



Using Physics-Informed Machine Learning to Partition Eddy Covariance-measured Evapotranspiration

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1. Introduction

- Transpiration (T) drives global water, carbon & energy cycles yet isolating T from total evapotranspiration (ET) remains a challenge.
- Existing ET partitioning methods rely on ecosystem-specific assumptions, limiting cross-biome applicability.
- Methods require scarce ground-truth T measurements for validation.
- Physics-informed machine learning offers a new approach: learn the underlying physical processes directly with no T training data needed.

Can physics-informed machine learning reliably partition ET using FLUXNET data in a soybean agricultural setting?

2. Physics-Informed Transpiration Estimates (PITE)

Gradient:

$$T/ET_{PITE} = \frac{\partial(\text{Meteorology})}{\partial T/ET} + \frac{\partial(\text{Ecosystem flux})}{\partial T/ET}$$

Boundary conditions:

$$\frac{T}{ET} = \begin{cases} 0, & \text{if } NEE > 1 \\ 1, & \text{if } T_{air} = P_{99} \text{ and } VPD = P_{99} \\ 1, & \text{if } P > 0.1 \text{ and } VPD = P_5 \end{cases}$$

Underlying physical equation (PDE):

$$\frac{d^2 T/ET}{dt^2} + \omega^2 \frac{T}{ET} = 0$$

Loss:

$$L_{total} = L_{BC} + L_{PDE}$$

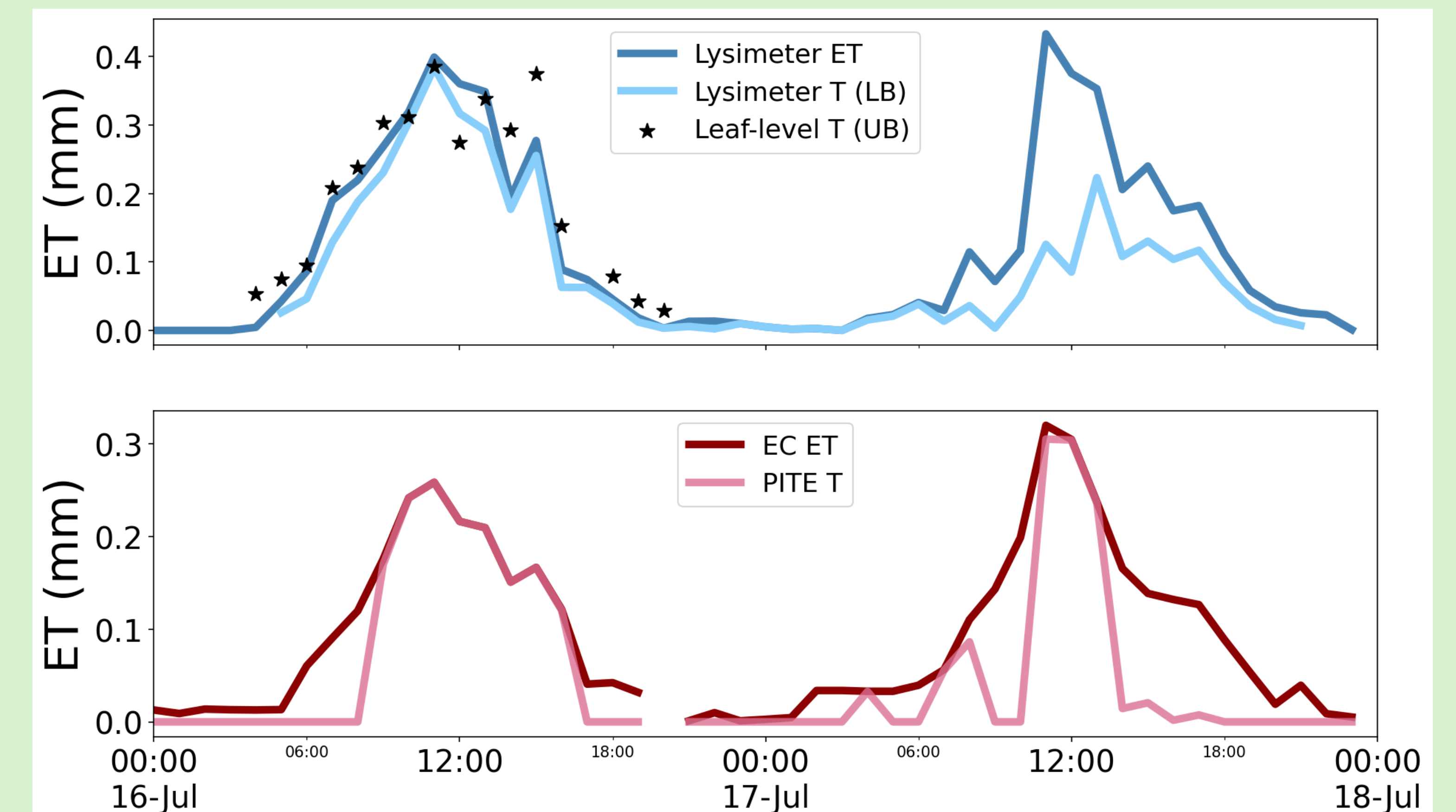
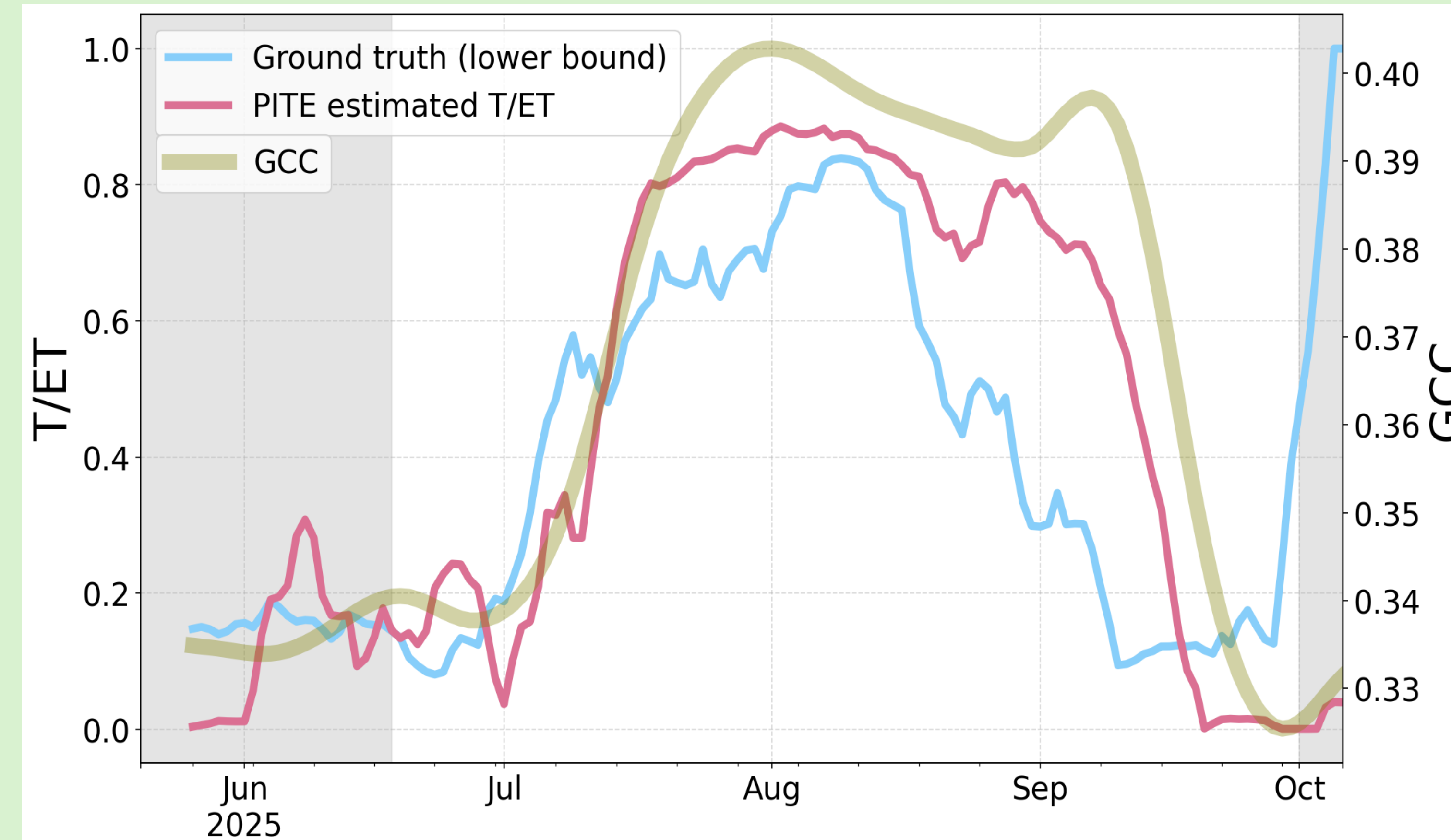
3. Comparison methods

