FORECAST EVAPOTRANSPIRATION: FUNDAMENTAL INFORMATION FOR AGRICULTURAL IRRIGATION MANAGEMENT

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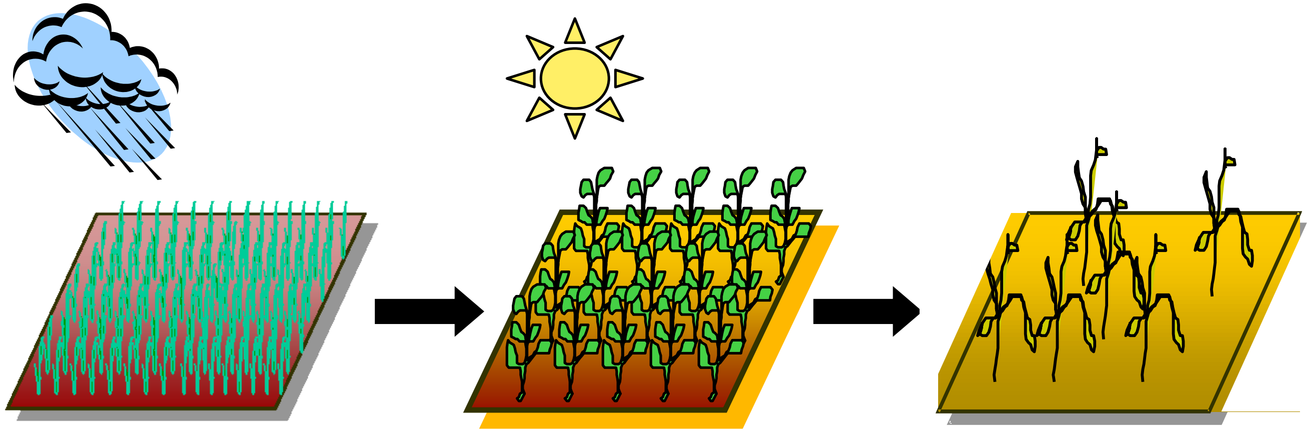
Evapotranspiration

$ET_c = ET_o \times K_c$

$ET_a = ET_c \times K_s$



Reference	Potential	Actual
ET_o	ET_c	ET_a
	Energy Limited	Water Limited

single irrigation event

Distribution Uniformity (DU)

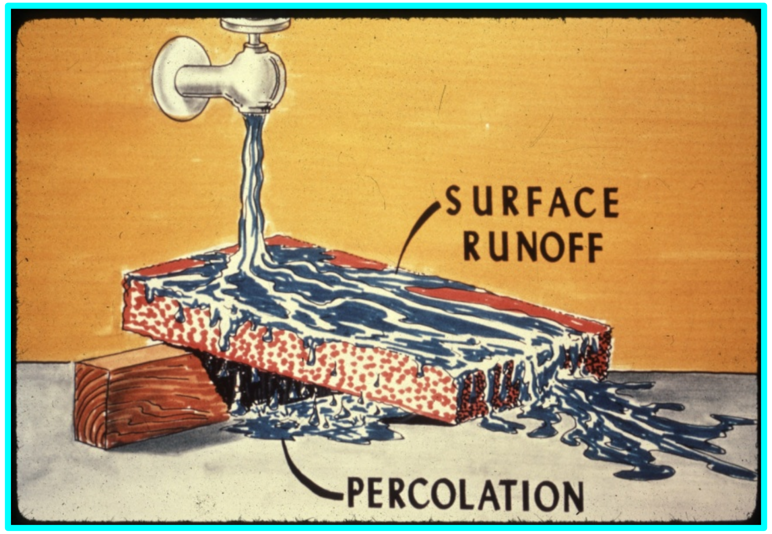
$$DU = \frac{Mean\ depth\ infiltrating\ the\ LQ}{Overall\ Mean\ depth\ infiltrated} \times 100$$

8 Liters per tree in July

DU = 100%; AE ≈ 1.00

Application Efficiency (AE)

$$AE = \frac{Water\ Stored\ in\ Root\ Zone}{Total\ Water\ Infiltrated} \times 100$$



If LQ=SWD, then AE=DU

AW=SWD/AE & SWD≈ΣETa

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G11 R

Typical Application Rate (AR) and Distribution Uniformity (DU)
Metric Units

Symbol	System	Appl. Rate (mm h^{-1})	Dist.Unif.
G	Gravity	11.20	75
D	Drip	0.70	85
M	Microsprinkler	1.30	80
S	Sprinkler	3.20	75
Su	Sprinkler (urban)	12.70	70
R	Rainfed	--	100

Typical Application Rate (AR) and Distribution Uniformity (DU)
English Units

Symbol	System	Appl. Rate (in./hr)	Dist.Unif.
G	Gravity	0.441	75
D	Drip	0.028	85
M	Microsprinkler	0.051	80
S	Sprinkler	0.126	75
Su	Sprinkler (urban)	0.500	70
R	Rainfed	--	100

Title Crop CropRef Climate Sched KcPlot ETPlot ET_Irrig System AppRate OrigCropRef

Ready

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W22

Emitters/ha	X	**lph/emitter**	÷	**min/hr**			=`	**lpm/ha**	=`	**mm/hr**
240	X	**57.00**	÷	**60**			=	**228.00**	=	**1.37**
Pump Rate (lpm)	÷	**Area (ha)**					=	**lpm/ha**	=	**mm/hr**
5700	÷	**25.00**					=	**228.00**	=	**1.37**
Emitters/plt	X	**lph/emitter**	÷	**min/hr**	X	**plt/ha**	=	**lpm/ha**	=`	**mm/hr**
2	X	**57.00**	÷	**60**	X	**120**	=	**228.00**	=	**1.37**

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... | Crop | CropRef | Climate | Sched | KcPlot | ETPlot | ET_Irrig | System | AppRate | OrigCropRef

Ready

High-frequency, low-volume drip & micro-irrigation

Drip Irrigation

Micro-spray Irrigation

- Water is applied in small amounts near each plant with high distribution uniformity
- Excellent control of the amount and timing of irrigation
- Weed growth is minimized
- Fertilizers and other chemicals can be injected

Urban Landscape Evapotranspiration

$$ET_L = ET_o \times K_L$$

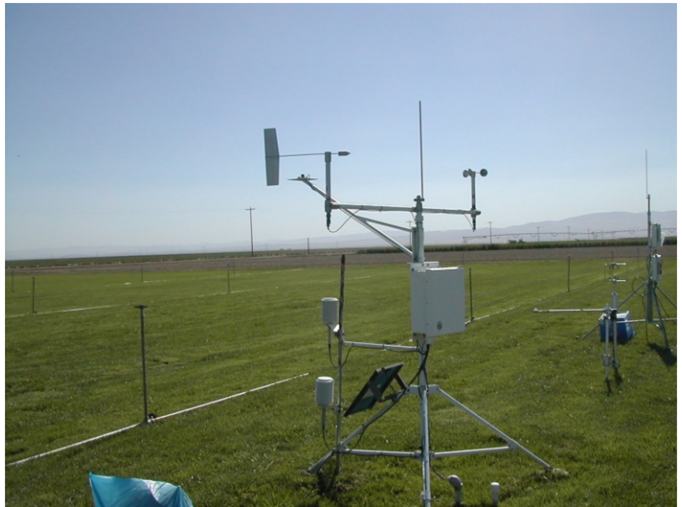
ET_L = Landscape ET

ET_o = Reference ET

Landscapes typically have high frequency irrigation that use controllers

Standardized Reference Evapotranspiration (ET_o)

Evapotranspiration of a large field of short *0.12* m vegetation having known canopy and aerodynamic resistance and no soil, water, or plant limitations to *ET*, i.e., the ET_o rate is only energy limited.



