UC Cooperative Extension | University of California Agriculture and Natural Resources

Appraising Inaccuracy and Errors of Satellite Remote Sensing ET for Specialty Crops in the Context of SGMA

2025 Irrigation and Nutrient Management Meeting for Vegetable and Berry Crops

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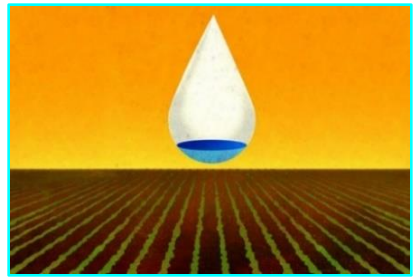
PRESENTATION OUTLINE



1) Background Info on Citrus & Pistachio Production in California
2) Ground-based ET vs. SRS-based ET for Citrus & Pistachio Orchards
3) Preliminary Results from Comparisons
4) Conclusive Remarks + Citrus ET Survey

DISCLAIMER

This presentation shows only preliminary data and findings from UC research studies. Methodologies and Final Conclusions have yet to be peer-reviewed.

CALIFORNIA CITRUS & PISTACHIO PRODUCTION 2022-2023 (NASS + CDFA, 2024)

Citrus Production (2023)

Total 270,103 acres: 259,111 bearing; 10,990 non-bearing acres

Total Production: 4.90 million tons (79% of US production)

Economic Value (2023): $2.6 Billion – **5th largest CA commodity**

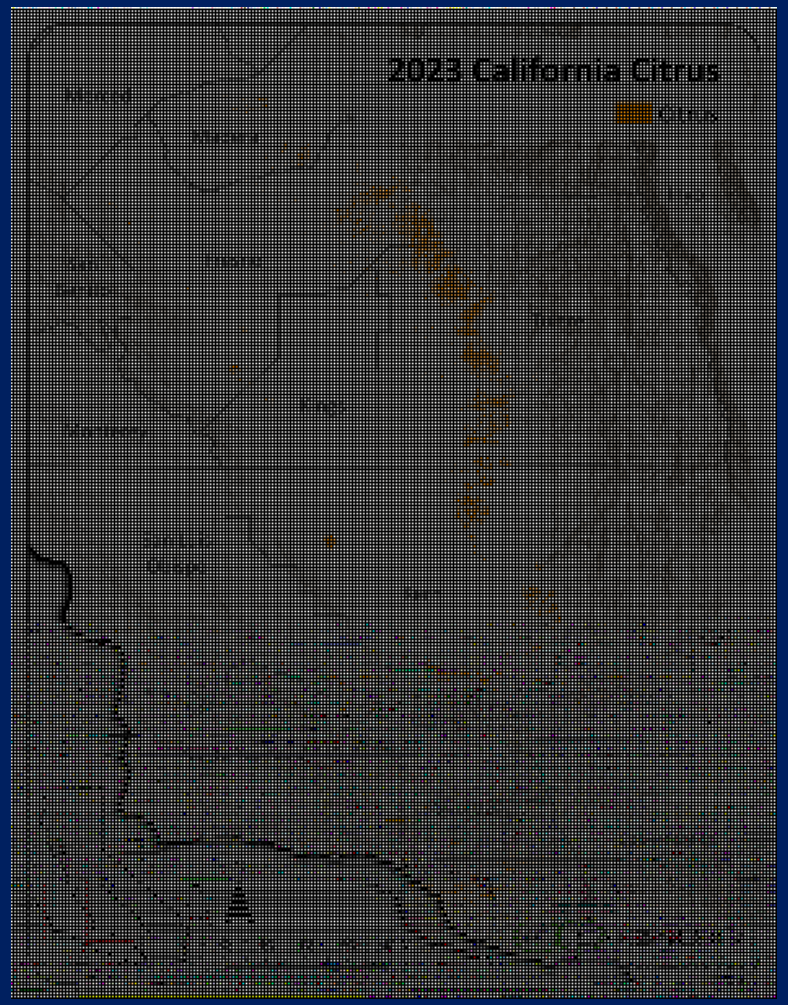
Pistachio Production (2023)

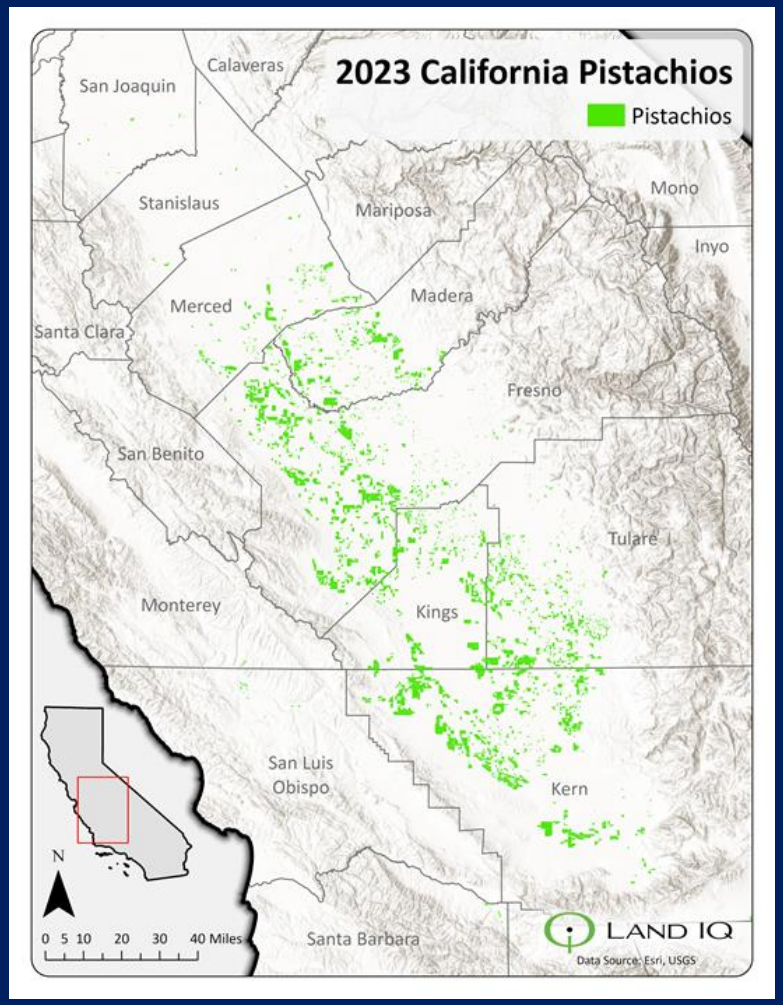
Total 605,000 acres: 461,000 bearing acres; 144,000 non-bearing acres

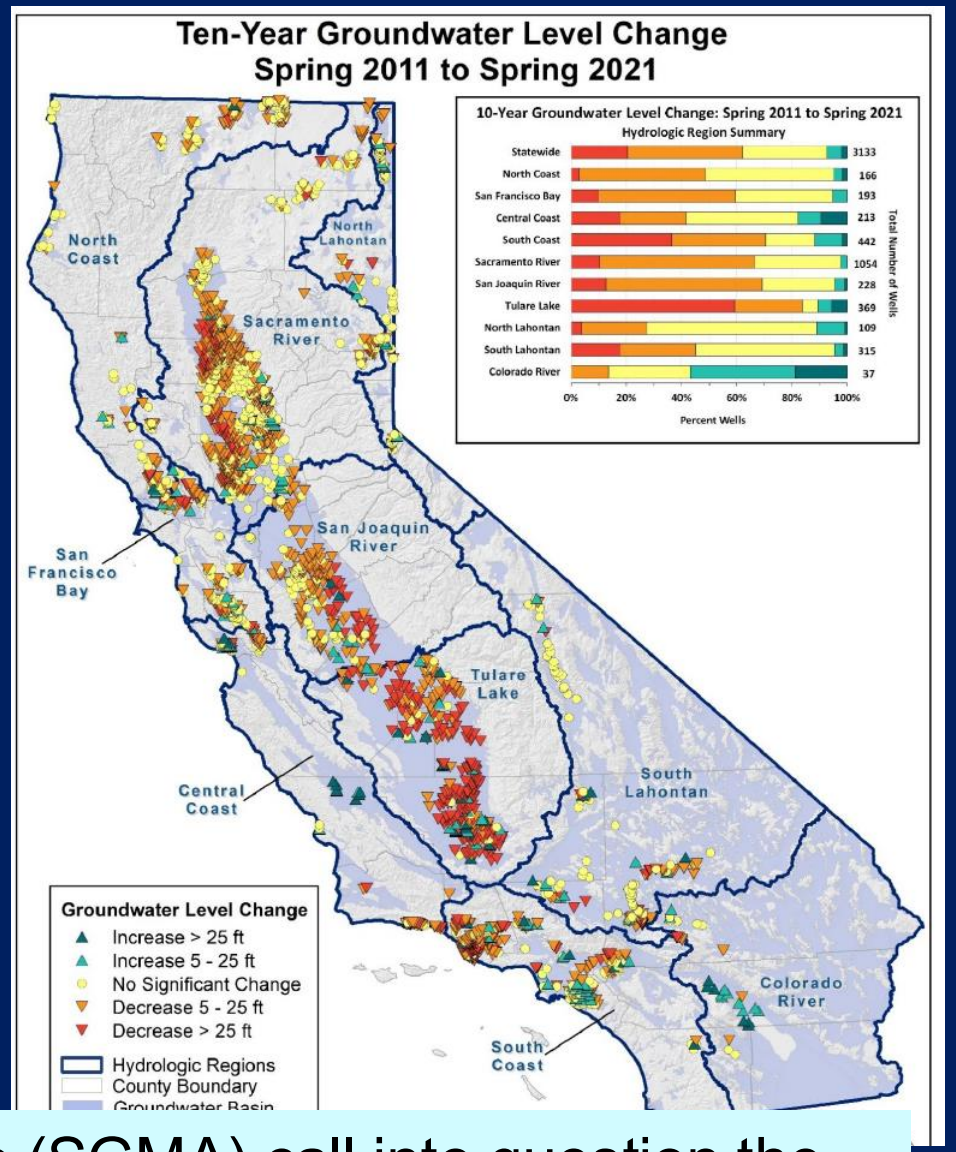
Total Production: 1.49 million pounds => Economic Value: $3.0 Billion industry

Pistachios rank as the state's **4th largest agricultural commodity**

LOCATION OF CALIFORNIA CITRUS & PISTACHIO PRODUCTION (Land IQ, 2024)







Recurring Droughts and Regulatory Water Limitations (SGMA) call into question the sufficiency of water supplies to maintain the Citrus & Pistachio production acreage in CA

CONTEXT FOR INVESTIGATING CITRUS & PISTACHIO ET

Several Irrigation Districts and GSAs adopted SRS models/platforms to estimate crop ET for SGMA-related assessments => **without solid ground-truthing/validation against ET measurements**

ACCURACY OF SRS-ET WAS JUST ASSUMED

based on some work conducted on corn & wheat in the Mid-West

SRS models have multiple sources of errors that can lead to highly inaccurate estimation of ET for orchards & vineyards (± 15-60% and beyond) due to:

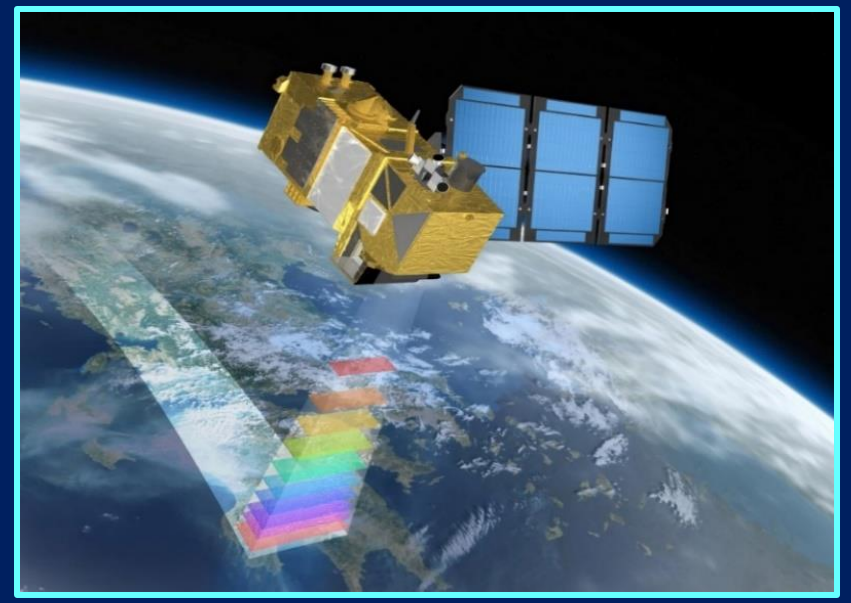
- Crop-specific responses to weather parameters (T; RH; VPD; Stress)
- Coarse pixel resolution (30m x 30m) & inability to separate tree/vine canopy from soil background
- Daily ET values inferred from instantaneous satellite snapshots capturing mid-morning tree behavior (Temperature & RH sensitive) => no adjustments for diurnal ET regulation due to crop physiology
- Propagation of Errors: need to interpolate daily ET values between satellite overpasses at 5-day, 8-day, or 16-day intervals => **ENORMOUS DATA-GAP FILLING (> 95%)**

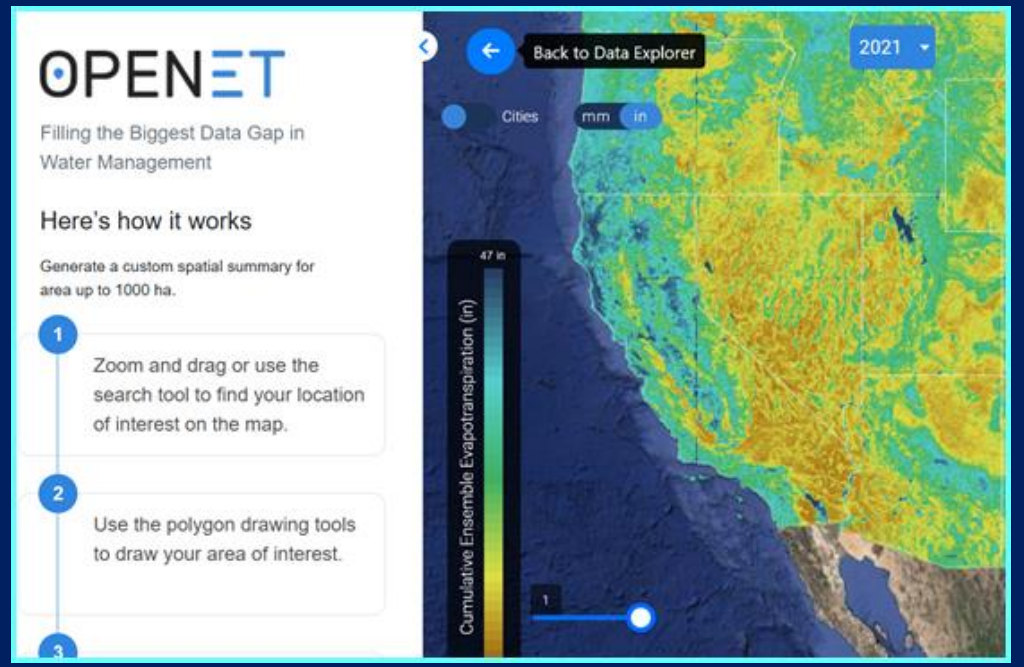
Inaccurate estimates of Orchard ET => Unrealistic Water Allocations & Penalty Fees

=> Risks to the Competitiveness & Profitability of CA Fruit & Nut Production

CITRUS, PISTACHIO, ALMONDS, WINE-GRAPES

Inaccuracy and Errors of ET estimated with SRS Methods (OpenET) versus ground-measured ET (eddy covariance)





The SRS-ET Web Platform

OPENET

Satellites:
Landsat 8, Sentinel-2; GOES; etc.

