



# Tools for measuring vineyard ET

Napa Valley GSA TAG Meeting

December 2025

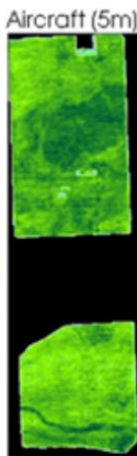
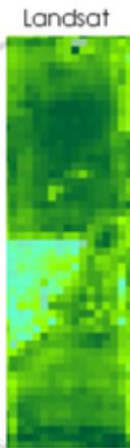
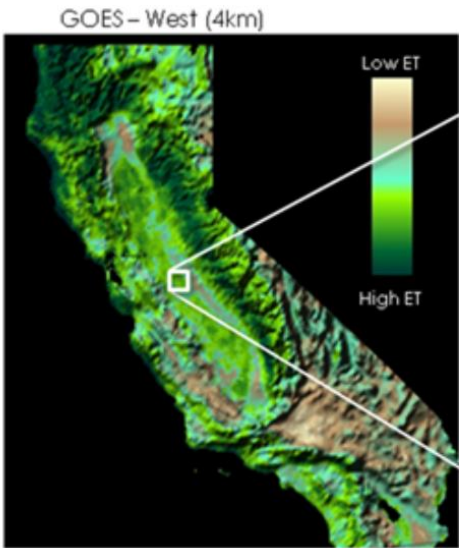
Andrew McElrone





