An aerial photograph of agricultural fields, likely in California, showing various crops and irrigation patterns. A semi-transparent white text box is overlaid on the center of the image, containing the title and presenter information. The fields are a mix of green, yellow, and brown, indicating different stages of crop growth and water usage.

Validating OpenET satellite measurements of water use in broccoli and lettuce

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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...

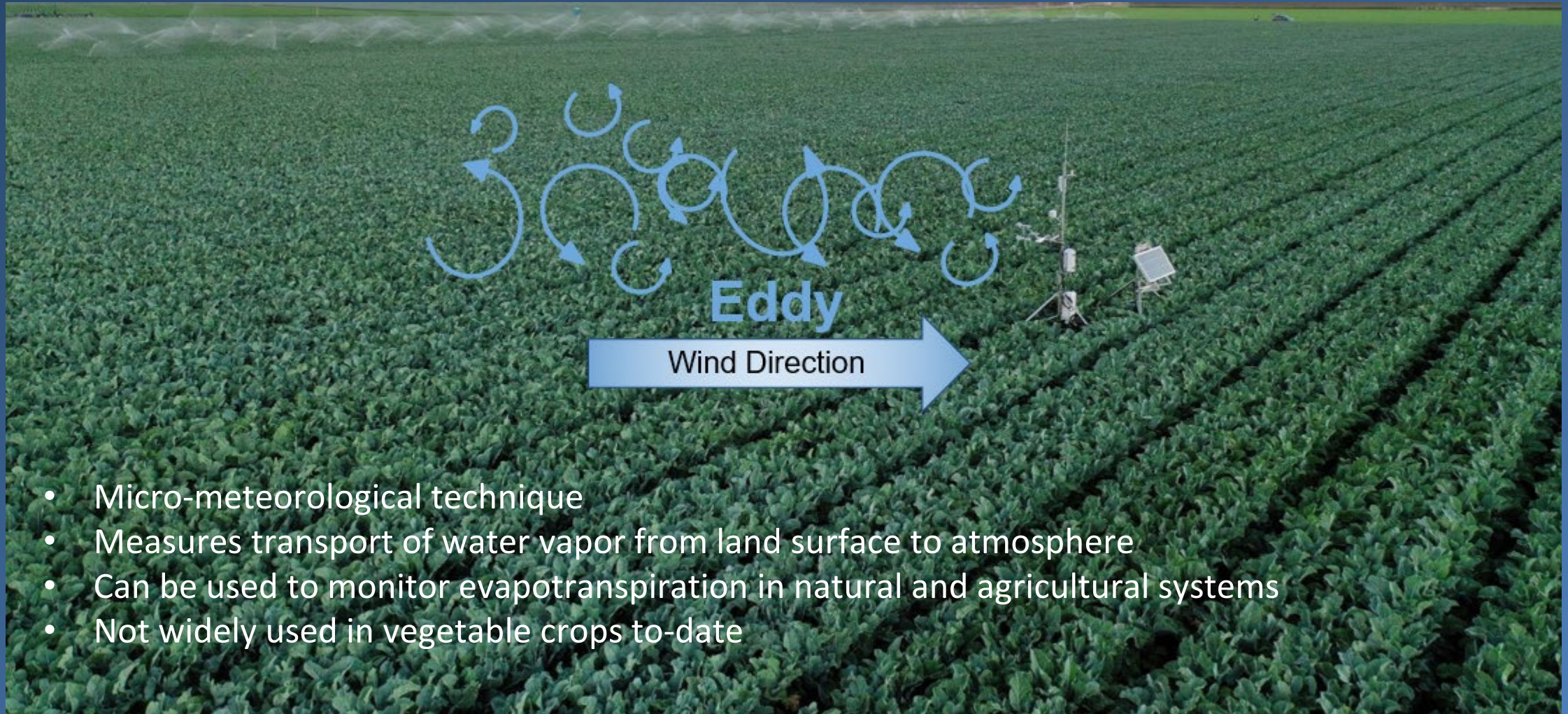
EVAPORATION TRANSPIRATION

A diagram illustrating crop water use. It shows three corn plants growing in a field. Blue wavy arrows point upwards from the soil surface, representing evaporation. Blue wavy arrows point upwards from the leaves of the corn plants, representing transpiration. The background is a light blue sky and a green field with brown soil. The text 'EVAPORATION' and 'TRANSPIRATION' is overlaid on the image.

Evapotranspiration (ET)

Sometimes called “consumptive use”

Eddy covariance

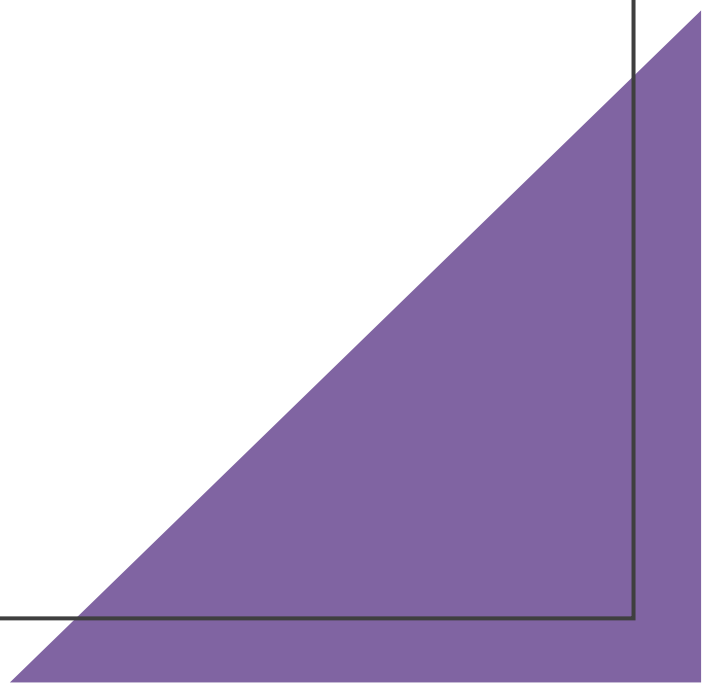


- Micro-meteorological technique
- Measures transport of water vapor from land surface to atmosphere
- Can be used to monitor evapotranspiration in natural and agricultural systems
- Not widely used in vegetable crops to-date



