Continuous measurement of stable CO_2 isotopes at Jungfraujoch, Switzerland

Simone M. Pieber[1], Béla Tuzson[1], Martin Steinbacher[1], Lukas Emmenegger[1]

[1] Laboratory for Air Pollution and Environmental Technology (Empa), Duebendorf, Switzerland

simone.pieber@empa.ch; bela.tuzson@empa.ch

Part of this programme: GAW, ICOS, RINGO

Keywords: stable CO_2 isotopes; quantum cascade laser absorption spectroscopy

---

1. Project description

Long-term observations of carbon dioxide (CO_2) provide direct information about their variability and rate of change in the atmosphere. Co-located observations of stable CO_2 isotope ratios add unique information on the CO_2 fluxes between the different pools involved in the carbon cycle owing to isotopic fractionation during environmental processes. Atmospheric CO_2 concentration and its stable isotope ratios ($\delta^{13}C$ and $\delta^{18}O$) are measured continuously and simultaneously by online quantum cascade laser absorption spectroscopy (QCLAS) since December 2008 at the Jungfraujoch research station as previously described (Tuzson et al., 2008 and 2011; Sturm et al. 2013). The data are available as 10 min averages and enable the analysis of variations at hourly and diurnal time-scales. Thereby, they allow insights on isotopic signatures from specific anthropogenic pollution and biospheric depletion events, which can be allocated to specific source/sink regions using backward Lagrangian particle dispersion modelling (Stohl et al., 2005). Further, the high data density also allows reliable determination of background conditions (Ruckstuhl et al., 2012; Herrmann et al., 2015). Here, we present seasonal trends obtained from a decade of continuous data records combined with statistical background filtering.

2. Results

Figure 1 presents the seasonal trend at background conditions for CO_2, $\delta^{13}C$ and $\delta^{18}O$ as monthly averages and parametric fit of data, which were corrected for the underlying long-term trends. Background filtering was applied to select a subset of the data. For this purpose, various filters were tested, following suggestions by Herrmann et al., 2015. These included chemical, meteorological, and statistical approaches. Here, we present data selected by statistical filtering as described by Ruckstuhl et al., 2012, since it yielded higher data coverage compared to chemical and meteorological filtering. Long-term trend subtraction as well as parametric fitting with four harmonics was performed through non-linear least squares regression analysis (Thoning et al., 1989). The trends indicate a strict anti-correlation of CO_2 and $\delta^{13}C$ concerning their maximum and minimum, and a phase-shift for the maximum and minimum in $\delta^{18}O$ compared to the other two species.

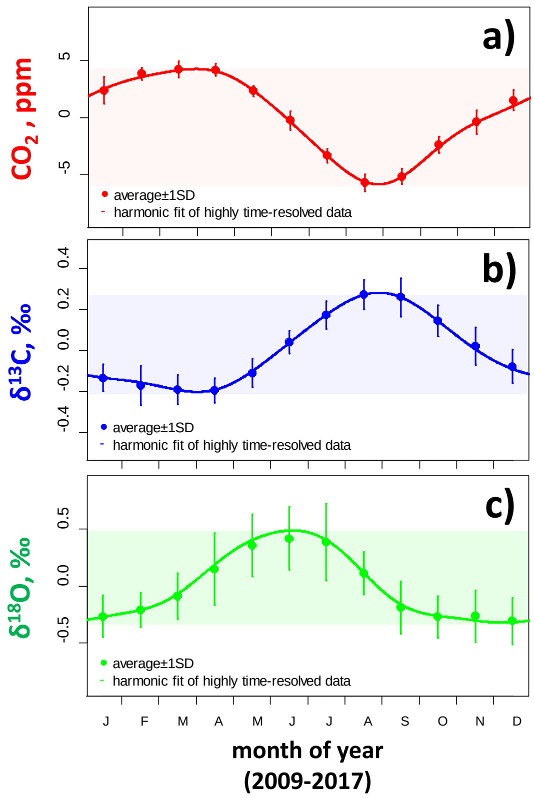

Figure 1. Seasonal variation of a) CO_2, b) $\delta^{13}C$ and c) $\delta^{18}O$ presented as monthly averages (±1 standard deviation) and parametric harmonic fit of de-trended continuous data collected in the period 2009-2017. Isotope data are referenced to the Vienna Pee Dee Belemnite (VPDB) scale. Shaded areas indicate maximum and minimum. The SD represents the year-to-year variability of de-trended data (i.e. the long-term-trend is subtracted and thereafter data are first aggregated to hourly, daily and monthly averages per year and then averaged over the whole period 2009-2017). Harmonic fitting of continuous data was performed on 10 min averages at statistical background conditions.

