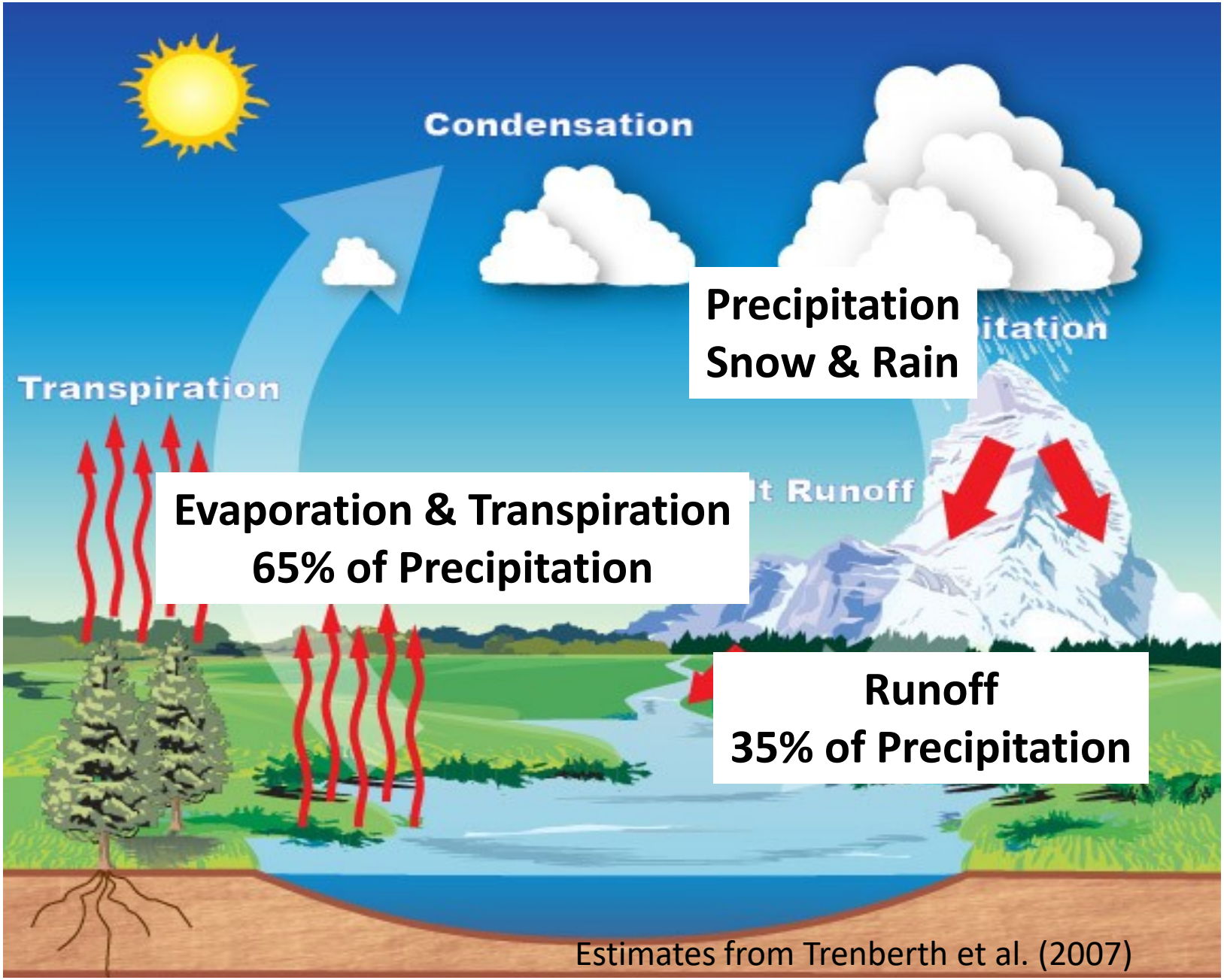
Principles of Evapotranspiration (ET) & Measuring Crop Water Use

World Alfalfa Congress, Irrigation Workshop – November 14, 2022

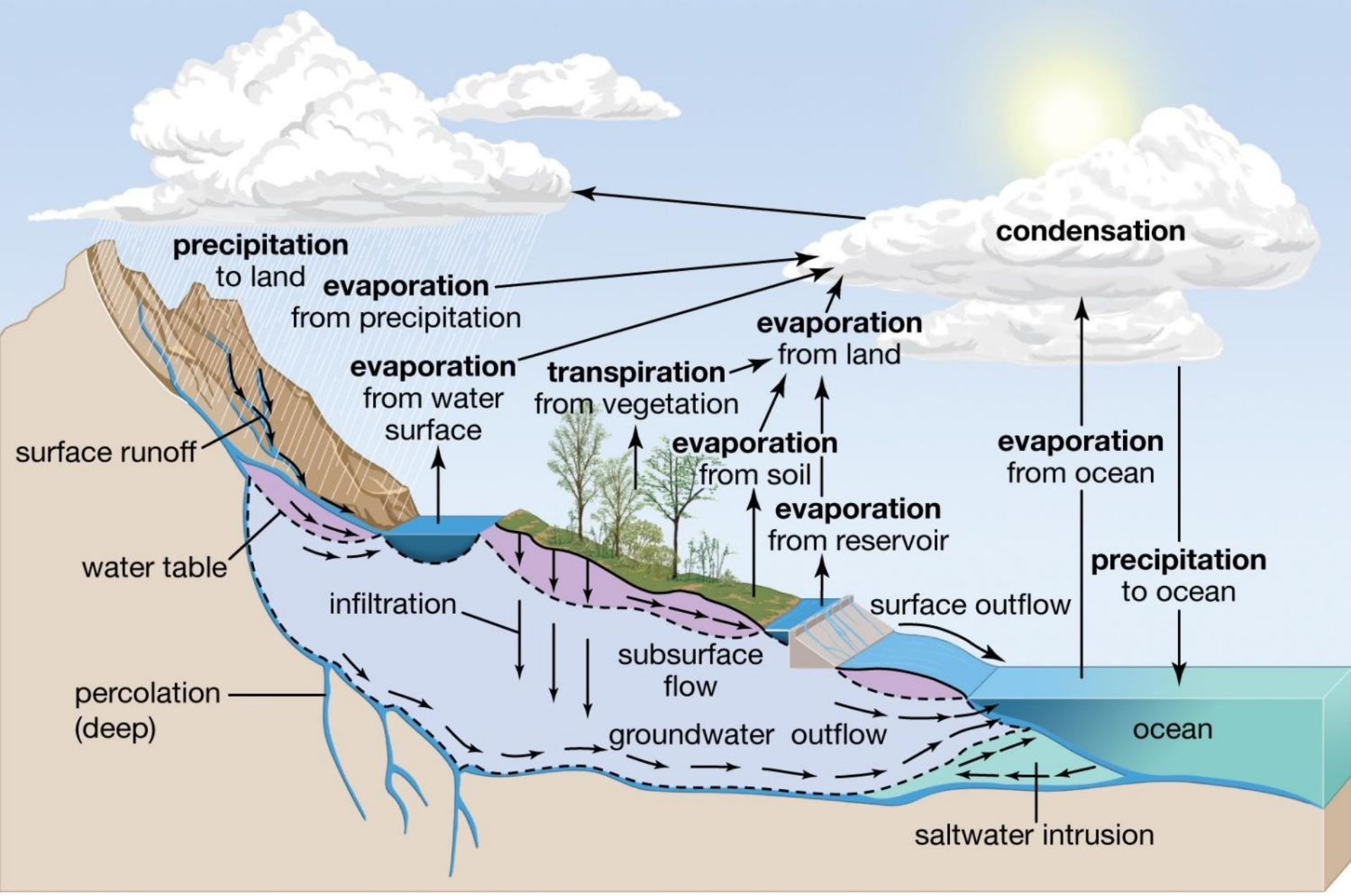
USDA Agricultural Research Service

Jason Kelley, Research Agricultural Engineer
USDA-ARS Water Management Research

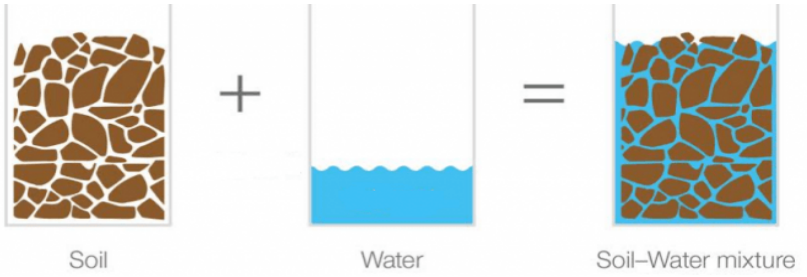
Agriculture within the hydrologic cycle

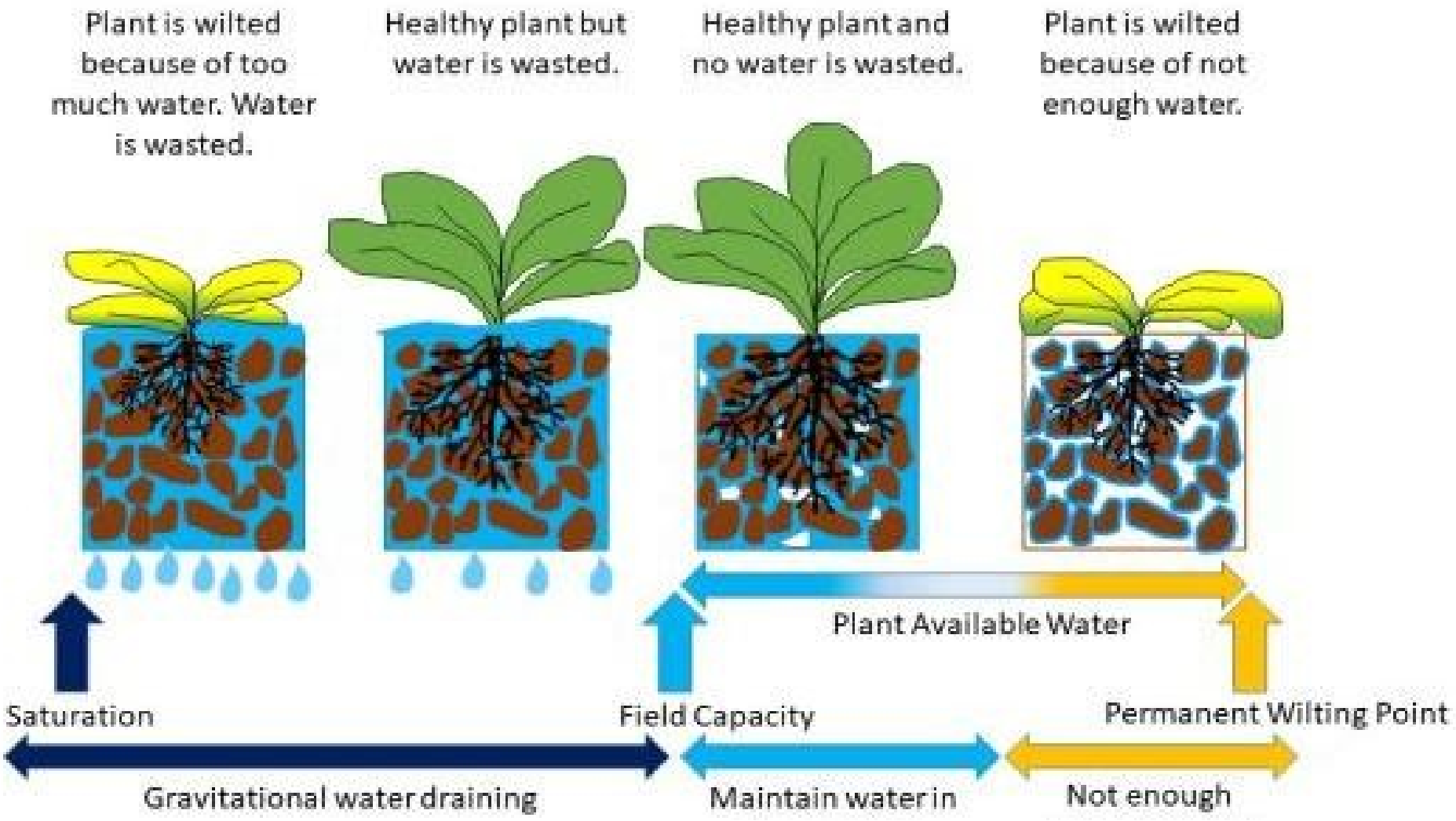


Estimates from Trenberth et al. (2007)