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

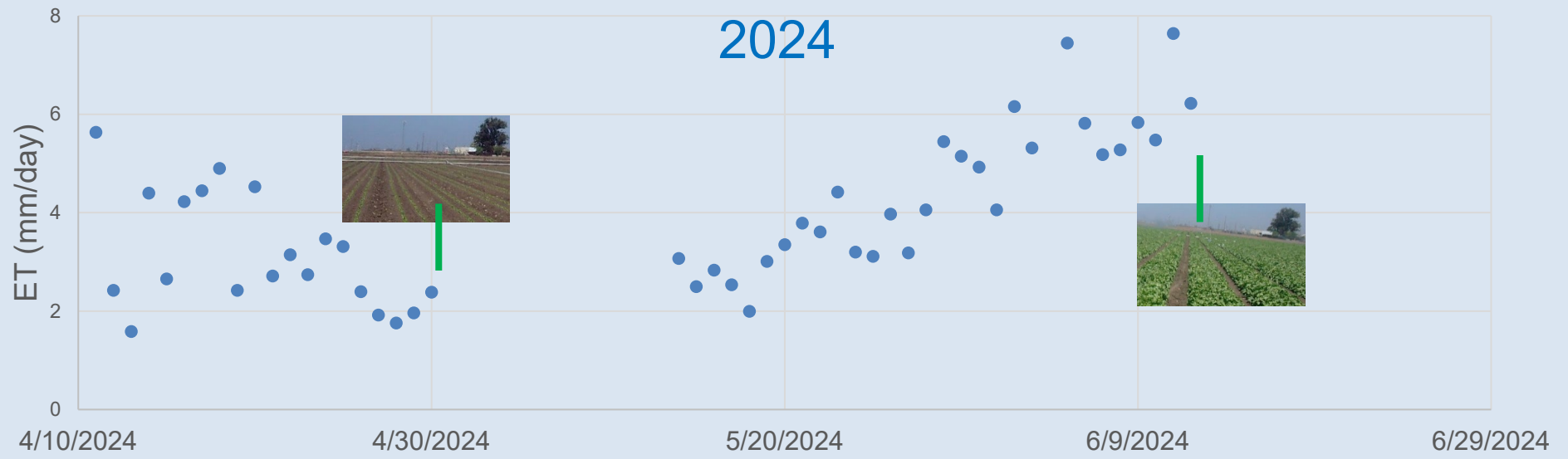
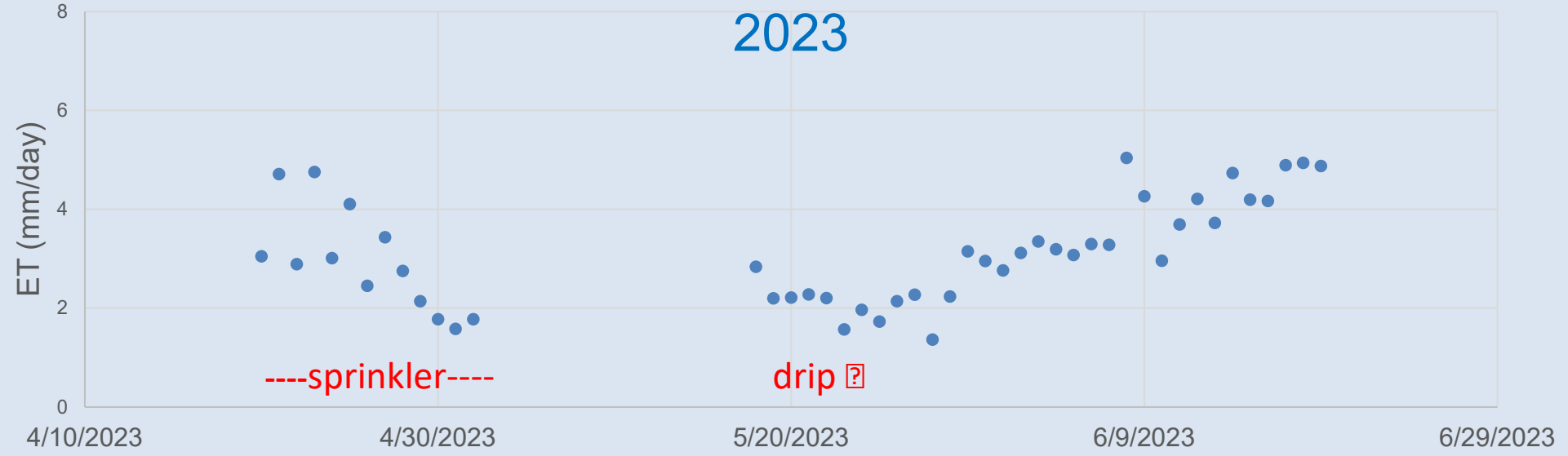
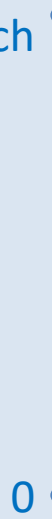
Eddy covariance stations





