Name of research institute or organization:

Climate and Environmental Division, Physics Institute, University Bern

Title of project:

High precision carbon dioxide and oxygen measurements at Jungfraujoch

Part of this programme:

ICOS, GAW, Obspack, Globalview

Project leader and team:

Prof. Dr. Markus Leuenberger, project leader
Michael Schibig, Peter Nyfeler, Hanspeter Moret and Tesfaye Berhanu

Project description:

Combined online CO_2 and O_2 measurements at Jungfraujoch were continued and trends were updated for the period 2005 to 2015 which resulted in a CO_2 increase rate of 2.17 ± 0.09 ppm y^{-1} and a $\delta O_2/N_2$ decrease rate of -24.3 ± 1.3 per meg y^{-1}, respectively (Figure 1).

Because of the non-linearity of the NDIR analyzer, the CO_2 calibration in the database was reprogrammed. Now the ppm-output of the NDIR analyzer is first converted back to a mV signal based on the coefficients used in the basic calibration of the device. Afterwards, this mV signal is calibrated with the low span, the high span, and the working gas. If the CO_2 mole fractions of the three standard gases are distant enough, a polynomial approach is used, otherwise the previously used linear approach is applied. With the polynomial approach, the small non-linarity effects of the NDIR analyzer will be damped.

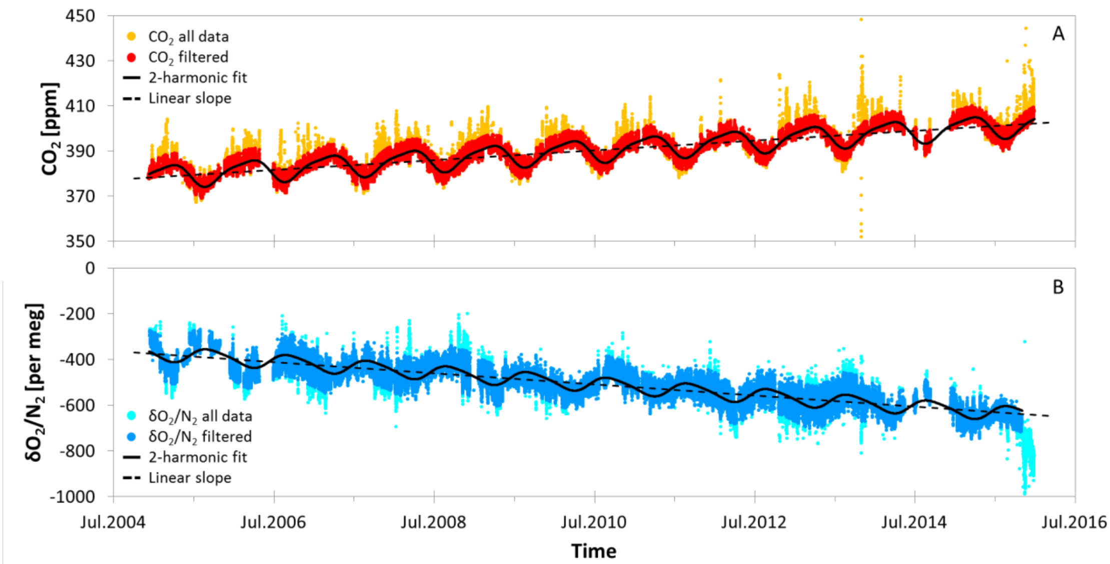

Figure 1. A: Unfiltered CO_2 in-situ measurements (orange), filtered CO_2 in-situ measurements (red), 2-harmonic fit with slope (black) as a function of time, and linear CO_2 increase (black dashed) as a function of time; B: Unfiltered $\delta O_2/N_2$ in-situ measurements (cyan), filtered O_2 in-situ measurements (blue), spline fit (black) as a function of time, and linear $\delta O_2/N_2$ decrease (black dashed) as a function of time.

