Geophysical Research Abstracts
Vol. 13, EGU2011-4951, 2011
EGU General Assembly 2011

Flexibility in carbon substrate use for isoprene emission in trees grown at different atmospheric CO2 concentrations

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Biogenically released isoprene is an important reactant in tropospheric photochemistry. It is known that isoprene emission rate from many tree species increases as atmospheric CO2 concentration decreases. Thus, during past geologic eras with reduced CO2 concentration, isoprene emission from terrestrial forests was likely higher than at present, and accordingly tropospheric chemistry dynamics were different. We studied the biochemical controls over isoprene emission rate at lower-than-present, higher-than-present and present atmospheric CO2 concentrations using poplar trees. We performed a 13CO2-labeling study using proton-transfer-reaction mass spectrometry (PTR-MS) to examine the kinetics of the incorporation of recently assimilated photosynthate into isoprene. We focused on the question: how does the partitioning of carbon compounds in leaves change in order to adjust to growth at low, high and normal CO2 concentrations? We used special capabilities of the PTR-MS system to isolate carbon substrate coming from recent photosynthate channeled within the chloroplast versus older, stored photosynthate channeled from the cytosol (outside the chloroplast). Dynamics in the ratio of carbon fragments from recovered isoprene revealed the trend of greater substrate use from cytosolic substrate, derived from older stored carbon, compared to carbon derived directly from recent photosynthesis, when grown at lower atmospheric CO2 concentration. This facilitated the requirement for higher rates of carbon substrate use for isoprene biosynthesis when grown with limited access to CO2. Our results show that carbon channeling between the cytosol and chloroplast within the leaf adjusts to growth of trees at different atmospheric CO2 concentrations, and permits leaves to synthesize and emit even higher rates of isoprene at low CO2 concentrations, despite lower rates of carbon assimilation. This capability for acclimation of the isoprene biosynthesis rate to growth in different CO2 atmospheres may have allowed trees to enhance protective mechanisms against abiotic stress during past geologic periods when turnover of the chloroplast cycle responsible for CO2 assimilation was limted by insufficient CO2 availability.