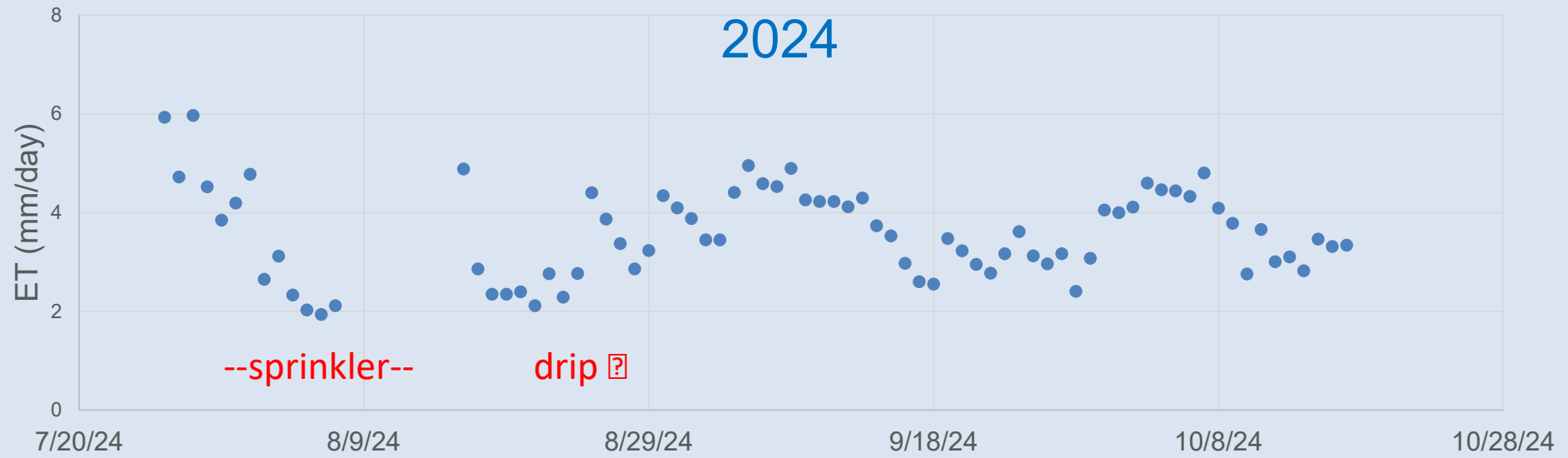
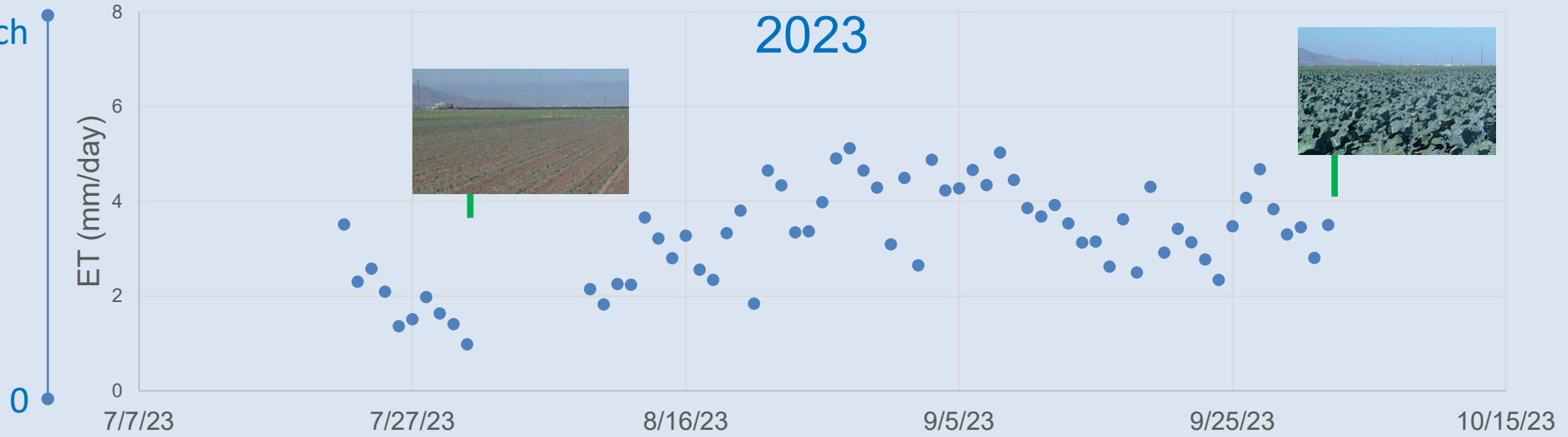
Eddy covariance results: Daily ET for lettuce

