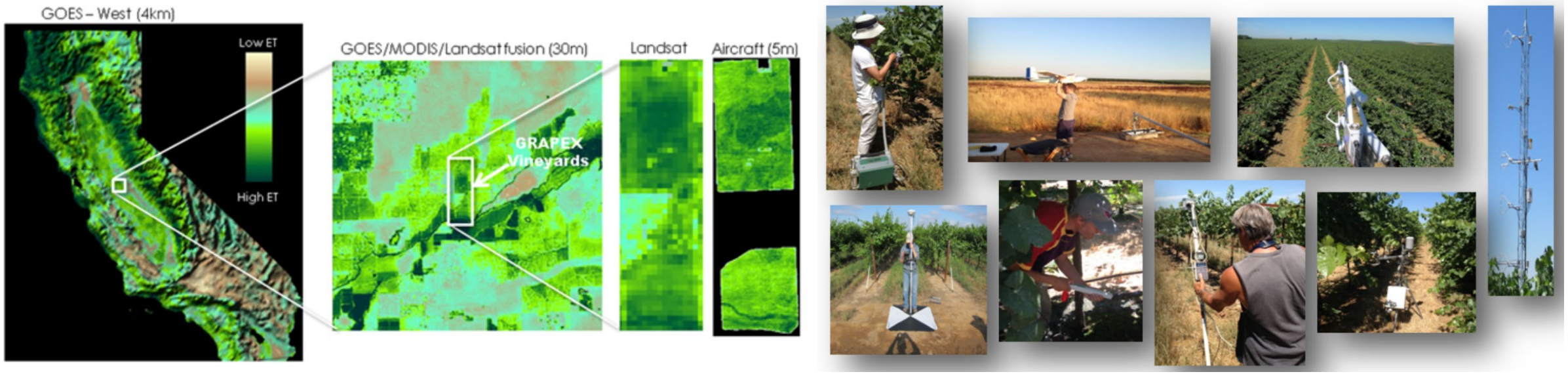
USDA Agricultural Research Service | UC DAVIS UNIVERSITY OF CALIFORNIA | UC ANR | UtahState University | California State University MONTEREY BAY | NASA EARTH SCIENCE APPLIED SCIENCES | COMPLUTIG EMPRESA DE BASE TECNOLÓGICA DE LA UNIVERSIDAD DE ALCALÁ

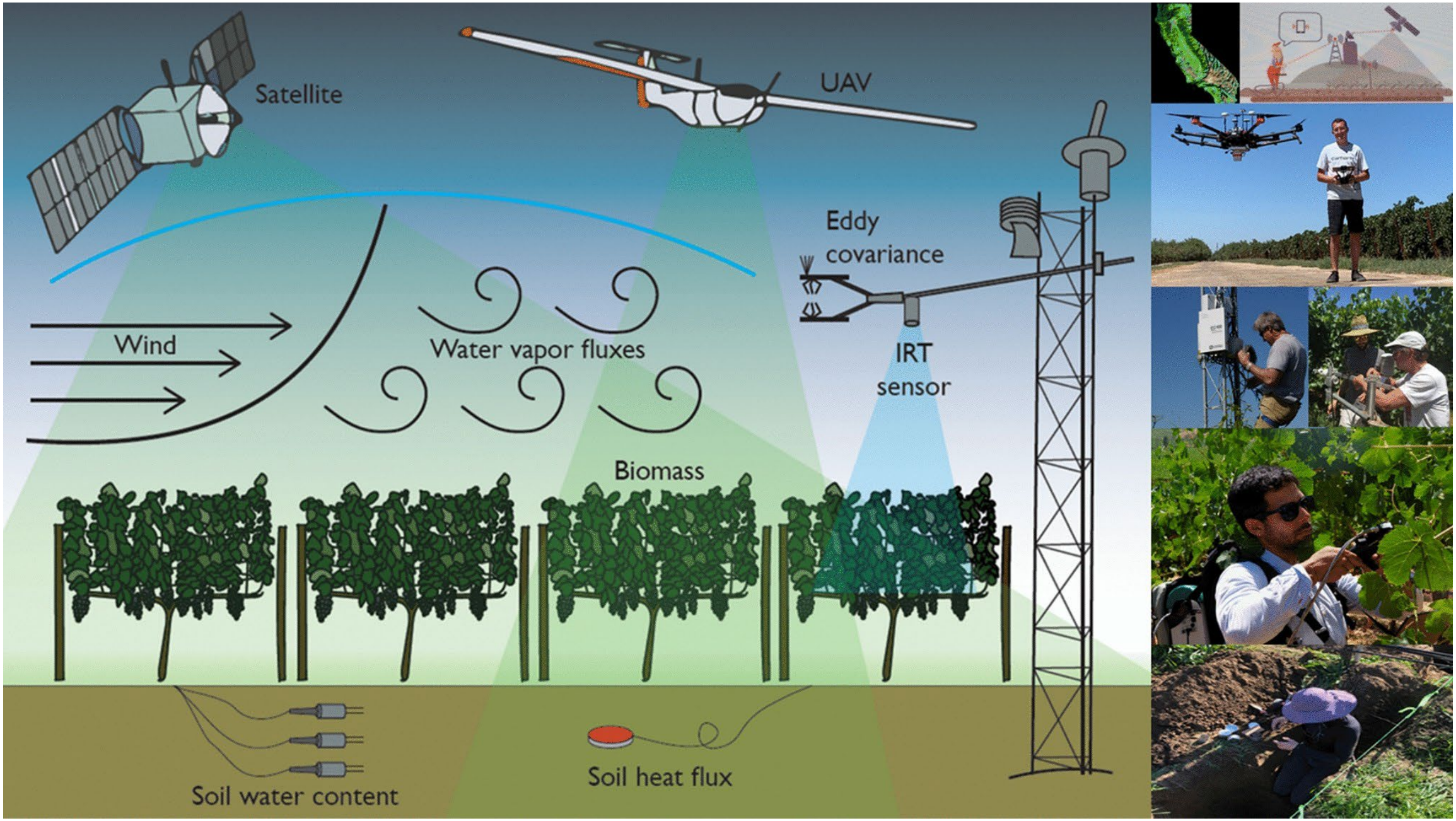
William Kustas, Nicolas Bambach, Kyle Knipper, Mimar Alsina, Martha Anderson, Lawrence Hipps, Lynne McKee, Forrest Melton, Hector Nieto, John Prueger, Joe Alfieri, Mallika Nocco, Alfonso Torres-Rua, Seba Castro-Bustamante, Andy Gal, Ian Wright, E&J Gallo….

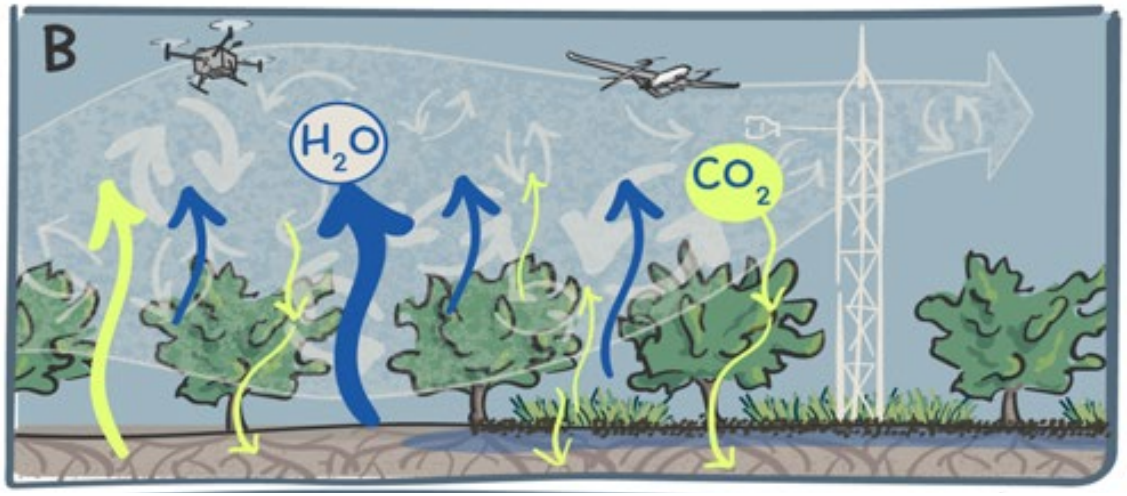
Grape Remote sensing Atmospheric Profile & Evapotranspiration eXperiment

grapex

Refine and apply a multi-scale remote sensing ET toolkit for mapping crop water use and stress for improved irrigation management in California

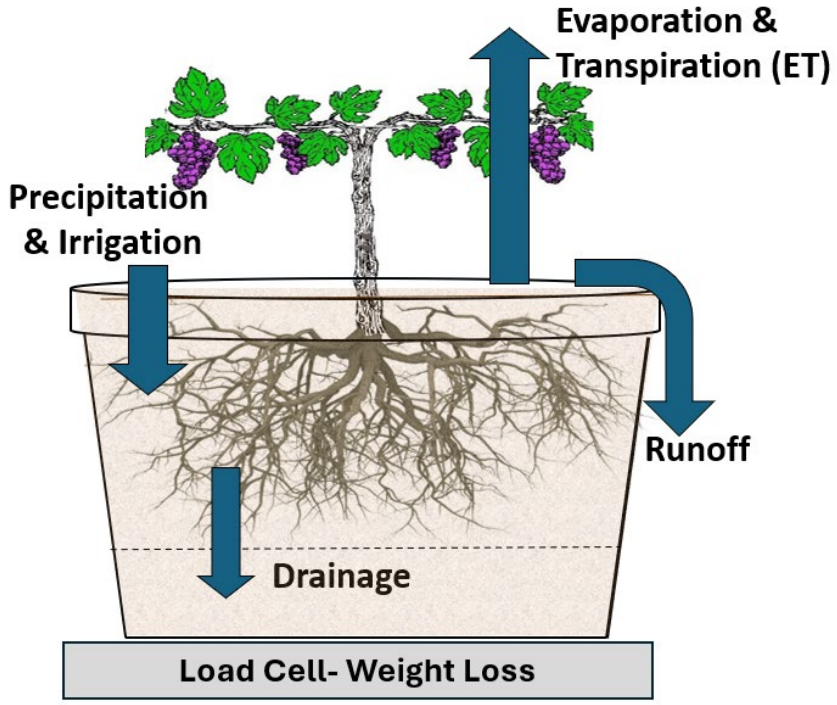



Satellite
UAV
Eddy
covariance
IRT
sensor
Wind
Water vapor fluxes
Biomass
Soil water content
Soil heat flux



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

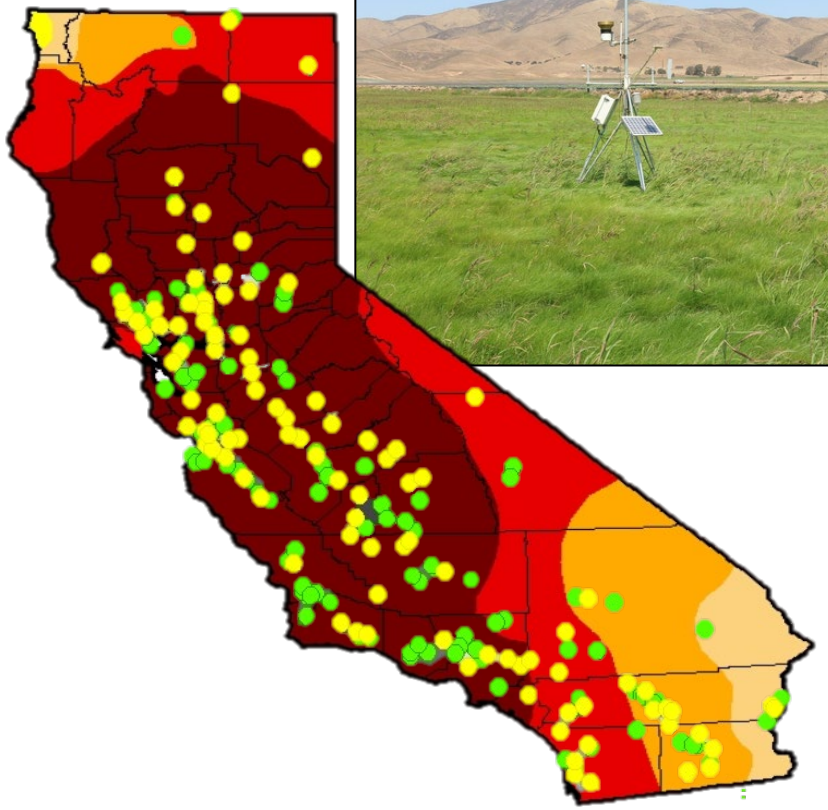
Crop coefficient

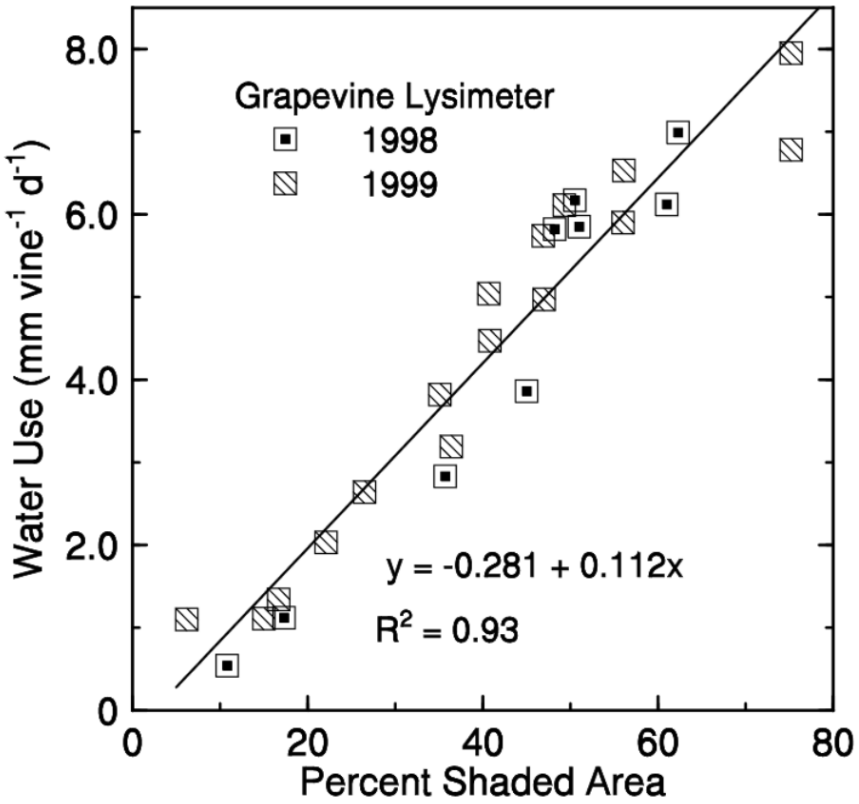
Reference ET (well-watered model grass)

