UC Cooperative Extension | University of California Agriculture and Natural Resources

Using Forecast ETo for Prospective Irrigation Scheduling

Avocado Café – September 20, 2022

Understanding Irrigation – Part 4: Irrigation Scheduling

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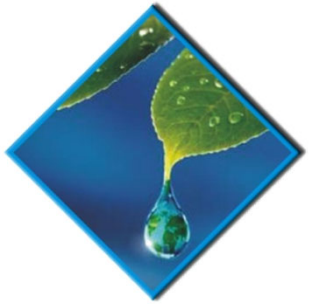
PRESENTATION OUTLINE

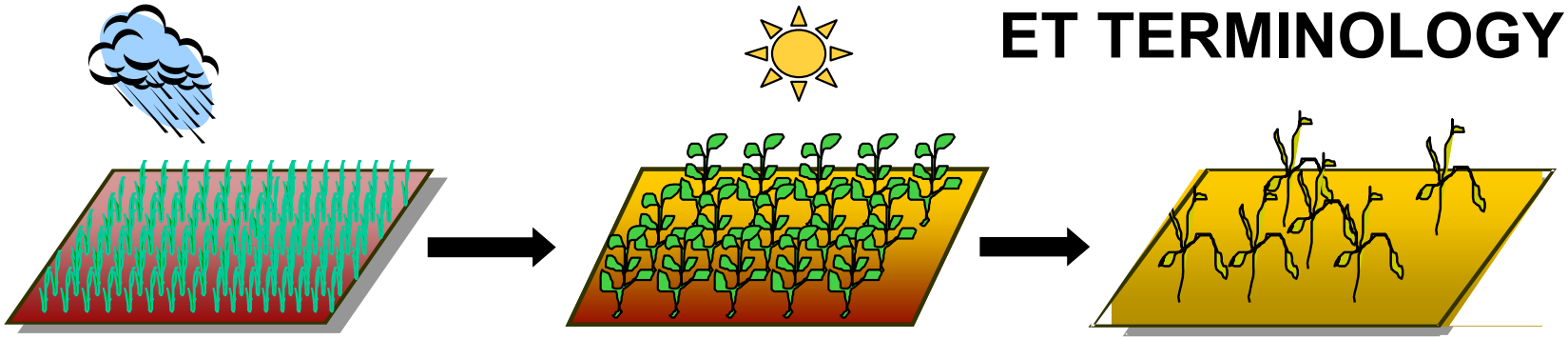


1) Background Info on Evapotranspiration Terminology

2) ETo Products available to support Irrigation Management

3) Validation of Forecast ETo vs. CIMIS ETo across California

ET TERMINOLOGY



Reference

ET_o

Energy-limited evapotranspiration of a short canopy grass having a height of 4.7 in. (0.12 m), which is similar to a well-watered pasture

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma\left(\frac{900}{T+273}\right)u_2(e_s - e)}{\Delta + \gamma(1 + 0.34u_2)}$$

ASCE – EWRI, 2005

Potential

ET_c

Energy Limited

$ET_c = ET_o \times K_c$

Actual

ET_a

Water Limited

$ET_a = ET_c \times K_s$

RATIONALE FOR OPTIMAL IRRIGATION SCHEDULING

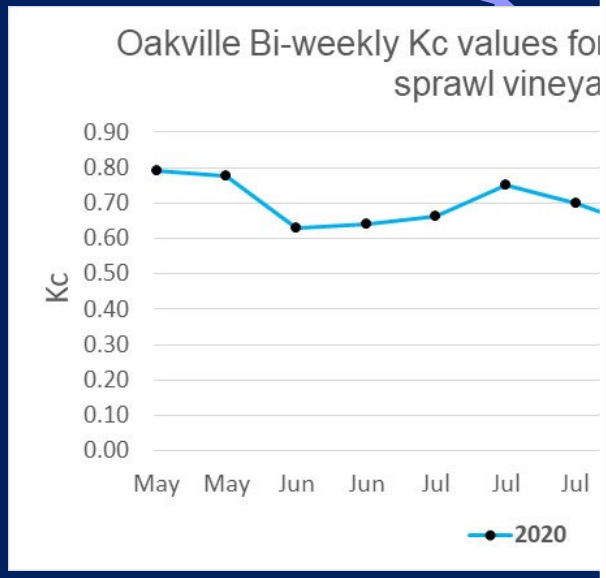
IRRIGATE ACCORDING TO CROP CONSUMPTIVE WATER USE (ETc)

Crop ET = Reference ET x Crop Coefficient

WELL-WATERED CONDITIONS

ETc = ETo x Kc => (Kc = ETc/ETo)

CIMIS
CALIFORNIA DEPARTMENT OF WATER RESOURCES



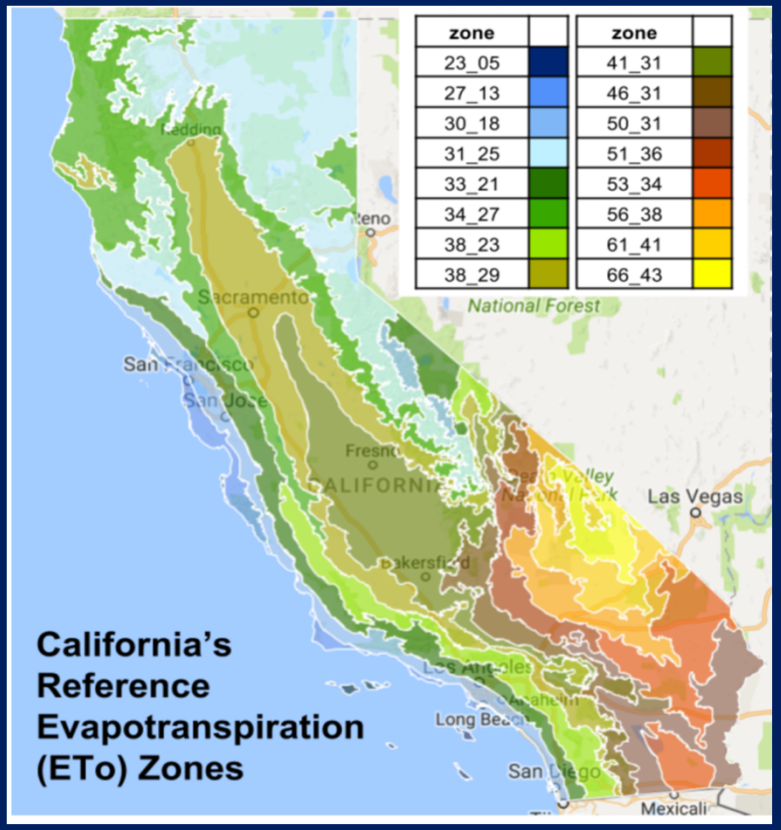
Year 2020	Bi-weekly Kc
5/6/2020	0.79
5/20/2020	0.78
6/3/2020	0.63
6/17/2020	0.64
7/1/2020	0.66
7/15/2020	0.75
7/29/2020	0.70
8/12/2020	0.63
8/26/2020	0.55
9/9/2020	0.62
9/23/2020	0.54
10/7/2020	0.47
10/21/2020	0.44

AVAILABLE ETo INFORMATION FOR IRRIGATION MANAGEMENT

CIMIS NETWORK - STATEWIDE COVERAGE

2005 (~ 60 ETo stations)

2017 (152 ETo stations)




https://cimis.water.ca.gov/
Welcome RICK Logoff | Accoun
CIMIS
CALIFORNIA IRRIGATION MANAGEMENT INFORMATION SYSTEM
CALIFORNIA DEPARTMENT OF WATER RESOURCES
HOME
STATIONS
DATA
SPATIAL
RESOURCES
CIMIS Station Reports
CIMIS Station Reports | FTP Reports | My Reports | Preferences
1. Select report style and date range
More Info?
Create a Daily CSV Report in Metric Units from 7/1/2018 to 7/8/2018
2. Select one-to-many stations. Click on Column headers to sort
Id Name Region County Status Connect Disconnect
002 FivePoints San Joaquin Valley Fresno Active 6/7/1982 ---
005 Shafter San Joaquin Valley Kern Active 6/1/1982 ---
006 Davis Sacramento Valley Yolo Active 7/17/1982 ---
007 Firebaugh/Telles San Joaquin Valley Fresno Active 9/22/1982 ---
012 Durham Sacramento Valley Butte Active 10/19/1982 ---
013 Camino Sierra Foothill El Dorado Active 10/19/1982 ---
Sensor
Average Relative Humidity
ETo
Penman-Monteith ETo
Penman-Monteith ETr
Dew Point
Wind Run
3. Advanced settings (optional)
Show Inactive Stations (scroll to bottom of list)
Select Sensors
Zip Code(s)
Run Report

Station List

HOME | STATIONS | DATA | SPATIAL | RESOURCES

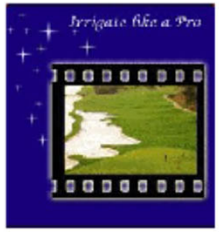
Notice

To get access to all of the CIMIS data and features, register as a user.

