PLANT WATER-STRESS PARAMETERIZATION DETERMINES THE STRENGTH OF LAND-ATMOSPHERE COUPLING

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WAGENINGEN UR

1. PROBLEM

Plants exhibit various responses to soil moisture stress, which are difficult to categorize and parameterize in land-surface models. Misrepresentations of plant water-stress in such models can generate significant errors in:

- Transpiration fluxes
- Carbon assimilation
- Surface energy balance

errors which then affect the dynamics and composition of the atmospheric boundary layer (ABL) in coupled land-atmosphere models (Fig. 1). Here we explore the impact of simulating two extreme water-stress responses under dry soil conditions.

2. MODELING FRAMEWORK

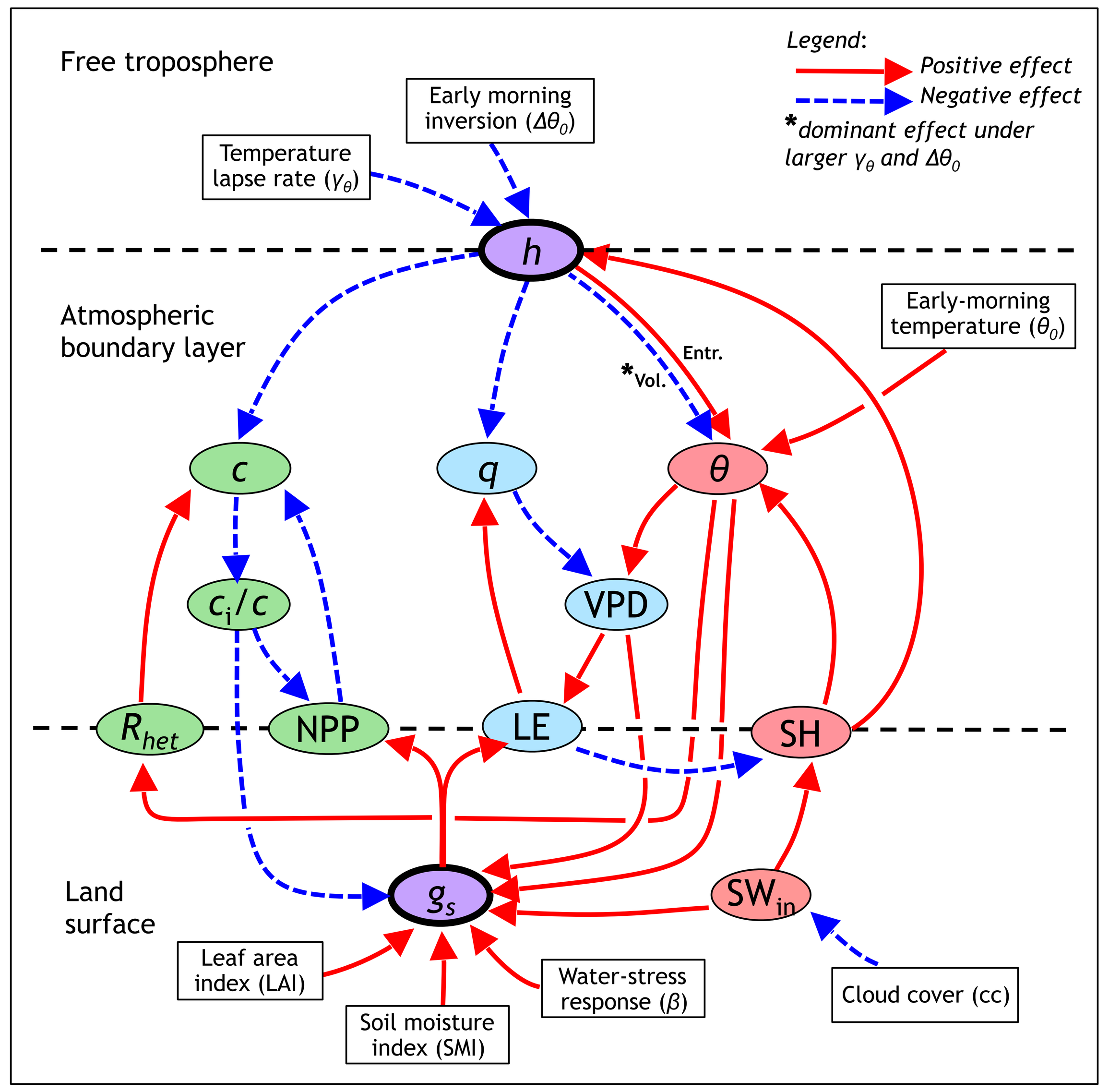


Fig. 1: Coupled land-atmosphere feedback diagram.