CIMIS

Approximately 150 ± Stations

National Weather Service

FRET

Forecast ET_o

Richard Snyder Cindy Palmer
Mike Anderson Morteza Orang

Calculating daily ETo from Forecast Data

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

$n/N = -0.0083 * C_C + 0.9659$ = actual to potential sunshine hours

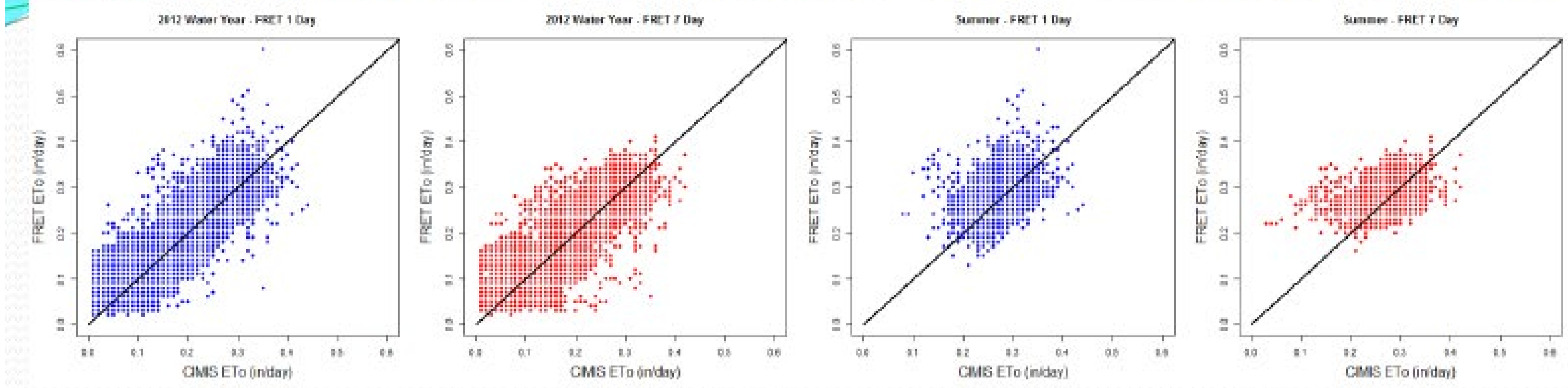
R_a= f(lat,date) = extra terrestrial radiation (MJ $m^{-2}d^{-1}$)

$R_s = (0.25 + 0.5 * n/N) * R_a$ = incoming solar radiation (MJ $m^{-2}d^{-1}$)

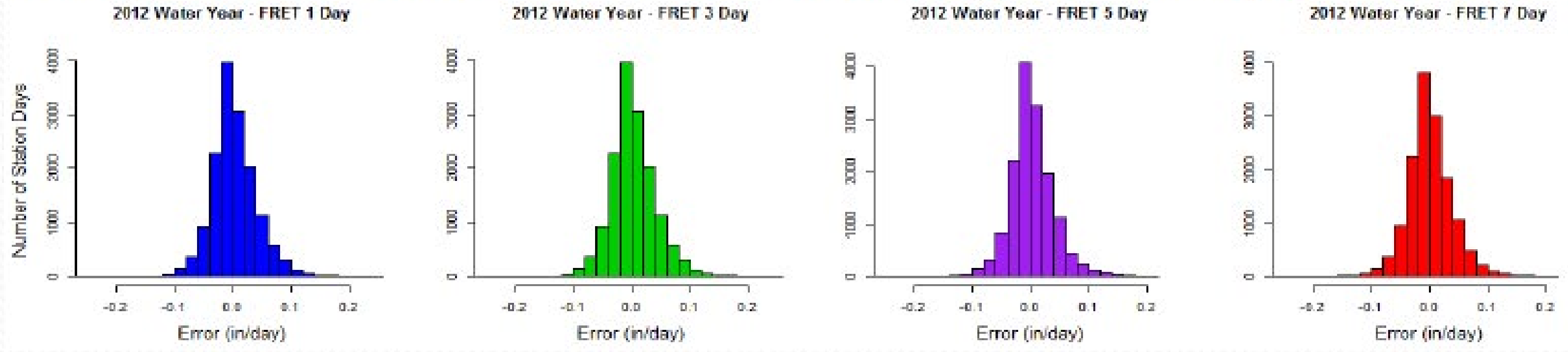
C_C=cloud cover (%)

UN-FAO 56 & UN-FAO 24

Verification of FRET against 48 CIMIS 2012 observation



Histograms of difference between FRET forecast ET_o and CIMIS ET_o for all stations



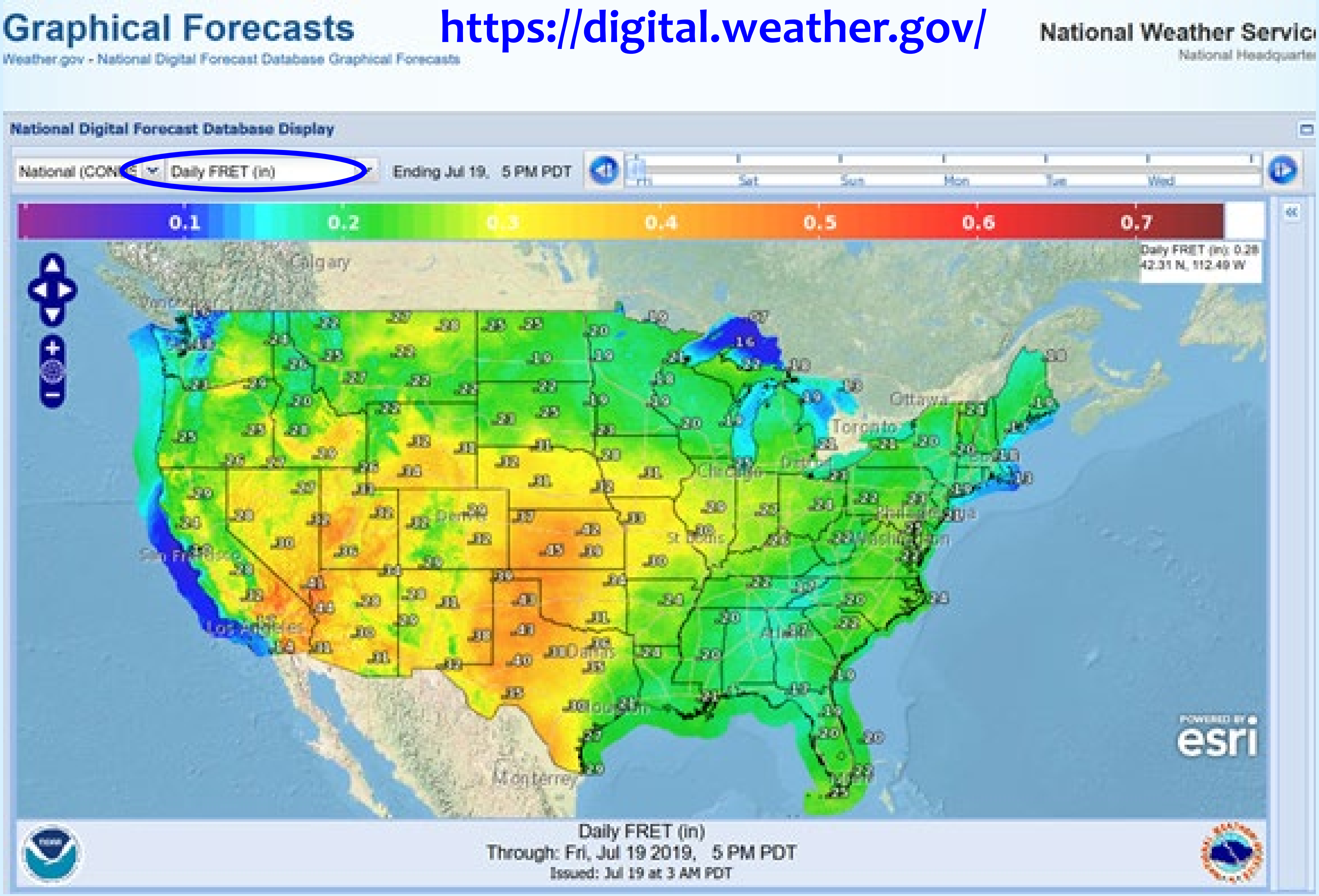
>80% of FRET values within 1.25 mm/day of CIMIS station ETo for all forecast periods

FRET has a slight positive bias relative to observed ET_o from CIMIS, especially in summer

Hobbins,M. Osborne, H., Rasch, W., Mittlestadt, J., Krone-Davis, P, Melton, F. 2014. National Weather Service forecast reference evapotranspiration (FRET). Poster presented at 94th AMS Annual Meeting.