Spatial scale:
30m x 30m (0.22 acres per pixel)

Temporal scale:
day; month; season; year

Models:

1. geeSEBAL
2. egMETRIC
3. DisALEXI

SEB (thermal & optical-MS)

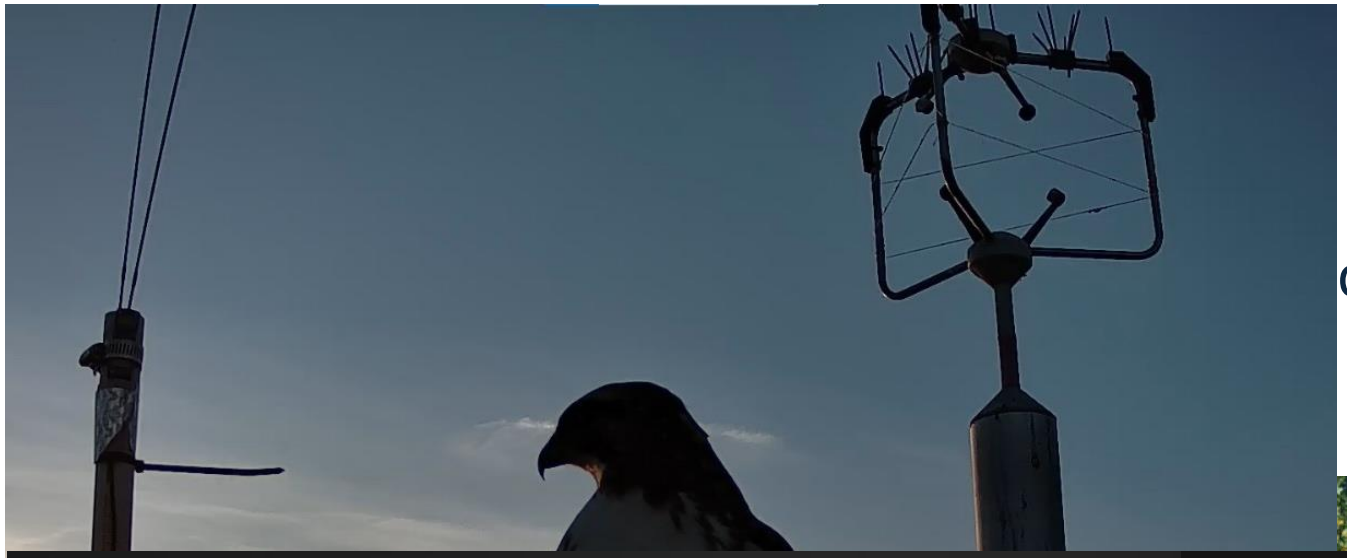
4. SSEBop
5. PT-JPL

Simplifying assumptions (thermal)

6. SIMS

Kc (optical-MS)

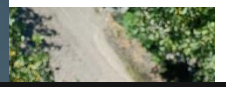
7. OpenET Ensemble



The field measurements

dual of Surface Energy Balance (SEB)

Rn – G – H

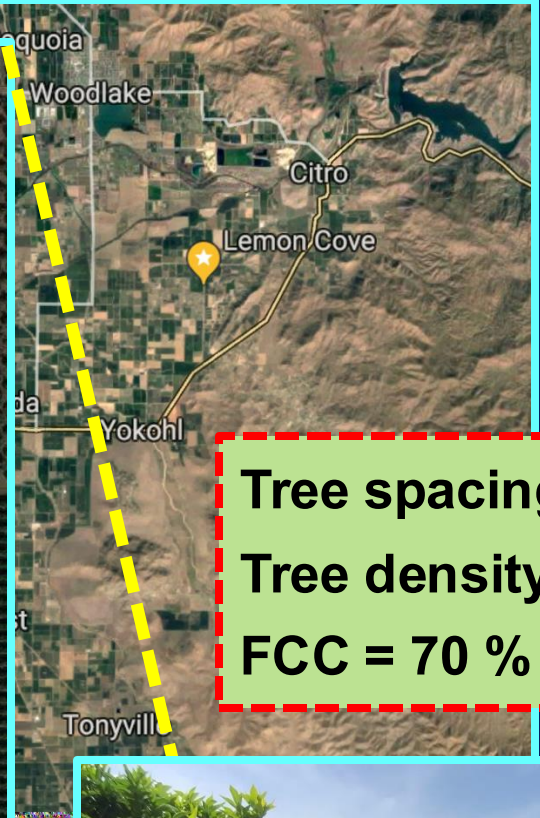


G (soil heat flux) –

PAGE MANDARINS
20 year-old

BLK 3: 6 Ac
E-W

BLK 4: 10 Ac
N-S



Tree spacing: 18 ft. x 9 ft.