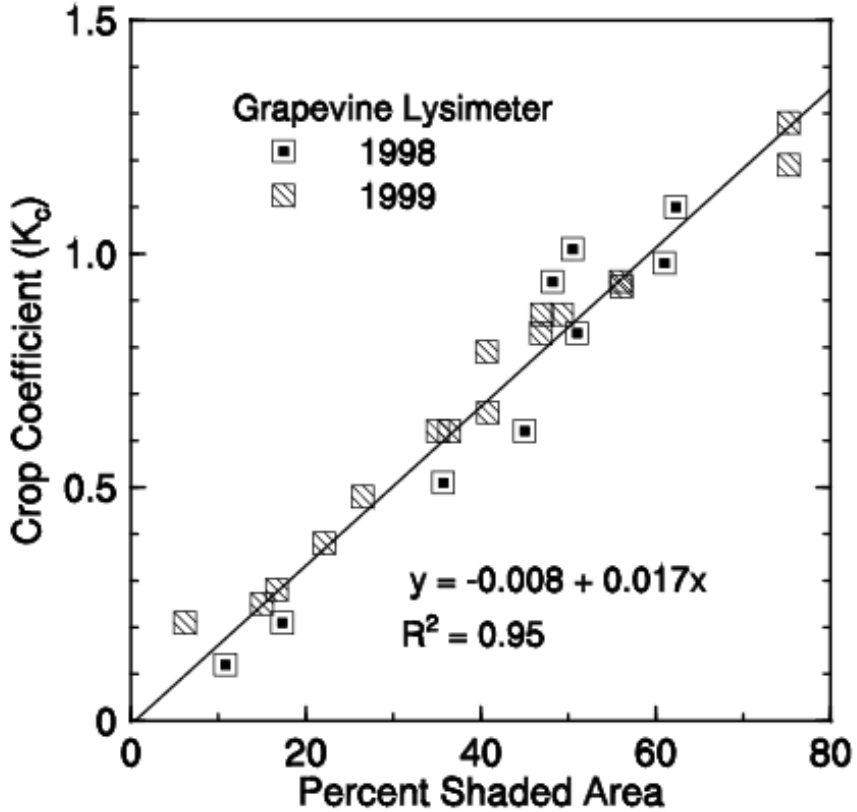
$$K_c = ET_c / ET_o$$

Obtained from vines in weighing lysimeter

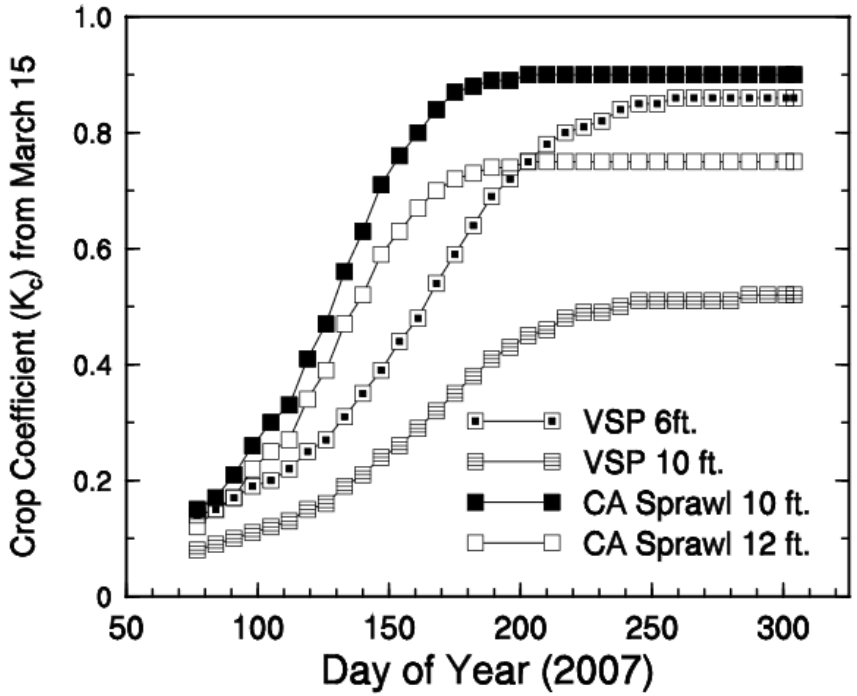
Kearney Agricultural Center
Univ. of California- Parlier CA







Williams and Ayars (2005)


Crop Coefficient (K_c) from March 15
1.0
0.8
0.6
0.4
0.2
0
50
100
150
200
250
300
Day of Year (2007)
VSP 6ft.
VSP 10 ft.
CA Sprawl 10 ft.
CA Sprawl 12 ft.

California Irrigation Management Information System (CIMIS)

$$ET_c = K_c * ET_o * K_s$$

Stress coefficient

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

Issues:

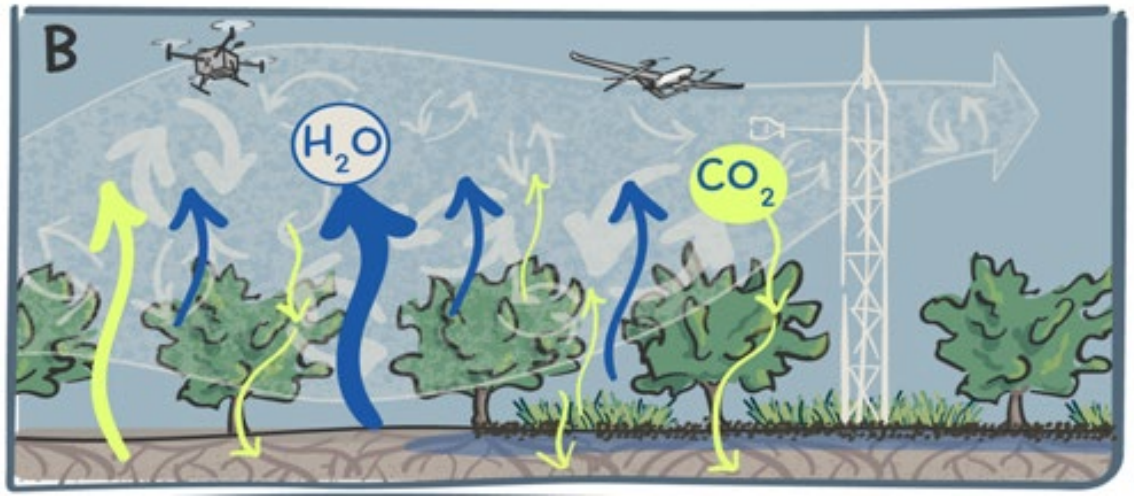
- CIMIS stations often not well maintained
- Located far from target field
- K_c & K_s -difficult to determine
- Translated from two "potted" vines