The link to register is at the upper right-hand corner of the CIMIS web page.

Station List | Station Location Map | Sting | Sensors | Maintenance

Click on the "+" arrows below to see details of each CIMIS station. Details of location, station siting, history, and zip codes are included. Click the downward arrow "V" to collapse the station details. Select the headers to sort by column. Note: page size and forward and back arrows are also at the bottom of the table.



Station Id	Name	County	Status
1	Fresno/F.S.U. USDA	Fresno	Inactive
2	FivePoints	Fresno	Active
3	Beach /Santa Cruz CO	Santa Cruz	Inactive
4	Webb /Santa Cruz CO	Santa Cruz	Inactive
5	Shafter	Kern	Active
6	Davis	Yolo	Active
7	Firebaugh/Telles	Fresno	Active
8	Gerber	Tehama	Inactive
9	Lamont	Kern	Inactive
10	Bakersfield/Greenlee	Kern	Inactive
11	Bakersfield/Bonanza	Kern	Inactive
12	Durham	Butte	Active
13	Camino	El Dorado	Active
14	Orland	Glenn	Inactive
15	Stratford	Kings	Active
16	San Juan	Monterey	Inactive
17	El Centro	Imperial	Inactive
18	Westmorland	Imperial	Inactive
19	Castroville	Monterey	Inactive
20	Corcoran	Kings	Inactive

1 2 3 4 5 6 7 8 9 10 ... Page size: 20 264 items in 14 pages

Station Map

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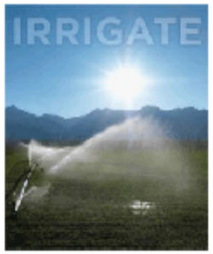
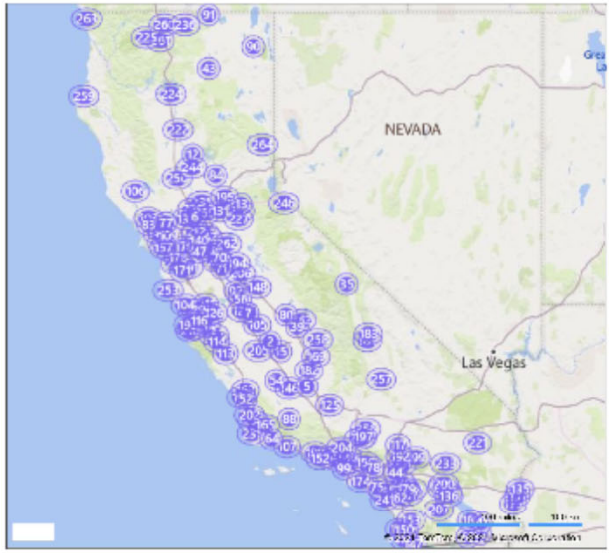
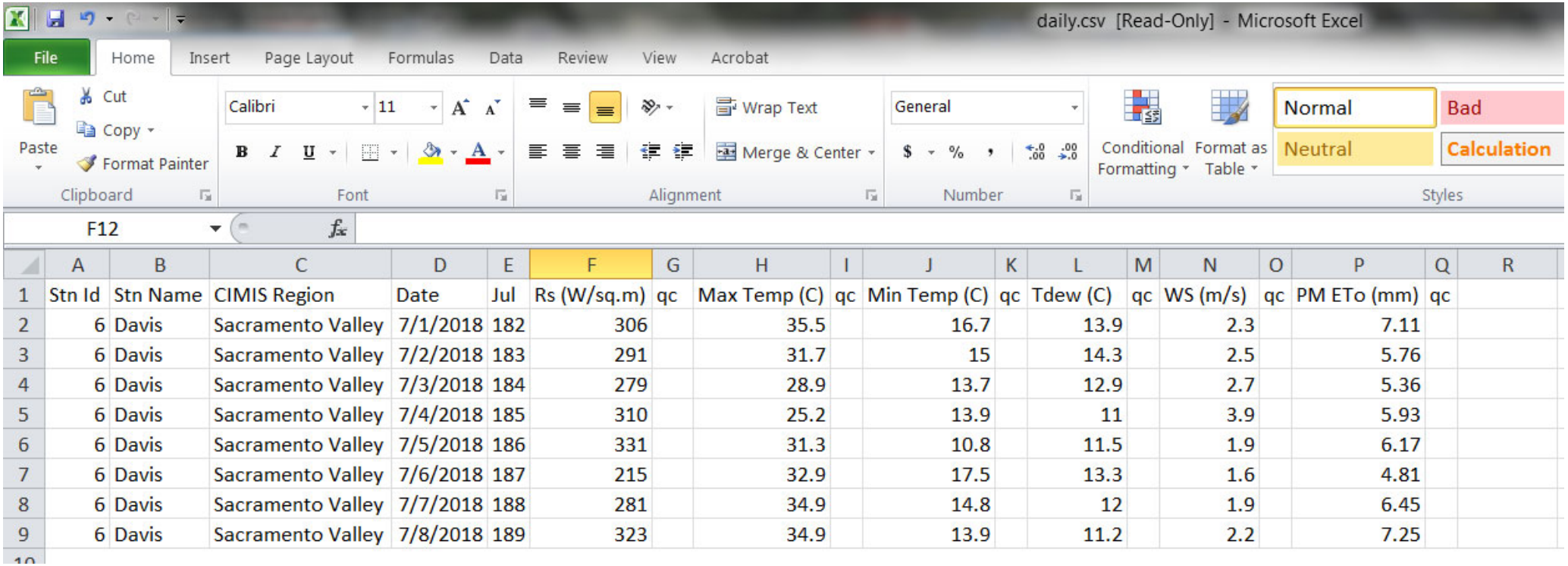
Station List | Station Location Map | Sting | Sensors | Maintenance

This Sting Map shows CIMIS station coordinate points. You can zoom in and out to see the exact station locations. Click the station marker for more detailed information.

