A FULLY COUPLED 3SEB-PT SCHEME

that represents soil–vegetation–atmosphere exchanges as a fully coupled resistance network in series

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Introduction

Context. The Three-Source Energy Balance (3SEB) model allows to partition the latent heat fluxes into canopy transpiration (***LE*~OV~**), cover crop transpiration (***LE*~UN~**), and soil evaporation (***LE*~S~**).

Problem. The original Priestley–Taylor formulation (3SEB-PT) uses a parallel resistance scheme for canopy and substrate fluxes, limiting interactions between these components.

Proposal. We introduce a revised 3SEB-PT approach that represents soil–vegetation–atmosphere exchanges as a fully **coupled resistance network in series**, improving interactions among canopy, cover crop, and soil components.

Methods

Resistance scheme. Development a series-series resistance scheme to represent overstory (canopy) and substrate (cover crop + soil) fluxes.

Temperature formulation. Account for the influence of understory vegetation on the canopy air space (T_{AC}) Priestley Taylor Formulation.

Evaluation. Comparison of models using synthetic data (Sobol sampling) and assessment of model's disagreement.

Resistance scheme

Original 3SEB (Parallel-Series)

No coupling between components

Direct link to air temperature

$$H = H_{OV} + H_{SUB} = \rho C_P \left[\frac{T_{OV} - T_A}{R_A} + \frac{T_{SUB} - T_A}{R_A + R_{SUB}}\right]$$

New 3SEB (Fully Coupled Series)

Full coupling through T_{AC}

Includes sensible heat effects on T_{AC}

$$H = H_{OV} + H_{UN} + H_S = \rho C_P \frac{T_{AC} - T_A}{R_A}$$

$$T_{AC} = \frac{\frac{T_A}{R_A} + \frac{T_{OV}}{R_{X,OV}} + \frac{T_{UN}}{R_{X,UN}} + \frac{T_S}{R_S}}{\frac{1}{R_A} + \frac{1}{R_{X,OV}} + \frac{1}{R_{X,UN}} + \frac{1}{R_S}}$$