# Evapotranspiration eXperiment

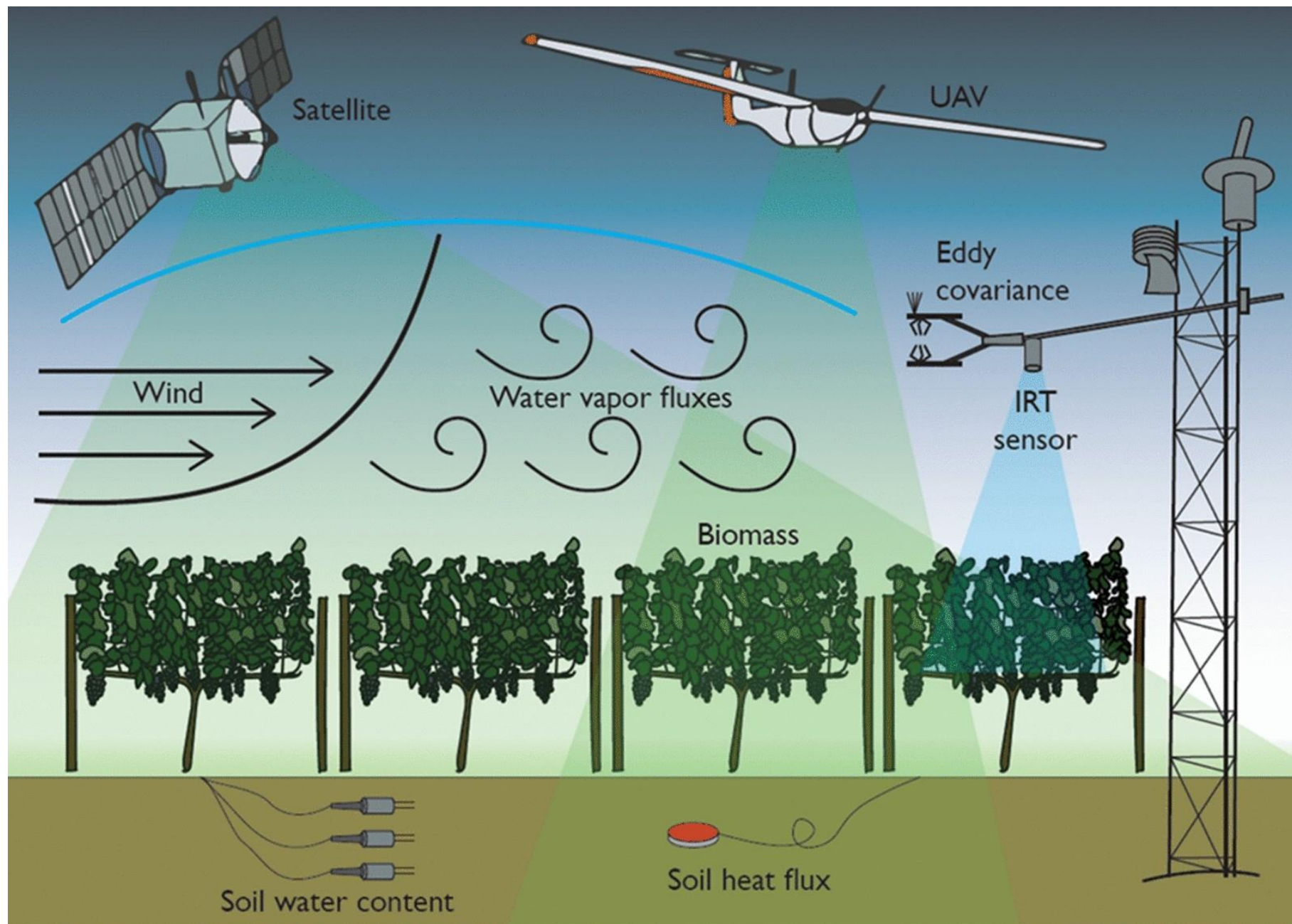
grapex



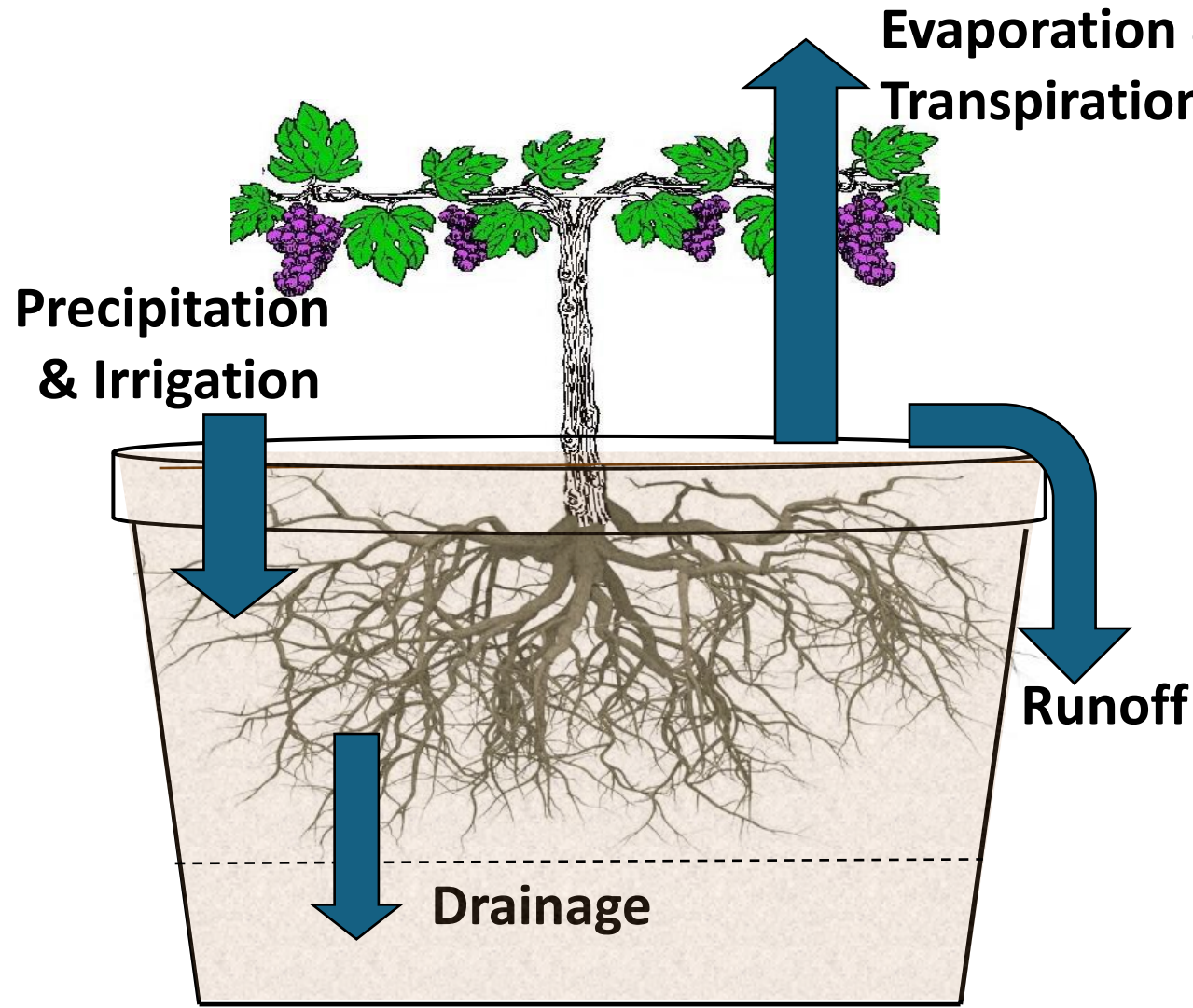


Almonds, Pistachios, Olives, Table Grapes



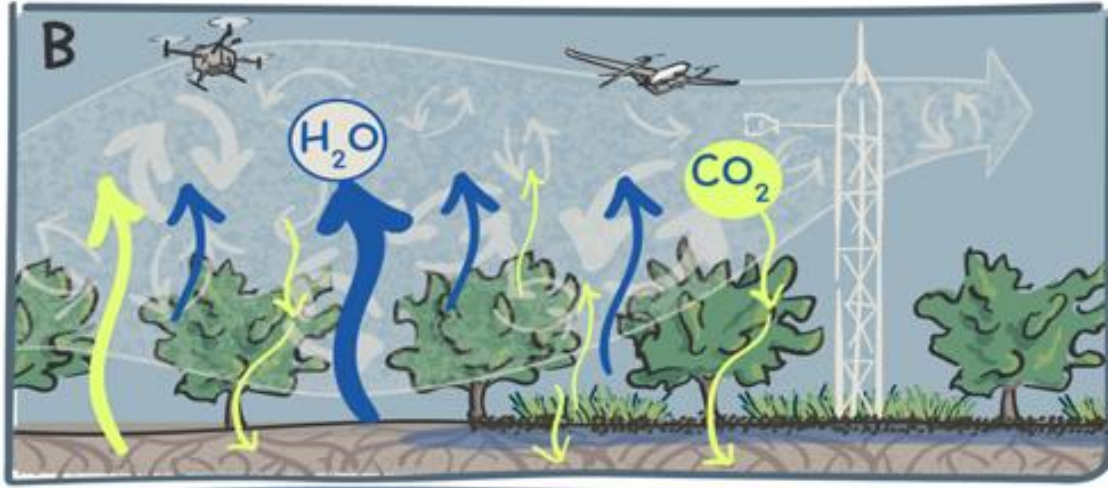


# Vineyard Water Balance



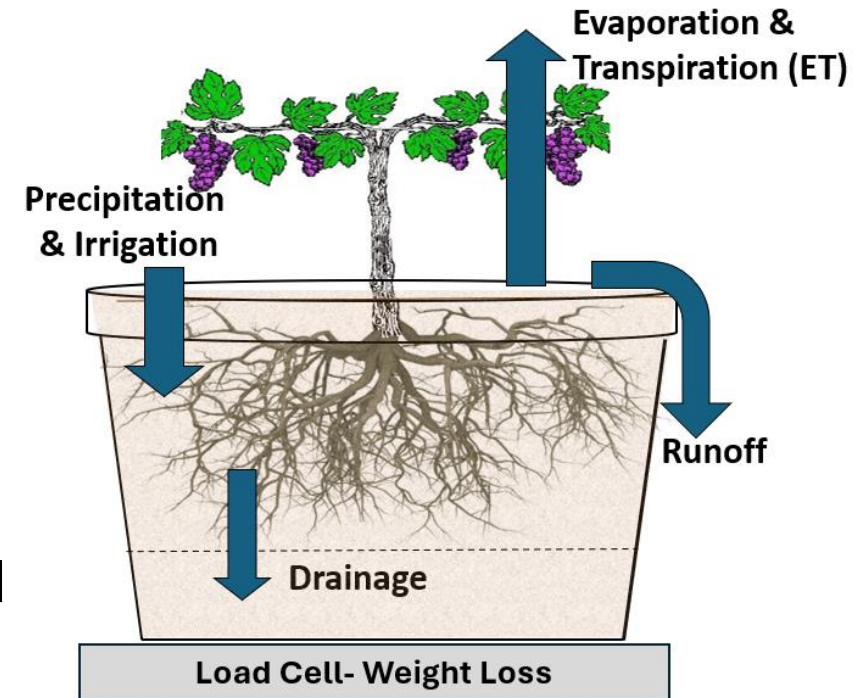
## Factors Impacting Water Use

- Evaporative demand
- Growth stage of vines
- Presence of a cover crop
- Canopy Size/Trellis type
- Row/Vine spacing
- Vineyard slope and aspect
- Vine health
- Hard pan
- Rooting depth
- Soil type



Lots of ways to measure/estimate ET:

- Soil Water Balance
- Weighing Lysimeters
- Calculated ET- CIMIS
- Measured Directly- Eddy Covariance
- Energy Balance Residual
  - Ground-based & Remotely Sensed
  - Measured vs. Modelled
  - Advection & Closure Issues



# California Irrigation Management Information System (CIMIS)

$$ET_c = K_c * ET_o$$

Grapevine evapotranspiration

Crop coefficient

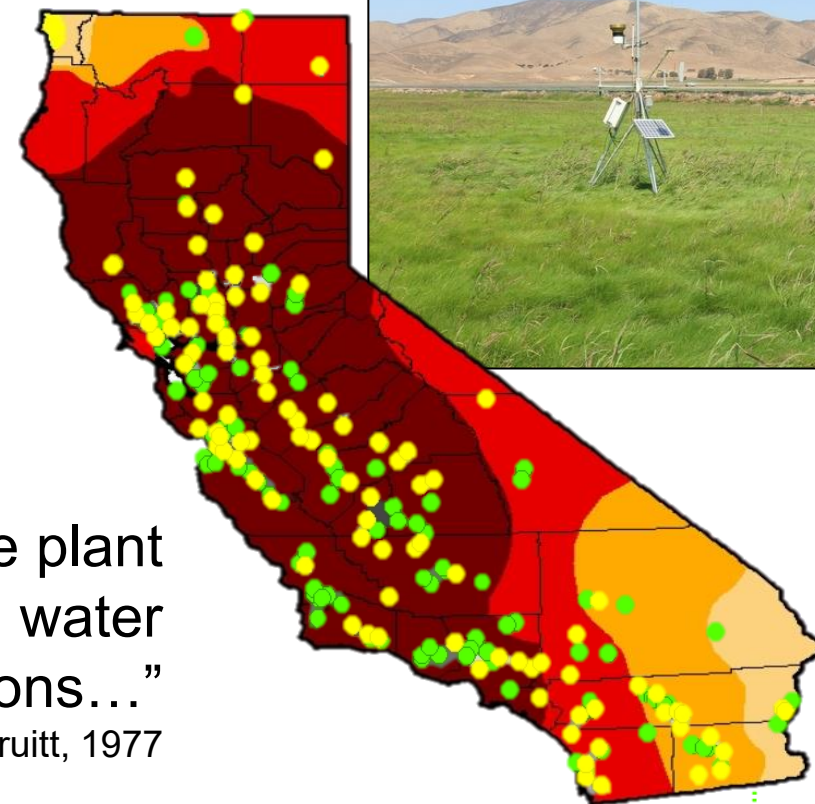
Reference ET  
(well-watered  
model grass)

$$K_c = ET_c / ET_o$$

Obtained from vines  
in weighing lysimeter



Kearney Agricultural Center  
Univ. of California- Parlier CA



“...assumes a disease-free plant  
grown under optimum soil water  
and nutrient conditions...”

Doorenbos and Pruitt, 1977

# California Irrigation Management Information System (CIMIS)

$$ET_c = K_c * ET_o * K_s$$

Grapevine evapotranspiration

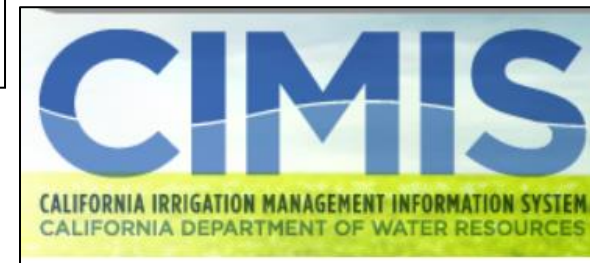
Crop coefficient

Reference ET  
(well-watered  
model grass)

Stress  
coefficient

$$K_c = ET_c / ET_o$$

Obtained from vines  
in weighing lysimeter



Kearney Agricultural Center  
Univ. of California- Parlier CA



## Issues:

- CIMIS stations often not well maintained
- Located far from target field
- $K_c$  is difficult to determine
- Translated from two "potted" vines

