Factors controlling the triple oxygen isotope composition of grass leaf water and phytoliths: insights for paleo-environmental reconstructions

Anne Alexandre1, Clément Outrequin1, Christine Vallet-Coulomb1, Amaelle Landais2, Clément Piel3, Sébastien Devidal3, Christophe Peugeot4, Théodor Ouani5, Simon Afouda5, Martine Couapel1, Corinne Sonzogni1, Jean-Charles Mazur1, Frédéric Prié5, and Elizabeth Webb6

1Aix Marseille University, CNRS, IRD, INRA, Coll France, CEREGE, Aix-en-Provence, France (alexandre@cerege.fr)
2Laboratoire des Sciences du Climat et de l’Environnement (LSCE/IPSL/CEA/CNRS/UVSQ), Gif-sur-Yvette, France
3Ecotron Européen de Montpellier, Centre National de la Recherche Scientifique (CNRS), Montferrier-sur-Lez, France
4Hydrosciences Montpellier, IRD, CNRS, Univ. Montpellier, Montpellier, France
5IRD Bénin, Cotonou, Bénin
6Department of Earth Sciences, The University of Western Ontario, London, Ontario, Canada

The oxygen isotope signature of leaf water is used to trace several processes at the soil-plant-atmosphere interface. During photosynthesis, it is transferred to the oxygen isotope signature of atmospheric CO₂ and O₂, which can be used for reconstructing past changes in gross primary production. The oxygen isotope signature of leaf water additionally imprints leaf organic and mineral compounds, such as phytoliths, used as paleoclimate and paleovegetation proxies when extracted from sedimentary materials.

Numerous experimental and modelling studies were dedicated to constrain the main parameters responsible for changes in the δ¹⁸O of leaf water. Although these models usually correctly depict the main trends of δ¹⁸O-enrichment of the leaf water when relative humidity decreases, the calculated absolute values often depart from the observed ones by several ‰. Moreover, the δ¹⁸O of leaf water absorbed by plants is dependent on the δ¹⁸O value of meteoric and soil waters that can vary by several ‰ at different space and time scales. These added uncertainties make our knowledge of the parameters responsible for changes in the δ¹⁸O of leaf water and phytoliths flawed.

Changes in the triple oxygen isotope composition of leaf water, expressed by the ¹⁷O-excess, are controlled by fewer variables than changes in δ¹⁸O. In meteoric water the ¹⁷O-excess varies slightly as it is weakly affected by temperature or phase changes during air mass transport. This makes the soil water fed by meteoric water and the atmospheric vapour in equilibrium with meteoric water changing little from a place to another. Hence the ¹⁷O-excess of leaf water is essentially controlled by the evaporative fractionation. The latest depends on the ratio of vapor pressure in the air to vapor pressure in the stomata intercellular space, close to relative humidity. Leaf water evaporative fractionation can lead to ¹⁷O-excess negative values that can exceed most of surficial
Here we present the outcomes of several recent growth chamber and field studies, for the purpose of i) refining the grass leaf water and phytoliths $\delta^{18}$O and $^{17}$O-excess modelling, ii) assessing whether the $\delta^{18}$O and $^{17}$O-excess of grass leaf water can be reconstructed from phytoliths, and iii) examining the precision of the $^{17}$O-excess of phytoliths as a new proxy for past changes in continental atmospheric relative humidity. Atmospheric continental relative humidity is an important climate parameter poorly constrained in global climate models. A model-data comparison approach, applicable beyond the instrumental period, is essential to progress on this issue. However, there is currently a lack of proxies allowing quantitative reconstruction of past continental relative humidity. The $^{17}$O-excess signature of phytoliths could fill this gap.