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Does the response of leaf stomata to light and vapour pressure follow from limitations in long distance transport?

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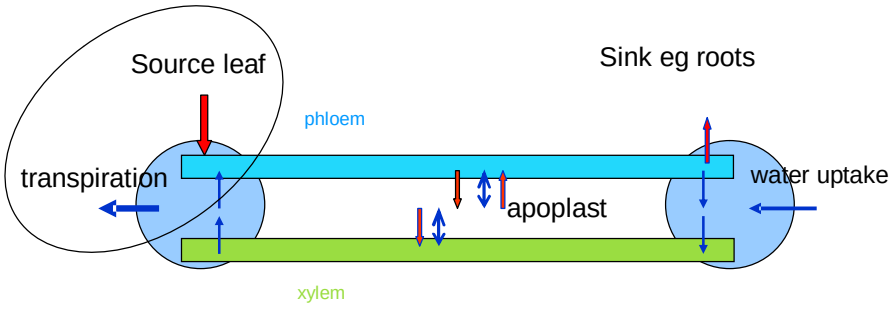
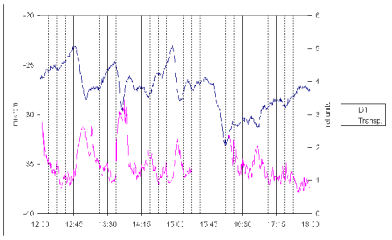
Phloem-xylem interactions

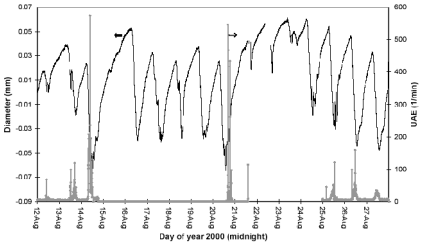


How would stomatal conductance need to vary to enhance the xylem -to- phloem water flux and phloem transport?

Stomata control xylem transport

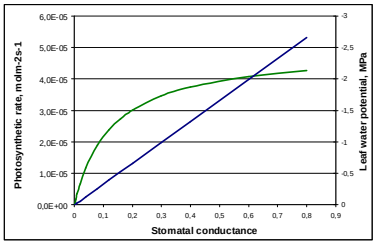
- Transpiration lowers leaf water potential and creates tension gradient in xylem that drives replacing water flux from soil
- $Q = g_{sto}\ D = k_x(\Psi_{xl} - \Psi_{xu})$
- Transpiration rate reflect rapidly on tension of tree stem even at tree base
- Large tensions break water columns in xylem (cavitation)
- Reducing transpiration during high evaporative demand prevents excess cavitation





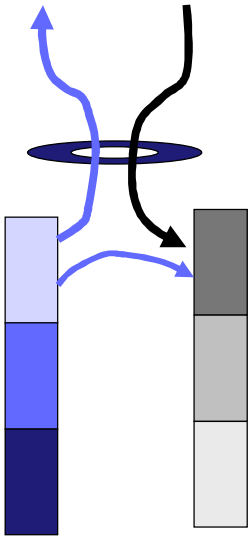
In leaves phloem cells ”compete” osmotically with transpiration pull

- Loading of sugars into phloem draws water from xylem if osmotic strength matches the hydrostatic (negative) pressure of transpiring leaves
- There is competition for water between transpiration and phloem transport
- Net flow of water from xylem to phloem at source is a requirement for continuous assimilate transport
- How will stomatal conductance influence the situation?
  - Transpiration rate and xylem tension are linearly related to stomatal conductance with given evaporative demand
  - Stomatal conductance has saturating relation to CO_2 intake ie. sugar loading potential in given light



Trade off

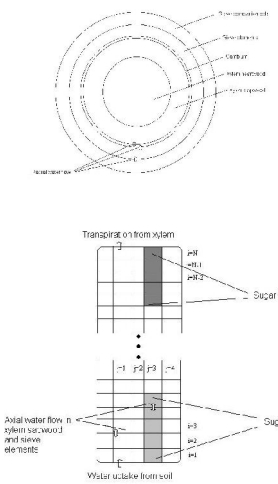
- Open stomata allow high uptake of carbon
- Assimilation allow high sugar loading rate
- High loading rate draws osmotically water from apoplast, creates high turgor pressure and high phloem transport rate
- But! open stomata mean high transpiration, low xylem water potential and low xylem – phloem water flow, low phloem turgor and low phloem transport rate
- Compensation with high loading rate leads to lowered transport rate due to increased phloem sap viscosity
- Critical if stomatal opening increases more the possible loading rate than the water tension due to transpiration