## Oakville CIMIS Station



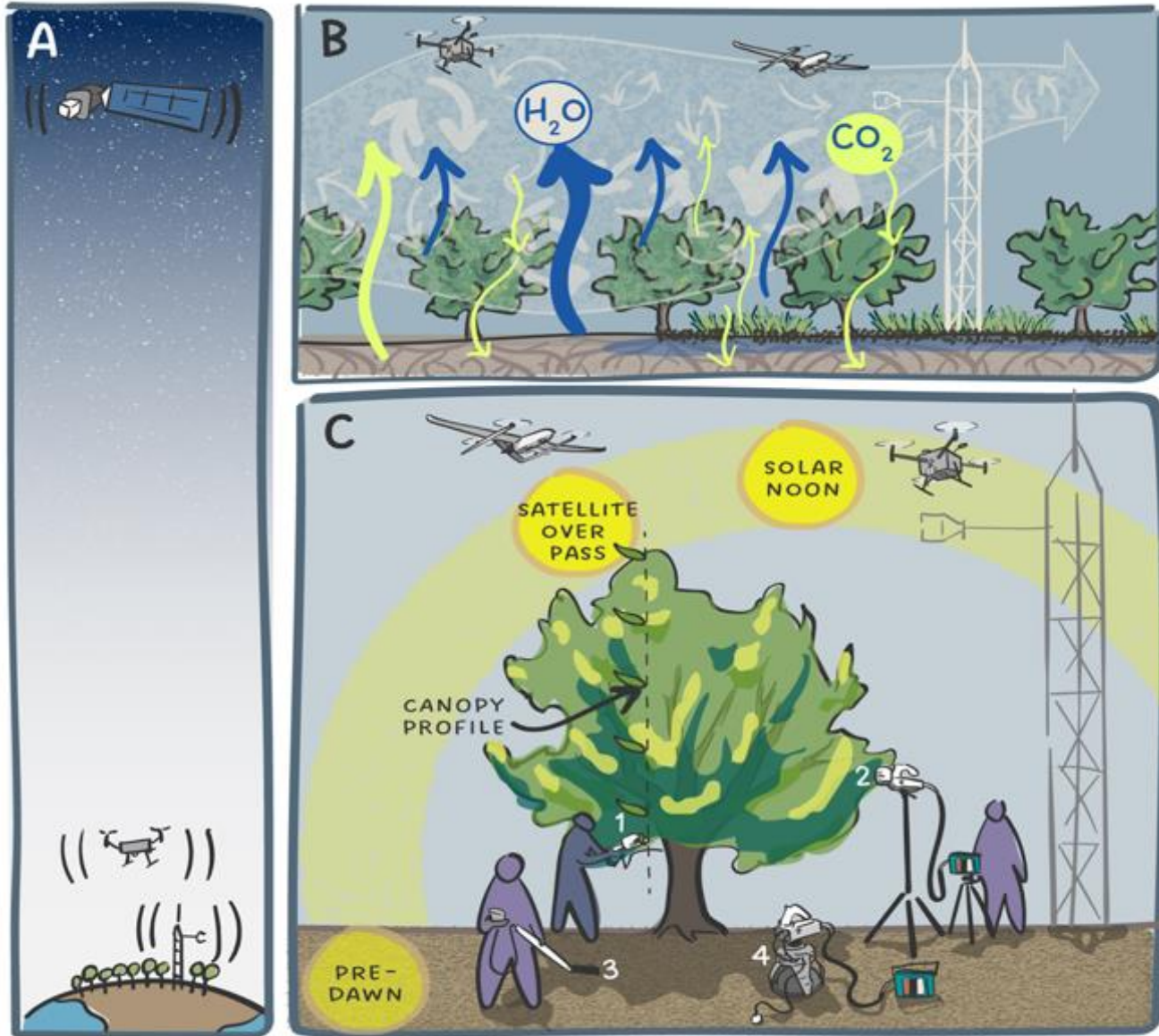
10/30/2020



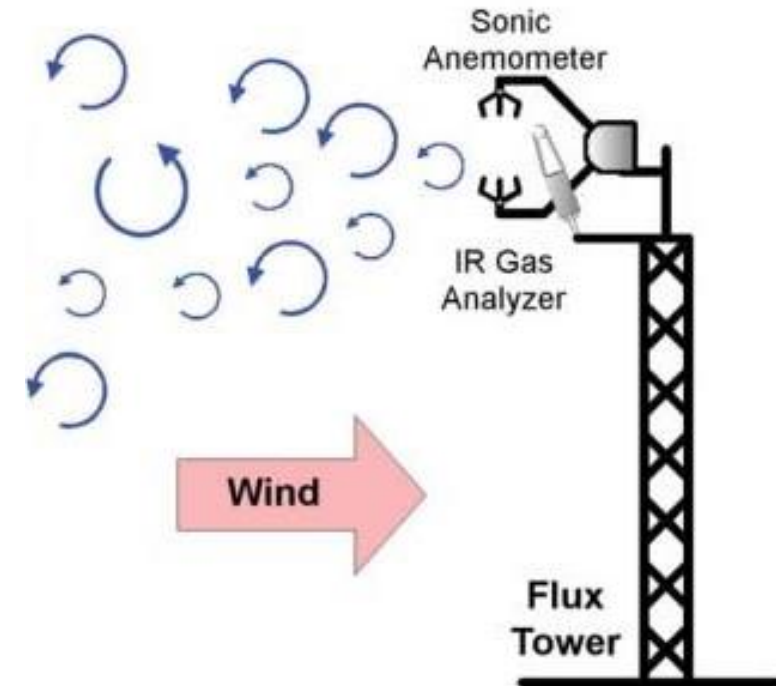
8/30/2023



2/29/2024



## Turbulent fluxes measured directly with Eddy Covariance

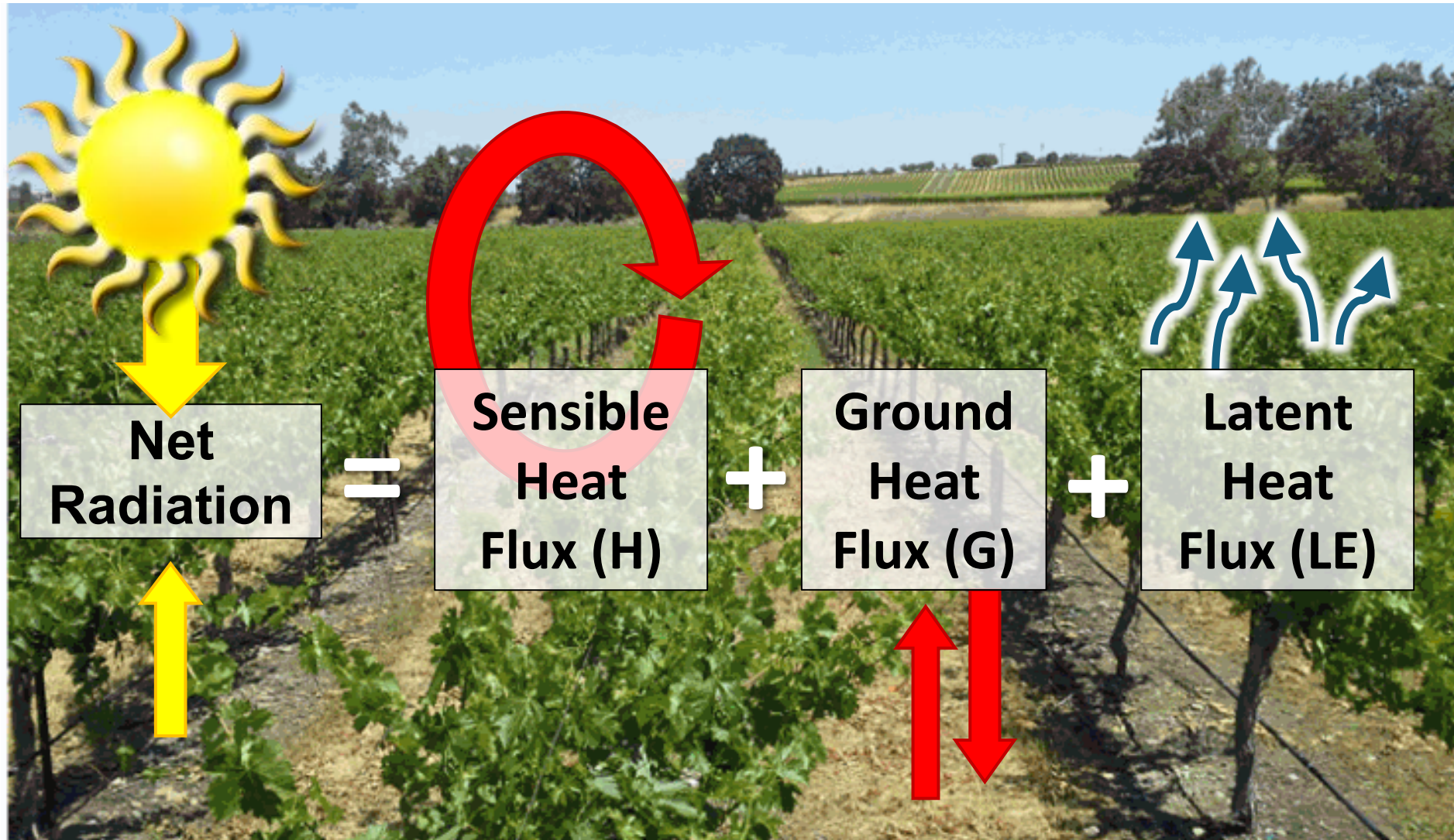


- “Gold standard” but some uncertainty
- Ideal= large, flat, homogeneous
- Dynamic footprint
  - dependent on wind & stability
- Advection (i.e. additional heat)
  - hot dry grassland next to wet cool crops



Bird's eye view

# Thermal Energy Balance Approaches to Quantify ET




Partitioning the energy at the crop surface

Available Energy

$$\text{Energy Balance Residual} = \overbrace{\text{Net Radiation} - G}^{\text{Available Energy}} - \underbrace{H - LE}_{\text{Turbulent Fluxes}}$$