We use a diurnal land-atmosphere (L-A) modeling framework, called the MXL-A-gs model. Our model represents the daytime surface fluxes of carbon (green), water (blue), and energy (red circles) coupled to the dynamics of a convective boundary layer (see Fig. 1). Its strength is to include the essential diurnal processes of the L-A in a concise manner. Note the two coupling points (in purple) at the surface and at top of the ABL.

3. METHOD

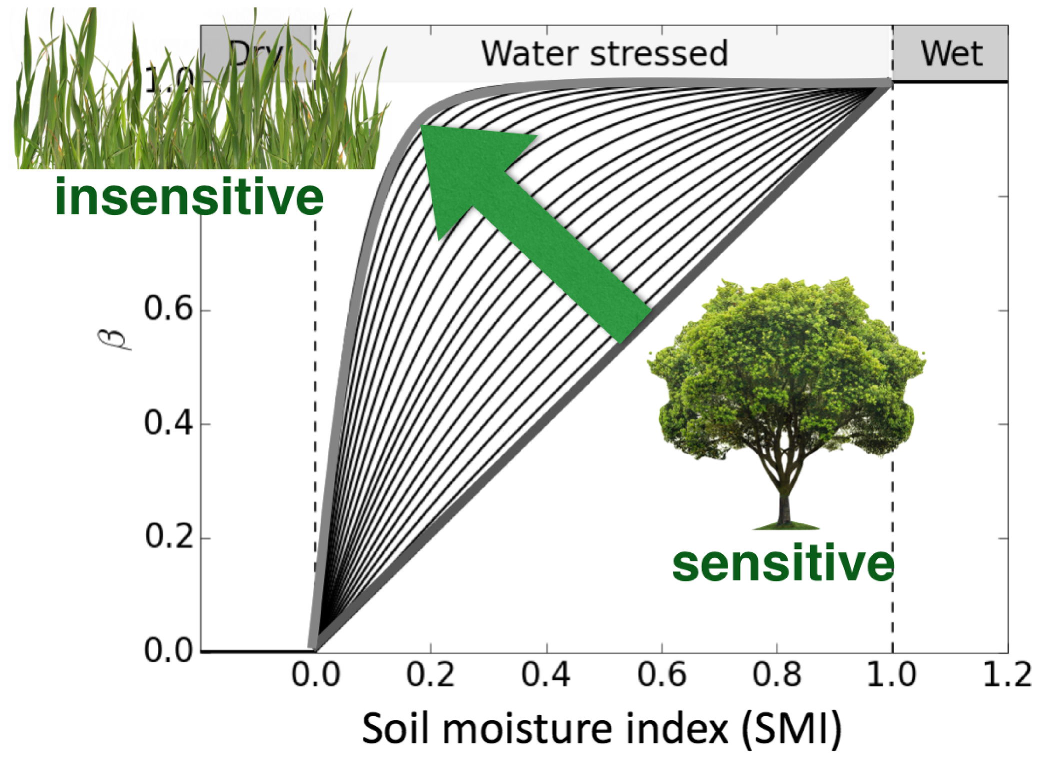


Fig. 2: Modeled plant water-stress responses.

We design a control case that reproduces a sunny summer day above a maize crop in the Netherlands [1]. We introduce a flexible plant water-stress function β (see Fig. 2) that multiplies the net leaf assimilation used to compute the stomatal conductance g_s. We vary the curvature of β and systematically assess:

- the impact on g_s (Fig. 3) and the atmospheric boundary layer,
- the cumulative impact over weeks (Fig. 4),
- the effect of using different plant responses on modeling errors (Fig. 5).

We summarize our findings in Box 7.

4. SURFACE COUPLING

We vary the water stress response in the control case (y-axis), as well as soil moisture (x-axis).