(•) Active Stations
( ) Inactive Stations



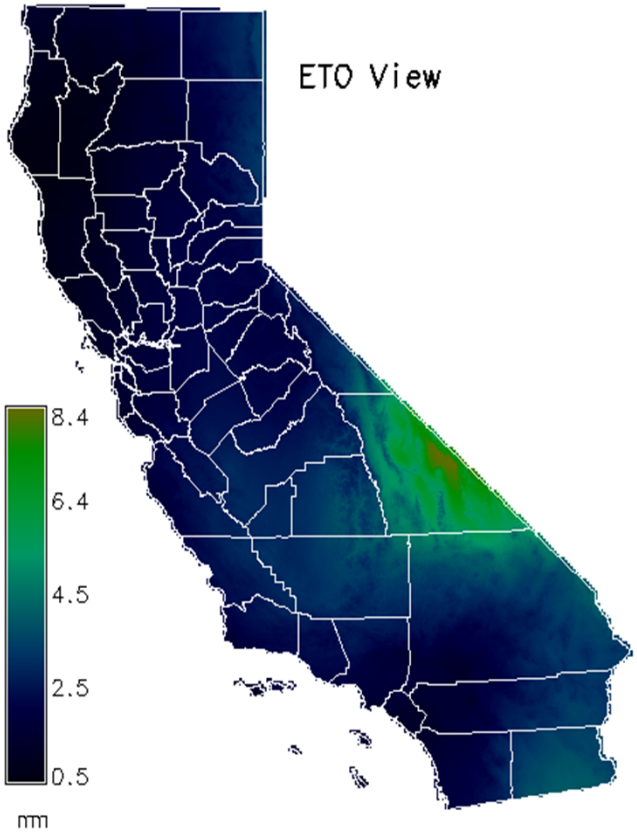




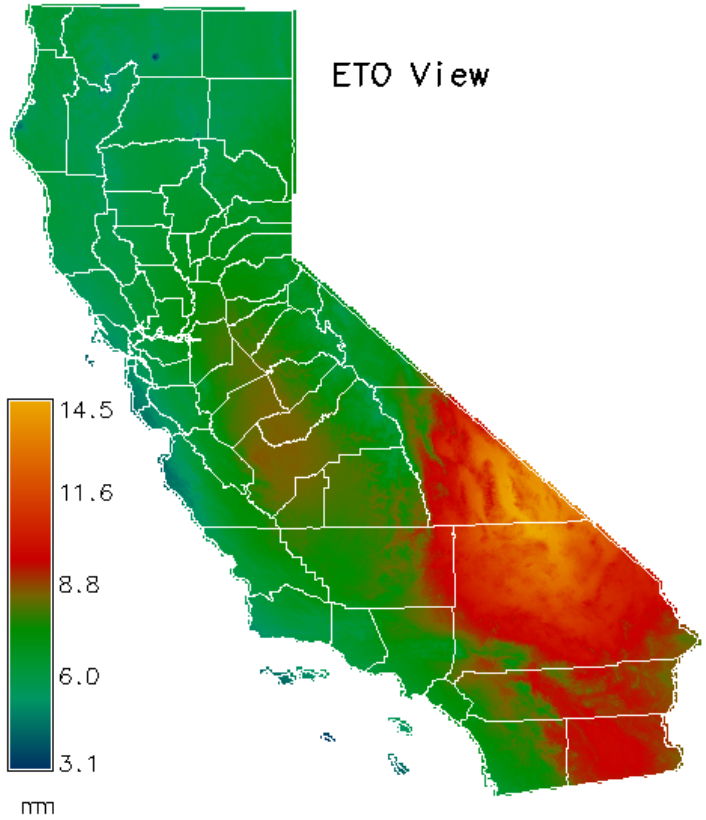
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Stn Id	Stn Name	CIMIS Region	Date	Jul	Rs (W/sq.m)	qc	Max Temp (C)	qc	Min Temp (C)	qc	Tdew (C)	qc	WS (m/s)	qc	PM ETo (mm)	qc	
2	6	Davis	Sacramento Valley	7/1/2018	182	306		35.5		16.7		13.9		2.3		7.11		
3	6	Davis	Sacramento Valley	7/2/2018	183	291		31.7		15		14.3		2.5		5.76		
4	6	Davis	Sacramento Valley	7/3/2018	184	279		28.9		13.7		12.9		2.7		5.36		
5	6	Davis	Sacramento Valley	7/4/2018	185	310		25.2		13.9		11		3.9		5.93		
6	6	Davis	Sacramento Valley	7/5/2018	186	331		31.3		10.8		11.5		1.9		6.17		
7	6	Davis	Sacramento Valley	7/6/2018	187	215		32.9		17.5		13.3		1.6		4.81		
8	6	Davis	Sacramento Valley	7/7/2018	188	281		34.9		14.8		12		1.9		6.45		
9	6	Davis	Sacramento Valley	7/8/2018	189	323		34.9		13.9		11.2		2.2		7.25		

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

Oct. 18, 2015



June 20, 2016



Quinn Hart & Susan Ustin
UC Davis - LAWR Dept.

SPATIAL CIMIS

ET_o (2-km grid)

Inputs:

- CIMIS
- Remote sensing
- Topography

http://www.cimis.water.ca.gov/SpatialData.aspx

Spatial CIMIS

HOME | STATIONS | DATA | SPATIAL | RESOURCES

Spatial Overview | Spatial Maps | Spatial Report | Schedule Spatial Report

Spatial Report

This report provides daily ETo and Solar Radiation data at a 2 km resolution. Spatial Report data covers from 2/20/2003 to yesterday's date. Reports are available in several data formats and in English or Metric units. You may specify date ranges and zip codes, map coordinate points, or data search by address. Bing Map tools to center the page on California, recall previously selected points, and clear selected points are also available at the bottom-right.

Create a CSV Report in English Units from 1/21/2019 to 1/27/2019 using Coordinate List

Run Report

Address Search

Search to add locations to the coordinate list or double-click the map interface. (ex: 1315 10th St, Sacramento, CA 95814)

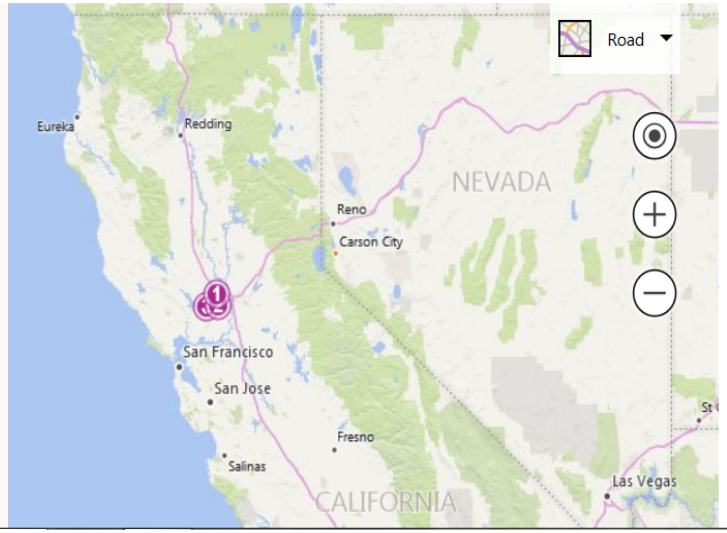
address, city, state zip-code

Search

Coordinate List

You must click the "Save Coordinates" button to keep your selection in your coordinate list.

1. 1 Main St, Woodland, CA 95695(38.6776,
2. 1 Shields Ave, Davis, CA 95616(38.5398, -
3. 1 Main St, Winters, CA 95694(38.5220, -12
4. (empty)



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Spatial Overview Spatial Maps Spatial Reports Login

Spatial Overview

The California Irrigation Management Information System (CIMIS) currently manages over 145 active weather stations throughout the state. Archived data is also available for 85 additional stations that have been disconnected from the network for various reasons. Most of the CIMIS stations produce estimates of reference evapotranspiration (ETo) for the station location and their immediate surroundings, often in agricultural areas. Because of California's diverse landmass and climate, many locations within the state lack a representative CIMIS station. Some counties, for example, do not have a CIMIS station and others have only one or two stations. As a result, there are significant spatial ETo data gaps, especially in urban areas. In an attempt to mitigate this problem, CIMIS initiated a study to investigate the possibility of coupling remotely sensed satellite data with point measurements from the CIMIS weather stations to generate spatially distributed ETo values (ETo maps).

A contract was awarded to the University of California Davis (UCD) remote sensing group, lead by Professor Susan Ustin, to conduct the study. The Department of Water Resources (DWR) formed an advisory committee comprised of individuals with expertise in remote sensing, GIS, modeling, and water management from DWR and UCD. The committee met, on an as needed basis to discuss new developments and plan future actions. After thorough research, the team decided to use combinations of data derived from satellites and interpolated from CIMIS station measurements to estimate ETo at a 2 kilometer (km) spatial resolution. The resulting product has been vigorously tested and has demonstrated a degree of accuracy that is acceptable for most irrigation applications. The CIMIS program will continue to evolve and expand to meet the future irrigation information needs of California. For a brief description of the methodology used to generate the ETo maps, see the Spatial Model discussion below.

Spatial Model

Daily reference evapotranspiration (ETo) at a 2 km spatial resolution are calculated statewide using the American Society of Civil Engineers version of the Penman-Monteith equation (ASCE-PM). Required input parameters for the ASCE-PM ETo equation are solar radiation, air temperature, relative humidity, and wind speed at two meters height. These parameters are estimated for each 2 km pixel using various methods.

Daily solar radiation is generated from the visible band of the National Oceanic and Atmospheric Administration's (NOAA) Geostationary Operational Environmental Satellite (GOES) using the Heliosat-II model. This model is designed to convert images acquired by the Meteosat satellite into maps of global (direct plus diffused) irradiation received at ground level. The model has also been used with other geostationary satellites such as the GOES. For details on the Heliosat-II model and its accuracy, please refer to the HelioClim web page.

Interpolation

Air temperature, relative humidity, and wind speed values at each pixel were obtained by interpolating point measurements from CIMIS stations. Originally two interpolation methods, Spline and DayMet, were selected based on accuracy of results, code availability, and computational efficiency. Spline – the method currently used – is an interpolation method that fits a surface through or near known points using a function with continuous derivatives. Two- or three-dimensional Spline is used based on which weather parameter is to be interpolated.

