Halogenated Greenhouse Gases at Jungfraujoch and in AGAGE

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AGAGE (Advanced Global Atmospheric Gases Experiment)
Jungfraujoch – The International Swiss Monitoring Site

GAW: Global Atmosphere Watch of WMO

NABEL: National Air Pollution Monitoring Network

AGAGE: Advanced Global Atmospheric Gases Experiment

EMEP: European Monitoring and Evaluation Programme

ICOS: Integrated Carbon Observation System

ACTRIS: European Infrastructure for the observation of Aerosol, Clouds, and Trace gases
AGAGE Network (Halocarbons)

Medusa-GC-MS
preconcentration

mass spectrometry
gas chromatography

Advanced Global Atmospheric Gases Experiment

- Ny-Alesund (Svalbard)
- Jungfraujoch (Switzerland)
- Mace Head (Ireland)
- Shangdianzi (China)
- Gosan (Korea)
- Hateruma (Japan)
- Cape Grim (Tasmania)
- Cape Matatula (American Samoa)
- Ragged Point (Barbados)
- Monte Cimone (Italy)
- Trinidad Head (California)

● AGAGE sampling stations
  collaborative sampling stations
  - U. Urbino
  - NIES
Halocarbons – why?

- Applications: Refrigeration, Foam blowing, Fire Suppression, Solvents

- Stratospheric ozone depletion

- Potent greenhouse gases: combined 0.35 W/m² (CO₂: ~2 W/m²)

- Global, long-term trends, global emissions

- Regional variability, regional emissions

- Top-down emissions (observations based) vs bottom-up (industry estimates)
Four Generations of Halocarbons

1st Generation
- CFCs, Halons
- CCl₄, CH₃CCl₃, CH₃Br

2nd Generation
- HCFCs

3rd Generation
- HFCs
- PFCs

4th Generation
- HFOs

Montreal Protocol

Ozone Depletion Substances

Greenhouse Gases
- Chlorofluorocarbons
- Hydrochlorofluorocarbons
- Hydrofluorocarbons
- Perfluorocarbons
- Hydro(chloro)fluoro-olefines

1st Generation
- CFC-11, CFC-12, CFC-13, CFC-113, CFC-114
- H-1211, H-1301, H-2402, CH₃CCl₃, CCl₄

2nd Generation
- HCFC-21, HCFC-22, HCFC-31, HCFC-114b, HCFC-142b

3rd Generation
- HFC-23, HFC-32, HFC-134a, HFC-125, HFC-245fa, HFC-365mfc
- SF6, CF4, PFC-116, PFC-218, PFC-318, others

4th Generation
- HFO-1234yf, HFO-1234zeE, HCFO-1233zdE
Four Generations Halocarbons

1st generation halocarbons (CFCs)

2nd generation halocarbons (HCFCs)

3rd generation halocarbons (F-gases = HFCs, PFCs, others)

4th generation halocarbons (HFOs)

adapted from Velders et al., Science, 2012
First Generation: CFC-115 observations

Jungfraujoch
Cape Grim

Atm Lifetime: 540 yr
GWP: 7'600
ODP: 0.6
First Generation: CFC-115 Global Emissions

- Atm Lifetime: 540 yr
- GWP: 7'600
- ODP: 0.6
3rd Generation Example: Inhalation Anesthetics

**Desflurane:** 2-(difluoromethoxy)-1,1,1,2-tetrafluoro-ethane

- **Atm Lifetime:** 14 yr
- **GWP:** 2'540
- **Market Intro.:** 1995
Generation 3: HFC-134a Observations

HFC-134a [ppt]

Jungfraujoch
Mace Head
Cape Grim

Atm Lifetime: 14 yr
GWP: 1'500

Global Emissions 180'000 t/yr
Generation 3: HFC-134a Swiss Emissions

Atm Lifetime: 14 yr
GWP: 1'500
Reduce HFC Emissions

HFC-134a

Atmospheric lifetime: 14 years
GWP_{100}: 1500

Short-lived HFOs (Hydrofluoro-olefines)

HFO-1234yf

Atmospheric lifetime: 8-16 days
GWP_{100}: <1
Fourth Generation: Example HFO-1234yf

Atm Lifetime: 8-16 days

GWP: <1

Percentage detectable HFO-1234yf (~4,000 measurement / year)

Jungfraujoch
Environmental Concerns: HFO-1234yf

- Atm Lifetime: 8-16 days
- GWP: <1

Trifluoroacetic acid (TFA)

Deposition
Predicted >180 kt/yr

Threat to aquatic ecosystems
Conclusions

- Halocarbons are important ozone-depletion and greenhouse gases
- Independent Validation of bottom-up emission estimates
- More challenges ahead:  
  ● Implement 4th Generation Compounds (HFOs) measurements at more sites  
  ● TFA assessment
- Measurement Techniques (APRECON – GC – ToF- MS)

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