Name of research institute or organization:

Empa – Materials Science and Technology

Title of project:

Continuous measurement of stable CO_2 isotopes at Jungfraujoch, Switzerland

Project leader and team:

Lukas Emmenegger, project leader
Béla Tuzson
Stephan Henne

Project description:

The isotopic composition of atmospheric CO_2 is continuously measured *in-situ* at high temporal resolution (1s) using a quantum cascade laser based absorption spectrometer. This real-time measurement approach offers unprecedented insights into a wide range of processes and their atmospheric dynamics. The high temporal resolution allows capturing, in addition to seasonal variations and long-term trends, also variations on hourly and diurnal time scales. Furthermore, it permits combining the measurements with meteorology and relating the observations to high-resolution transport models, regional-scale ecosystem models, and regional-scale flux inversions (Figure 1).

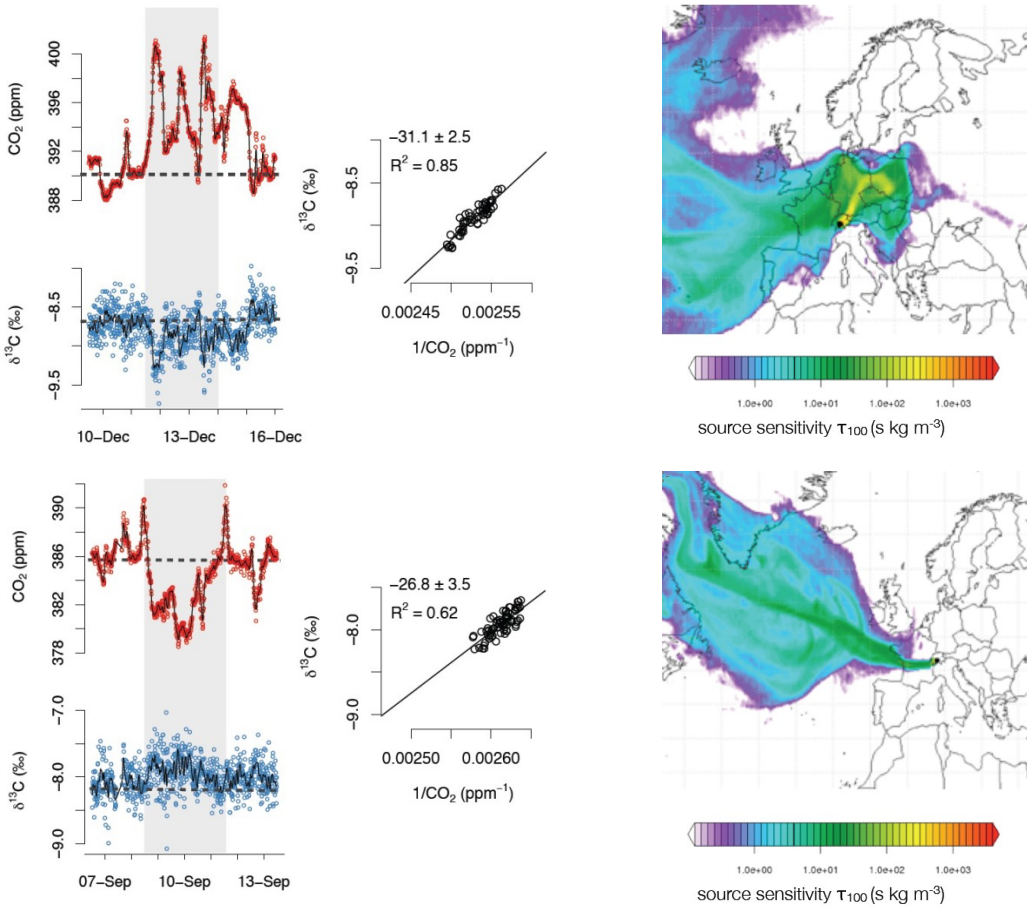

Figure 1. CO_2 source (top) and sink (bottom) processes captured at Jungfraujoch. The associated Keeling-plot indicates the isotopic signature of the process. The Flexpart Lagrangian model determines the origin of the air masses.

A close link between air composition and prevailing transport regimes has been established by using backward Lagrangian particle dispersion model simulations. This can explain much of the observed variability in terms of transport history and influence region.

The analysis of the CO_2 time-series reveals mean annual cycles with peak-to-peak amplitudes of 11 µmol·mol^{-1} for CO_2, 0.60 ‰ for $\delta^{13}C$ and 0.81 ‰ for $\delta^{18}O$ (Figure 2).