In 2015, we faced only a few problems with the online system. In summer 2015 it was discovered, that the keyboard of the NDIR analyzer wasn't working anymore, which made it impossible to check and change the settings of the analyzer. Since it wasn't possible to repair the analyzer at Jungfraujoch, it was decided to change the device with a spare analyzer, which was done in September 2015. Unfortunately, the short-term precision of the replacement unit is inferior compared with the old one, however the accuracy on hourly averages is equivalent. The old analyzer was sent to the manufacturer (Sick Maihak) for repair and will be reinstalled in February 2016.

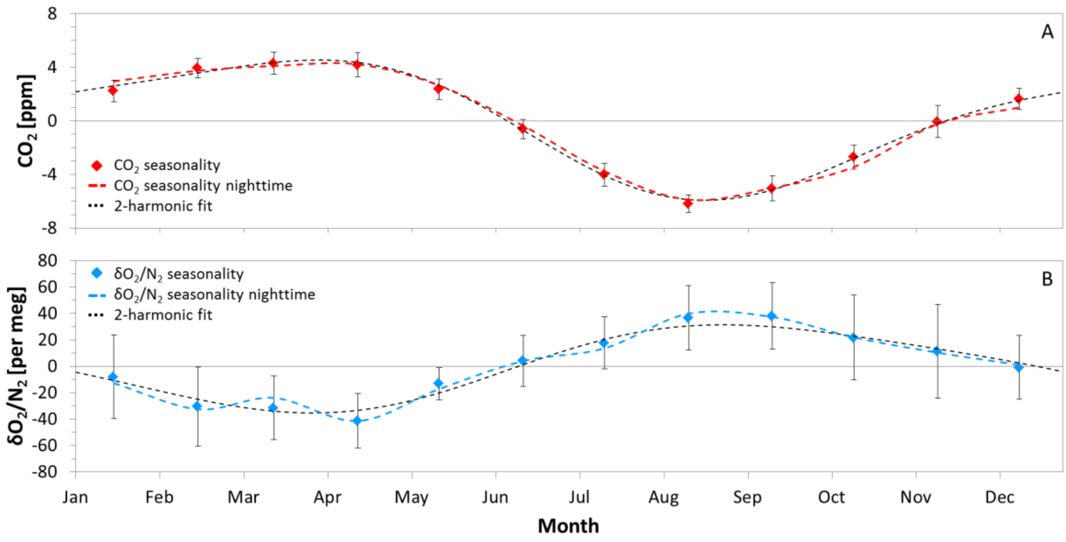

Figure 2. A: Monthly mean CO_2 seasonalities at Jungfraujoch for the period 2005 to 2015 for all samples (red diamonds), nighttime values only (red dashed line), and the 2-harmonic fit (black dashed line); B: Monthly mean $\delta O_2/N_2$ seasonalities at Jungfraujoch for the period 2005 to 2015 for all samples (blue diamonds), nighttime values only (blue dashed line), and the 2-harmonic fit (black dashed line).

In November 2013, a working gas cylinder change followed by a pump change led to some enhanced noise in the CO_2 signal and a drop in the $\delta O_2/N_2$ of the ambient air, which is why these measurements of this period are presently excluded from the background values. As soon as it is possible to correct these effects properly, they will be included again.
The seasonal amplitudes for CO_2 and $\delta O_2/N_2$ are 10.5 ± 1.0 (10.1 ± 1.3) ppm and 80 ± 32 (81 ± 41) per meg for all and nighttime only (in paranthesis) in-situ data, respectively (Figure 2).

Also the flask sampling at Jungfraujoch was continued and trends were updated for the period 2000 to 2015 which resulted in a CO_2 increase rate of 1.94 ± 0.1 ppm y^{-1}, a $\delta O_2/N_2$ decrease rate of -25.3 ± 1.5 per meg y^{-1}, and a $\delta^{13}C$ of CO_2 decrease rate of -0.023 ± 0.007 ‰ y^{-1}, respectively (Figure 3). The trends of the flask measurements are in good agreement with the online measurements. The seasonalities based on the data of the flask measurements were 9.34 ± 2.4 ppm, 73 ± 75 per meg, and 0.51 ± 0.23 ‰ for CO_2, $\delta O_2/N_2$, and $\delta^{13}C$ of CO_2, respectively (Figure 4). These values are slightly lower than the seasonality calculated based on the measurements of the online system.