~ 1/3 inch



Daily ET for **broccoli**

~ 1/3 inch

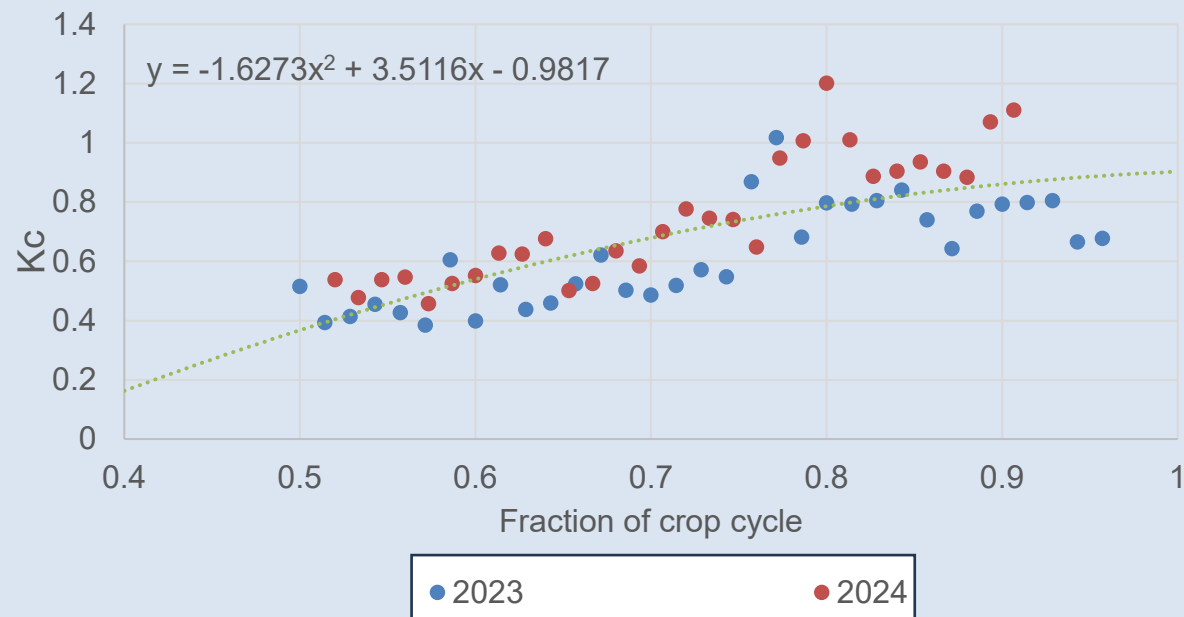




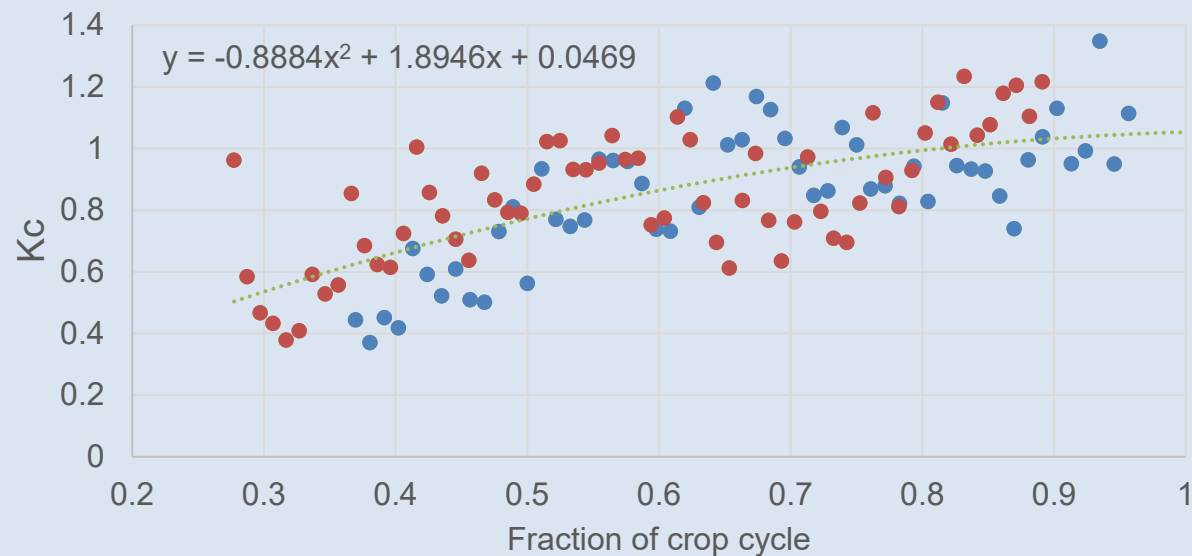
Crop coefficients (Kc) through post-establishment period (*canopy cover >10%*)

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

Lettuce



Broccoli





- OpenET...




OPENET

ETdata.org

OpenET uses best available science to provide easily accessible satellite-based evapotranspiration (ET) data for improved water management across the western United States. Using the Data Explorer or Application Programming Interface (API), users can access ET data at the field scale for millions of individual fields or at the original quarter-acre resolution of the satellite data.

 Explore Data  Explore API



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

Salinas, CA, USA

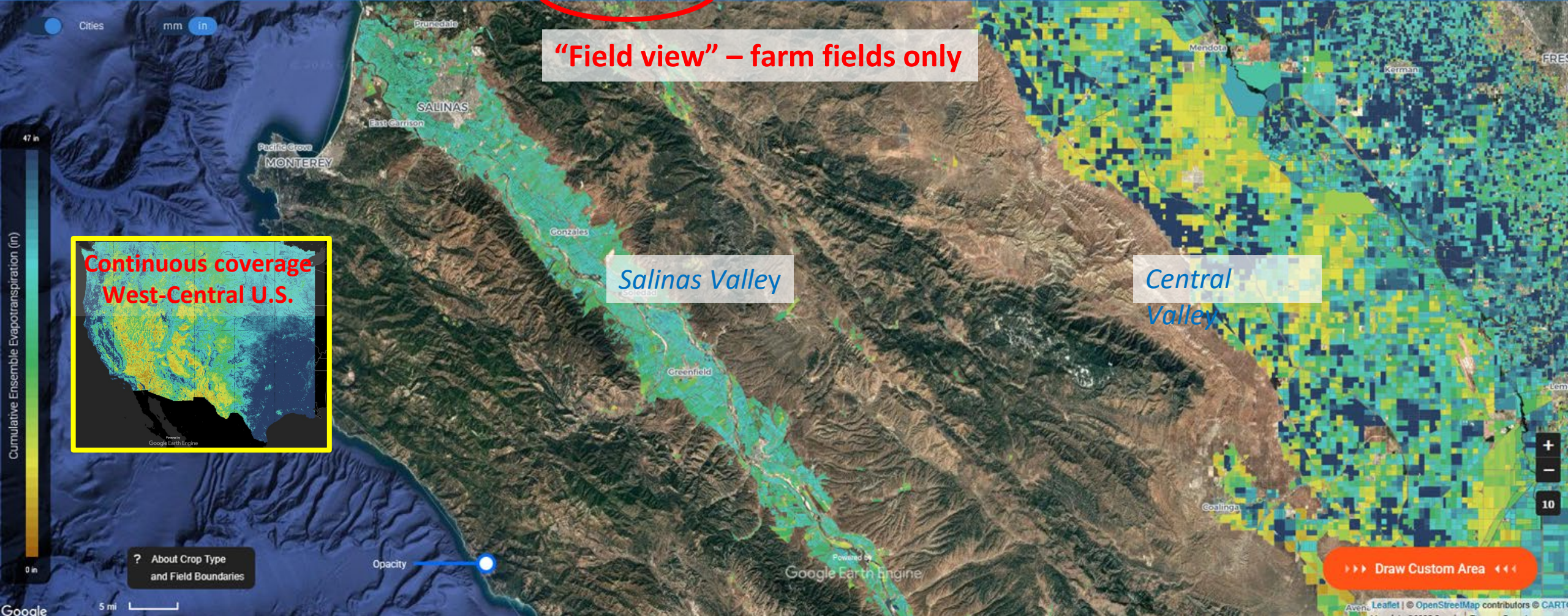


Select Year
2024

Variable
ET

Raster View Field View

New Here? Take a Tour!



