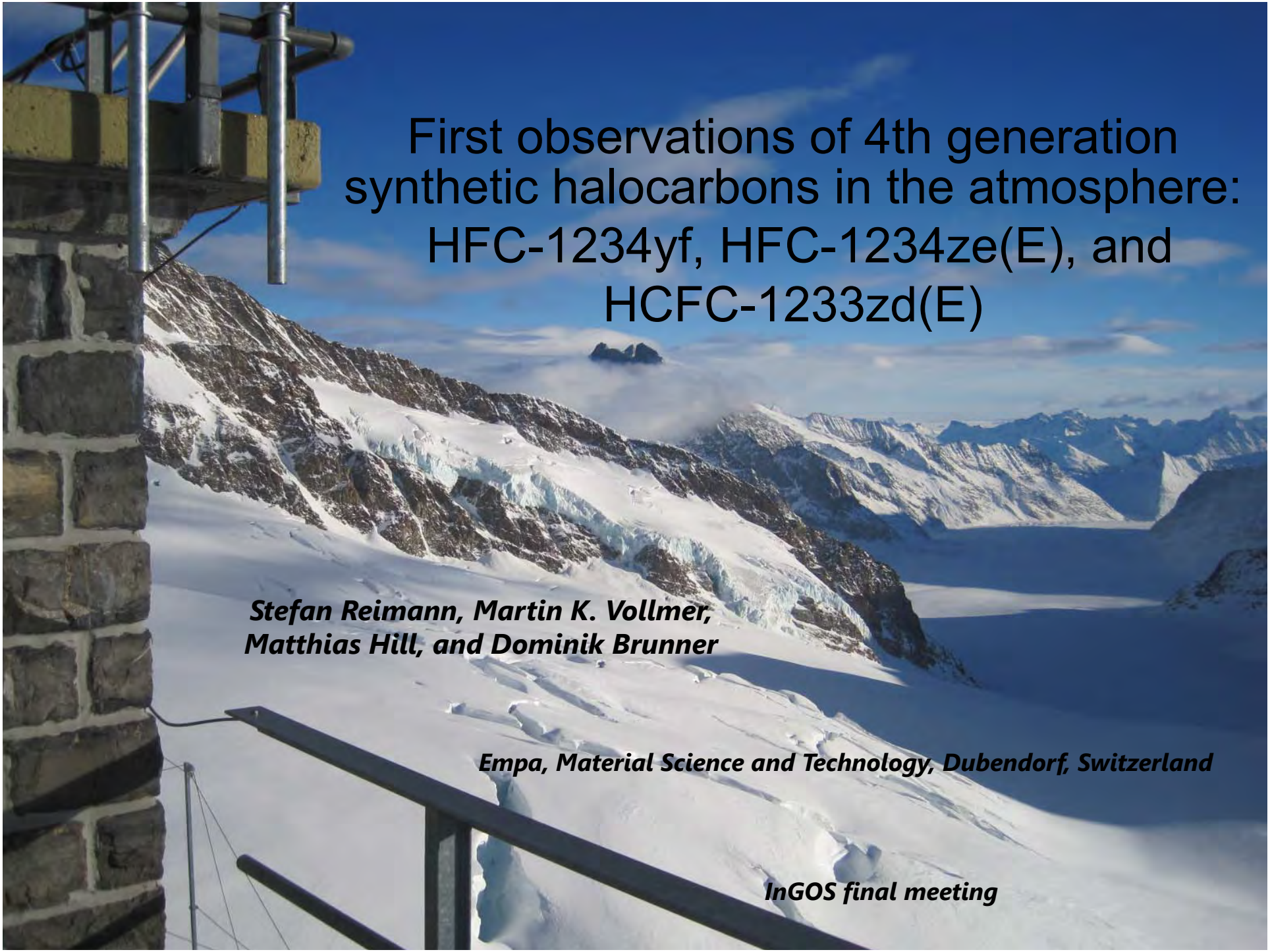


First observations of 4th generation synthetic halocarbons in the atmosphere: HFC-1234yf, HFC-1234ze(E), and HCFC-1233zd(E)

