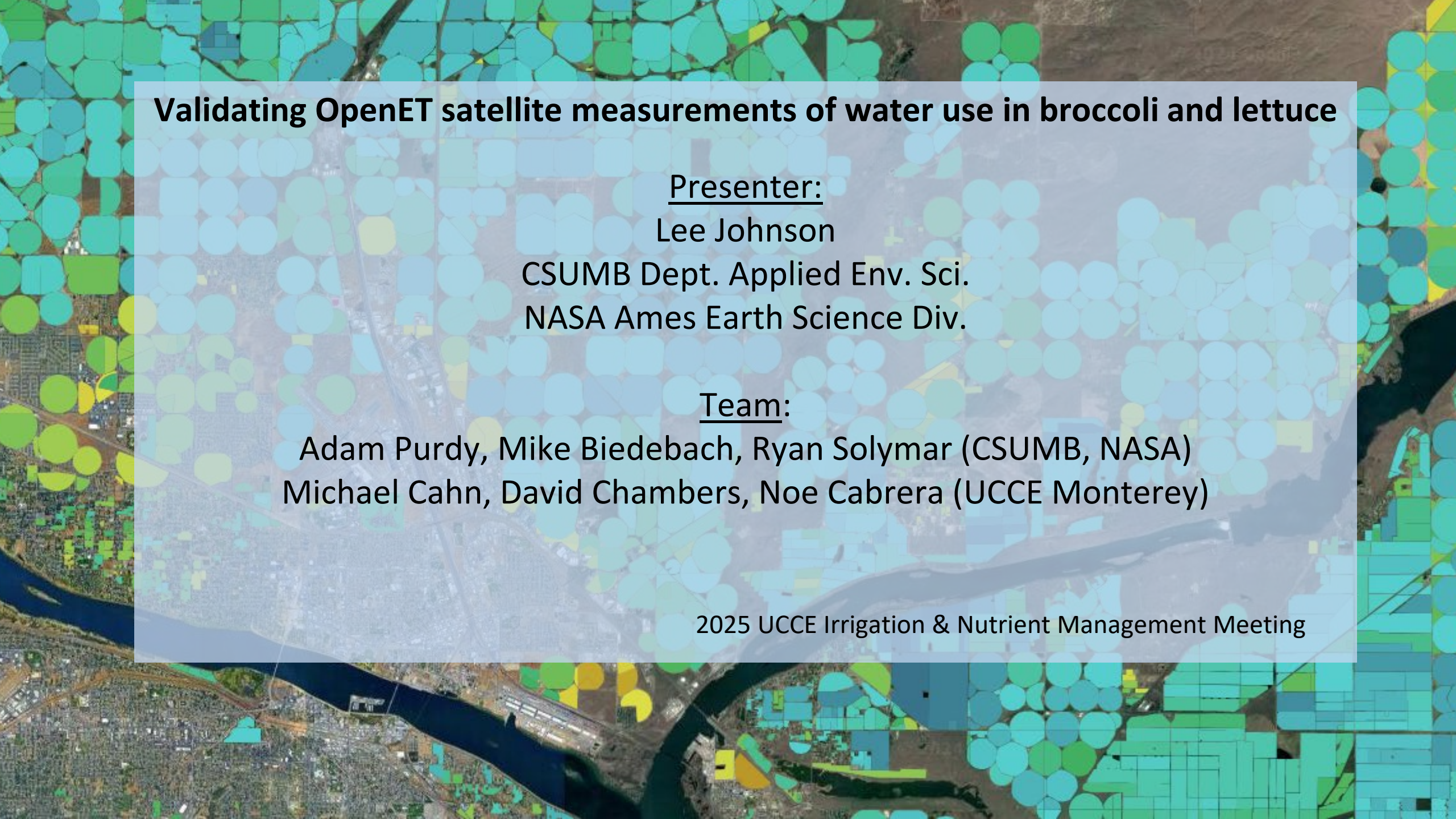


Validating OpenET satellite measurements of water use in broccoli and lettuce

Presenter:

Lee Johnson

CSUMB Dept. Applied Env. Sci.

NASA Ames Earth Science Div.

Team:

Adam Purdy, Mike Biedebach, Ryan Solymar (CSUMB, NASA)

Michael Cahn, David Chambers, Noe Cabrera (UCCE Monterey)

2025 UCCE Irrigation & Nutrient Management Meeting

Main reasons for study

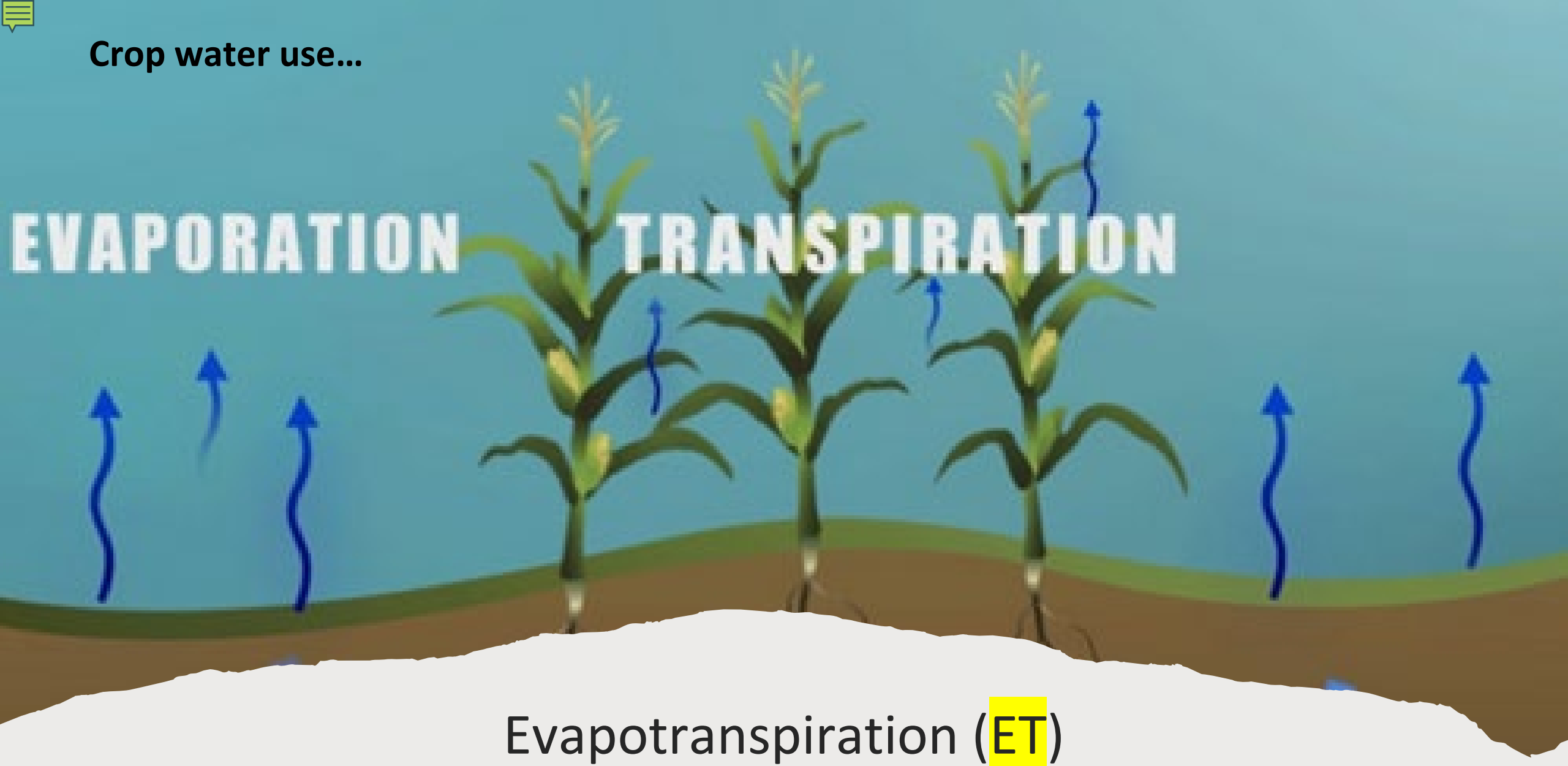
- Need for accurate basin-scale assessments of crop water use
- This need might be supported by use of satellite data
- Yet, little work has been done to verify performance of satellite based systems in vegetable crops in Salinas or elsewhere.