Oakville CIMIS Station

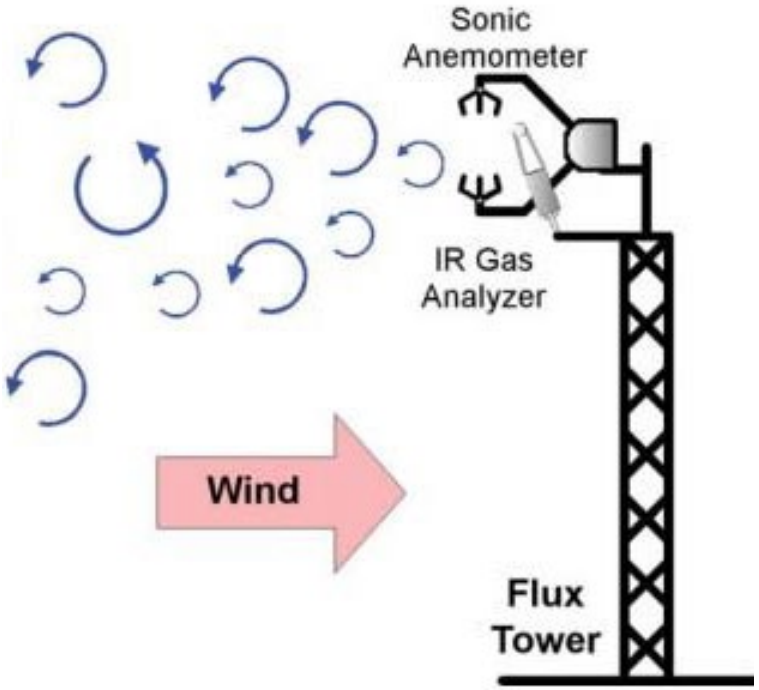
10/30/2020

8/30/2023

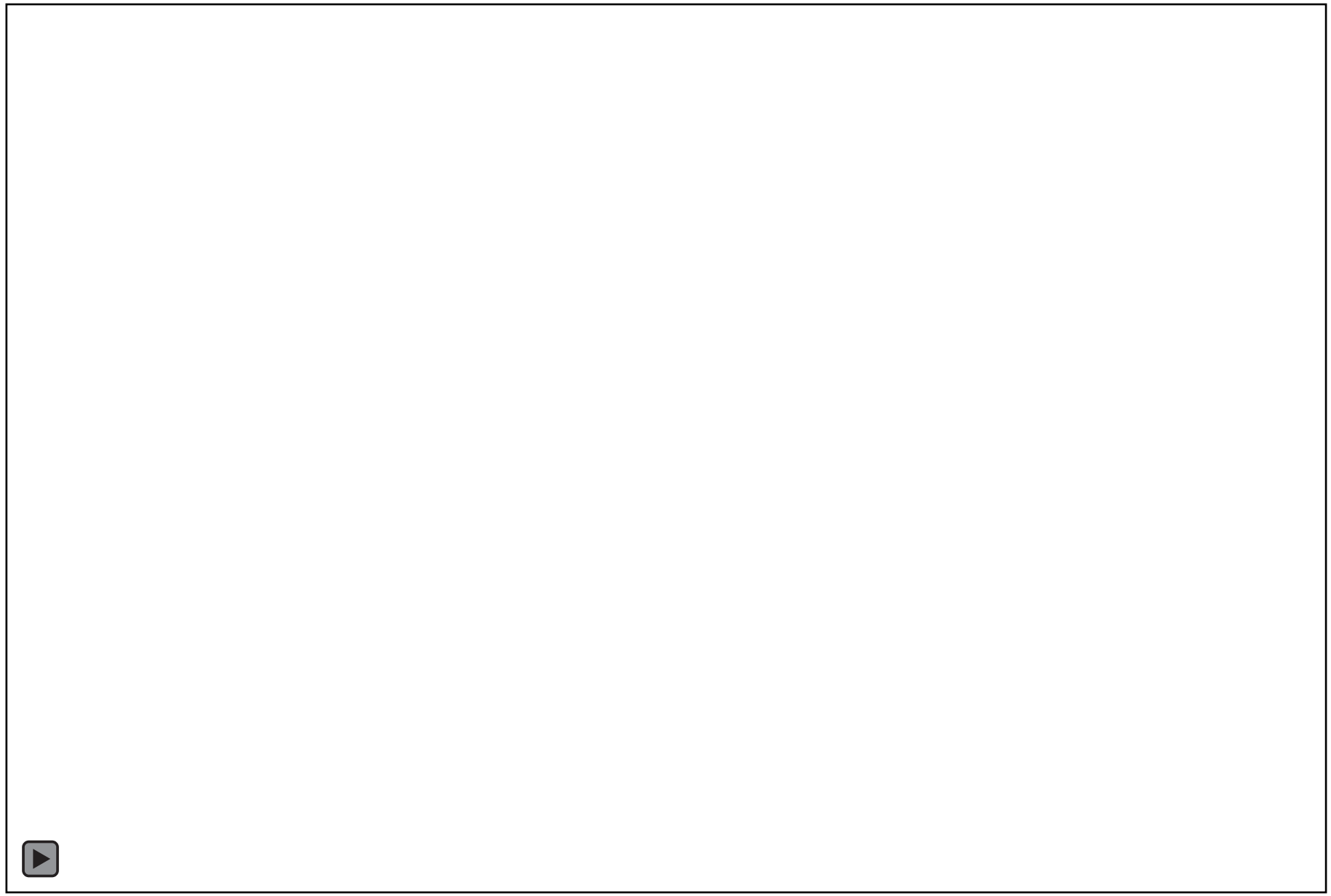
2/29/2024



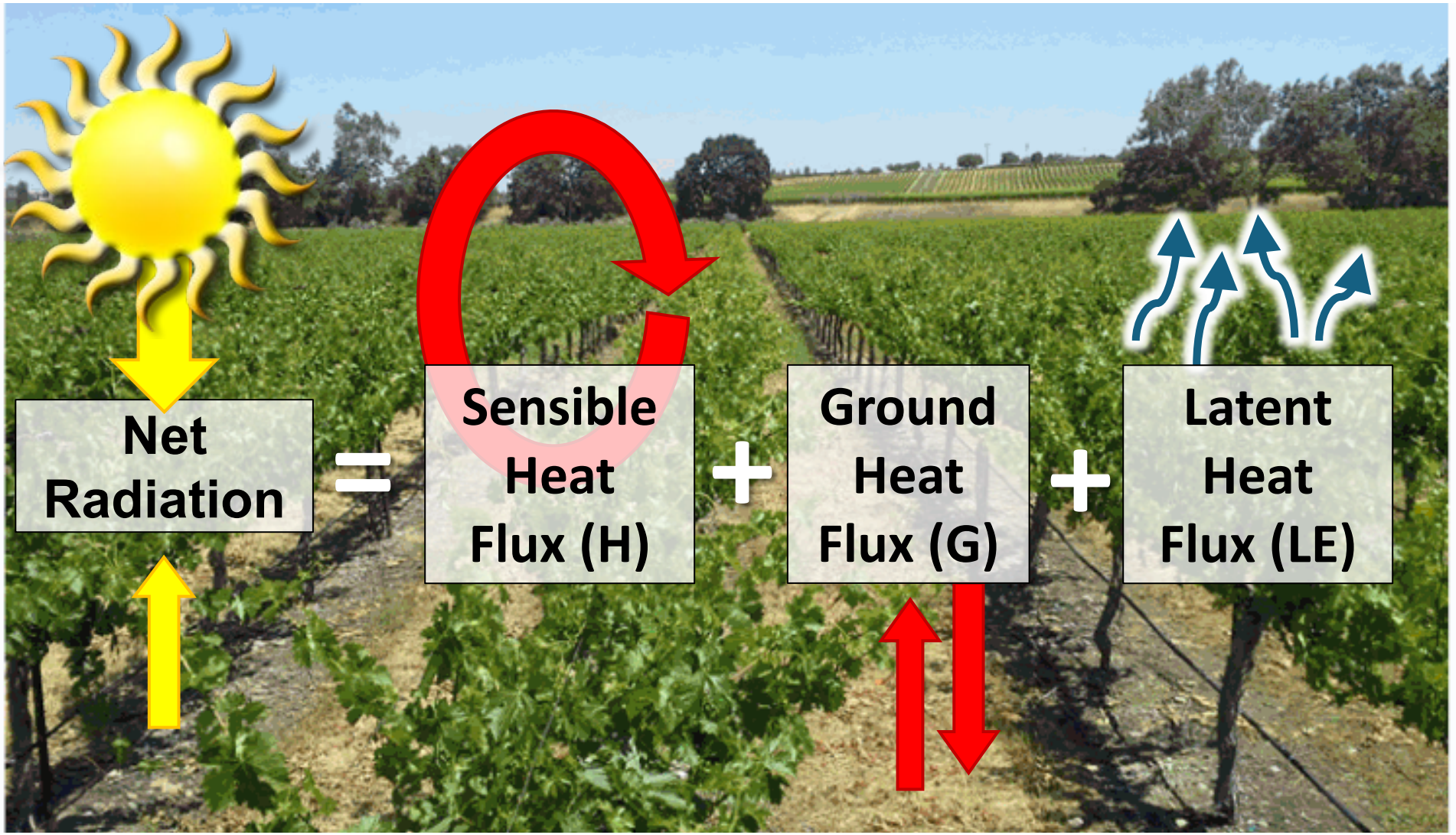
Turbulent fluxes measured directly with Eddy Covariance



- “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 cool wet crops



Thermal Energy Balance Approaches to Quantify ET



Partitioning the energy at the crop surface

Available Energy

Energy Balance Residual= Net Radiation – G – H – LE

Turbulent Fluxes

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

Irrigation Science (2022) 40:445–461
https://doi.org/10.1007/s00271-022-00783-1

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

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

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

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

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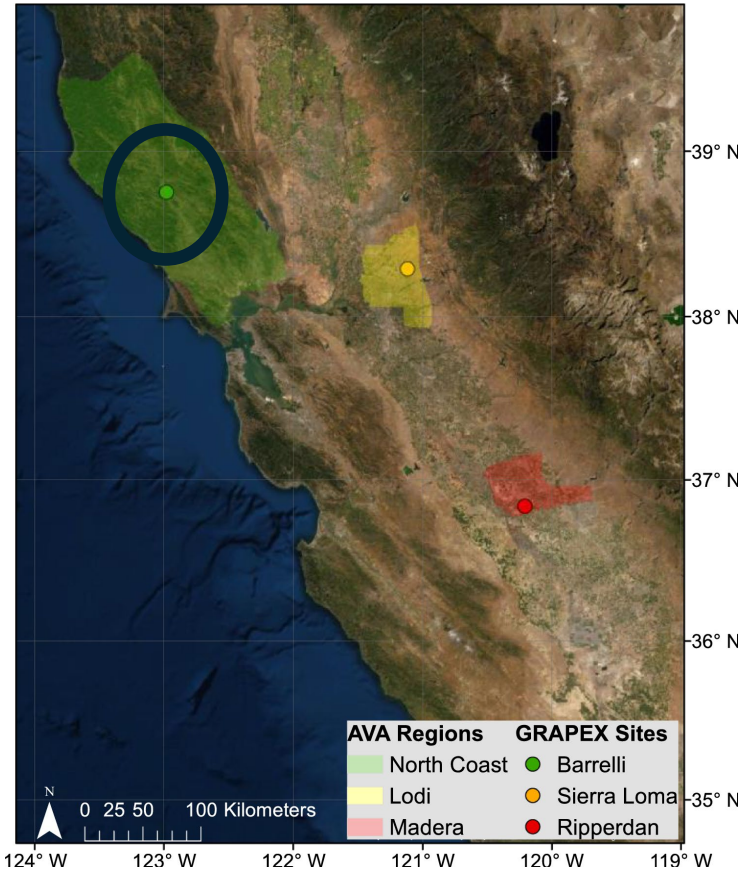
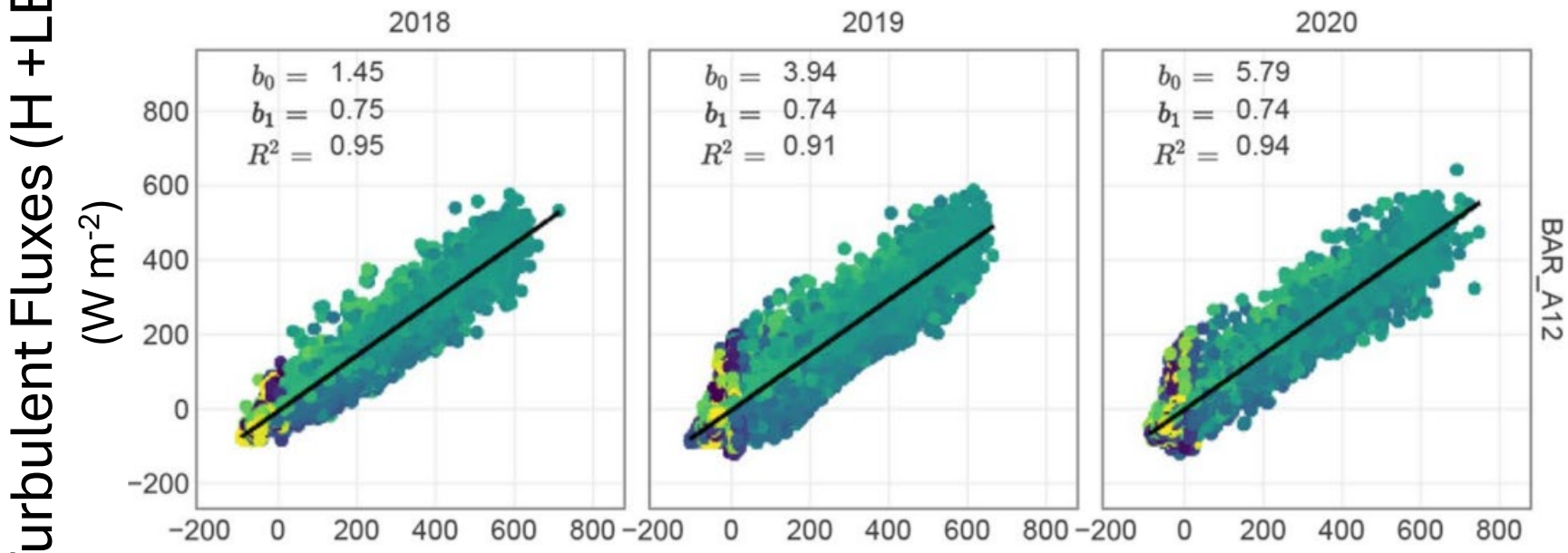


Data for Barelli- near Cloverdale, CA



Available Energy (R_N -G)
(W m^{-2})

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

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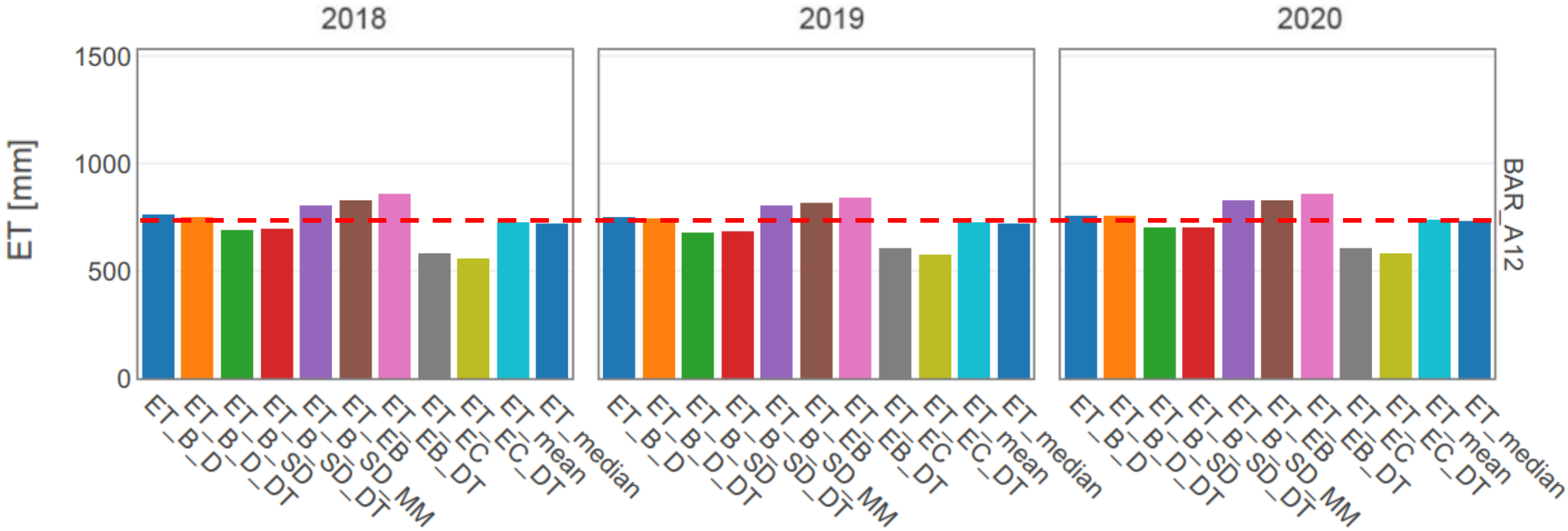
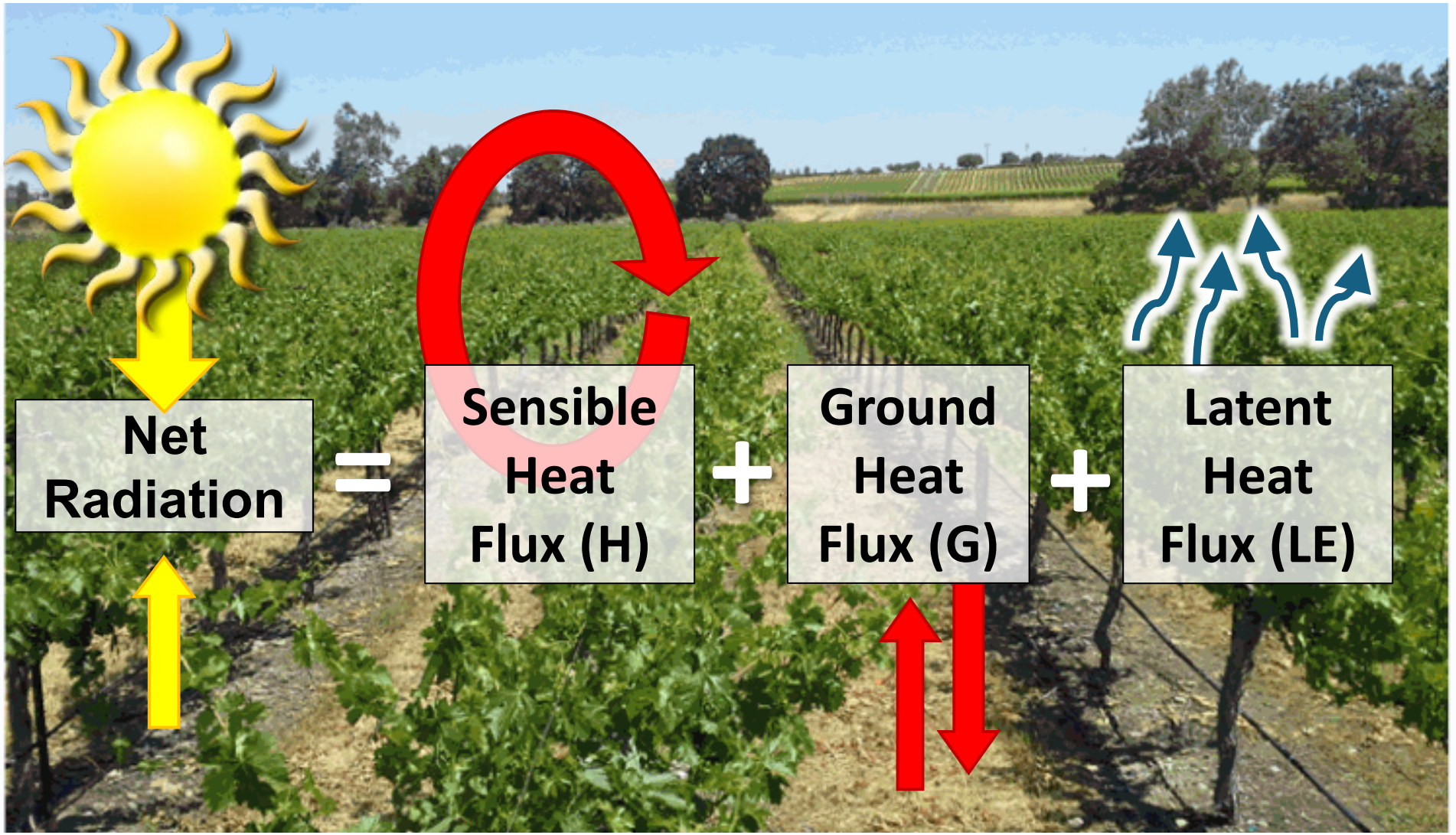