Correction methods for EBR (i.e. Bowen ratio-  $H/LE$ )


# Evapotranspiration uncertainty at micrometeorological scales: the impact of the eddy covariance energy imbalance and correction methods

N. Bambach<sup>1</sup>  · W. Kustas<sup>2</sup> · J. Alfieri<sup>2</sup> · J. Prueger<sup>3</sup> · L. Hipps<sup>4</sup> · L. McKee<sup>2</sup> · S. J. Castro<sup>5</sup> · J. Volk<sup>6</sup> · M. M. Alsina<sup>7</sup>  
A. J. McElrone<sup>5,8</sup>

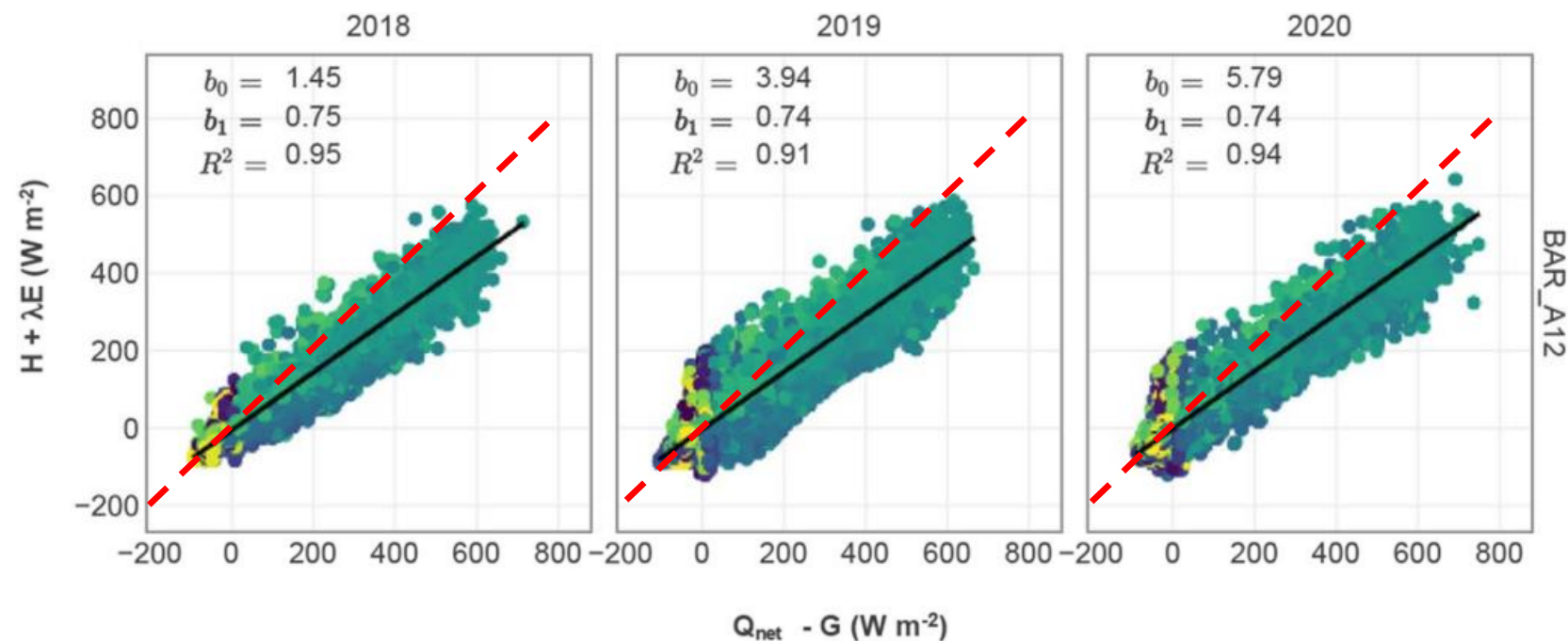
**Table 1** Summary description of micrometeorological methodological approaches for daily *ET* estimates

Methodological approach	Abbreviated name	Equation	Description
Eddy covariance <i>ET</i>	$ET_{EC}$	Equation 2	Sum of eddy covariance <i>ET</i> flux
Eddy covariance daytime <i>ET</i>	$ET_{EC-DT}$	Equation 3	Sum of daytime eddy covariance <i>ET</i> flux (nighttime fluxes excluded)
Eddy covariance <i>ET</i> corrected by <i>EBR</i> partitioned based on $B_o$	$ET_{B-SD}$	Equation 5	Sum of eddy covariance <i>ET</i> fluxes corrected by <i>EBR</i> partitioned based on $B_o$ at each AP
Eddy covariance daytime <i>ET</i> corrected by <i>EBR</i> partitioned based on $B_o$	$ET_{B-SD-DT}$	Equation 6	Sum of daytime eddy covariance <i>ET</i> fluxes corrected by <i>EBR</i> partitioned based on $B_o$ at each AP
Eddy covariance <i>ET</i> corrected by mean <i>EBR</i> partitioned based on $B_o$	$ET_{B-D}$	Equation 7	Sum of eddy covariance <i>ET</i> fluxes corrected by <i>EBR</i> partitioned based on a daily mean $B_o$
Eddy covariance daytime <i>ET</i> corrected by mean <i>EBR</i> partitioned based on $B_o$	$ET_{B-D-DT}$	Equation 8	Sum of daytime eddy covariance <i>ET</i> fluxes corrected by <i>EBR</i> partitioned based on a daily mean $B_o$
Eddy covariance daytime <i>ET</i> corrected by <i>EBR</i> partitioned based on a moving median $B_o$	$ET_{B-SD-MM}$	Equation 9	Sum of eddy covariance <i>ET</i> fluxes corrected by <i>EBR</i> partitioned based on a $B_o$ derived as a centered $\pm 15$ days moving median
Energy balance residual <i>ET</i>	$ET_{EB}$	Equation 10	Sum of energy balance residual <i>ET</i>
Energy balance residual <i>ET</i>	$ET_{EB-DT}$	Equation 11	Sum of daytime energy balance residual <i>ET</i>


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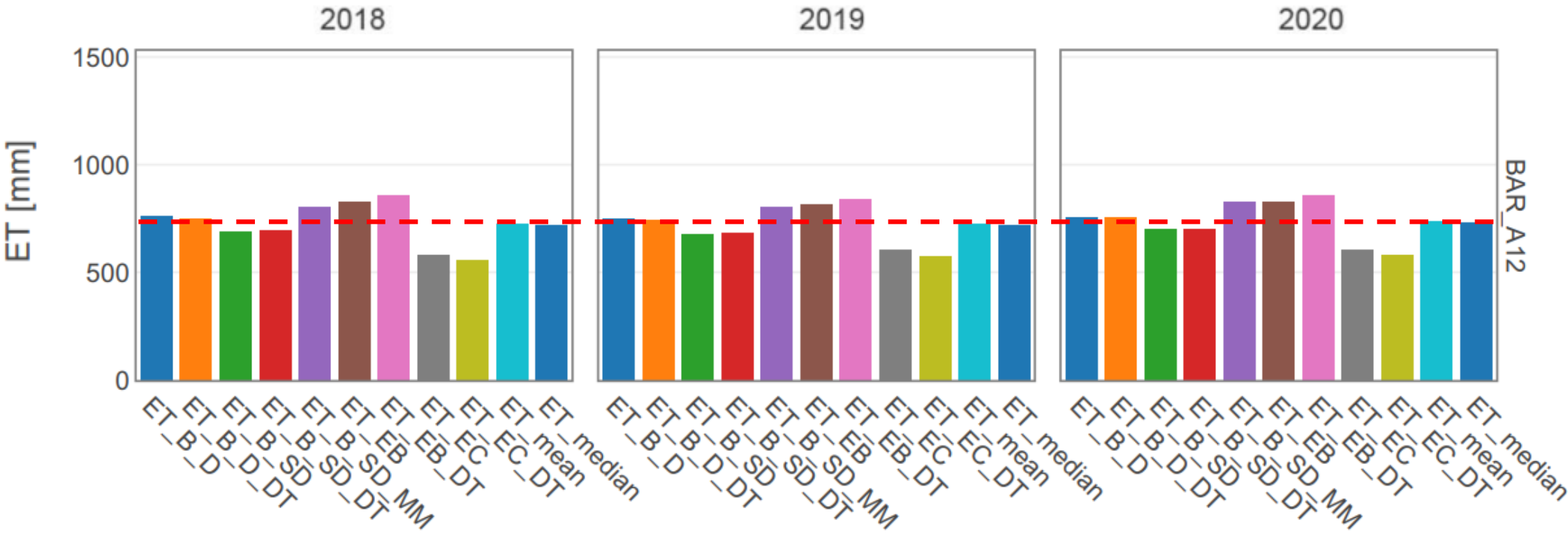
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Location map?




