High precision carbon dioxide and oxygen measurements at Jungfraujoch

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1. Project description

Oxidation ratios of different processes like photosynthesis, respiration or fossil fuel combustion are relatively stable over time. Therefore, combined CO_2 and O_2 measurements can be used to determine how much of the emitted CO_2 is taken up by the ocean and the biosphere and how much stays in the atmosphere.

The in-situ CO_2 and O_2 measurements were continued throughout the whole year with some minor interruptions due to technical issues and one long gap from the end of April until the beginning of June due to renovation works at the Sphinx observatory. The increase of CO_2 and corresponding decrease of O_2 due to fossil fuel combustion were observed in 2021, too, modulated by a seasonal cycle mainly due to photosynthesis and respiration of the biosphere. To calculate the annual changes and the seasonality of atmospheric CO_2 and O_2 at Jungfraujoch, only night-time values (22:00-3:59 UTC) were used because they represent mostly background air from the free troposphere. Months with a coverage of less than 50 % were excluded from further calculations. The trends for CO_2 and O_2 from 2005 to 2021 were calculated to be 2.28 ± 0.03 ppm yr^{-1} and -23.3 ± 0.4 per meg yr^{-1}, respectively (Figure 1). The average seasonal amplitude of CO_2 over this period was 10.92 ± 1.14 ppm with a maximum in March/April and a minimum in August. Because the CO_2 and the O_2 cycles are coupled via the biosphere, the seasonality of CO_2 is mirrored by the seasonality of O_2 and shows a minimum in April and a maximum in August with an amplitude of 100.9 ± 30.4 per meg (Figure 2).

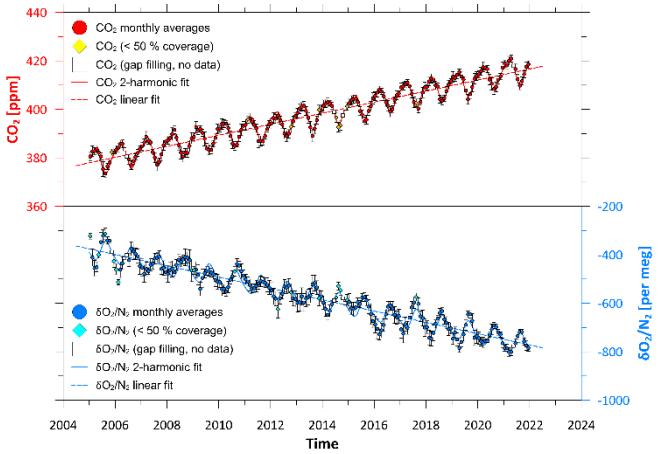

Figure 1. Monthly averages of the CO_2 (upper panel) and O_2 (lower panel) measurements from Jungfraujoch (Sphinx) calculated by using hourly means (22:00-3:59 UTC) from 2005 to 2021. The red (CO_2) and blue (O_2) dots mark months with a coverage better than 50 %, the yellow (CO_2) and cyan (O_2) diamonds correspond to months where the coverage is less than 50 %, the empty squares represent months with no measurements at all. The values of months with no coverage were calculated using 2-harmonic fit functions, which are represented by the red (CO_2) and blue (O_2) lines, the red (CO_2) and blue (O_2) dashes lines indicate the annual linear increase.