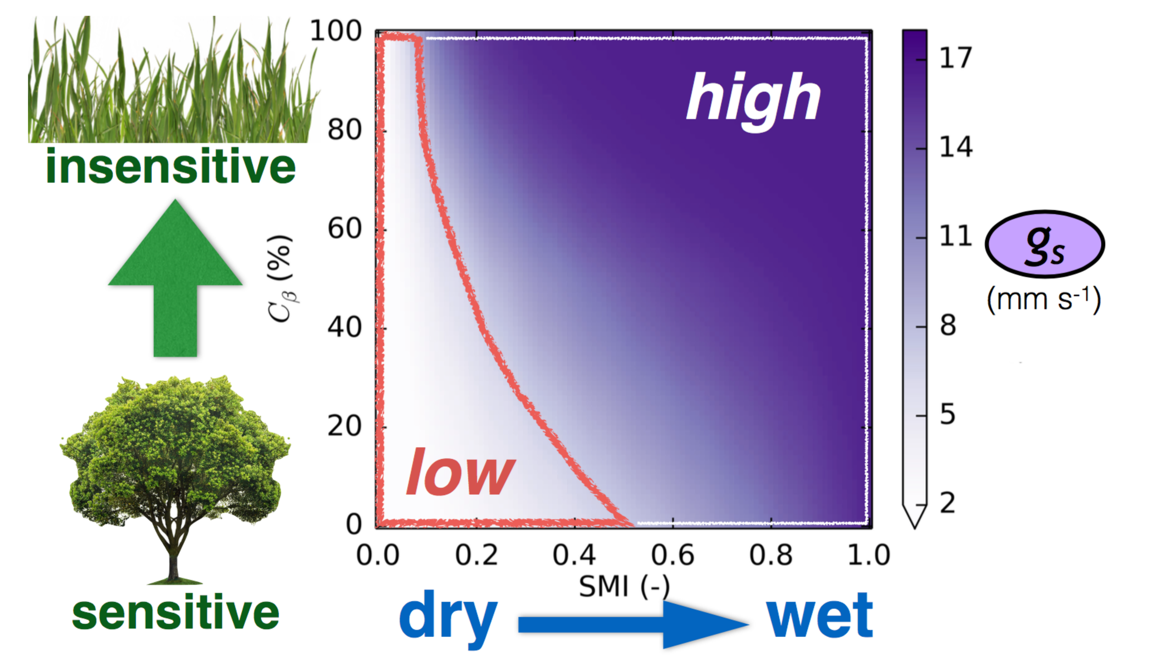
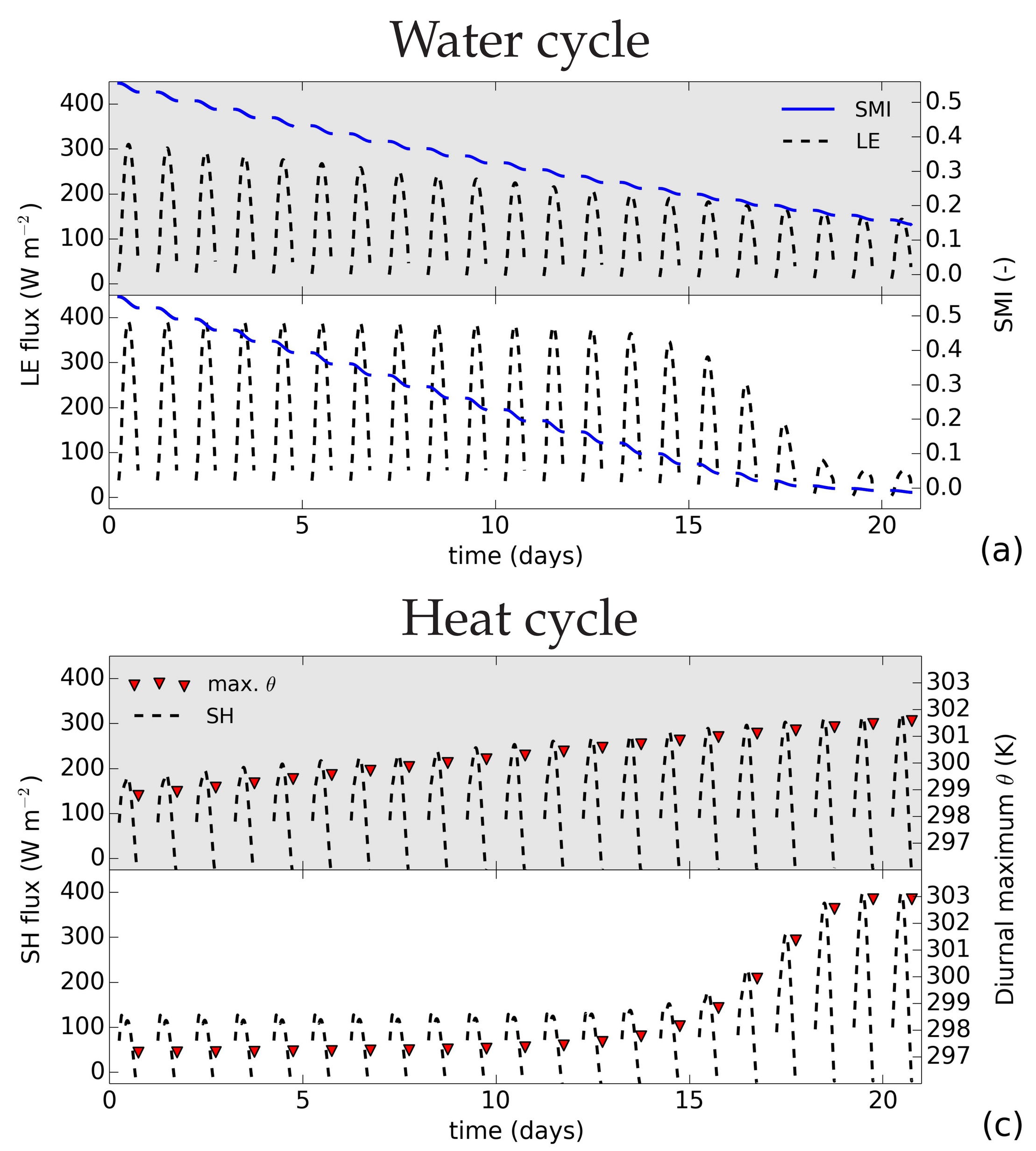