Outline

- Eddy covariance ground measurements
- OpenET accuracy assessment
- Some possible uses

- Eddy covariance ground measurements…

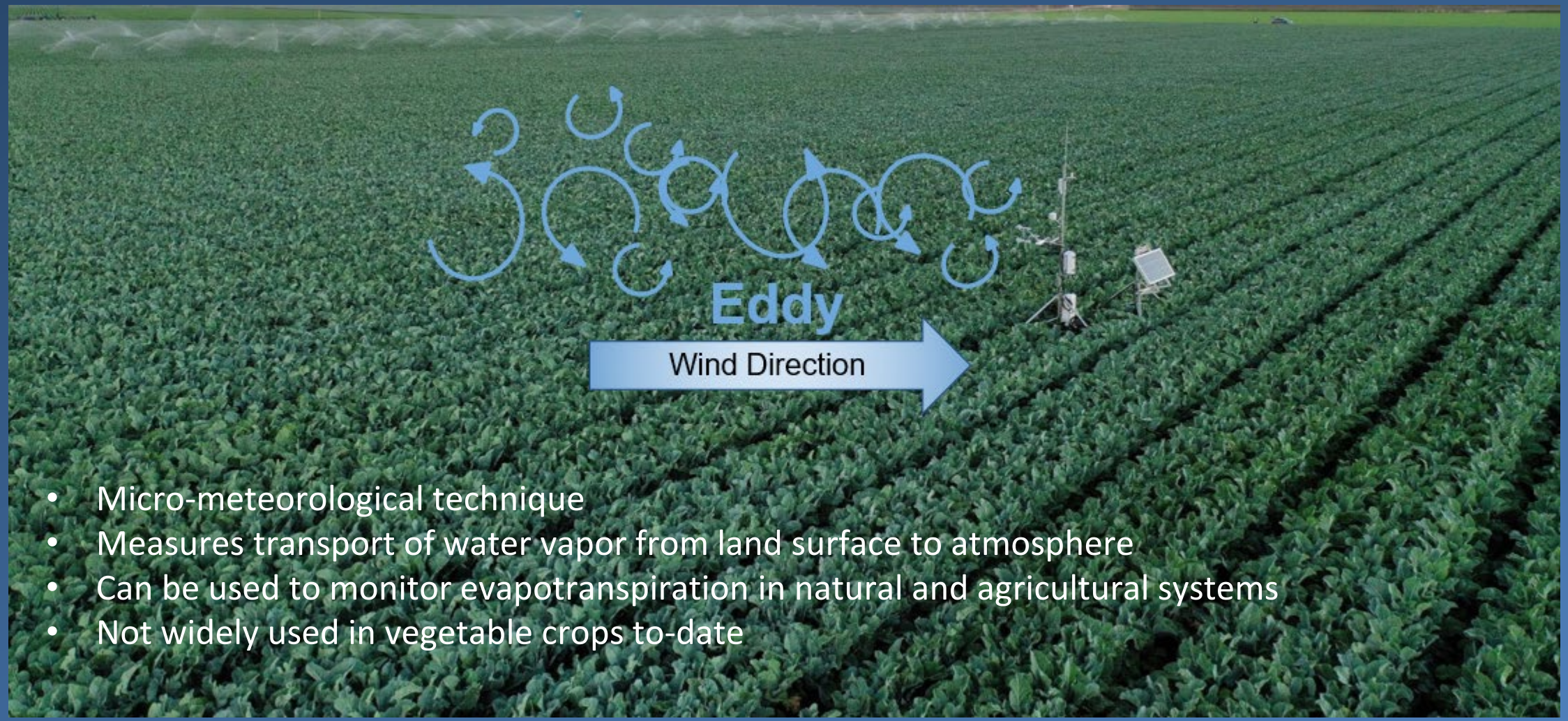
Crop water use…



Evapotranspiration (ET)

Sometimes called “consumptive use”

Eddy covariance



- Micro-meteorological technique
- Measures transport of water vapor from land surface to atmosphere
- Can be used to monitor evapotranspiration in natural and agricultural systems
- Not widely used in vegetable crops to-date

Drone image courtesy Jon Detka

Crop	Year	Crop cycle dates	Days	Eddy cov obs days	Configuration	Irrigation	Field size (ac)
Head lettuce	2023	4/14-6/22	69	46	2 row, 40" bed	sprinkler/drip	10.7
Head lettuce	2024	4/6-6/19	74	50	2 row, 40" bed	sprinkler/drip	10.7
Broccoli	2023	7/7-10/6	92	66	2 row, 40" bed	sprinkler/drip	10.2
Broccoli	2024	7/20-10/28	101	76	2 row, 40" bed	sprinkler/drip	11.4