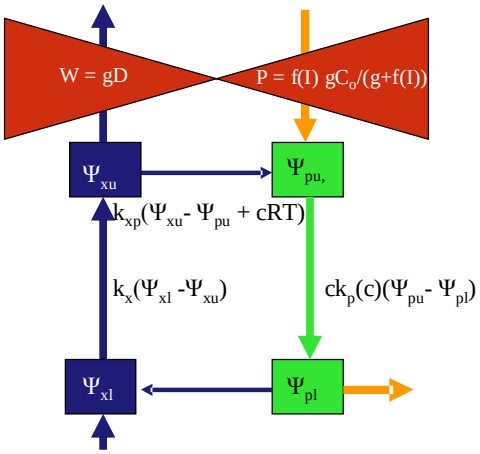


How would stomata behave if they were to maintain high sugar transport from source to sink?

- Linked xylem – phloem transport model (Hölttä et al 2006) was modified to include stomatal control of transpiration and photosynthetic production
- Photosynthesis was linearly related to leaf internal CO2 concentration and with saturating function to light intensity
- Loading at source assumed proportional to photosynthesis
- Stomatal opening that gave maximal water flux from xylem to phloem was selected at every time step
  - maximises phloem flow rate and gives close to maximal sugar flux
  - direct maximizing of sugar flux gave similar results but model behaviour was unstable (time lags)