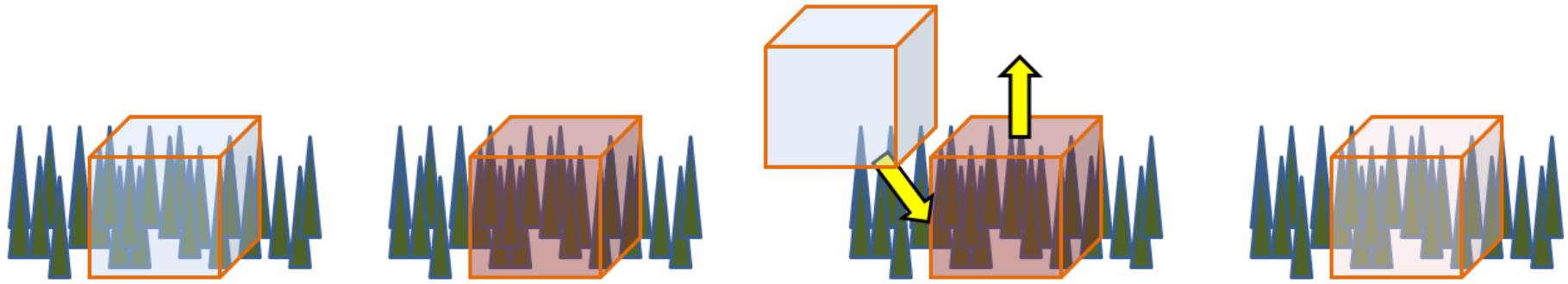
Data for Barelli- near Cloverdale, CA

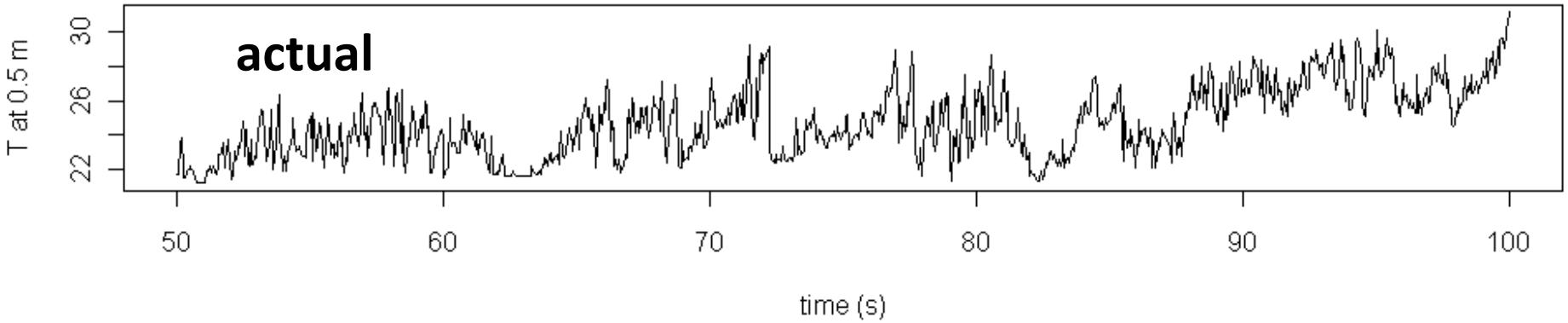
Thermal Energy Balance Approaches to Quantify ET



Partitioning the energy at the crop surface

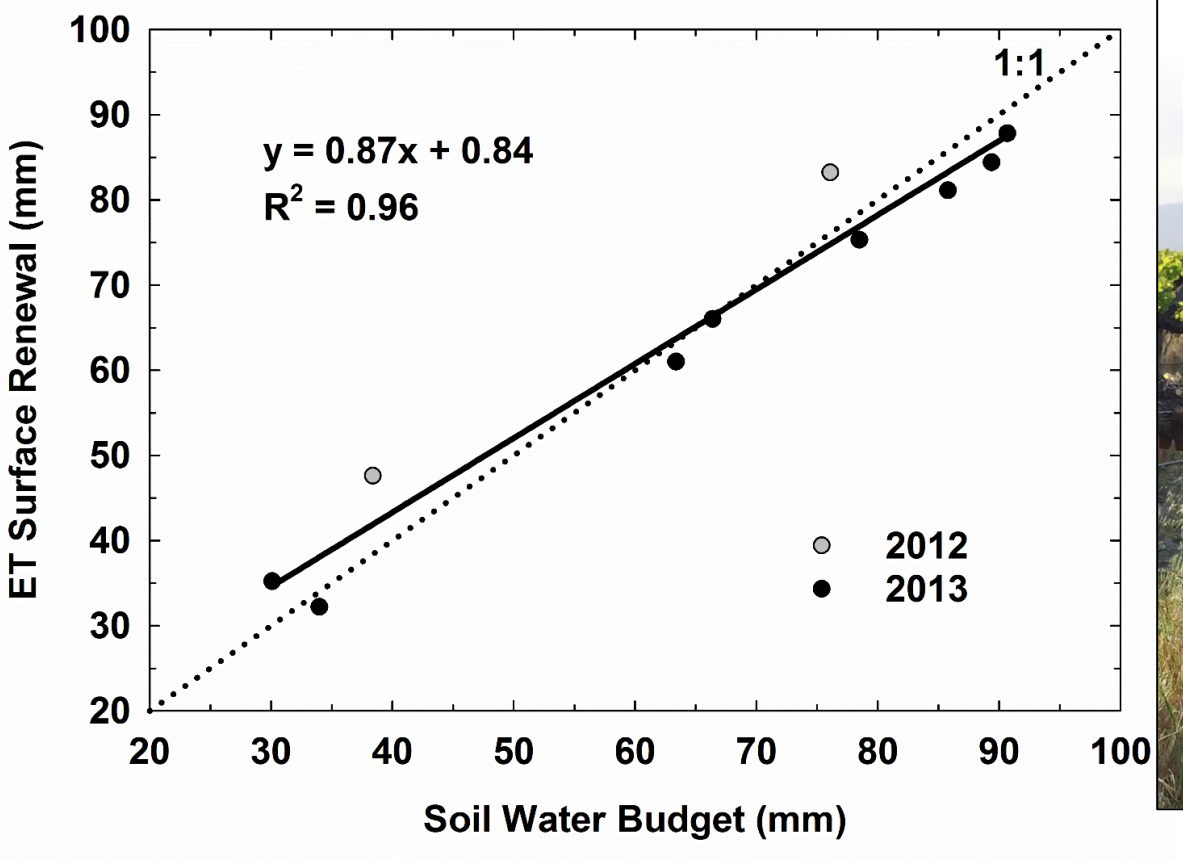
Surface Renewal- Theory vs. Reality



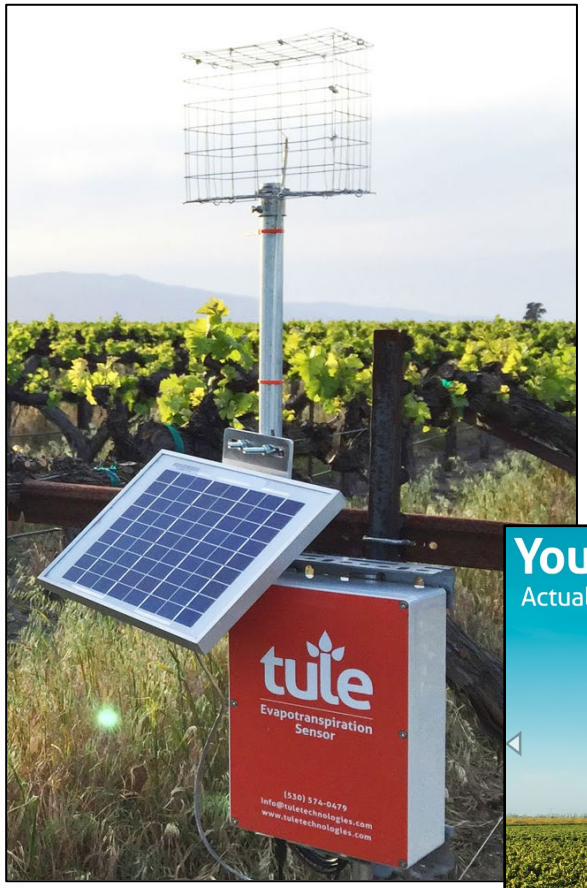


Successfully removed the need to calibrate against expensive research grade system (Shapland et al. 2012a,b, 2014)