3. Conclusions and Outlook

Real-time observations allow for robust estimation of seasonal cycles. Further, real-time observations have additional value by capturing hourly and diurnal variations and thereby providing additional insights into the dynamics of atmospheric CO_2. Ongoing classification and clustering of the data based on atmospheric transport model simulations is aiming at determining the isotopic signatures of pollution and depletion events and associated implications for the sources and sinks of CO_2.

References

Herrmann, E., Weingartner, E., Henne, S., Vuilleumier, L., Bukowiecki, N., Steinbacher, M., Conen, F., Coen, M. C., Hammer, E., Jurányi, Z., Baltensperger, U. and Gysel, M: Analysis of long-term aerosol size distribution data from Jungfraujoch with emphasis on free tropospheric conditions, cloud influence, and air mass transport. JGR, **120**, 9459-9480, doi: 10.1002/2015JD023660, 2015.

Ruckstuhl, A. F., Henne, S., Reimann, S., Steinbacher, M., Vollmer, M. K., O'Doherty, S., Buchmann, B. and Hueglin, C: Robust extraction of baseline signal of atmospheric trace species using local regression. AMT, **5**, 2613-2624, doi: 10.5194/amt-5-2613-2012, 2012.

Stohl, A., Forster, C., Frank, A., Seibert, P., and Wotawa, G.: Technical note: The Lagrangian particle dispersion model FLEXPART version 6.2, ACP, **5**, 2461-2474, doi: 10.5194/acp-5-2461-2005, 2005.

Sturm, P., Tuzson, B., Henne, S. and Emmenegger, L: Tracking isotopic signatures of CO_2 at the high altitude site Jungfraujoch with laser spectroscopy: Analytical improvements and representative results. AMT, **6**, 1659-1671, doi: 10.5194/amt-6-1659-2013, 2013.

Thoning, K.W., Tans, P.P., Komhyr, W.D.:Atmospheric carbon dioxide at Mauna Loa Observatory: 2. Analysis of the NOAA GMCC data, 1974–1985. JGR: Atmosphere D6, **95**, 8549-8565, doi: 10.1029/JD094iD06p08549, 1989.

Tuzson, B., Henne, S., Brunner, D., Steinbacher, M., Mohn, J., Buchmann, B. and Emmenegger, L: Continuous isotopic composition measurements of tropospheric CO_2 at Jungfraujoch (3580 m a.s.l.), Switzerland: Real-time observation of regional pollution events. ACP, **11**, 1685-1696, doi: 10.5194/acp-11-1685-2011, 2011.

Tuzson, B., Mohn, J., Zeeman, M. J., Werner, R. A., Eugster, W., Zahniser, M. S., Nelson, D. D., McManus, J. B. and Emmenegger, L: High precision and continuous field measurements of $\delta^{13}C$ and $\delta^{18}O$ in carbon dioxide with a cryogen-free QCLAS. Appl. Phys. B, **92**, 451-458, doi: 10.1007/s00340-008-3085-4, 2008.

Internet data bases

http://www.empa.ch
http://empa.ch/web/s503/laser
https://www.icos-ri.eu/

Collaborating partners / networks

Institut für Umweltgeowissenschaften, University of Basel
Climate and Environmental Physics, University of Bern
Max Planck Institute for Biogeochemistry, Jena, Germany
GAW – Global Atmosphere Watch
ICOS – Integrated Carbon Observation System
RINGO – Readiness of ICOS for Necessities of integrated Global Observations

Scientific publications and public outreach 2018

Conference Papers

Pieber S.M., D. Brunner, S. Henne, M. Steinbacher, B. Tuzson and L. Emmenegger, A decade of continuous atmospheric CO_2 isotope ratio measurements at Jungfraujoch, Swiss Geoscience Meeting, Bern, Switzerland, December 1, 2018.

Address

Laboratory for Air Pollution and Environmental Technology
Empa
CH-8600 Duebendorf
Switzerland

Contacts

Dr. Simone M. Pieber
Tel.: +41 58 765 4397
e-mail: simone.pieber@empa.ch

Dr. Béla Tuzson
Tel.: +41 58 765 4642
e-mail: bela.tuzson@empa.ch

Dr. Lukas Emmenegger
Tel.: +41 58 765 4699
e-mail: lukas.emmenegger@empa.ch