Name of research institute or organization:

Empa, Swiss Federal Laboratories for Materials Science and Technology

Title of project:

Halogenated Greenhouse Gases at Jungfraujoch

Part of this programme:

AGAGE

Project leader and team:

Martin K. Vollmer, Stefan Reimann (project leader), Matthias Hill, Simon A. Wyss, Lukas Emmenegger

Project description:

Halogenated ozone-depleting substances (ODSs) and greenhouse gases (GHGs) have been monitored at Jungfraujoch since 2000. These measurements are combined with atmospheric transport models for identifying and quantifying national and regional emissions (Switzerland and neighboring countries). The "top-down" (observation based) estimates are then used to verify "bottom-up" estimates of the national reporting authorities, which are based on industry information (import/export/manufacture). Furthermore, the measurements help to track global trends of ODSs and GHGs in the "background" air. Measurements at Jungfraujoch comprise a suite of over 50 compounds, such as chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), perfluorocarbons (PFCs and SF_6), and hydrofluorocarbons (HFCs), which are regulated under the Montreal and Kyoto Protocols, and additional halogenated hydrocarbons. Most of these compounds are core-substances measured by the AGAGE program (Advanced Global Atmospheric Gases Experiment), of which Empa is a partner. Measurements are conducted with 2 liters of air and using gas chromatography mass spectrometry techniques.

The above groups of compounds, loosely referred to as 1st generation (CFCs, halons), 2nd generation (HCFCs), both Montreal Protocol compounds, and 3rd generation (HFCs, PFCs, Kyoto Protocol compounds) are now extended to a new (4th) generation of compounds, the fluorinated alkenes (carbon double bonds), sometimes also referred to as HFOs (hydrofluoroolefines). These new compounds are now also being used as refrigerants, foam-blowing substances, and solvents and are planned to replace some of the HFCs. These HFOs have much shorter lifetimes (days to months) compared to most HFCs and are removed from the atmosphere more quickly. Most prominently is HFC-1234yf (or HFO-1234yf, 2,3,3,3-tetrafluoroprop-1-ene, $CF_3CF=CH_2$), which is now widely used as mobile air conditioner replacing HFC-134a. It is important to characterize the atmospheric abundances of these compounds to track the transition from the 3rd to the 4th generation halocarbons and to provide first top-down (observation-based) estimates of emissions. Also, some of these compounds (e.g. HFC-1234yf) react with the OH radical to create trifluoro-acetic acid (TFA), which is readily washed out from the atmosphere, and which has adverse effects on terrestrial and aquatic ecosystems.

Empa has started to make the world-wide first atmospheric measurements of HFC-1234yf, HFC-1234ze(E) (E-1,3,3,3-tetrafluoroprop-1-ene, *trans*-$CF_3CH=CHF$), and HCFC-1233zd(E) (E-1-chloro-3,3,3-trifluoroprop-1-ene, *trans*-$CF_3CH=CHCl$) in ambient air at Jungfraujoch and at urban Dübendorf. First results for the observational period 2011–2014 were published (Vollmer et al., 2015a), and are here updated for 2015. The multi-year records show the onset of these compounds in the atmosphere and their growing abundances and frequencies of pollution events at Jungfraujoch.

HFC-1234yf (lifetime 10–16 days) has virtually been absent in the >7'000 samples analyzed in 2011/2012 at Jungfraujoch, but the number of detectable mole fractions and their magnitude has increased since, and this trend also holds for the update in the 2015 measurements (Figure 1). These results are suggestive of a growing use of HFC-1234yf in Europe, which is also supported by the increasing mole fractions detected at urban Dübendorf.

HFC-1234ze(E) (lifetime 15–23 days), a foam-blowing compound has been present in 27% of all Jungfraujoch measurements and is now detectable in most air samples, while the compound is measurable in all air samples at Dübendorf in 2015. Peculiar large pollution events were observed at Jungfraujoch in spring 2013 and 2014, and now also in 2015. The causes of these events are still not fully understood but they are believed to be real observations, and not an artefact.

