

Name of research institute or organization:

**Empa, Swiss Federal Laboratories for Materials Science and Technology**

Title of project:

Halogenated Greenhouse Gases at Jungfrauoch

Project leader and team:

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Project description:

Halogenated ozone-depleting substances (ODSs) and greenhouse gases (GHGs) have been monitored at Jungfrauoch since 2000. These measurements are combined with atmospheric transport models for identifying and quantifying national and regional emissions (Switzerland and neighboring countries). These "top-down" 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 these compounds in the "background" air. Measurements at Jungfrauoch comprise a suite of >50 compounds, such as chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), perfluorocarbons (PFCs and SF<sub>6</sub>), 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.

For the 2013 activities we chose to present results of the group of hydrofluorocarbons (HFCs). These are mainly used in refrigeration and foam blowing in substitution for the CFCs and HCFCs. The figures below show atmospheric abundances at Jungfrauoch and Cape Grim (Tasmania, southern hemisphere) as examples of semi-remote to remote stations. In addition, we started to conduct measurements at Empa/Dübendorf using the same GCMS-Medusa measurement technique as at Jungfrauoch. Our first plots in Figure 1 show HFC-32 (CH<sub>2</sub>F<sub>2</sub>), HFC-125 (CHF<sub>2</sub>CF<sub>3</sub>), HFC-134a (CH<sub>2</sub>FCF<sub>3</sub>), and HFC-143a (CH<sub>3</sub>CF<sub>3</sub>). These compounds are typically mixed into refrigerant blends (R-blends, e.g. R-404A). At Jungfrauoch, we observe frequent pollution events indicating their wide-spread use in Europe. The Cape Grim record shows also pollution events, albeit smaller in magnitude. These can be linked to air mass transport from the Port Phillip Bay area (Melbourne). By contrast, the Dübendorf site shows very large pollution events, which are presumably due to the nearby sources of these compounds. In fact, the Dübendorf record shows consistently higher mole fractions compared to Jungfrauoch, i.e. there are no events of 'background / baseline', indicating that these compounds are ubiquitous in the surrounding of this urban measurement site.

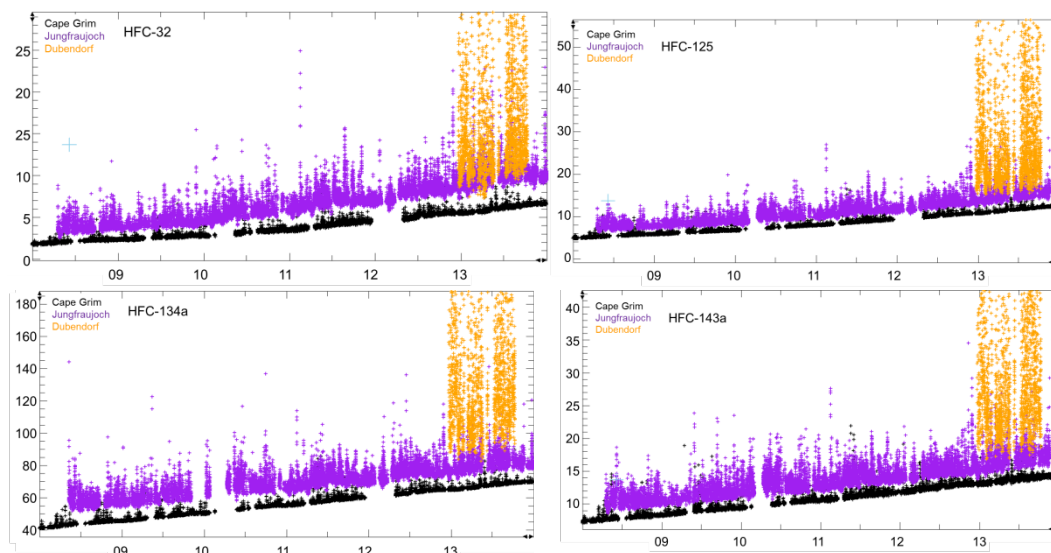


Figure 1. Atmospheric abundances of the refrigerant hydrofluorocarbons (HFC) HFC-32 (top left), HFC-125 (top right), HFC-134a (bottom left), and HFC-143a (bottom right) for 2008 -- 2013. The records are from Jungfrauoch (purple), Cape Grim (Tasmania, Australia, in black), and from the urban site Dübendorf (Switzerland, in yellow). The x-label defines years, the y-label dry-air mole fractions in parts per trillion (ppt). The plots show the general global increase of these compounds in the atmosphere, the interhemispheric difference, and the large mole fraction near the sources (Dübendorf).

By contrast, we show HFC-23 ( $\text{CHF}_3$ ) and HFC-236fa ( $\text{CF}_3\text{CH}_2\text{CF}_3$ ) in Figure 2. HFC-23, a by-product in the HCFC-22 ( $\text{CHClF}_2$ ) manufacture, has no other major known sources and hence the pollution events at Jungfrauoch (advected from the south, mainly from HCFC-22 production plants in northern Italy) are smaller in magnitude than those of the refrigerants in Figure 1. HFC-236fa is used in specialized cooling application and not permitted for use in Switzerland. It shows no significant pollution event at Jungfrauoch and Dübendorf. The global background of this compound is small but growing rapidly (on a relative basis), and is expected to continue to do so due to the long atmospheric lifetime of  $\sim 240$  yr.