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



~$10,000-$100,000

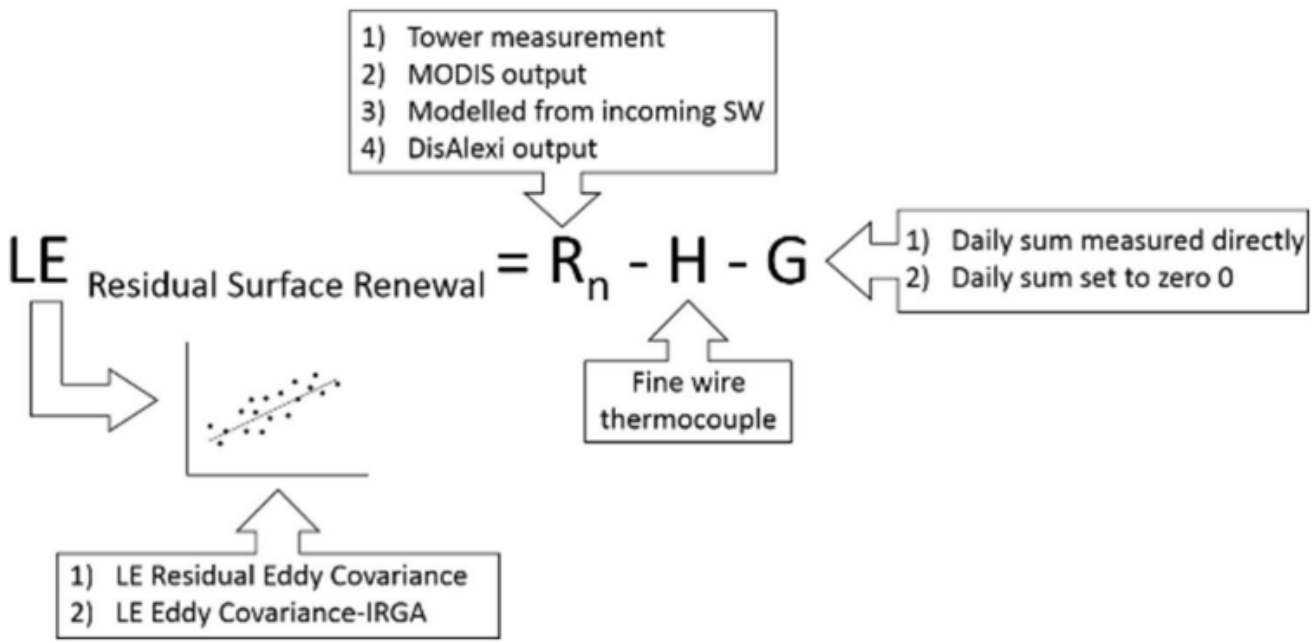


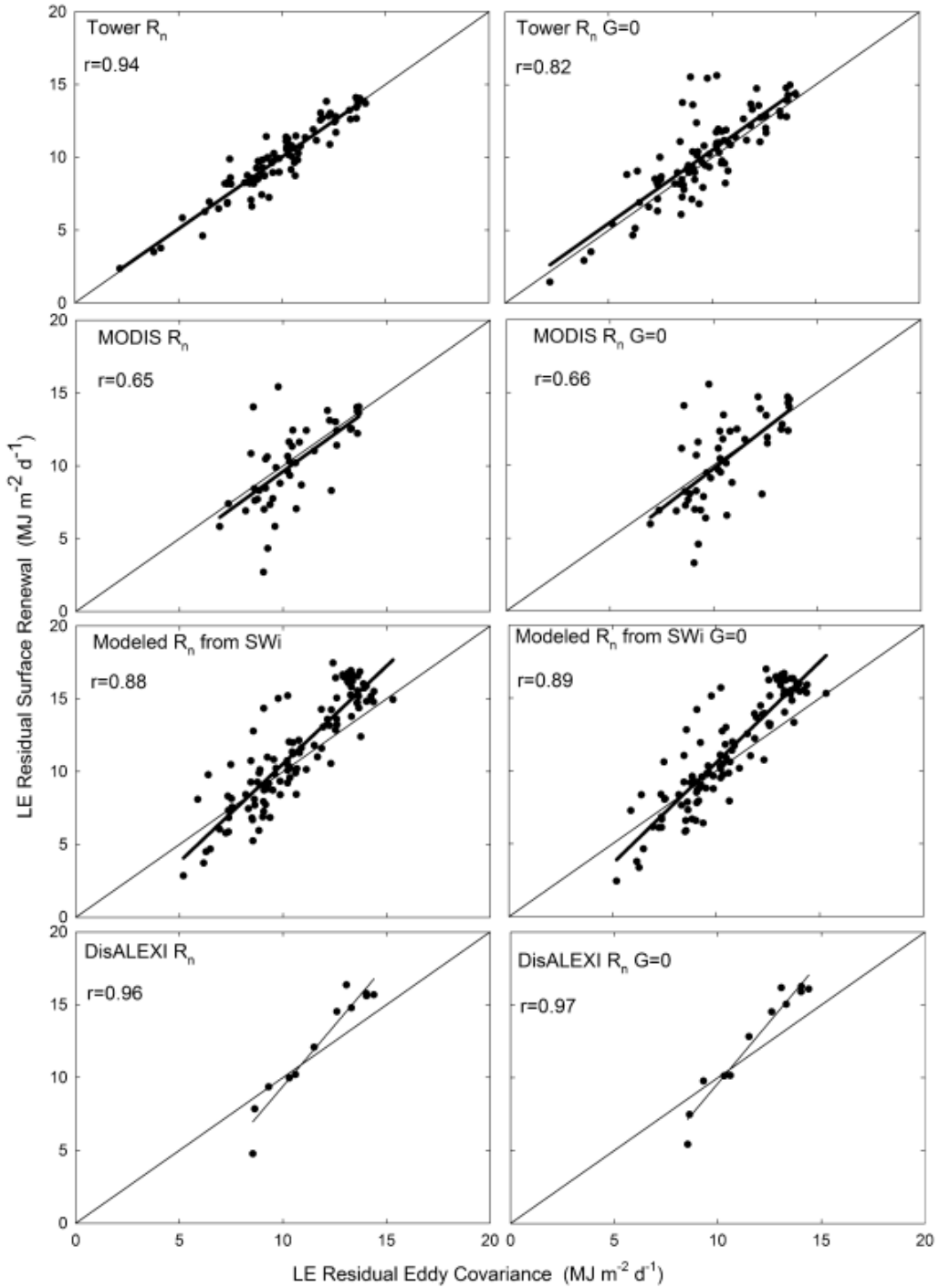
New Commercial System (Tule Technologies)
Joint patent between USDA & UC Davis

Irrigation Science (2019) 37:333–343
https://doi.org/10.1007/s00271-018-00618-y

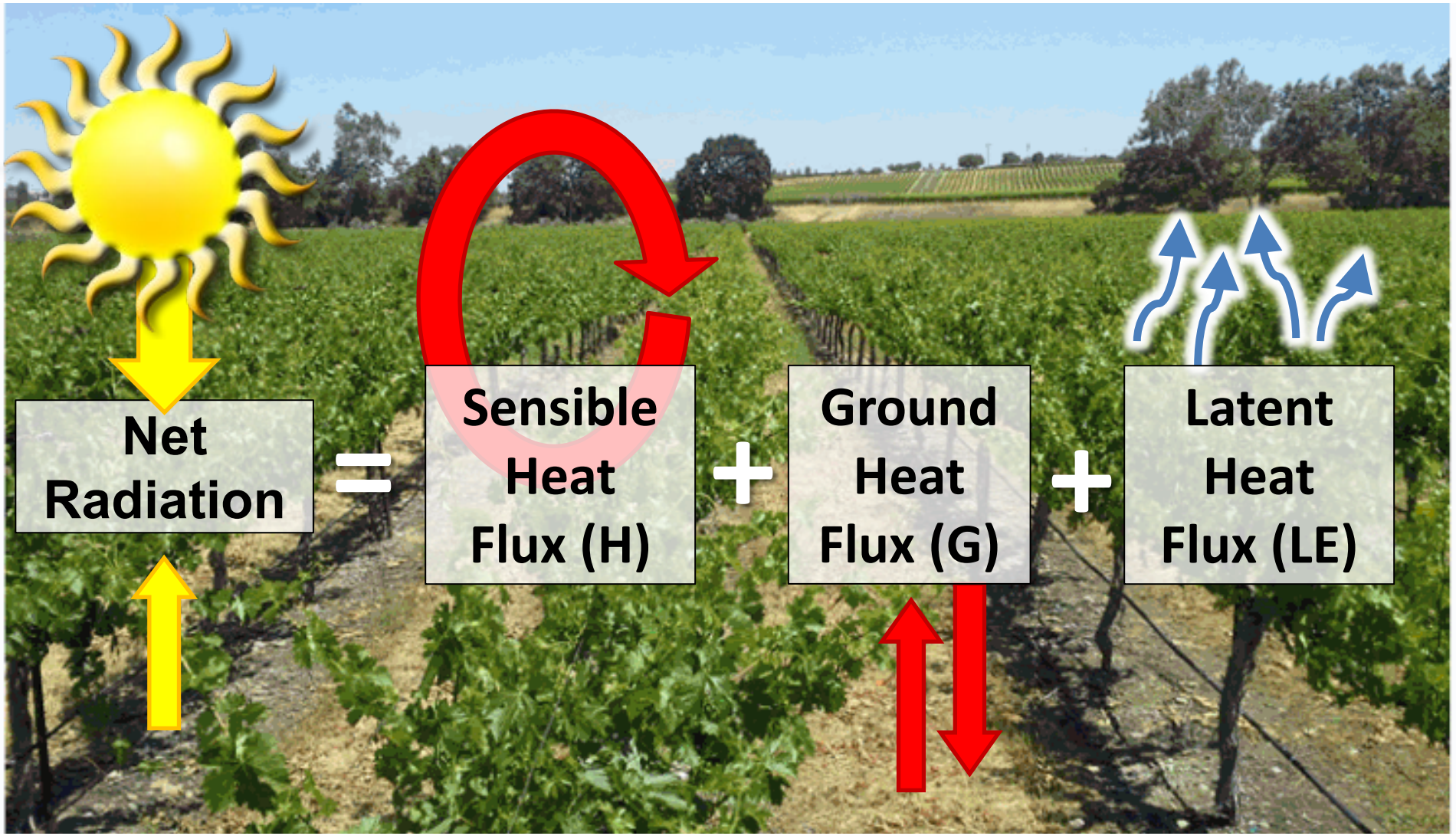
Comparison of vineyard evapotranspiration estimates from surface renewal using measured and modelled energy balance components in the GRAPEX project

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



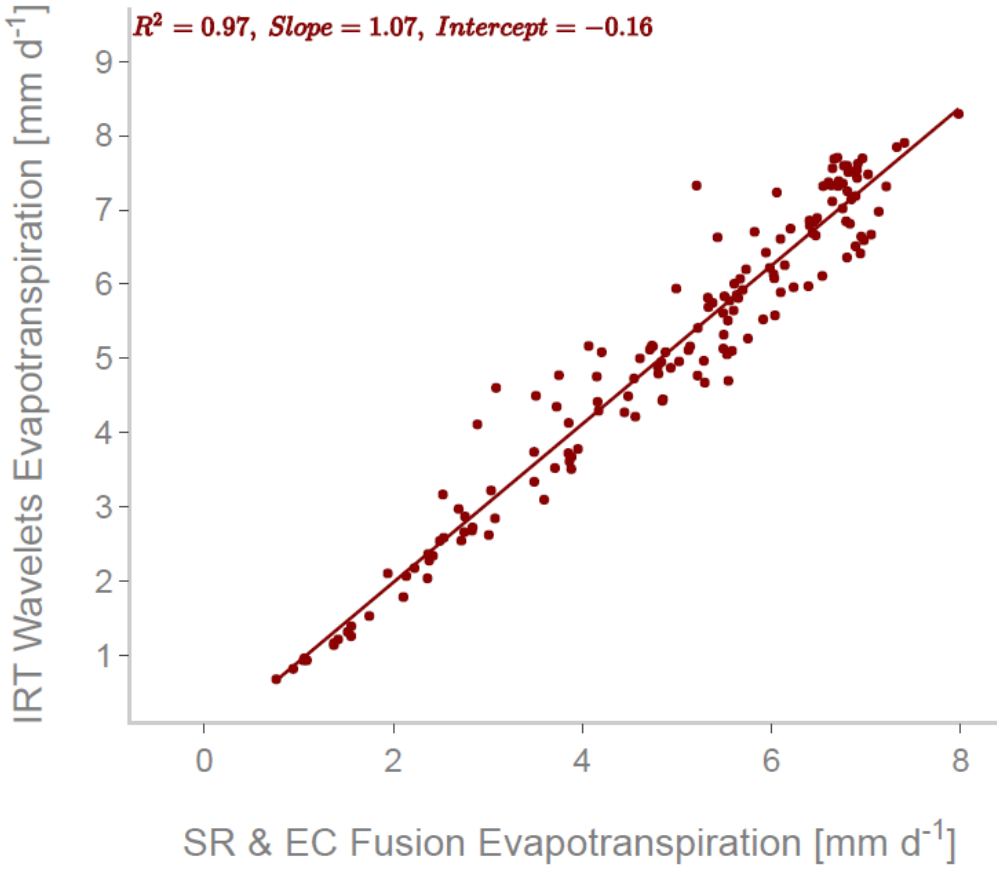


Thermal Energy Balance Approaches to Quantify ET



Partitioning the energy at the crop surface

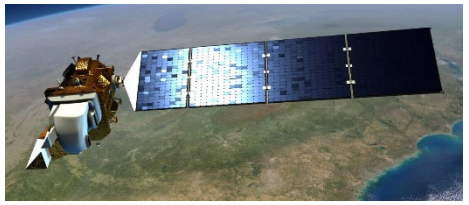
New IRT Wavelet method to estimate crop water use

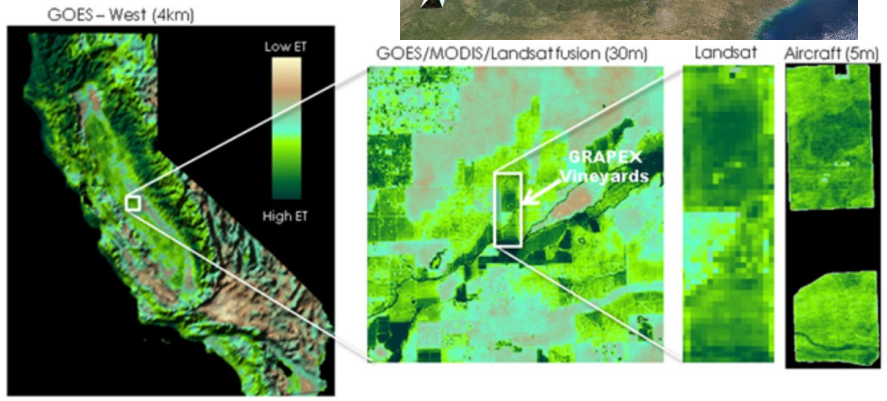


Developing tools to facilitate grower adoption of this technique- citizen science model

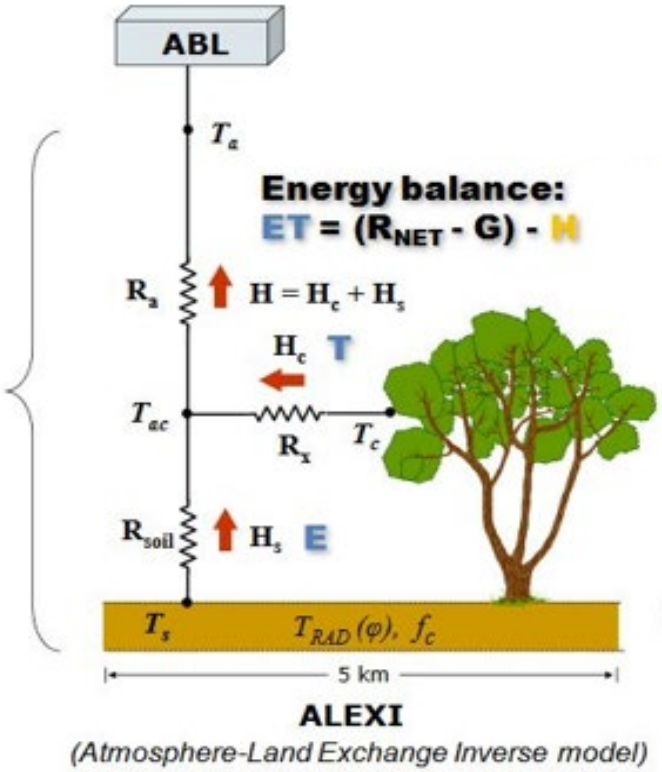
Grape Remote sensing Atmospheric Profile & Evapotranspiration eXperiment