HCFC-1233zd(E) has the longest lifetime of the three HFCs discussed here (24–46 days), and is present at very low mole fractions, maximally tens of ppq (parts-per quadrillion, fmol/mol, in dry air). The 2015 extension of the record shows a clear increase of the 'background' mole fraction of this compound. Still, HFC-1233zd(E) is not elevated at Dübendorf compared to Jungfraujoch. This indicates that this compound is likely not currently used within the footprint of the Dübendorf site. Longer-range transport of HFC-1233zd(E) from the US or Asia appears to be a more applicable explanation. This compound contains chlorine, and hence can be considered to some extent as a 'Montreal Protocol' compound. The European regulations for its use are currently not clear.

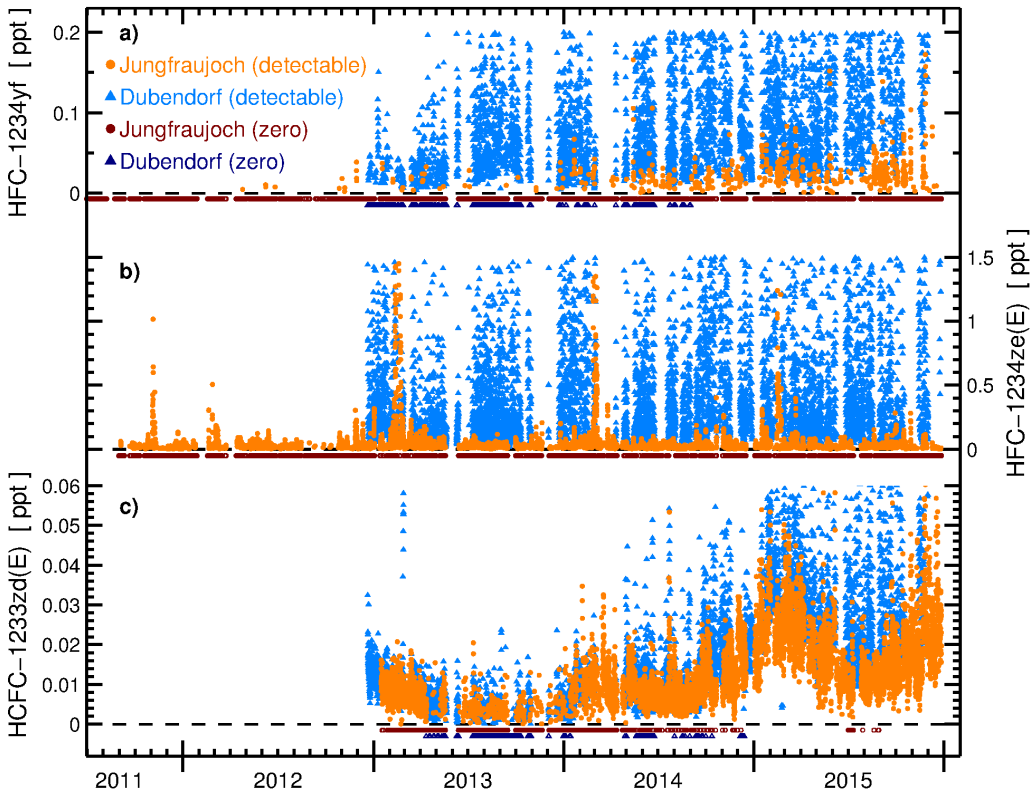

Figure 1. Atmospheric abundances of the 4th generation anthropogenic halocarbons HFC-1234yf, HFC-1234ze(E), and HCFC-1233zd(E) at Jungfraujoch and urban Dübendorf. The absences of detectable mole fractions are separately shown as dark brown and dark blue symbols and are slightly shifted to negative for better illustration. Above-detection-limit mole fractions are shown in orange and light blue whereas some of the higher abundances, particularly for Dübendorf, are not shown. Figure adopted from Vollmer et al., 2015a and updated to 2015.

These 4th generation halocarbons are continued to be monitored at Jungfraujoch and Dübendorf and some of the other AGAGE stations have begun some monitoring. These observations will help providing a better understanding of regional use around those parts of the world, where they are monitored. However, given their short lifetimes, quantitative modeling of their emissions will remain highly challenging in the near future.