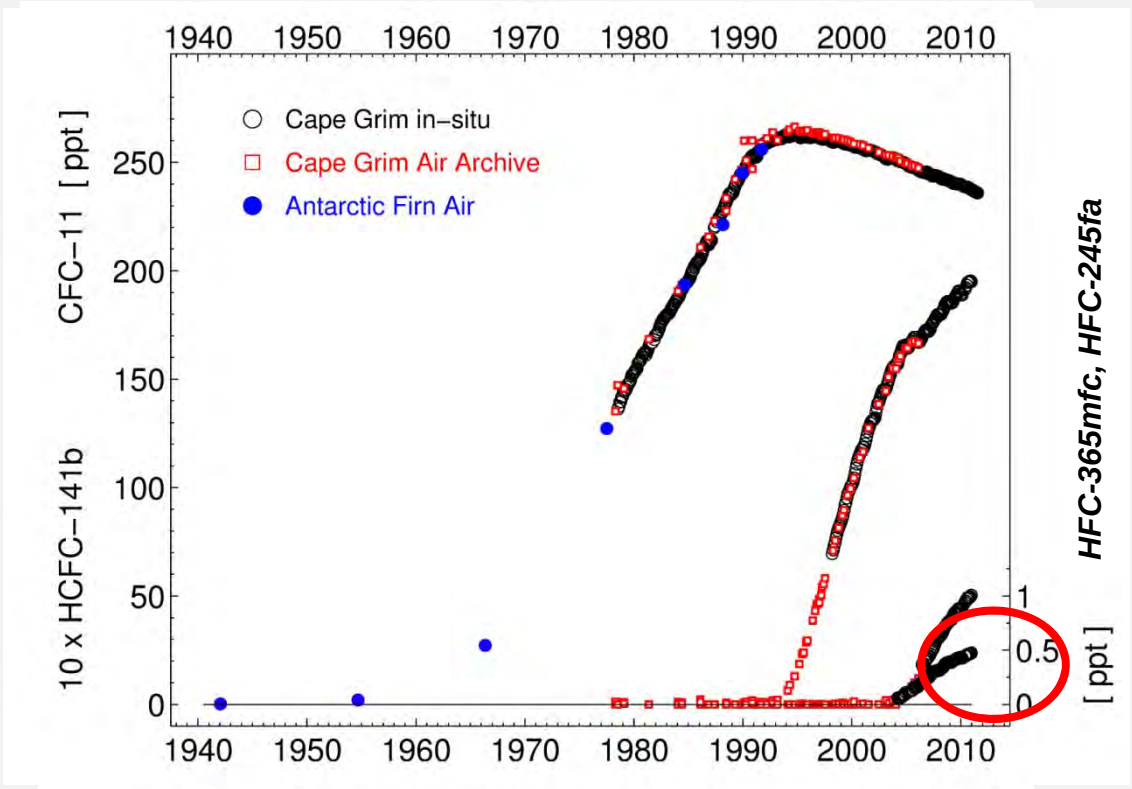
Stefan Reimann, Martin K. Vollmer, Matthias Hill, and Dominik Brunner

Empa, Material Science and Technology, Dubendorf, Switzerland

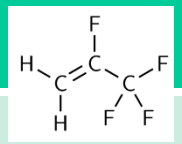
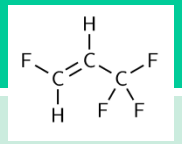
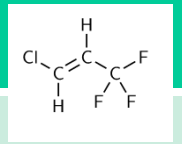
InGOS final meeting

History of synthetic halogenated compounds

- 1950s: 1st generation: chlorofluorocarbons (CFCs), halons: Cl, F, Br, -
- 1990s: 2nd generation: hydrochlorofluorocarbons (HCFCs): H, Cl, F, -
- 1990s: 3rd generation: hydrofluorocarbons (HFCs), perfluorocarbons (PFC): H, F, -
- 2010s: 4th generation hydrohaloalkenes (hydrohaloolefines, hydro-fluoroolefines, HFOs) H, Cl, F, =



Properties of hydrohaloalkenes

	HFC-1234yf 	HFC-1234ze(E) 	HCFC-1233zd(E) 	For comparison: CFC-11
Chemical Formula	CF_3-CF=CH_2	trans-CF_3-CH=CHF	trans-CF_3-CH=CHCl	CCl_3F
lifetime	10 – 16 days	14 – 19 days	26 – 46 days	52 years
ODP	0	0	0.0005	1
GWP (100 yr)	< 4	< 7.5	< 14	4’800
Current abundance	0 – few ppt	0 – few ppt	0 – 50 ppq	240 ppt
Use	refrigerant (mainly mobile)	foam blowing (Europe), solvent	solvent, foam blowing	foam blowing
Global Emissions	?	?	0.5	~70 kt/yr
Detection limits	2 – 4 ppq	2 – 4 ppq	0.5 – 1 ppq	<1 ppt