About Crop Type and Field Boundaries

Opacity

Salinas, CA, USA



Select Year
2024

Variable
ET

Raster View Field View



Cumulative Ensemble Evapotranspiration (m)

0 in

? About Crop Type
and Field Boundaries

Opacity

Powered by
Google Earth Engine

Draw Custom Area

5 mi

Leaflet | © OpenStreetMap contributors © CARTO

Prior OpenET verification study

➤ Cropland

- Mostly grains
- Few vegetables, none in CA

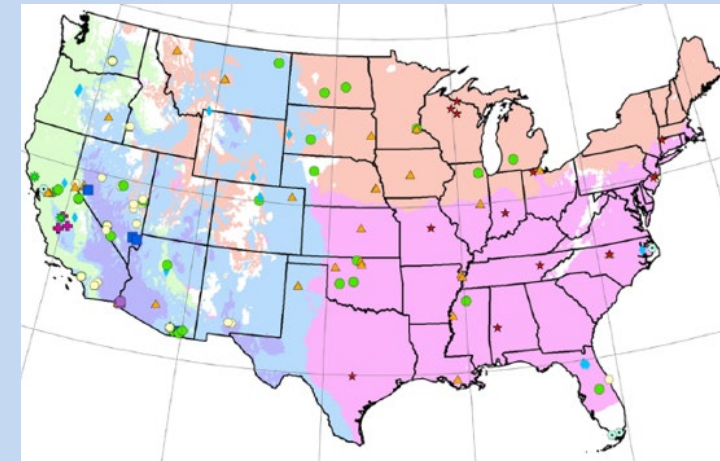
➤ Evergreen forest

➤ Grassland

➤ Mixed forest

➤ Shrubland

➤ Wetland



Multiple stations across U.S operated by:



+ 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

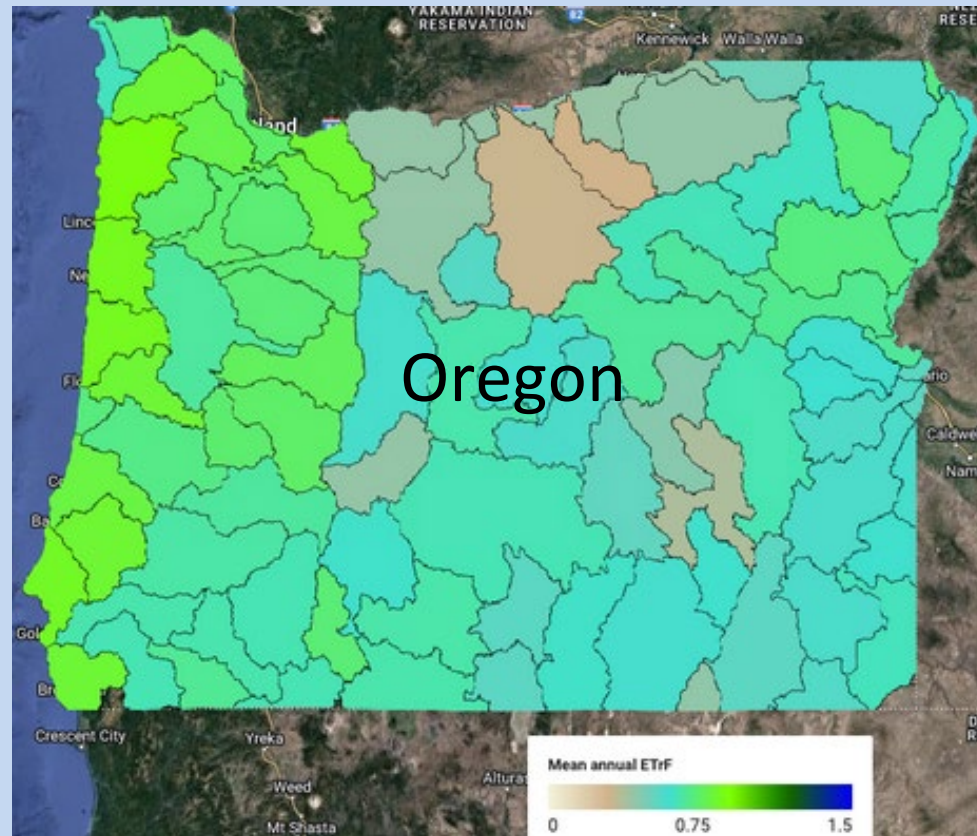
The screenshot displays the OPENET FARMS BETA interface. At the top left, the logo 'OPENET FARMS BETA' is visible. Below it, the title 'CA Example' is shown with a 'Manage Report' button. The main chart area is titled 'disalexi et' and shows a line graph with five data series representing different field IDs: 135165 (blue), 134547 (green), 134183 (yellow), 134044 (red), and 133714 (purple). The x-axis shows dates from 2024-09-29 to 2024-10-23, and the y-axis shows values from 0 to 0.15. Below the chart, the 'Field Report Data' section provides details for Field ID: 133714 and Acres: 77.09. It includes buttons for 'Print Report' and 'Download CSV'. A navigation bar shows the model 'disalexi', variable 'et', and field ID 'id:133714'. At the bottom, a table lists the data points.

Date	Value (inches)	Acre-Feet
2024-10-26	0.013	0.084
2024-10-25	0.013	0.084
2024-10-24	0.016	0.103
2024-10-23	0.022	0.141
2024-10-22	0.02	0.128
2024-10-21	0.025	0.161