Tree density: 270 Tree/ac

FCC = 70 %

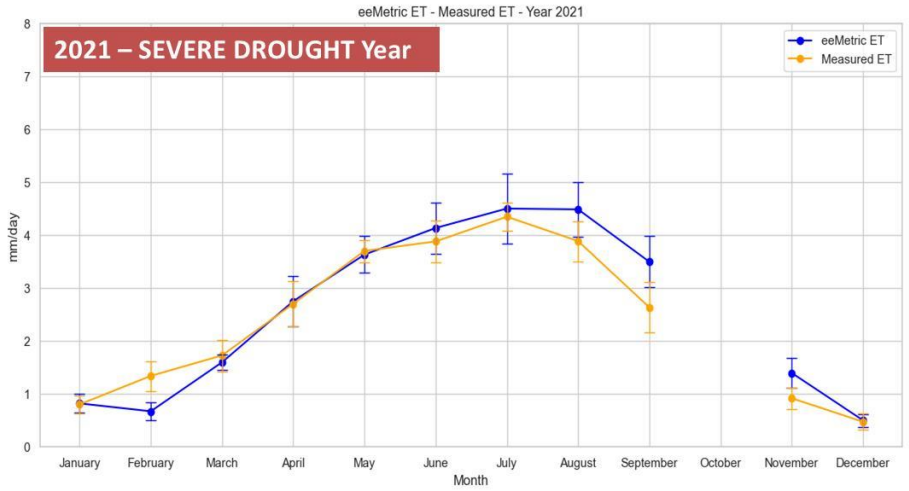
Page mandarin - Strathmore

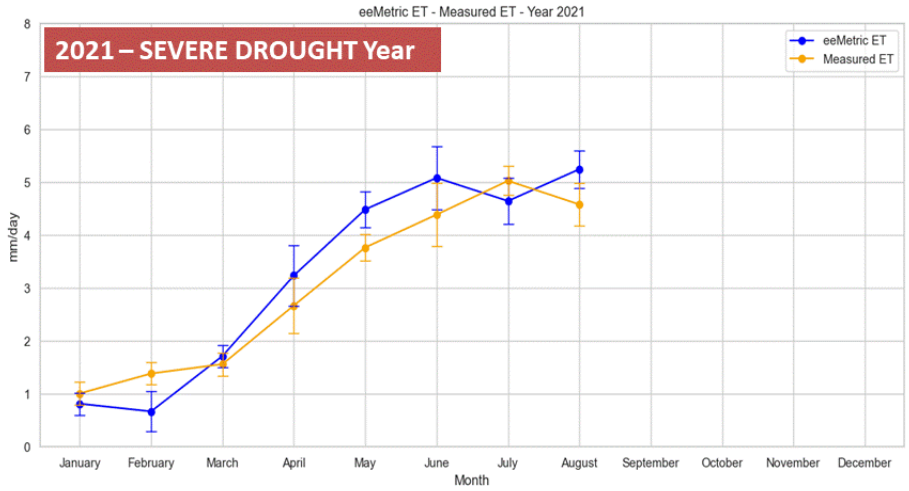
Modeled ET

Measured ET

EW **eeMETRIC** **NS**

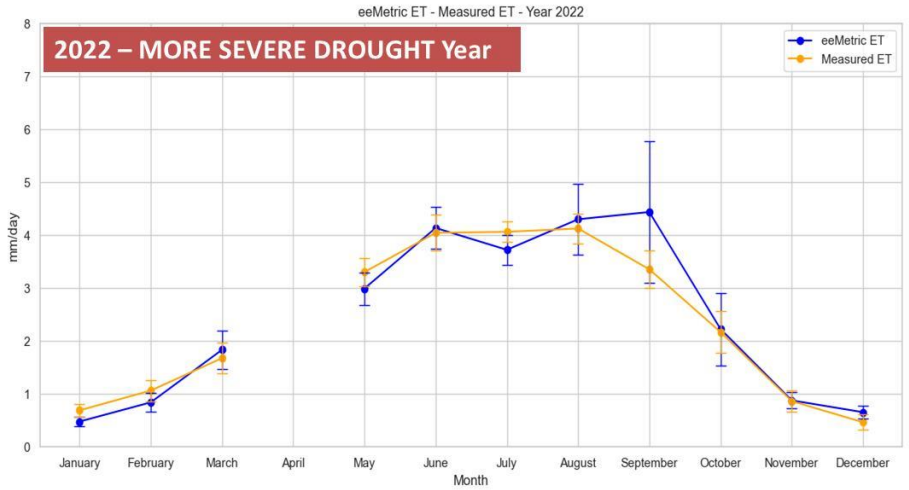
Δ: 15-35%

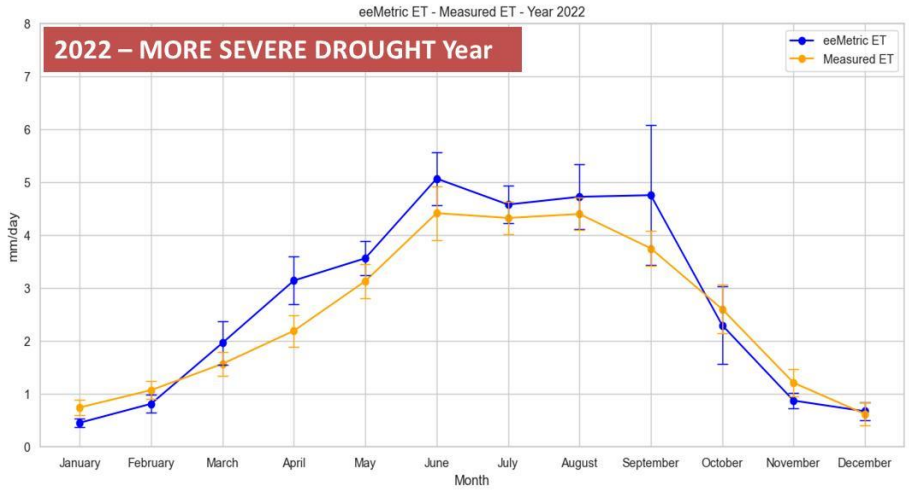




Δ: 20-50%

Δ: 15-50%





Δ: 20-50%

Page mandarin - Strathmore

Modeled ET

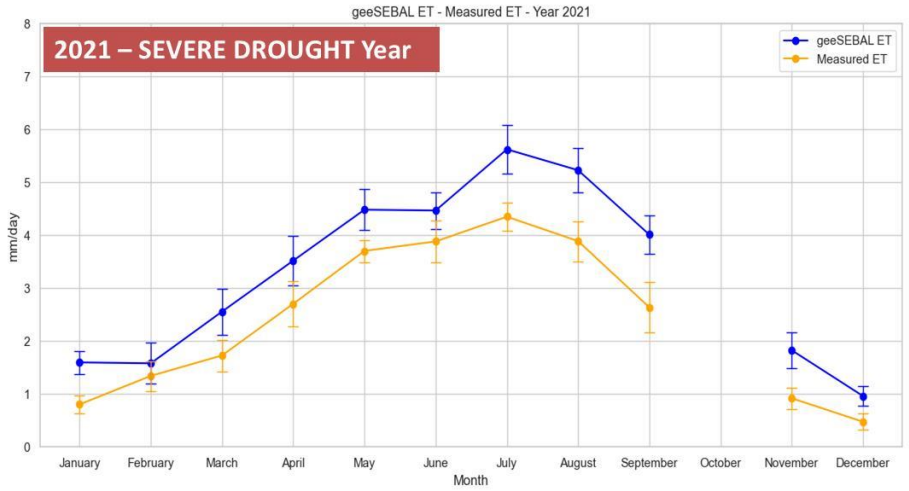
Measured ET

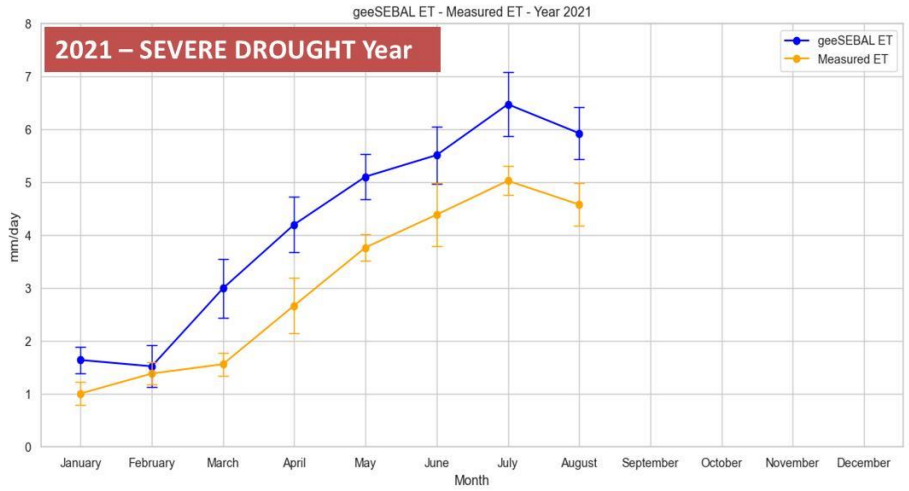
EW

geeSEBAL

NS

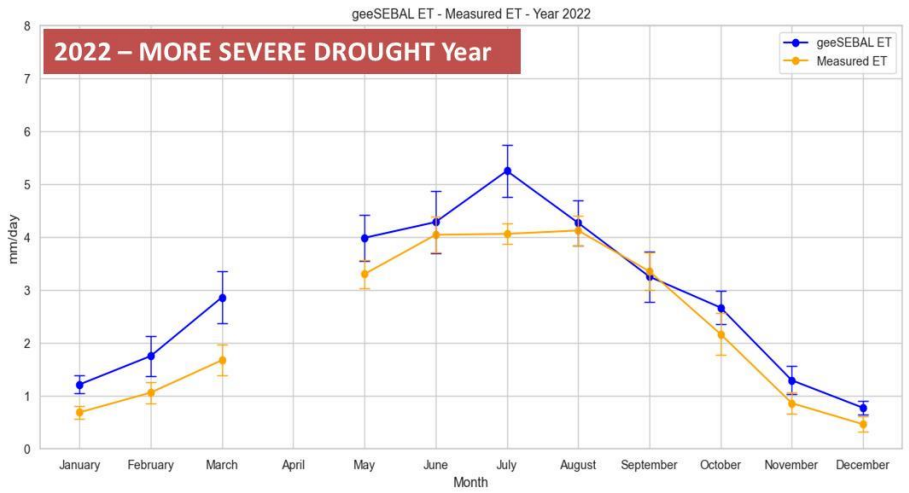
Δ: 20-55%

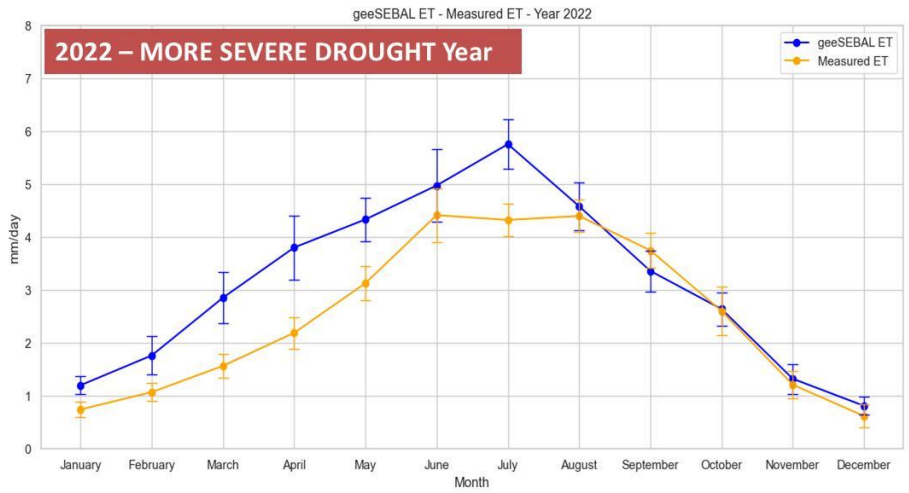




Δ: 30-40%

Δ: 25-50%





Δ: 15-40%

Page mandarin - Strathmore

Modeled ET

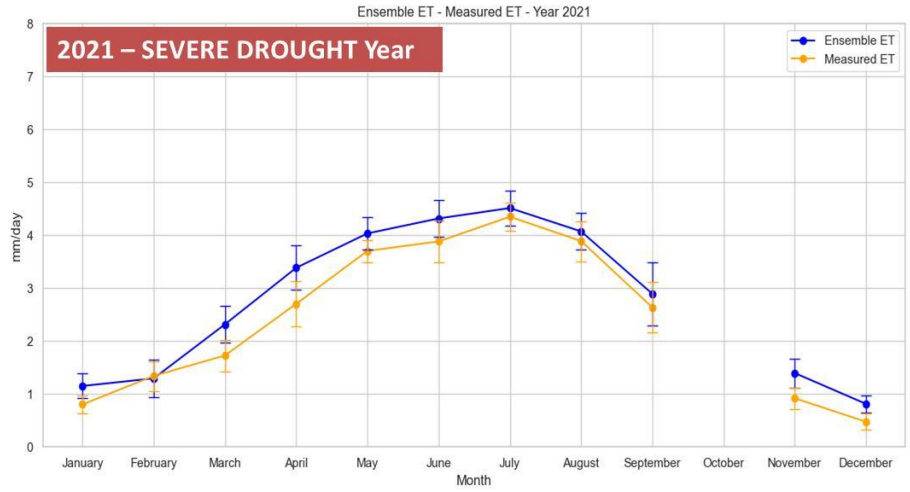
Measured ET

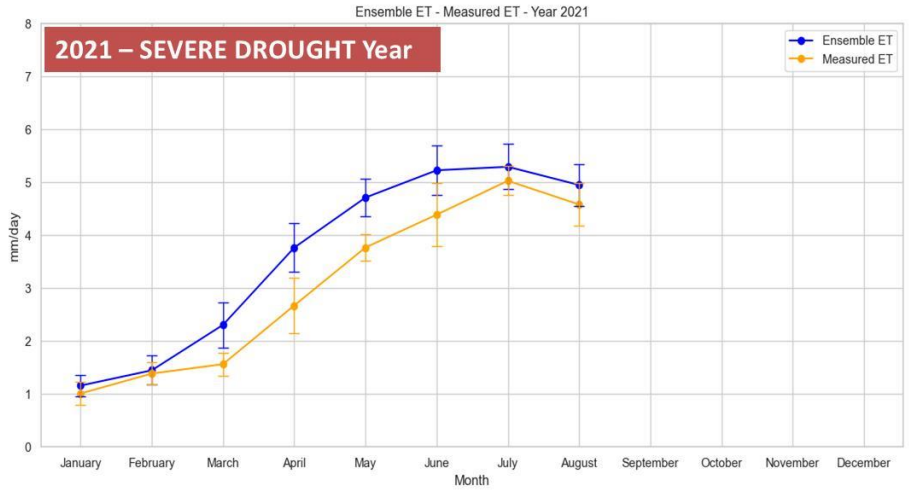
EW

OpenET Ensemble

NS

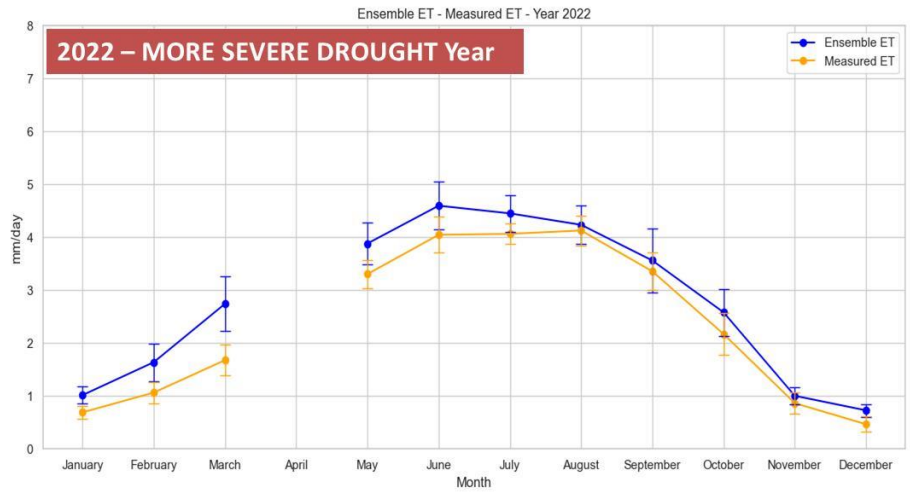
Δ: 15-20%

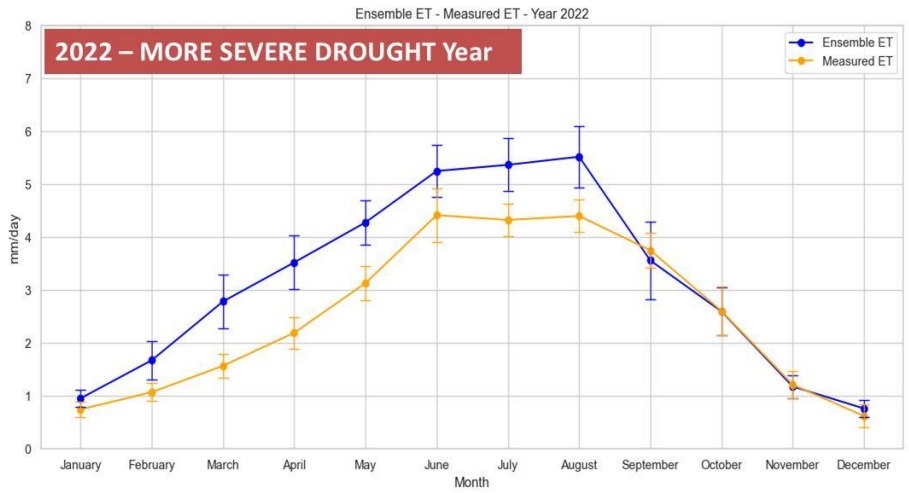




Δ: 10-30%

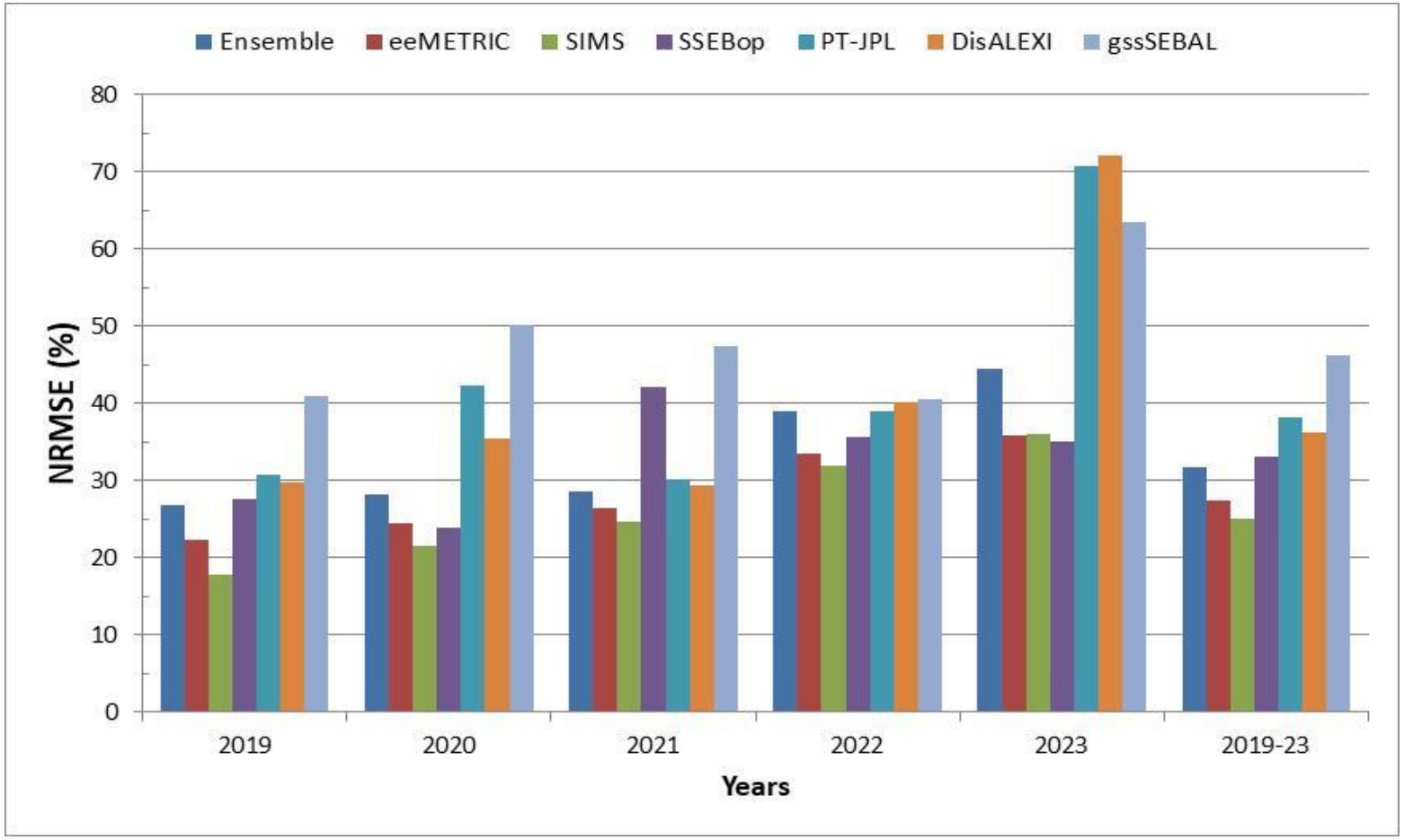
Δ: 20-25%





Δ: 25-30%

Strathmore, CA - Page Mandarins North-South (2019 – 2023)



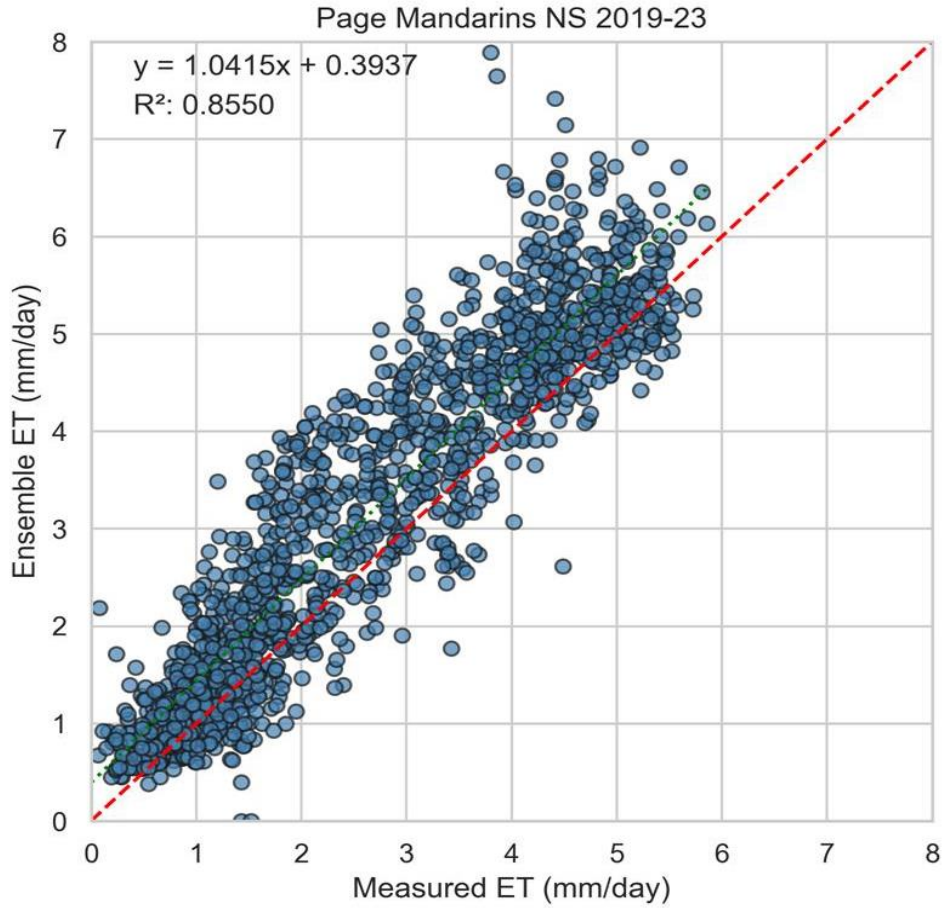
$$NRMSE = \frac{\sqrt{\frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}{n}}}{\bar{y}}$$