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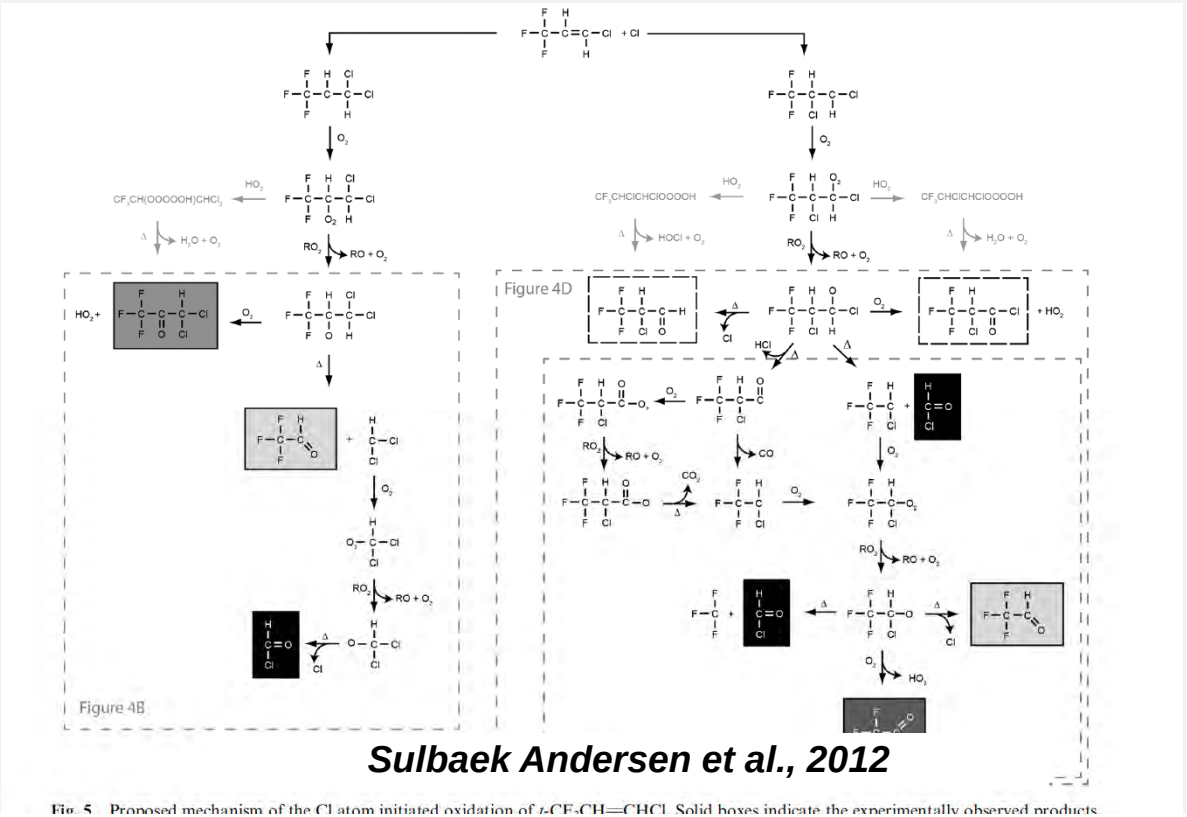
Why measure Hydrohaloalkenes?

Potentially huge amounts used in the future:

- potential replacement of:
  first + second generation (CFCs, HCFCs, halons etc)
  emissions: 650 Gg / yr
  third generation (HFCs, PFCs etc) emissions: 360 Gg / yr
  (ongoing activities to include HFCs in the Montreal Protocol)