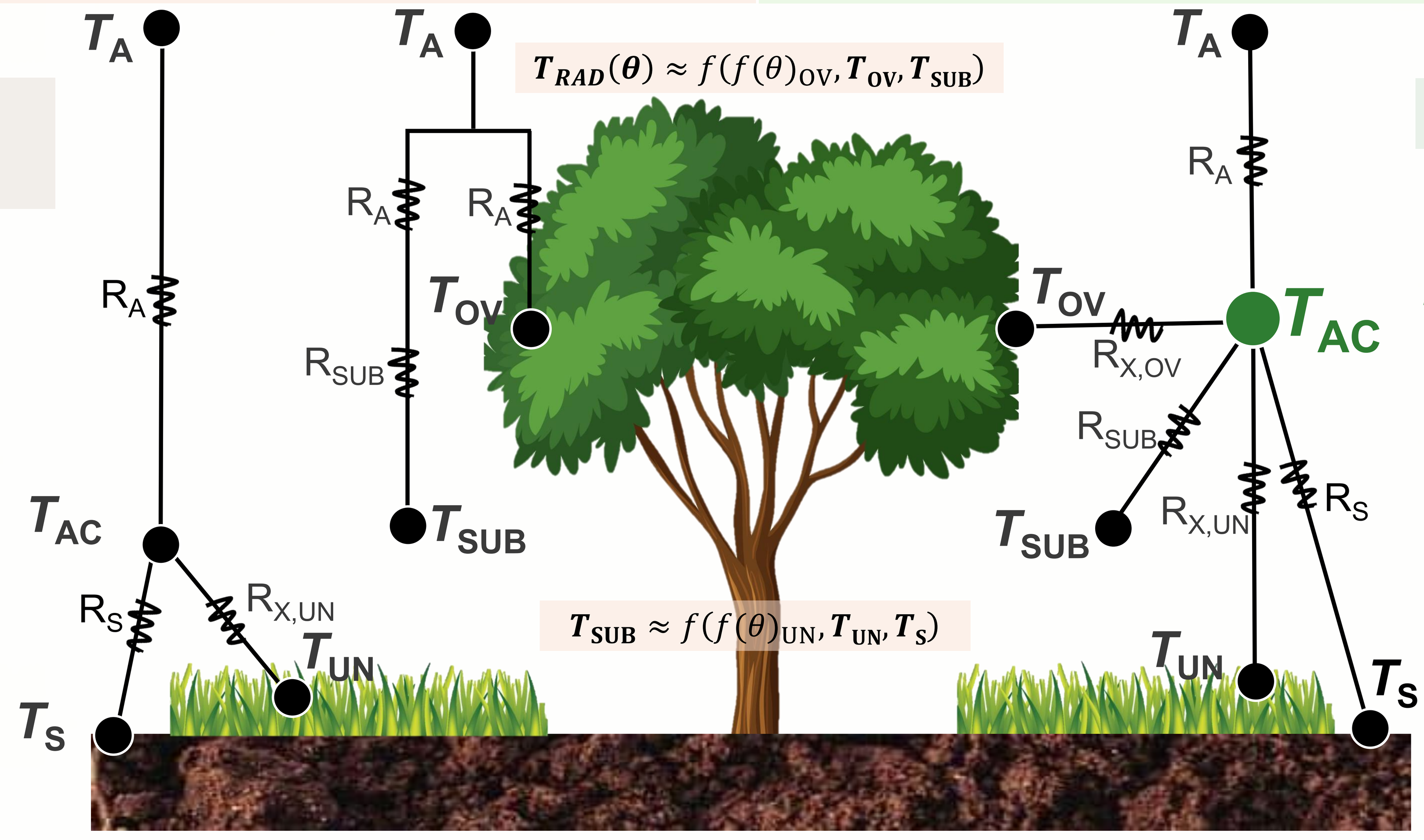
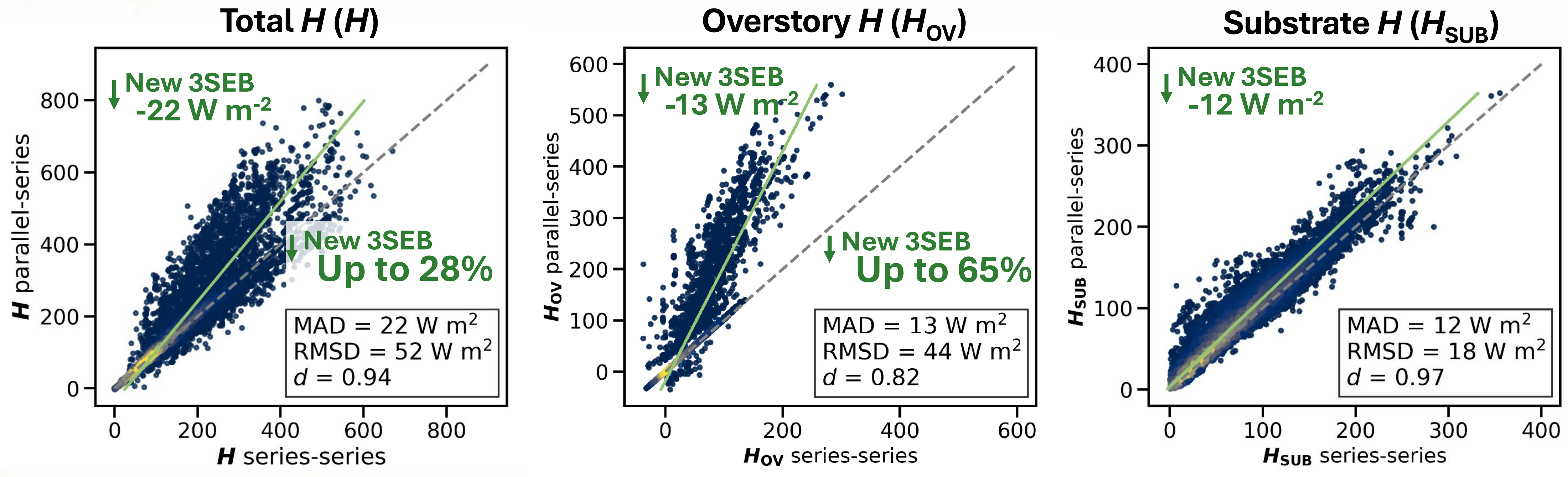


Fig 1. Schematic diagram illustrating resistance network for parallel-series scheme and series-series scheme.

Results

New 3SEB reduces *H* estimations in certain conditions



Lower *H*, H_{OV}, and H_{SUB} in new 3SEB under certain conditions

Dampened response vs original model

Under which contexts the disagreement between models is important? (See Drivers' evaluation)

Fig 2. Comparison of Sensible Heat Fluxes (*LE*) estimated by 'parallel-series' versus 'series-series' resistance approaches using synthetic inputs. The graphs are colored by the density of nearby points.