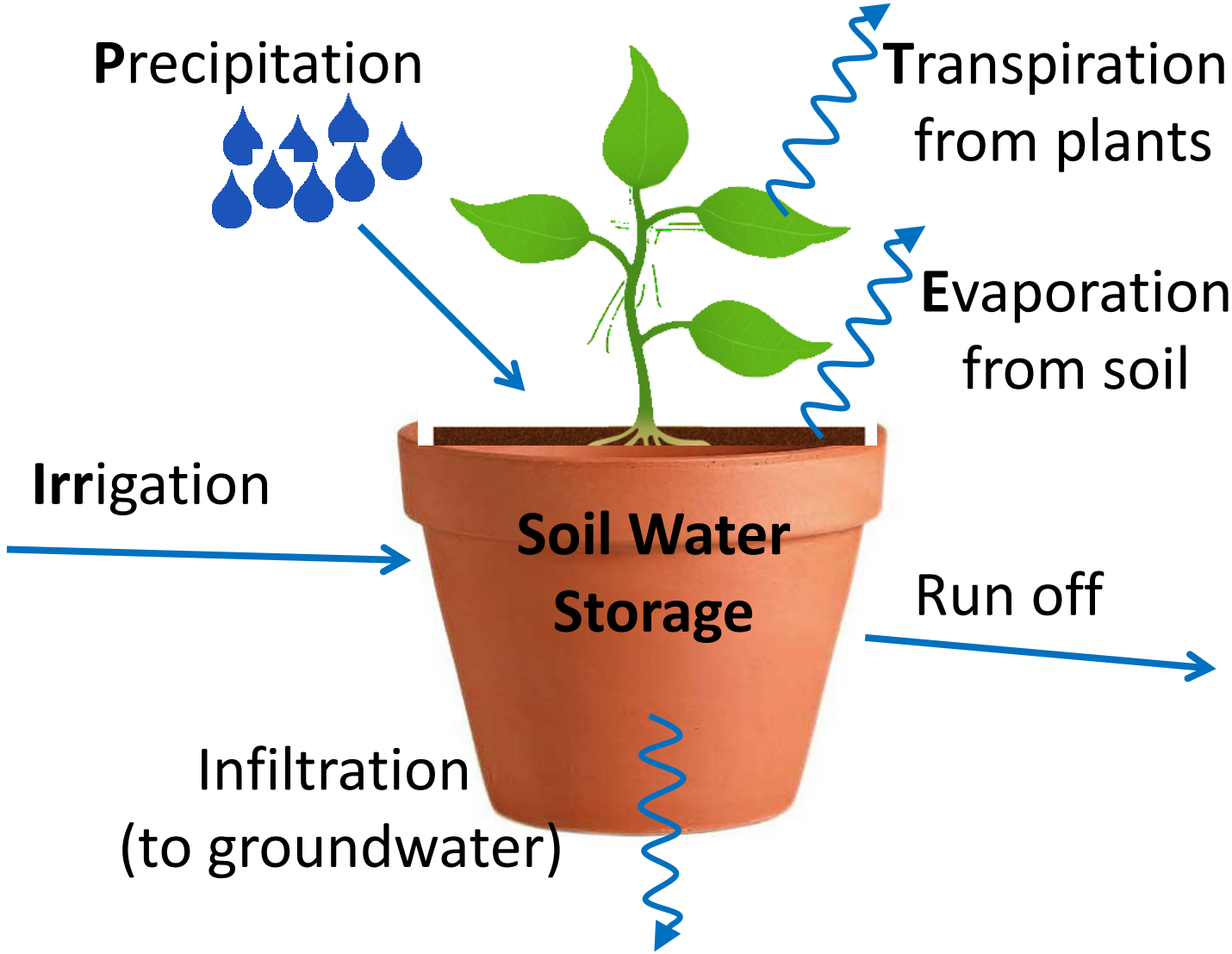
Crop perspective: Store water in soil





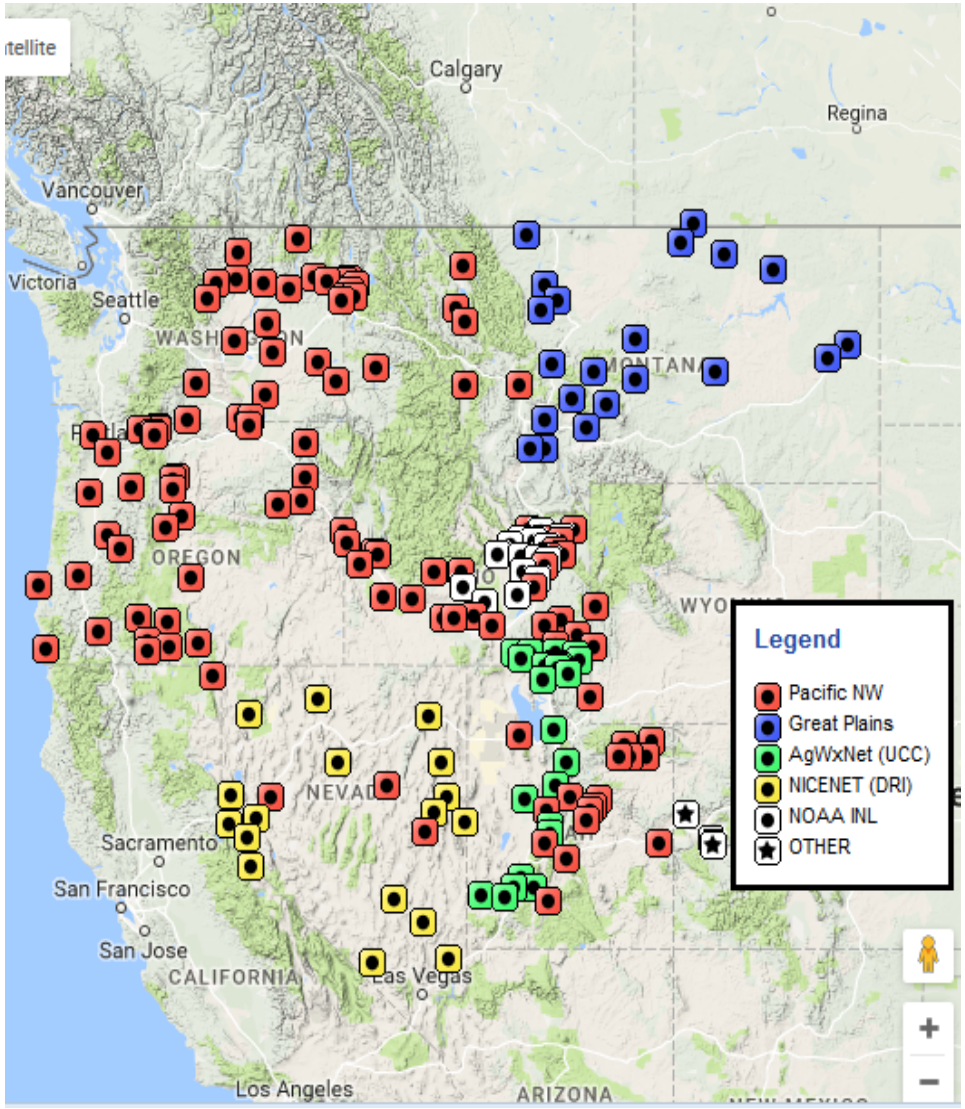
https://www.civilengineeringforum.me/soil-moisture-content/ *https://extension.umn.edu/irrigation/basics-irrigation-scheduling*

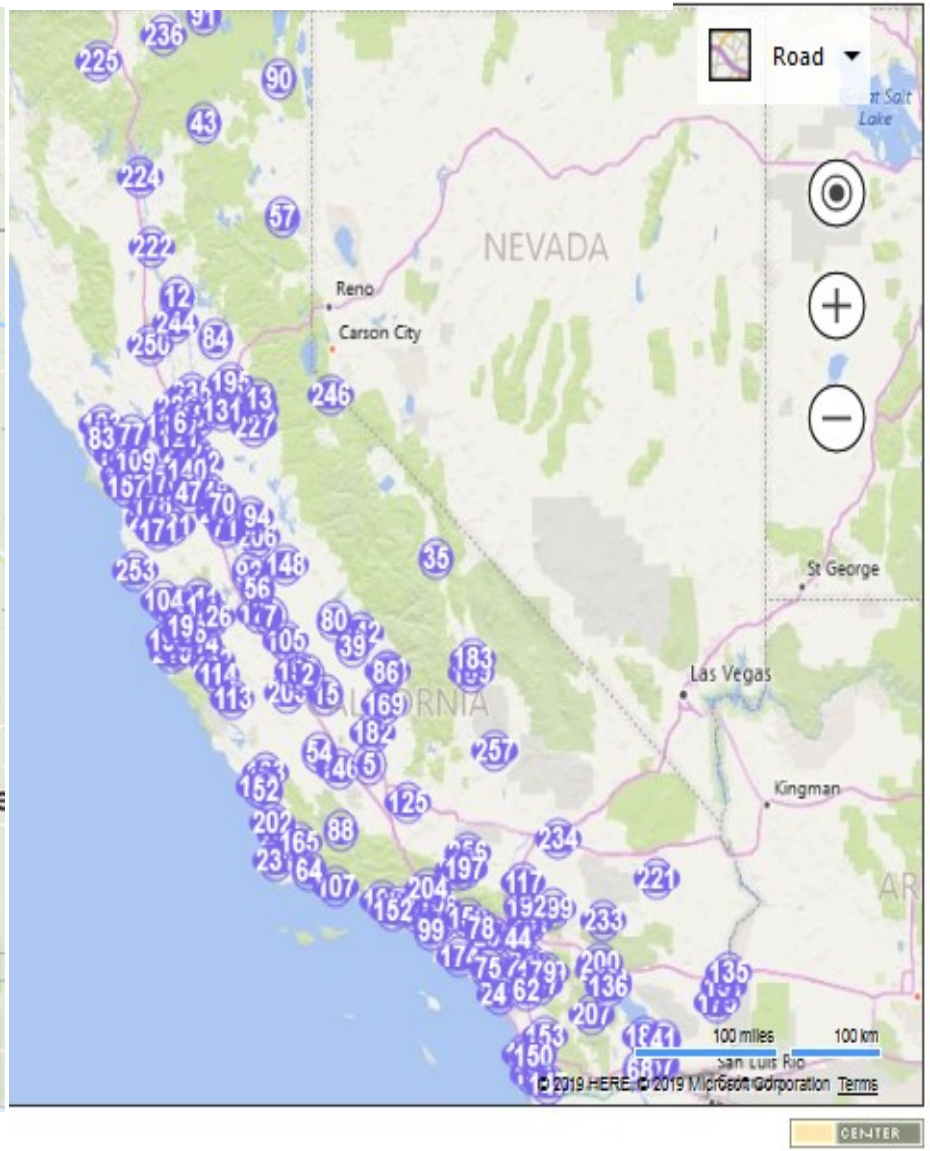
Water Budgeting – "Bucket model"



Δ Storage = P + Irr - ET - Runoff - Infiltration

Agricultural Weather Networks

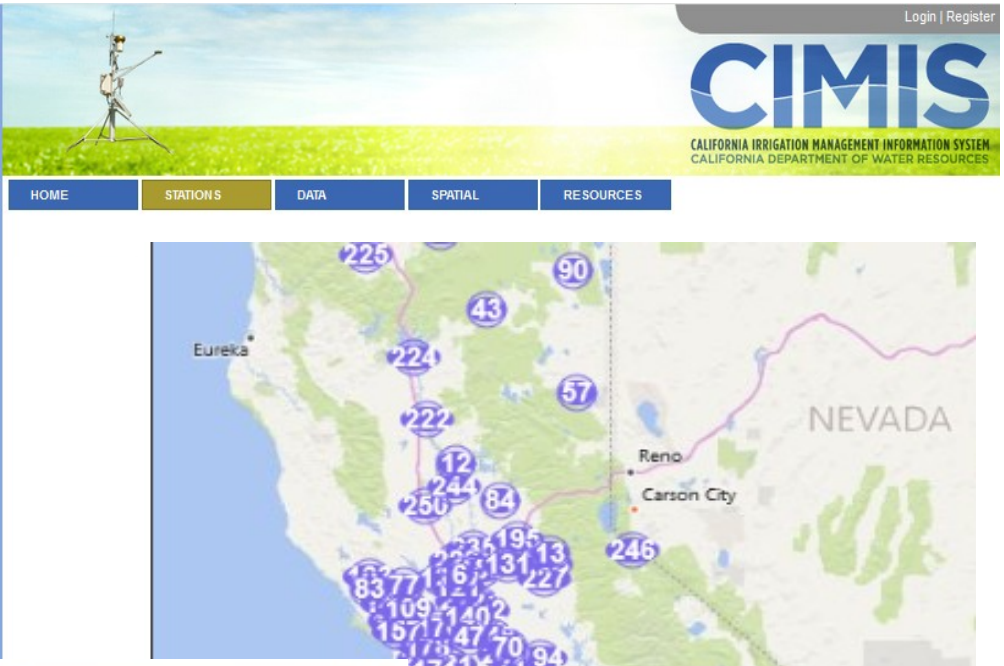


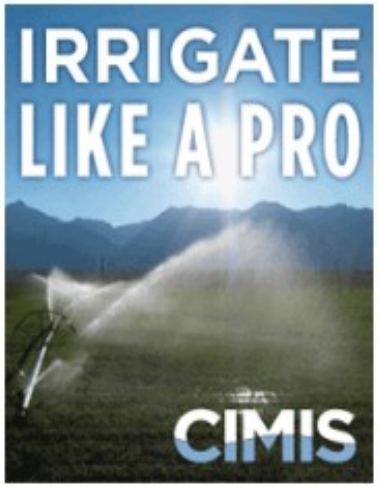


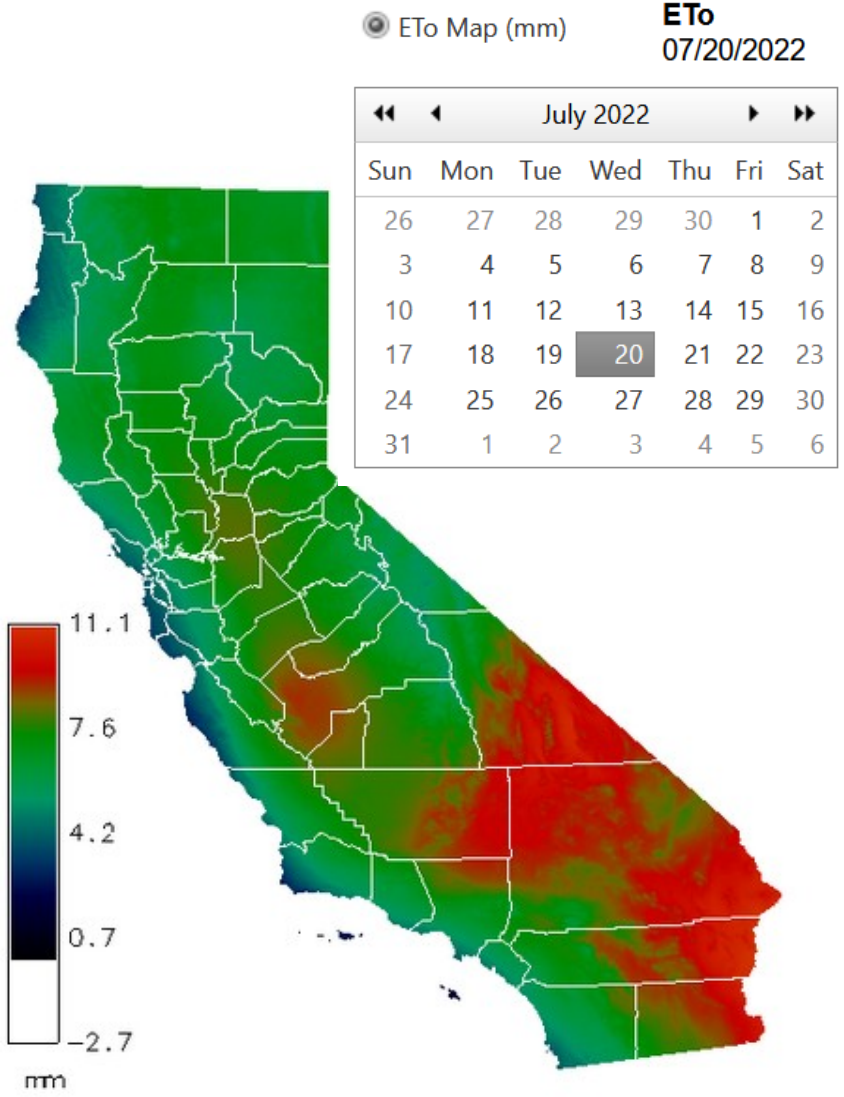
AGRIMET – Bureau of Reclamation
http://www.usbr.gov/pn/agrimet/