- Decay products,
  fate in water
  and soils, toxicity:
  TFA issue

- Potential use as
  atmospheric tracers

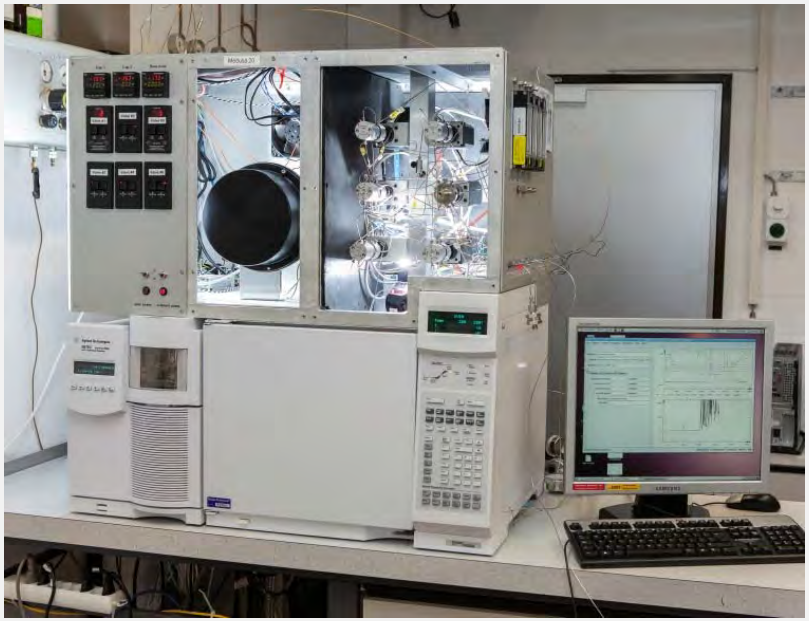


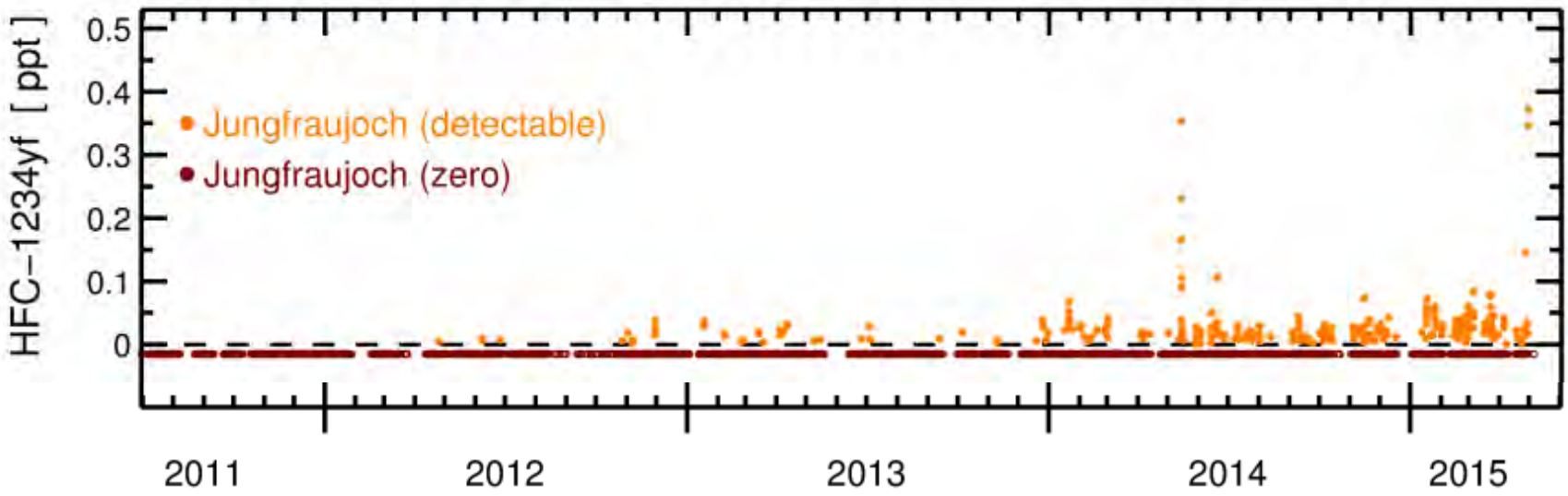
Sulbaek Andersen et al., 2012

Fig. 5. Proposed mechanism of the Cl atom initiated oxidation of *t*-$CF_3CH{=}CHCl$. Solid boxes indicate the experimentally observed products

Analytical Techniques for hydrohaloalkenes

- Measure with Medusa GCMS technology
- Measure at Jungfraujoch (Switzerland) at 3545 m. a. s. l.