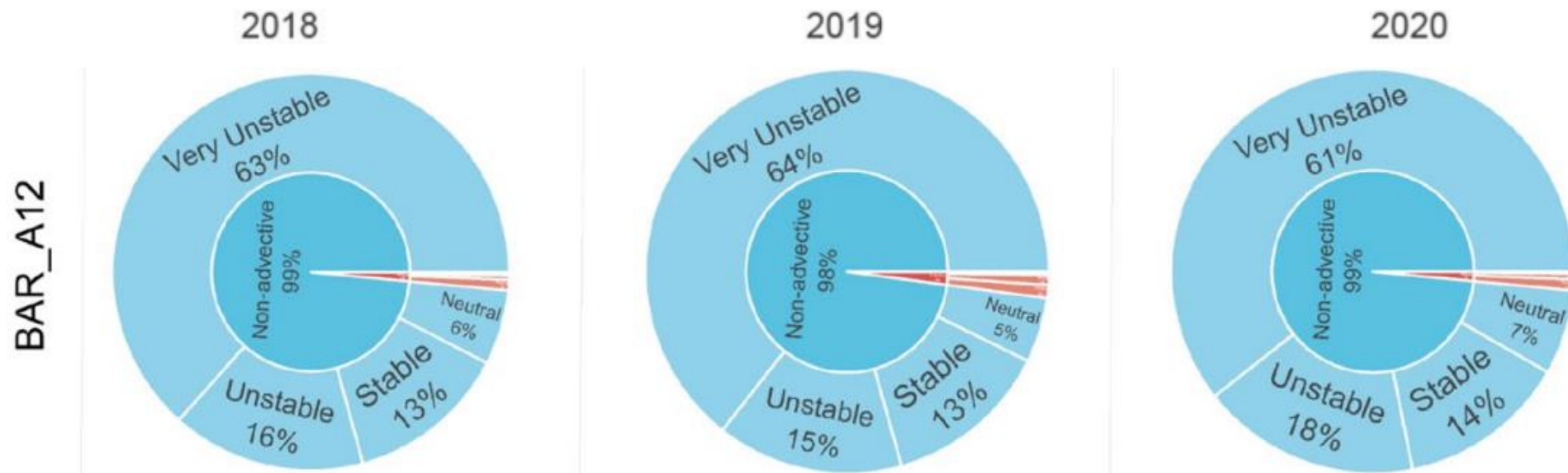
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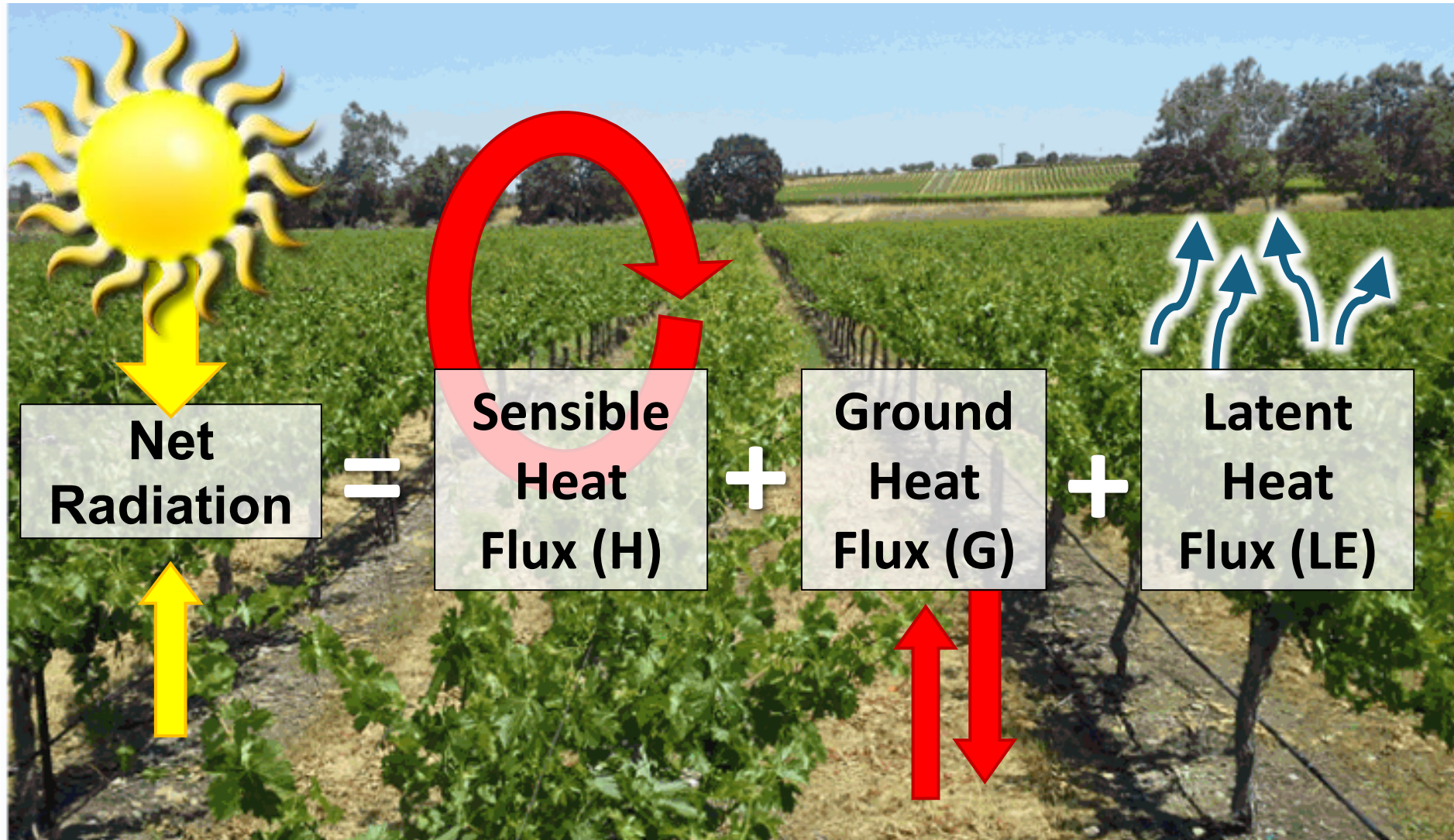


# Evapotranspiration uncertainty at micrometeorological scales: the impact of the eddy covariance energy imbalance and correction methods

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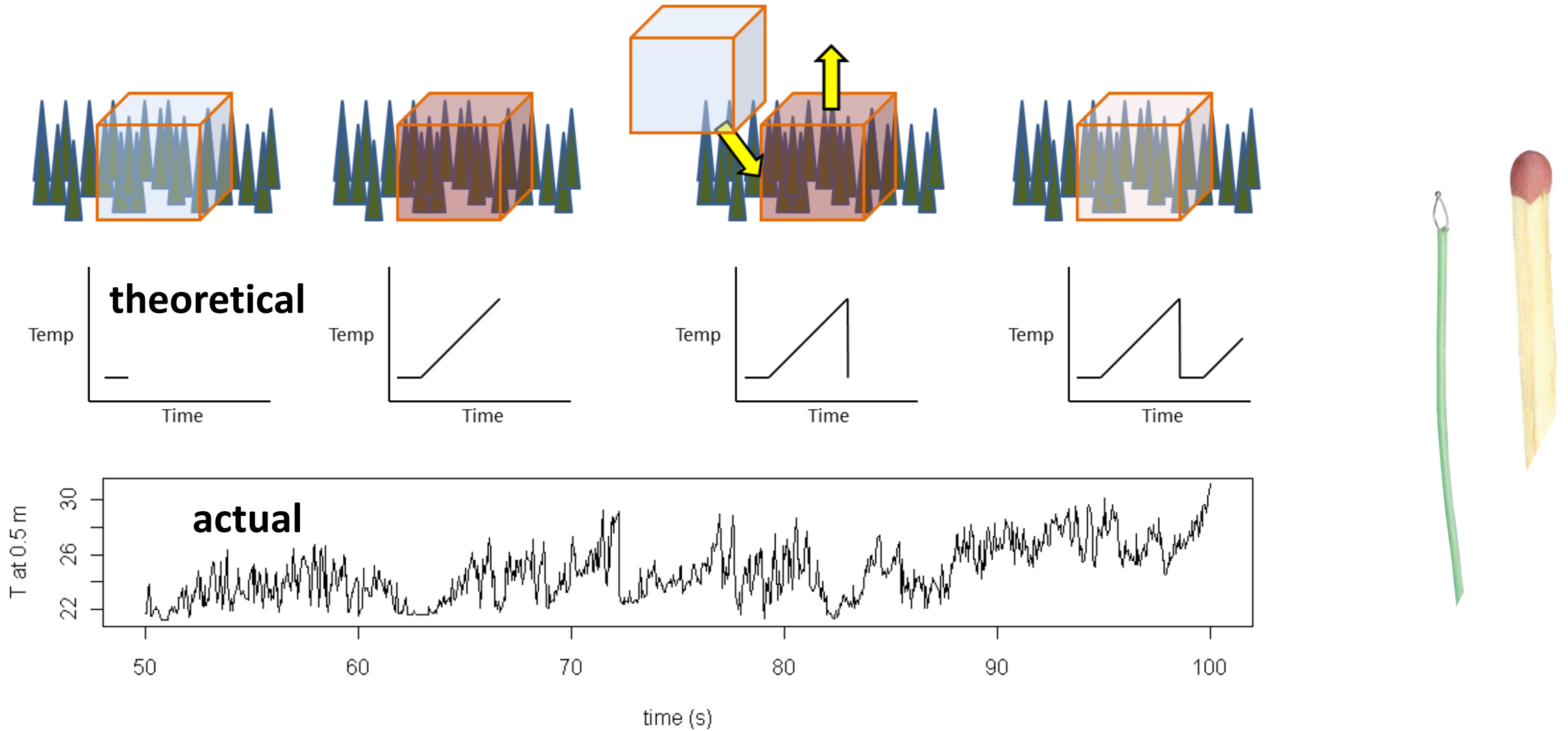