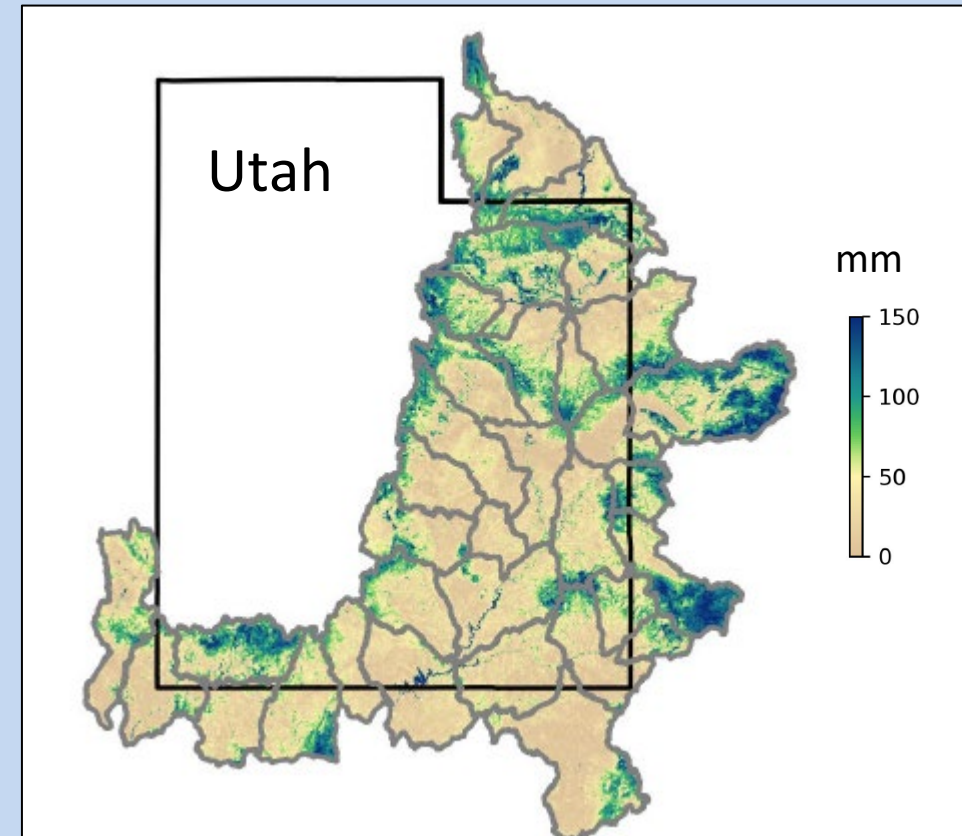
- Step 1: Log in
- Step 2: Define your region of interest
- Step 3: Build your report
- Step 4: Download**
- Step 5: Share or Mark Private

<https://farms.etdata.org>

Regional analysis...



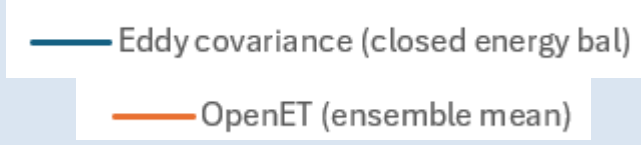
Ratio of actual ET to reference ET by watershed, mean for 1990-2020