Results: Drivers' evaluation

Differences between schemes are driven by $T_{RAD} - T_A$ (ΔT) and LAI_{OV}

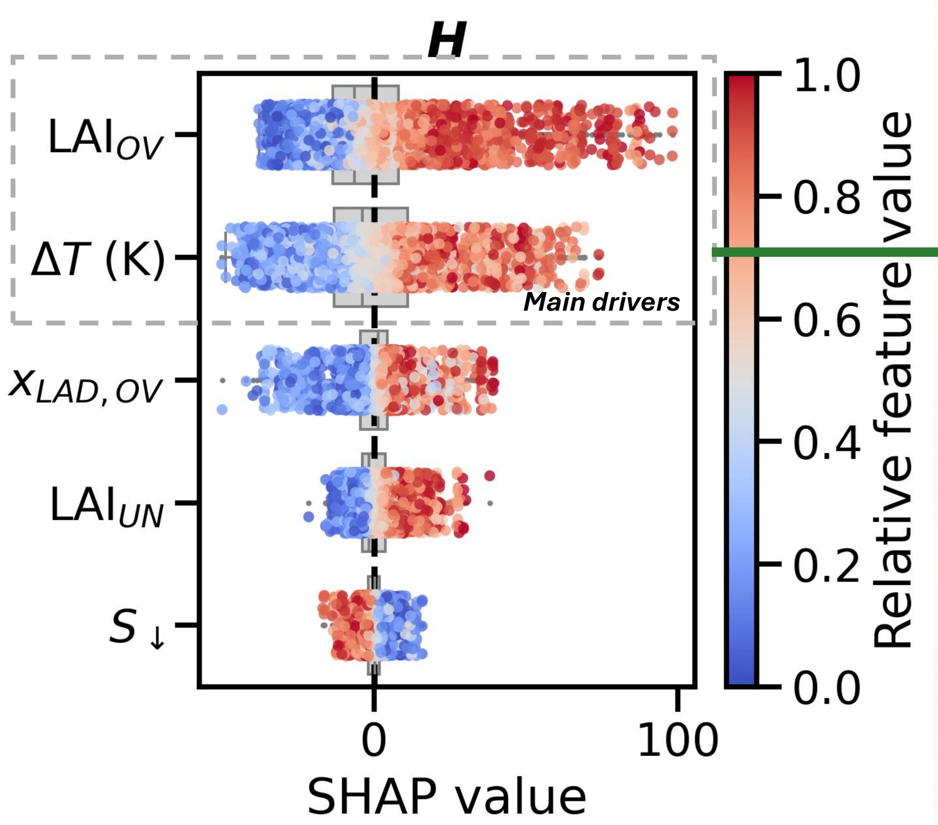


Fig 3. Global SHAP summary plot for Mean Absolute Differences (MAD) of the sensible heat fluxes between parallel-series and series-series.

Model disagreement increases for $LAI_{OV} > 3$

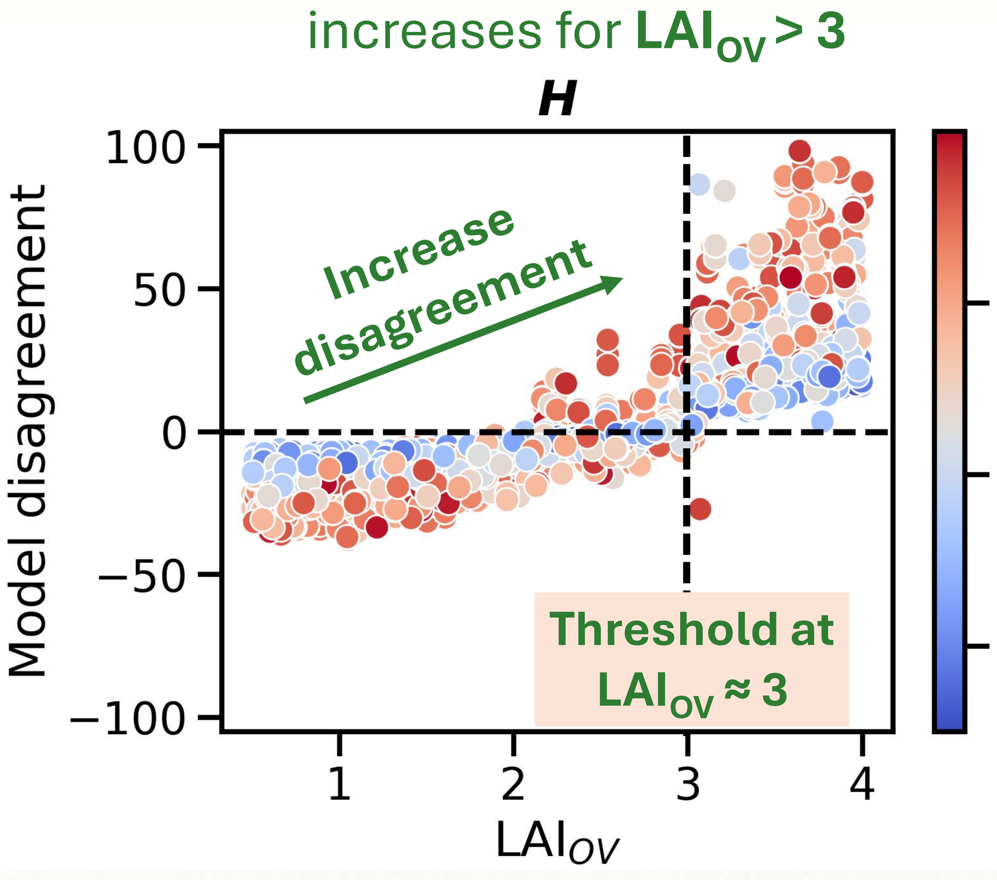


Fig 4. SHAP dependence plots showing the effect of LAI_{ov} and $T_{RAD} - T_A$ (ΔT) on model disagreement, expressed as MAD.

Main Takeaways

- **H_{OV}** shows the largest differences (RMSD = 44 W m^{-2}) and reductions up to 65% using **new 3SEB**
- **LAI_{OV}** and **$T_{RAD} - T_A$ (ΔT)** drive differences between models
- **Dense canopies** enhance coupling through T_{AC}, making the new series-series scheme more physically consistent
- **Future work**: validation across orchard conditions