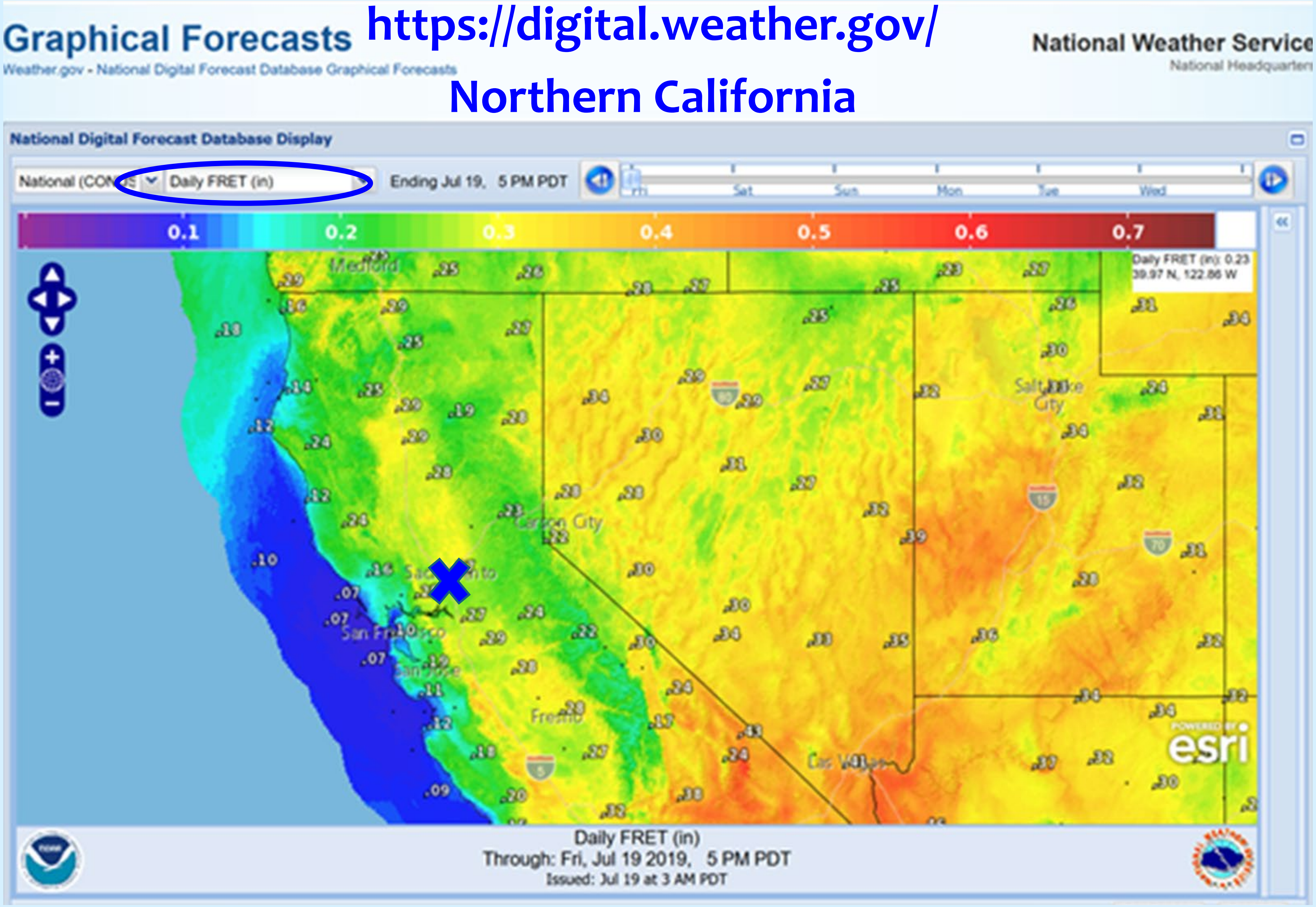
Graphical Forecasts

https://digital.weather.gov/



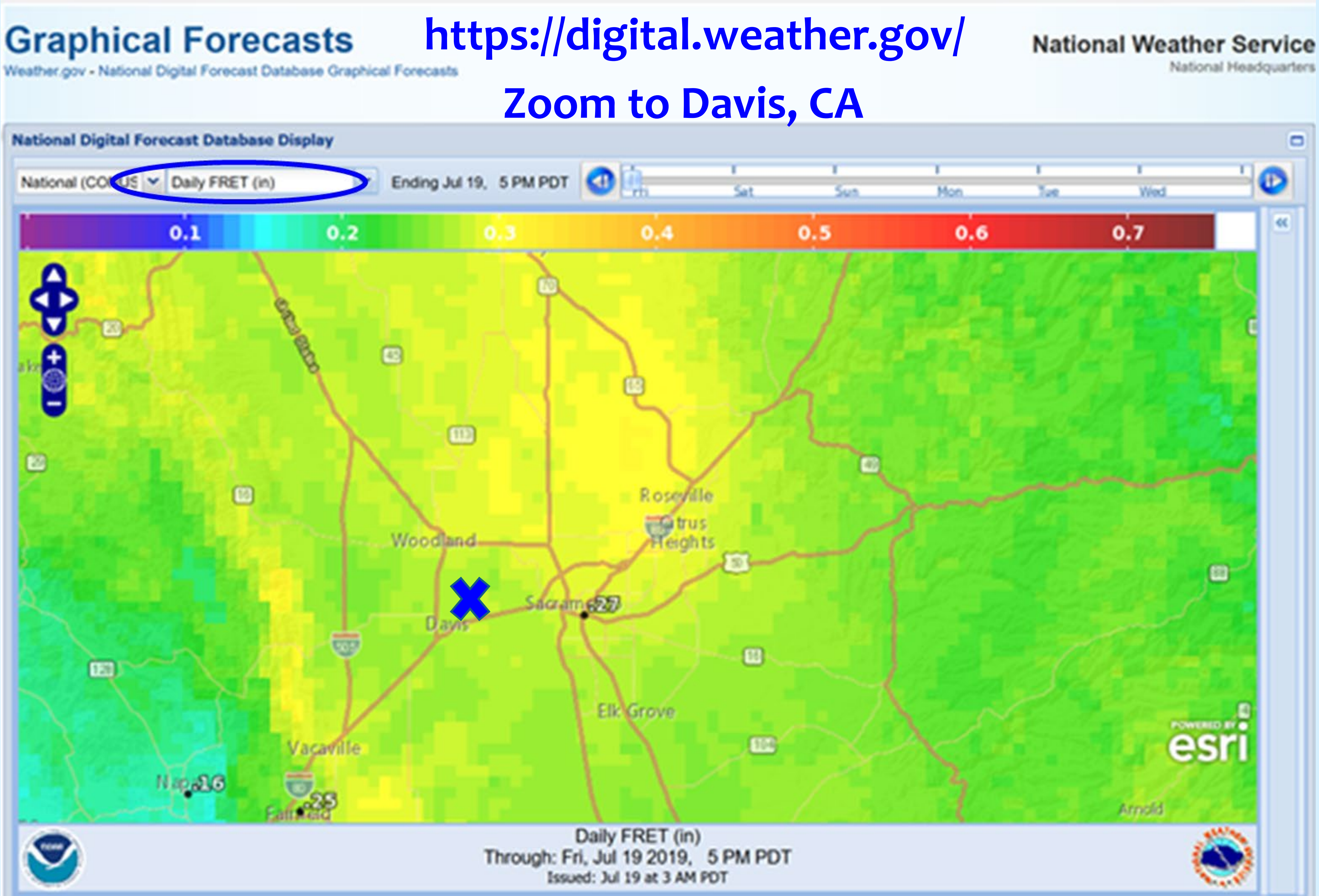
https://digital.weather.gov/

Northern California



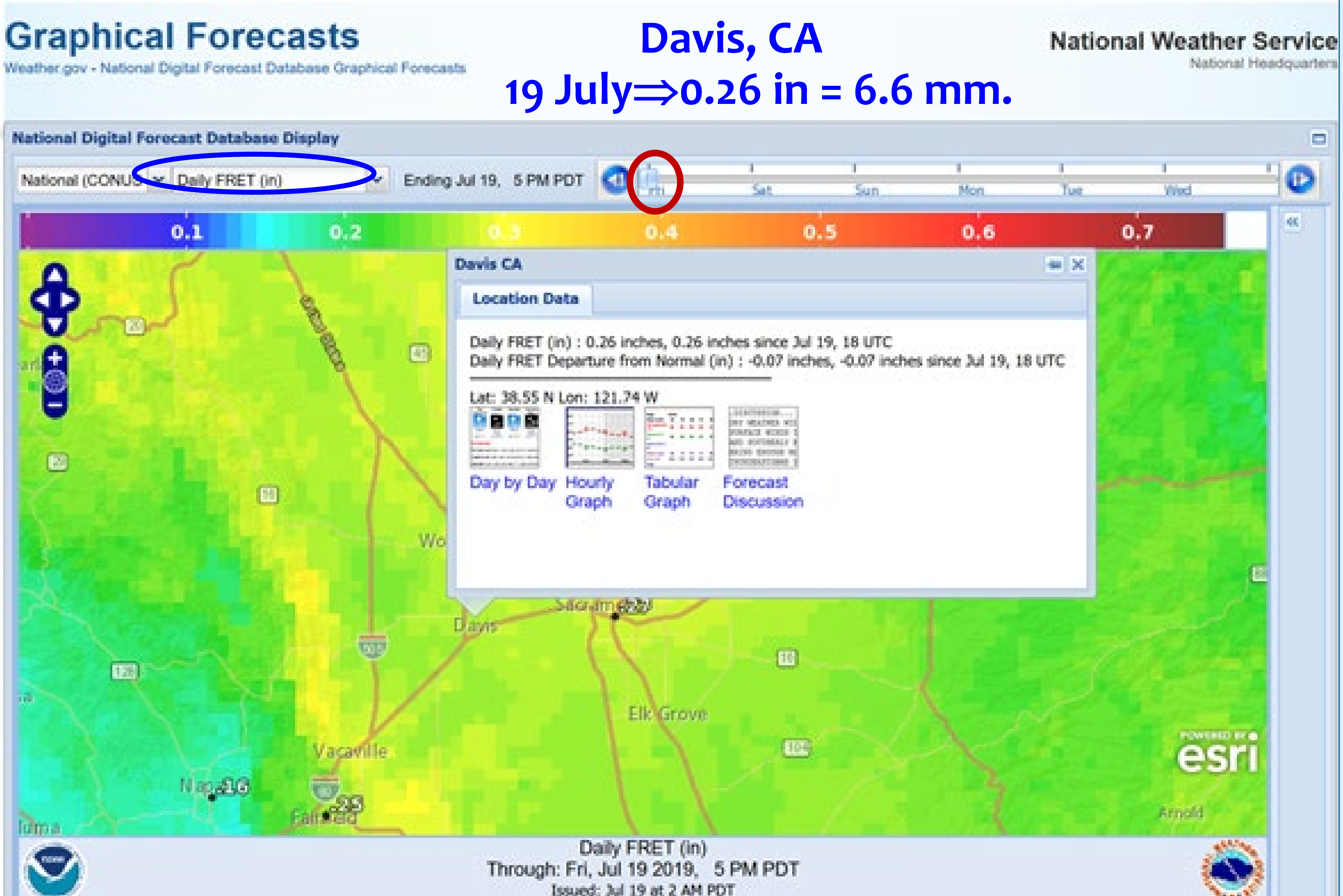