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

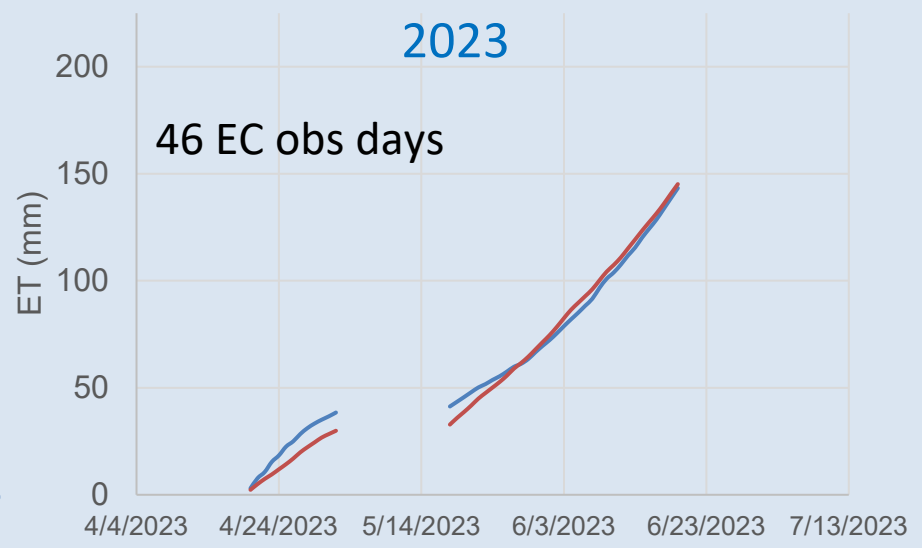


Results from this study: Cumulative ET; ground vs. satellite

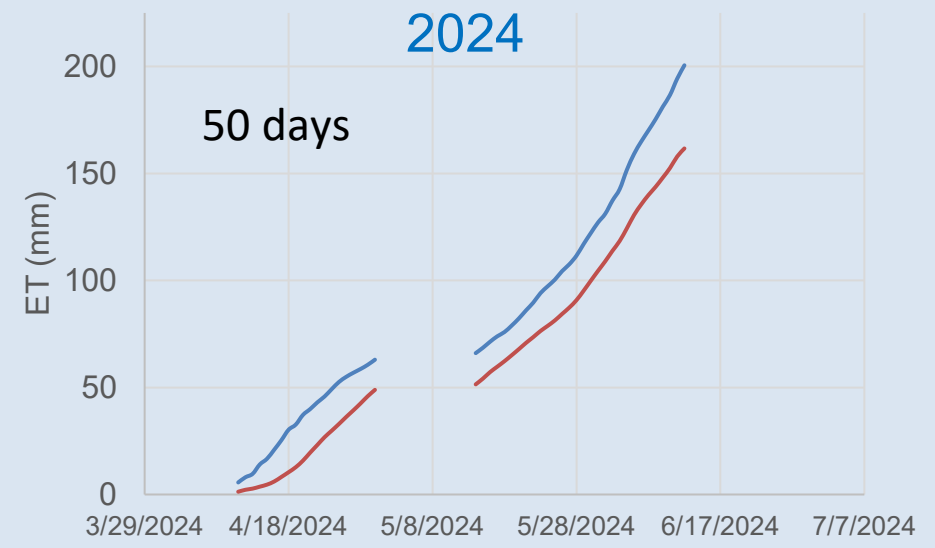


~ 8 inch

0

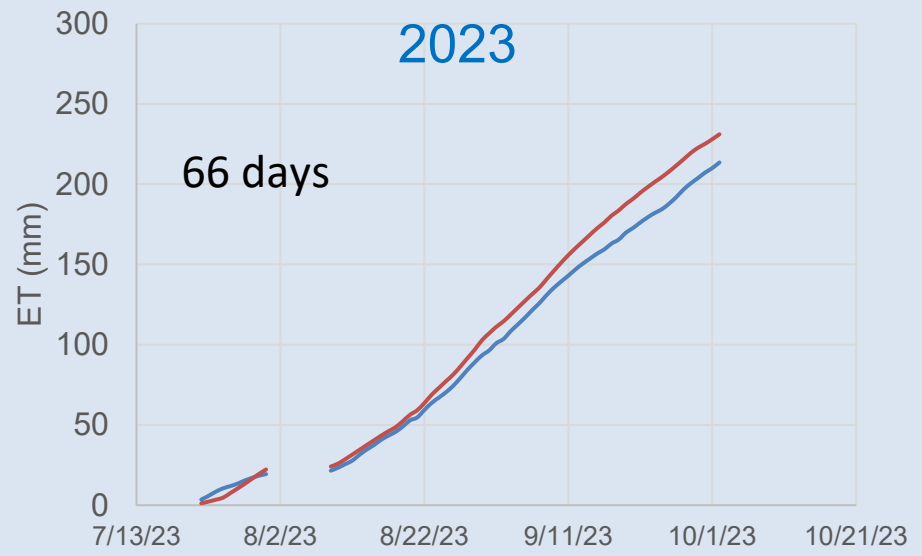


lettuce

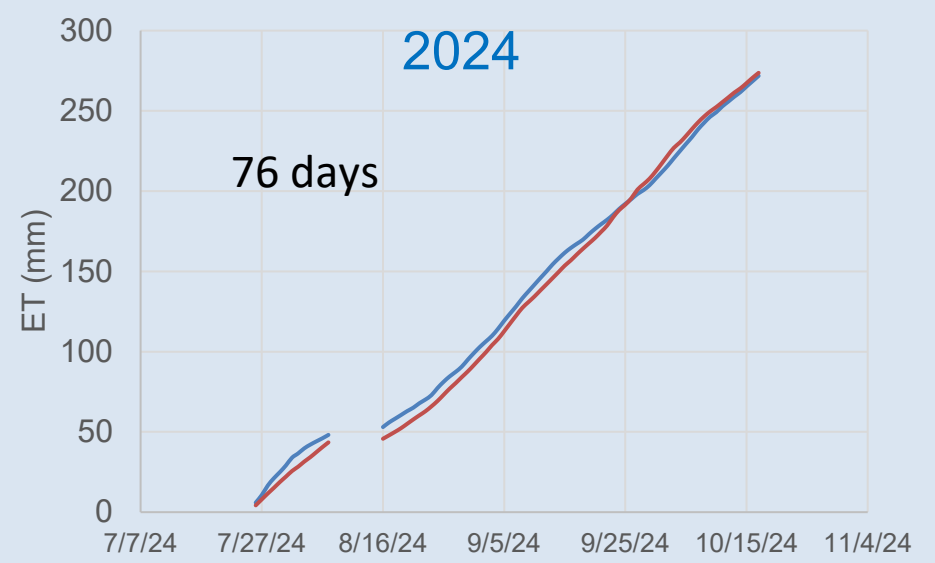


~ 12 inch

0



broccoli



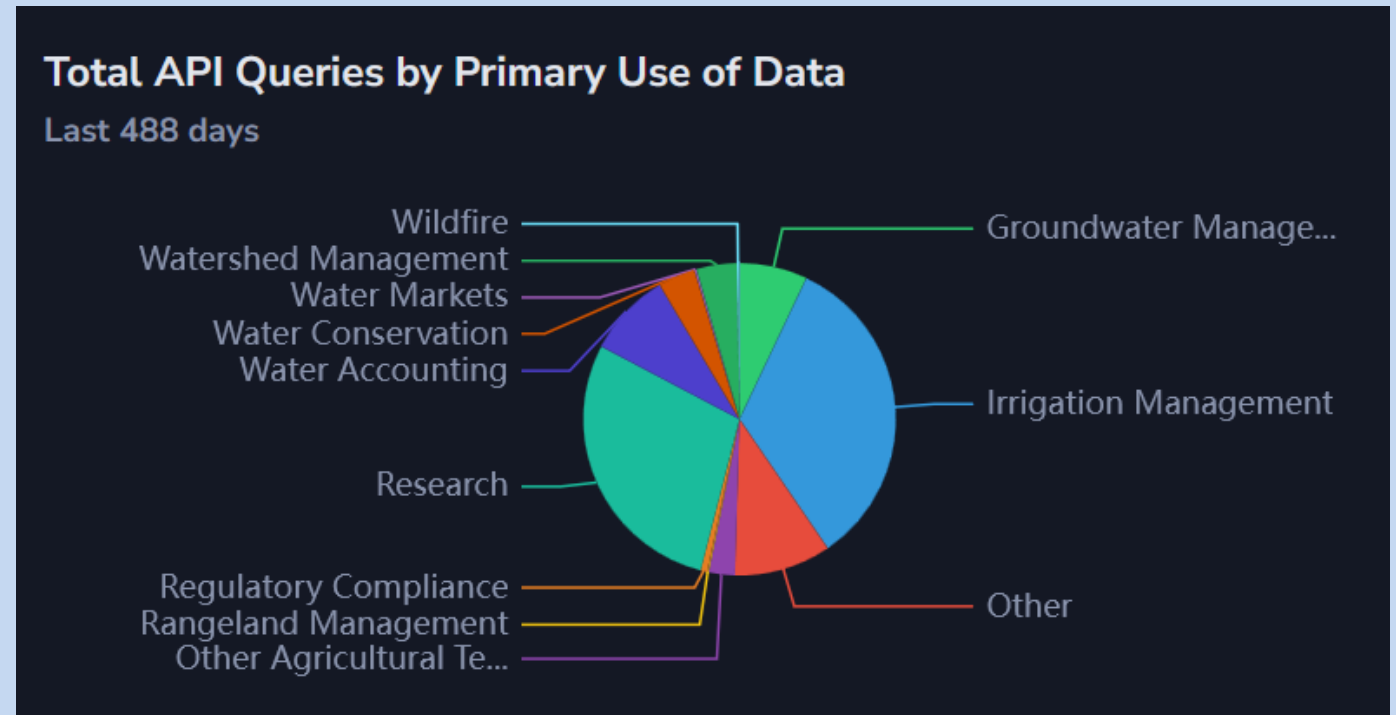
Accuracy of OpenET ensemble mean at the study sites

<i>site</i>			# obs days	<u>Error</u>	
				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?