CIMIS – CA Dept.Water Resources
https://cimis.water.ca.gov/

Efficient irrigation scheduling requires knowing how much water crops need to grow







https://cimis.water.ca.gov/

Penman Monteith → Reference ET

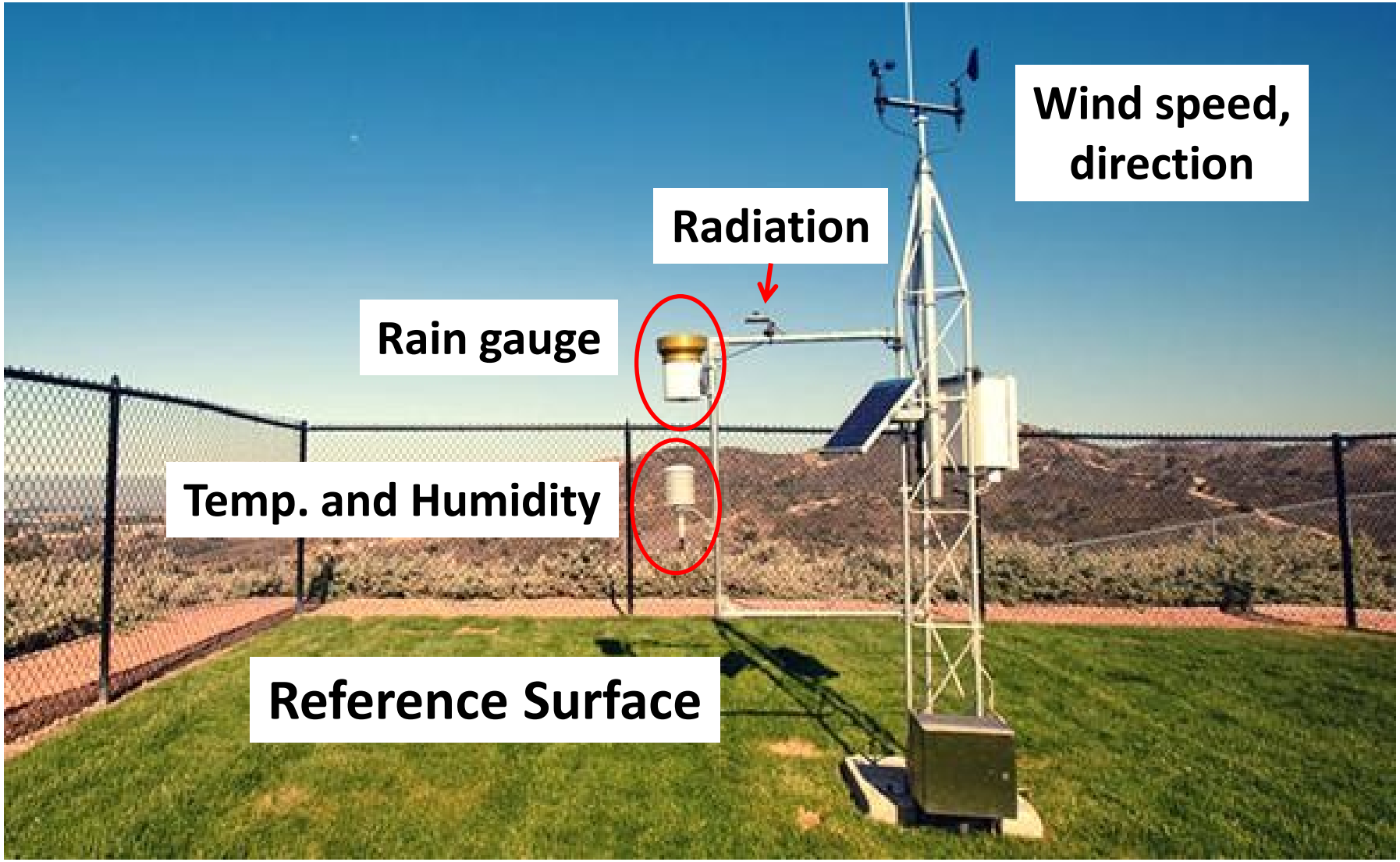


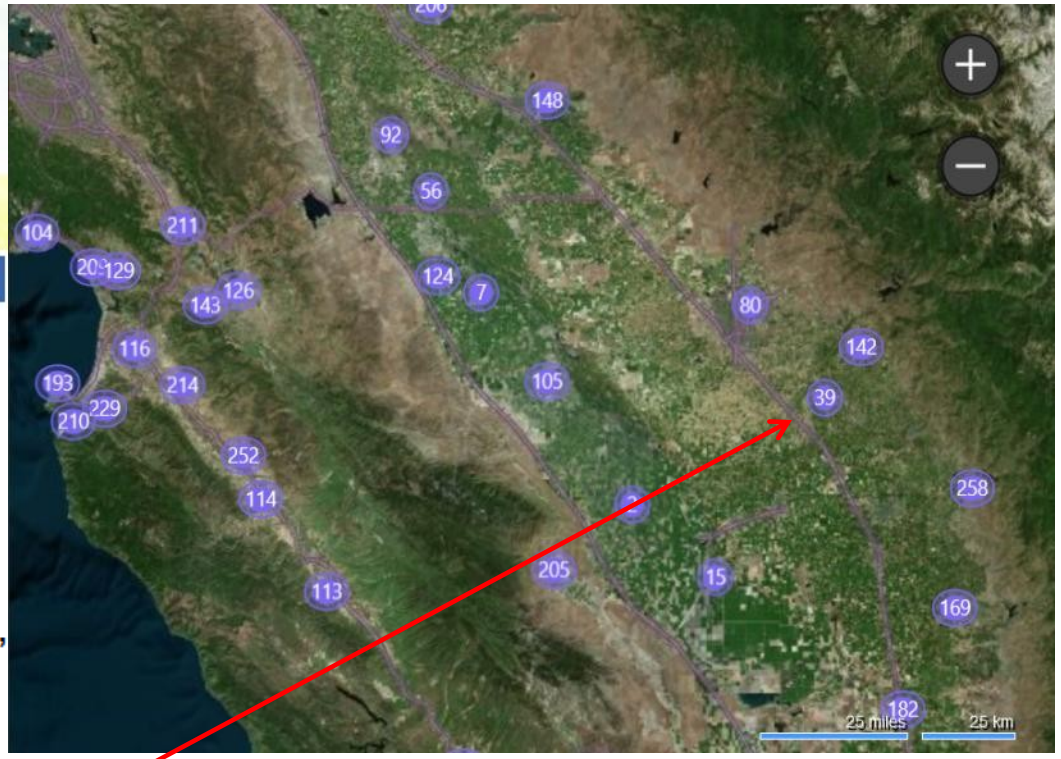
Photo courtesy Irvine Ranch Water District, irwd.com, Accessed Jan2017

Login | Register

CIMIS

CALIFORNIA IRRIGATION MANAGEMENT INFORMATION SYSTEM
CALIFORNIA DEPARTMENT OF WATER RESOURCES

HOME | STATIONS | DATA | SPATIAL | RESOURCES



CIMIS Daily Report

Rendered in ENGLISH Units.
Monday, July 25, 2022 - Sunday, July 31,
Printed on Monday, August 1, 2022

Parlier - San Joaquin Valley - Station 39

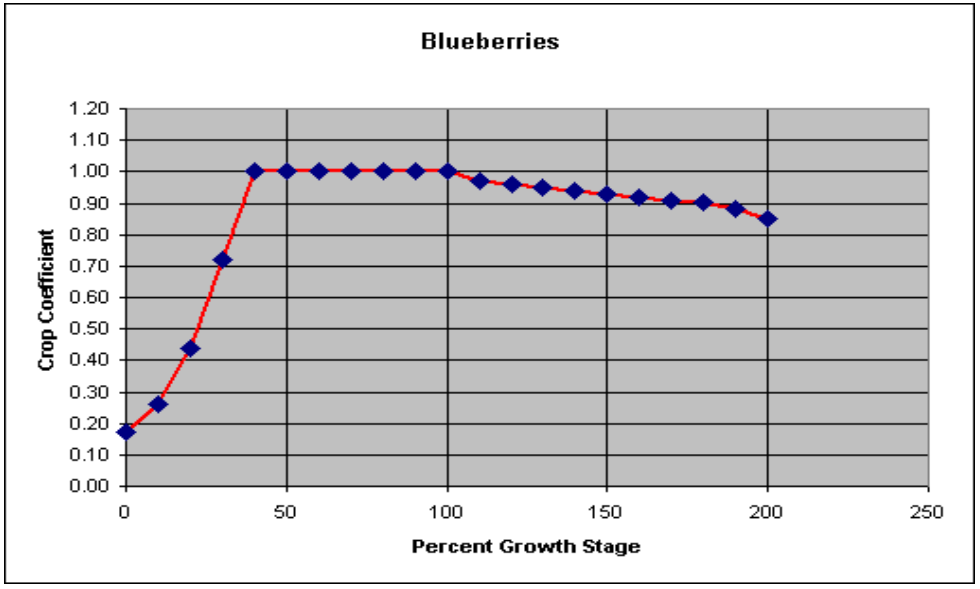
Date	ETo (in)	Precip (in)	Sol Rad (Ly/day)	Avg Vap Pres (mBars)	Max Air Temp (°F)	Min Air Temp (°F)	Avg Air Temp (°F)	Max Rel Hum (%)
7/25/2022	0.28	0.00	676	16.1	100.5	62.9	81.6	84
7/26/2022	0.28	0.00	647	15.7	100.6	65.3	82.9	79
7/27/2022	0.29	0.00	642	14.4	99.1	64.6	82.2	76
7/28/2022	0.27	0.00	605	14.4	100.4	67.5	83.5	73
7/29/2022	0.27	0.00	658	17.9	101.2	66.7	84.7	82
7/30/2022	0.26 H	0.00	606	-- S	101.0	73.3 Y	86.2	72 H
7/31/2022	0.26 H	0.00	476	-- S	99.4	74.2 Y	85.1	69 H
Tots/Avgs	1.91	0.00	616	15.7	100.3	67.8	83.7	76

https://cimis.water.ca.gov/

Crop Coefficients - Applying ET_{ref}

Data from local Agrimet Station

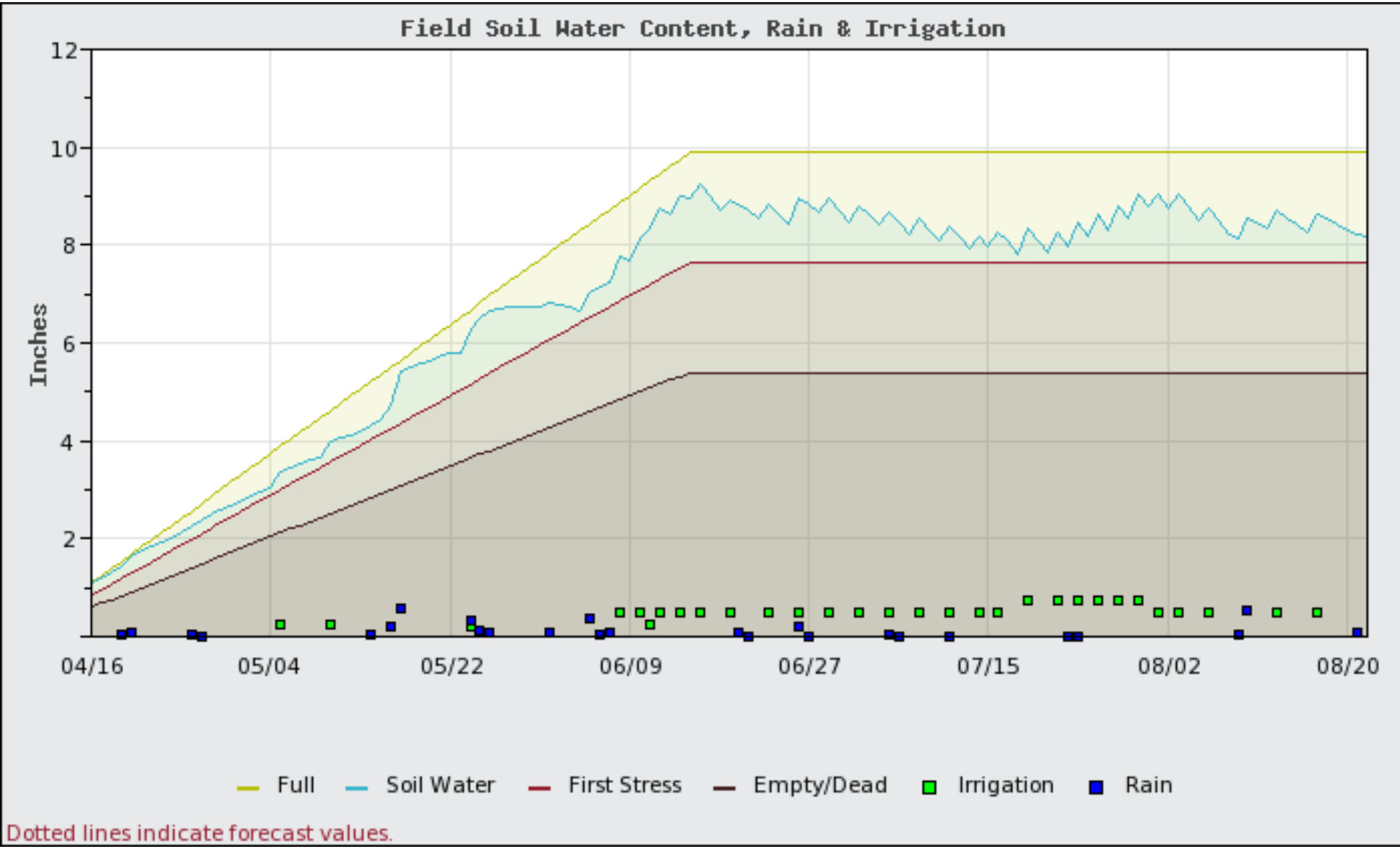
DATE	ET Kimb-Penman (in)	ET - ASCE (in)	Air Temp (F)	Precip. (in)	Rnet (langleys)	Rel Humidity	Wind Speed (mph)
5/1/2016	0.28	0.23	64.31	0	657.94	57.39	9.73
5/2/2016	0.21	0.18	64.57	0	575.63	60.56	2.9
5/3/2016	0.14	0.11	59	0	417.86	79.26	2.3
5/4/2016	0.1	0.08	56.3	0.04	240.86	84.45	6.48
5/5/2016	0.21	0.16	58.36	0.01	616.61	75.45	5.87