grapex



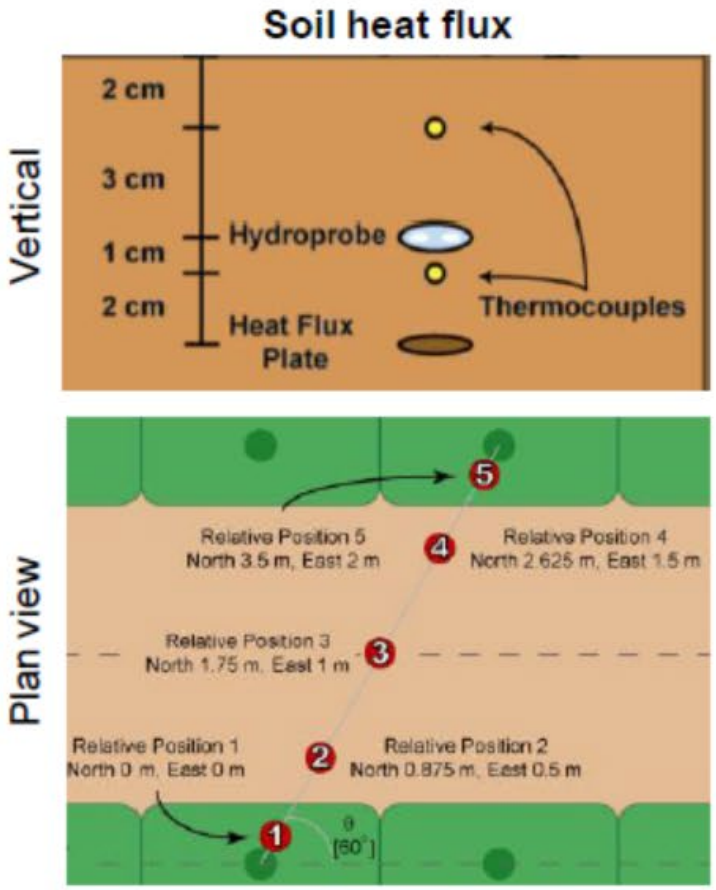


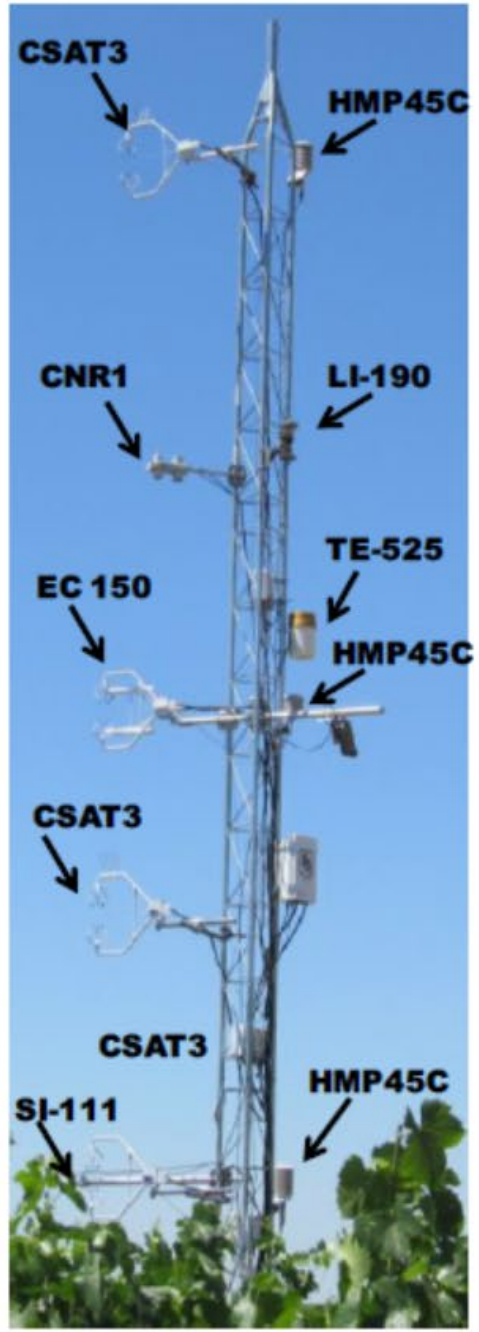
Two Source Energy Balance



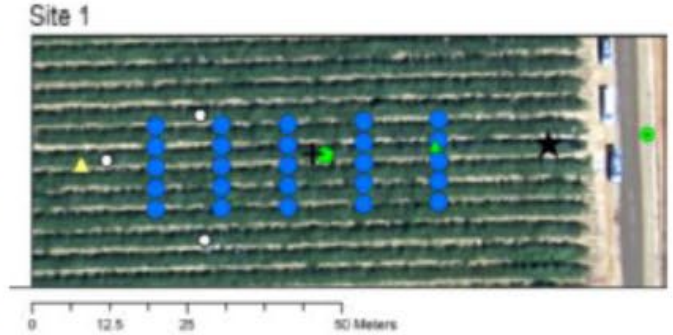
ALEXI

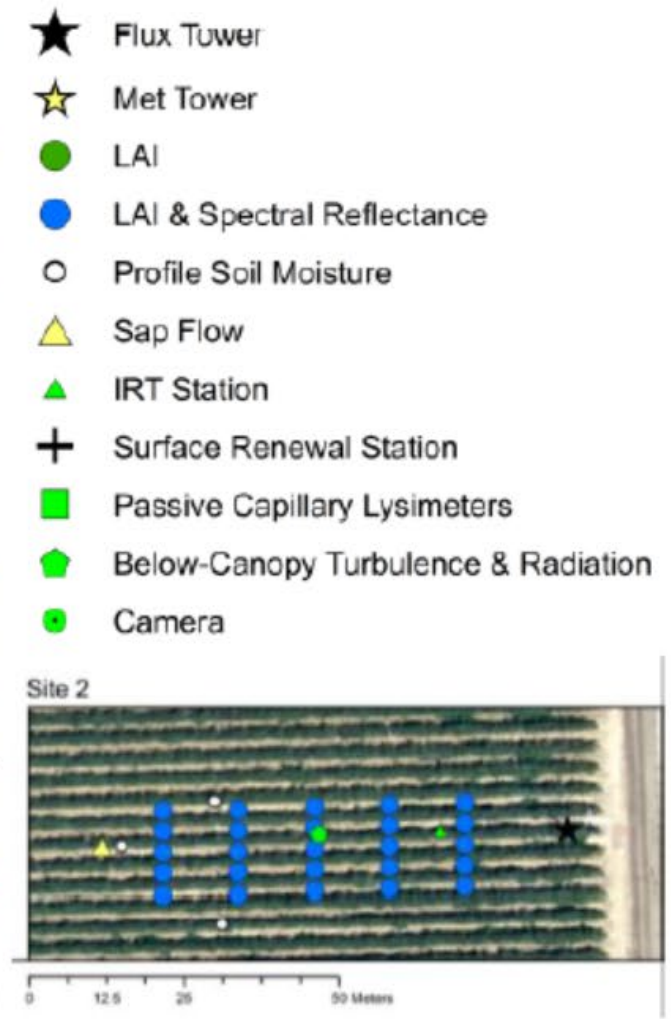
(Atmosphere-Land Exchange Inverse model)


Soil heat flux
Vertical
2 cm
3 cm
1 cm
2 cm
Hydroprobe
Thermocouples
Heat Flux Plate
Plan view
Relative Position 5
North 3.5 m, East 2 m
Relative Position 4
North 2.625 m, East 1.5 m
Relative Position 3
North 1.75 m, East 1 m
Relative Position 1
North 0 m, East 0 m
Relative Position 2
North 0.875 m, East 0.5 m
θ
[60°]


CSAT3
HMP45C
CNR1
LI-190
TE-525
EC 150
HMP45C
CSAT3
CSAT3
HMP45C
SI-111

0
125
250
500 Meters


Site 1
0
12.5
25
50 Meters

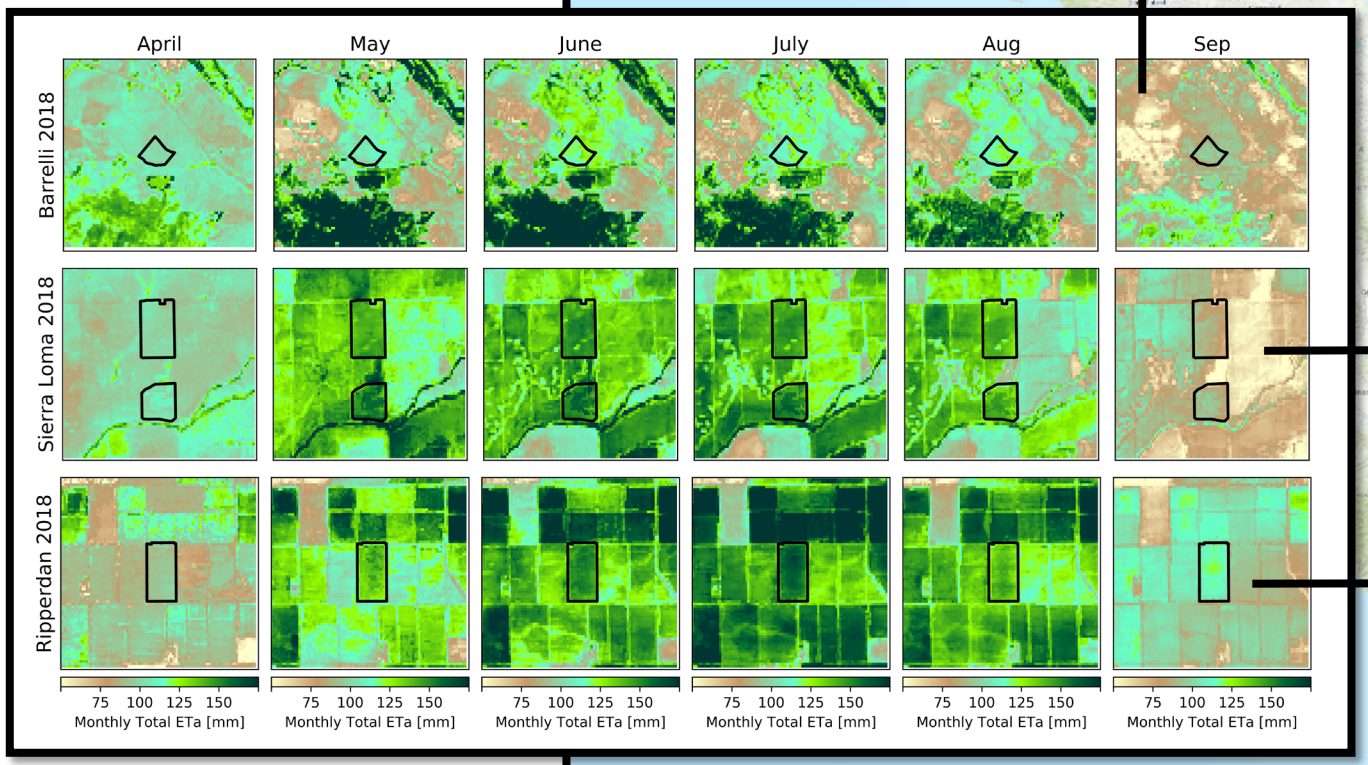

Flux Tower
Met Tower
LAI
LAI & Spectral Reflectance
Profile Soil Moisture
Sap Flow
IRT Station
Surface Renewal Station
Passive Capillary Lysimeters
Below-Canopy Turbulence & Radiation
Camera
Site 2
0
12.5
25
50 Meters

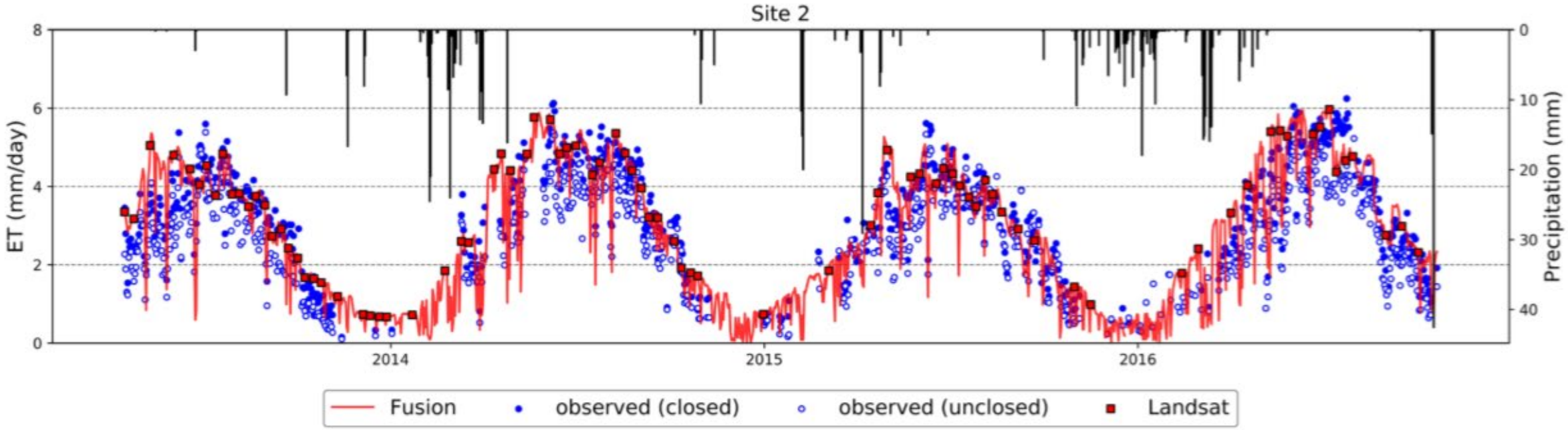
Monitor various vineyards

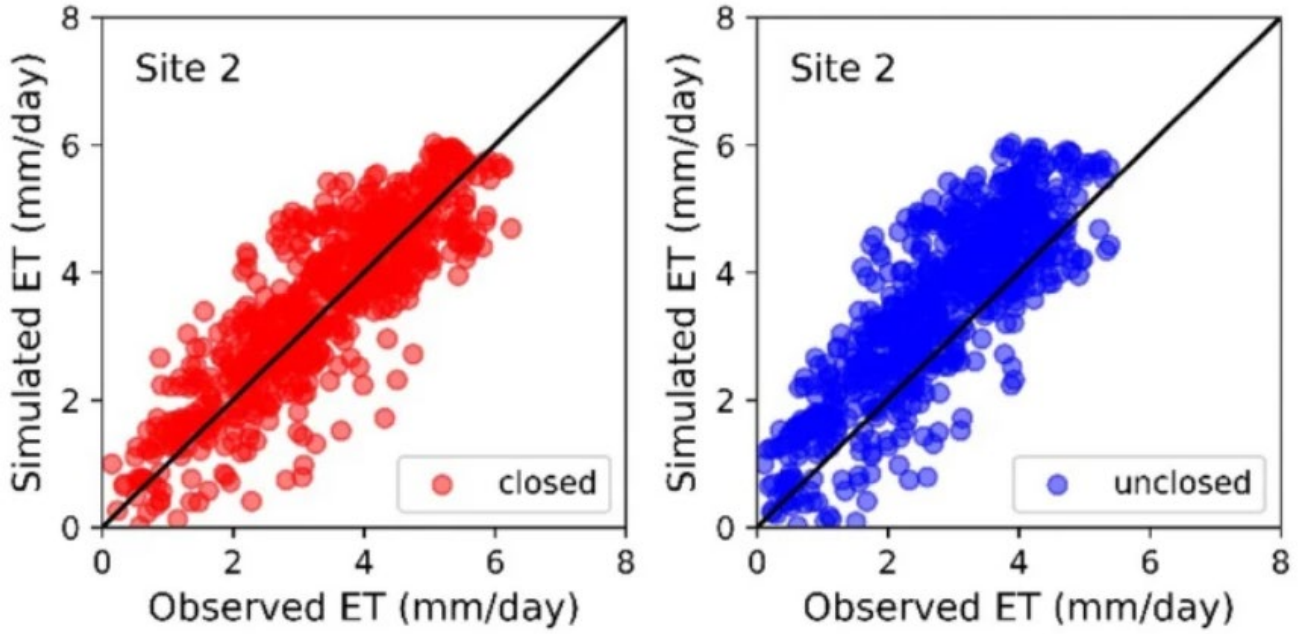
Test variations in:

Climate, Vine Type, Trellis Design…

GRAPEX

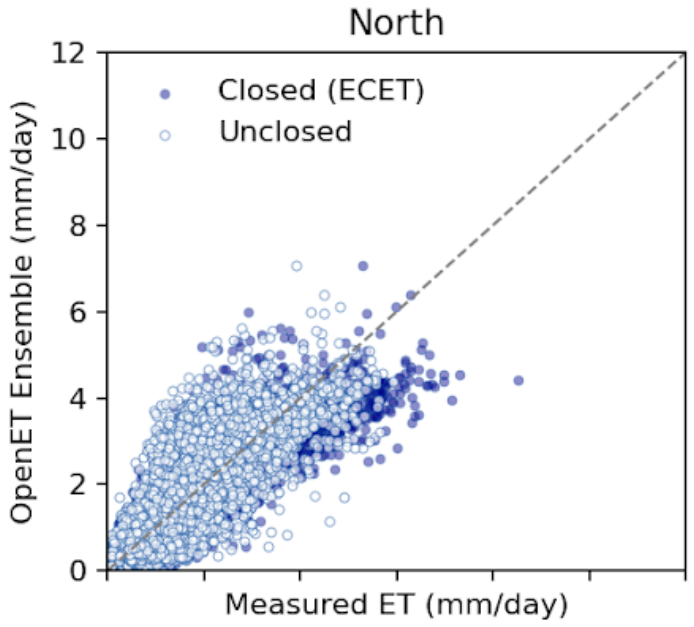


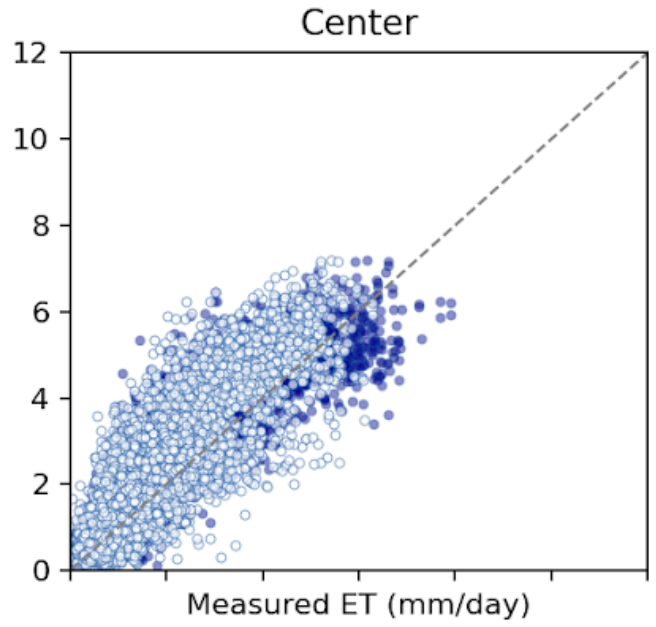


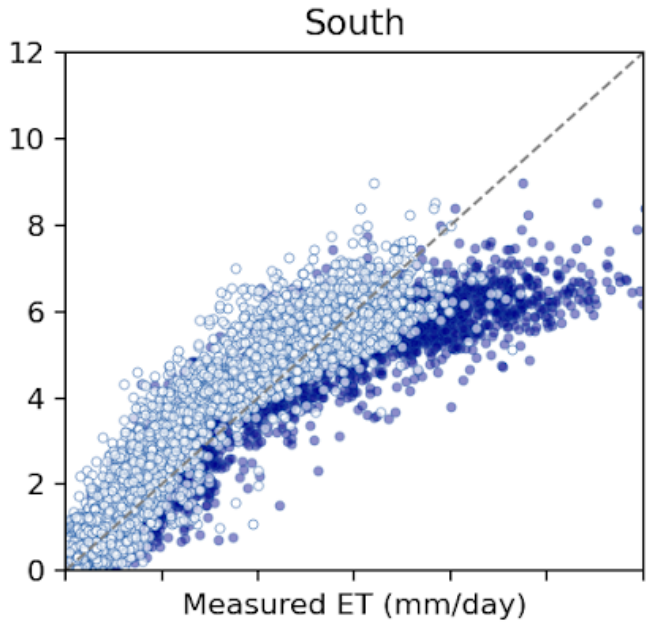


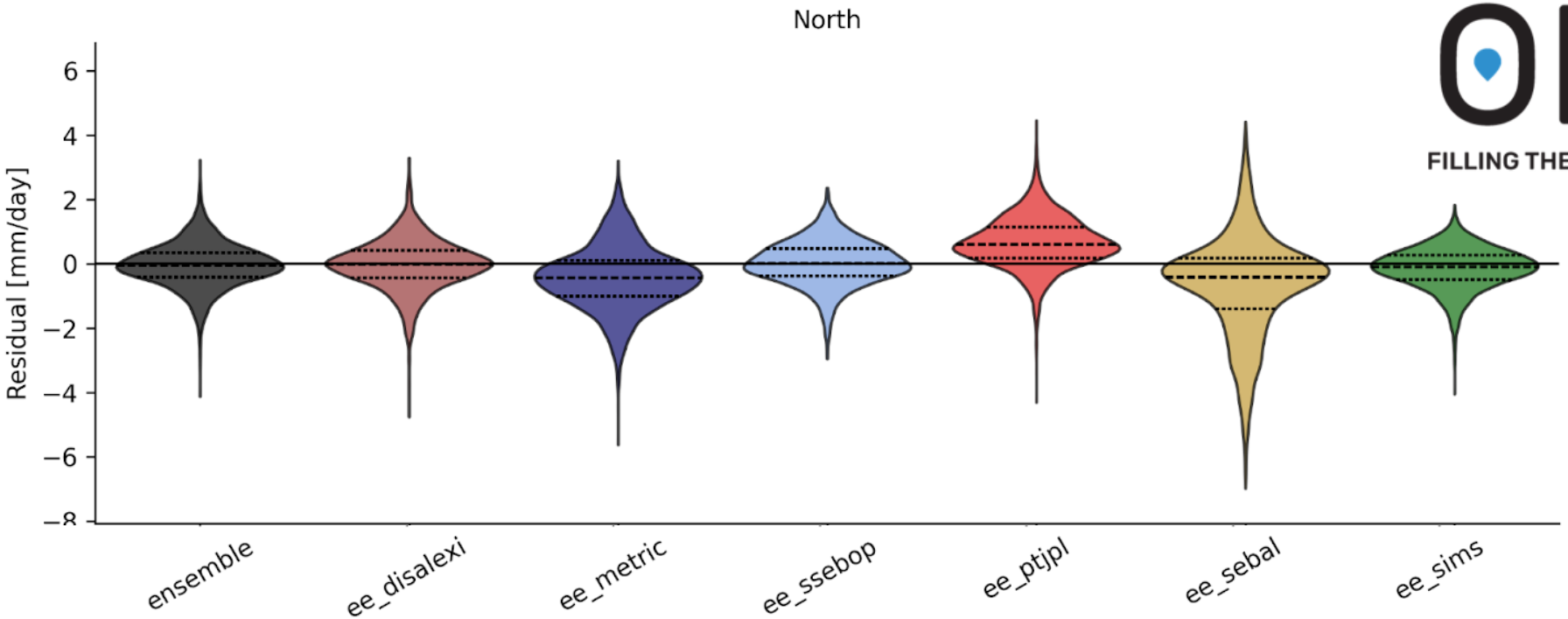
Sierra Loma- Lodi

Knipper *et al*. 2019 *Irrigation Science*









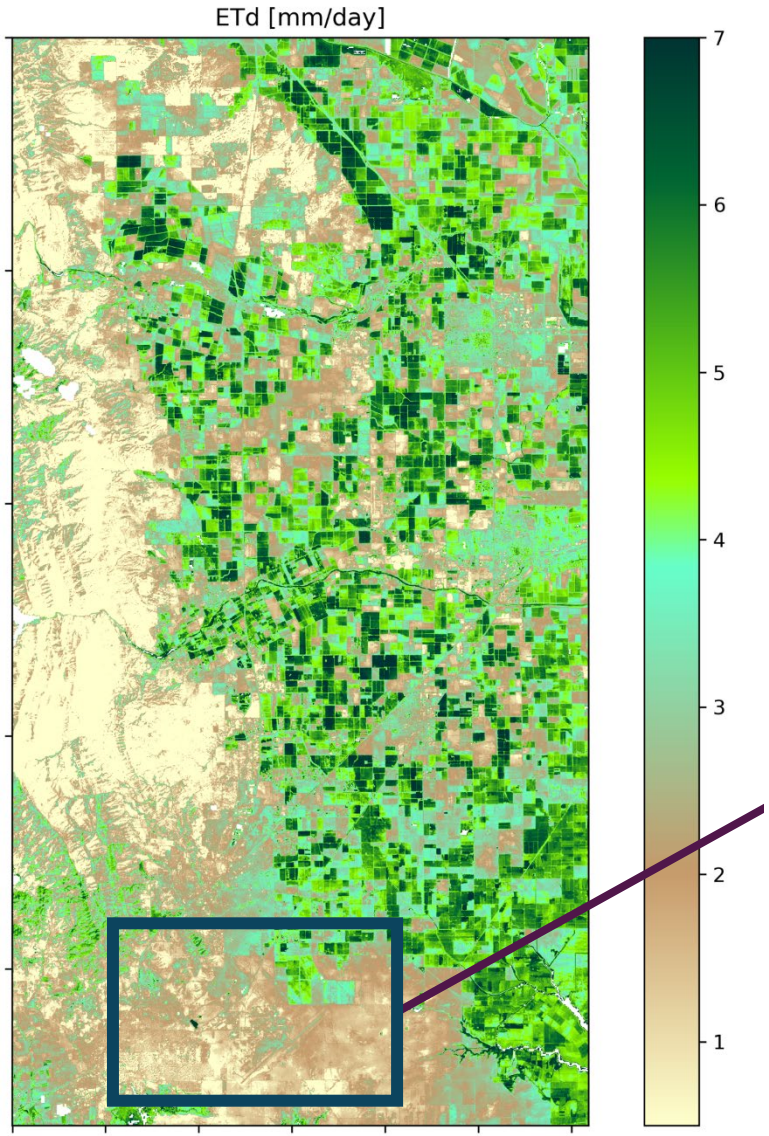
OPENET

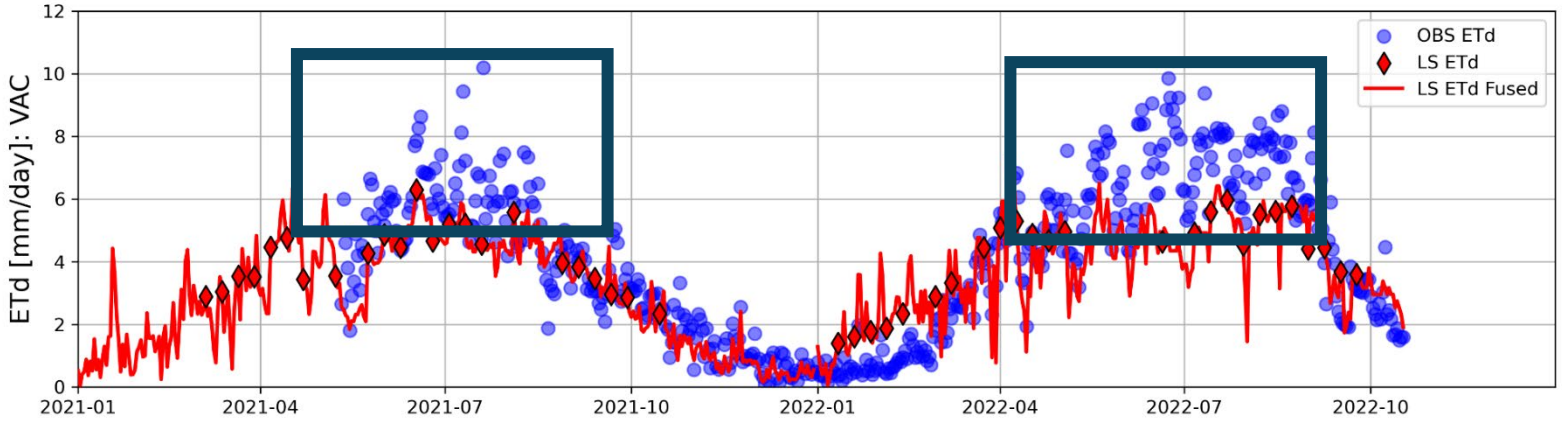
FILLING THE BIGGEST DATA GAP IN WATER MANAGEMENT

