S1 Willow Lysimeter (L2): Root Density Profile

Below we report the vertical distribution of root density (Figure S1) used to initialize the root water uptake distribution in GEOSPACE, specifically within the BrokerGEO component (see Section 3.1 and Figure 8 of the main text). The measurements represent average root density within 25-cm depth intervals, and were interpolated to obtain a continuous profile consistent with the numerical discretization of the soil column. This interpolated distribution provides the root-density value assigned to each control volume and forms the basis for root water uptake in the model.

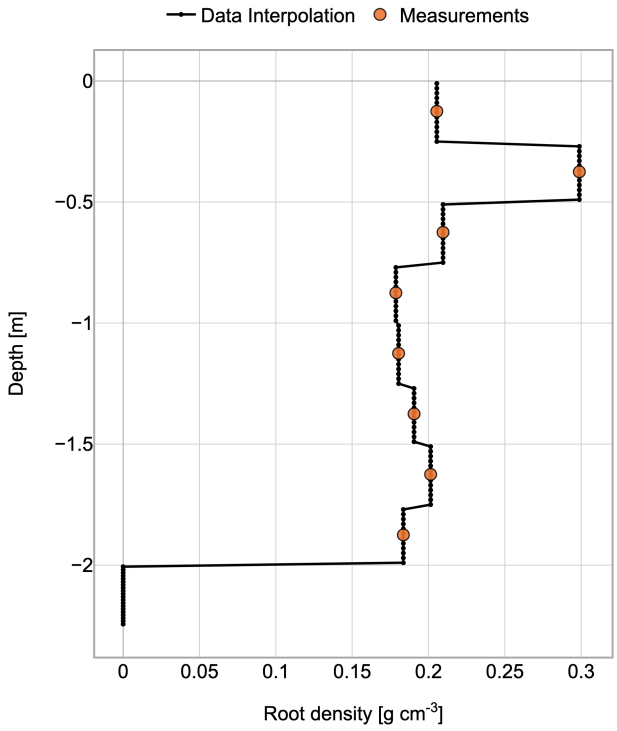

Figure S1: Vertical profile of root density (g cm^{-3}) along the soil column. Orange markers indicate measured root density values, each representing the average within a 25-cm depth interval. The black markers and connecting line represent the interpolated profile, computed in order to assign a root-density value to every control volume used in the numerical discretization of the soil column.

S2 Evapotranspiration and Evaporation Validation for Grass (L1, L4) and Bare Soil (L3) Lysimeters

To complement the willow lysimeter analysis discussed in Section 3 of the main text, here we examine the evapotranspiration results obtained for the other three weighed lysimeters from the "Spike II" experiment: one bare-soil lysimeter (L3) and two grass lysimeters (L1 and L4). All lysimeters