# Thermal Energy Balance Approaches to Quantify ET



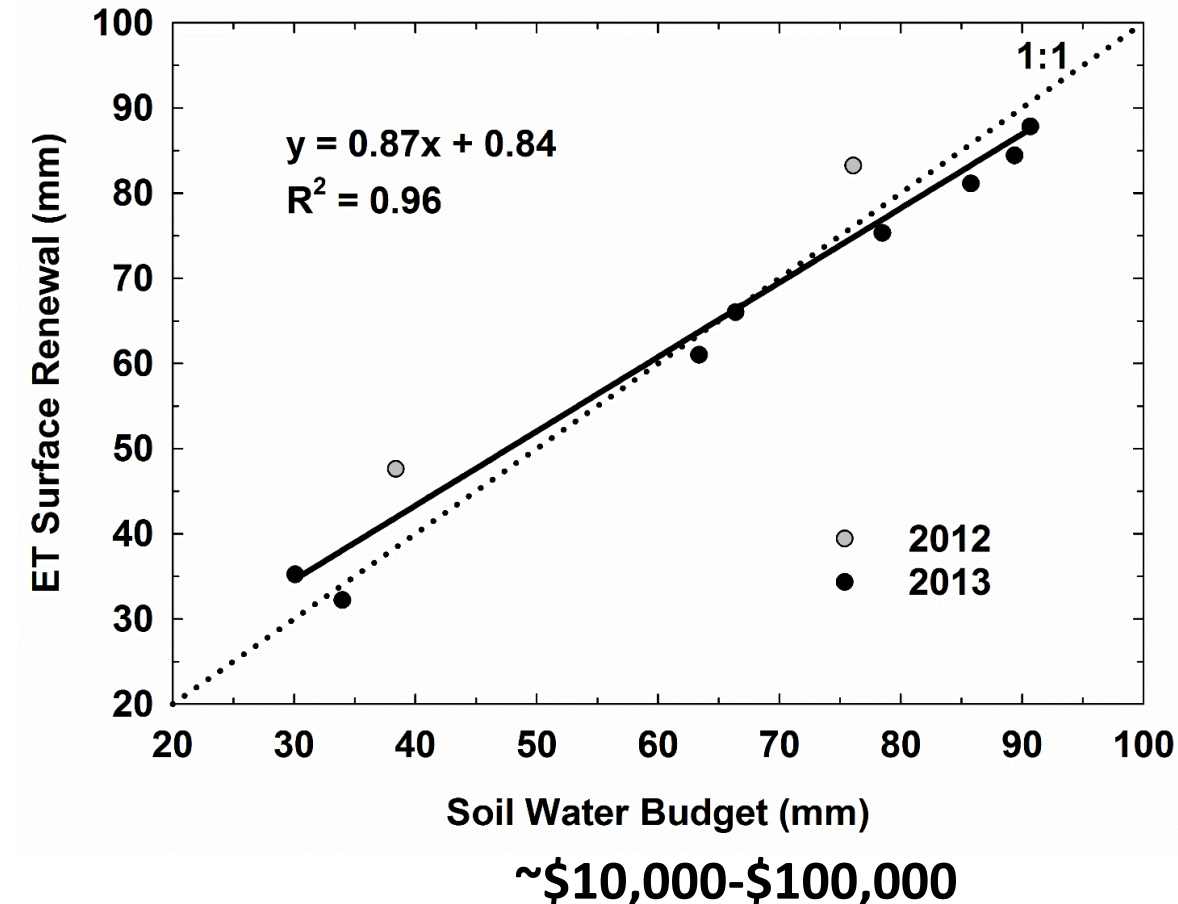
Partitioning the energy at the crop surface

# Surface Renewal- Theory vs. Reality



Successfully removed the need to calibrate against expensive research grade system (Shapland et al. 2012a,b, 2014)

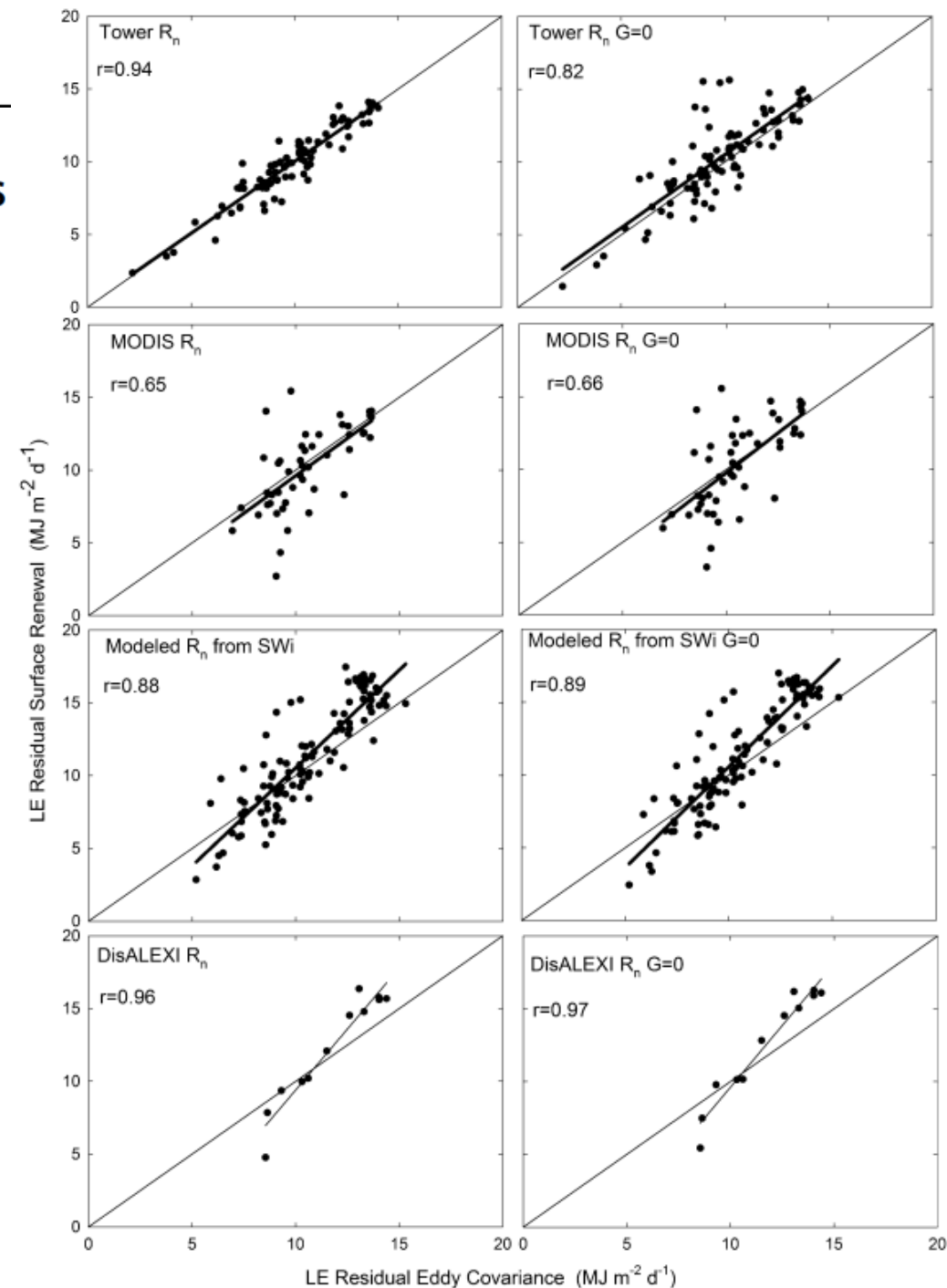
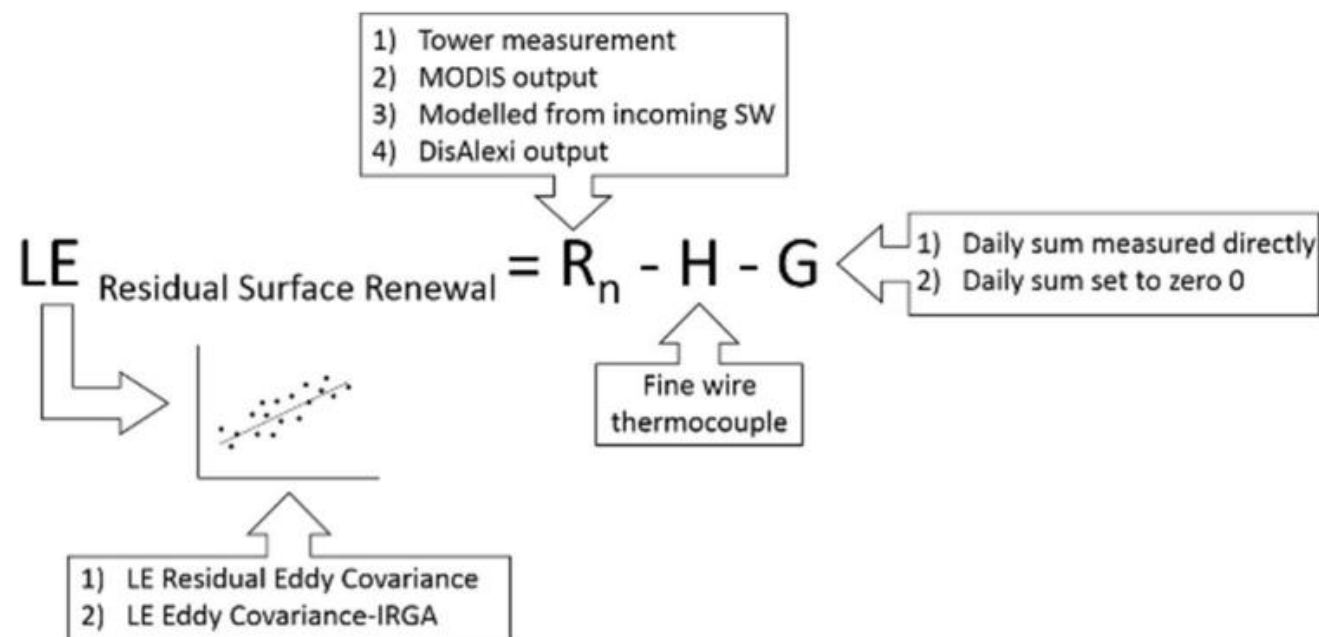
# New Surface Renewal System: A reliable & automated ET measurement system