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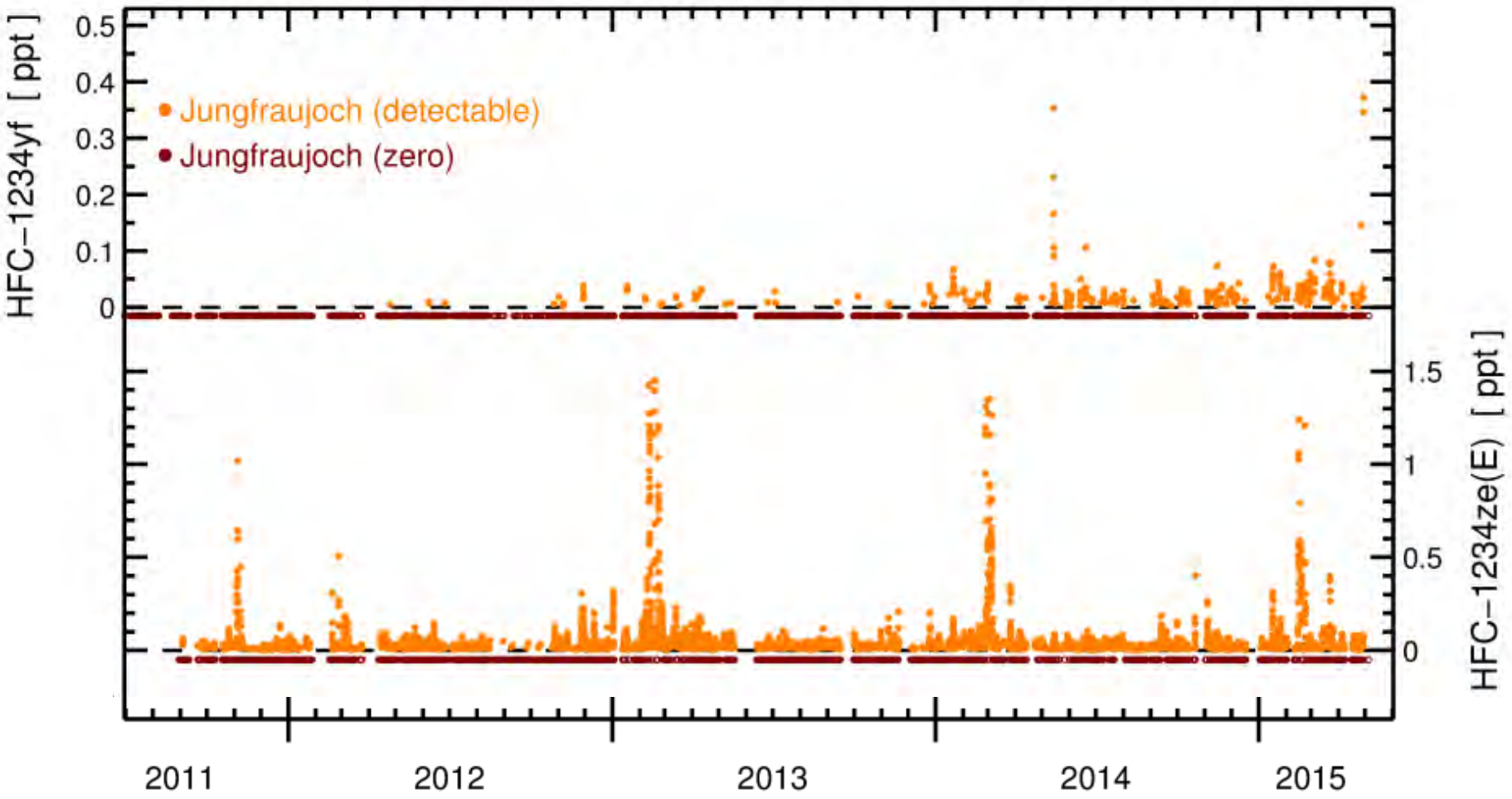