Site details

Crop ranking

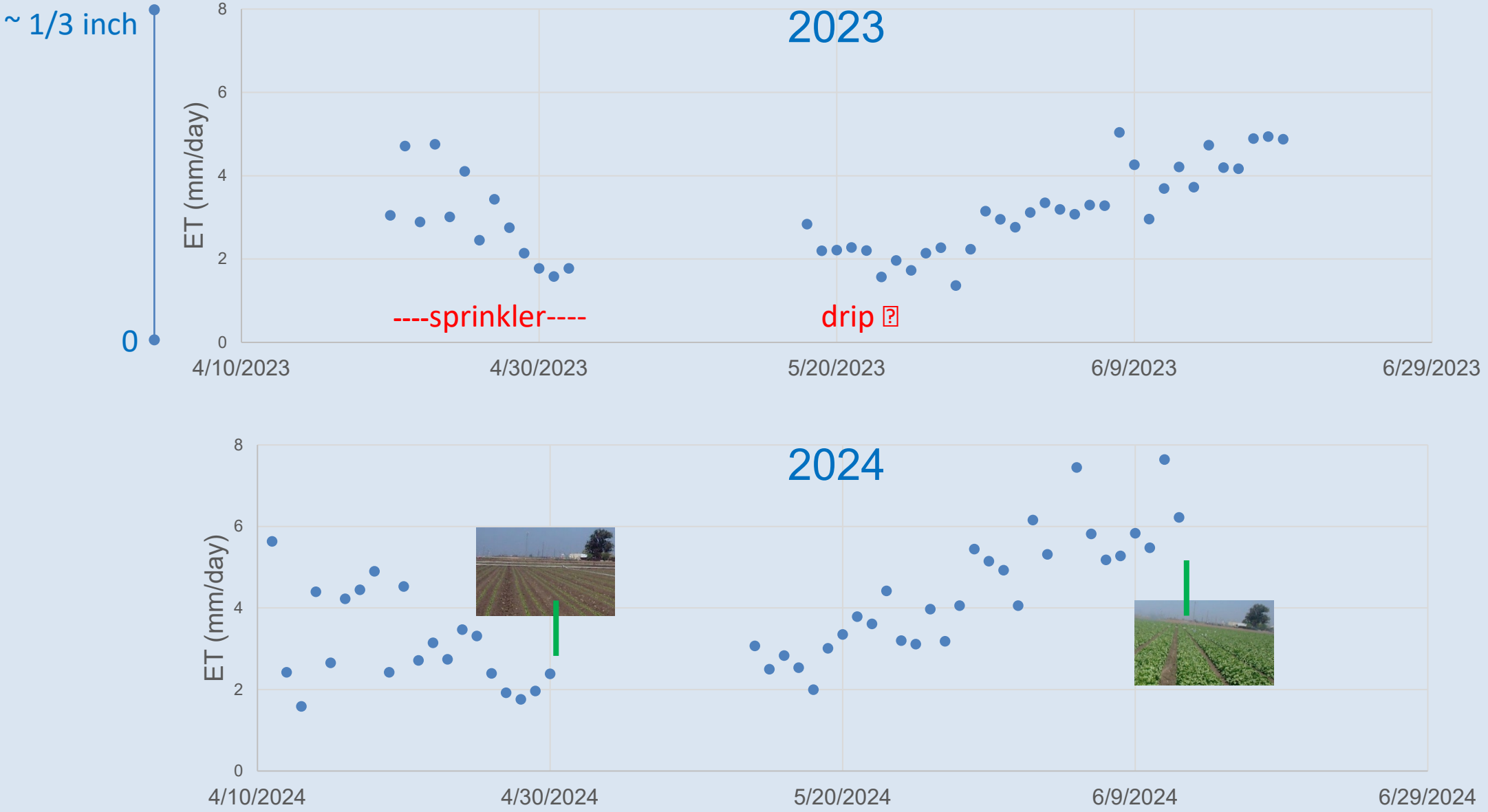
COUNTY OF MONTEREY'S TOP CROPS

CROP	2023 CROP VALUE	2023 CROP RANKING	2022 CROP RANKING
Strawberry	$903,791,000	1	1
Leaf Lettuce	$782,134,000	2	2
Head Lettuce	$493,464,000	3	3
Broccoli	$468,871,000	4	4

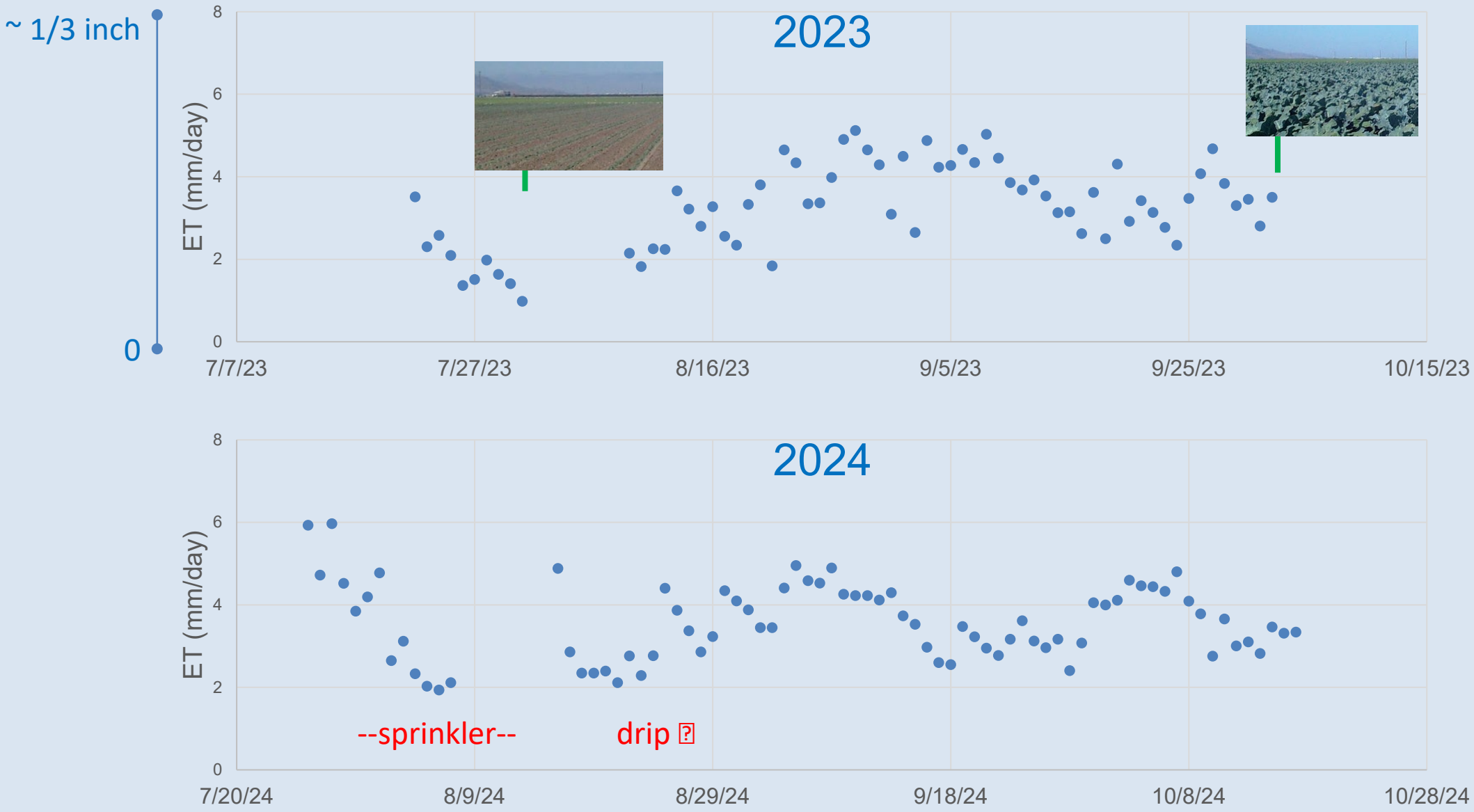
From: Monterey Co. Crop & Livestock Report, 2023