In 1982, a flight campaign took place over the Swiss plateau where samples were taken in different heights. Their CO_2 content was measured by a laser spectroscope as well as with CO_2 extraction (Friedli et al, 1987). In 1988, air samples were taken at Jungfraujoch and again the air samples' CO_2 contents were measured by CO_2 extraction. Adding the flight measurements from 3000-4000 m a.s.l. and the measurements of the Jungfraujoch samples from 1988 to the actual filtered flask dataset shows that the old measurements fit quite well with the 2-harmonic fit of the actual flask dataset. However, the slightly lower values of the linear slope of the flask measurements compared with the CO_2 values from the 80's indicate growing CO_2 emissions over time (Figure 5).

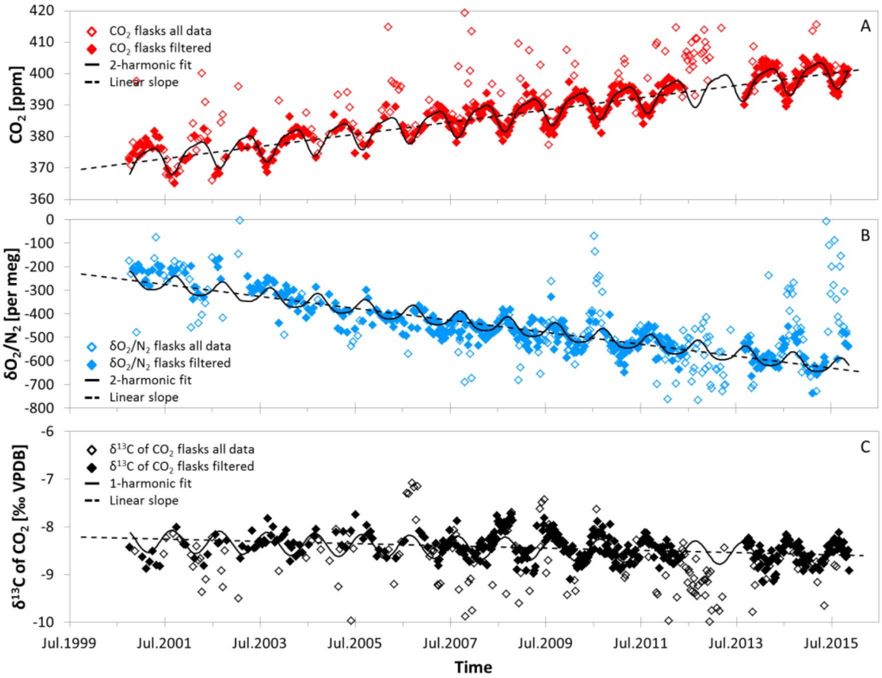

Figure 3. Flask measurements from Jungfraujoch for the period 2000 to 2015. A: CO_2 for all samples (open red diamonds), background values (full red diamonds), 2-harmonic fit (black line) and linear slope (black dashed line); B: $\delta O_2/N_2$ for all samples (open blue diamonds), background values (full blue diamonds), 2-harmonic fit (black line) and linear slope (black dashed line); C: $\delta^{13}C$ of CO_2 for all samples (open black diamonds), background values (full black diamonds), 1-harmonic fit (black line,) and linear slope (black dashed line).