T_{TEA} = random forest machine learning predicting water use efficiency via 75th percentile regression when $ET \approx T$ [1]

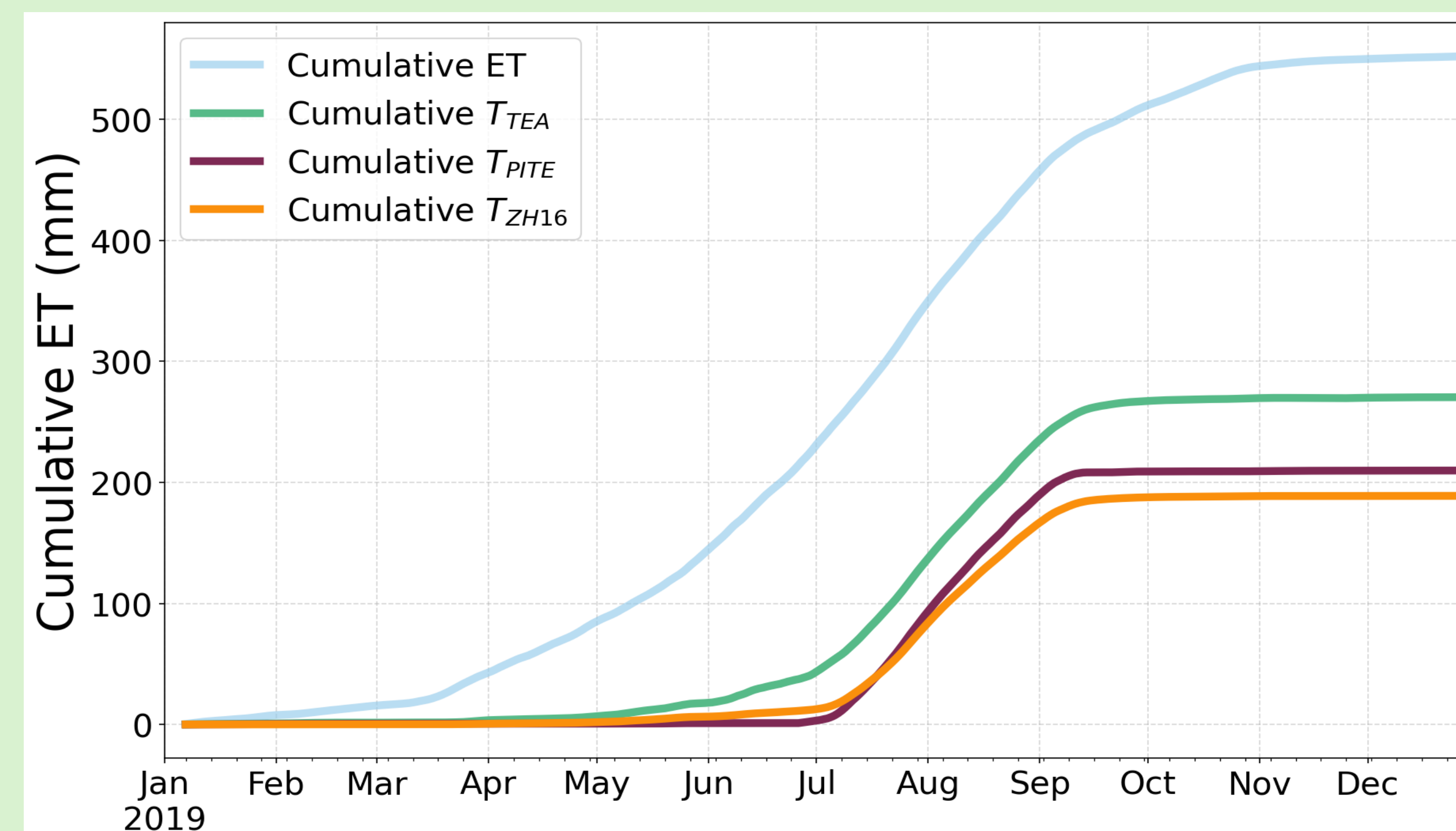