https://digital.weather.gov/

Zoom to Davis, CA



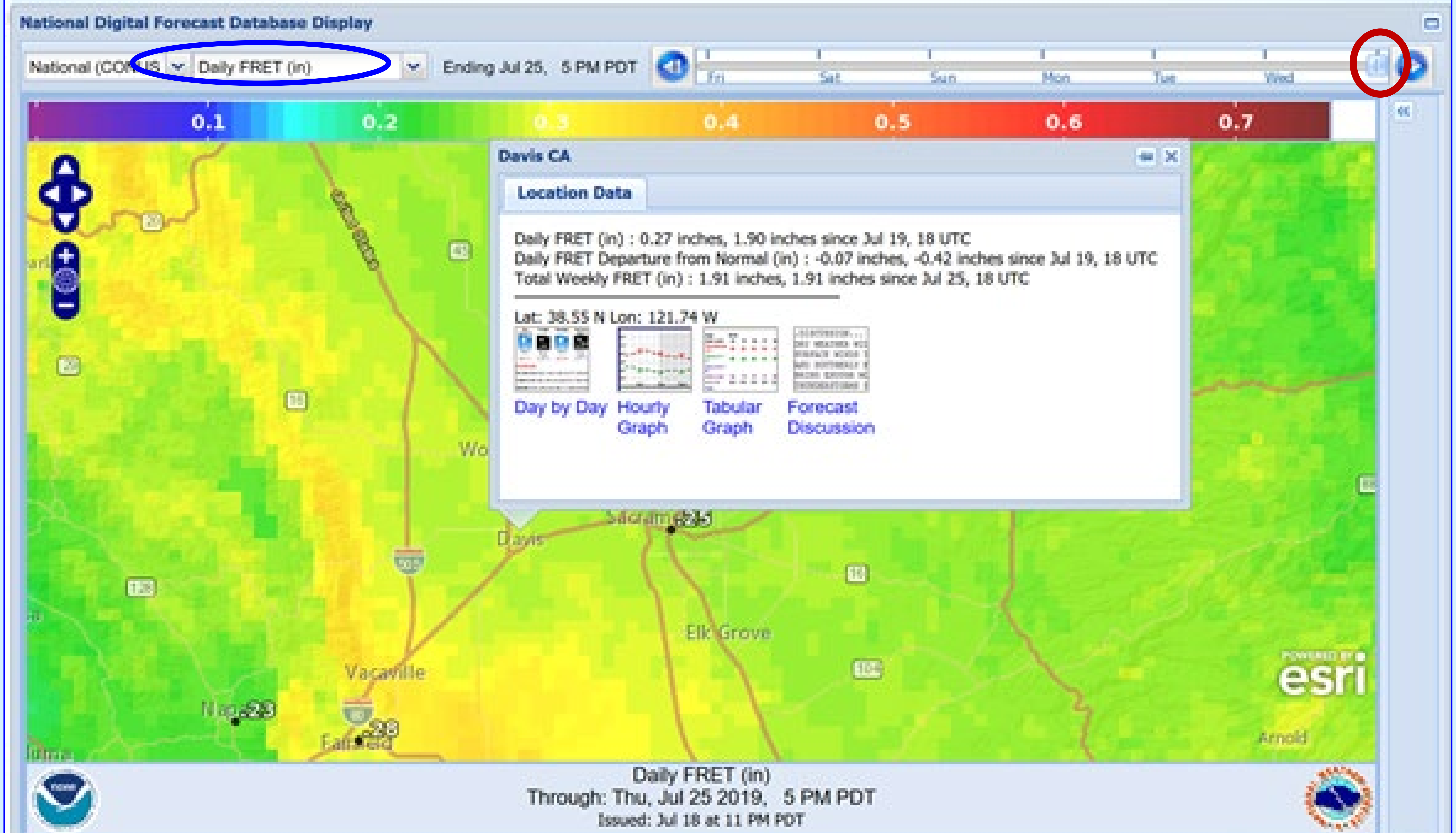
Davis, CA

19 July⇒0.26 in = 6.6 mm.



https://digital.weather.gov/

19-25 July⇒1.90 in. and 25 July ⇒ 0.27 in.