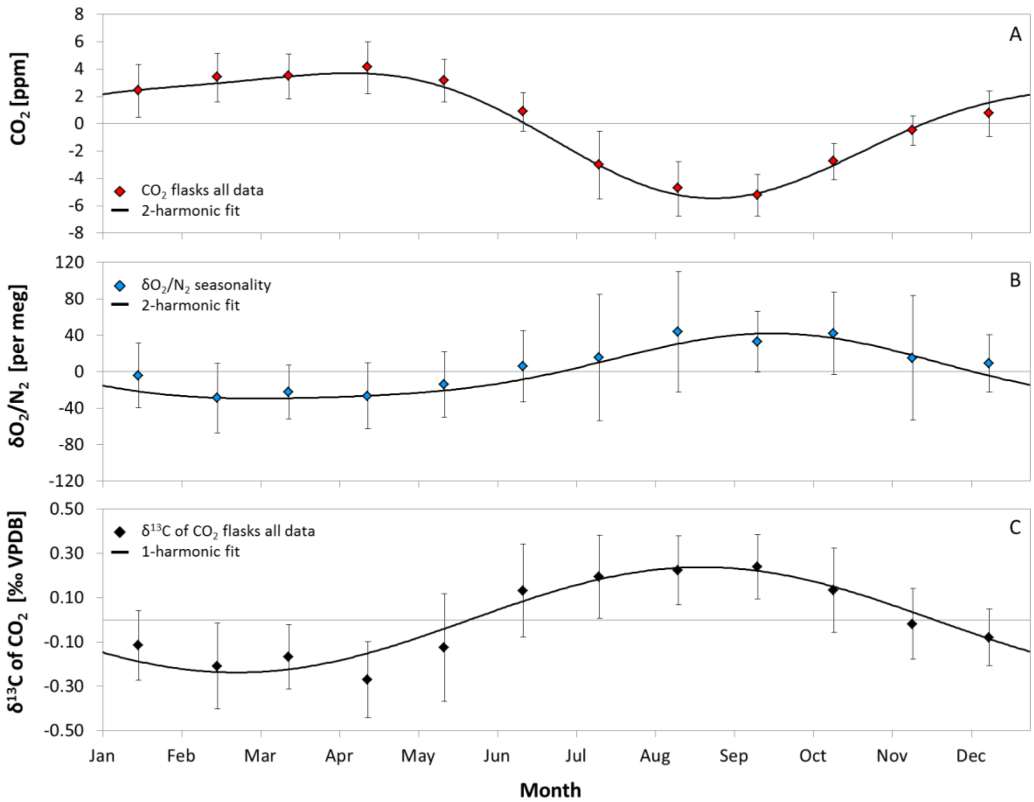

Figure 4. Seasonality based on flask measurements from Jungfraujoch for the period 2000 to 2015. A: Seasonality of CO_2 (red diamonds) and 2-harmonic fit (black line); B: Seasonality of $\delta O_2/N_2$ (blue diamonds) and 2-harmonic fit (black line); C: Seasonality of $\delta^{13}C$ of CO_2 (black diamonds), and 1-harmonic fit (black line).