Growth (%)	Crop Coefficient	Growth Stage Indicators
0	0.17	First Leave Opens
10	0.26	
20	0.44	
30	0.72	
40	1.00	First Blue Fruit
...	...	...
90	1.00	
100	1.00	Fruit 100% Blue

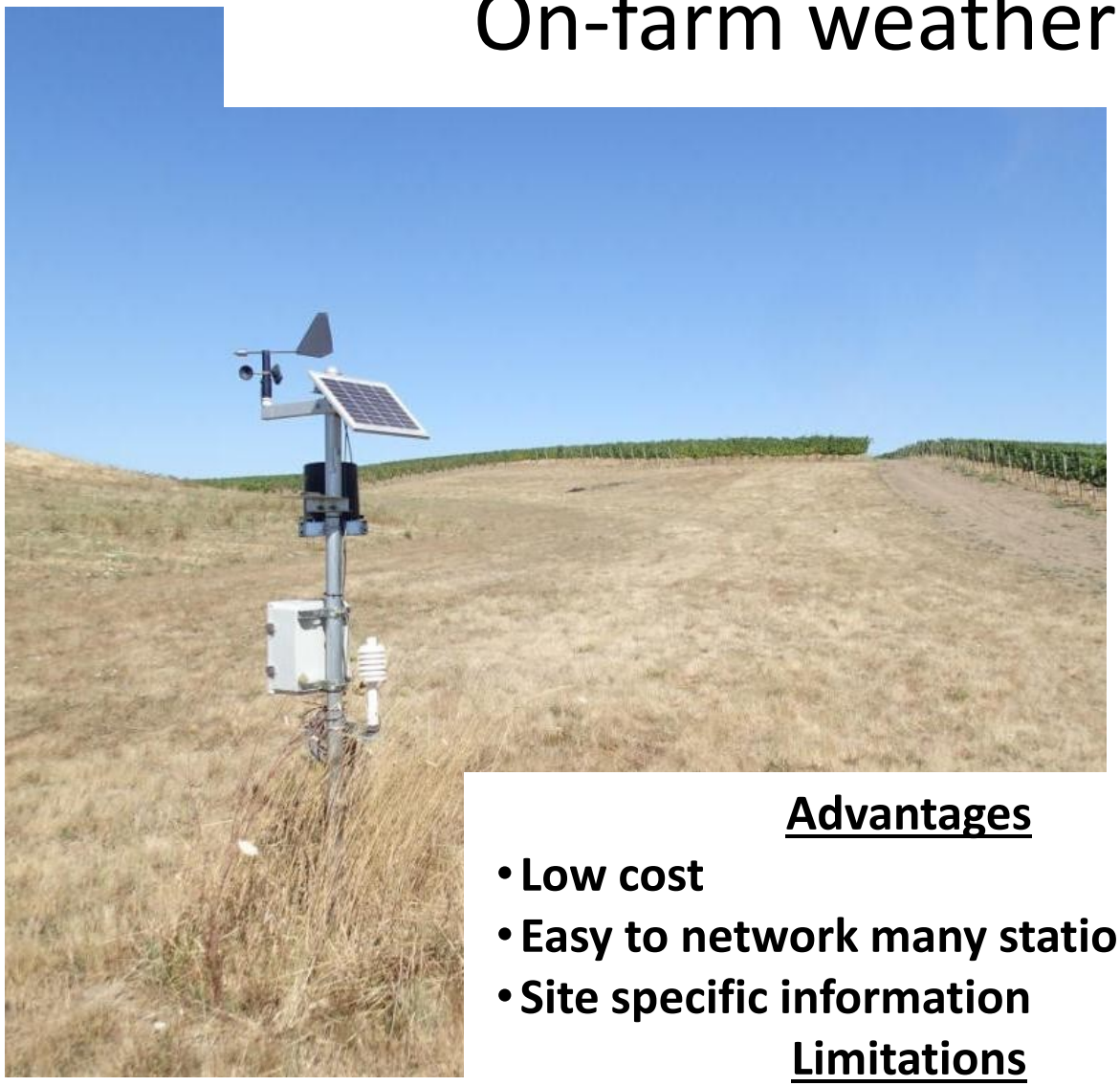
http://www.usbr.gov/pn/agrimet/, Accessed Jan 2017

ET + Soil water budget = irrigation schedule



Irrigation Scheduler Software (online) http://weather.wsu.edu/, Accessed Jan 2019

On-farm weather stations



Advantages

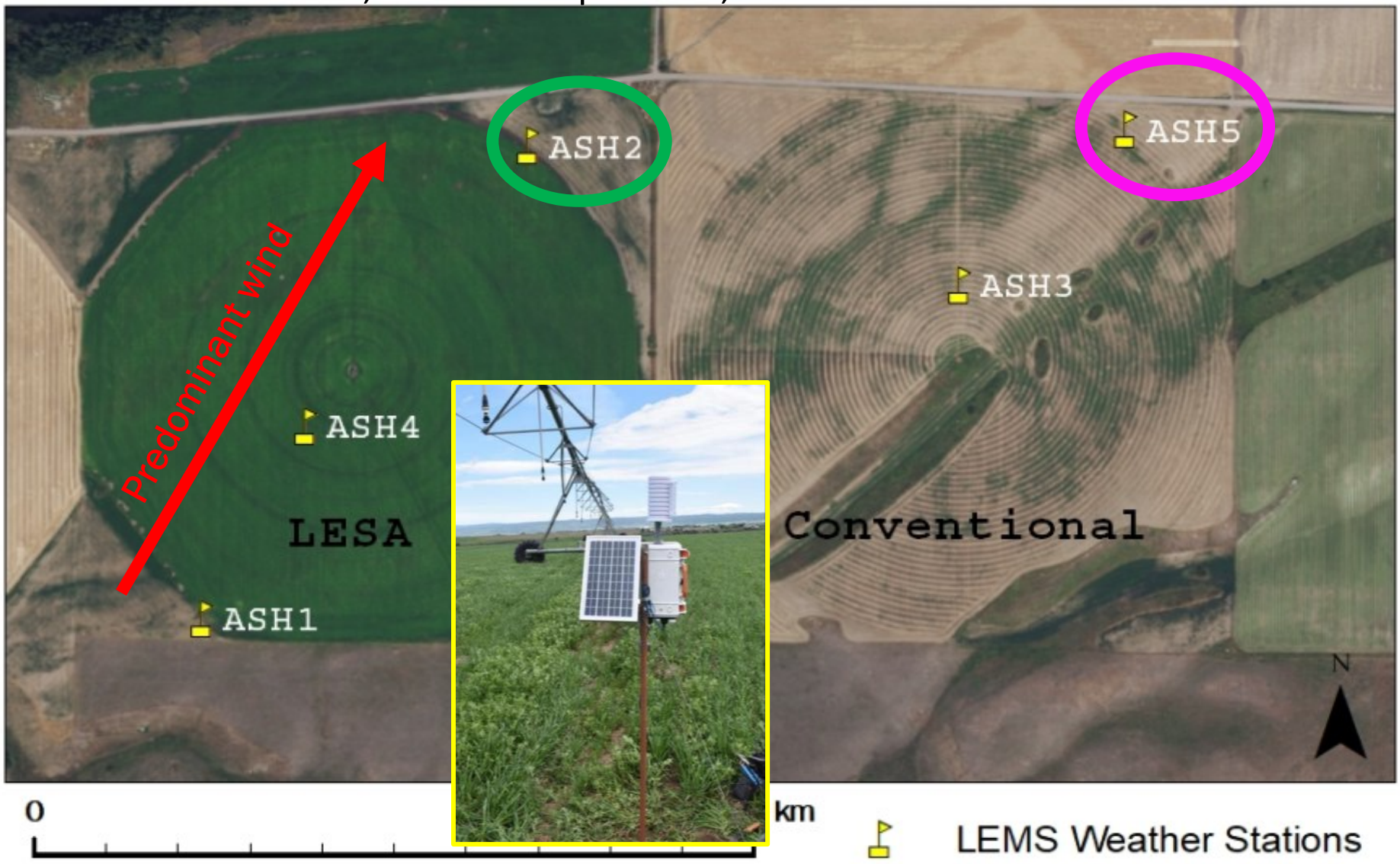
- **Low cost**
- **Easy to network many stations**
- **Site specific information**

Limitations

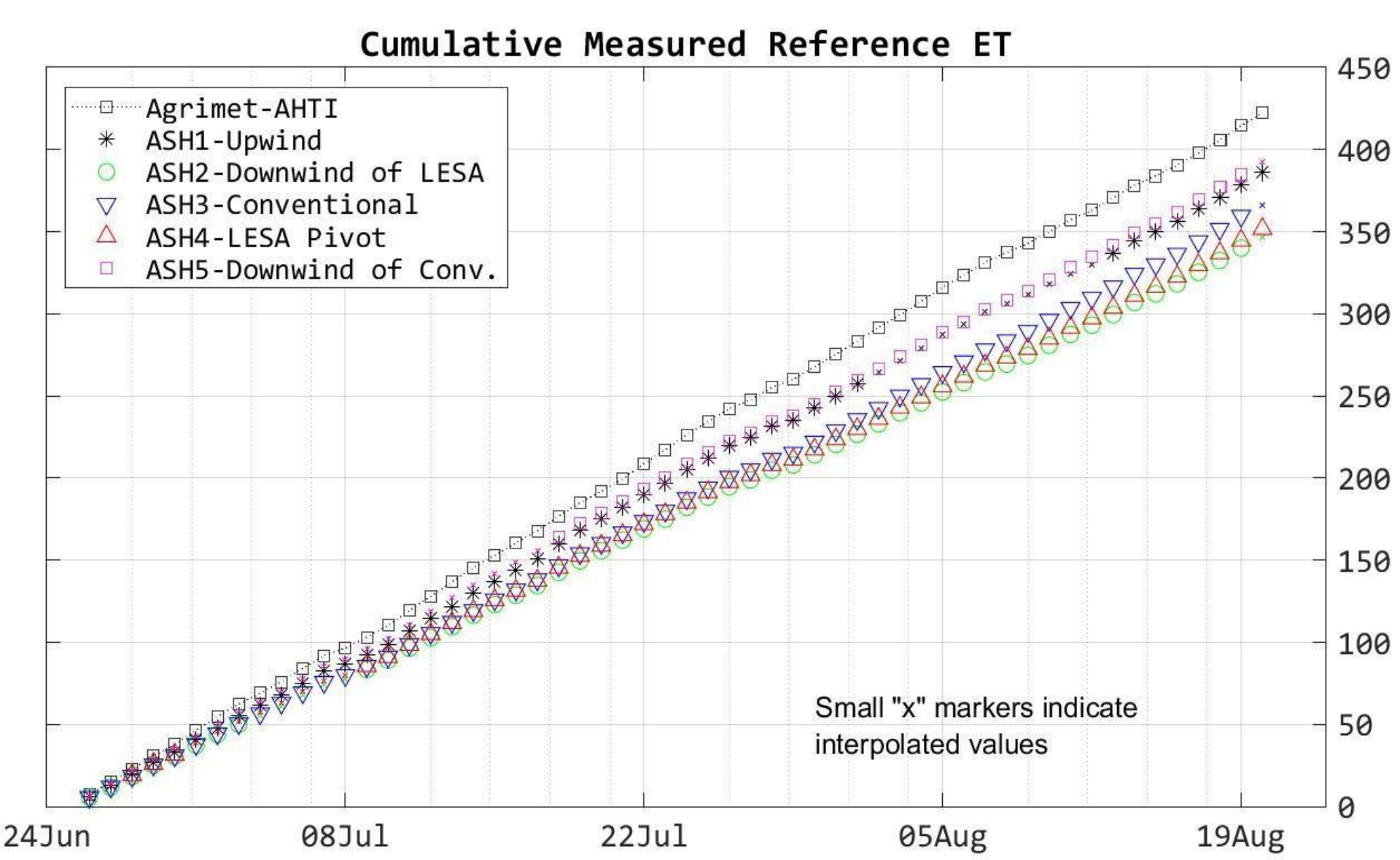
- **Often low quality sensors**
- **Difficult to maintain**
- **Raw data is not useful information**

Weather and soil sensors at 5 stations in two adjacent center pivots w/ LESA & MESA

Measured Reference ET, surface temperature, soil water content



McCauley, D.M., Nackley, L.L., Kelley, J., 2021. Demonstration of a low-cost and open-source platform for on-farm monitoring and decision support. Computers and Electronics in Agriculture 187, 106284. https://doi.org/10.1016/j.compag.2021.106284