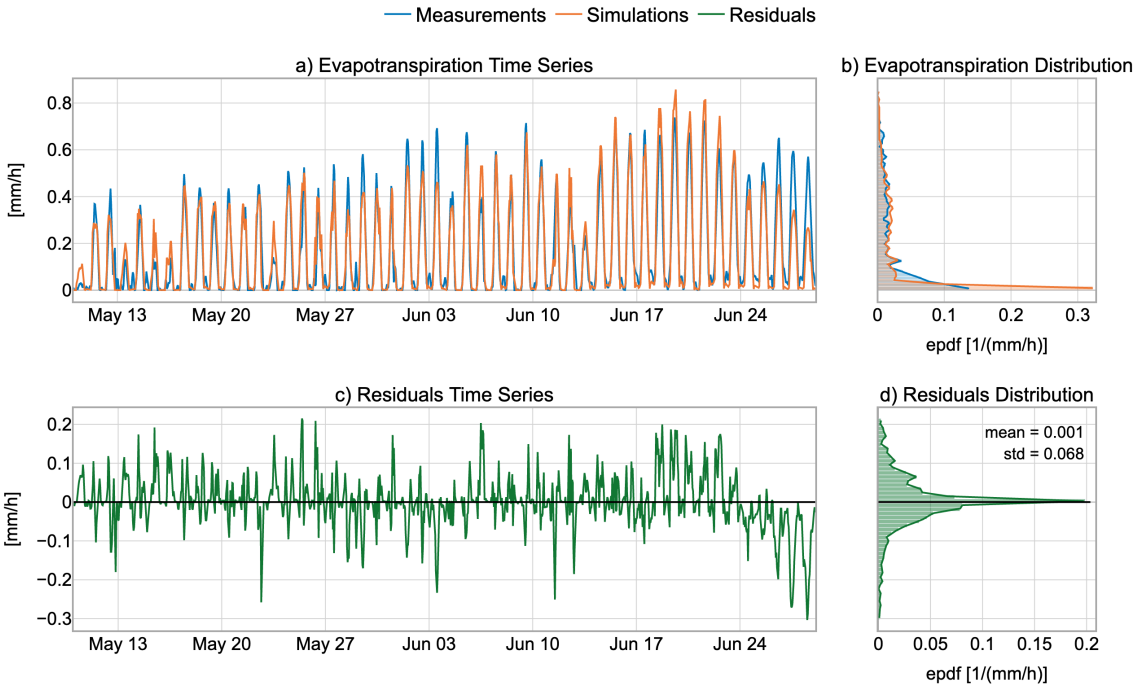

Figure S2: Multidimensional analysis of evapotranspiration time series and distributions in L1 lysimeter simulation: A comparison between evapotranspiration measurements and simulations. Panels a) and b) depict time series and distributions of evapotranspiration, while Panels c) and d) highlight residuals and their distributions.

consist of fiberglass cylindrical columns with a surface area of 1.12 m^2. L1 and L3 have a depth of 1 m, while L4 has a depth of 0.5 m. Evapotranspiration (or evaporation for L3) was derived from measured weight changes following the approach described by Benettin et al. (2021). The GEOSPACE simulations for these lysimeters were compared with the measured evapotranspiration (or evaporation for L3) fluxes to further assess the model skill in reproducing land–atmosphere exchange across different vegetation covers, complementing the scatterplot analysis and R^2 values reported in Figures 7b–d of the main text. Figures S2–S4 summarize these validation results. Across all figures, panel (a) shows the observed and simulated time series; panel (b) illustrates the corresponding distribution of evapotranspiration fluxes; panel (c) reports the residuals (simulation – measurement); and panel (d) presents the distribution of residuals along with their mean and standard deviation.

Figure S3: Multidimensional analysis of evapotranspiration time series and distributions in L4 lysimeter simulation: A comparison between evapotranspiration measurements and simulations. Panels a) and b) depict time series and distributions of evapotranspiration, while Panels c) and d) highlight residuals and their distributions.

Figure S4: Multidimensional analysis of evaporation time series and distributions in L3 lysimeter simulation: A comparison between evaporation measurements and simulations. Panels a) and b) depict time series and distributions of evaporation, while Panels c) and d) highlight residuals and their distributions.

S3 GEOET Formulations Intercomparison for the Willow Lysimeter (L2)

To further assess the modularity of the GEOSPACE framework, we repeated the willow lysimeter (L2) simulation as discussed in Section 3.1 of the main text using two alternative GEOET evapotranspiration formulations (D'Amato et al., 2025): the GEOET–Priestley–Taylor (GEOET–PT) and GEOET–Penman–Monteith FAO (GEOET–PM–FAO) approaches. All simulations employed the same soil configuration (WHETGEO), so that differences in model performance reflect only the choice of evapotranspiration scheme. Figure S5 compares measured evapotranspiration with the three GEOSPACE simulations (Prospero–PM, GEOET–PT, GEOET–PM–FAO) at hourly, daily, and cumulative scales. Figure S6 displays the corresponding residuals (simulation – measurement) and their distributions. Summary statistics (mean and standard deviation of residuals) are reported in Table 5 of the main text.

References

Benettin, P., Nehemy, M. F., Asadollahi, M., Pratt, D., Bensimon, M., McDonnell, J. J., and Rinaldo, A.: Tracing and closing the water balance in a vegetated lysimeter, Water Resour. Res., 57, 2021.

D'Amato, C., Tubini, N., and Rigon, R.: A component-based modular treatment of the soil–plant–atmosphere continuum: the GEOSPACE framework (v.1.2.9), Geosci. Model Dev., 18, 7321–7355, https://doi.org/10.5194/gmd-18-7321-2025, 2025.