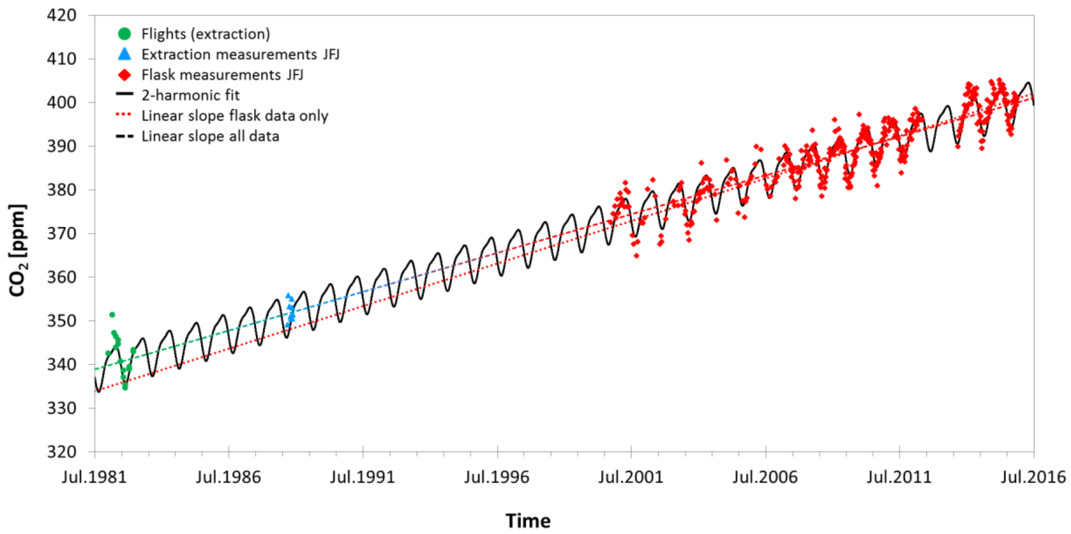

Figure 5. CO_2 extraction measurements of samples from a flight campaign in 1982 above the Swiss plateau at heights from 3000-4000 m a.s.l. (green dots); CO_2 extraction measurements of samples from Jungfraujoch obtained in 1988 (blue triangles); CO_2 background values of flask measurements sampled at Jungfraujoch from 2000 to 2015 (red diamonds), 2-harmonic fit of the flask samples (black line), linear slope of the flask samples (red dashed line), and linear slope of all data points (gradient dashed line).

References:

Friedli, H., U. Siegenthaler, D. Rauber, and H. Oeschger, Measurements of concentration, $^{13}C/^{12}C$ and $^{18}O/^{16}O$ ratios of tropospheric carbon dioxide over Switzerland, Tellus B, 39B (1-2), 80-88, 1987.

Key words:

Greenhouse gas, climate change, CO_2 emissions

Internet data bases:

The Jungfraujoch data can be downloaded from our homepage (http://www.climate.unibe.ch/?L1=research&L2=atm_gases) or from the WMO GAW: World Data Centre for Greenhouse Gases (http://ds.data.jma.go.jp/gmd/wdcgg/cgi-bin/wdcgg/accessdata.cgi?index=JFJ646N00-KUP&select=inventory)

Collaborating partners/networks:

ICOS partners, Globalview, Obspack, Swiss GCOS office, EMPA, University of Groningen, the Netherlands, MPI BGC Jena, Germany

Scientific publications and public outreach 2015:

Refereed journal articles and their internet access

Schibig, M. F., M. Steinbacher, B. Buchmann, I.T. van der Laan-Luijkx, S. van der Laan, S. Ranjan, and M.C. Leuenberger, Comparison of continuous in-situ CO_2 observations at Jungfraujoch using two different measurement techniques, Atmos. Meas. Tech., **8**, 57-68, doi: 10.5194/amt-8-57-2015, 2015. http://www.atmos-meas-tech.net/8/57/2015/amt-8-57-2015.html

Leuenberger, M. C., M.F. Schibig, and P. Nyfeler, Gas adsorption and desorption effects on cylinders and their importance for long-term gas records, Atmos. Meas. Tech, **8**, 5289-5299, doi: 10.5194/amt-8-5289-2015, 2015. http://www.atmos-meas-tech.net/8/5289/2015/amt-8-5289-2015-discussion.html

Conference papers

Leuenberger, M., M. Schibig, T. Berhanu, P. Nyfeler and H. Moret, APO variations in Central Europe obtained at the Jungfraujoch Research Station, Switzerland in comparison to a combined record of Scripps La Jolla and Alert values, in APO Workshop, Scripps Institution of Oceanography, Abstracts, La Jolla, USA, September 18-20, 2015.

Leuenberger, M., M. Schibig, T. Berhanu, P. Nyfeler and H. Moret, APO variations in Central Europe obtained at the Jungfraujoch Research Station, Switzerland in comparison to a combined record of Scripps La Jolla and Alert values, in *VAO Symposium 2015 Abstracts*, p. 64, Salzburg, Austria, October 27-30, 2015.

Theses

Schibig, M., Carbon and oxygen cycle related atmospheric measurements at the terrestrial background station Jungfraujoch, PhD thesis, Bern, pp. 144, 2015.

Data books and reports

Leuenberger M., WMO World Data Centre for Greenhouse Gases, c/o Japan Meteorological Agency 1-3-4, Otemachi, Chiyoda-kuTokyo 100-8122, Japan, CO_2 Data from Jungfraujoch (2015).

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