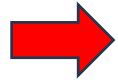


Planned sites for 2025



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



Eddy covariance post-processing

Standardized procedures:

Gap filling

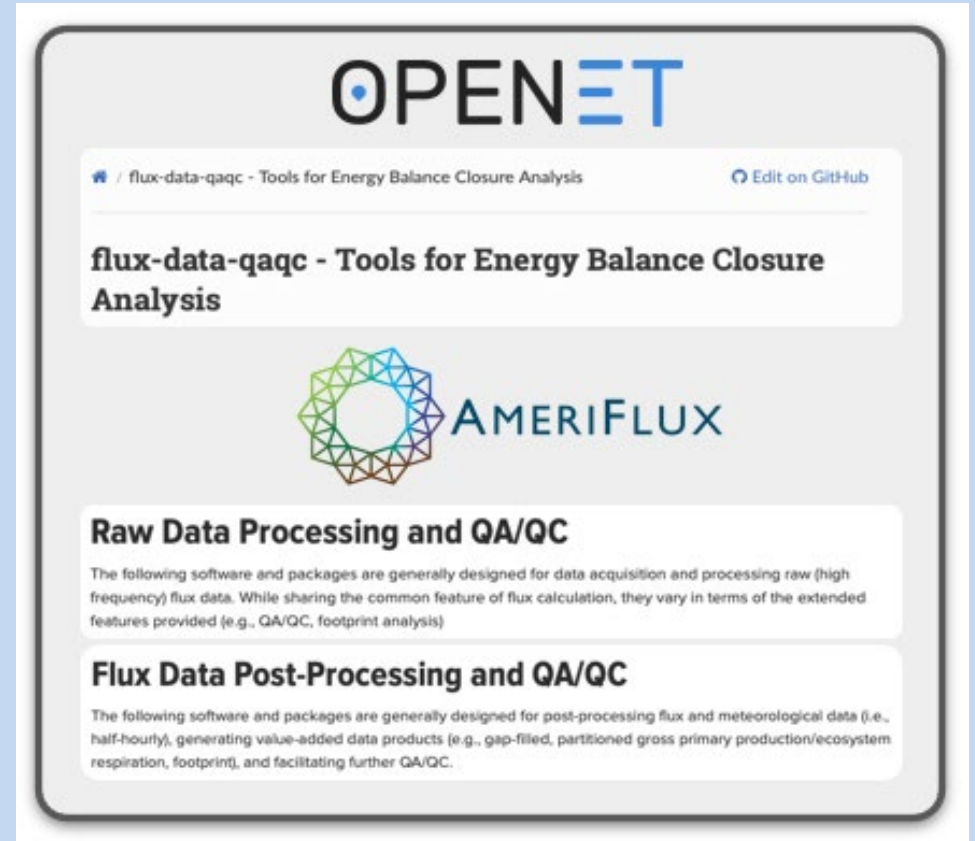
Time aggregation

Energy balance
assessment/closure

ET conversion

Quality control QA-QC

Data archiving

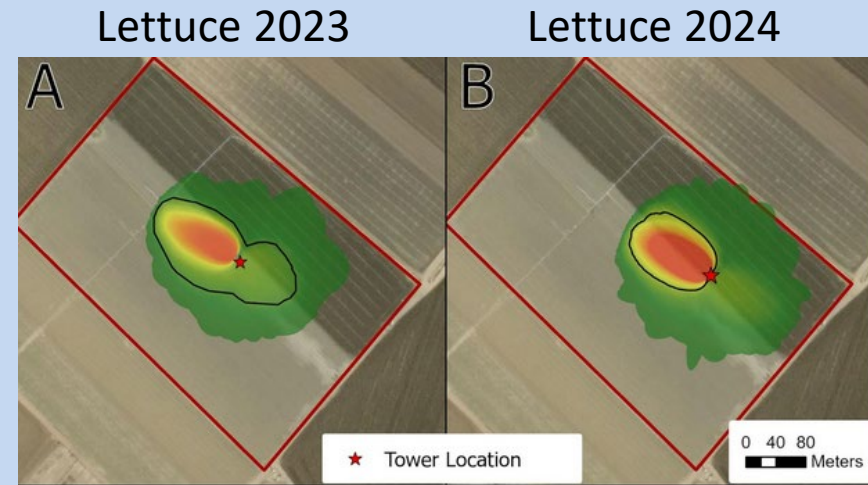


Volk et al., 2021 (see Further Reading)

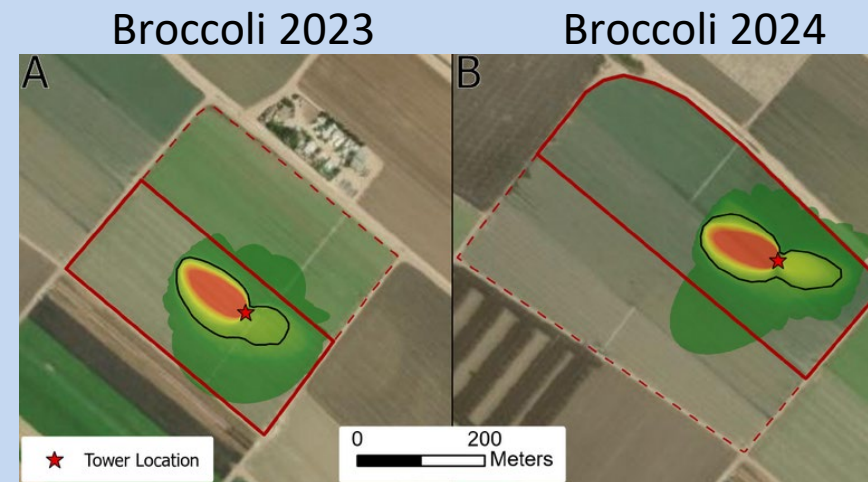
EC flux footprint analysis

Kljun flux footprint prediction Python library:

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



↓
Prevailing winds



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.

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

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)

<i>site</i>			# 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](#)