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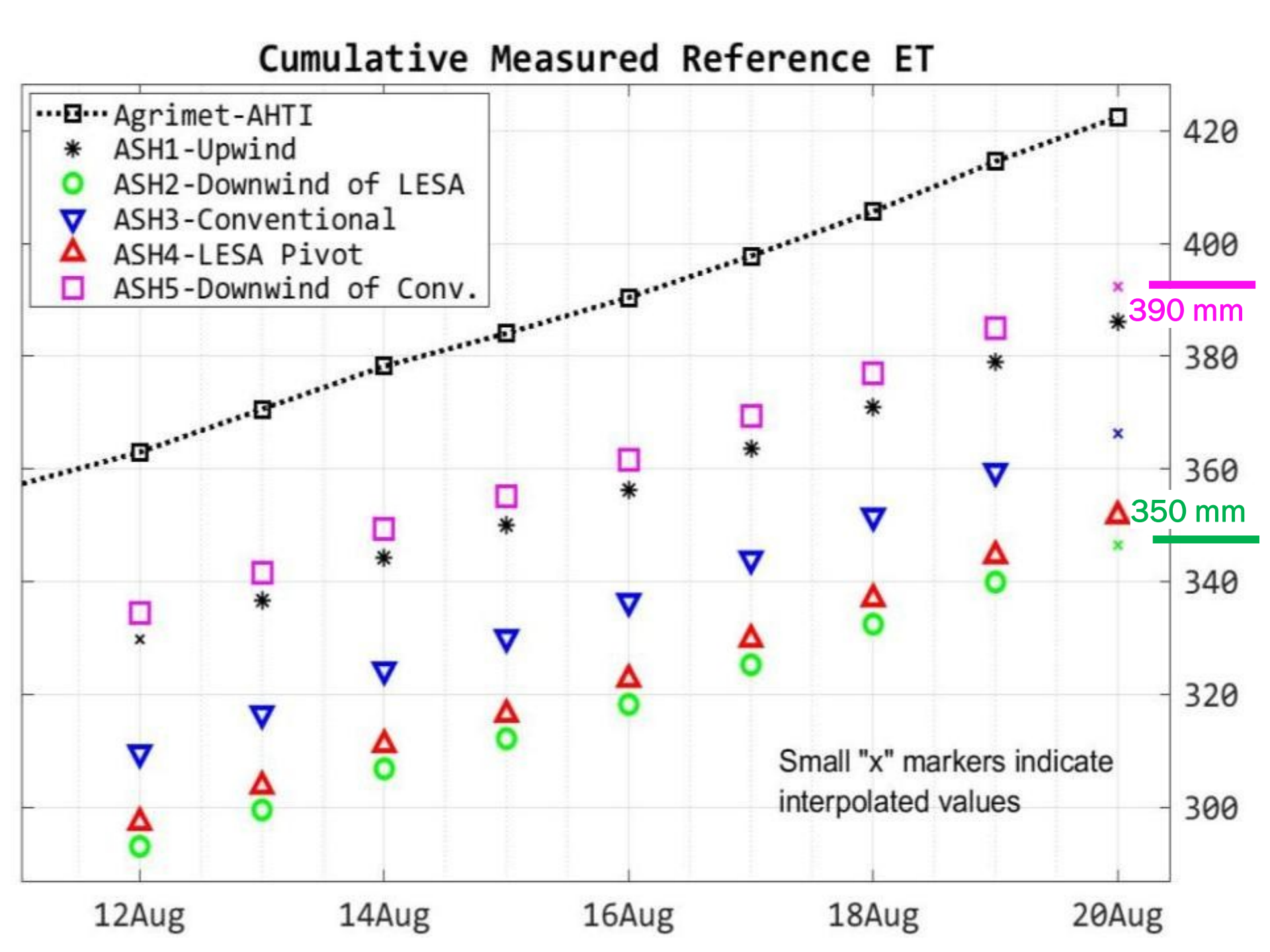
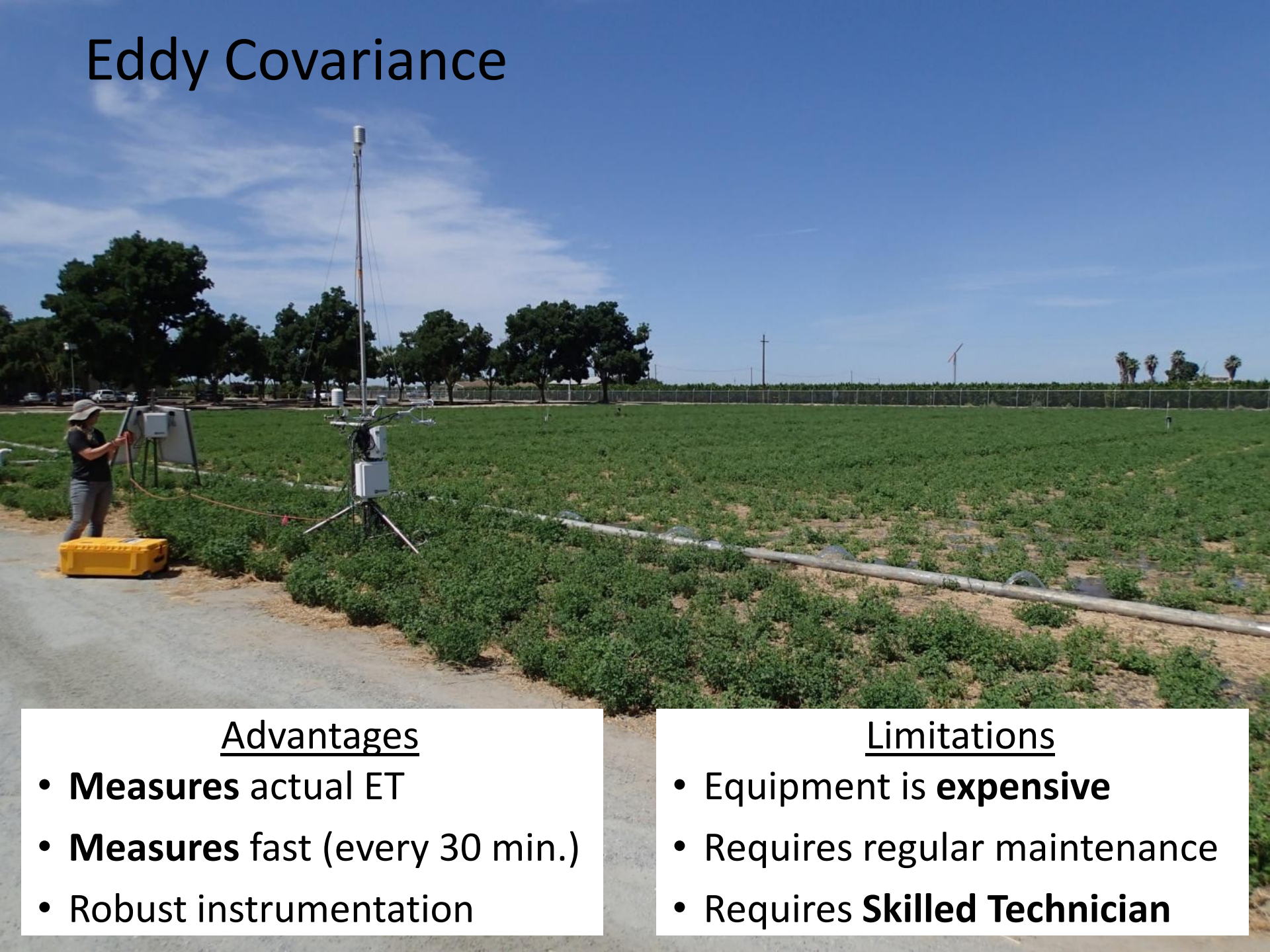

Cumulative Measured Reference ET
Agrimet-AHTI
ASH1-Upwind
ASH2-Downwind of LESA
ASH3-Conventional
ASH4-LESA Pivot
ASH5-Downwind of Conv.
420
400
380
360
340
320
300
390 mm
350 mm
Small "x" markers indicate
interpolated values
12Aug
14Aug
16Aug
18Aug
20Aug

Eddy Covariance

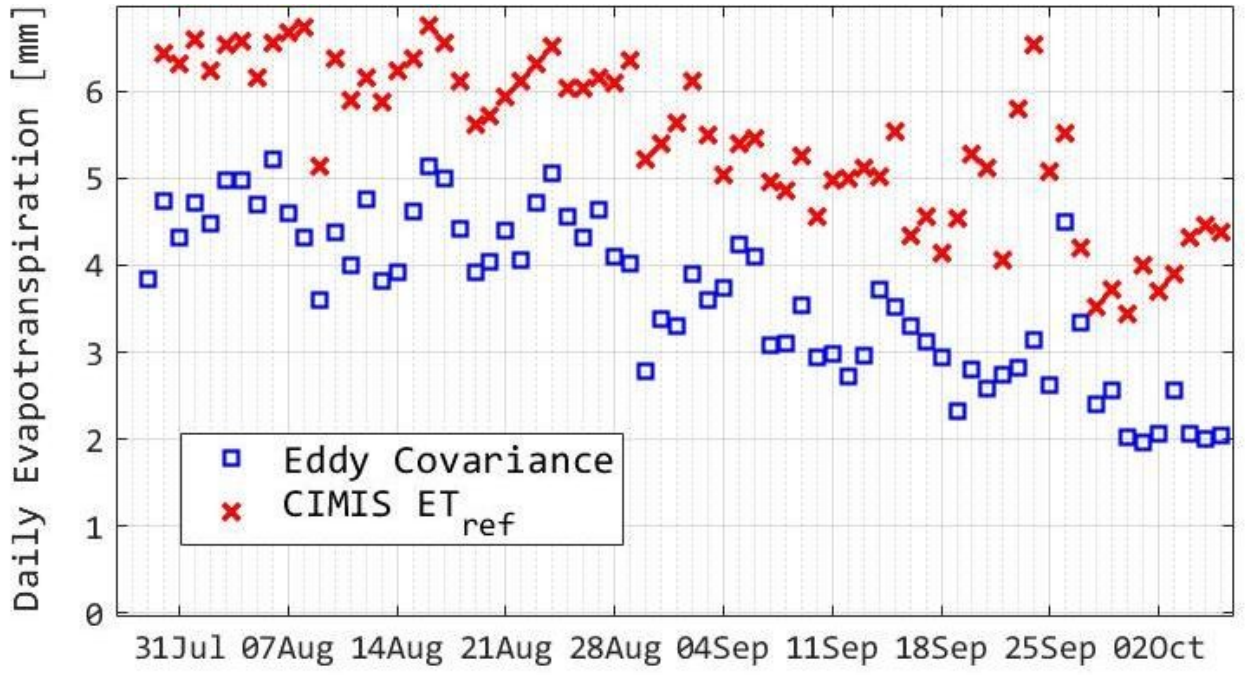


Advantages

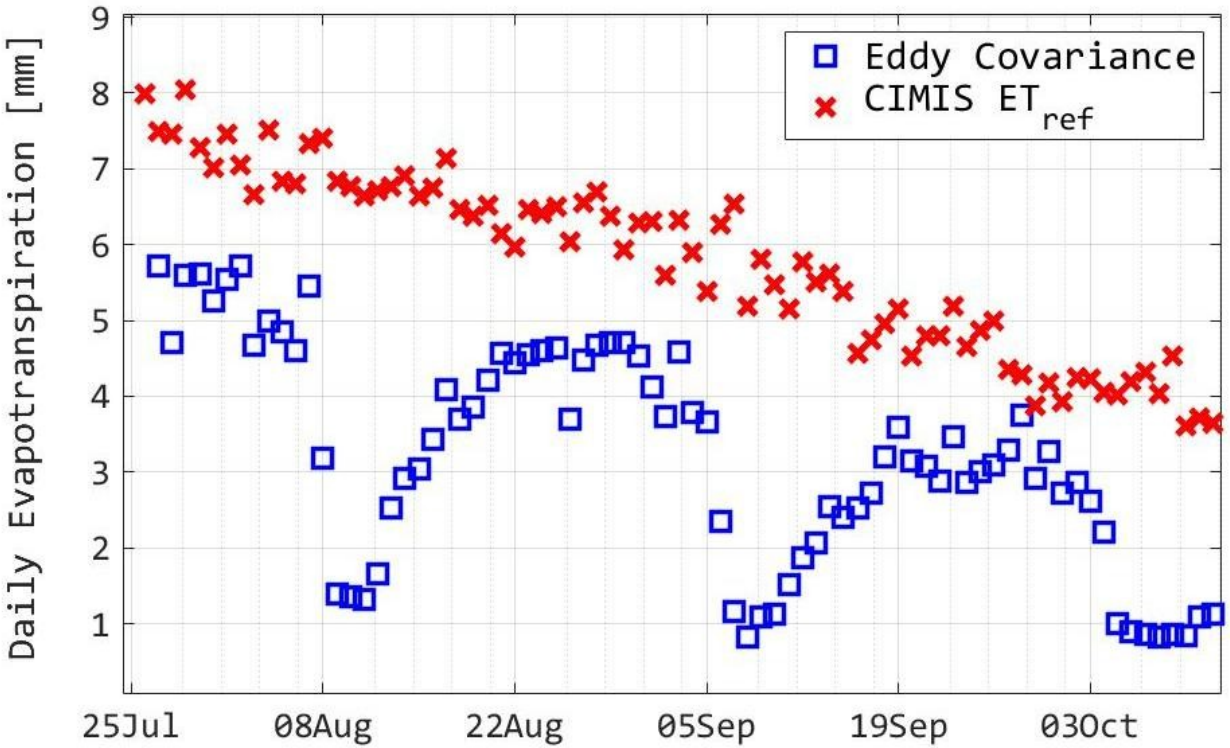
- **Measures** actual ET
- **Measures** fast (every 30 min.)
- Robust instrumentation

Limitations

- Equipment is **expensive**
- Requires regular maintenance
- Requires **Skilled Technician**