The accuracy of both methods has been tested using cross-validation analysis, but DayMet is no longer used. DayMet is an interpolation method that was developed at the University of Montana to generate daily surfaces of temperature, precipitation, humidity, and radiation over large regions of complex terrain. It determines the weights associated with a given weather station for each point where weather parameters are to be determined depending on the distance and density of the stations.

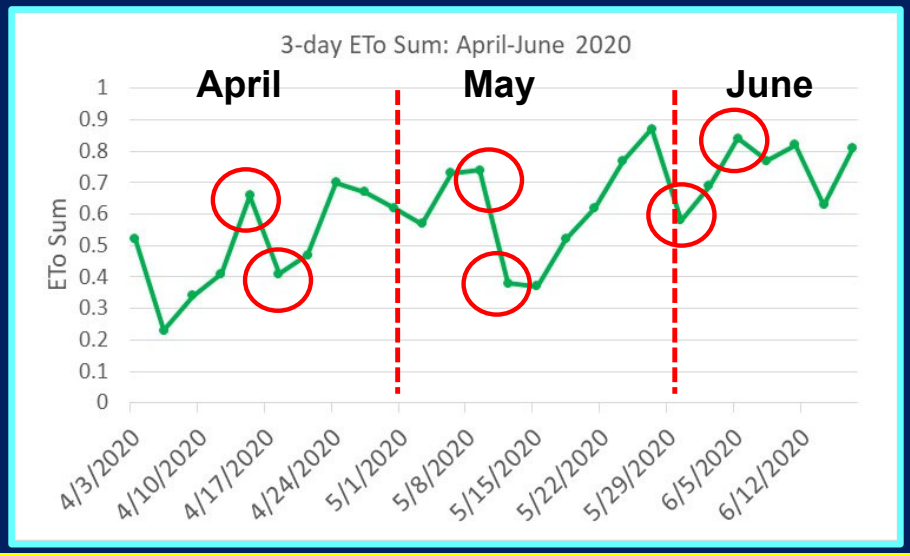
The accuracy of ETo values estimated from these methods depends on many factors. For example, solar radiation remotely sensed through GOES is significantly affected by such factors as cloudiness and snow cover. Therefore, mountainous areas with snow cover and coastal areas with cloud and fog are more susceptible to errors. Also, interpolation accuracy is affected by the density of the weather stations and geographic features of the region. CIMIS stations are purposely placed in irrigated, open, flat areas – usually valleys – to provide the best reference data for adjacent farmlands and other irrigated areas. As a result, interpolation in valleys between CIMIS stations may not provide accurate data for mountainous terrain. Despite these potential problems, however, we believe the ETo estimates provided will be superior to only using data from a distant weather station with a different microclimate. For CIMIS station Siting criteria click the "Siting" tab.

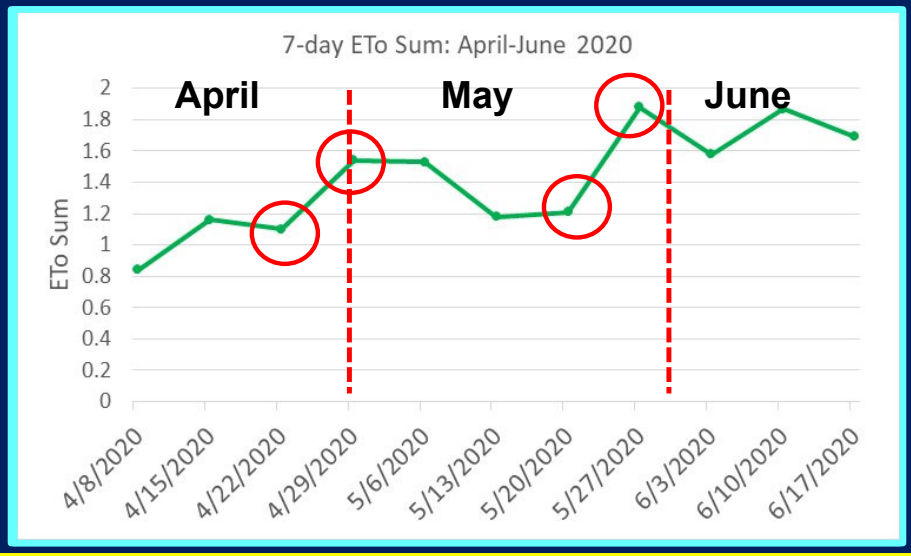
Further Details

For detailed descriptions of the methodology used to map daily ETo, refer to the RESOURCES navigation button above, click on the Publications tab, select Other Published Articles, and then select the pdf file named "**Daily reference evapotranspiration for California using satellite**

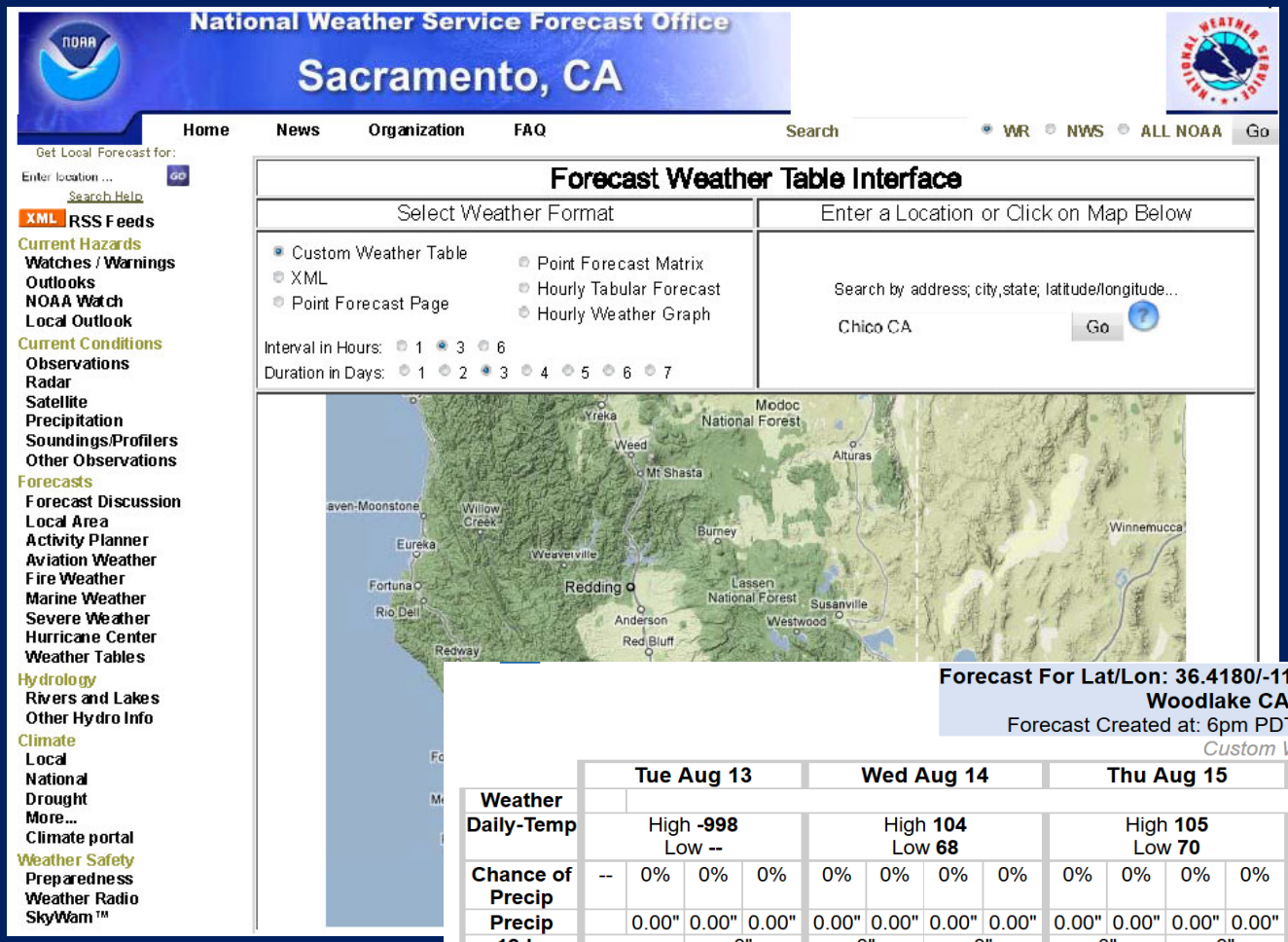
ETo data from CIMIS are considered near real-time, but they are retrospective when it comes to scheduling water deliveries (districts) and on-farm irrigation

- ✓ This basically means that ETo data from the period just past (1 day, 3 day, 1-week, 2-week) are used for scheduling water delivery to growers and/or irrigation for the next period ahead.
- ✓ For many locations in California there are periods of the year when the weather conditions vary a lot from day to day, or every 2-3 days, and from week to week **(Ex. Napa Valley)**.