FRET data from 19-25 Jul 2019 for Davis, CA

Day	July	ETo (in)	ETo (mm)
Fri	19	0.26	6.6
Sat	20	0.26	6.6
Sun	21	0.26	6.6
Mon	22	0.27	6.9
Tue	23	0.28	7.1
Wed	24	0.29	7.4
Thu	25	0.27	6.9
SUM		1.89	48.0

Excel Program

FREToM.xlsx

How to calculate ETo from forecast weather data

FRETоM1.xlsx - Exc...

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R22 | fx | 30.4128

Davis

latitude (rad)	0.6726		
latitude (deg)	38.54	N	"+" for North or "-" for South of EQ
longitude (deg)	121.78	W	"+" for West or "-" for East of GM — 121.78 W
elevation (m)	18.5		18.50 elevation meters
z_w (m)	2.0		z_w = anemometer hgt (m)
meridian (deg)	120		
barometric pressure (kPa)	101.1		

$$b = \frac{\ln(e/0.6108)}{17.27}$$

$$T_d = 237.3\left(\frac{b}{1-b}\right)$$

day	date	ET_o	Input Variables							Dew Point Calculation							
	date da-mon	ET_o mm d^{-1}	T_x °C	T_n °C	T_d °C	u_z m s^{-1}	CC %	RH_x %	RH_n %	$e_s(T_x)$	$e_s(T_n)$	$e(T_x)$	$e(T_n)$	e	b	T_d	R_s MJ $m^{-2}d^{-1}$
0	10-Jun	6.5	30.5	12.7		2.3	1.4	93	35	4.37	1.47	1.53	1.37	1.45	0.05	12.5	30.3
1	11-Jun	6.6	31.9	12.2		2.0	1.0	94	33	4.73	1.42	1.56	1.34	1.45	0.05	12.5	30.4
2	12-Jun	7.3	34.2	13.5		2.2	2.1	91	26	5.38	1.55	1.40	1.41	1.40	0.05	12.0	30.2
3	13-Jun	6.8	32.9	12.7		2.1	8.1	95	27	5.00	1.47	1.35	1.40	1.37	0.05	11.7	29.2
4	14-Jun	6.0	28.5	13.1		2.9	20.0	91	41	3.89	1.51	1.60	1.37	1.48	0.05	12.9	27.2
5	15-Jun	6.1	26.9	13.1		3.3	5.3	85	46	3.54	1.51	1.63	1.28	1.46	0.05	12.6	29.7
6	16-Jun	6.0	28.7	11.6		2.3	5.8	94	41	3.94	1.37	1.61	1.28	1.45	0.05	12.5	29.6
			Input either		T_d	or	both	RH_x &	RH_n					1.45		12.5	30.4

Title | **Data**

Ready | 129%

10:53 AM 7/19/2019

FREToM1.xlsx - Excel

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R22 | fx 30.4128

6108)

27

$\frac{b}{1-b}$)

CC=cloud cover (%)

R_s=Solar Radiation

T_s=Daily Maximum Temperature

T_n=Daily Minimum Temperature

u_2=Daily Mean Wind Speed (2 m)

T_d=Daily Mean Dew point

$$u_2 = u_z\left(\frac{4.87}{\ln(67.8z_w - 5.42)}\right)$$

Extra Terrestria	Clear Sky	
		0.9659
		0.0083

	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
10		**Applied Variables**									Sun hrs	Rad	Rad	
11	T_d	R_s	T_x	T_n	u_2	T_d	Day	d_r	δ	ω_s	N	R_a	R_{so}	n/N
12		MJ $m^{-2}d^{-1}$	^oC	^oC	m s^{-1}	^oC					h	MJ $m^{-2}d^{-1}$	MJ $m^{-2}d^{-2}$	
14	12.5	30.3	30.5	12.7	2.3	12.5	161	0.969	0.402	1.916	14.64	41.68	31.28	0.95
15	12.5	30.4	31.9	12.2	2.0	12.5	162	0.969	0.403	1.917	14.65	41.71	31.30	0.96
16	12.0	30.2	34.2	13.5	2.2	12.0	163	0.969	0.404	1.918	14.66	41.74	31.32	0.95
17	11.7	29.2	32.9	12.7	2.1	11.7	164	0.969	0.405	1.919	14.66	41.76	31.33	0.90
18	12.9	27.2	28.5	13.1	2.9	12.9	165	0.968	0.406	1.920	14.67	41.78	31.35	0.80
19	12.6	29.7	26.9	13.1	3.3	12.6	166	0.968	0.407	1.921	14.68	41.79	31.36	0.92
20	12.5	29.6	28.7	11.6	2.3	12.5	167	0.968	0.407	1.922	14.68	41.81	31.37	0.92

FREToM1.xlsx - Excel

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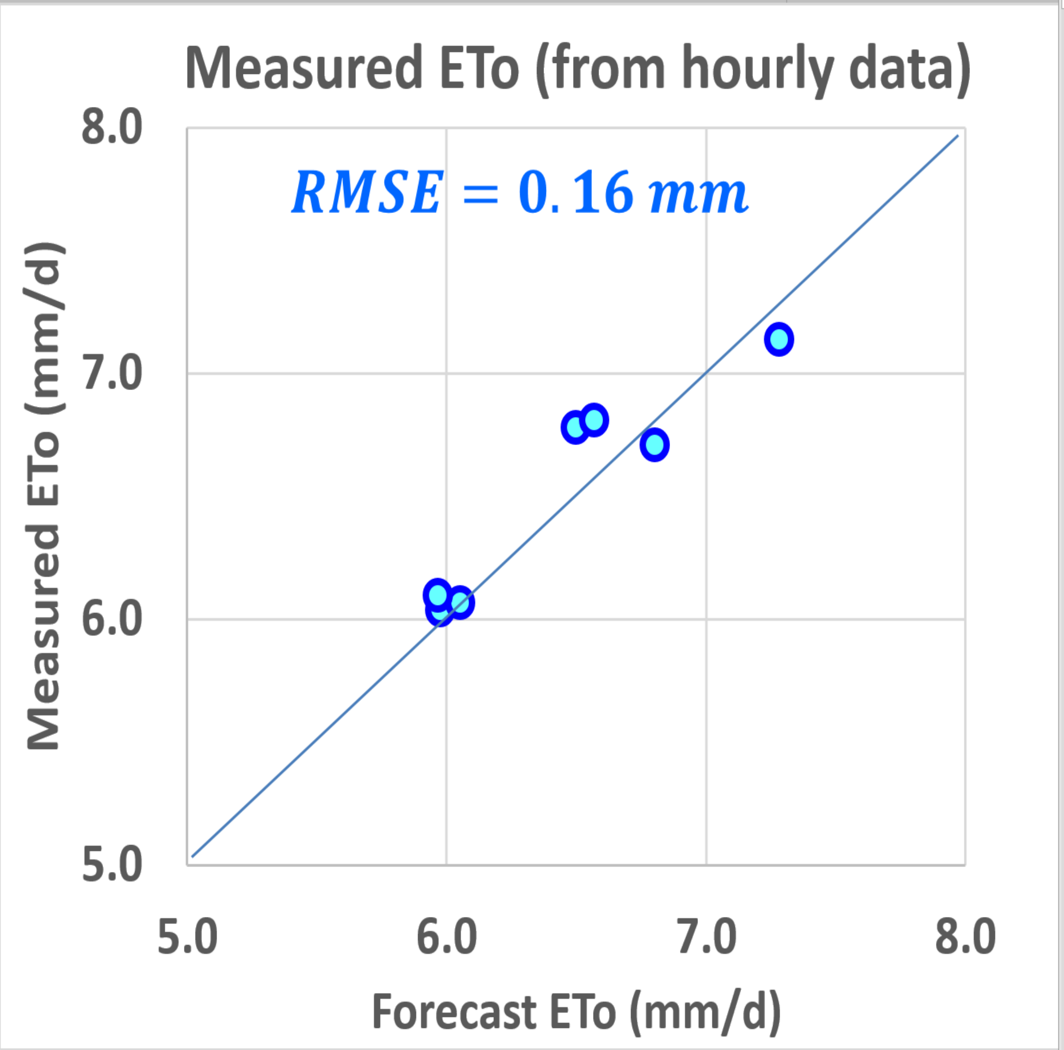
AY22 | =SQRT(SUM(AY14:AY20)/7)