Eddy covariance stations

Eddy covariance results: Daily ET for lettuce

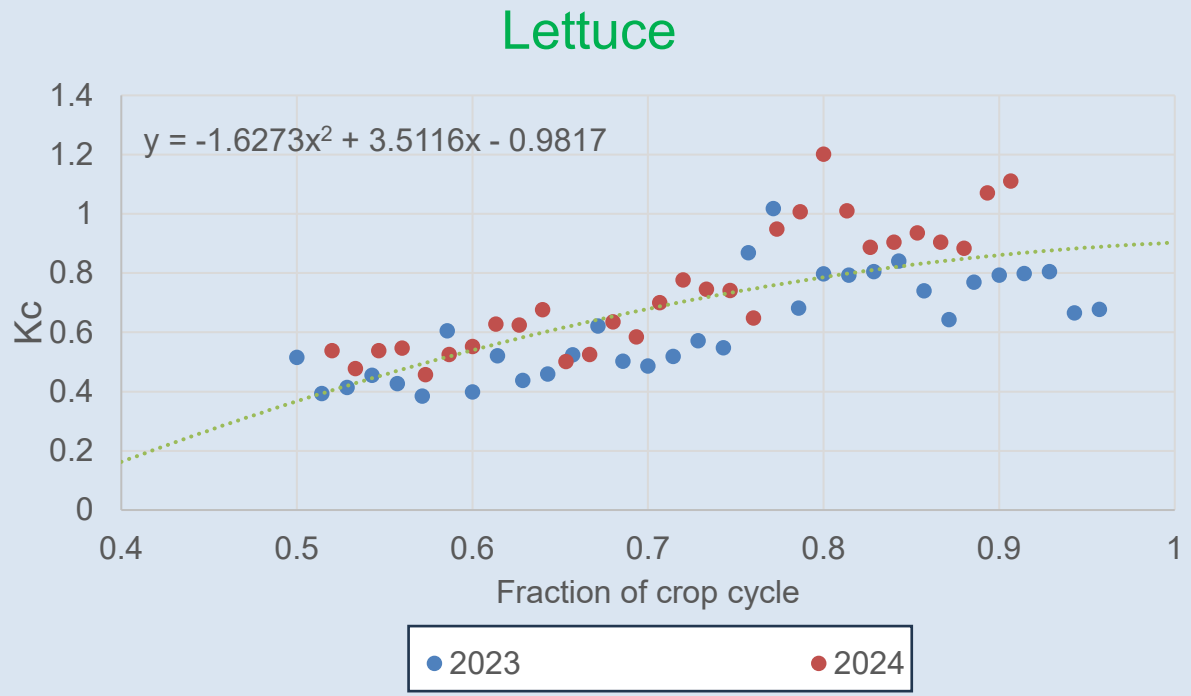


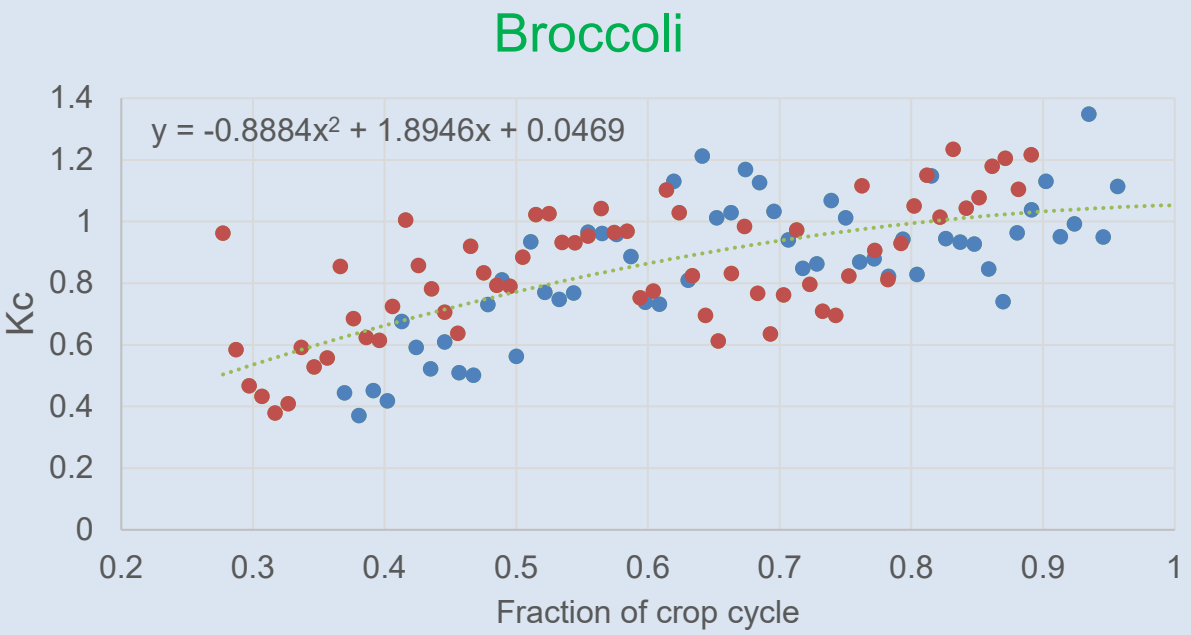
Daily ET for broccoli



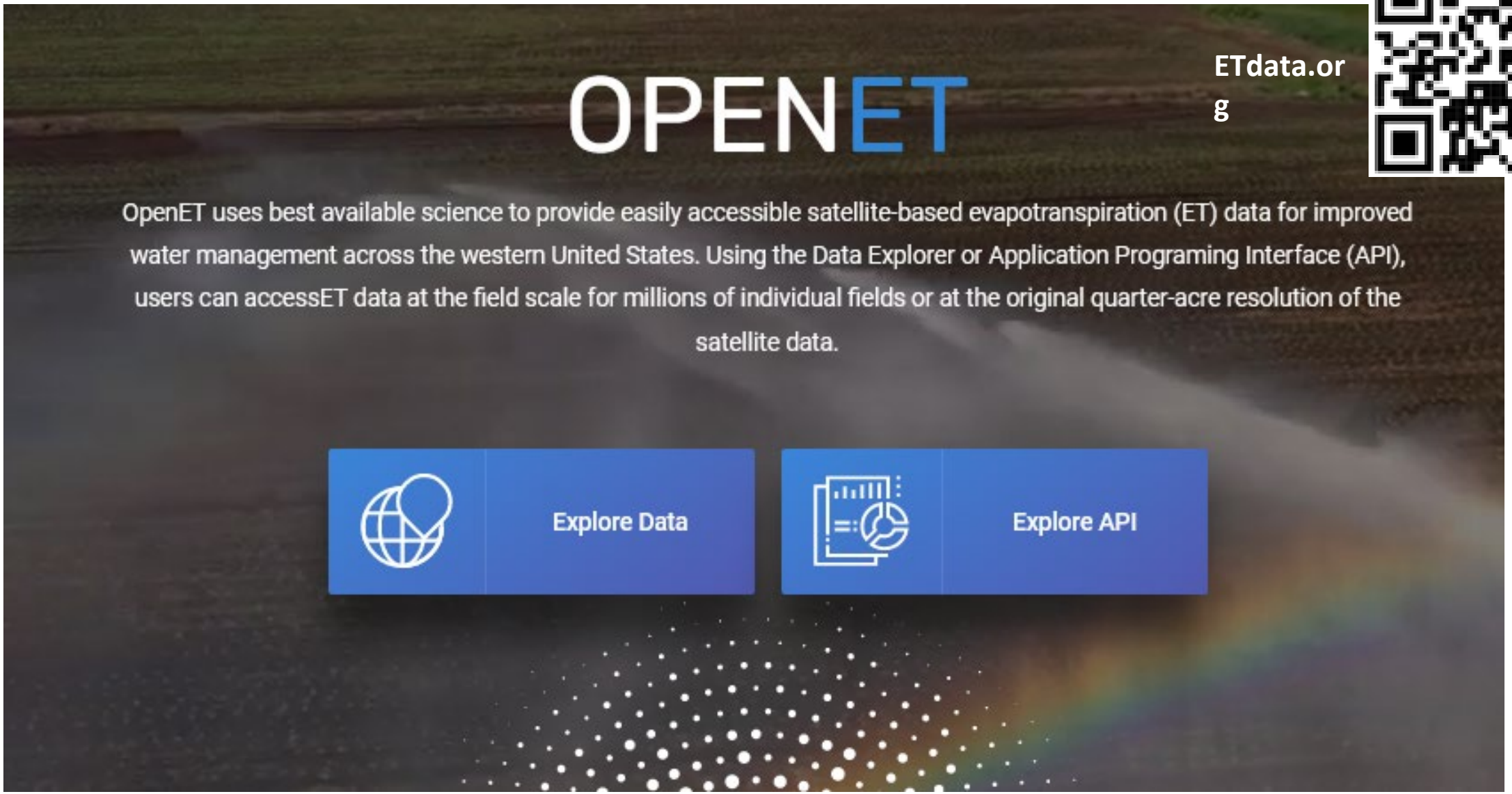
Crop coefficients (Kc) through post-establishment period *(canopy cover >10%)*