If we use a retrospective ETo, we may run the risk of over-irrigating or under-irrigating the crop during times/stages that may be sensitive for fruit yield and quality.



FRET ETo is a NSW product.

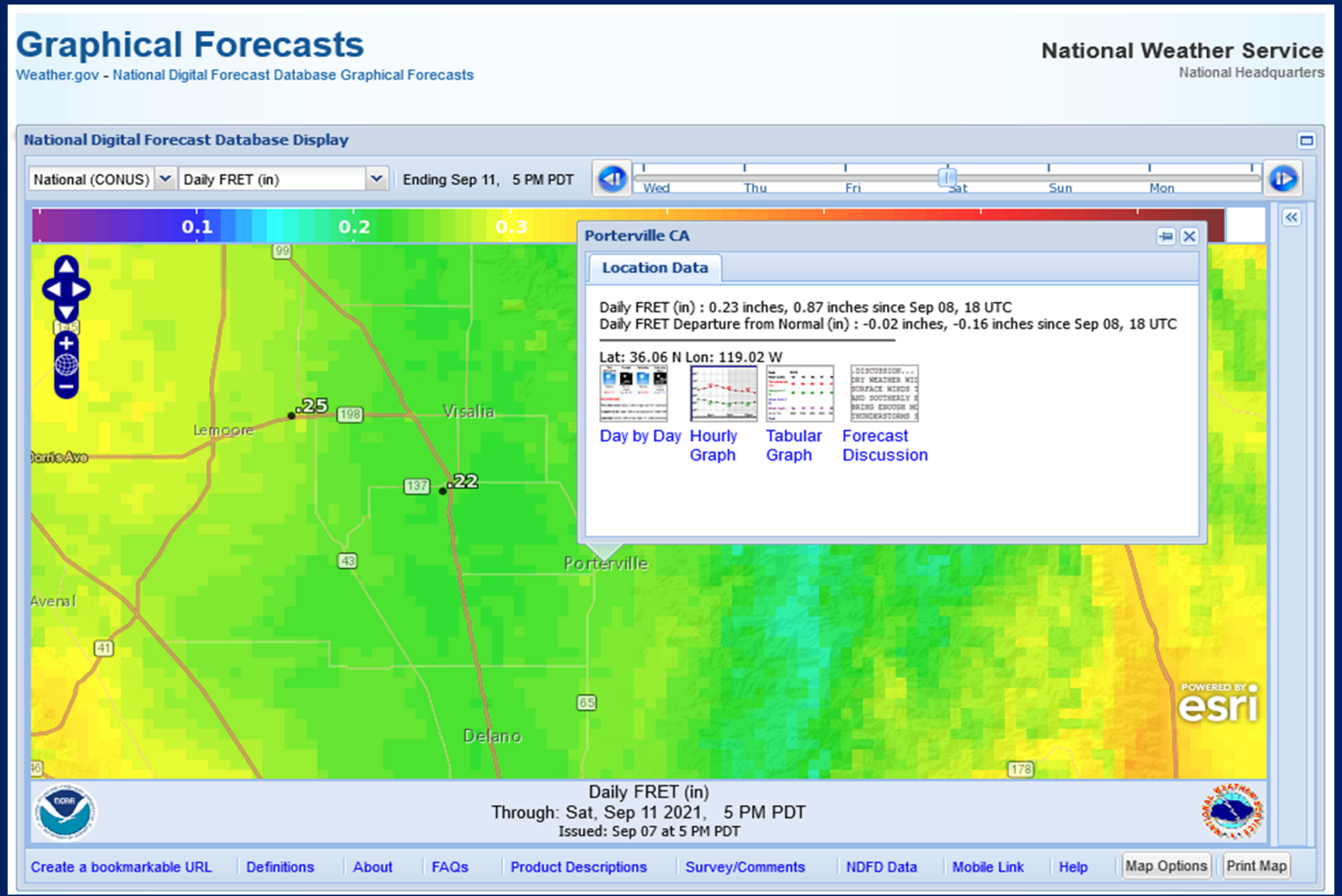
It was developed in 2008 collaboratively by UC Davis, DWR and NWS to improve high-frequency irrigation management and encourage the adoption of ET-based scheduling in CA

FRET ETo forecasts are now available for up to 7-day lead for the entire continental US

Forecast For Lat/Lon: 36.4180/-119.0920 (Elev. 472 ft)
Woodlake CA
Forecast Created at: 6pm PDT Aug 13, 2019

Custom Weather Forecast Table

	Tue Aug 13				Wed Aug 14				Thu Aug 15				Fri Aug 16				Sat Aug 17				Sun Aug 18			
Weather																								
Daily-Temp	High **-998** Low **--**				High **104** Low **68**				High **105** Low **70**				High **104** Low **71**				High **97** Low **68**				High **94** Low **63**			
Chance of Precip	--	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Precip		0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.0
12-hr Snow Total	--		0"		0"		0"		0"		0"		0"		0"		0"		0"		0"		0"	
FRET	-999"				0.24"				0.26"				0.25"				0.23"				0.21"			
Snow Ratio		2	2	2	2	2	1	1	1	2	1	1	1	1	0	0	0	0	0	0	1	1	1	1
6-Hour	5am	11am	5pm	11pm	5am	11am	5pm	11pm	5am	11am	5pm	11pm	5am	11am	5pm	11pm	5am	11am	5pm	11pm	5am	11am	5pm	11p
Temp		89	98	82	71	92	102	84	73	94	103	85	74	94	103	82	70	87	96	76	65	82	93	7


Graphical Forecasts
Weather.gov - National Digital Forecast Database Graphical Forecasts
National Weather Service
National Headquarters
National Digital Forecast Database Display
National (CONUS)
Daily FRET (in)
Ending Sep 11, 5 PM PDT
Wed
Thu
Fri
Sat
Sun
Mon
0.1
0.2
0.3
Porterville CA
Location Data
Daily FRET (in) : 0.23 inches, 0.87 inches since Sep 08, 18 UTC
Daily FRET Departure from Normal (in) : -0.02 inches, -0.16 inches since Sep 08, 18 UTC
Lat: 36.06 N Lon: 119.02 W
Day by Day
Hourly Graph
Tabular Graph
Forecast Discussion
.25
.22
Visalia
Lemoore
Porterville
Delano
Avenal
Daily FRET (in)
Through: Sat, Sep 11 2021, 5 PM PDT
Issued: Sep 07 at 5 PM PDT
Create a bookmarkable URL
Definitions
About
FAQs
Product Descriptions
Survey/Comments
NDFD Data
Mobile Link
Help
Map Options
Print Map

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma\left(\frac{900}{T_m+273}\right)u_2(e_s - e_d)}{\Delta + \gamma(1 + 0.34u_2)}$$

u_2 = mean daily wind speed at 2 m height
e_s = saturation vapor pressure at T_m
e_d = vapor pressure at the mean daily dew point temp T_d

FRET forecasts all the weather variables (Global Forecast System, GFS) needed for the ETo equation except solar radiation.
***R_s* is calculated from forecast daily fraction cloud cov**
***n/N*) and extraterrestrial radiation (*R_a*), which is functio**

VALIDATION WORK

Selected 15 locations across California

Compared the FRET forecast values of individual weather variables against the values measured at CIMIS stations for summer 2019