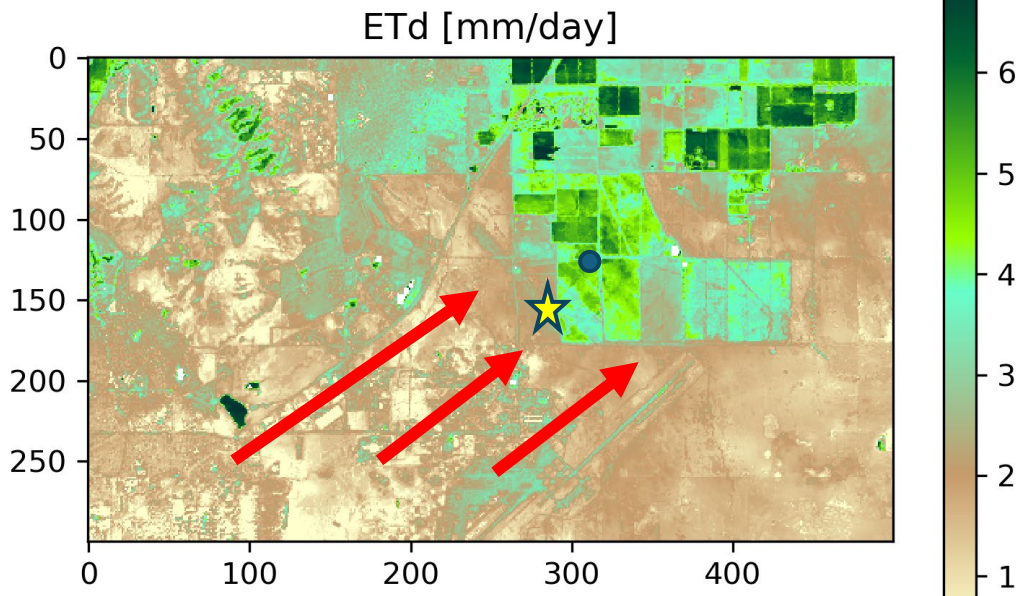
Knipper *et al.*

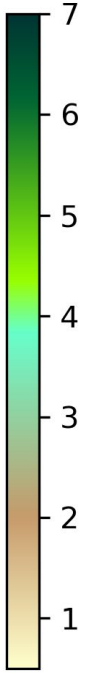
unpublished data

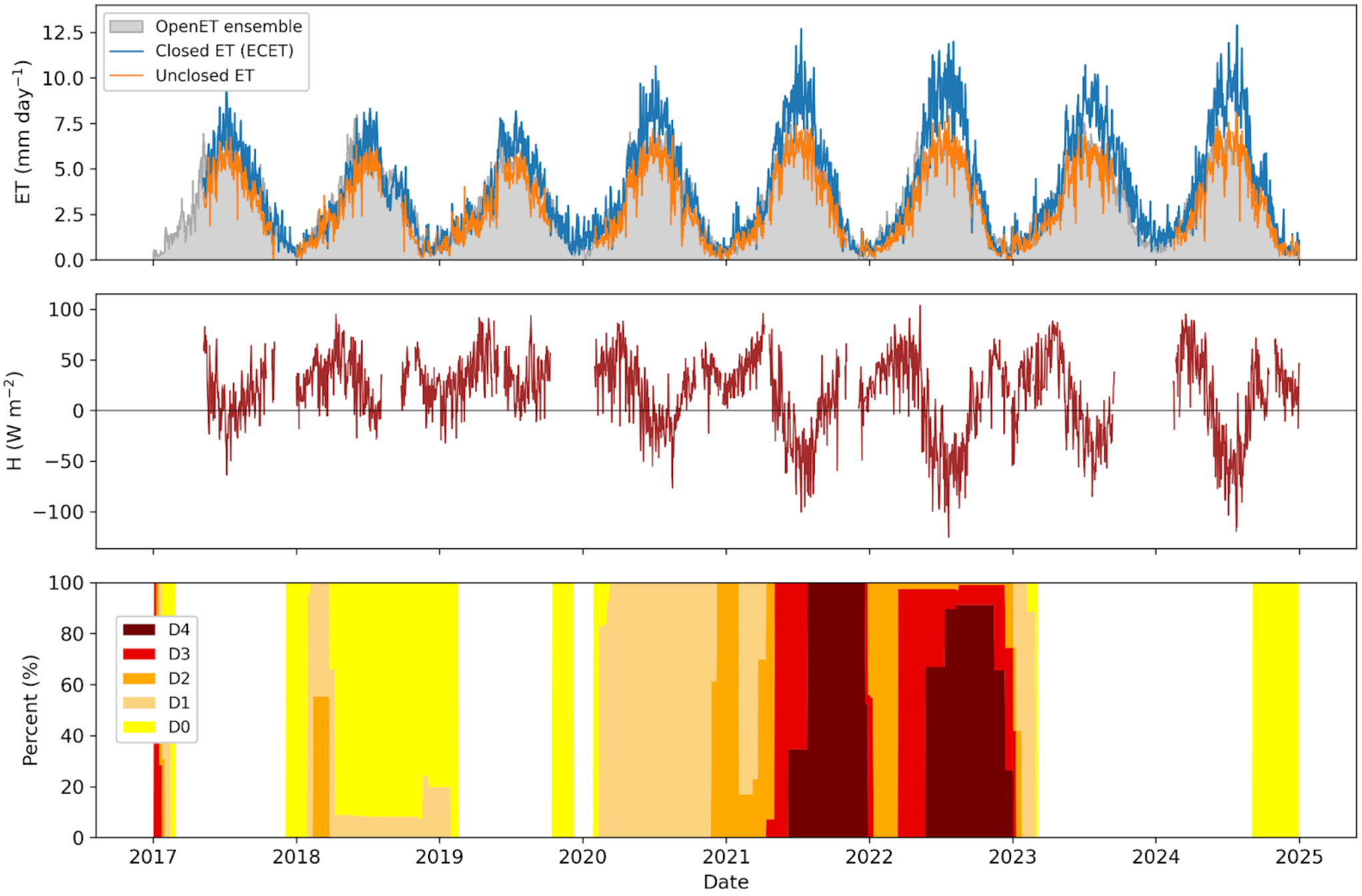
Additional Heat Source via Advection

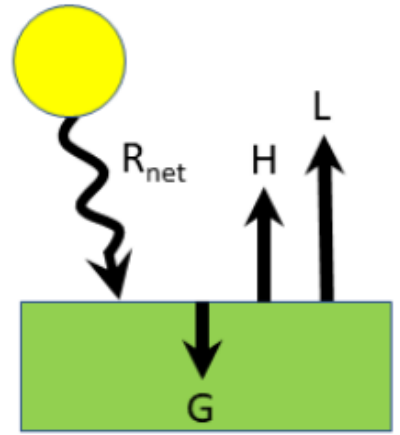


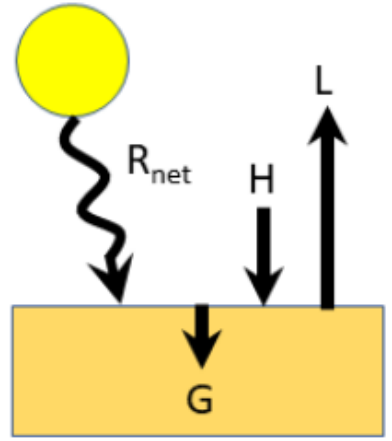












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unpublished data

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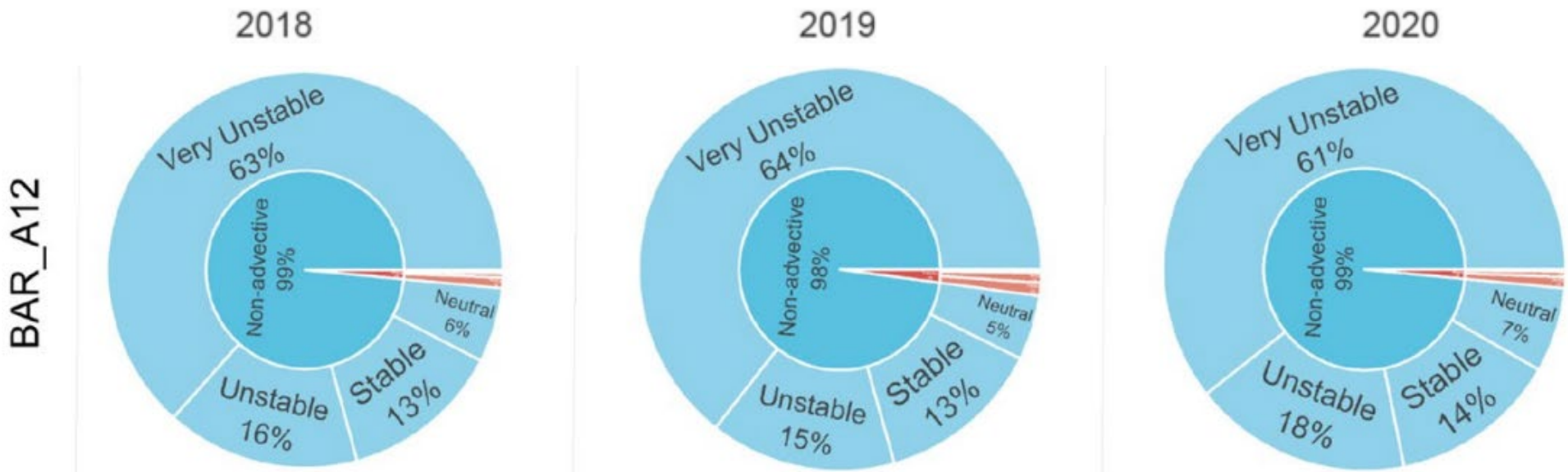
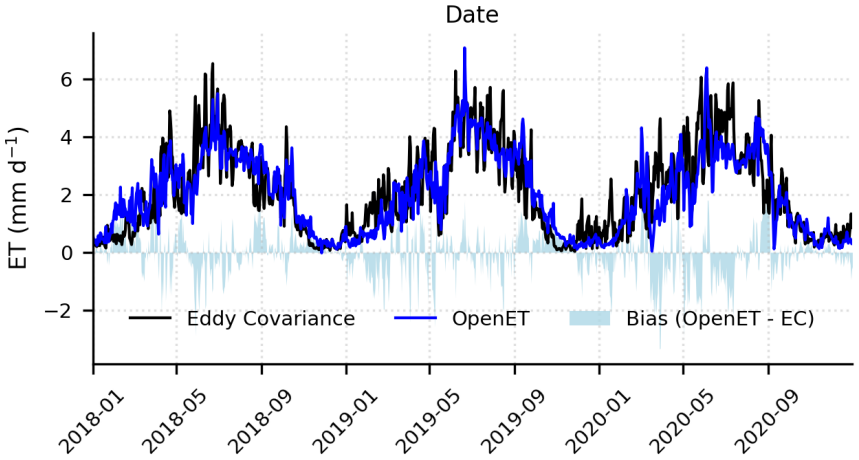
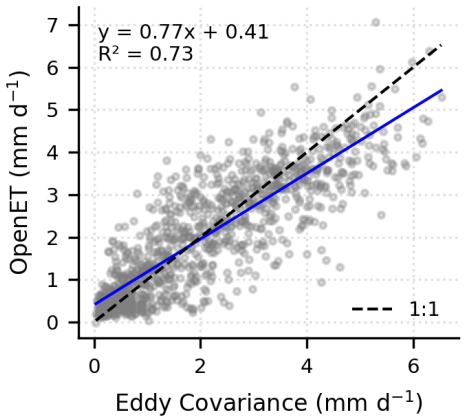
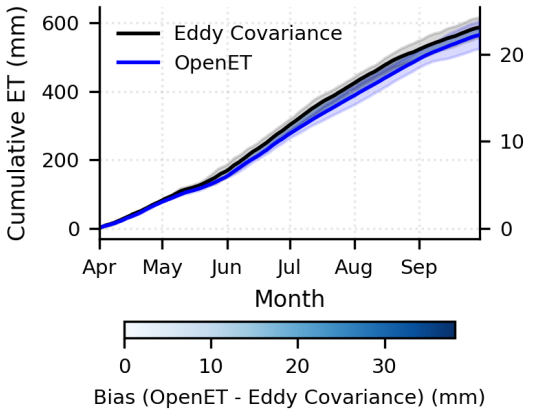
Evapotranspiration uncertainty at micrometeorological scales: the impact of the eddy covariance energy imbalance and correction methods

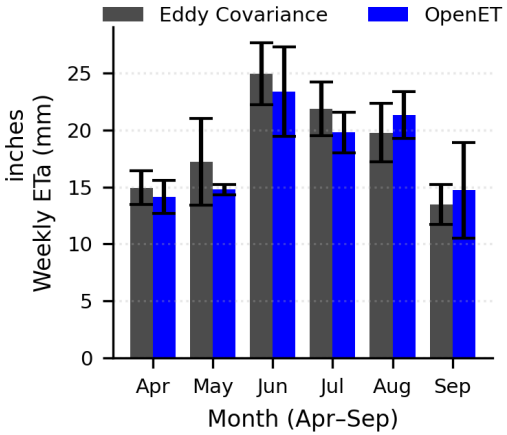
N. Bambach[1] · W. Kustas[2] · J. Alfieri[2] · J. Prueger[3] · L. Hipps[4] · L. McKee[2] · S. J. Castro[5] · J. Volk[6] · M. M. Alsina[7] · A. J. McElrone[5,8]

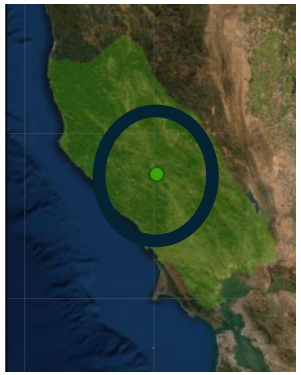












Data for Barelli- near Cloverdale, CA

Bambach *et al.* unpublished data