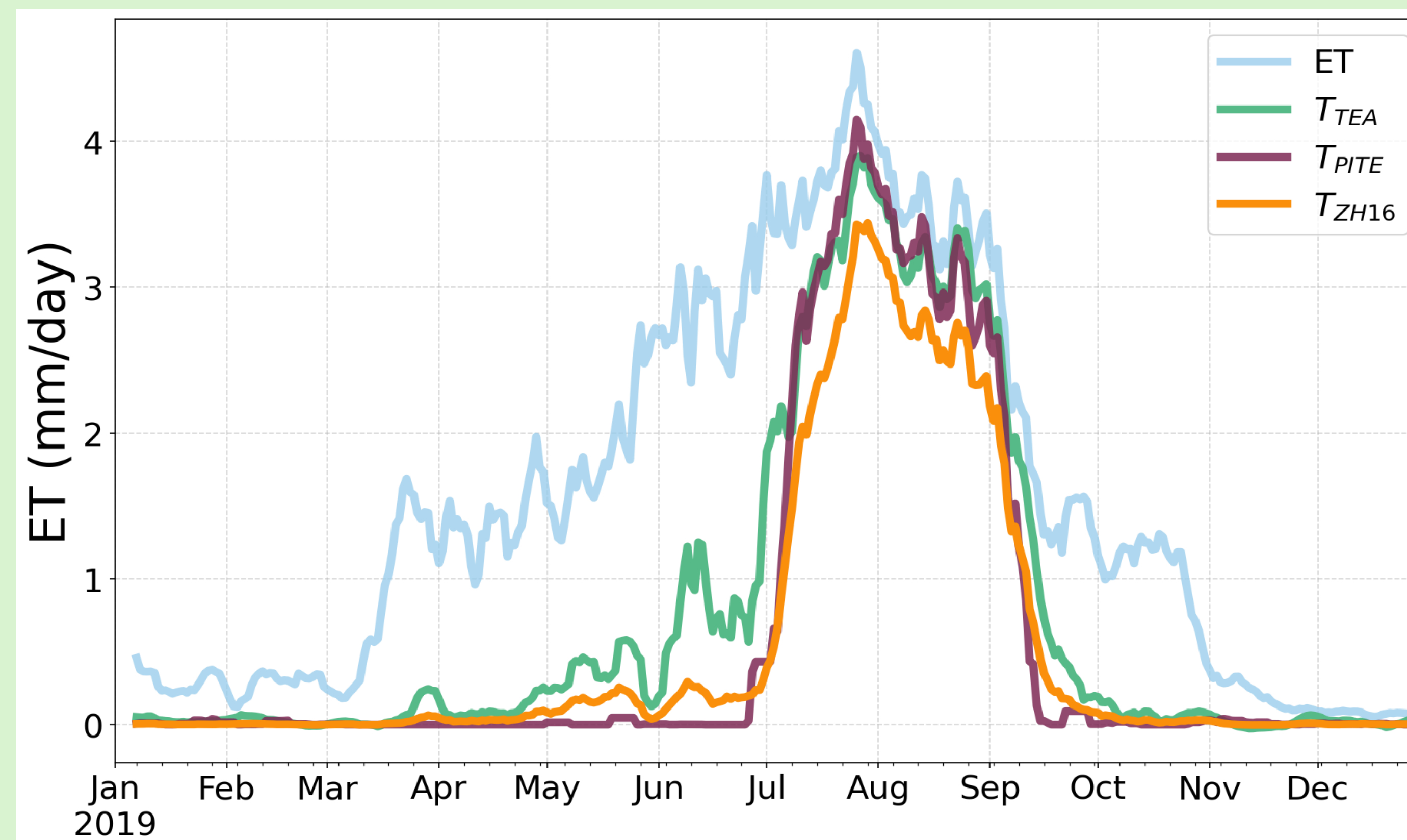
T_{ZH16} = based on the concept of underlying water use efficiency and a 95th percentile regression between $GPP * \sqrt{VPD}$ and ET [2]