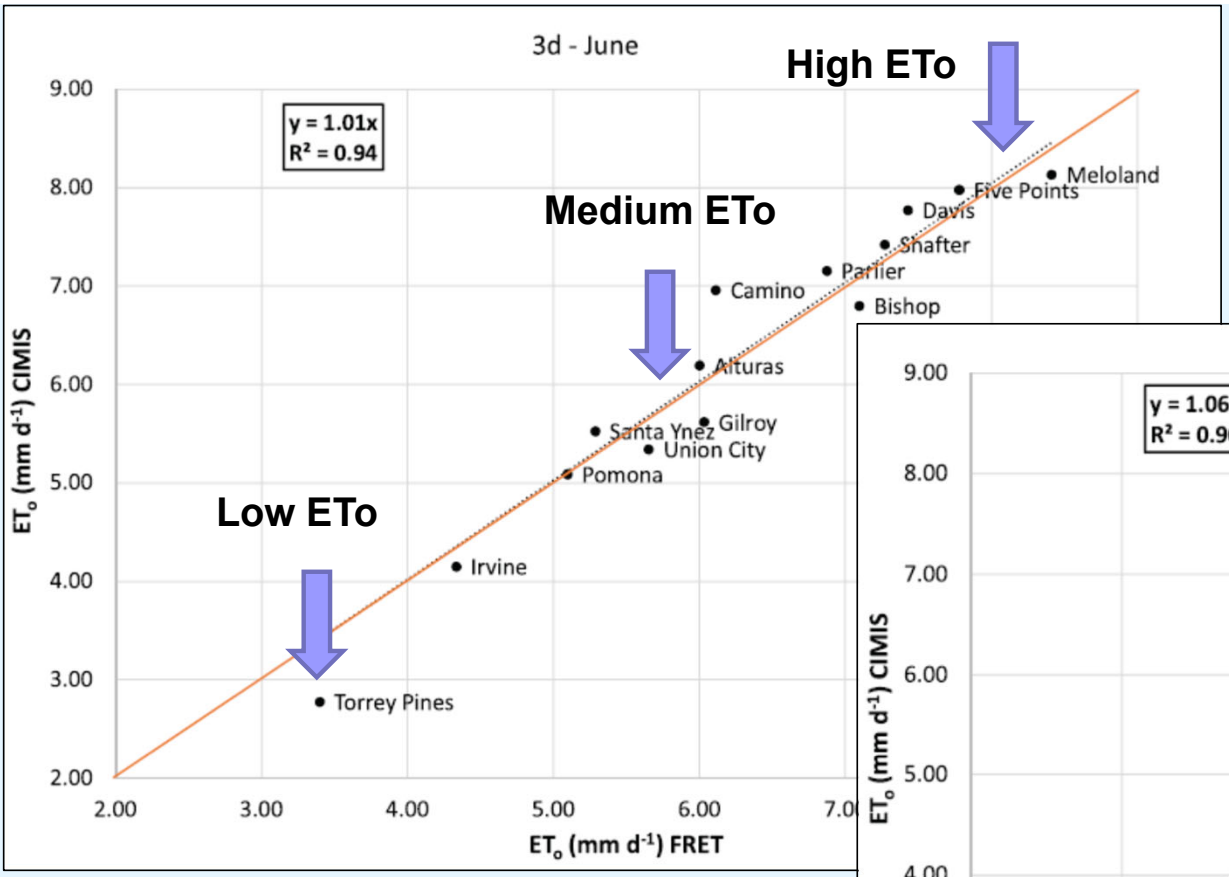
Compared forecast ETo values for 1-, 3-, 5-, 7-day lead against values of ETo calculated at CIMIS stations from observed weather data

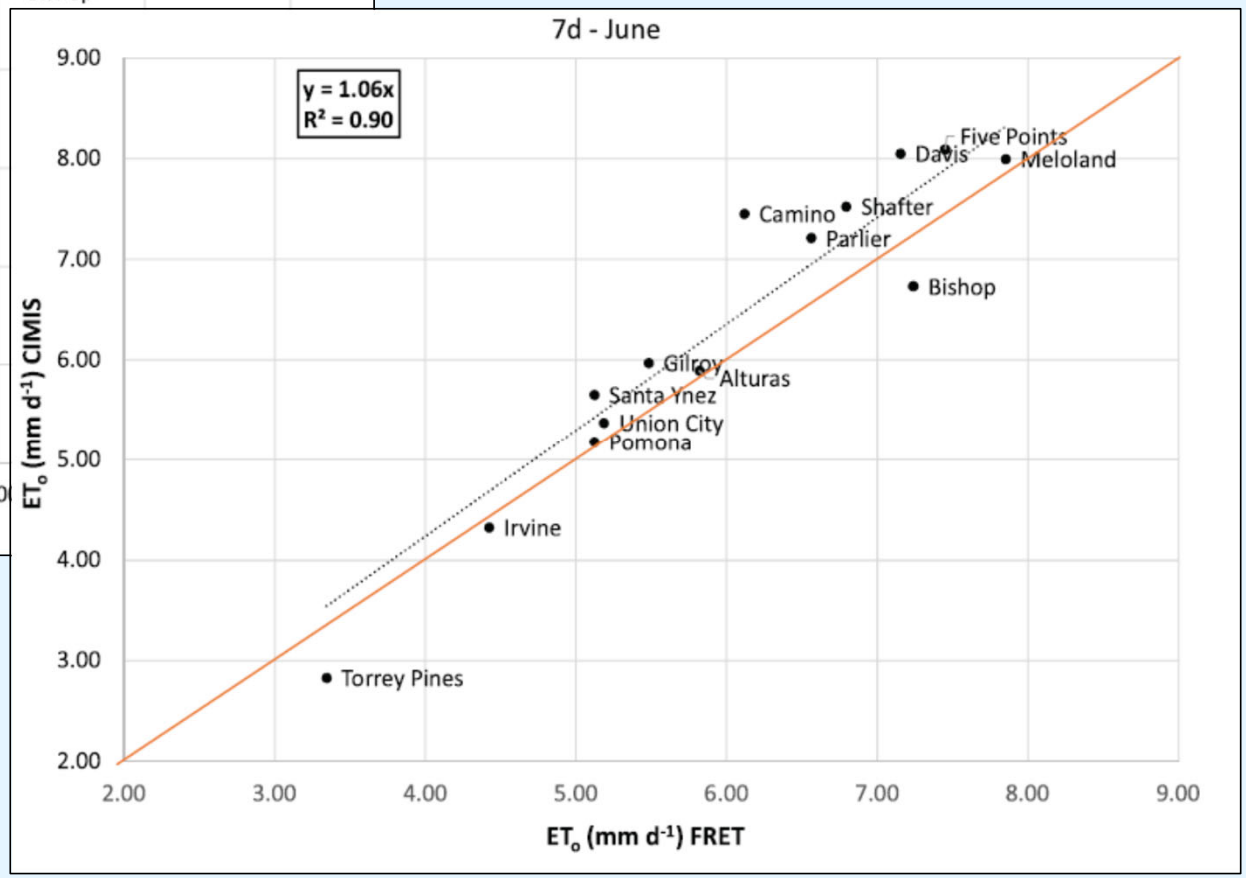
ET_o zone	Station name	Climate class[a]
16	Five Points South West	Semiarid, steppe (BSk)
15	Shafter	Arid low latitude desert (BWh)
14	Davis	Mediterranean/hot summer (Csa)
13	Camino	Mediterranean/hot summer (Csa)
14	Bishop	Semiarid, steppe (BSk)
12	Parlier	Semiarid, steppe (BSk)
3	Santa Ynez	Mediterranean/cool summer (Csb)
4	Irvine	Semiarid, steppe (BSk)
8	Oakville	Mediterranean/cool summer (Csb)
9	Pomona	Mediterranean/hot summer (Csa)
18	Meloland	Arid low latitude desert (BWh)
7	Alturas	Cool continental/dry summer (Dsb)
		Mediterranean/cool summer (Csb)
		iarid, steppe with summer fog (BSkn)
		Mediterranean/cool summer (Csb)