$\hat{y}_i$ is the modeled ET;

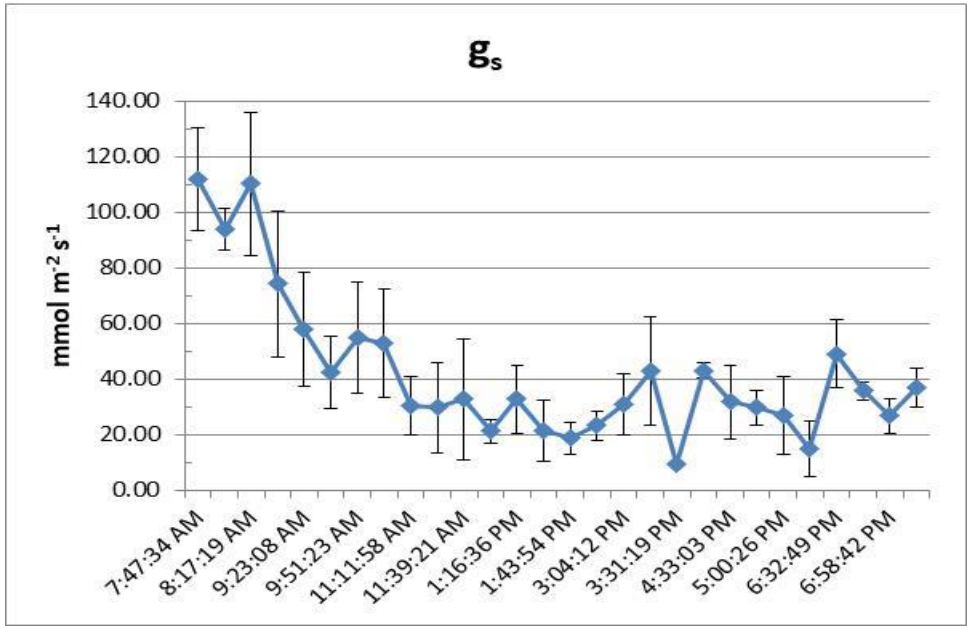
y_i is the measured ET;

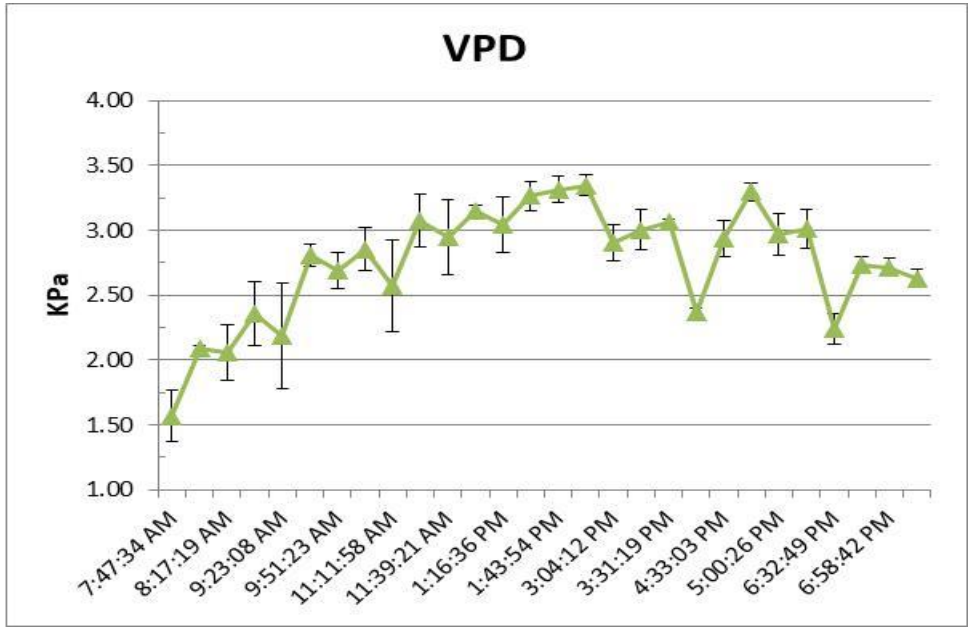
$\bar{y}$ is the mean value of the measured ET over the datase

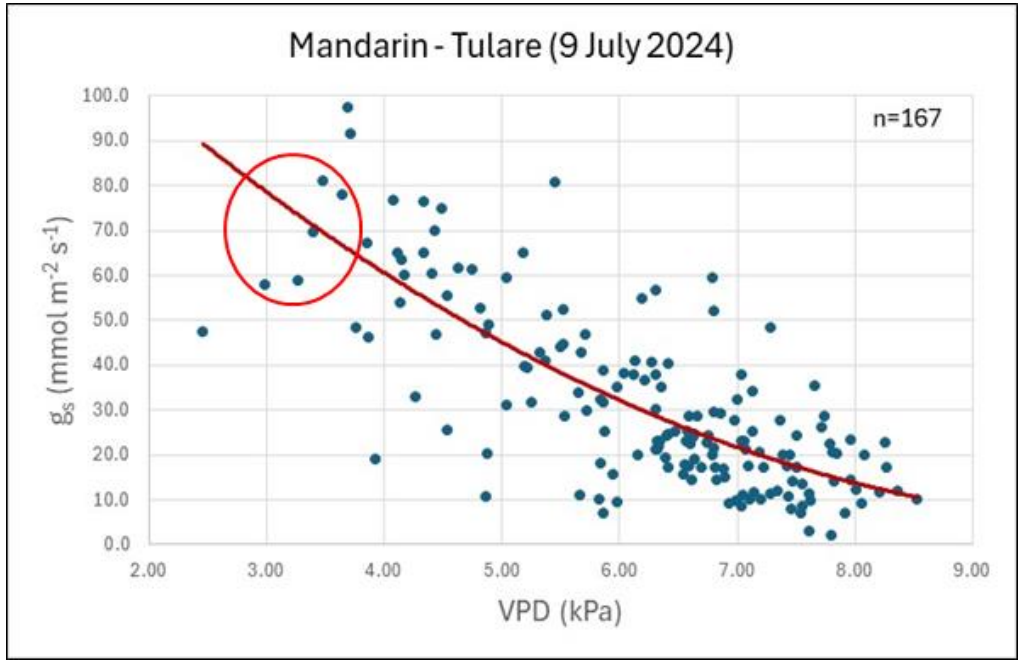
n is the number of pair ET value (modeled-measured)



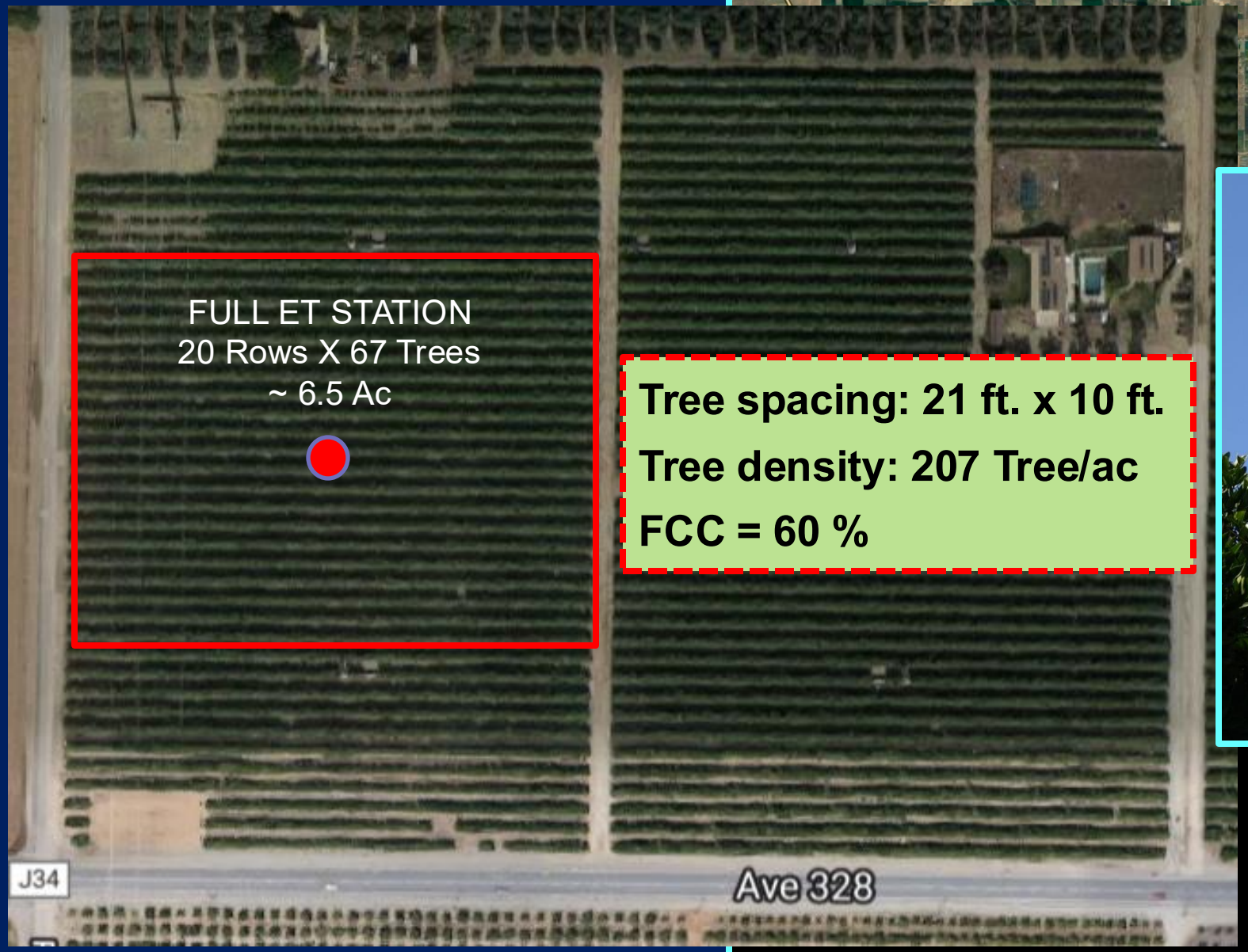
Page mandarin – Strathmore, CA: June 2023 & July 2024







Navel orange (20-year old) near Ivanhoe, CA



Tree spacing: 21 ft. x 10 ft.

