

Continuous records of the greenhouse gas data (CO₂, CH₄, N₂O) and their radiative forcing since the penultimate glacial maximum



Peter Köhler¹, Christoph Nehrbass-Ahles², Jochen Schmitt², Thomas F. Stocker², and Hubertus Fischer²

¹: Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (AWI), 27515 Bremerhaven, Germany

²: Climate and Environmental Physics, Physics Institute, and Oeschger Centre for Climate Change Research, University of Bern, Switzerland



Motivation

Continuous records of the atmospheric greenhouse gases (GHGs) CO₂, CH₄, and N₂O are necessary input data for transient climate simulations and their related radiative forcing important components in analyses of climate sensitivity and feedbacks. Since the available data from ice cores are discontinuous and partly ambiguous a well-documented decision process during data compilation followed by some interpolating post-processing are necessary to obtain those desired time series. Here we document our best-guess data compilation of published ice core records and recent measurements on firn air and atmospheric samples covering the time window from the penultimate glacial maximum (~156 kyr BP) to the beginning of year 2016 CE. A smoothing spline method is applied to translate the discrete and irregularly spaced data points into continuous time series. These splines are assumed to represent the evolution of the atmospheric mixing ratios for the three GHGs.

Summary

Global-mean radiative forcing for each GHG is computed using well-established, simple formulations. Newest published age scales are used for the ice core data. While CO₂ is representing an integrated global signal, we compile only a southern hemisphere record of CH₄ and identify how much larger a northern hemisphere or global CH₄ record might have been due to its inter-hemispheric gradient. Temporal resolution and uncertainties of the data points are used in the calculation of a smoothing spline. Typical cutoff periods, defining the degree of smoothing, range from 5000 years for the less resolved older parts of the records to 4 years for the densely-sampled recent years. The data sets describe seamlessly the GHG evolution on orbital and millennial time scales for glacial and glacial-interglacial variations and on centennial and decadal time scales for anthropogenic times.

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Data connected with this paper, including raw data and final splines, are available at <https://doi.pangaea.de/10.1594/PANGAEA.871273>.

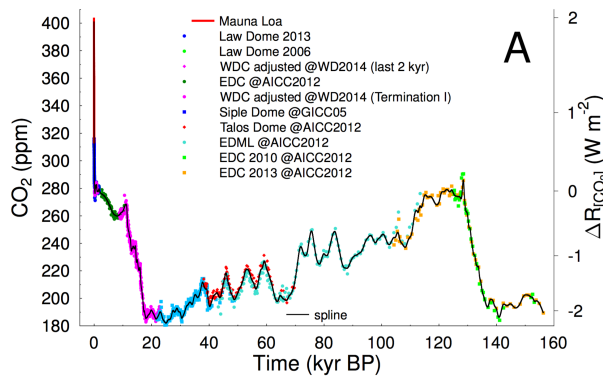


Figure 1. CO₂ spline covering all data: 2016 CE - 156,307 BP. WDC data have been adjusted to reduce offsets, see text for details. The right axis contains the resulting radiative forcing $\Delta R_{CO_2} = 5.35 \cdot \ln(CO_2 / (278 \text{ ppm})) \text{ W m}^{-2}$ calculated after Myhre et al. (1998).

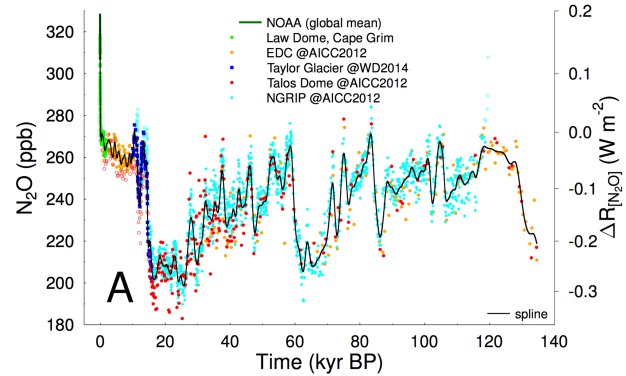


Figure 3. N₂O spline covering all data: 2016 CE - 134,519 BP. Details on plotted data are explained in the text. The right axis contains the resulting radiative forcing approximated with $\Delta R_{N_2O} \sim 0.12 \cdot ((N_2O / \text{ppb}) - 272) \text{ W m}^{-2}$ after Myhre et al. (1998), neglecting interacting effects of CH₄ and N₂O. Filled symbols: data taken for spline; open symbols: data not taken for spline.

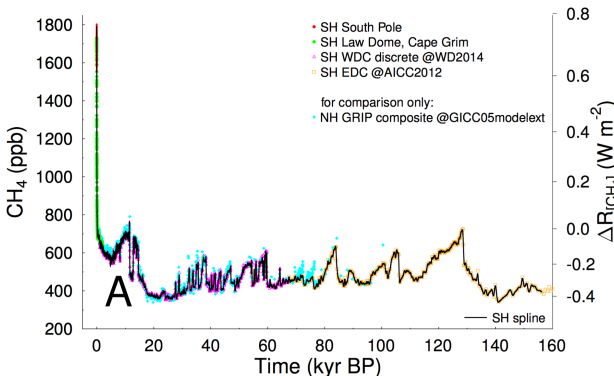


Figure 2. CH₄ spline covering all data: 2016 CE - 156,211 BP. Details on plotted data are explained in the text. The right axis contains the resulting radiative forcing approximated with $\Delta R_{CH_4} \sim 1.4 \cdot 0.036 \cdot ((CH_4 / \text{ppb}) - 742) \text{ W m}^{-2}$ based on Myhre et al. (1998), but neglecting interacting effects of CH₄ and N₂O, and considering indirect effects of CH₄ on stratospheric H₂O and tropospheric O₃ (Hansen et al., 2005; Köhler et al., 2010). Latitudinal origin of data is indicated by NH and SH, implying northern and southern hemisphere, respectively.

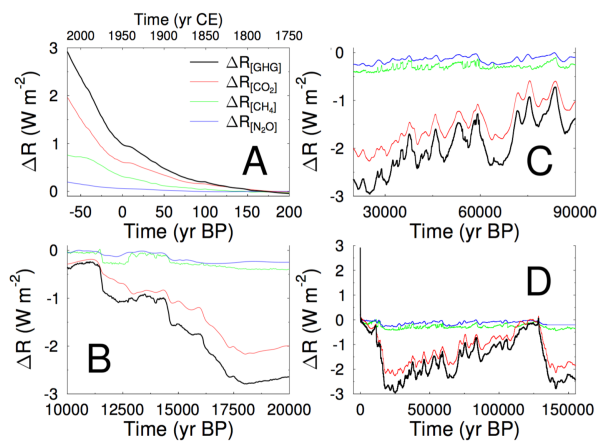


Figure 4. Calculated radiative forcing of CO₂, CH₄, N₂O, and of their sum (ΔR_{GHG}). The calculations are based on the Eqns. given in the captions to Figures 1-3 (following Myhre et al., 1998). Sub-panels focus on specific time windows: (A) Anthropogenic rise since 1750 CE; (B) Termination I; (C) 20-90 kyr BP including the abrupt changes during D/O event; (D) Full record from 2016 CE to 156 kyr BP, here N₂O was kept constant beyond 134 kyr BP.

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