Geophysical Research Abstracts
Vol. 16, EGU2014-14801, 2014
EGU General Assembly 2014

Stomata size and spatial pattern effects on leaf gas exchange – a quantitative assessment of plant evolutionary choices

Dani Or (1), Shmuel Assouline (2), Milad Aminzadeh (1), Erfan Haghighi (1), Stan Schymanski (1), and Peter Lehmann (1)

(1) ETH Zurich, Soil and Terrestrial Environmental Physics, Zurich, Switzerland (dani.or@env.ethz.ch), (2) Dept. of Environmental Physics and Irrigation, A.R.O - Volcani Center, Israel

Land plants developed a dynamically gas-permeable layer at their leaf surfaces to allow CO_2 uptake for photosynthesis while controlling water vapor loss through numerous adjustable openings (stomata) in the impervious leaf epidermis. Details of stomata structure, density and function may vary greatly among different plant families and respond to local environmental conditions, yet they share basic traits in dynamically controlling gaseous exchange rates by varying stomata apertures. We implement a pore scale gas diffusion model to quantitatively interpret the functionality of different combinations of stomata size and pattern on leaf gas exchange and thermal management based on data from fossil records and contemporary data sets. Considering all available data we draw several general conclusions concerning stomata design considerations: (1) the sizes and densities of stomata in the available fossil record leaves were designed to evaporate at rates in the range $0.75 \leq e/e0 \leq 0.99$ (relative to free water evaporation); (2) examination of evaporation curves show that for a given stomata size, the density (jointly defining the leaf evaporating area when fully open) was chosen to enable a high sensitivity in reducing evaporation rate with incremental stomatal closure, nevertheless, results show the design includes safety margins to account for different wind conditions (boundary layer thickness); (3) scaled for mean vapor flux, the size of stomata plays a minor role in the uniformity of leaf thermal field for a given stomata density. These principles enable rationale assessment of plant response to raising CO_2, and provide a physical framework for considering the consequences of different stomata patterns (patchy) on leaf gas exchange (and thermal regime). In contrast with present quantitative description of traits and functionality of these dynamic covers in terms of gaseous diffusion resistance (or conductance), where stomata size, density and spatial pattern are lumped into a single effective resistance parameter, the present approach enables derivation of nuanced insights and offers predictive capabilities that link changes in stomata structure and geometrical attributes to quantifying environmental influences and feedbacks on leaf structure and function.