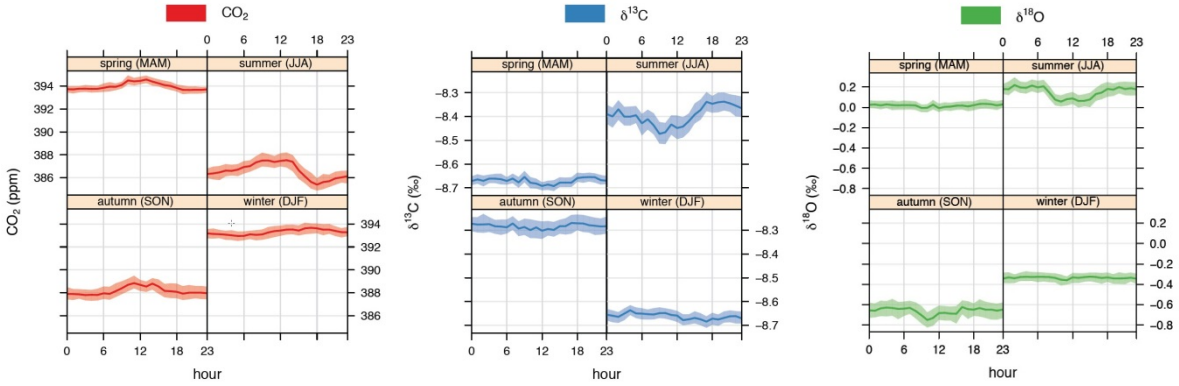

Figure 2. Overview of the data recorded since December 2008. Mean diurnal cycles of CO_2, and isotopic ratios of $\delta^{13}C$ and $\delta^{18}O$ for the different seasons are shown. The shaded area is the 95% confidence interval of the hourly mean.

For CO_2, the mean diurnal peak-to-peak amplitude is about 1 µmol·mol^{-1} in spring, autumn and winter, and about twice as high in summer. During summer, the mean amplitude reaches its maximum at midday, which quickly drops by about 2 µmol·mol^{-1} in the afternoon, most likely due to uplift of boundary layer air, which is depleted in CO_2 because of photosynthetic uptake. These observations are in line with the PBL influence that was established for other parameters. The diurnal variability is also seen in the isotope ratios, which is largest during the summer months, with an amplitude of 0.1 ‰ for both $\delta^{13}C$ and $\delta^{18}O$, and a smaller or not discernible diurnal cycle during the other seasons. The day-to-day variability, however, is much more pronounced and depends on the origin of the air masses arriving at Jungfraujoch.

Key words:

Isotope ratio measurements, carbon dioxide, laser spectroscopy, quantum cascade laser

Collaborating partners/networks:

Max-Planck-Institute for Biogeochemistry, Jena, Germany
ETHZ - Inst. for Quantum Electronics, Switzerland
Alpes Lasers SA, Switzerland
University of Berne, Switzerland

Scientific publications and public outreach 2013:

Refereed journal articles and their internet access

Sturm, P., B. Tuzson, S. Henne, and L. Emmenegger, Tracking isotopic signatures of CO_2 at the high altitude site Jungfraujoch with laser spectroscopy: analytical improvements and representative results, Atmos. Meas. Tech., 6, 1659-1671, doi: 10.5194/amt-6-1659-2013, 2013.
http://www.atmos-meas-tech.net/6/issue7.html

Conference papers

Tuzson, B., P. Sturm, S. Henne, and L. Emmenegger, Mid-IR quantum cascade laser based spectrometer for isotope ratio measurements of tropospheric CO_2, 41st Freiburg Infrared Colloquium, Freiburg, Germany, February 26-27, 2013.

Emmenegger, L., B. Tuzson, P. Sturm, M. Mangold, and S. Henne, Four years of laser based $\delta^{18}O$ and $\delta^{13}C$-CO_2 monitoring in the free troposphere, European Geophysical Union (EGU), Vienna, Austria, March 07-12, 2013.

Emmenegger, L., B. Tuzson, P. Sturm, M. Mangold, and S. Henne, Tracking stable CO_2 isotopes with QCL spectroscopy at Jungfraujoch, Goldschmidt 2013, Florence, Italy, August 25-30, 2013.

Emmenegger, L., B. Tuzson, P. Sturm, M. Mangold, and S. Henne, Recent advances in QC laser spectroscopy for ambient air monitoring, International Conference on THz and Mid Infrared Radiation and Applications to Cancer Detection Using Laser Imaging, Sheffield, UK, October 10-11, 2013.

Tuzson, B., M. Mangold, P. Sturm, S. Henne, H. Looser, Y. Bonetti, J. Faist, and L. Emmenegger, Frontiers of isotope ratio measurements and the first analyzers fully based on QC technology, Mid-Infrared Coherent Sources (MICS), Paris, France, October 27-November 02, 2013.

Address:

Empa
Laboratory for Air Pollution and Environmental Technology
Überlandstrasse 129
CH-8600 Dübendorf

Contacts:

Lukas Emmenegger
Tel.: +41 58 765 4699
Fax: +41 58 765 6244
e-mail: lukas.emmenegger@empa.ch
URL: http://empa.ch/abt134