EVALUATE THE PERFORMANCE OF THE FORECASTING MODEL AND THE ACCURACY OF FORECAST ETo

JUNE 2019

Daily forecast ETo vs CIMIS ETo

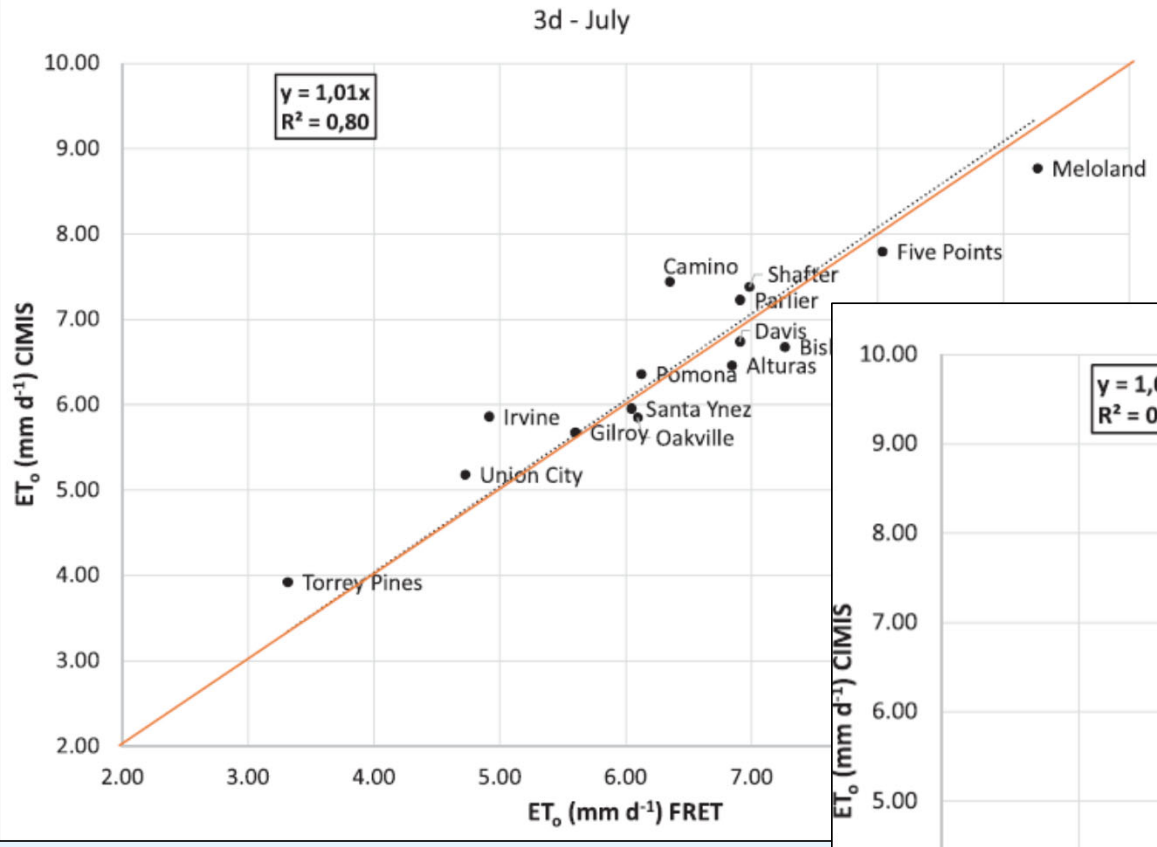


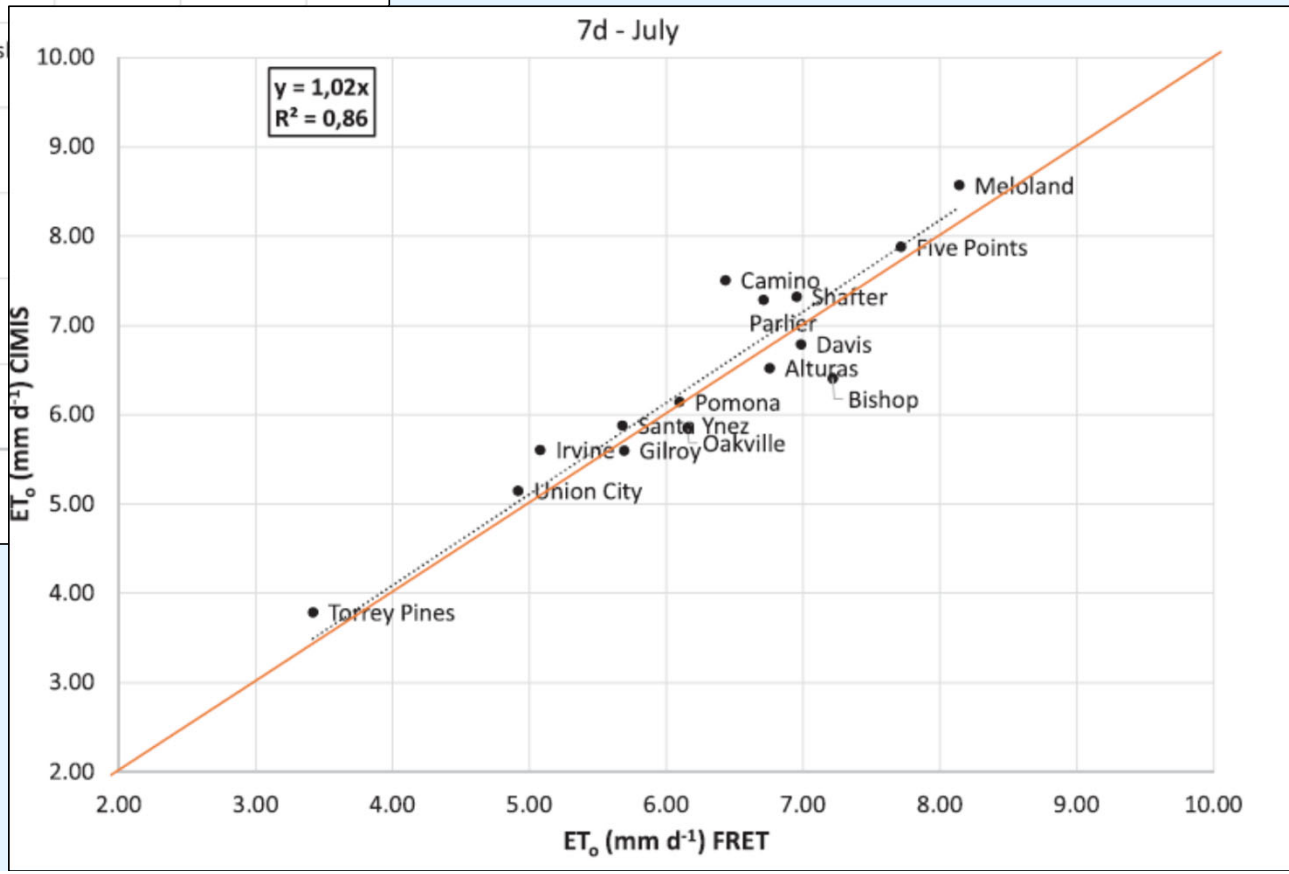


JULY 2019

Daily forecast ETo vs CIMIS ETo

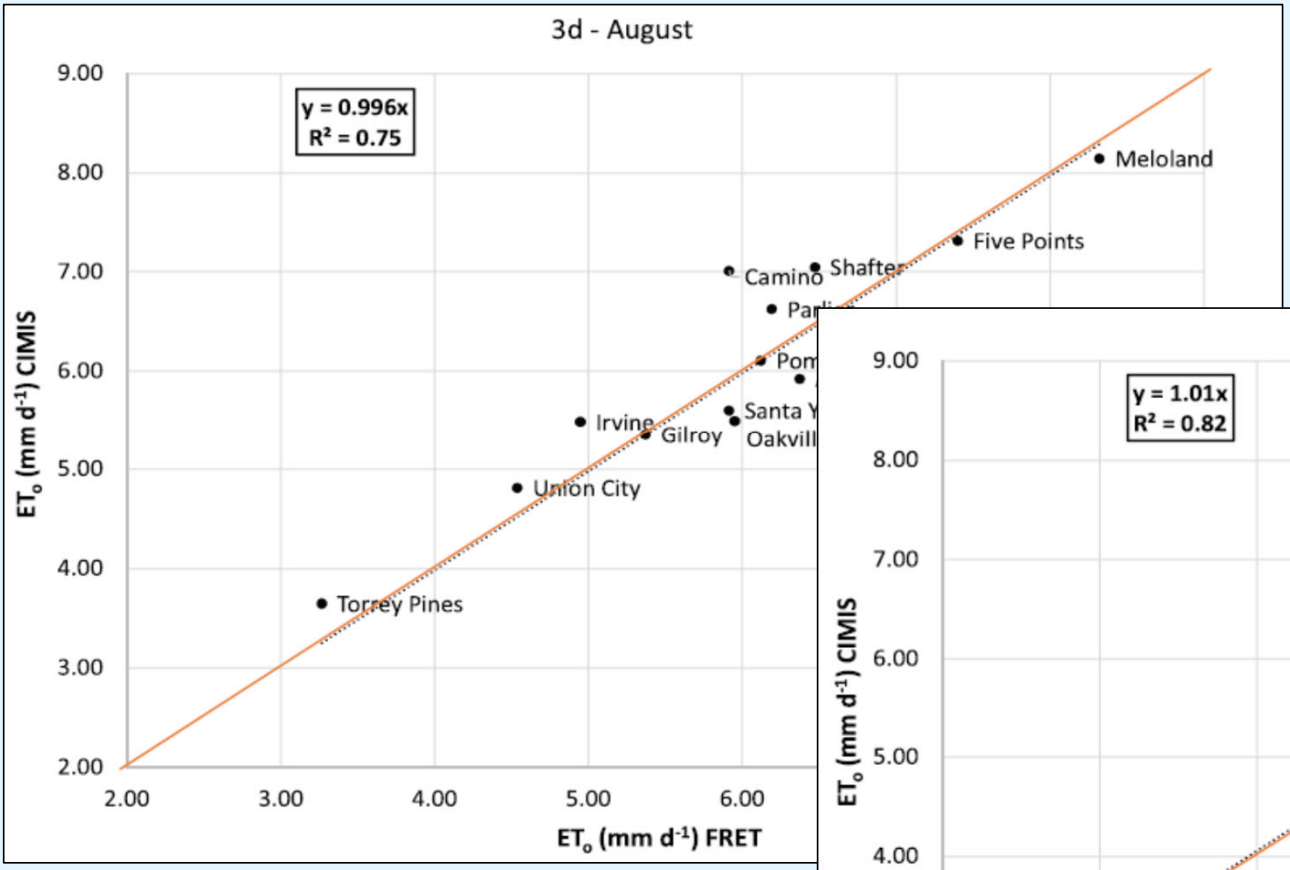
warmest month; highest irrigation requirements