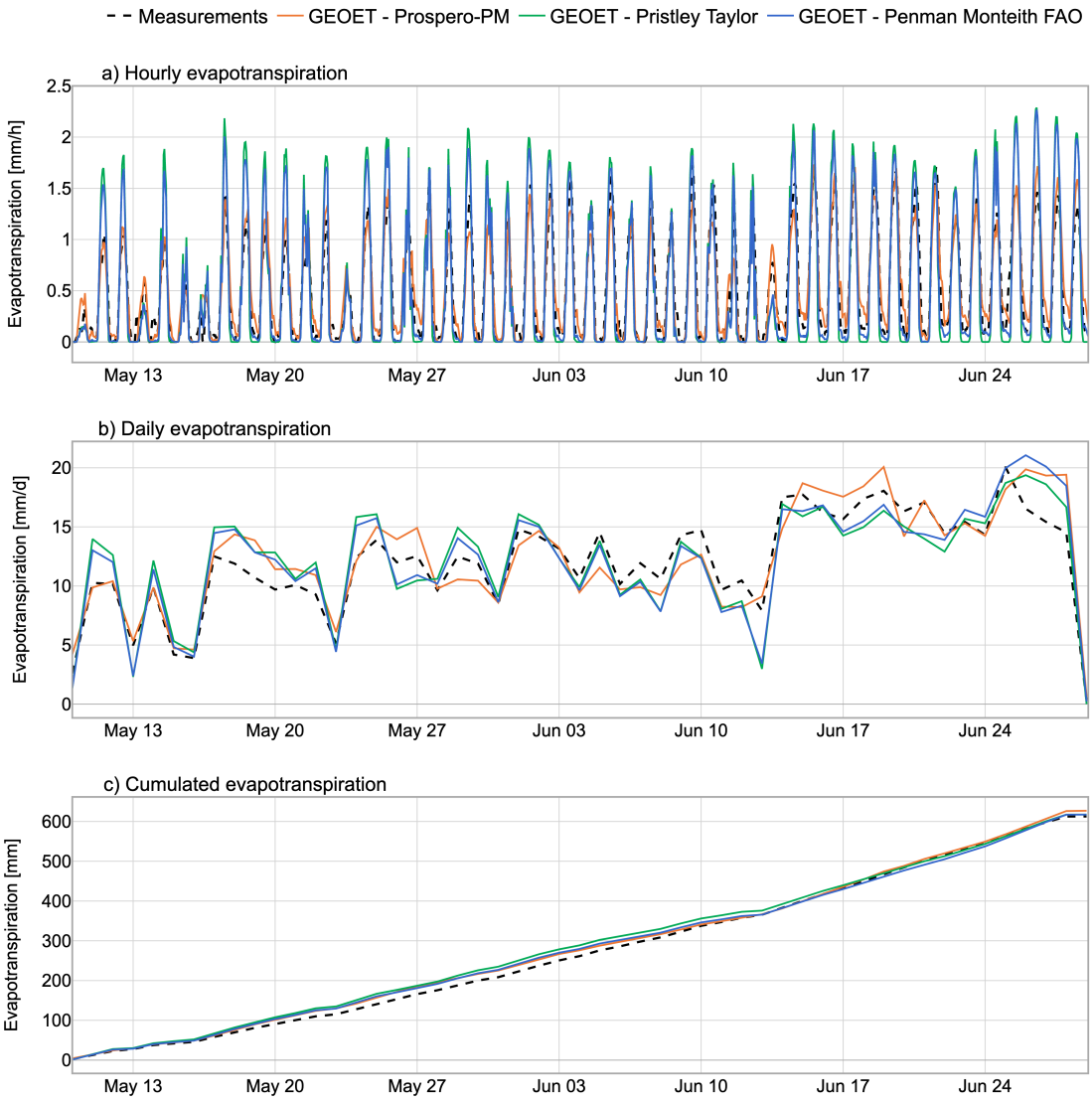

Figure S5: Comparison between measured evapotranspiration in the willow lysimeter (L2) and GEOSPACE simulations using three evapotranspiration formulations (GEOET-Prospero-PM, GEOET-PT, GEOET-PM-FAO). Panel a) shows hourly evapotranspiration, comparing measured data (dashed black line) with GEOSPACE simulations based on the Prospero-PM (orange), Priestley-Taylor (green), and Penman-Monteith FAO (blue) models. Panel b) presents the corresponding daily evapotranspiration, while panel c) depicts the cumulated evapotranspiration over time.

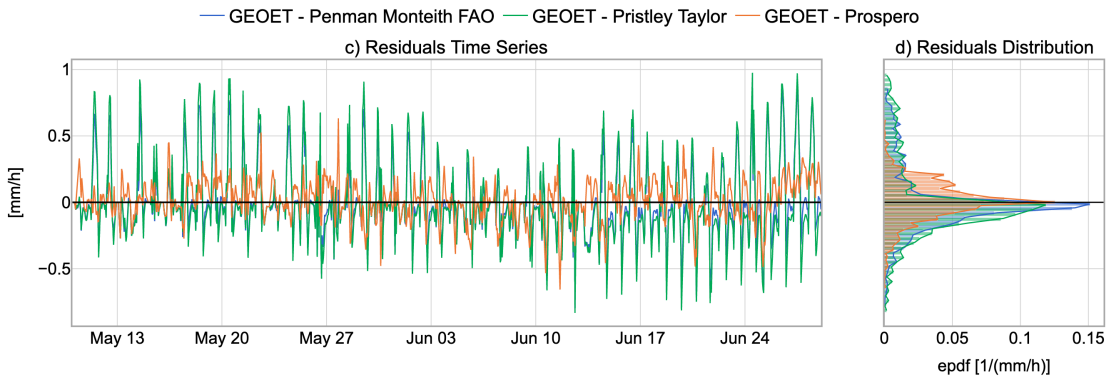

Figure S6: Residuals (simulation – measurement) for the three evapotranspiration formulations, shown as residual time series and corresponding distributions. Summary statistics are reported in Table 5 of the main text.