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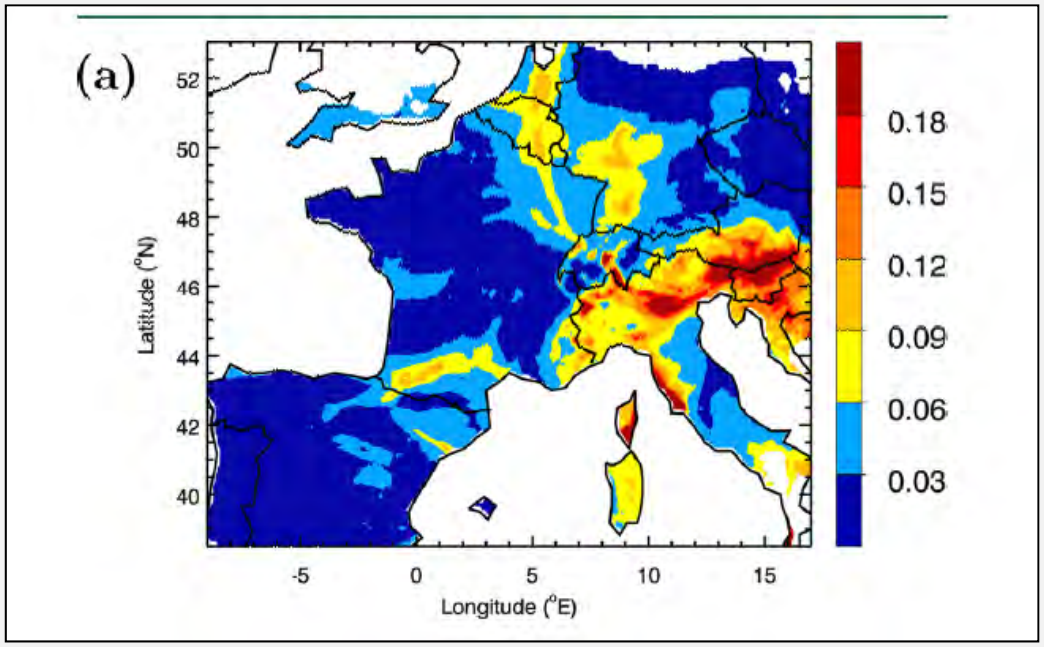
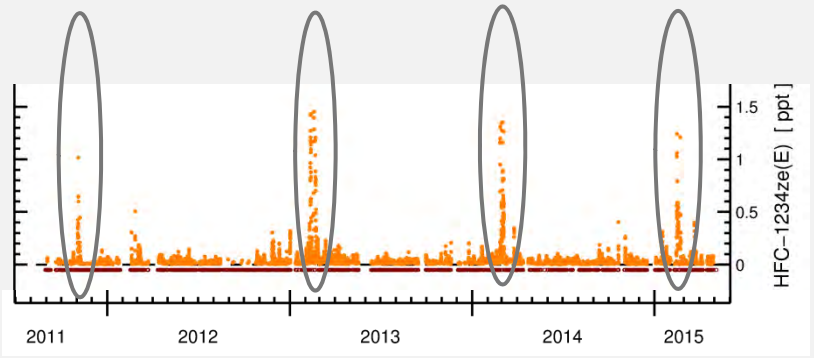
HFC-1234ze(E) source regions