- Kc = crop ET / cimis reference ET
- Indication of crop water requirement

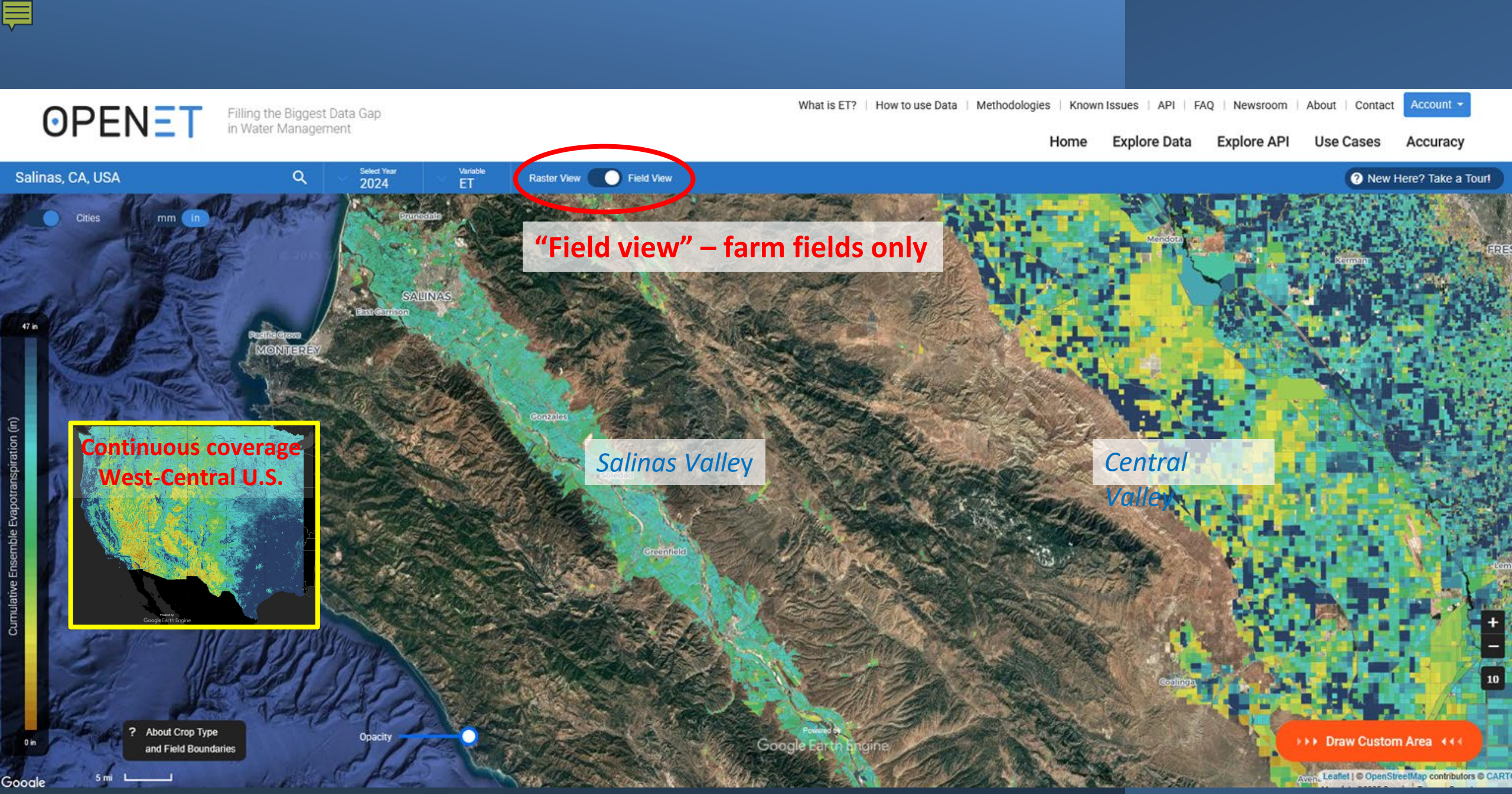




- OpenET…



(…**see also** last year's presentation, available on UCCE website…)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OPENET

Filling the Biggest Data Gap in Water Management

What is ET? | How to use Data | Methodologies | Known Issues | API | FAQ | Newsroom | About | Contact | Account

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Salinas, CA, USA

Select Year 2024

Variable ET

Raster View Field View

New Here? Take a Tour!

Cities mm in

47 in

Cumulative Ensemble Evapotranspiration (in)

0 in

? About Crop Type and Field Boundaries

Opacity

Draw Custom Area

Google

5 mi

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What is ET? | How to Use Data | Methodologies | Known Issues | API | FAQ | Newsroom | About | Our Team | Contact | Login

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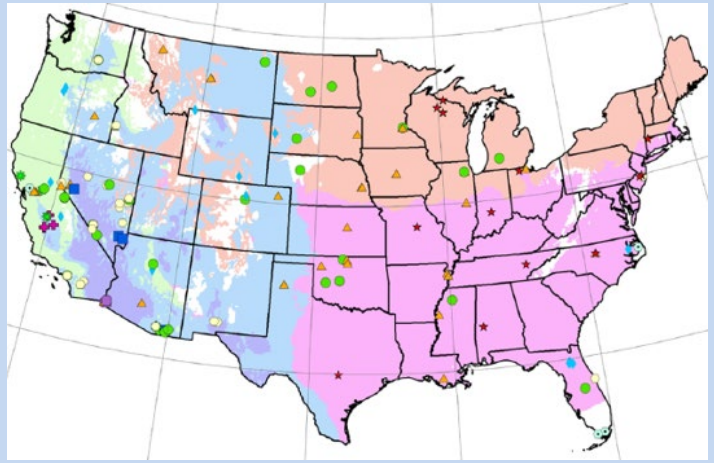
Prior OpenET verification study

- **Cropland**
  - Mostly grains
  - Few vegetables, none in CA
- Evergreen forest
- Grassland
- Mixed forest
- Shrubland
- Wetland



Multiple stations across U.S operated by:

AmeriFlux

USGS

USDA ARS

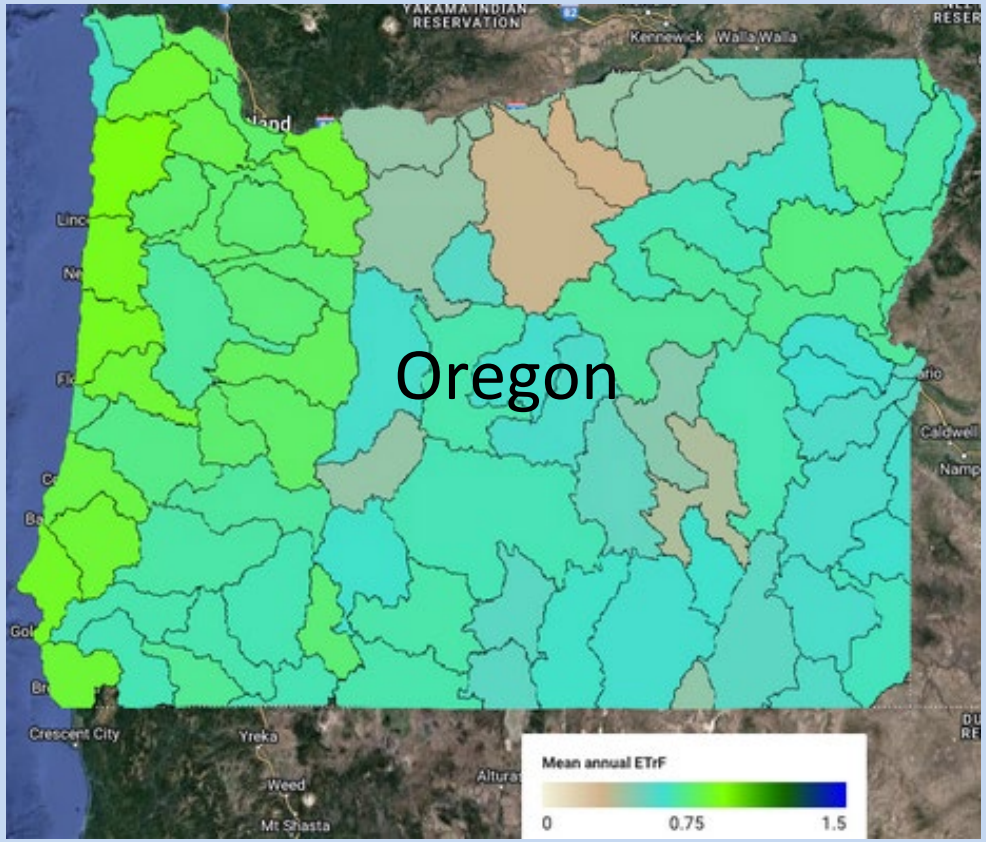
+ others…

Volk *et al*, Jan 2024

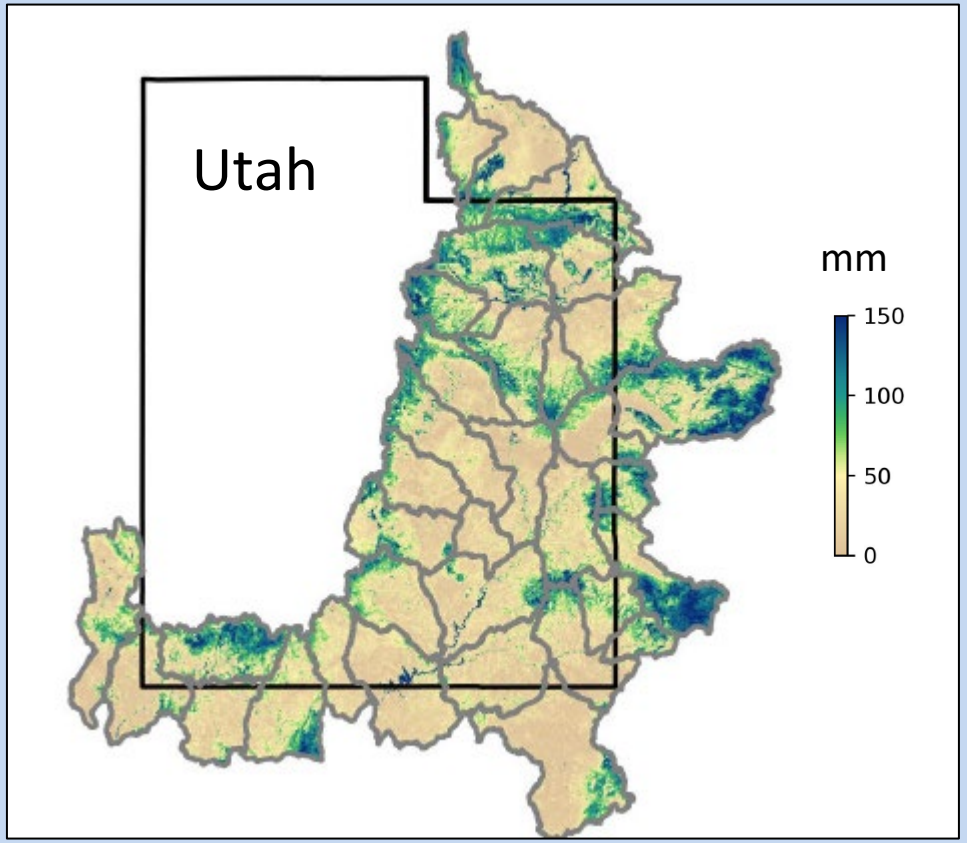
Key considerations: quality of ground data and matching the source area to the satellite data