Tree density: 207 Tree/ac

FCC = 60 %

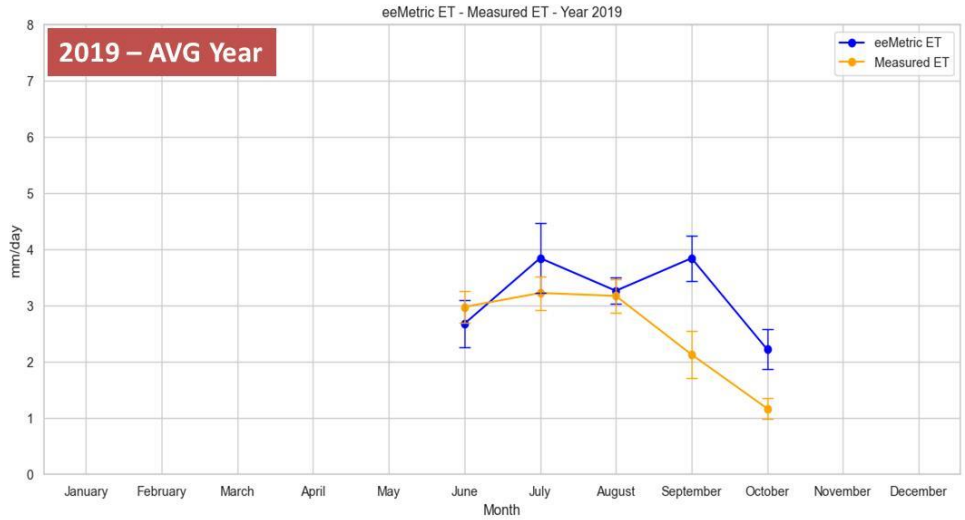
Navel orange - Ivanhoe

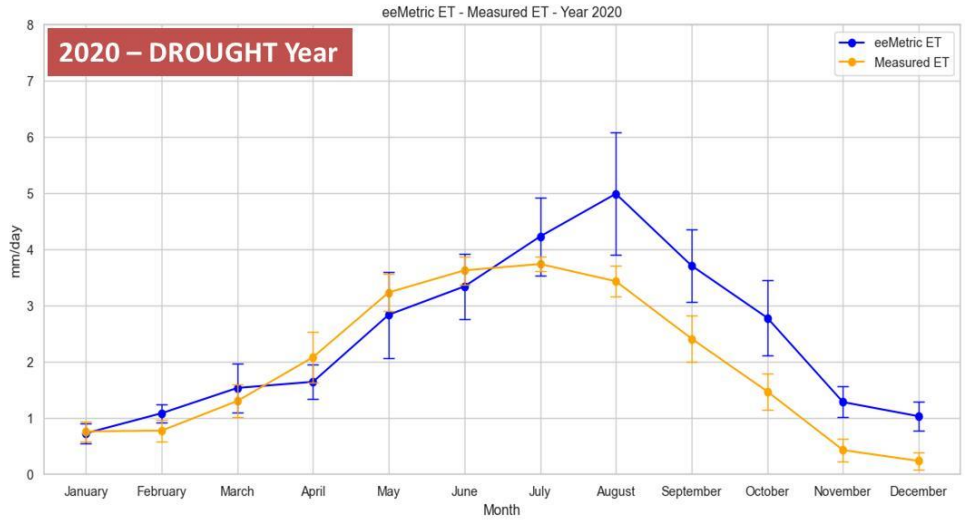
Modeled ET

Measured ET

eeMETRIC **EW**

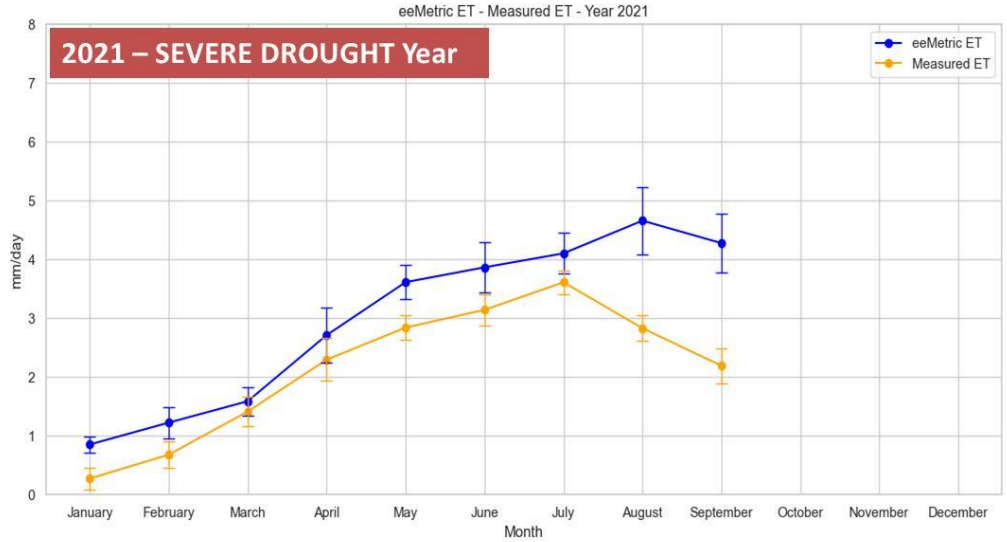
Δ: 20-50%





Δ: 25-60%

Δ: 20-70%



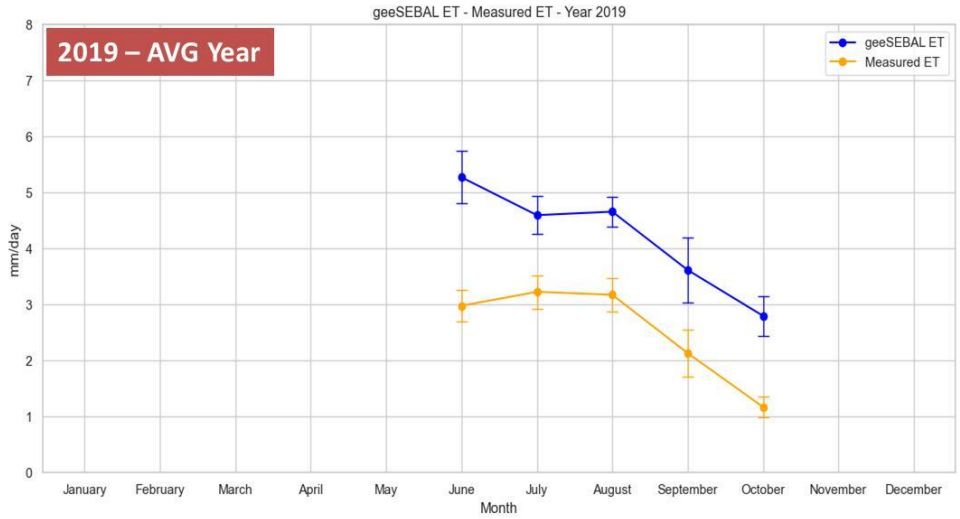
Navel orange - Ivanhoe

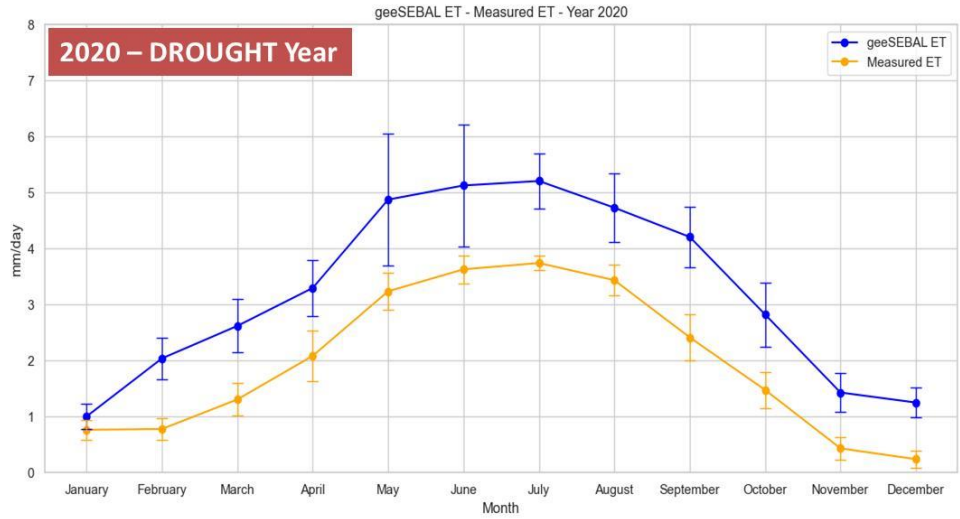
Modeled ET

Measured ET

geeSEBAL **EW**

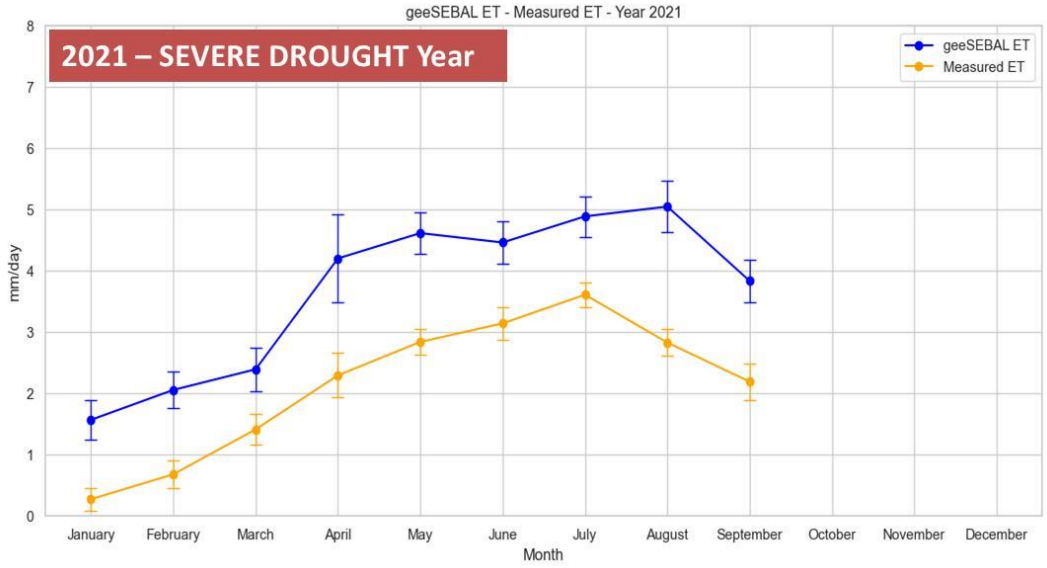
Δ: 45-80%





Δ: 40-80%

Δ: 35-80%



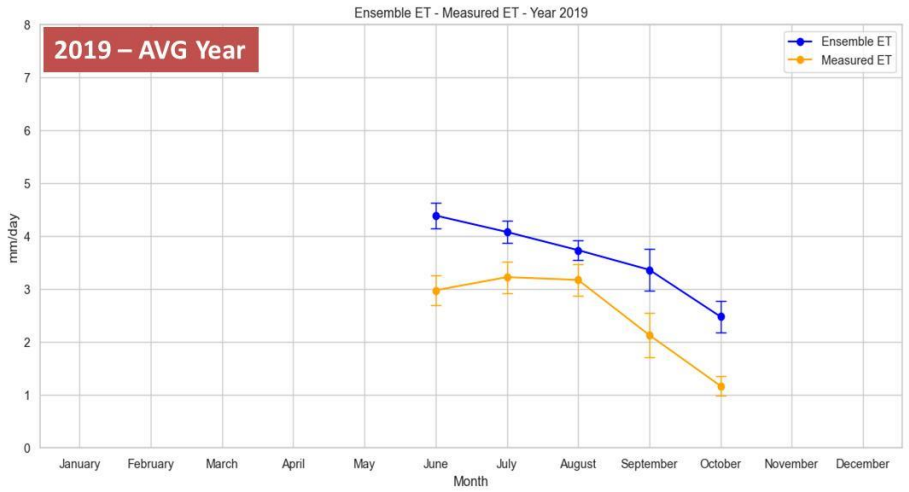
Navel orange - Ivanhoe

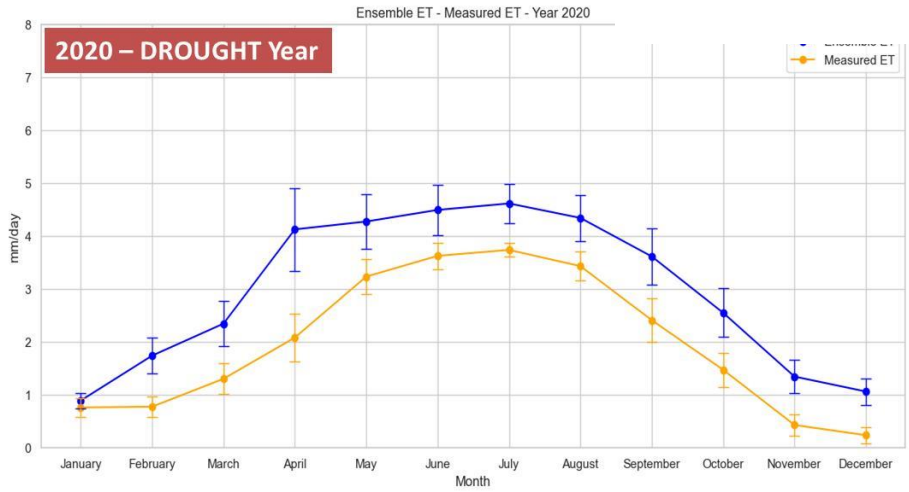
OpenET Ensemble **EW**

Modeled ET

Measured ET

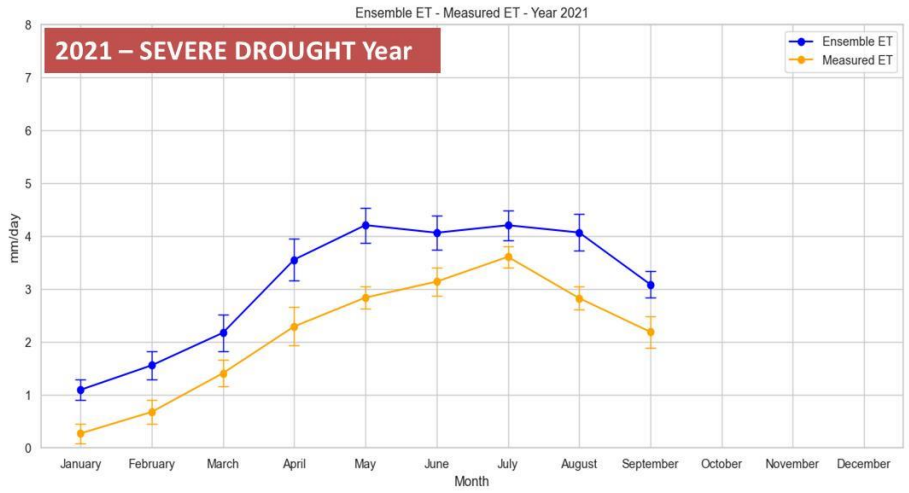
Δ: 25-50%



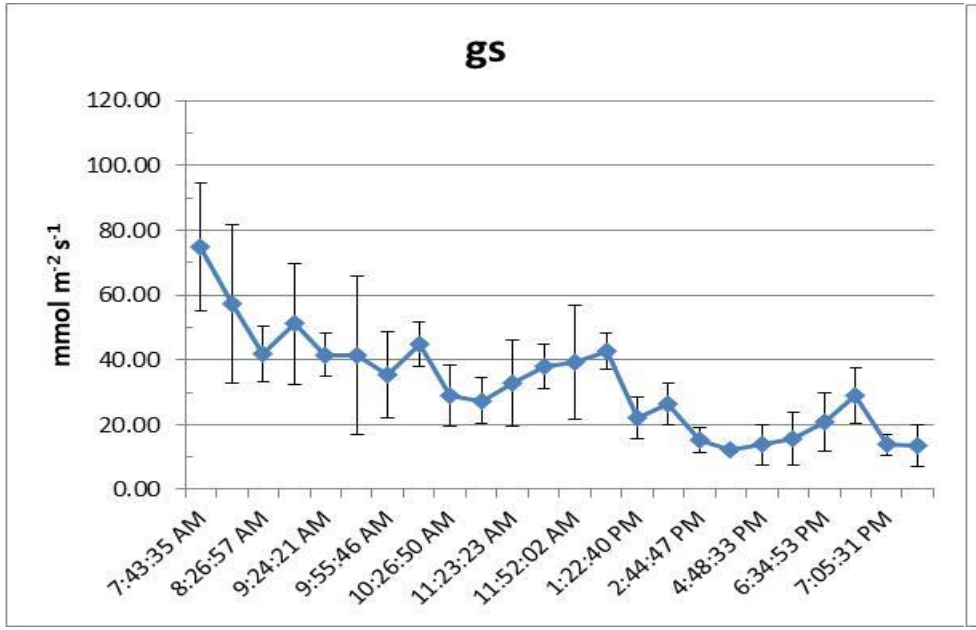


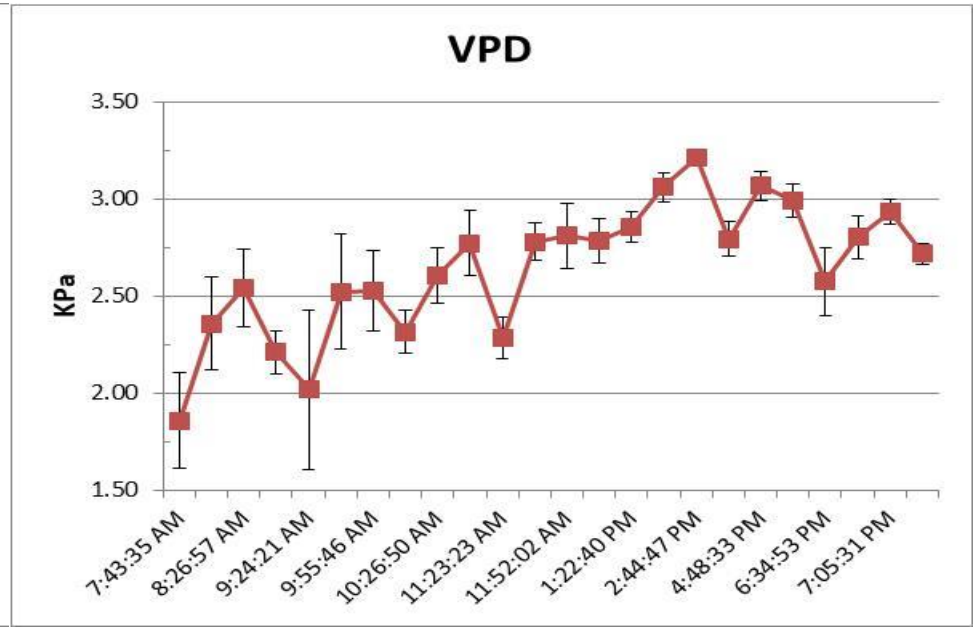
Δ: 25-40%