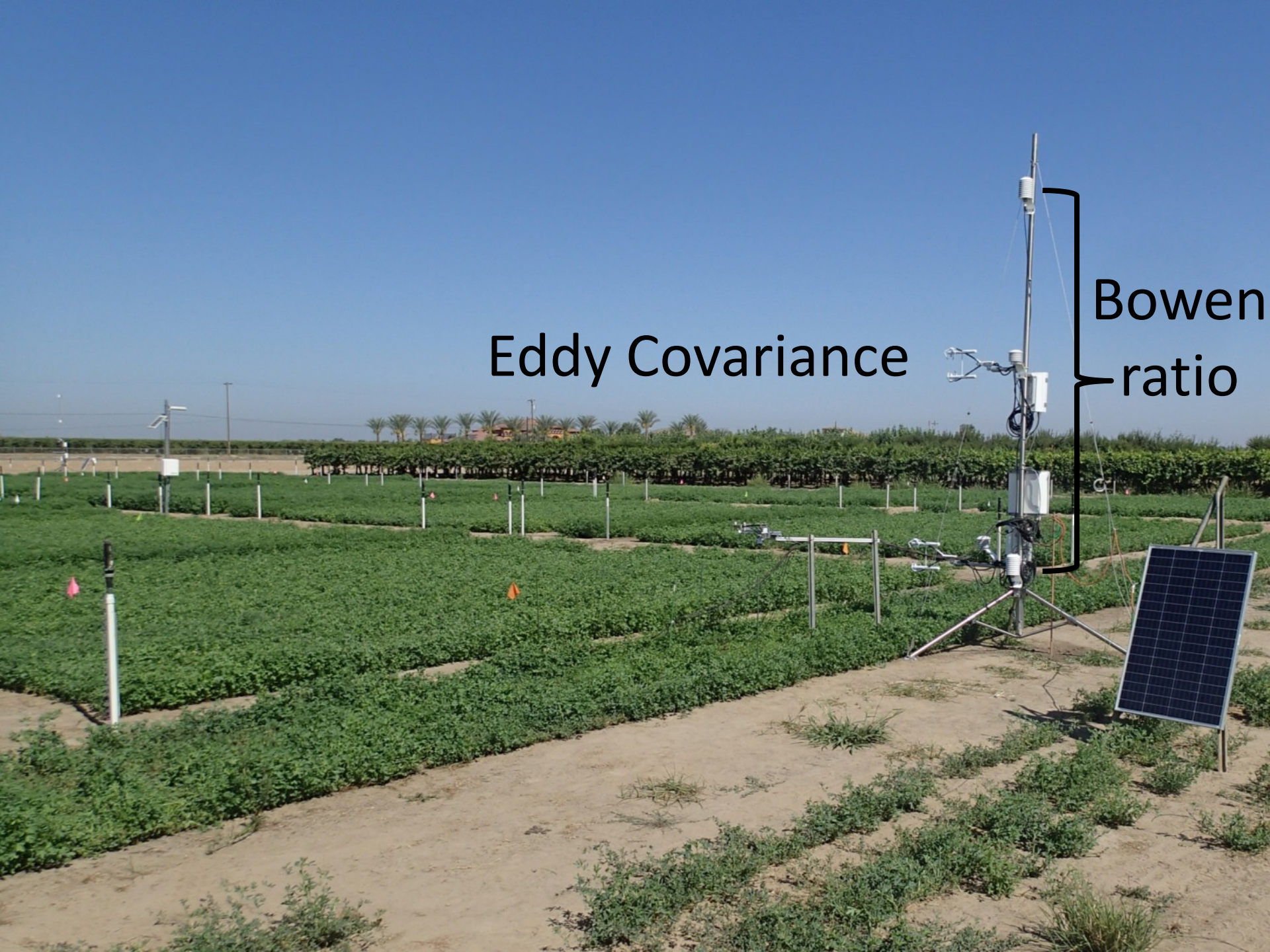


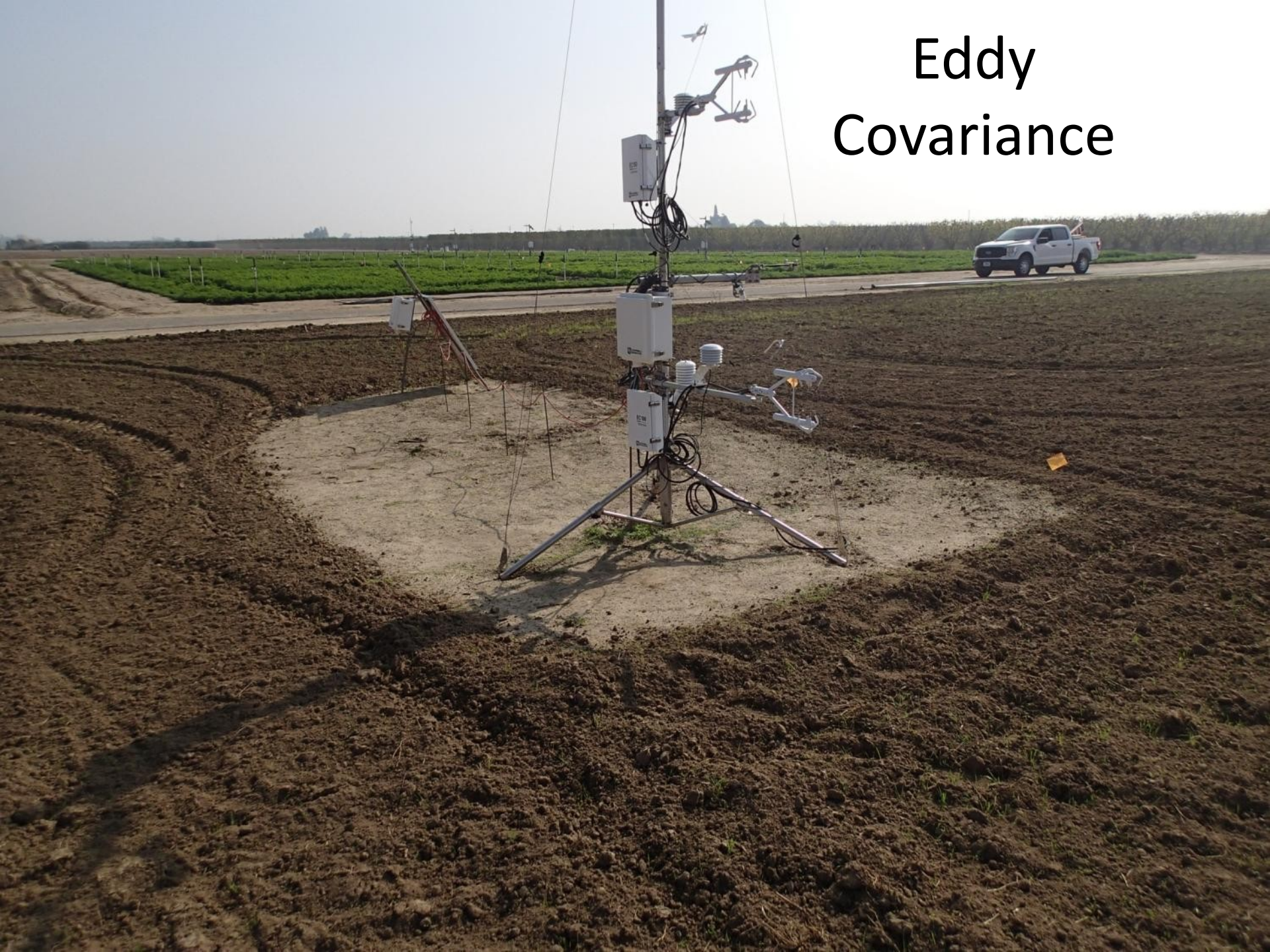
Irrigated Pasture



Irrigated Alfalfa

Kelley, J., McCauley, D., Alexander, A., Gray, W., Siegfried, R., Oldroyd, H.J., 2020. Using Machine Learning to Integrate On-Farm Sensors and Agro-Meteorology Networks into Site-Specific Decision Support. Transactions of the ASABE 63. https://doi.org/10.13031/trans.13917

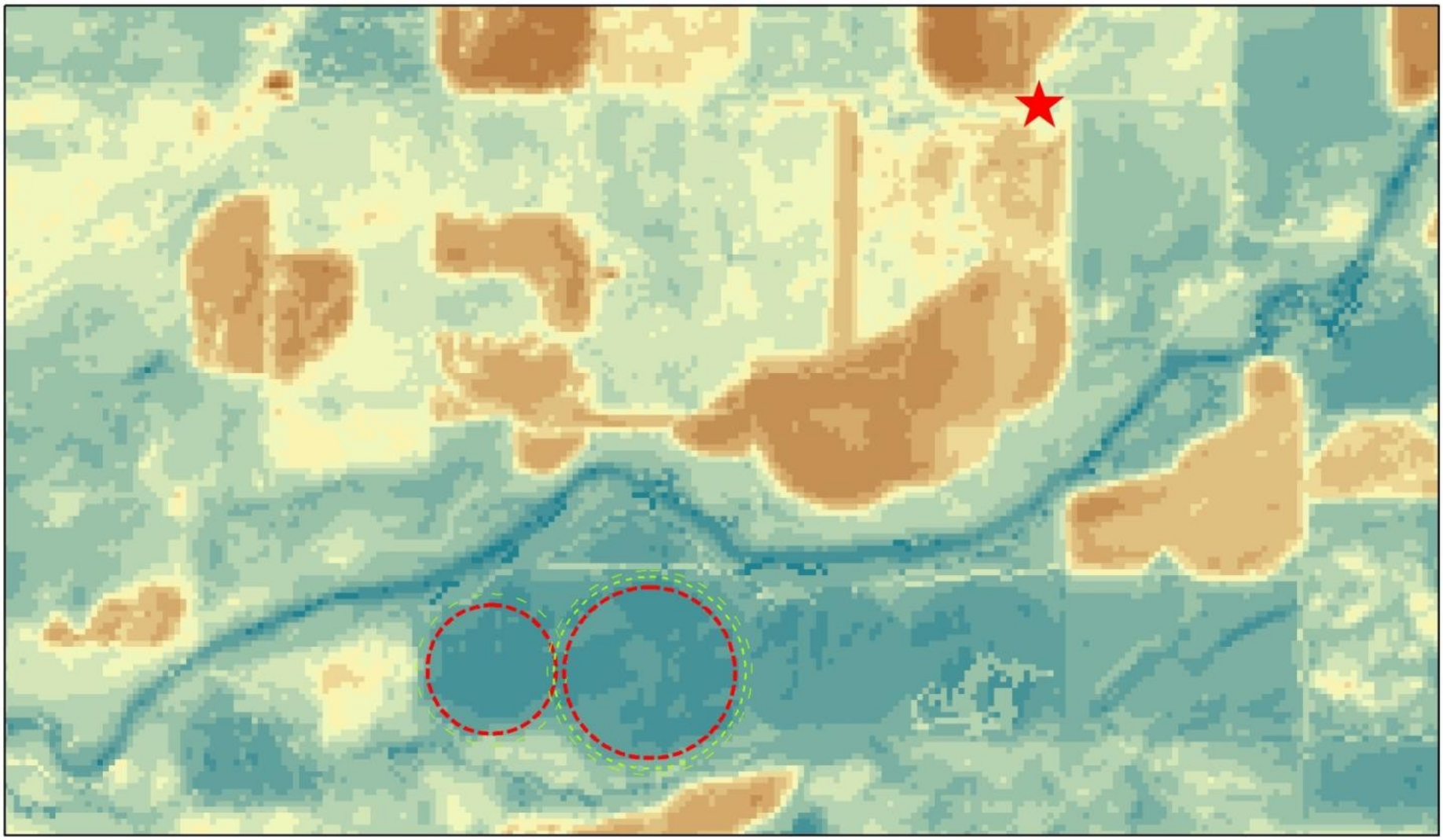

Eddy Covariance
Bowen
ratio


Eddy
Covariance

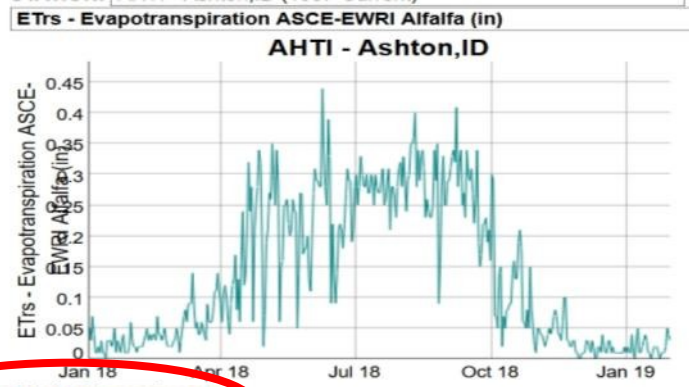
Evapotranspiration measured at Field 14SW [mm/day]