N =	ω_s*24/π	Potential Sunshine	(hours)
G_{SC} =	0.082	Solar Constant	(MJ $m^{-2}min^{-1}$)
φ =	0.67	Latitude (radians)	
σ =	4.9E-09	Steffan-Boltzmann Const MJ $m^{-2}d^{-1}K^{-4}$	
λ =	2.45	Latent heat vaporization (MJ kg^{-1})	
γ =	0.067	Psychrometric Const.	(kPa K^{-1})

e_a-e_d kPa	e_sTm kPa	Δ kPa °C^{-1}	RAD mm d^{-1}	AERO mm d^{-1}	PM ET_o mm d^{-1}	Hrly PM ETo mm d^{-1}	diff sq
1.470	2.580	0.158	3.99	2.50	**6.5**	6.78	0.079804
1.627	2.652	0.162	4.14	2.43	**6.6**	6.81	0.058438
2.060	2.957	0.178	4.15	3.13	**7.3**	7.14	0.019641
1.862	2.776	0.168	3.98	2.82	**6.8**	6.71	0.008723
1.216	2.457	0.151	3.42	2.55	**6.0**	6.04	0.004051
1.070	2.338	0.145	3.52	2.54	**6.1**	6.07	0.000274
1.202	2.360	0.146	3.82	2.15	**6.0**	6.1	0.018239

rmse= 0.16



Excel Program

FRETIS.xlsx

How to make a schedule from FRET ETo data

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AY33

Station Name:	Davis
Station Number:	6
Latitude (deg):	38.5
Elevation (m):	18.5

albedo = 0.23

BPress = 101.1 kPa

fetch (m) =

Month	R_s MJ $m^{-2}d^{-1}$	T_x °C	T_n °C	U_2 m s^{-1}	T_d °C	Pcp mm	NRD #	ETo mm	Input ETo mm	PM ETo mm	HS ETo mm	Input Ep mm
1	6.5	12.7	3.6	2.6	5.4	102.6	8.6	1.0		1.0	1.2	
2	10.4	16.0	5.0	2.7	6.6	107.3	6.5	1.7		1.7	1.9	
3	15.9	19.0	6.0	2.7	7.2	69.6	5.8	2.7		2.7	2.9	
4	21.5	22.8	7.8	3.0	6.9	17.8	1.7	4.4		4.4	4.3	
5	25.5	26.3	10.4	3.0	9.2	19.0	1.5	5.5		5.5	5.4	
6	28.8	30.1	12.7	3.0	10.8	6.0	0.6	6.8		6.8	6.4	
7	29.0	32.9	13.7	2.7	12.7	3.3	0.3	7.1		7.1	6.9	
8	26.0	32.5	13.2	2.5	11.5	2.3	0.1	6.5		6.5	6.1	
9	20.9	30.8	12.1	2.4	10.2	7.4	0.7	5.3		5.3	4.8	
10	14.8	26.3	9.6	2.4	7.6	17.6	1.5	3.8		3.8	3.1	
11	9.4	18.4	5.4	2.4	5.3	35.7	3.5	2.1		2.1	1.7	
12	6.5	12.8	2.7	2.7	4.3	60.8	4.9	1.1		1.1	1.1	

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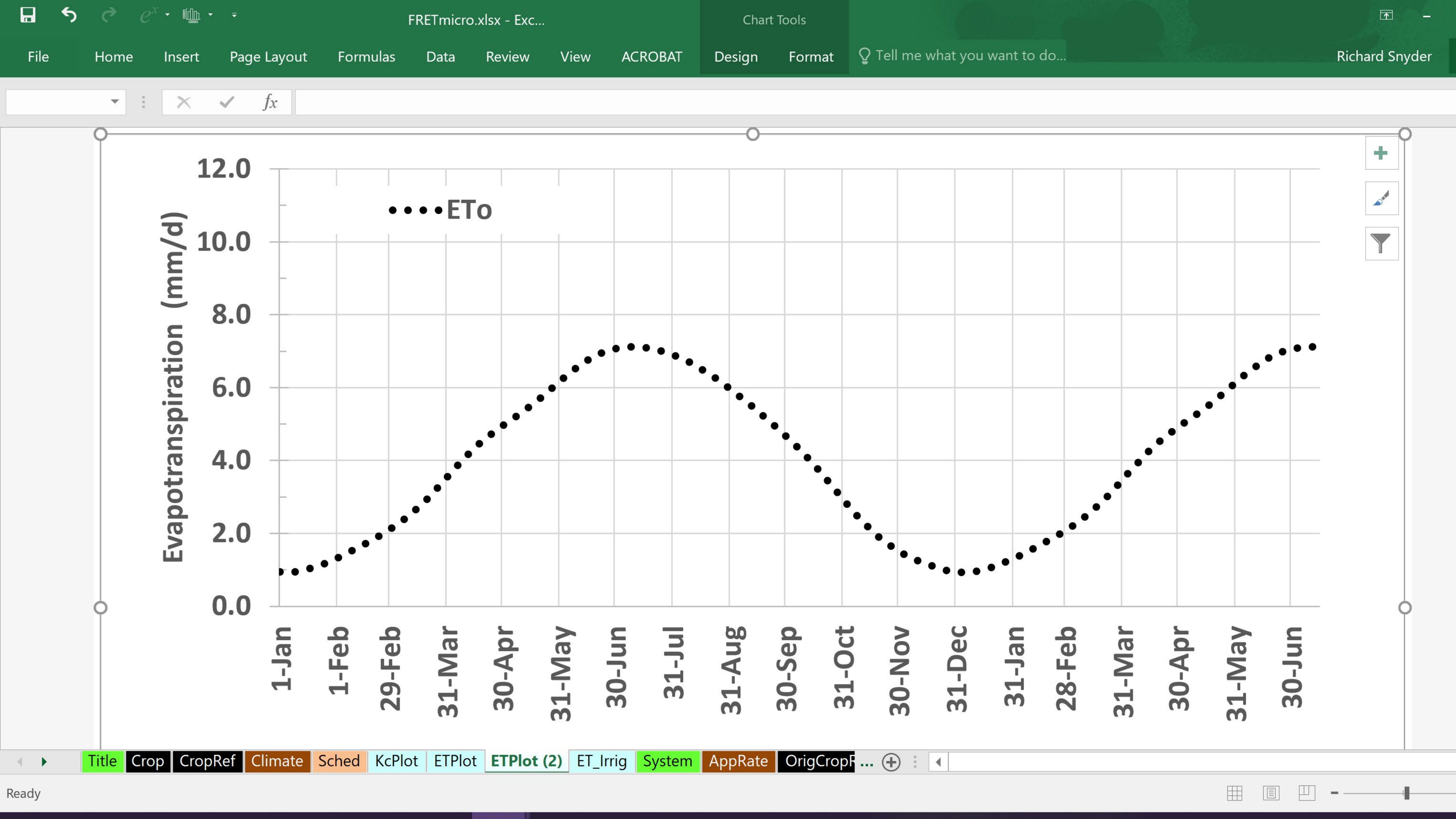
Title | Crop | CropRef | Climate | Sched | KcPlot | ETPlot | ET_Irrig | System | AppRate | OrigCropRef