All data 2011 – 2014



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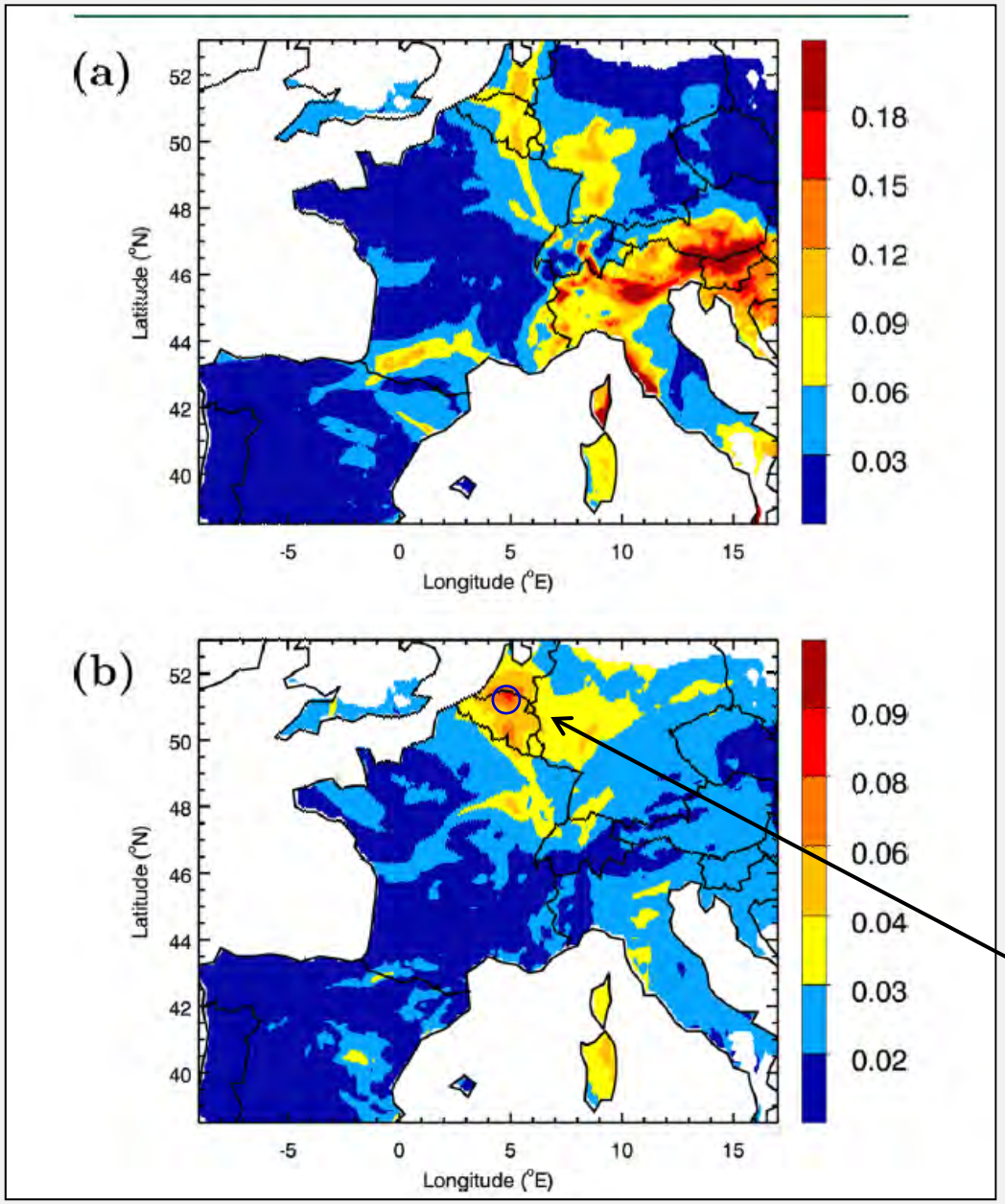
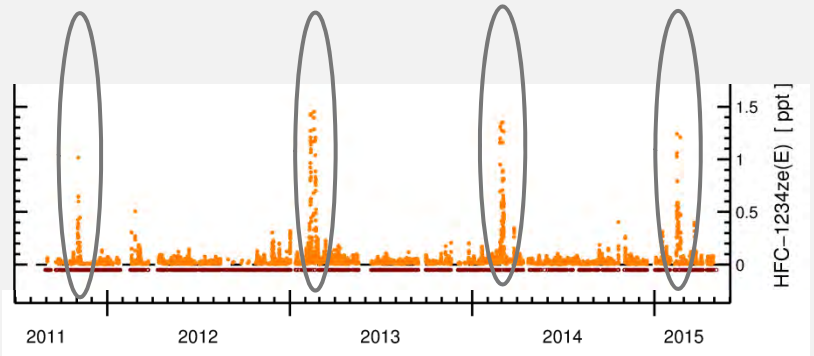
HFC-1234ze(E) source regions



All data 2011 – 2014



3 Major events removed

Jackon, Olen/Antwerp: currently only large XPS manufacturer using 1234ze(E) [2014: 115 t]