ET Fallow

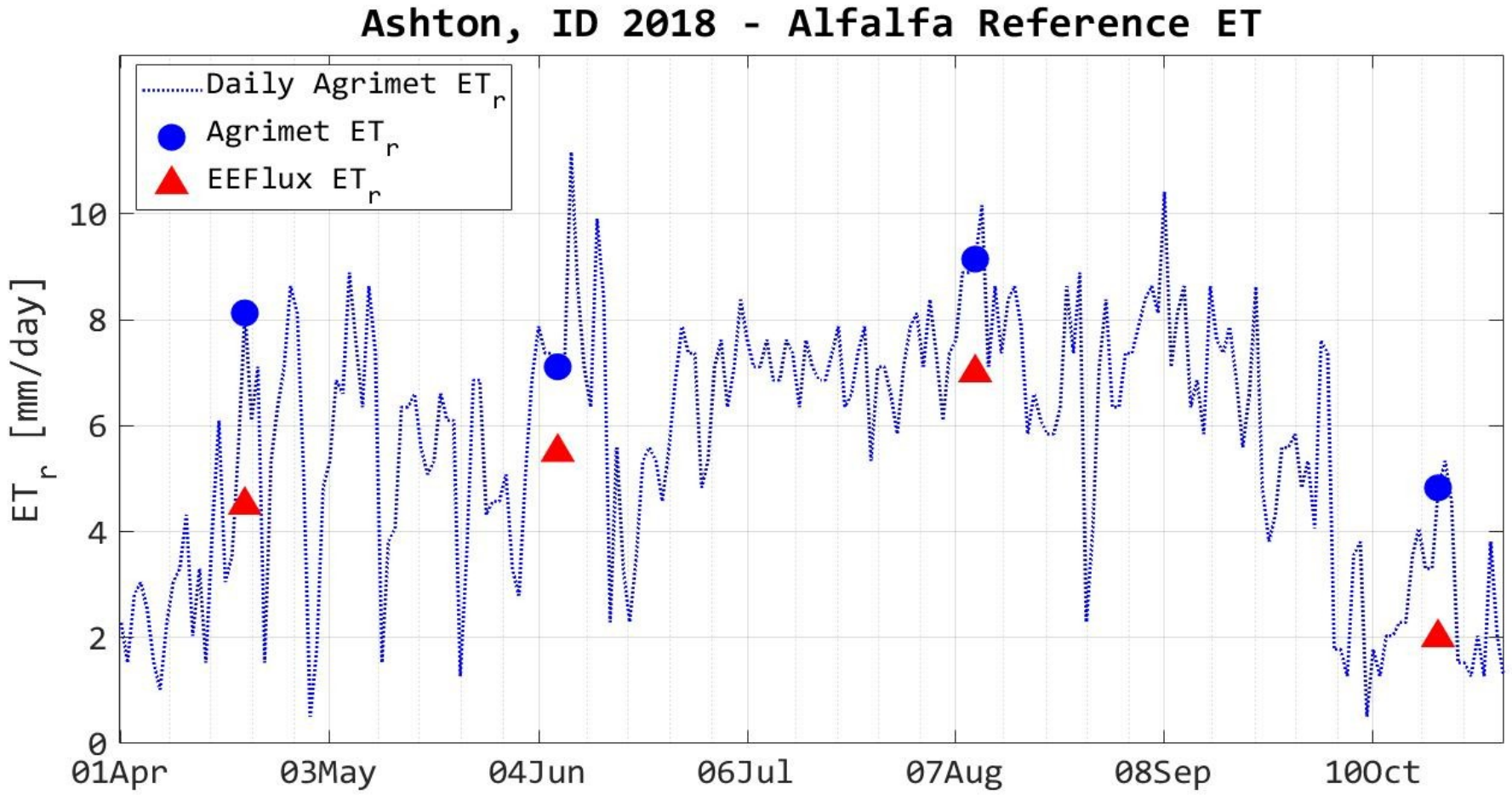
ET Alfalfa

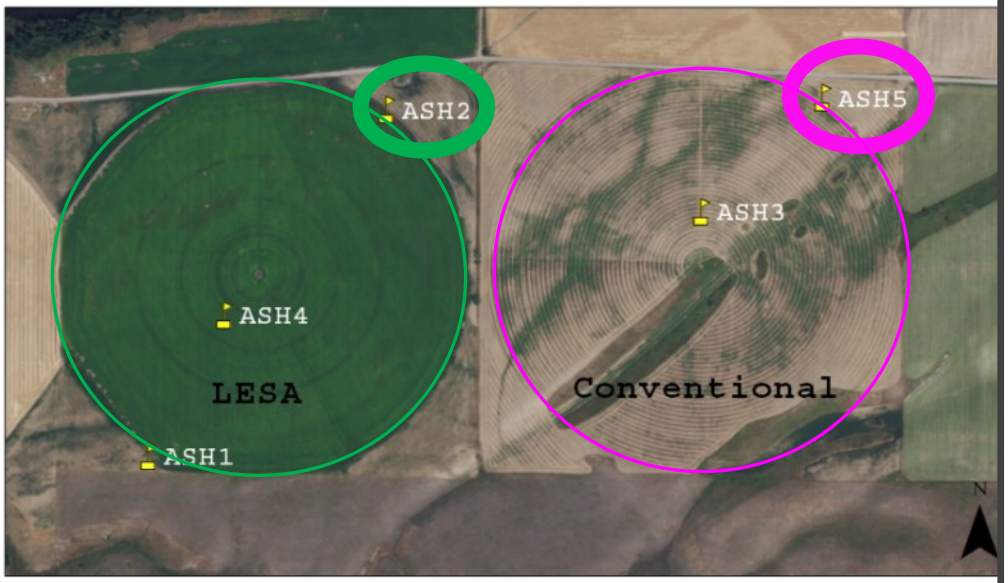

0
1
2
3 km
AHTI Agrimet Station
Actual ET [mm/day]
0
4.0
8.0
Actual Evapotranspiration (METRIC)
07 JUN 2018 - DOY158
LS8 - Path 38 Row 30 - Downloaded 09MAR2019
EEFlux Version 0.10.4 - jasonrk@uidaho.edu