Ready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Richard Snyder
ETo
Evapotranspiration (mm/d)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1-Jan
1-Feb
29-Feb
31-Mar
30-Apr
31-May
30-Jun
31-Jul
31-Aug
30-Sep
31-Oct
30-Nov
31-Dec
31-Jan
28-Feb
31-Mar
30-Apr
31-May
30-Jun
Title
Crop
CropRef
Climate
Sched
KcPlot
ETPlot
ETPlot (2)
ET_Irrig
System
AppRate
OrigCropR
Ready

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N61 =IF(A1=$A61,B61,"")

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
43	1.39	Strawberries w/mulch	15	45	80	0.20	0.70	0.70	0.70	5	1	9	30				
44	1.40	Sugarbeet	15	45	80	0.20	1.15	1.15	0.95	3	15	9	30				
45	1.41	Sunflower	20	45	80	0.20	1.10	1.10	0.40	5	1	9	10				
46	1.42	Sweet Potatoes	20	45	78	0.80	1.10	1.10	0.70	4	15	8	15				
47	1.43	Tomato	25	50	80	0.30	1.10	1.10	0.60	4	1	8	31				
48	1.44	Vegetables	33	67	92	0.80	0.90	0.90	0.90	3	1	8	31				
49	1.45	Wheat	20	45	75	0.33	1.05	1.05	0.15	11	1	5	31				
50	1.46	Watermelon	20	50	75	0.80	1.00	1.00	0.75	4	1	11	15				
51	2.01	Alfalfa (annual)	25	50	75	1.00	1.00	1.00	1.00	1	1	12	31				
52	2.02	Improved Pasture	25	50	75	0.95	0.95	0.95	0.95	1	1	12	31				
53	2.03	Turfgrass (cool-season)	25	50	75	0.80	0.80	0.80	0.80	1	1	12	31				
54	2.04	Turfgrass (warm-season)	25	50	75	0.60	0.60	0.60	0.60	1	1	12	31				
55	3.01	Almonds	0	50	90	0.55	1.15	1.15	0.65	3	1	10	15				
56	3.02	Apple	0	50	75	0.55	1.05	1.05	0.80	4	1	11	15				
57	3.03	Grapes (wine)	0	25	75	0.45	0.80	0.80	0.35	4	1	10	1				
58	3.04	Grapes (table)	0	25	75	0.45	1.10	1.10	0.35	3	15	9	10				
59	3.05	Grapes (raisin)	0	25	75	0.45	1.10	1.10	0.35	3	15	9	10				
60	3.06	Kiwifruit	0	22	67	0.30	1.05	1.05	1.00	5	1	10	31				
61	3.07	Stone fruits	0	50	90	0.55	1.15	1.15	0.65	3	1	10	15	Stone fruits	0	50	
62	3.08	Walnuts	0	50	75	0.55	1.15	1.15	0.80	4	1	11	15				
63	4.01	Avocado	0	33	67	0.70	0.70	0.70	0.70	1	1	12	31				
64	4.02	Citrus (>3.8 m tall)	0	33	67	1.00	1.00	1.00	1.00	1	1	12	31				
65	4.03	Citrus (<3.0 m tall)	0	33	67	0.70	0.70	0.70	0.70	1	1	12	31				
66	4.04	Date Palm	0	33	67	0.95	0.95	0.95	0.95	1	1	12	31				
67	4.05	Evergreen	0	33	67	1.15	1.15	1.15	1.15	1	1	12	31				
68	4.06	Olives	0	33	67	0.70	0.55	0.55	0.70	1	1	12	31				

Title Crop CropRef Climate Sched KcPlot ETPlot ETPlot (2) ET_Irrig System AppRate OrigCropR ...

Ready

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AA32

B	C	D	E	F	G	J	K	L	M	N	O	P	Q	R	S	T
Crop #:		3.07			Crop Name			Irrig. Freq. Adjust	Immaturity Adjustment			Immaturity Adjustment			Cover Crop Dates	
Planting Year:		2019														
Growth	Sample				Stone fruits			Irrigation Frequency days		Deciduous Tree & Vine			Subtropical Orchards		e.g., 1-Jan	
Date	Date	Date	Date		Kc		Initial		Growth			Growth				1st cycle
A	1-Mar		01-Mar-19	KcA		Table Kc	Kc		Date	% GC	Kc	Date	% GC	Kc	start	
B		1-Mar	1-Mar	KcB	0.55	0.55			B			B		0.55	end	
C		23-Jun	23-Jun	KcC	1.15	1.15	2.10		C		1.15	C		1.15		2nd cycle
D		23-Sep	23-Sep	KcD	1.15	1.15	0.99	= Kx	D		1.15	D		1.15	start	
E	15-Oct		15-Oct-19	KcE	0.65	0.65	2.6	= Beta	E			E		0.65	end	
	# days	229	229													

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Title | Crop | CropRef | Climate | Sched | KcPlot | ETPlot | ET_Irrig | System | AppRate | OrigCropRef

Ready 88%

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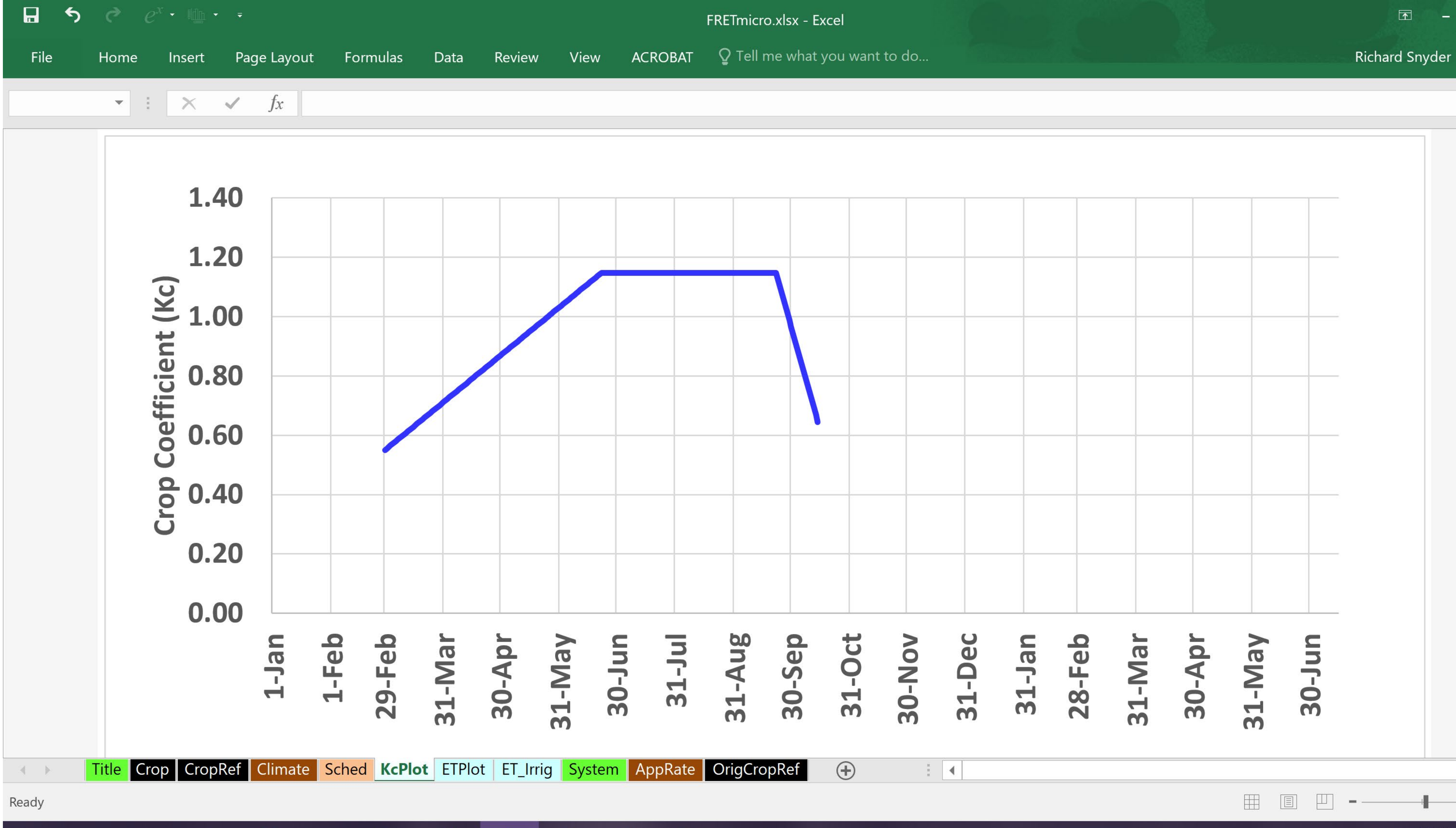
FRETmicro.xlsx - Excel
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ACROBAT
Tell me what you want to do...
Richard Snyder
Crop Coefficient (Kc)
1.40
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Title
Crop
CropRef
Climate
Sched
KcPlot
ETPlot
ET_Irrig
System
AppRate
OrigCropRef
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Chart Tools