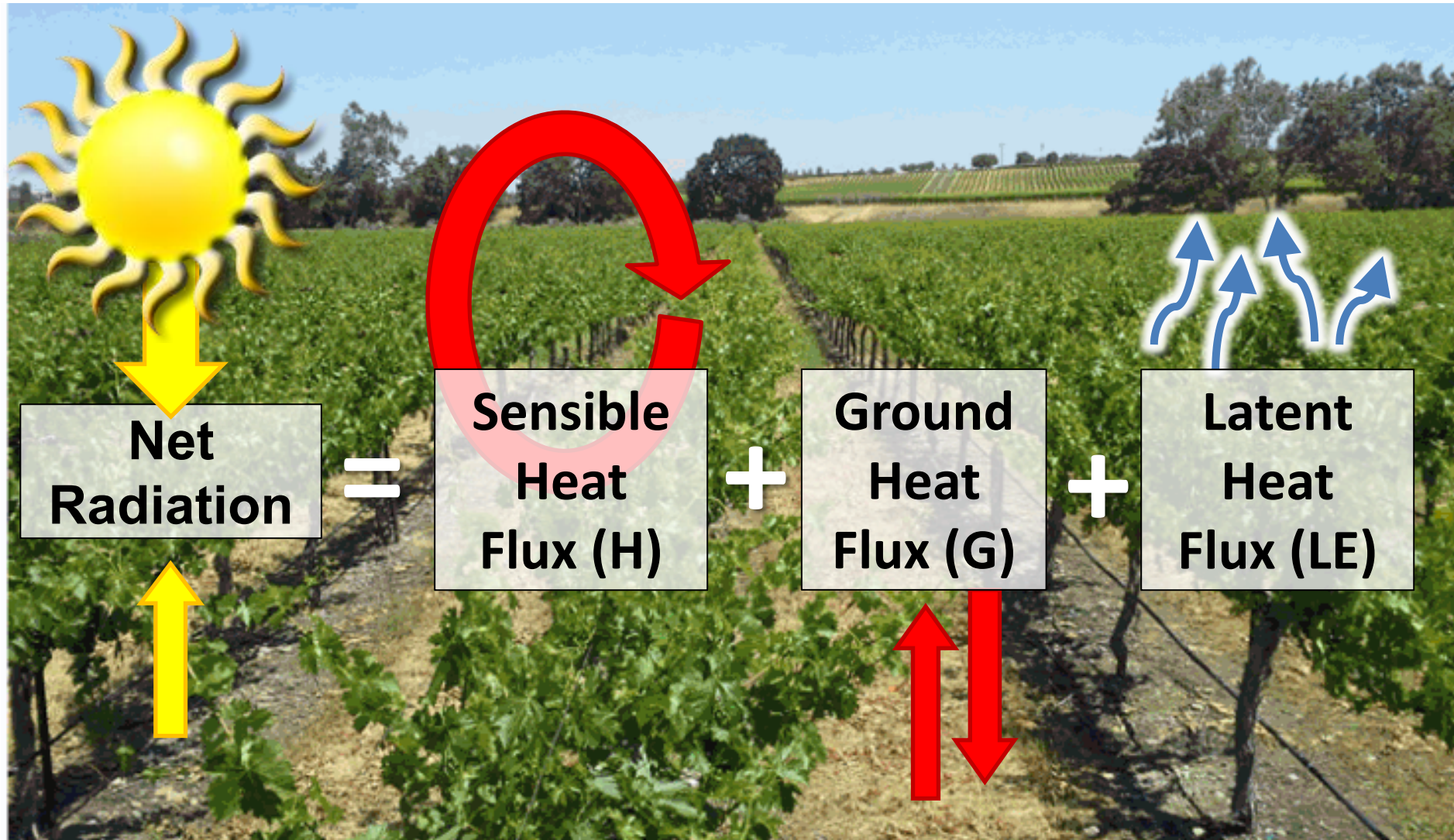
**New Commercial System (Tule Technologies)**  
**Joint patent between USDA & UC Davis**

# Comparison of vineyard evapotranspiration estimates from surface renewal using measured and modelled energy balance components in the GRAPEX project

Christopher K. Parry<sup>1</sup> · William P. Kustas<sup>2</sup> · Kyle R. Knipper<sup>2</sup> · Martha C. Anderson<sup>2</sup> · Joseph G. Alfieri<sup>2</sup> · John H. Prueger<sup>3</sup> · Andrew J. McElrone<sup>1,4</sup> 