Field/farm level analysis

Regional analysis…

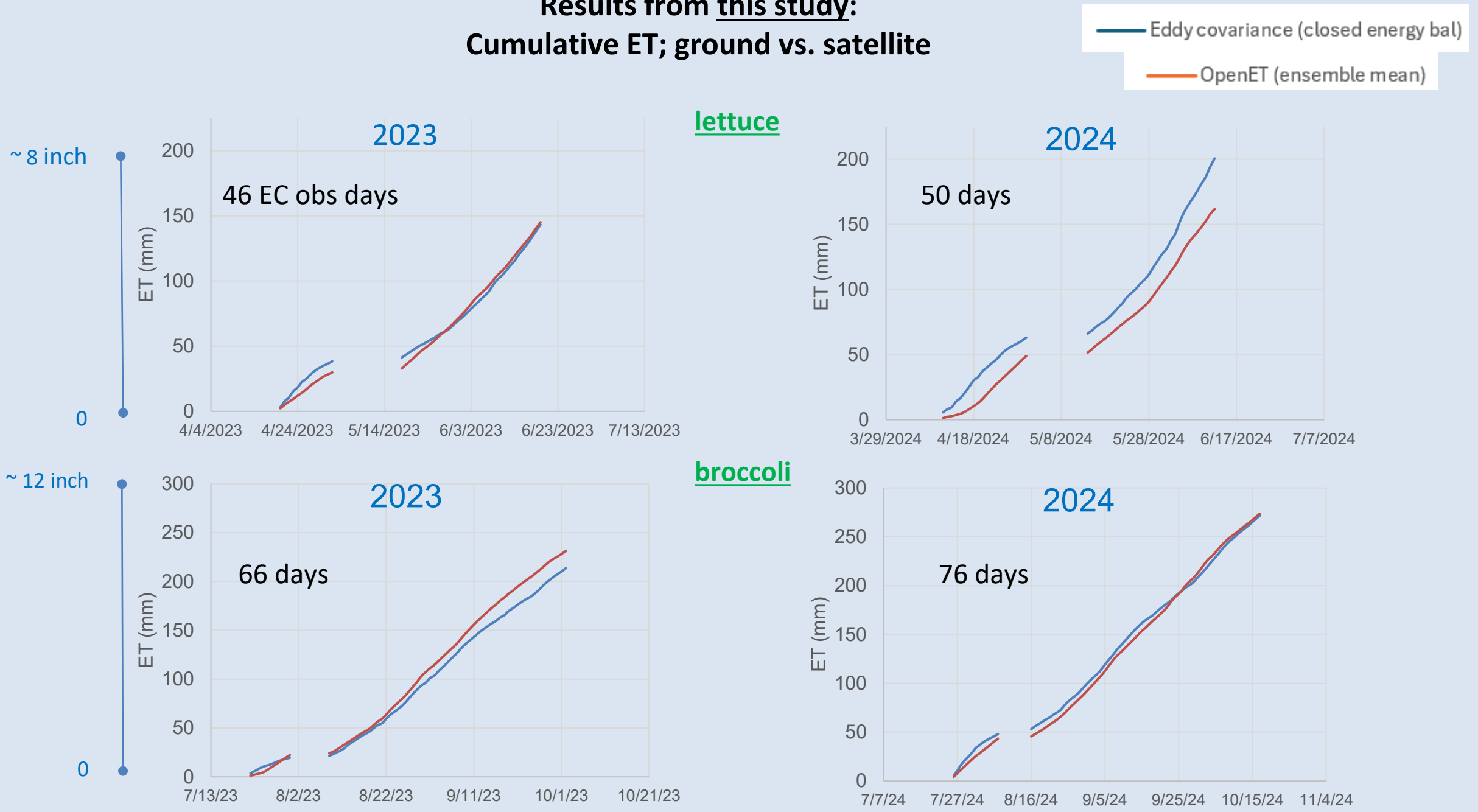


Ratio of actual ET to reference ET by watershed, mean for 1990-2020



ET during June 2021. Watershed boundaries shown within Colorado River Basin. Higher values are irrigated agriculture.

Results from this study:
Cumulative ET; ground vs. satellite



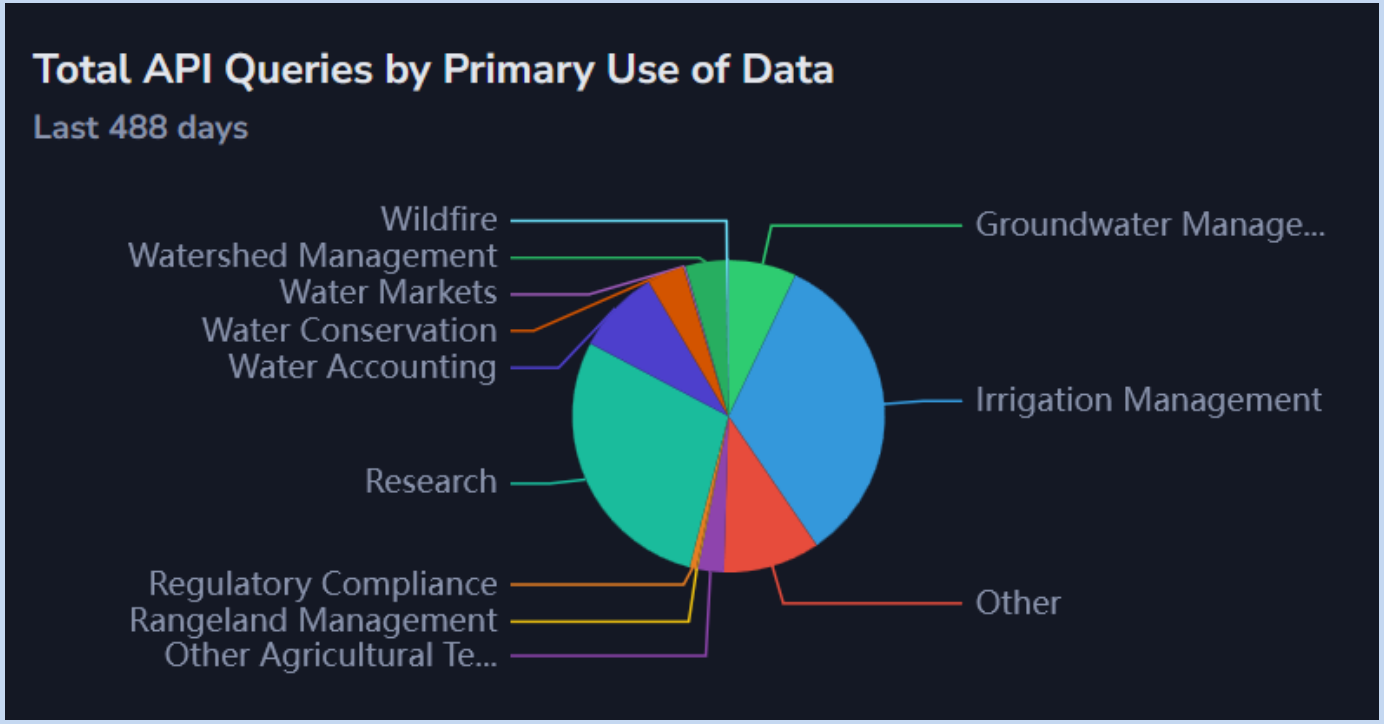
Accuracy of OpenET ensemble mean at the study sites

				Error	
site			# obs days	**Avg** daily	**Total** crop cycle
1	lettuce	2023	46	19%	1%
2	lettuce	2024	50	29%	-19%
3	broccoli	2023	66	20%	8%
4	broccoli	2024	76	17%	1%

(see Appendix for mean absolute error and mean bias error as mm/day + further info on data collection/processing methods and quality control)

Some possible uses for OpenET (in Salinas)

- Inform basin-level groundwater extraction modeling
- Provide field/farm level ET data for regulatory reporting
- Offer secondary data source for CropManage irrigation scheduling app
- Other?



Planned sites for 2025

COUNTY OF MONTEREY'S TOP CROPS

CROP	2023 CROP VALUE	2023 CROP RANKING	2022 CROP RANKING
Strawberry	$903,791,000	1	1
Leaf Lettuce	$782,134,000	2	2
Head Lettuce	$493,464,000	3	3
Broccoli	$468,871,000	4	4
Wine Grape	$194,642,000	5	7
Cauliflower	$188,242,000	6	5

Lee.f.johnson@nasa.gov

Appendix…

-Technical
details
-Further reading

Eddy covariance sensor package
main components & configuration

Instrument Type and Position	Value
IGRASON height (Campbell Scientific, Logan, Utah)	2m
IRGASON orientation (Campbell Scientific, Logan, Utah)	315°
CNR4 4-way net radiometer height (Kipp and Zonen, Delft, Netherlands)	1.5m
HFP01 soil heat flux plate (Huskeflux, Delft, Netherlands)	16cm
TCAV averaging soil thermocouple probe depth (Campbell Scientific, Logan, Utah)	12-17cm
CS655 soil moisture and temperature sensor (Campbell Scientific, Logan, Utah)	10cm

CSUMB WATRS Lab

Eddy covariance post-processing

Standardized procedures:

Gap filling

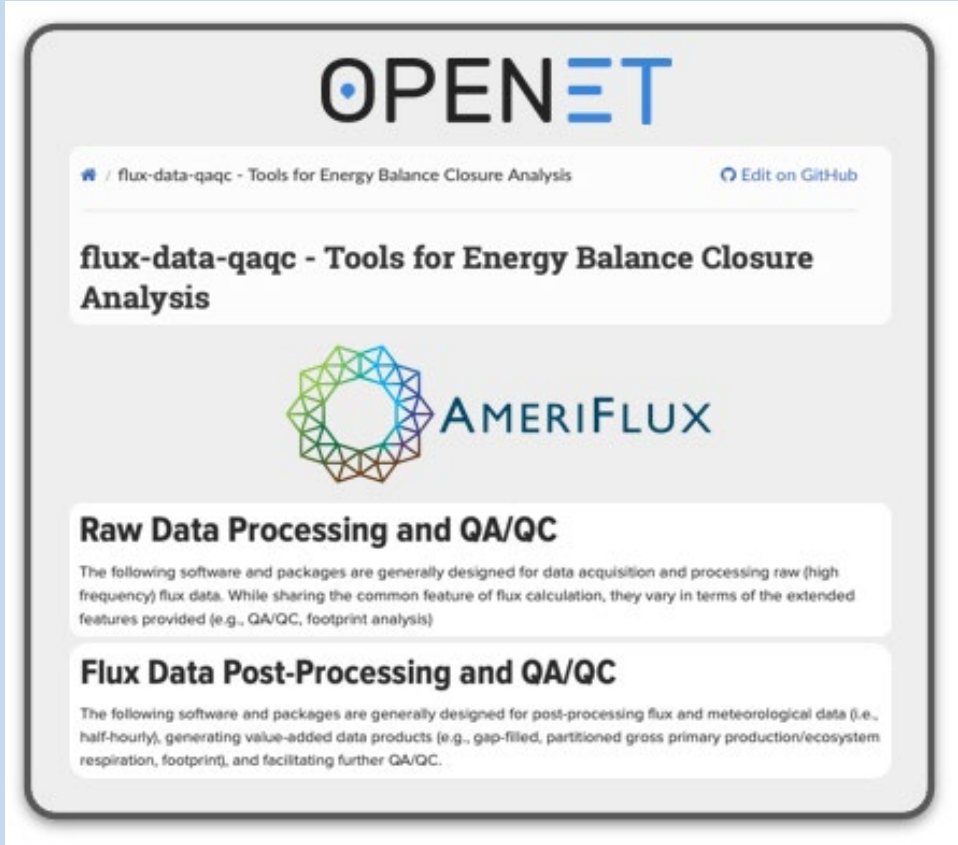
Time aggregation

Energy balance assessment/closure

ET conversion

Quality control QA-QC

Data archiving



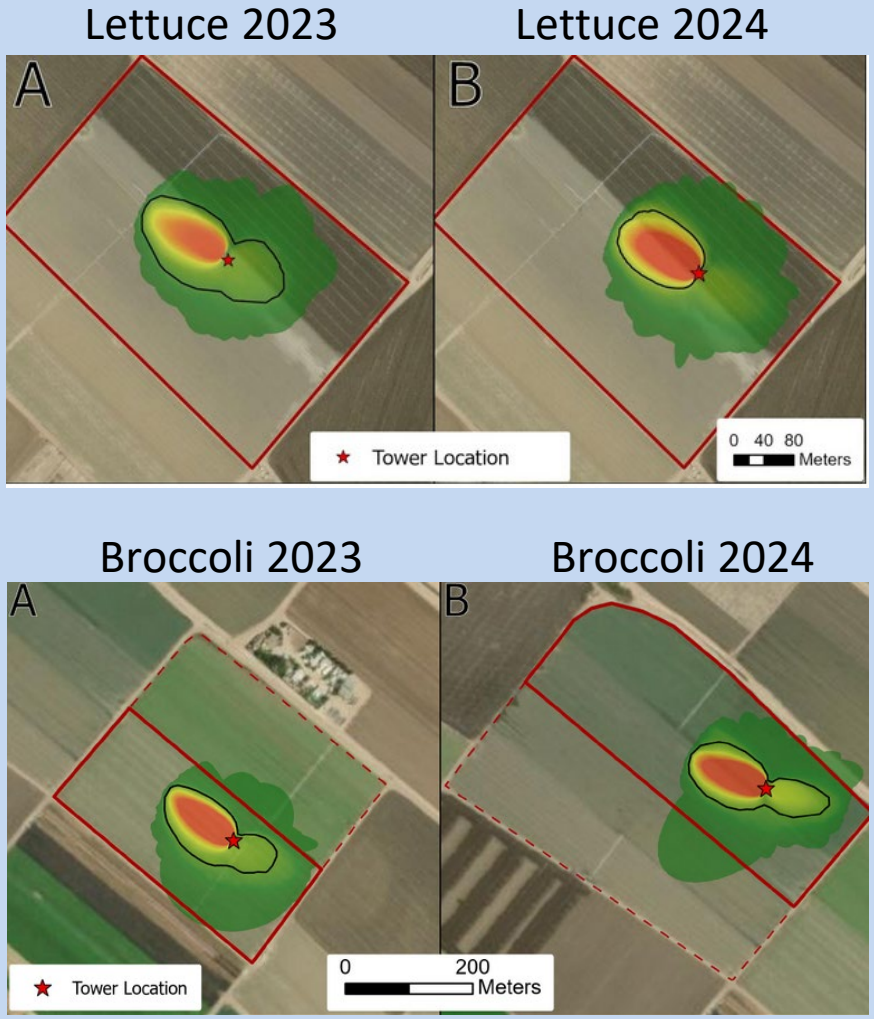
Volk et al., 2021 (see Further Reading)

EC flux footprint analysis

Kljun flux footprint prediction Python library:

- Verify EC towers had adequate fetch
- Facilitate comparison of EC with OpenET satellite data (pixel extraction)

after Kljun et al., 2015 (see Further Reading)



Area of contribution estimates generated by dynamic footprint model. Red/orange tones represent higher summed contributions of individual 30-minute footprints, green represents lower. Black line shows area of OpenET satellite data extraction.

Eddy covariance

mean energy balance closure ratios for daily data

- Lettuce 2023
  0.88
- Lettuce 2024
  0.72
- Broccoli 2023
  0.84
- Broccoli 2025
  0.85

OpenET accuracy:
mean absolute error (MAE),
mean bias error (MBE)

site			# obs days	MAE (mm/day)	MBE (mm/day)
1	lettuce	2023	46	0.59	0.04
2	lettuce	2024	50	1.15	-0.78
3	broccoli	2023	66	0.65	0.27
4	broccoli	2024	76	0.62	0.03

Further reading

Melton, F. et al., 2022. OpenET: Filling a critical data gap in water management for the western United States. *J. Amer. Water Resources Assn*. 58:971-994. link

Volk J., et al., 2024. Assessing the accuracy of OpenET satellite-based evapotranspiration data to support water resource and land management applications. *Nature Water 2:193-205* link

Volk, J. et al., 2021. flux-data-qaqc: a Python package for energy balance closure and post-processing of eddy flux data. *J. Open Source Software.* 6, 1–5. link

Kljun, N., et al., 2015. A simple two-dimensional parameterisation for Flux Footprint Prediction (FFP). *Geosci. Model Dev.* 8, 3695–3713. link