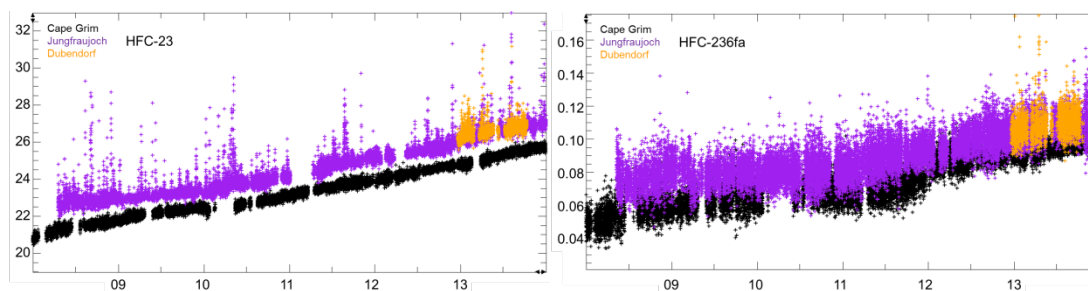


Figure 2. Same as Fig. 1 but for HFC-23 (left) and HFC-236fa (right). HFC-23, a by-product of the HCFC-22 manufacture, is seen in polluted air from the south. These compounds are not used in Switzerland and hence show smaller or no pollution events at the urban site of Dübendorf and the baseline values of Dübendorf match those at Jungfrauoch.

Our examples demonstrate the need and value of background stations for the measurements and quantification of halogenated trace gases. The location of Jungfrauoch and its air advection patterns allow for the detection of pollution events from large parts of Europe without significant disturbance by regional sources. In contrast, an urban site like Dübendorf is of limited value for measurements of locally emitted compounds, but allows for the detection of new compounds, through pollution events of nearby emitted substances, for which the background concentrations are yet too small to be detected at Jungfrauoch.

Key words:

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Halogenated ozone-depletion substances (ODS), greenhouse gases (GHG), F-gases, hydrofluorocarbons (HFCs)

Internet data bases:

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<http://empa.ch/abt503>; <http://agage.eas.gatech.edu>

Collaborating partners/networks:

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Bundesamt für Umwelt (BAFU) / Federal Office for the Environment (FOEN)  
Global Atmosphere Watch (GAW), World Meteorological Organization (WMO)  
Advanced Global Atmospheric Gases Experiment (AGAGE)

Scientific publications and public outreach 2013:

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**Refereed journal articles and their internet access**

Mahieu, E., R. Zander, G.C. Toon, M.K. Vollmer, S. Reimann, J. Muhle, W. Bader, B. Bovy, B. Lejeune, C. Servais, P. Demoulin, G. Roland, P.F. Bernath, C.D. Boone, K.A. Walker, and P. Duchatelet, Spectrometric monitoring of atmospheric carbon tetrafluoride (CF<sub>4</sub>) above the Jungfrauoch station since 1989: evidence of its continued increase but at a slowing rate, *Atmos. Meas. Tech.*, **6**, 7535-7563, doi:10.5194/amtd-6-7535-2013, 2013. <http://www.atmos-meas-tech-discuss.net/6/7535/2013/amtd-6-7535-2013.html>

Hall, B.D., A. Engel, J. Muhle, J.W. Elkins, F. Artuso, E. Atlas, M. Aydin, D. Blake, E.-G. Brunke, S. Chiavarini, P.J. Fraser, J. Happell, P.B. Krummel, I. Levin, M. Loewenstein, M. Maione, S.A. Montzka, S. O'Doherty, S. Reimann, G. Rhoderick, E.S. Saltzman, H.E. Scheel, L.P. Steele, M.K. Vollmer, R.F. Weiss, D. Worthy, Y. Yokouchi, Results from the International Halocarbon in Air Comparison Experiment (IHALACE), *Atmos. Meas. Tech.*, **6**, 8021-8069, doi:10.5194/amtd-6-8021-2013, 2013. <http://www.atmos-meas-tech-discuss.net/6/8021/2013/amtd-6-8021-2013.html>

Pieterse, G., M.C. Krol, A.M. Batenburg, C.A.M. Brenninkmeijer, M.E. Popa, S. O'Doherty, A. Grant, L.P. Steele, P.B. Krummel, R.L. Langenfelds, H.J. Wang, A.T. Vermeulen, M. Schmidt, C. Yver, A. Jordan, A. Engel, R.E. Fisher, D. Lowry, E.G. Nisbet, S. Reimann, M.K. Vollmer, M. Steinbacher, S. Hammer, G. Forster, W.T. Sturges, and T. Rockmann, Reassessing the variability in atmospheric H<sub>2</sub> using the two-way nested TM5 model, *J. Geophys. Res.*, **118**, 2003, doi: 10.1002/jgrd.50204, 2013. <http://onlinelibrary.wiley.com/doi/10.1002/jgrd.50204/abstract>

**Conference papers**

Vollmer, M.K. et al., Atmospheric histories and global emissions of the halons H-1211, H-1301, and H-2402, 47th AGAGE meeting, Seogwipo, Jeju, Korea, May 13, 2013.

Vollmer, M.K. et al., New compounds in the atmosphere, InGOS meeting, Bremen, Germany, March 12, 2013.

Reimann, S. et al., Re-evaluation of the lifetimes of ozone-depleting substances and related trace gases, EGU, Vienna, Austria, April 9, 2013.

Steinbacher, M. et al., The Global GAW Station Jungfrauoch --- Measurement programme and selected results, GAW 2013 Symposium, Geneva, Switzerland, March 18, 2013.

Hoerger, C.C. et al., ACTRIS Inter-laboratory comparison of VOCs in Europe: measurements of synthetic mixture and ambient air from pressurized cylinders, EGU, Vienna, Austria, April 9, 2013.

**Radio and television**

Reimann, S. (interview), HFC-1234yf: A new refrigerant for mobile air conditioners and its consequences, Radio Suisse Romande, 2013.

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