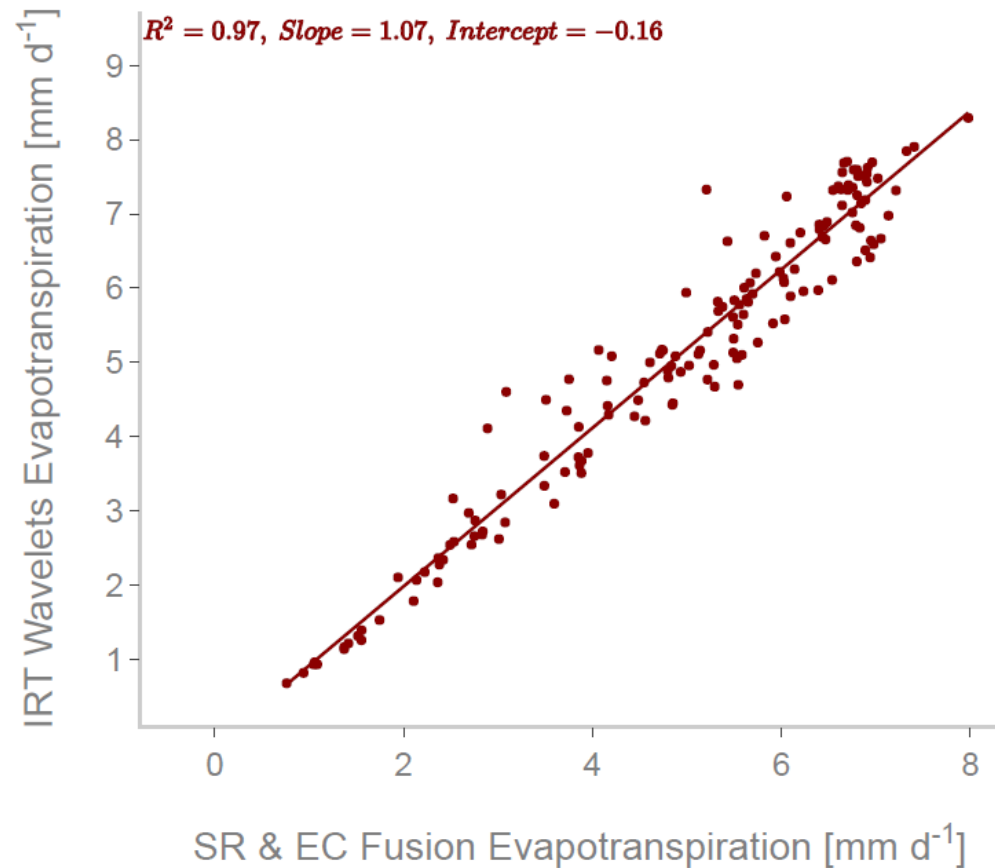


# Thermal Energy Balance Approaches to Quantify ET



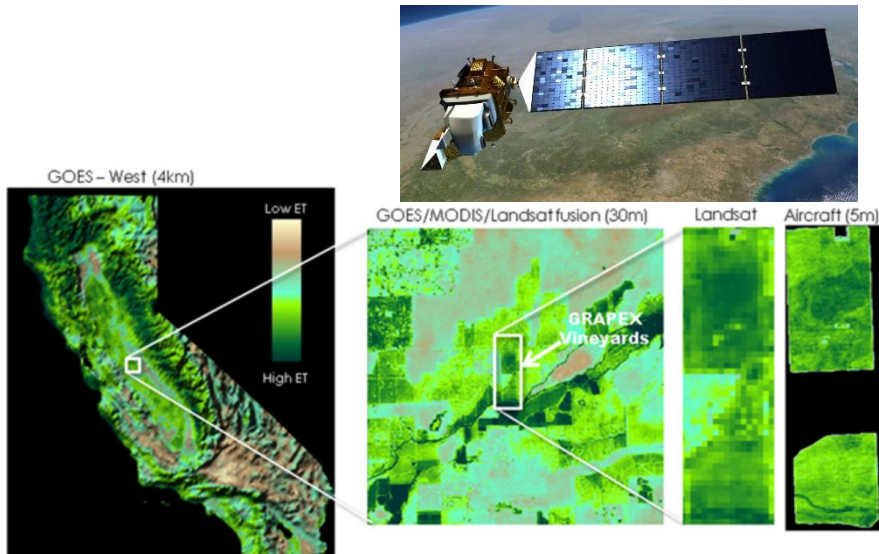
Partitioning the energy at the crop surface

# New IRT Wavelet method to estimate crop water use

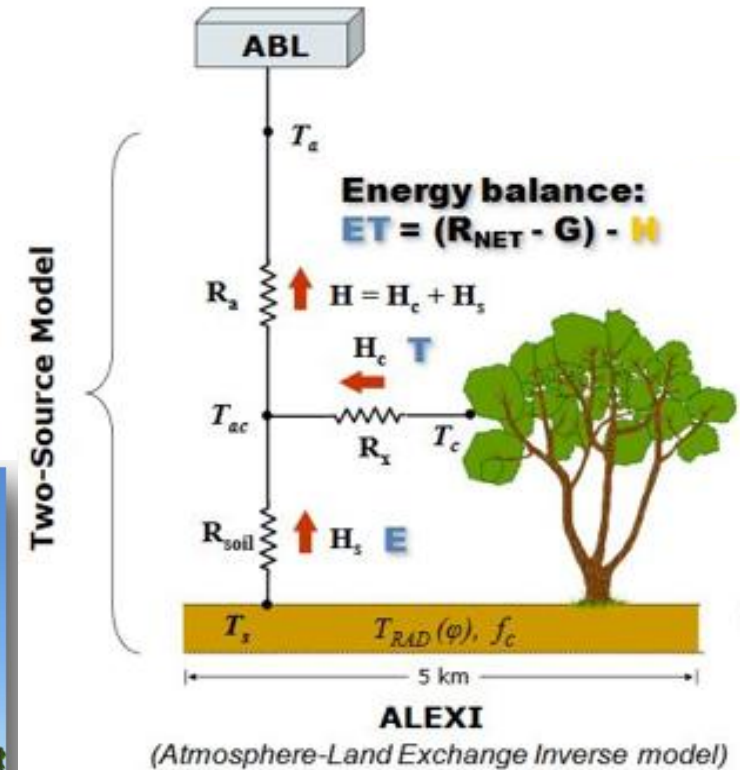


Developing tools to facilitate grower adoption of this technique- citizen science model

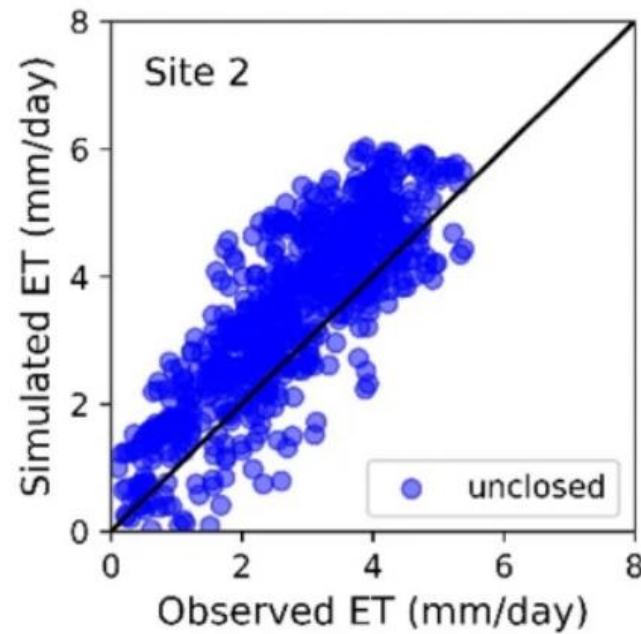
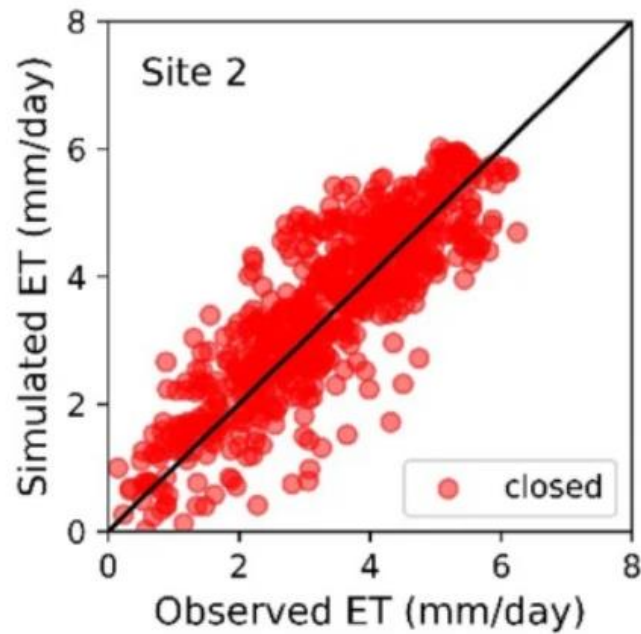
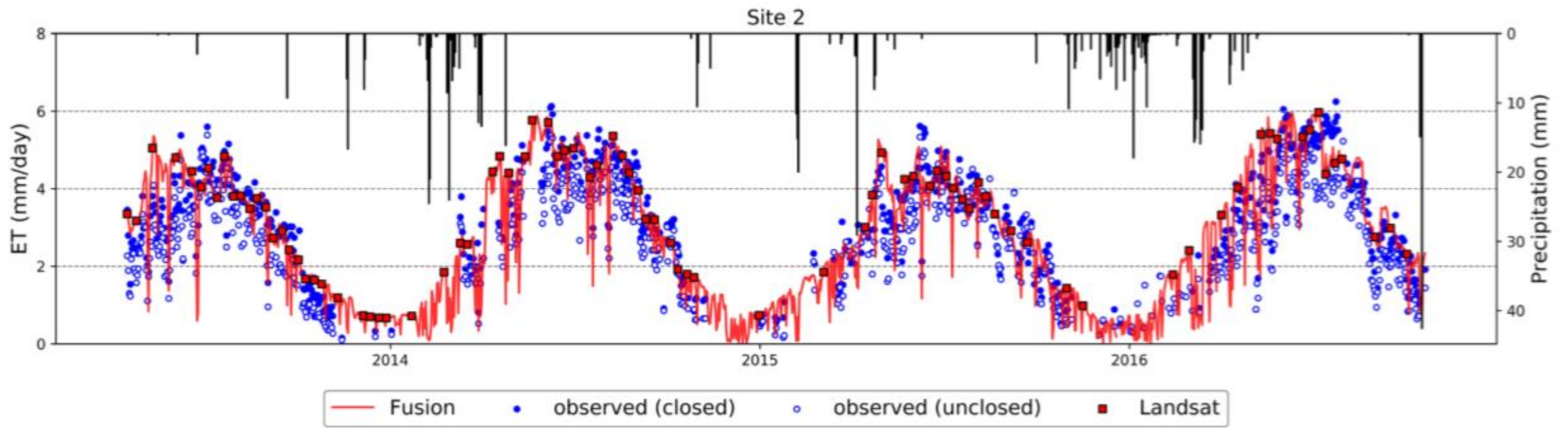
# Grape Remote sensing Atmospheric Profile & Evapotranspiration eXperiment



## Two Source Energy Balance







Sierra Loma- Lodi  
Knipper *et al.* 2019 *Irrigation Science*

# Unpublished Data Discussion