4. Results: Soybean plot in Ontario, Canada (FLUXNET site ID: CA-ER1)

2025



2019



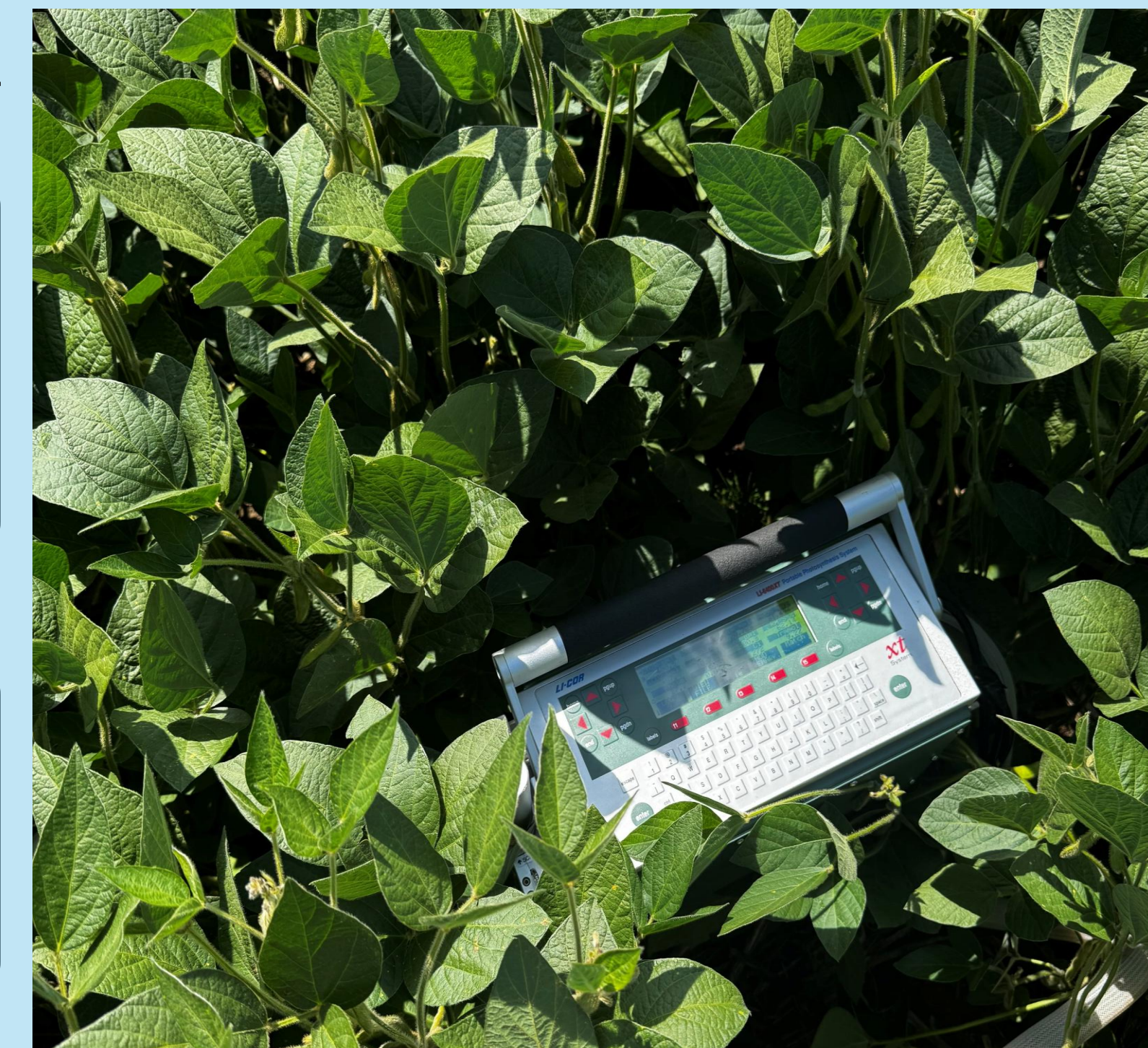
5. Ground truth validation

Leaf-level (upper bound):

LI-6400XT leaf-level T measurements scaled to ecosystem level using LAI, represents maximum possible T

Lysimeters (lower bound):

Bare lysimeter captures soil evaporation (E), setting the floor for ecosystem T estimates



6. Conclusions

- PITE reliably partitions ET across diel, seasonal, and annual scales, validated against lysimeter and leaf-level T measurements.
- PITE values fall between T_{TEA} and T_{ZH16} , suggesting eddy covariance-based ET partitioning methods capture seasonal T dynamics.
- T/ET tracks with seasonal leaf area (GCC), confirming PITE is able to capture the ecosystem's biological signal.
- More ground-truth T measurements across diverse biomes are needed to validate all methods globally.

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References

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