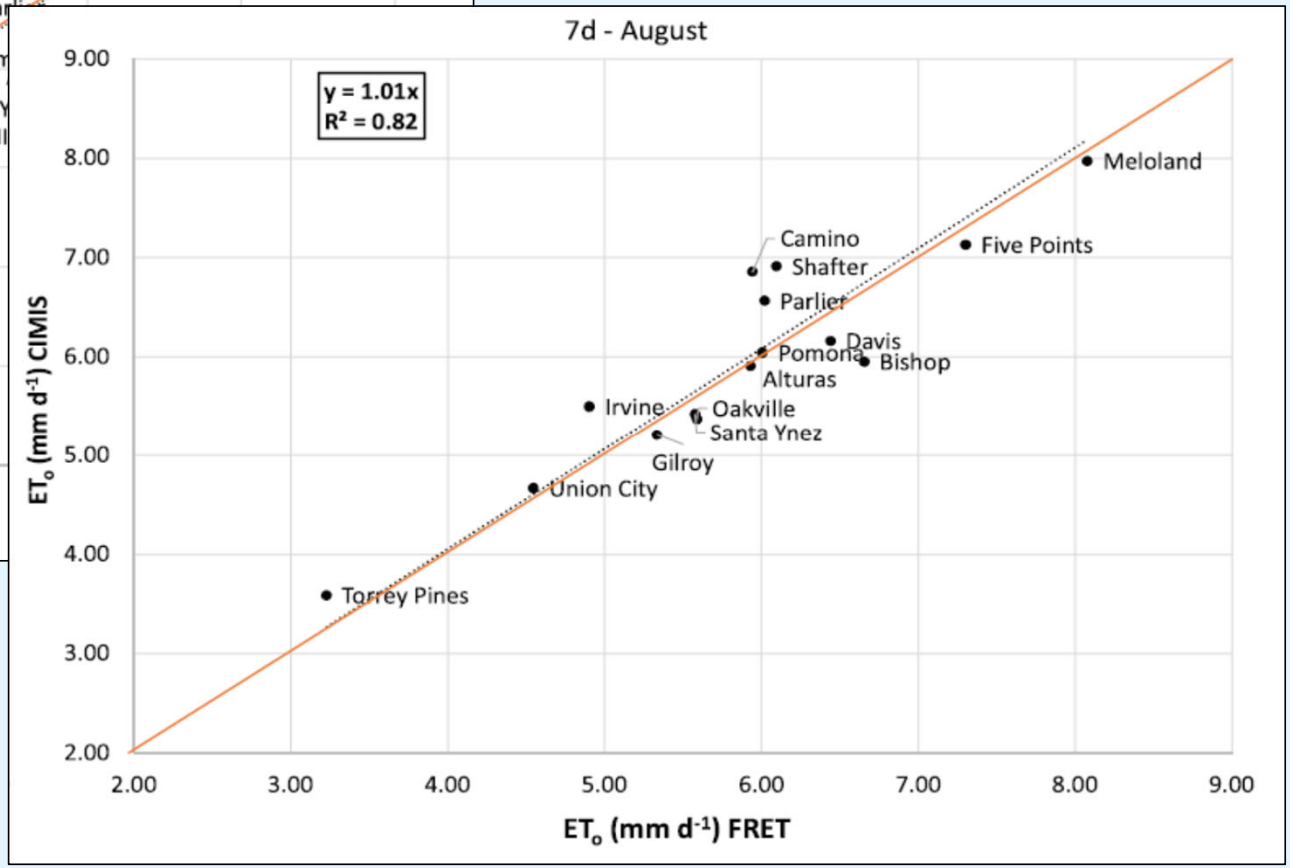




AUGUST 2019

Daily forecast ETo vs CIMIS ETo





			RMSE				R^2			
Site	Sta ID	Name	1d	3d	5d	7d	1d	3d	5d	7d
			(mm)	(mm)	(mm)	(mm)				
1	2	Five Point	0.60	0.60	0.60	0.60	0.99	0.99	0.99	0.99
2	5	Shafter	0.80	0.80	0.80	0.90	0.99	0.99	0.99	0.99
3	6	Davis	0.50	0.70	0.70	0.80	0.99	0.99	0.99	0.99
4	13	Camino	1.10	1.10	1.10	1.20	1.00	1.00	1.00	1.00
5	35	Bishop	1.00	1.20	1.00	1.10	0.99	0.98	0.98	0.98
6	39	Parlier	0.70	0.70	1.00	0.80	0.99	0.99	0.98	0.98
7	64	Santa Yne	0.70	0.70	0.80	0.90	0.99	0.99	0.98	0.97
8	75	Irvine	1.10	1.00	1.00	1.00	0.96	0.97	0.97	0.97
9	77	Oakville	0.50	0.60	0.60	0.60	0.99	0.99	0.99	0.99
10	78	Pomona	0.80	0.60	0.80	0.80	0.99	0.99	0.98	0.99
11	87	Meloland	1.50	1.50	1.70	1.40	0.97	0.97	0.96	0.97
12	90	Alturas	0.60	0.80	0.60	0.70	0.99	0.98	0.99	0.98
13	171	Union City	0.70	0.70	0.60	0.70	0.98	0.98	0.99	0.98
14	173	Torrey Pin	0.90	1.00	0.90	0.80	0.95	0.94	0.93	0.95
15	211	Gilroy	0.60	0.80	0.90	1.00	0.99	0.98	0.98	0.97

Root Mean Square Error (RMSE) and Coefficient of Determination (R^2) values obtained from comparing FRET ETo versus CIMIS ETo using 1-, 3-, 5-, and 7-day forecasts for 78 days during the Summer of 2019.

CONCLUSIVE REMARKS

- ✓ The comparisons between FRET forecast ETo and CIMIS ETo calculated from observed weather variable showed good agreement for all the 15 selected station locations across CA, which spanned from low to moderate, to high ET demand for all the considered months
- ✓ The results also show that the 7-day ETo forecasts are nearly as good as the 1-day ETo forecasts, while the 3-day and 5-day ETo forecast are slightly better.
- ✓ Considering all data together, the R^2 ranged between 0.9 and 1.0, while RMSE was mostly

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Evaluation of Forecast Reference Evapotranspiration for Different Microclimate Regions in California to Enable Prospective Irrigation Scheduling

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CIMIS

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

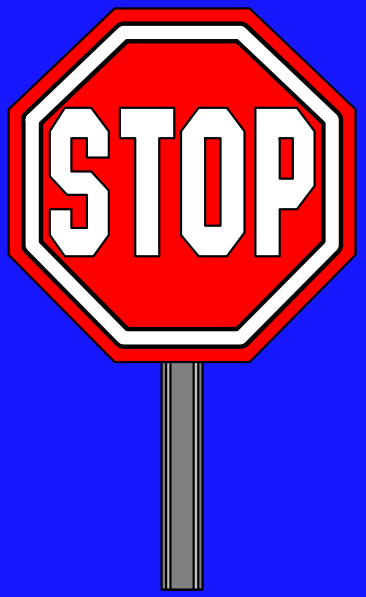
Spatial CIMIS App

http://cimis-mobile.cstars.ucdavis.edu

FRET

National Weather Service Graphical Forecasts

https://digital.weather.gov/?zoom=5&lat=33.85865&lon=-100.61988&layers=00BTFFTT&region=0&element=0&mxmz=false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