Comparing ground measurement to images

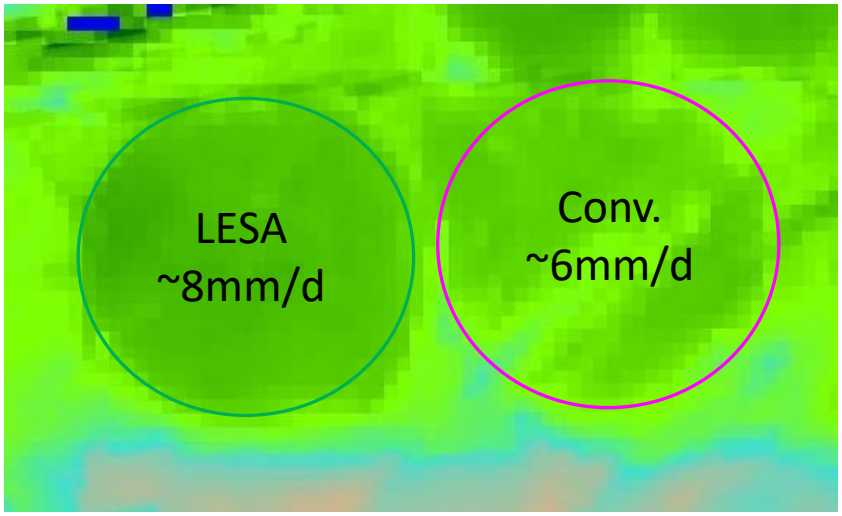


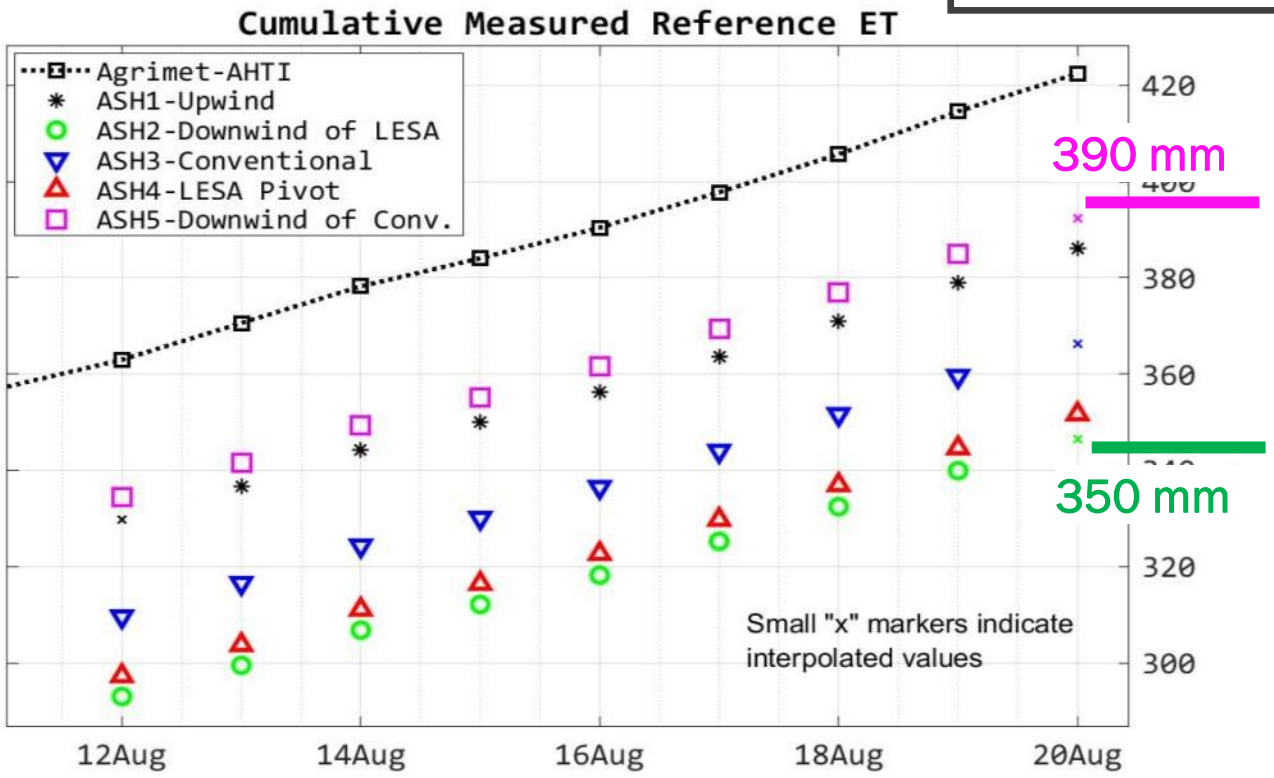
data in this graph





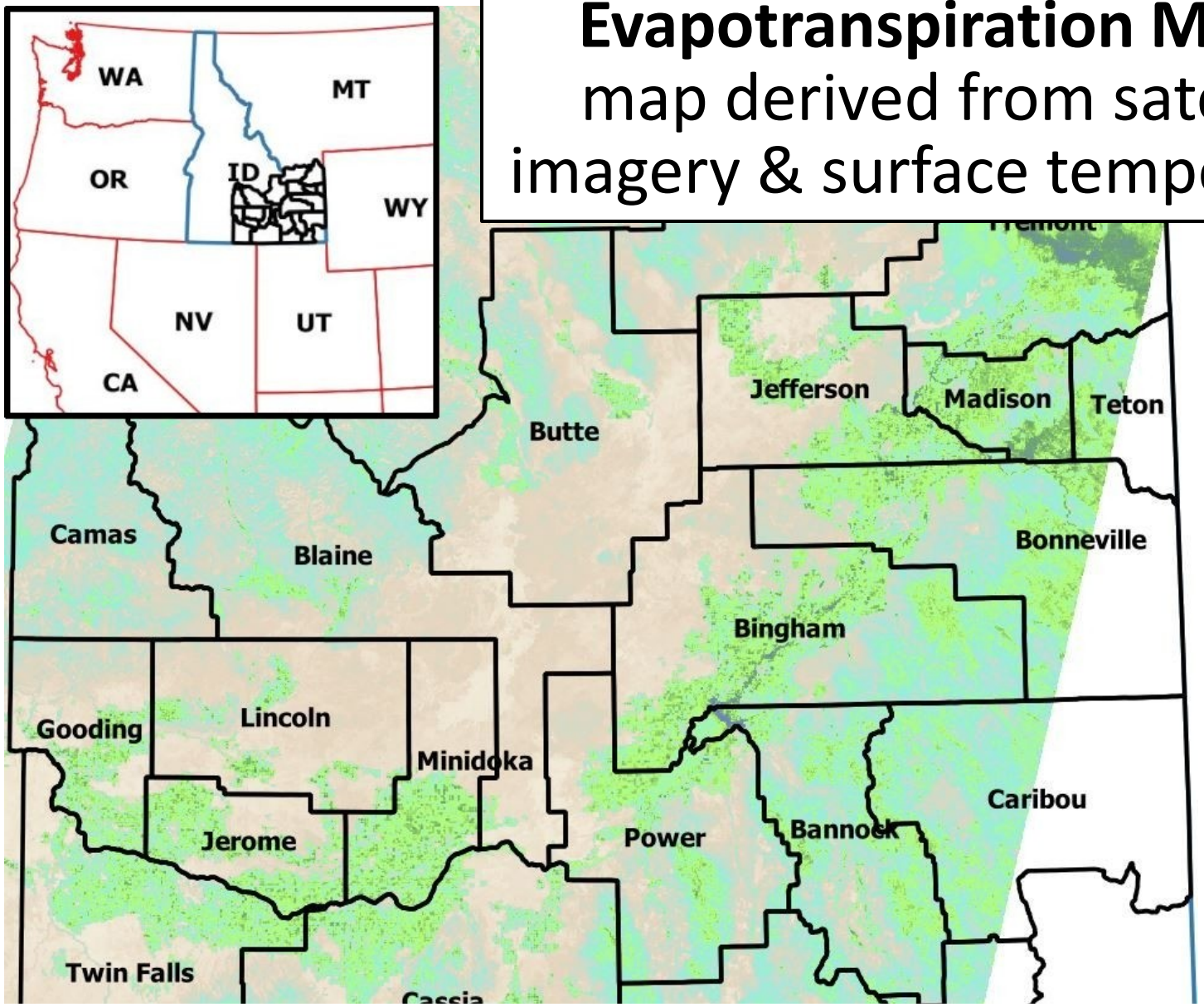
EEFlux/METRIC – Actual ET



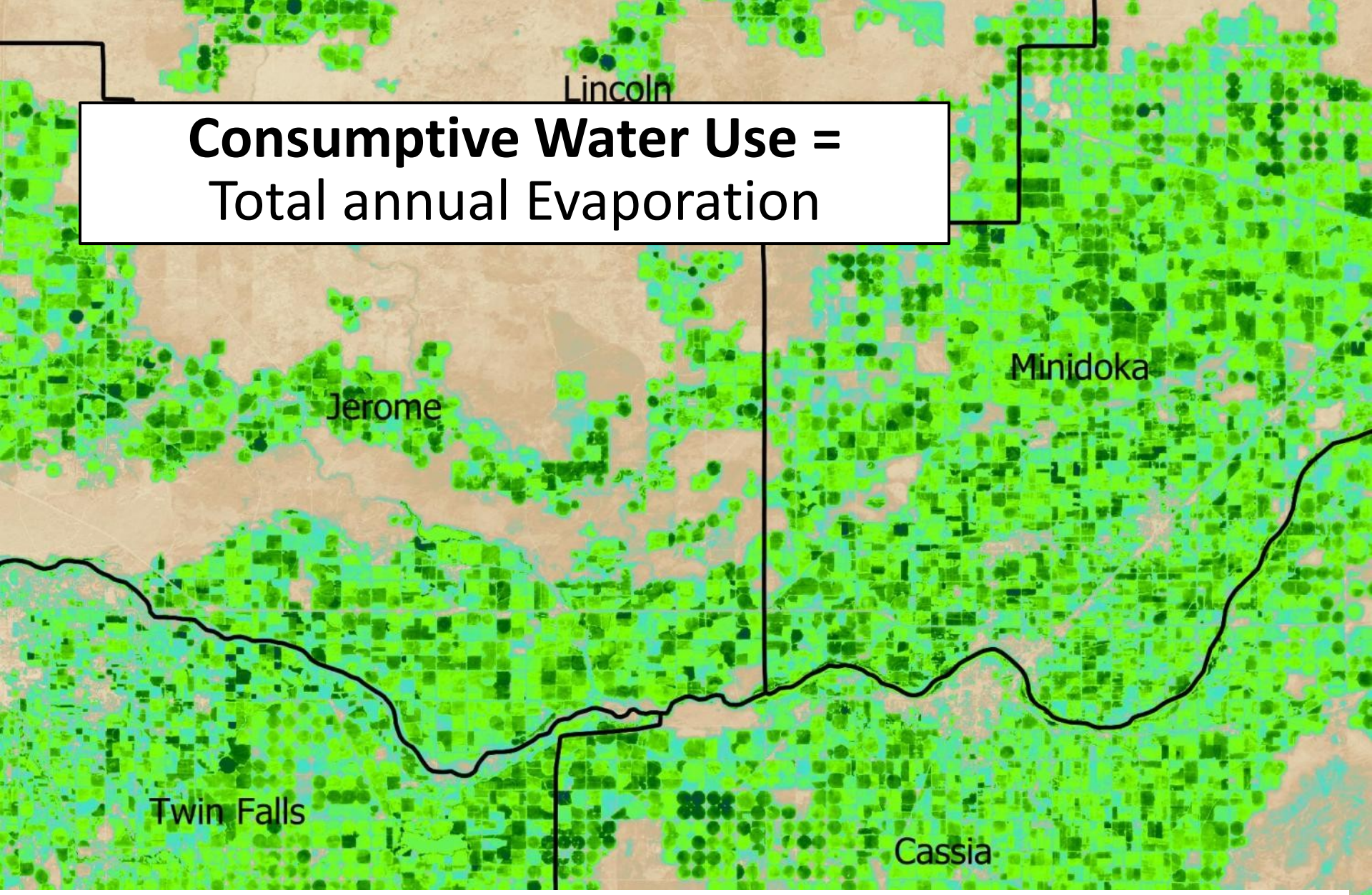


Evapotranspiration Model

map derived from satellite imagery & surface temperature



Kelley, J., Olson, B., 2022. Interannual variability of water productivity on the Eastern Snake Plain in Idaho, United States. Agricultural Water Management 265, 107532. https://doi.org/10.1016/j.agwat.2022.107532



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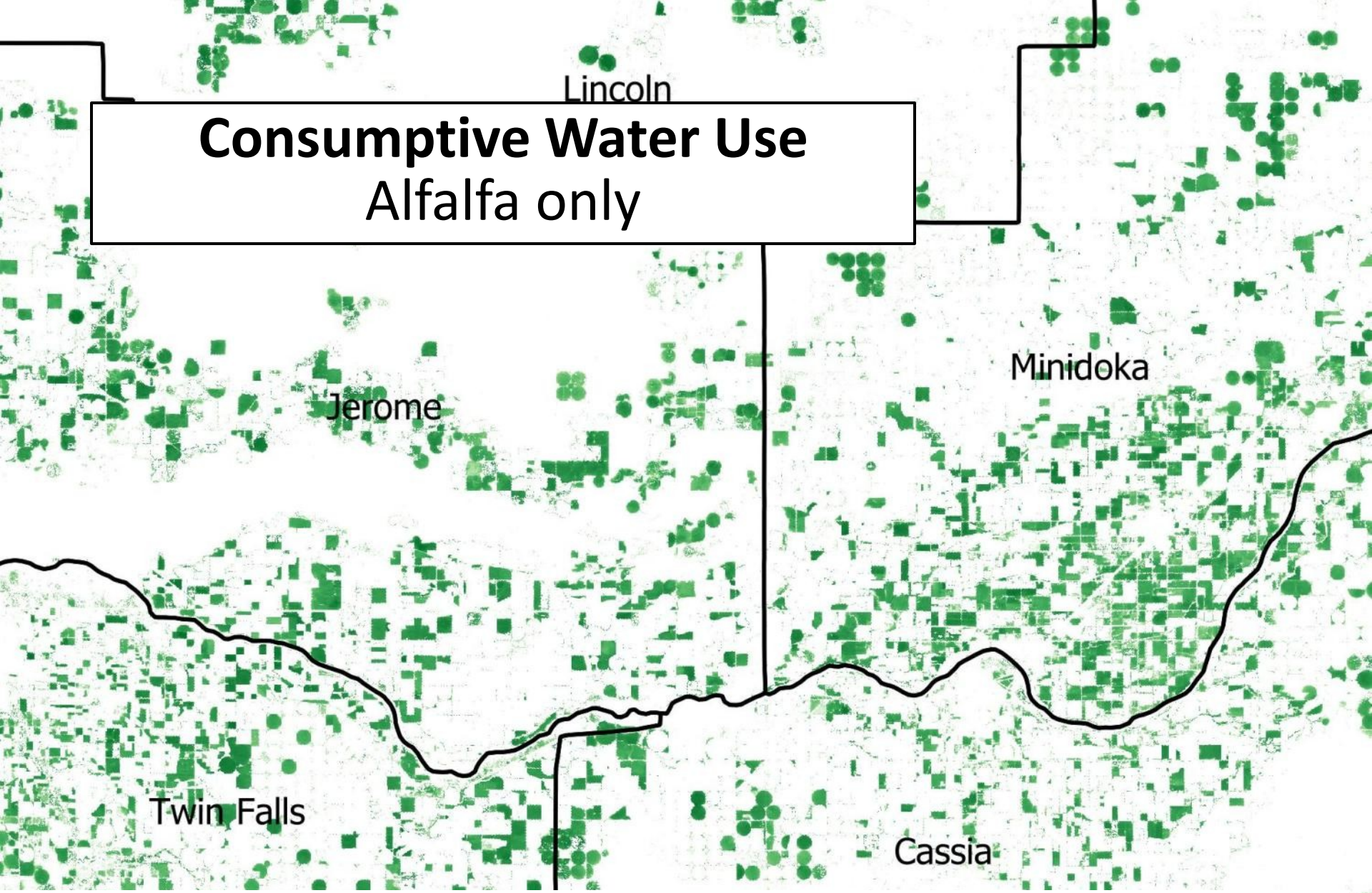

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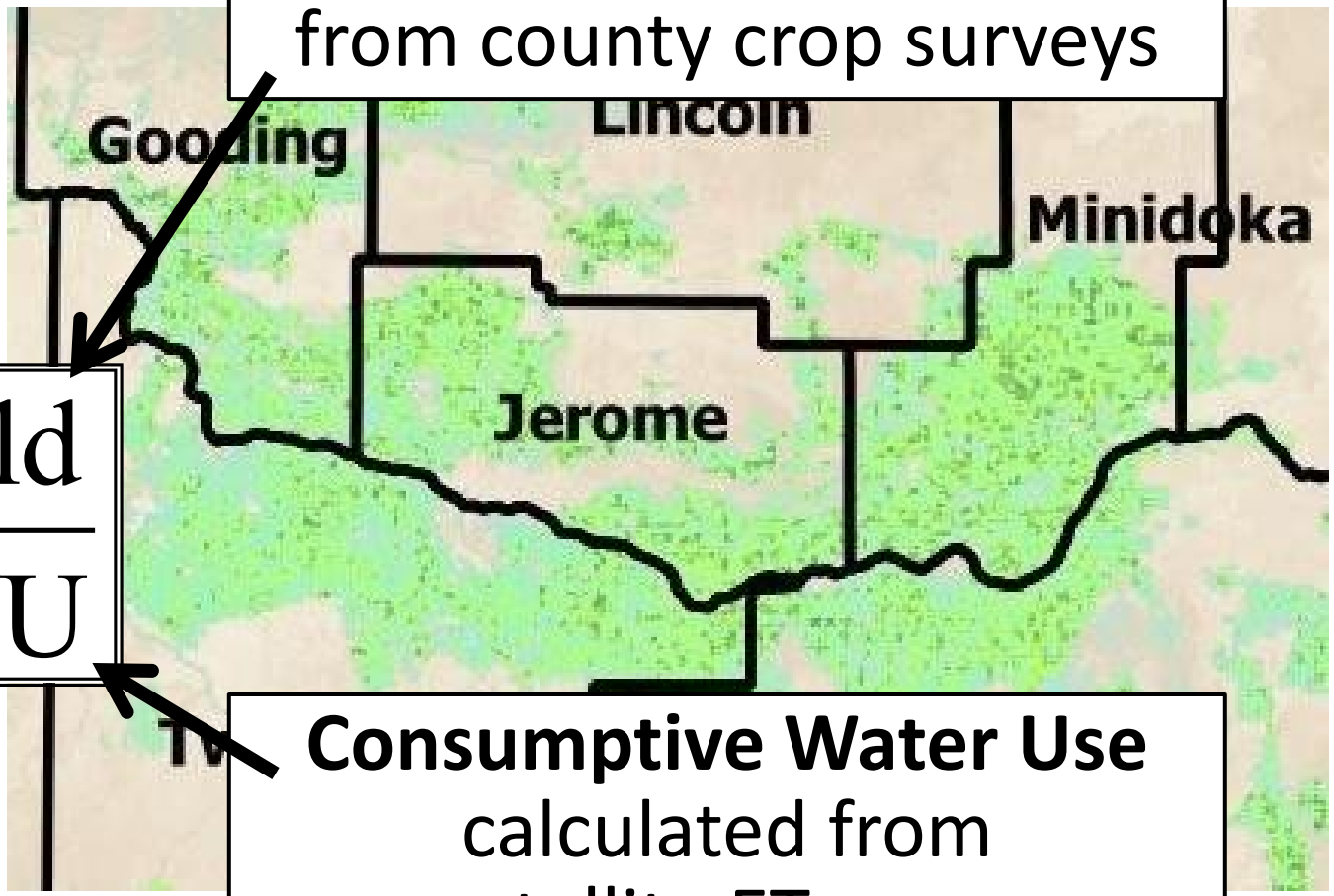
Water Productivity "Crop per drop"

Yield
from county crop surveys

Water Productivity Metric

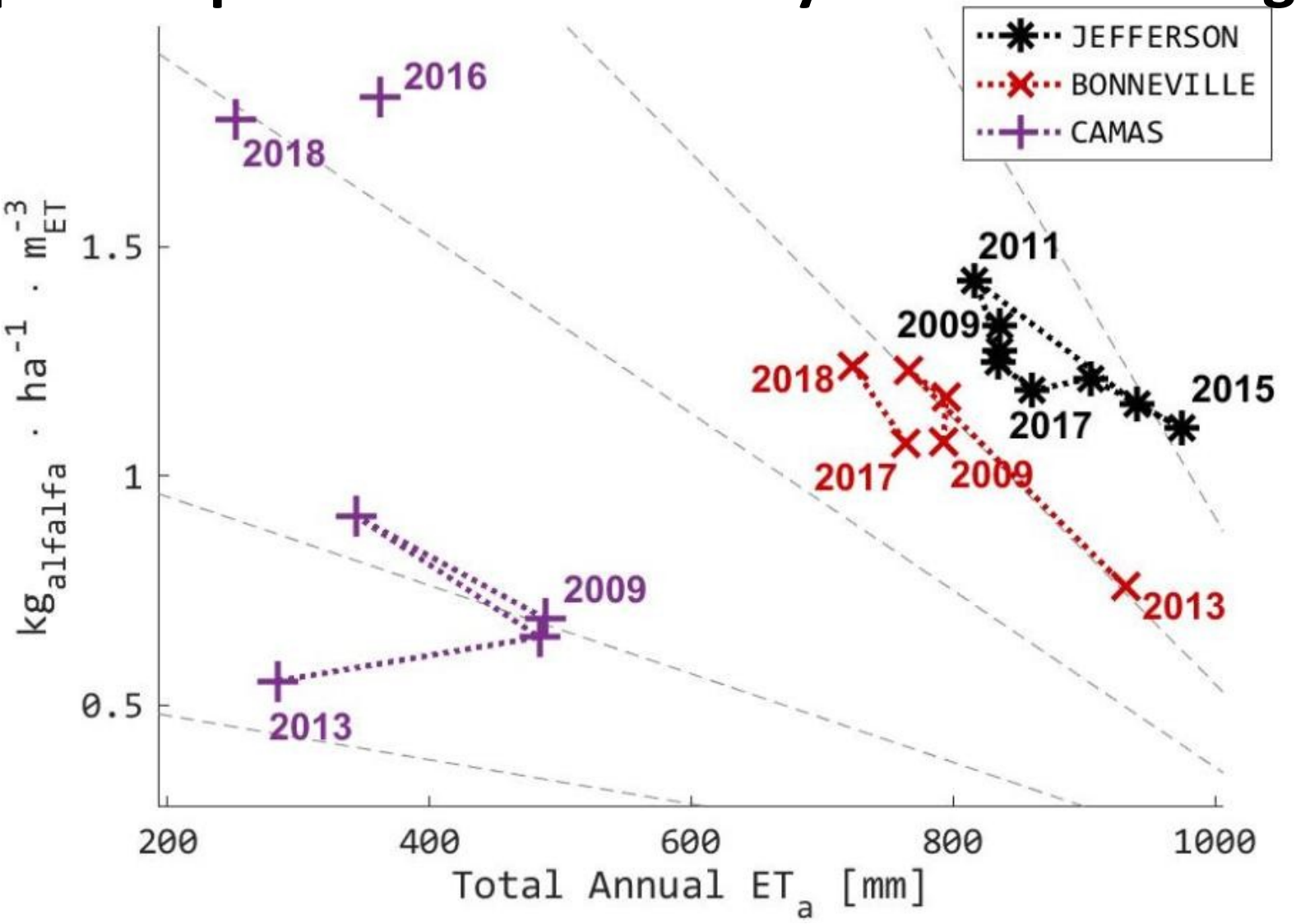
$$WP = \frac{Yield}{CWU}$$



Consumptive Water Use
calculated from
satellite ET maps

Kelley, J., Olson, B., 2022. Interannual variability of water productivity on the Eastern Snake Plain in Idaho, United States. Agricultural Water Management 265, 107532. https://doi.org/10.1016/j.agwat.2022.107532

Improved production efficiency evident in WP gains



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Questions?

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USDA-ARS Water Management Research