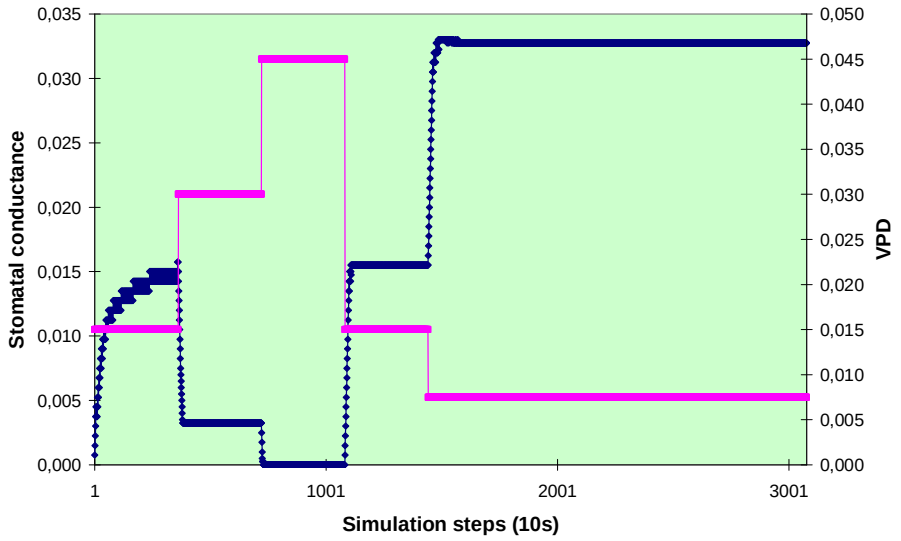
Schematic presentation of the model



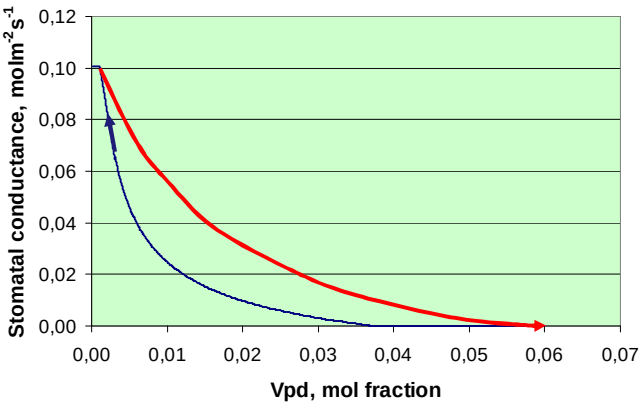


Results

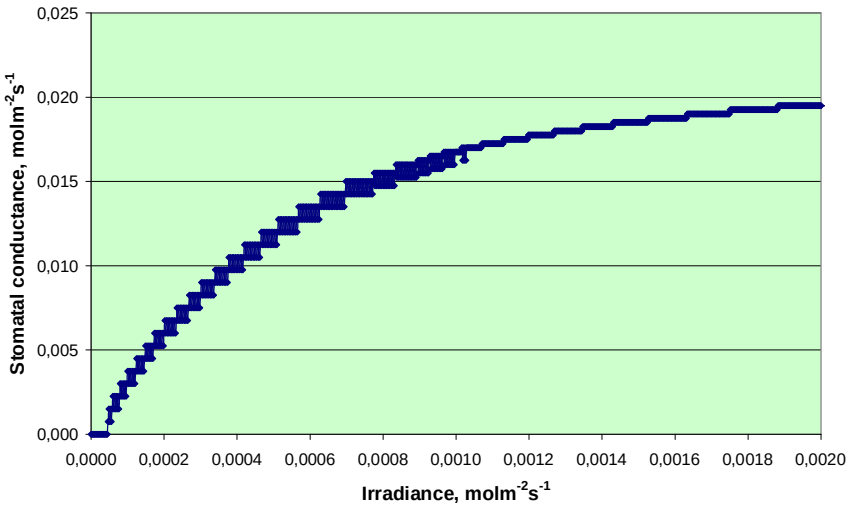
Dynamics



Stomatal conductance vs VPD



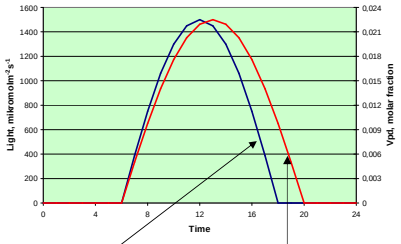
Stomatal conductance vs. light

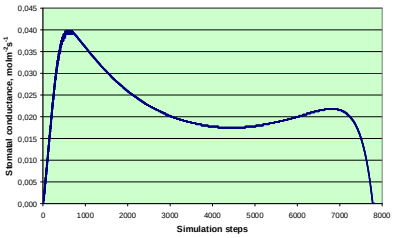


Daily course

Driving variables

Response

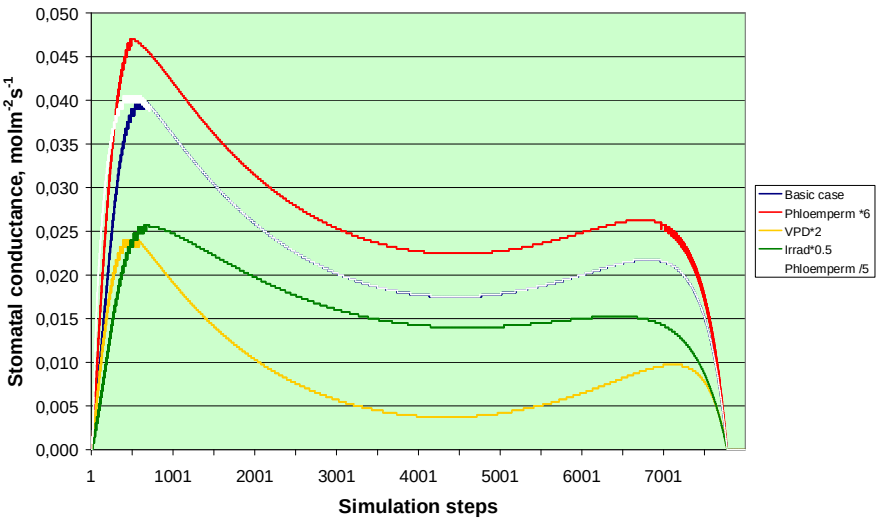




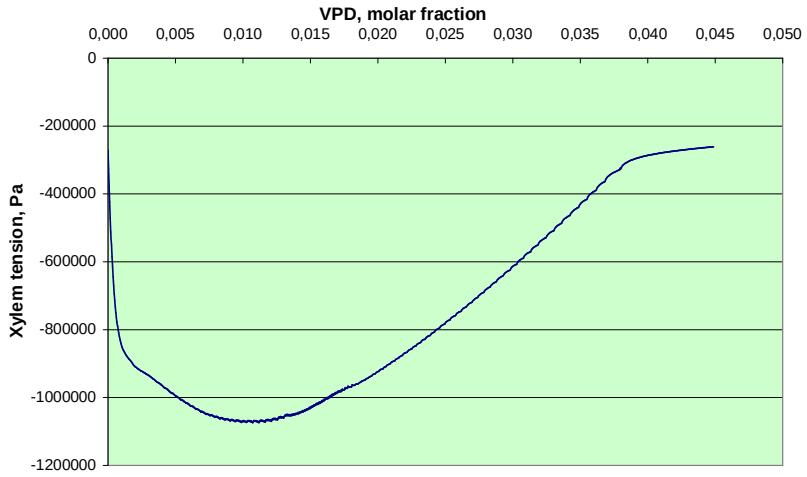
Light

VPD

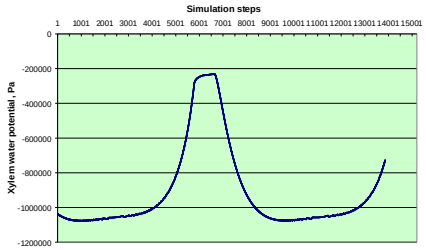
Impact of tree parameters & driving variables

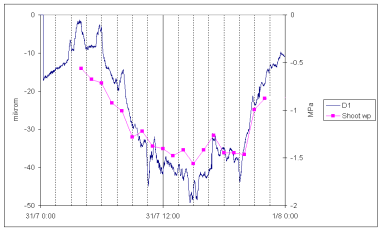


Predicts feedforward stomatal control (declining transpiration with increasing vpd)

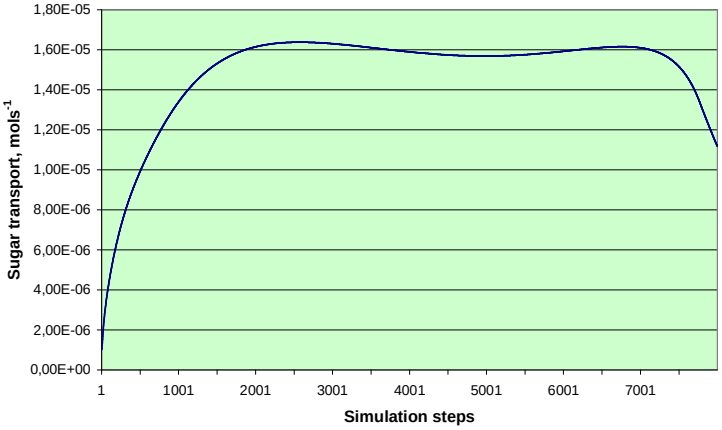


Produces realistic leaf water potential variation

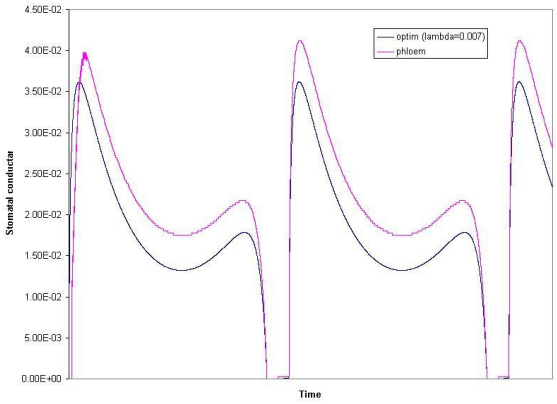




Produces stable sugar transport rate in phloem



Compares well with much tested optimal stomatal control model



Conclusions

- Requiring stomata to open in order to maximize water flux from xylem to phloem at source produces realistic response patterns of stomatal conductivity
  - Result similar as stomatal conductance models with optimal water use would produce
- Experimental verification underway
  - some parameters difficult to determine (e.g. radial xylem-phloem and axial phloem permeability)
- Possible sensing mechanism could be linked to competiton for water between transpiration, guard cells and phloem
  - high transpiration -> turgor loss in guard cells and phloem
  - high phloem loading -> turgor loss in guard cells
- Links source processes with transport and sink activity


Thank you!