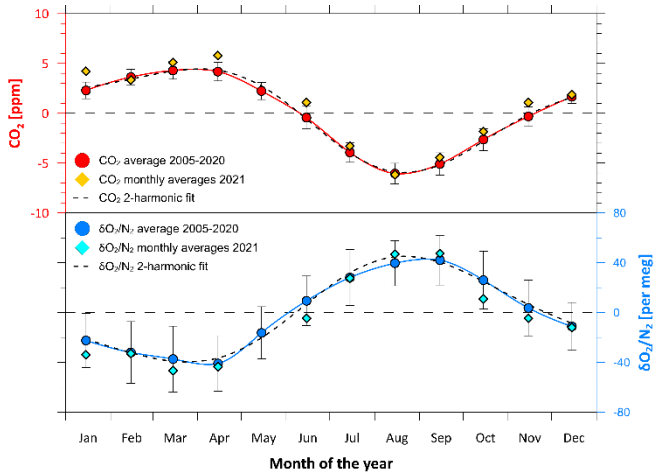

Figure 2. Seasonality of CO_2 (upper panel) and O_2 (lower panel) at Jungfraujoch (Sphinx). The orange and cyan diamonds represent the monthly averages of the detrended CO_2 and O_2 measurements in 2021 based on the filtered hourly means between 22:00 and 3:59 UTC. The red (CO_2) and blue (O_2) line with the dots show the average seasonality over the years 2005-2020 with their standard deviation, which follows very close the 2-harmonic fit function calculated based on the data from 2005 to 2020 indicated by black dashed lines.

Supplementing the CO_2 and O_2 measurements from Jungfraujoch with the most recent CO_2 emissions data (Friedlingstein et al., 2021) yielded an oceanic and biospheric CO_2 sink of 3.2 ± 0.6 Gt C y^{-1} and 2.4 ± 0.7 Gt C y^{-1}, respectively, 4.8 ± 0.7 Gt C y^{-1} remained in the atmosphere. This means that about 31 ± 6.0 % of the emitted CO_2 is taken up by the ocean, 23 ± 6.3 % goes into the biosphere and 46 ± 0.3 % stays in the atmosphere, where it contributes to the radiative forcing.

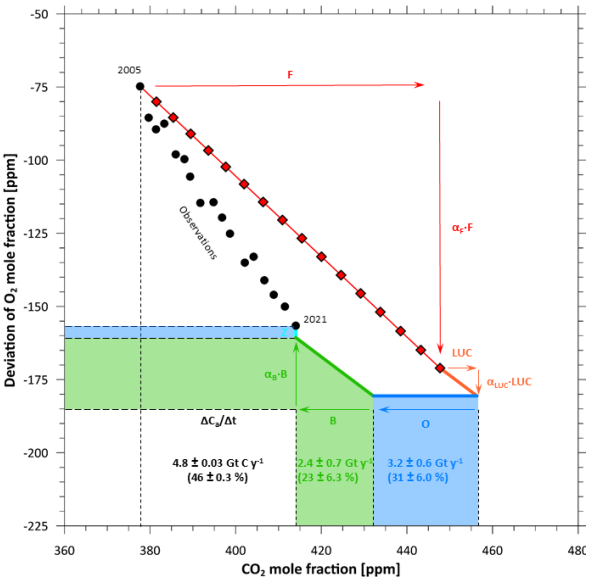

Figure 3. Partitioning based on the CO_2 and O_2 measurements at Jungfraujoch from 2005 to 2021. With the deviation of O_2 from a standard on the y-axis and CO_2 changes on the x-axis. The black dots represent the measurements, the red diamonds and the brown line show the expected atmospheric CO_2 increase and O_2 decrease due to fossil fuel combustion (F) and land use change (LUC) based on the emissions data and their respective oxidation ratios α_F and α_{LUC}. The blue line indicates the oceanic CO_2 uptake (O), the cyan line the oceanic O_2 outgassing (Z) and the green line represents the biospheric CO_2 uptake (B) based on the oxidation ratio α_B.

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Internet data bases

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Collaborating partners / networks

ICOS, ICOS-CH-partners
GAW, GAW-CH
Cooperative Global Atmospheric Data Integration Project; (2019): Multi-laboratory compilation of atmospheric carbon dioxide data for the period 1957-2018; obspack_co2_1_GLOBALVIEWplus_v5.0_2019_08_12; NOAA Earth System Research Laboratory, Global Monitoring Division http://dx.doi.org/10.25925/20190812.
SwissGCOS (Roundtables)
EMPA (Laboratory for Air Pollution / Environmental Technology)
MPI BGC Jena (Dr. Armin Jordan and staff members)
ICOS-ICOS - Flask and Calibration Laboratory
Technologie Center Felsenkeller (TCF), Jena, Germany
GLOBALVIEW, ObsPack

Scientific publications and public outreach 2021

Refereed journal articles and their internet access

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Conference Papers

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Magazine and Newspaper articles

World Meteorological Organization, WMO Greenhouse Gas Bulletin - No. 17: The State of Greenhouse Gases in the Atmosphere Based on Global Observations through 2020, October 25, 2021.

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