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Acclimation of intrinsic water use efficiency, Ci/Ca ratio and stomatal conductance in Norway spruce in response to century-long gradual CO_2 elevation

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To evaluate the strategies with which Norway spruce (Picea abies (L.) Karst.) trees have been responding to the rising atmospheric CO_2 concentration (Ca), we reconstructed hundred year-long courses of leaf internal CO_2 concentration (Ci) and intrinsic water use efficiency (WUEi) from 13C abundance in the cellulose of tree rings. Assuming that trees maximized the yield of carbon 'nutrition' (dA/dCa), we calculated concomitant changes in photosynthetic capacity (Vcmax and Jmax) and in stomatal conductance (gs) in the past century. A large set of cores was sampled across a range of elevations, soil and atmospheric conditions in Central Europe.
Generally, WUEi and Ci increased while gs decreased and the ratio Ci/Ca and slope s=dCi/dCa remained nearly constant in the past hundred years. However, we found that trees differed in the shape of responses to Ca, falling into one of two groups (Response Type 1 and 2; RT1, RT2). RT1 showed quasi-linear responses to Ca and relatively stable values of s (indicating balanced response of stomata and photosynthesis). RT2 exhibited non-monotonic responses of the Ci-derived traits with extremes in the 1970s to 1990s during a peak in industrial air pollution, and s approaching 1 since then indicating near-saturation of photosynthesis and limited profit from "CO_2 fertilization". Both increasing photosynthesis and decreasing gs contributed to the rise of WUEi in RT1, while gs reduction alone can explain the WUEi changes in RT2. Vcmax and Jmax decreased in the past hundred years by 7-8 % in both RT1 and RT2 trees. Our results indicate that spruce trees gradually cease in profiting from anthropogenic carbon "fertilization" and become carbon saturated in the present atmosphere.