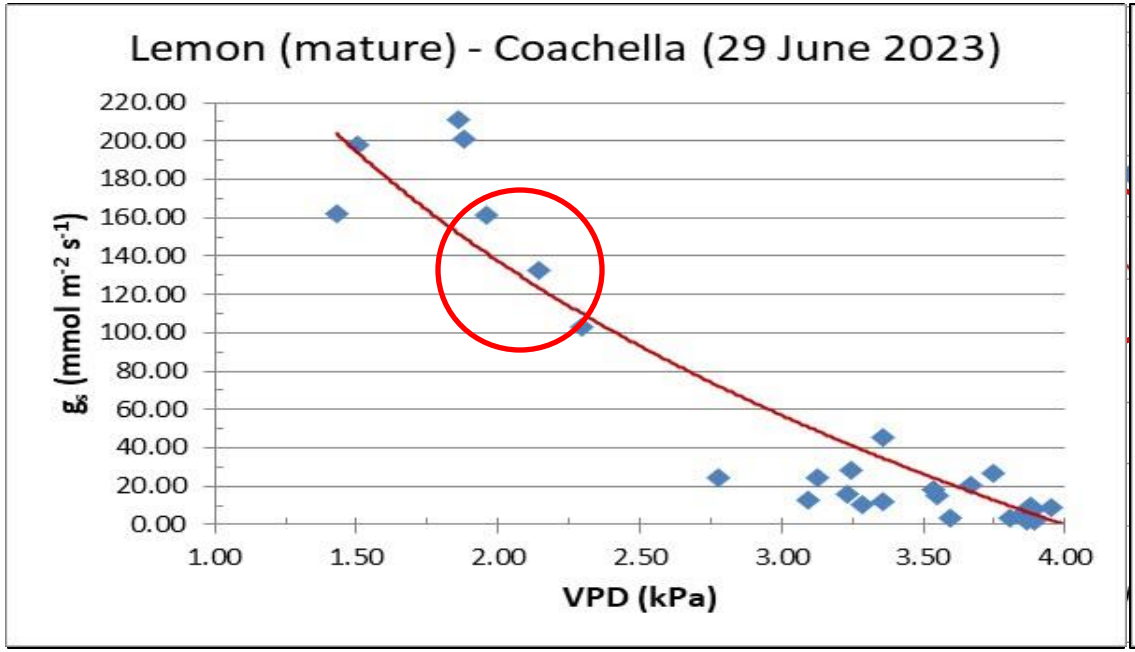
Δ: 20-50%

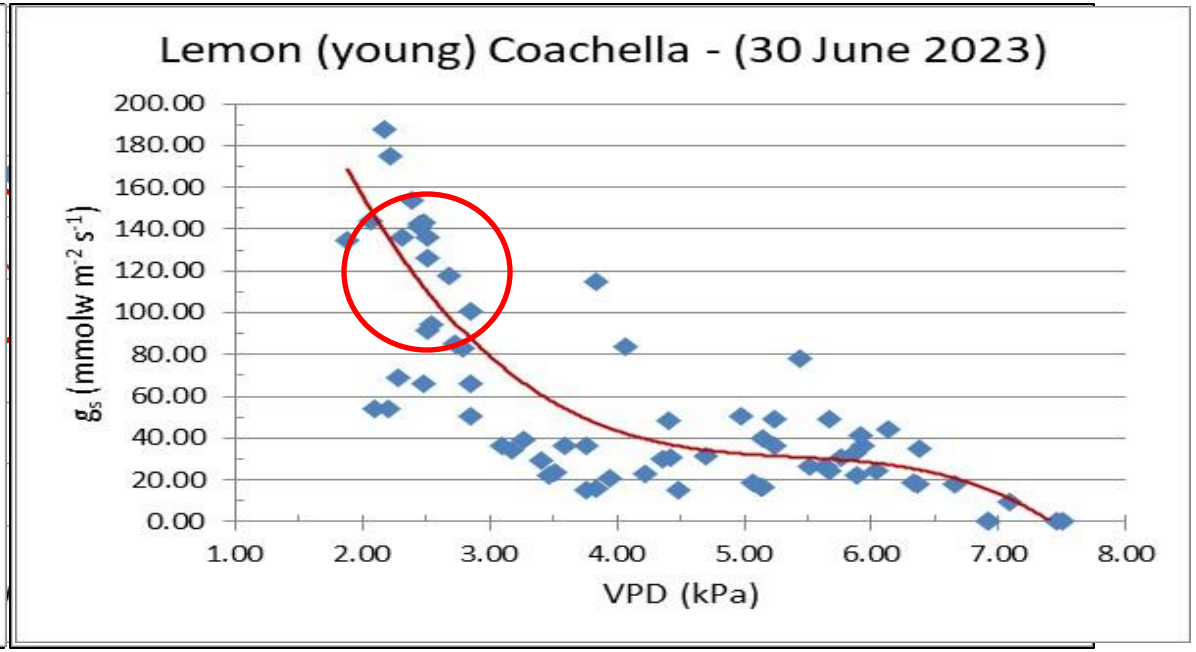


Navel orange – Ivanhoe, CA: 26 June, 2023









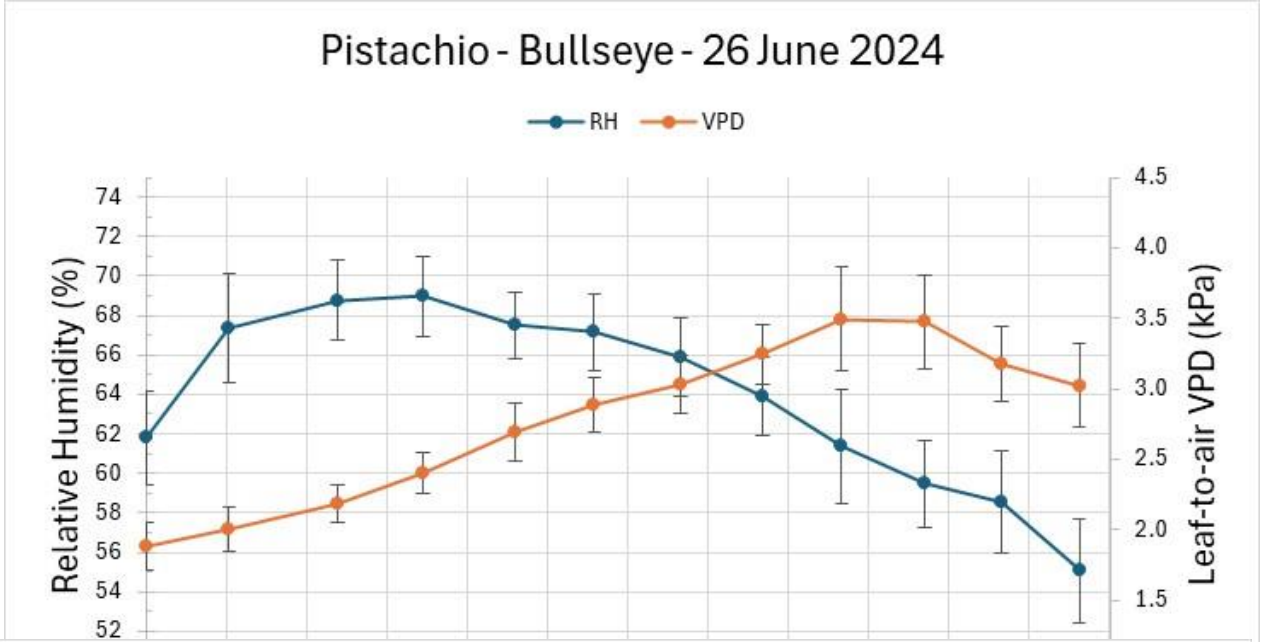
Tentative ranking of the OpenET models for their overall performance over the Citrus study orchards considered for this analysis:

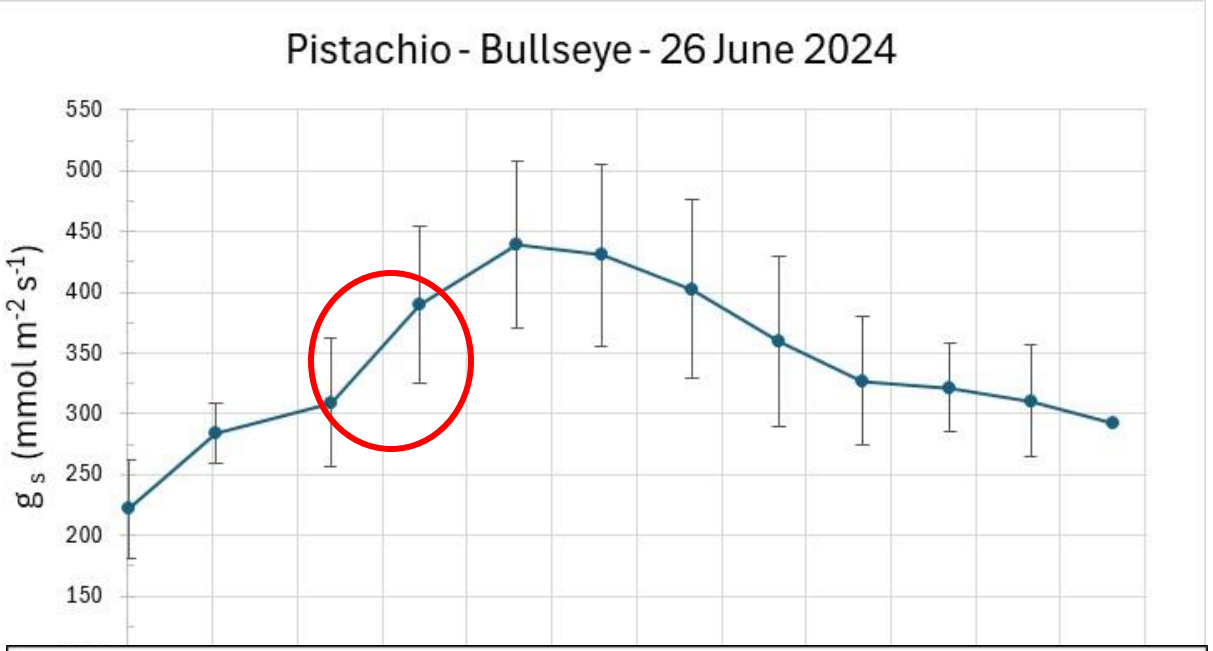
- **DisALEXI** as 1st best performing model **(Δ: 20-30%)**
- **Ensemble**, **eeMETRIC** and **SIMS** as 2nd best-performing group **(Δ: 20-40%)**
- **SSEBop**, 3rd best performing model **(Δ: 20-50%)**
- **PT-JPL**, 4th best performing model **(Δ: 20-60%)**
- **geeSEBAL**, 5th best performing model **(Δ: 40-80%)**

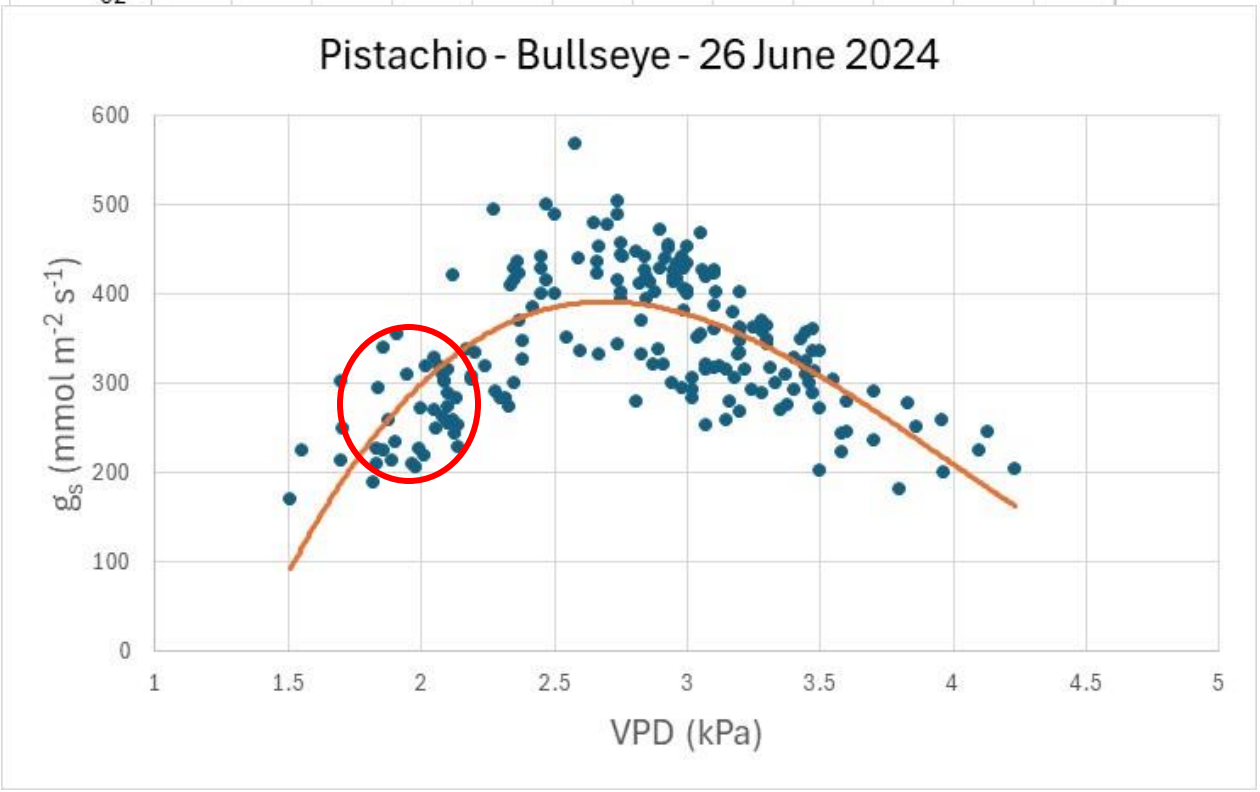
However, there is a substantial degree of inaccuracy by the OpenET models and inconsistency between years & orchards