Fig. 3: Low and high surface coupling regimes defined with the stomatal conductance g_s

5. SOIL DRYING EXPERIMENT



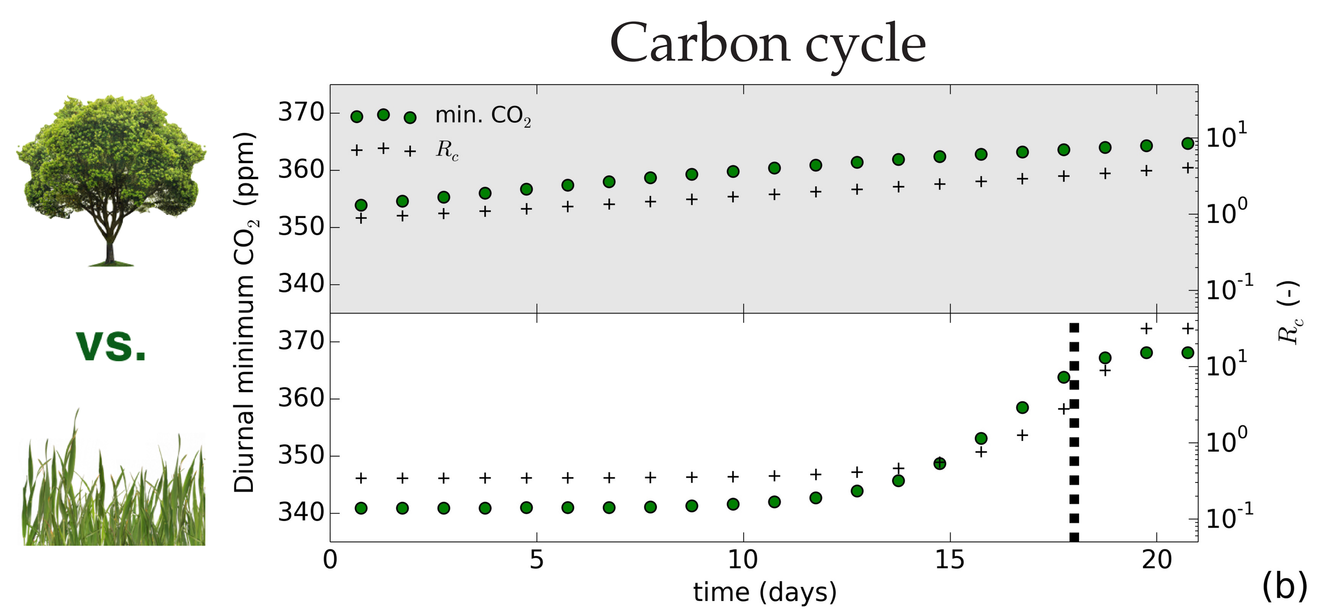


Fig. 4: Carry-over effects of soil moisture depletion on the water, carbon and heat cycles.