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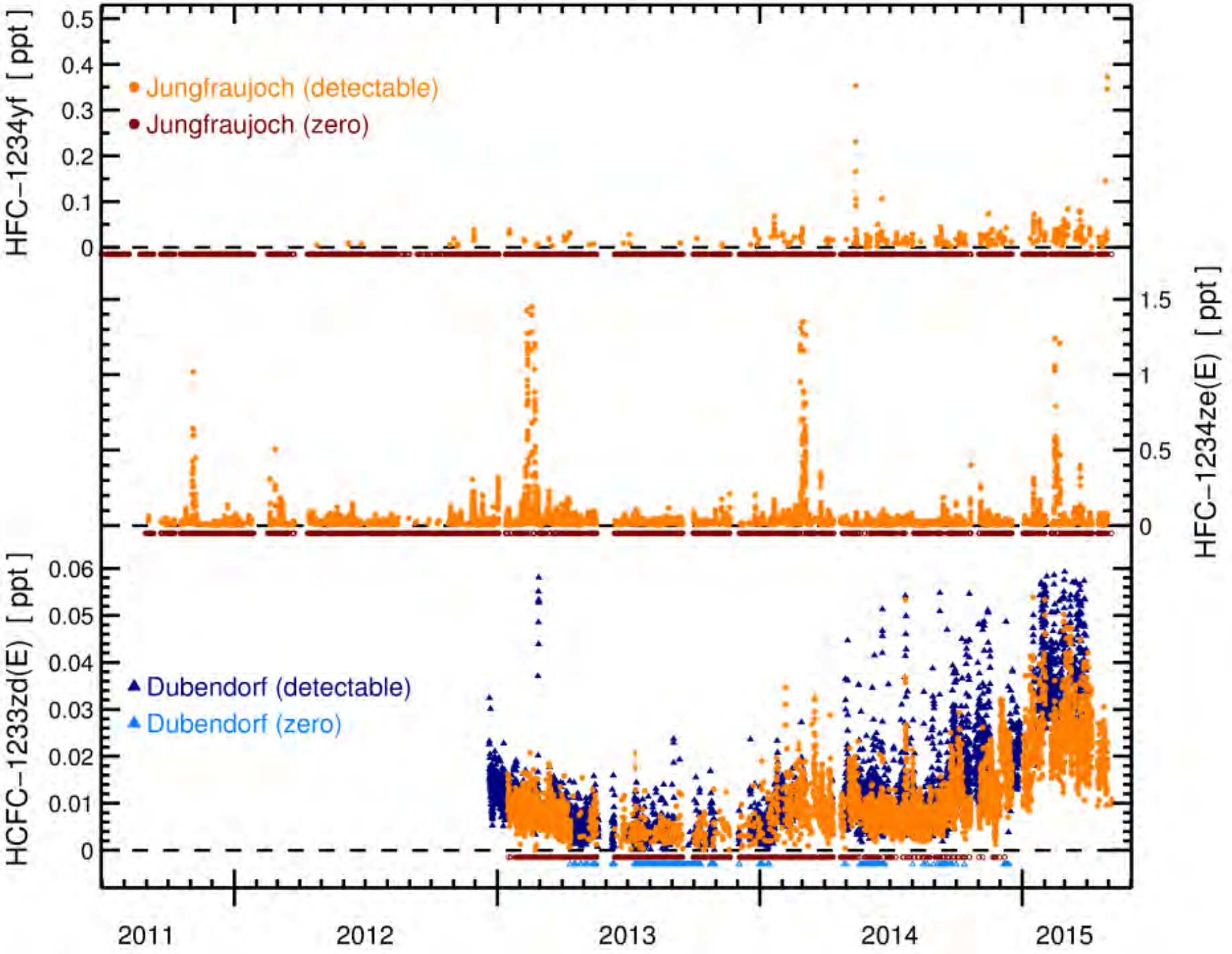
HFC−1234yf [ppt]
0.5
0.4
0.3
0.2
0.1
0
Jungfraujoch (detectable)
Jungfraujoch (zero)
HFC−1234ze(E) [ppt]
1.5
1
0.5
0
HCFC−1233zd(E) [ppt]
0.06
0.05
0.04
0.03
0.02
0.01
0
Dubendorf (detectable)
Dubendorf (zero)
2011
2012
2013
2014
2015

Conclusions

- First measurements of three important hydrohaloalkenes: on the rise
- First rough estimates of source regions and emissions:
  - HFC-1233zd(E) global emissions: 0.2 Gg in 2013 to 0.45 Gg in 2014
- New challenges: Decay products, fate in water and soils, toxicity
  - potential replacement of 1'000 Gg/yr of 1st – 3rd generation:

Acknowledgments

- Halclim (Swiss Federal Office for the Environment, FOEN)
- International Foundation High Altitude Research Station Jungfraujoch and Gornergrat (HFSJG)
- Integrated Non-CO_2 Greenhouse gas Observing System (InGOS, EU-FP-7)
- HIGHGAS, European Metrological Research Project ENV52 Metrology for high-impact greenhouse gases

- Station personnel at Jungfraujoch (Fischer and Otz families)
- Angelina Wenger, Fabian Schoenenberger, Christoph Zellweger, and Corinne Hoerger for help with preparation of primary calibration scale
- AGAGE / CSIRO, Ben Miller (NOAA): Cape Grim Records
- Rajiv R. Singh of Honeywell International for providing the pure compounds.


End