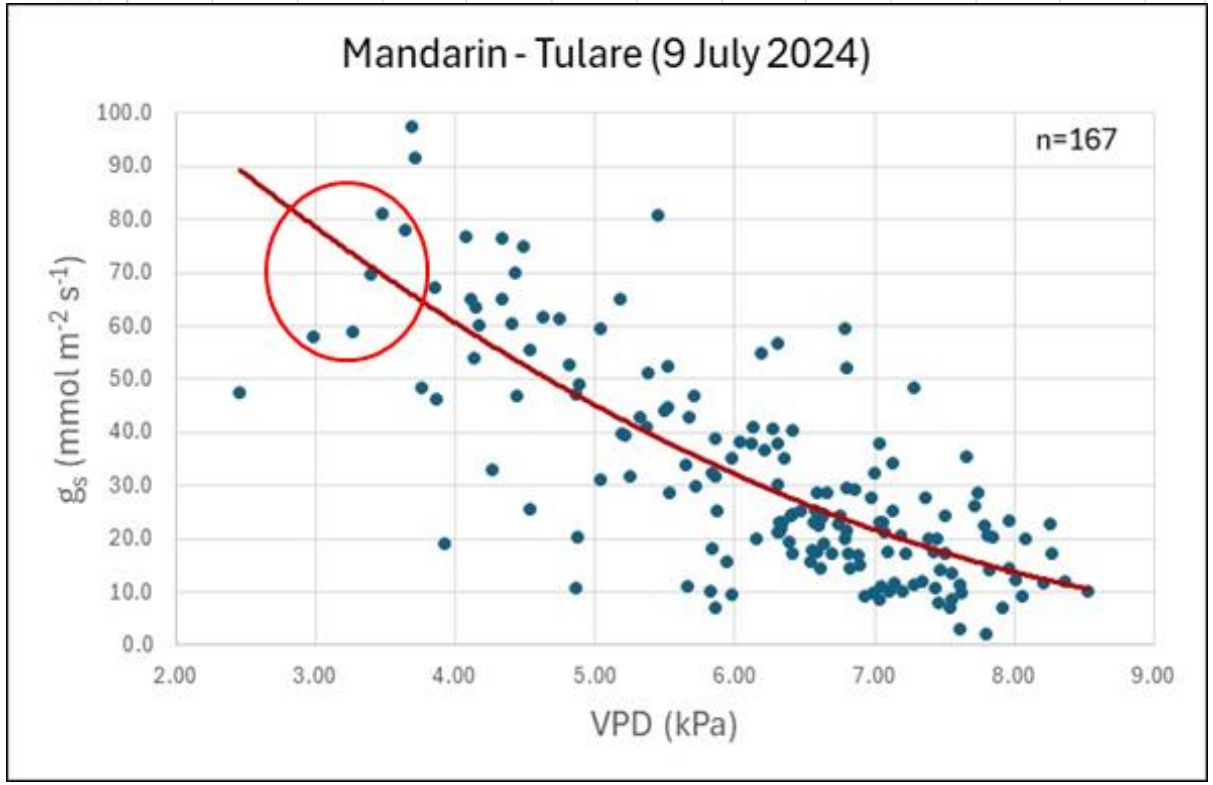
Preliminary Conclusions for Citrus

- Overall, all the models of OpenET over-estimate Citrus ET (+20-80%)
- The magnitude of Citrus ET over-estimation increases as the drought intensity increases (2019 => 2022) => **Counterintuitive or Contrary to Common Sense**
- The citrus ET over-estimation by OpenET models appears to be higher (around +10% but not consistently) for the orchard blocks with N-S than the E-W tree row orientations
- The OpenET models perform slightly better on mandarin orchards than on orange orchards


Pistachio - Bullseye - 26 June 2024
RH
VPD
Relative Humidity (%)
Leaf-to-air VPD (kPa)
74
72
70
68
66
64
62
60
58
56
54
52
4.5
4.0
3.5
3.0
2.5
2.0
1.5


Pistachio - Bullseye - 26 June 2024
g_s (mmol m^{-2} s^{-1})
550
500
450
400
350
300
250
200
150

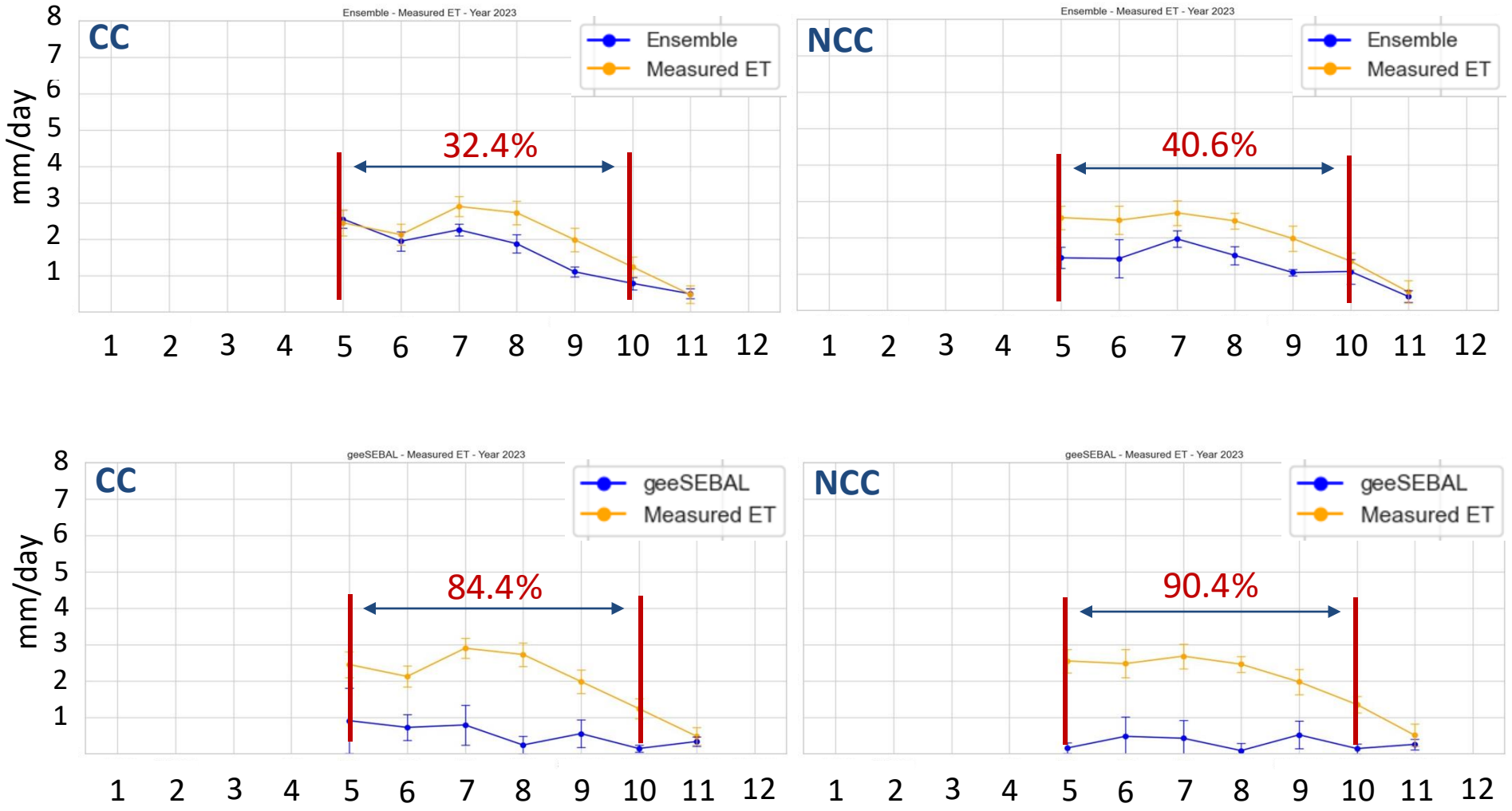

Pistachio - Bullseye - 26 June 2024
g_s (mmol m^{-2} s^{-1})
VPD (kPa)
600
500
400
300
200
100
0
1
1.5
2
2.5
3
3.5
4
4.5
5


Mandarin - Tulare (9 July 2024)
n=167
g_s (mmol m^{-2} s^{-1})
VPD (kPa)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00

BullsEye Ranch (Yolo

Monthly ET (NRMSE on May-Oct)

Young Pistachio Orchard: ~ 35% F_{cc}

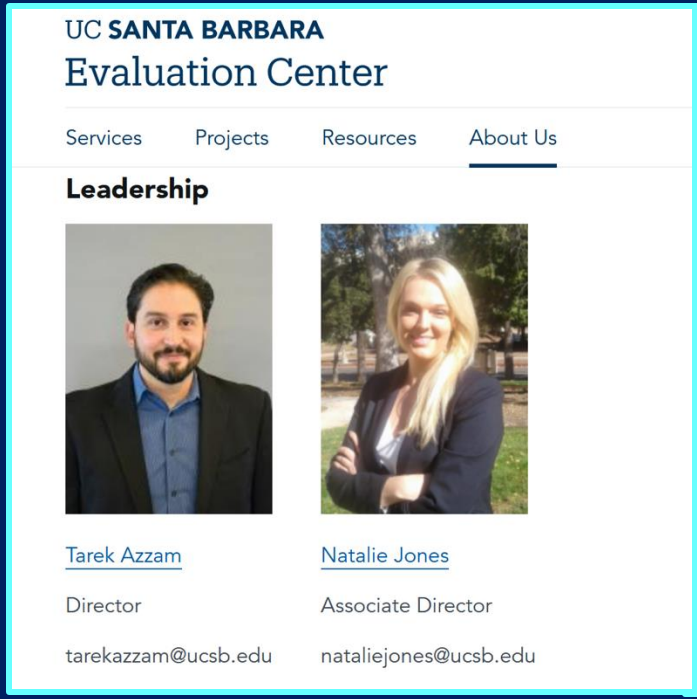


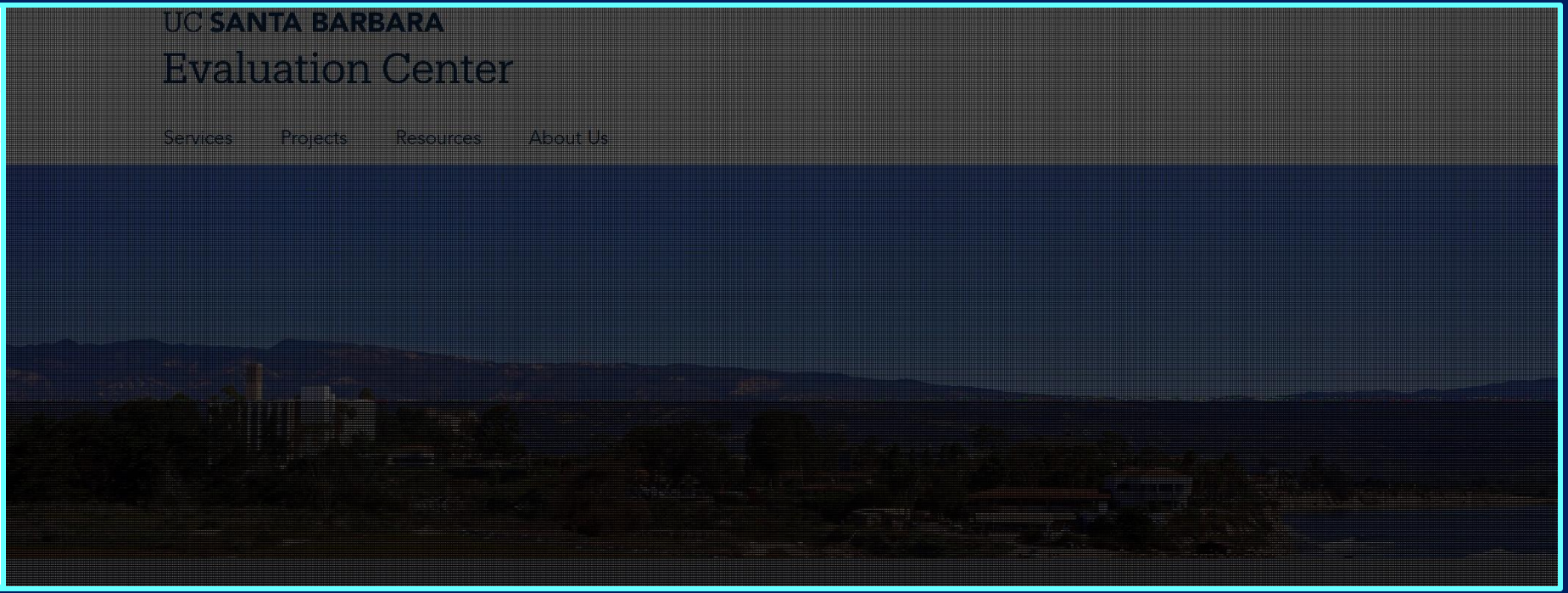
CITRUS STAKEHOLDER SURVEY LAUNCHED IN NOVEMBER 2024

UC Davis project team is collecting information from Citrus Growers and Water Actors about the expected and acceptable levels of accuracy of Citrus ET determination

Targeting various actors of the Citrus production community:

Citrus growers, orchard managers, crop and irrigation consultants, water

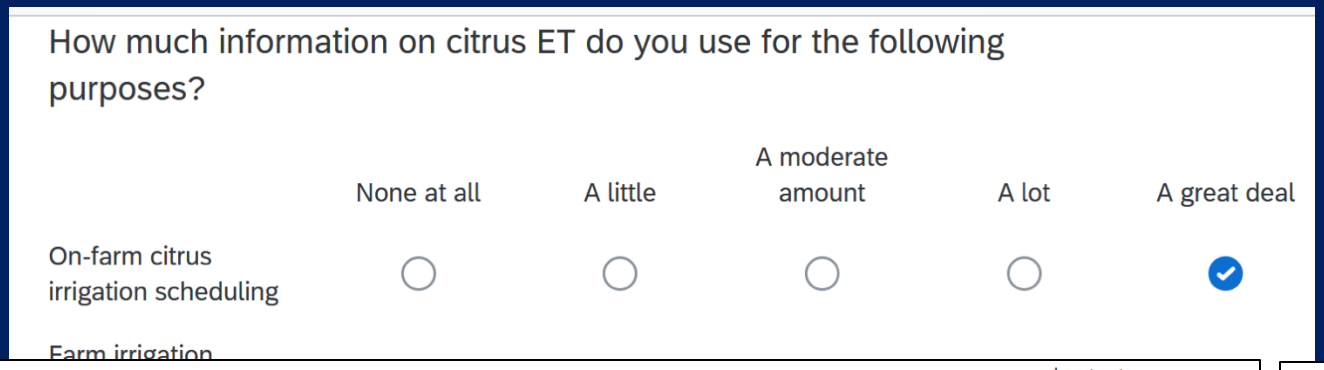


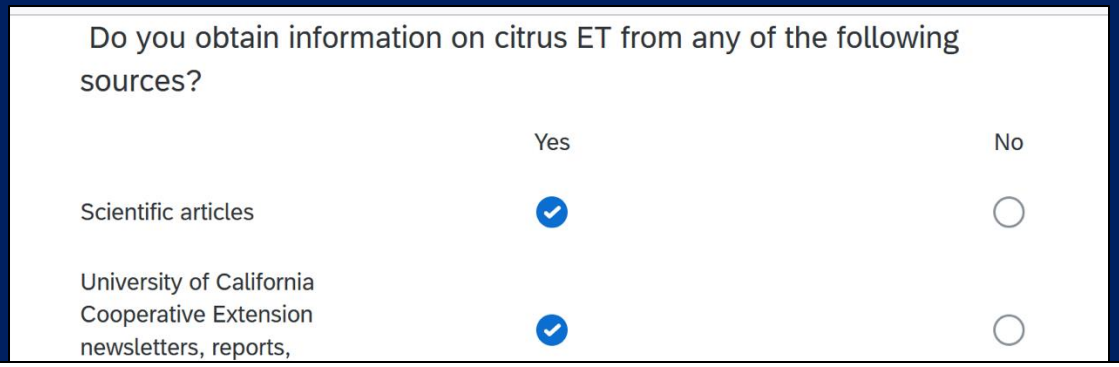


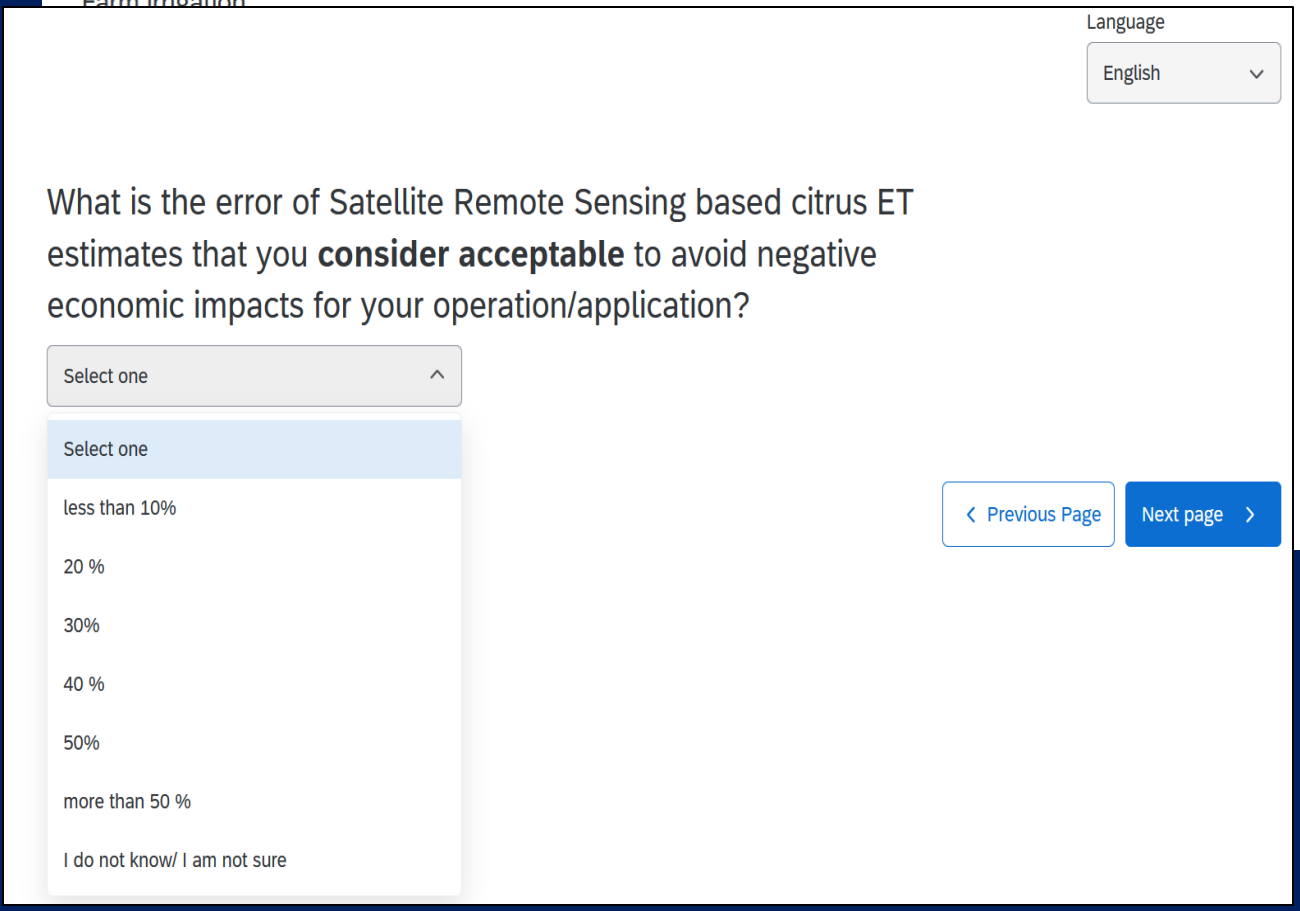
How much inaccuracy/errors can be accepted in estimating Citrus ET for water resource planning, water deliveries, and on-farm water management?

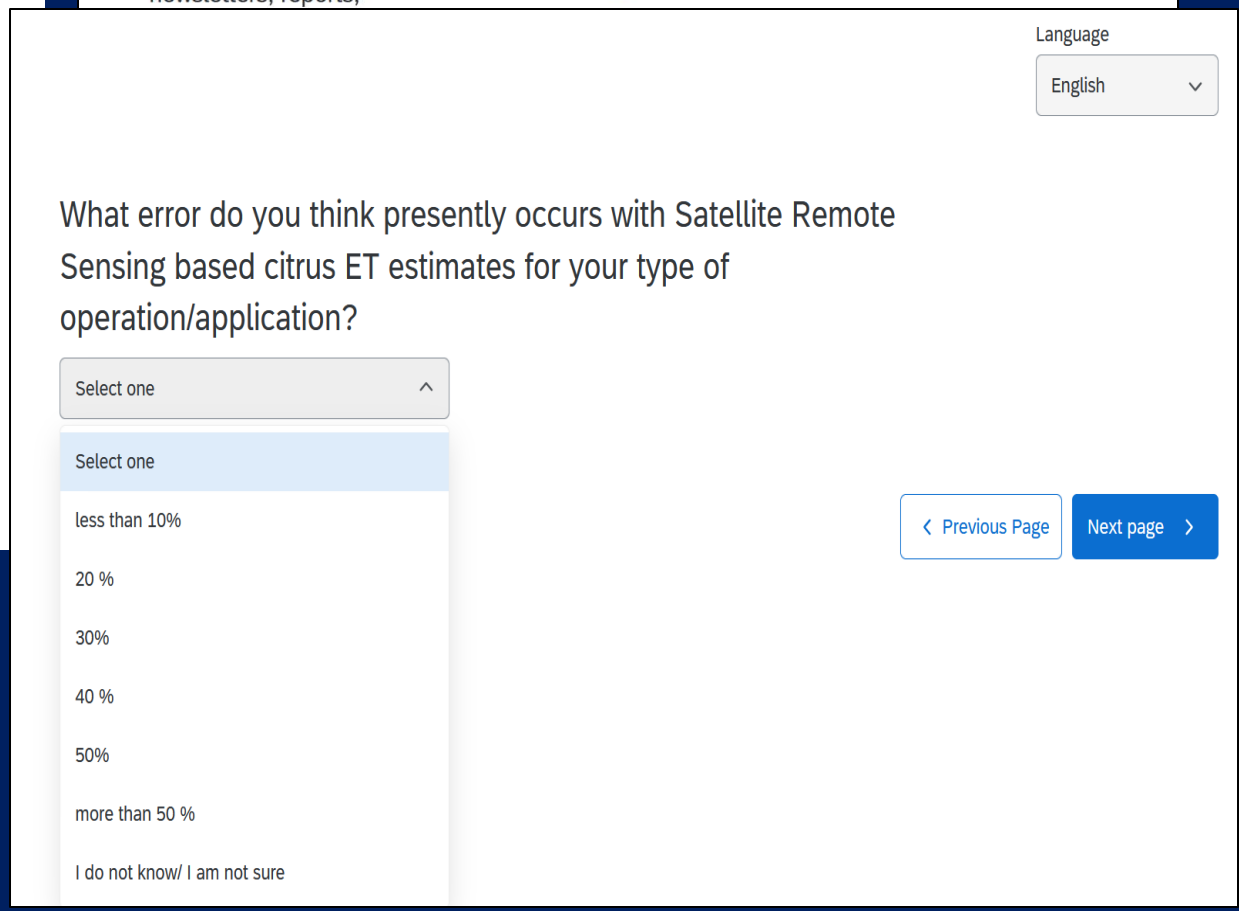
https://ucanr.co1.qualtrics.com/jfe/form/SV_e9h0Mw2UNqIeEZM

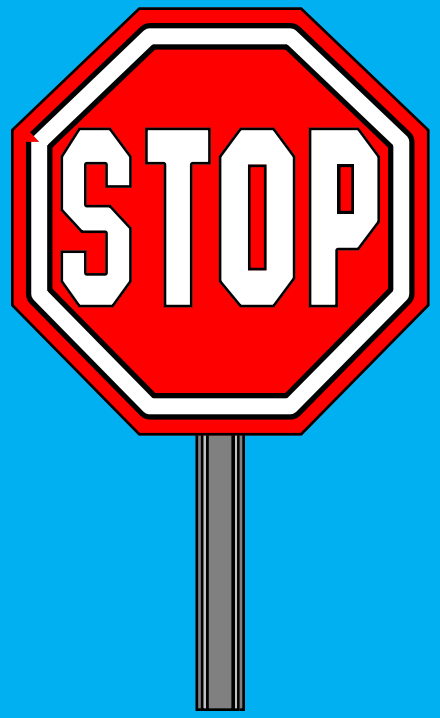
EXPECTED OUTCOMES










STOP

UC DAVIS COLLEGE OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES

COTH2O Consorcio Tecnológico del Agua

UNIVERSITY OF CALIFORNIA Agriculture and Natural Resources

2026 ADVANCED SCHOOL ON

MICROIRRIGATION FOR CROP PRODUCTION

NEW DATES!

CLASS LECTURES: MARCH 30 - APRIL 1
FIELD TRIPS: APRIL 2 - 3

Class lectures will be held in the UC Davis Conference Center. Field trips will be in the San Joaquin Valley and Central Coast of California.

ATTENDING THIS SCHOOL WILL PROVIDE:

- 3 days of practical class lectures on principles and implementation of microirrigation systems and management practices for crop production
- 2 days of field demonstration visits (one day in the San Joaquin Valley for modernized irrigation delivery systems, and fruit and nut crops; one day in the Central Coast for vineyards, vegetable crops, and berries)

QUESTIONS? PLEASE CONTACT US:

- **Daniele Zaccaria - UC Davis:** dzaccaria@ucdavis.edu
- **Mary Ann Dickinson:** maryann@dickinsonassociates.com

Instructors of the School are professionals with extensive experience on principles and practical applications of microirrigation for resource-efficient crop production.

WHAT YOU WILL LEARN:

- Technical aspects of water delivery systems to allow for successful adoption and management of microirrigation systems
- Soil-water movement and soil-plant-water relations with microirrigation
- Microirrigation systems design, operation, maintenance, automation, and performance evaluation
- Methods and tools for microirrigation scheduling
- Managing microirrigation for different crops (field and agronomic crops; vegetable crops; berry crops; fruit crops; nut crops; vineyards)
- Chemigation and fertigation
- Salinity management with microirrigation

MARCH 30 – APRIL 3, 2026
UC DAVIS

3 DAYS OF PRACTICAL CLASS LECTURES
+
2 DAYS OF FIELD/DEMONSTRATION VISITS

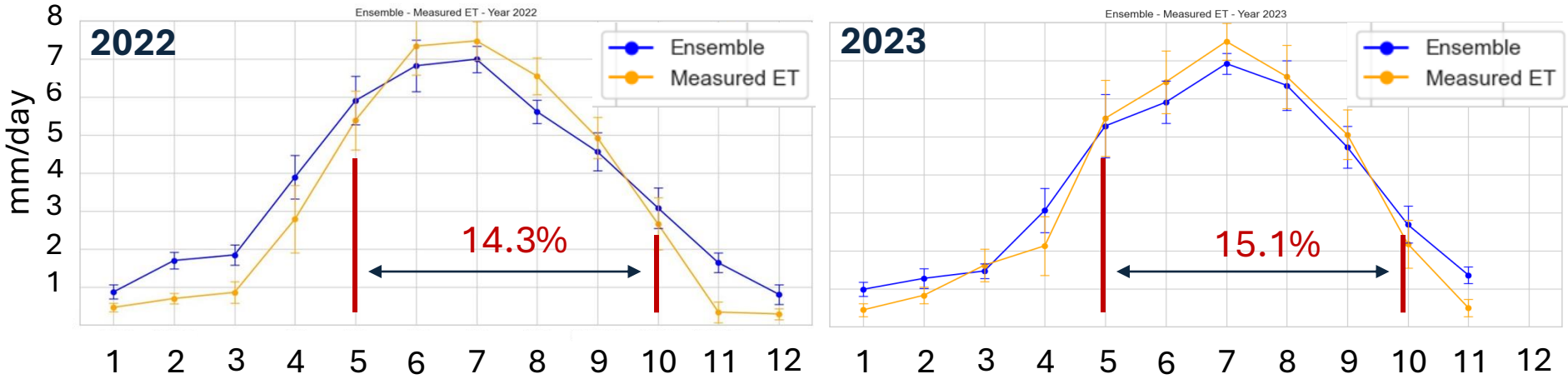
- ✓ CERTIFICATE OF COMPLETION
- ✓ ENDORSED BY THE IRRIGATION ASSOCIATION
- ✓ CEU CREDITS PROVIDED BY THE CAL-ASA
- ✓ CEU CREDIT HOURS FROM I.A.

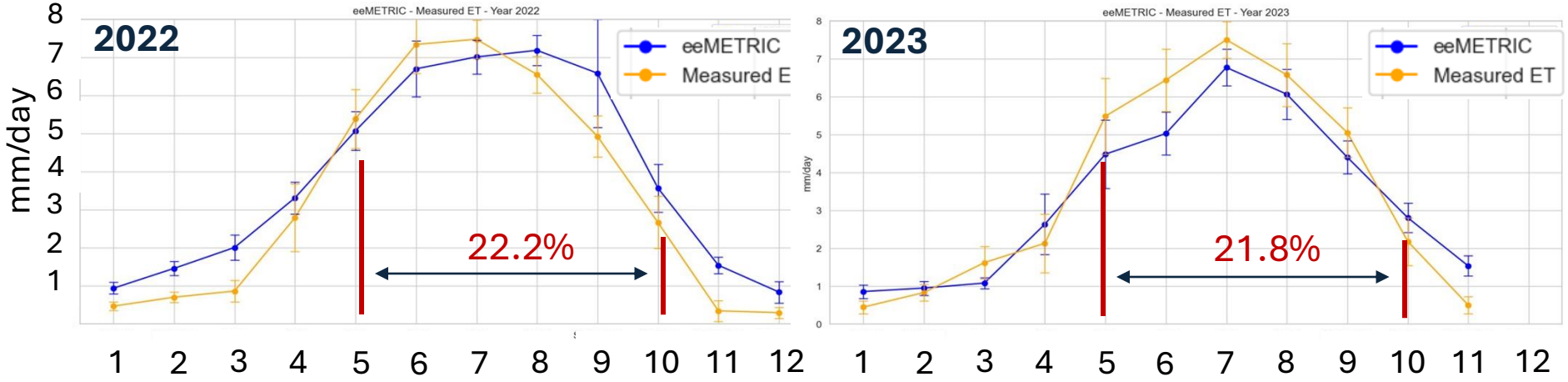
Home J Ranch (Tulare)

Non-saline Orchard

~ 76% F_{cc}

Monthly ET (NRMSE on May-Oct)





Ake Ranch (Tulare)

Salt-affected Orchard

~ 55% F_{cc}

Monthly ET (NRMSE on May-Oct)