

About the characteristics of delta¹⁸O in combustion derived CO₂

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Background

From the ratio of ¹⁸O/¹⁶O in atmospheric CO₂ one can distinguish different exchange processes, in which the background value is determined by the oxygen exchange with oceanic water. With focus on environmental conceptual formulations delta¹⁸O in CO₂ can be used to quantify the gross carbon flux of the terrestrial biosphere (Yakir and Sternberg, 2000), because of different signals obtained from assimilation and respiration. Furthermore, the release of CO₂ from the combustion of fossil fuel and from biomass burning contributes also to the atmospheric CO₂ content. However, the ¹⁸O source term from combustion processes is not known sufficient yet. In model investigations simulating the carbon cycle a general δ¹⁸O of -17‰ is used for combustion derived CO₂ (e.g. Clais et al., 1997), corresponding to an unfractionated transfer of atmospheric molecular oxygen into CO₂ (Kroopnick and Craig, 1972).

Attracted by field observations our hypothesis is that distinct different isotopic signatures are established during combustion, effected inter alia by two reasons: 1) The oxygen involved in the CO₂ formation emanates from different sources, namely from the atmosphere and from the burned material itself. 2) Depending on material structure and the kind of fire, i.e. smoldering / low temperature combustion compared to a high temperature burning with open flame. In consequence we assume that vice versa from the ratio of the stable isotopes in CO₂ information can be obtained about the formation process, and at least partially also the origin, of air samples affected by combustion processes.



δ¹³C and δ¹⁸O of different plant material

Characteristic isotopic signatures of different material, even from the same plant, is developed due to fractionation associated with uptake and biosynthesis. In figure 1 differences obtained by Pyrolysis-IRMS analyses are exemplified shown for samples of wood, needle and cone material from two spruce trees grown in Northern Sweden and in Central Germany, which are in the range of about 5‰.

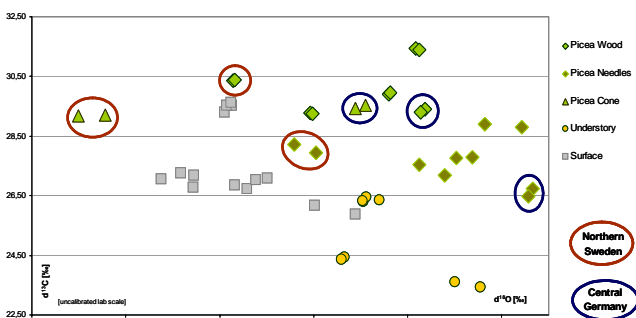


Figure1: δ¹³C and δ¹⁸O of different plant parts from *Picea abies* grown in Northern Sweden and Central Germany. The variation between needle and wood material is in both cases in the order of about 2‰; both on an uncalibrated lab-scale.



δ¹³C and δ¹⁸O in combustion derived CO₂

The δ¹⁸O of combustion derived CO₂ was found to be clearly distinguishable for the certain parts of the burned material and even enhanced the range of the variation detected for the intrinsic δ¹⁸O. A distinct difference was additionally observed between the plant material and the fossil fuel samples, which might be caused to some extent by the specific amount of inherent oxygen and by the substance characteristic C:O ratio: for wood of about 1:1 compared to fossil fuels of about 40:1.

In all cases shown in figure 2 the material was burned with an oxygen excess in the order of about 10 times the stoichiometric ratio needed for an optimal combustion, using pure oxygen with a δ¹⁸O of -13.6‰ vs. VPDB-CO₂.

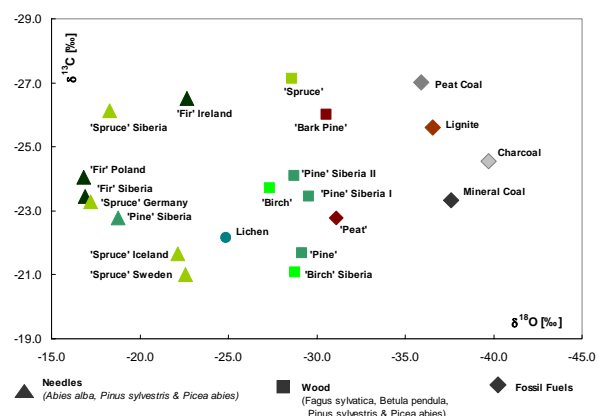


Figure2: δ¹³C and δ¹⁸O of different plant parts and fossil fuels; both on VPDB-CO₂ scale.

Conclusions

From the experiments a broad band of δ¹³C and δ¹⁸O signatures in combustion derived CO₂ became obvious clearly related to different kinds of burned material. The deviation from the so far used fixed value is thereby to large to be neglected - for simulations of the global carbon cycle, but the effect of combustion has also to be taken into account when investigate local air samples to distinguish plant and soil contributions because of a shifted background value.

References

- Clais, P., Denning, A.S., Tans, P.P. et al. (1997): A three-dimensional synthesis study of ¹⁸O in atmospheric CO₂:
 1. Surface fluxes, *Journal of Geophysical Research*, 102, 5857-5872
 Kroopnick, P. H. Craig (1972): Atmospheric Oxygen: Isotopic Composition and Solubility Fractionation, *Science*, 175, 54-55
 Yakir, D. and L.L. Sternberg (2000): The use of stable isotopes in study ecosystem gas exchange, *Oecologia*, 123, 297-311

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