We repeat the same sunny summer day 21 times, with two different water-stress responses, only carrying over the effects of soil moisture depletion by plants.

6. ATMOSPHERIC FACTORS

On day SMI=0.2 (Fig. 4), we apply additional perturbations to the atmospheric state that are consistent with a drought.

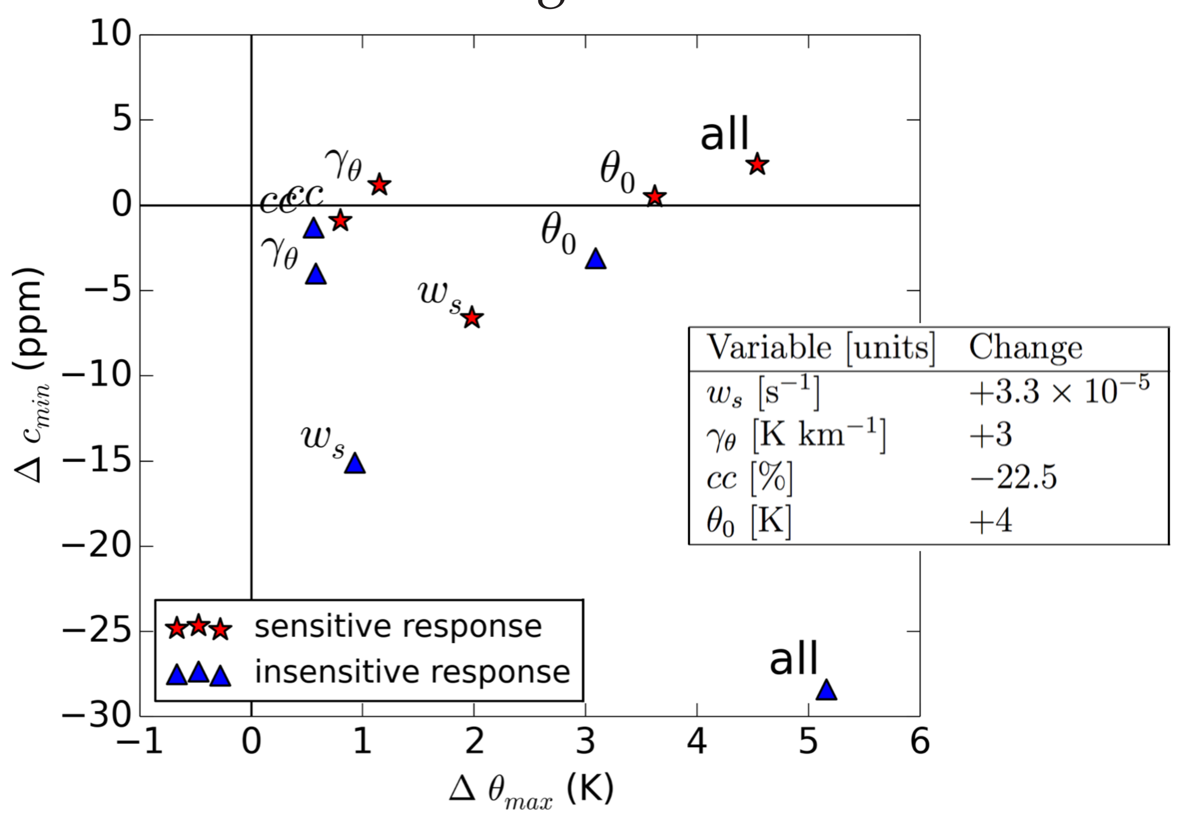


Fig. 5: Additional 6pm CO_2 and temperature change caused by added perturbations in early-morning temperatures (θ_0), cloud cover (cc), free-troposphere temperature lapse rate (γ_θ) and subsidence (w_s).

7. TAKE-HOME MESSAGES

- Different plant water-stress responses are currently used in land-surface models (problem)
- Plants with less sensitive responses increase the land-atmosphere coupling strength (Fig. 3)
- Plants insensitive to water stress delay atmospheric warming during dry spells (Fig. 4)
- The chosen water-stress response influences the model sensitivity to atmospheric factors (Fig. 5)

8. WORK PUBLISHED IN

[1] M. Combe et al. (2015) Two perspectives on the coupled carbon, water and energy exchange in the planetary boundary layer, *Biogeosciences*.

[2] M. Combe et al. (2016) Plant water-stress parameterization determines the strength of land-atmosphere coupling, *Agriculture and Forest Meteorology*.