Key words:

Halogenated ozone-depletion substances (ODSs), greenhouse gases (GHGs), F-gases, Hydrofluoroolefines (HFOs)

Internet data bases:

http://empa.ch/abt503
https://agage.mit.edu/

Collaborating partners/networks:

Bundesamt für Umwelt (BAFU) / Federal Office for the Environment (FOEN)
Global Atmosphere Watch (GAW), World Meteorological Organization (WMO)
Advanced Global Atmospheric Gases Experiment (AGAGE)
InGOS – Integrated non-CO_2 Greenhouse gas Observing System
ACTRIS – Aerosol, Clouds, and Trace Gases Research Network
Korea Polar Research Institute (KOPRI)
University of Bristol, UK

Scientific publications and public outreach 2015:

Refereed journal articles and their internet access

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Reimann, S., Measurements of atmospheric trace gases and their relevance for climate change and air pollution, GAS 2015, Rotterdam, Netherlands, June 11, 2015.

Reimann, S., M.K. Vollmer, F. Schoenenberger, S. Henne, D. Brunner and L. Emmenegger, New halogenated greenhouse gases in the atmosphere: from anesthetics to mobile air conditioning, 13th Swiss Geoscience Meeting, Basel, Switzerland, November 21, 2015.

Data books and reports

Reimann, S., M.K. Vollmer, D. Brunner, M. Steinbacher, M. Hill, S.A. Wyss, S. Henne, C. Hörger, and L. Emmenegger, Kontinuierliche Messung von Nicht-CO_2-Treibhausgasen auf dem Jungfraujoch (HALCLIM-5), Schlussbericht, Empa, Swiss Federal Laboratories for Materials Science and Technology, and FOEN, Federal Office for the Environment, 2015. http://www.bafu.admin.ch/luft/00612/00625/11899/index.html?lang=de

Magazine and Newspapers articles

Related to Vollmer 2015a: Wide-spread media response, Examples: „Klimaschonende Kühlmittel immer weiter verbreitet", bauernzeitung.ch, March, 24, 2015; „Searching for traces in the atmosphere", healthmedicinet.com, March 25, 2015; „La climatisation laisse des traces dans l'atmosphère", letemps.ch, March 24, 2015; „Searching for coolant traces in the atmosphere", phys.org, March 24, 2015, sciencedaily.com, March 24, 2015; „Klimaschonende Kühlmittel boomen", Die Botschaft, March 25, 2015; „Spurensuche in der Atmosphäre", analytik.de, March 25, 2015; „First Measurements of 4th generation coolants in air, reportingclimatescience.com, March, 26, 2015.

Related to Vollmer 2015b: Numerous press releases and media responses in many countries. Examples are: „Anesthetic gases raise Earth's temperature", agu.org, April 7, 2015; „Anaesthetics is warming the planet", dailymail.co.uk, April 8, 2015; „Studie: Anästhesiegase belasten das Klima, SDA/Schw. Depeschenagentur, April, 14, 2015; „Anaesthetic gases aiding change in climate too", asianage.com, April 9, 2015; „Anesthetic gases raise earth's temperature, natureworldnews.com, April 9, 2015; „Anaesthetic gases raising Earth's temperature too", nepalnational.com, April 9, 2015; „Anesthetic gases contribute to climate change", sci-news.com, April 9, 2015, topnews.in, April 9, 2015,

Related to Vollmer 2015c: Examples are: „Ozone destroyer drops mysteriously", blogs.agu.org, October 6, 2015; „A sharp decline in concentration of ozone destroying HCFC-133a gas reported", thewatchers.adorraeli.com, October 6, 2015; „Atmospheric concentration of an ozone destroying chemical drops mysteriously", sott.net, October 7, 2015; „Ozone-destroyer: significant drop in harmful gas", natureworldnews.com, October 14, 2015.

Radio and television

Television report on BBC newsnight. 100 world leaders have meet for the start of the Paris climate change conference (COP 21). Stefan Reimann and Rebecca Morelle from BBC Newsnight have a full primer on what to expect, November 24, 2015.

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