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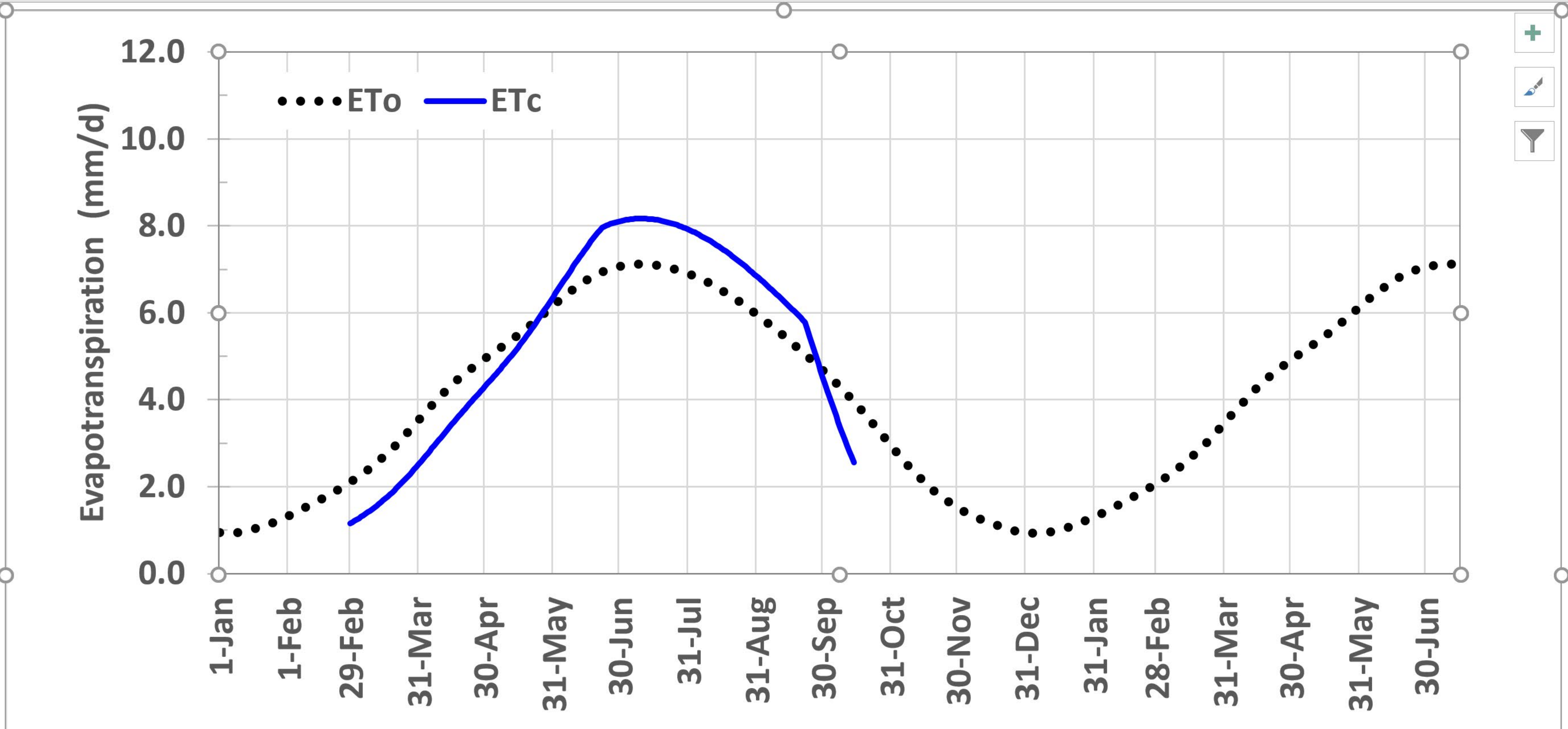

Title Crop CropRef Climate Sched KcPlot ETPlot ET_Irrig System AppRate OrigCropRef

Ready

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AE211 | fx | =IF(ISNUMBER(U211),SUM(AA211:AD211)/4,"")

CROP = **Stone Fruits**

1.37 0.90

AR = **1.37** (mm h^{-1}) DU = **90** (%)

Row	Date da-mon-yr (10 Jun 11)	Day #	FRET ETo (mm)	Hist. ETo (mm)	Select ETo (mm)	Obs. Precip. (mm)	Est. Kc --	Effect. Precip. (mm)	Pred. ETc (mm)	Sum ETc (mm) (sum 1256)	SWD LQ (mm)	Irrig. LQ (mm) (sum 687)	Appl. Water (mm) (sum 763)	Appl. Effic. (%)	Day of Week	Week Day #	ST=AW/AR Set Time (h)	Set Time (h)	Set Time (min)	AW (mm)	Applied by Quarter LQ (mm)	SQ (mm)	TQ (mm)	FQ (mm)	LQ SWD (mm)	Balance by Quarter LQB (mm)	SQB (mm)	TQB (mm)	FQB (mm)
9										0	0.0	0.0																	
191	1-Jul-19	182		7.1	7.1		1.15	0.0	8.1	548	8.1																		
192	2-Jul-19	183		7.1	7.1		1.15	0.0	8.1	556	16.3																		
193	3-Jul-19	184		7.1	7.1		1.15	0.0	8.1	564	0.0	24.4	27.1	90			19.8	19	47	27.1	24.4	26.2	28.0	29.8	24.4	0.0	1.8	3.6	5.4
194	4-Jul-19	185		7.1	7.1		1.15	0.0	8.1	572	8.1																		
195	5-Jul-19	186		7.1	7.1		1.15	0.0	8.1	580	16.3																		
196	6-Jul-19	187		7.1	7.1		1.15	0.0	8.2	589	0.0	24.4	27.1	90			19.8	19	47	27.1	24.4	26.2	28.0	29.8	24.4	0.0	1.8	3.6	5.4
197	7-Jul-19	188		7.1	7.1		1.15	0.0	8.2	597	8.2																		
198	8-Jul-19	189		7.1	7.1		1.15	0.0	8.2	605	16.4																		
199	9-Jul-19	190		7.1	7.1		1.15	0.0	8.2	613	0.0	24.5	27.2	90			19.9	19	52	27.2	24.5	26.3	28.1	29.9	24.5	0.0	1.8	3.6	5.4
200	10-Jul-19	191		7.1	7.1		1.15	0.0	8.2	621	8.2																		
201	11-Jul-19	192		7.1	7.1		1.15	0.0	8.2	629	16.4																		
202	12-Jul-19	193		7.1	7.1		1.15	0.0	8.2	637	0.0	24.5	27.2	90			19.9	19	52	27.2	24.5	26.3	28.1	29.9	24.5	0.0	1.8	3.6	5.4
203	13-Jul-19	194		7.1	7.1		1.15	0.0	8.2	646	8.2																		
204	14-Jul-19	195		7.1	7.1		1.15	0.0	8.2	654	16.4																		
205	15-Jul-19	196		7.1	7.1		1.15	0.0	8.2	662	0.0	24.5	27.2	90			19.9	19	52	27.2	24.5	26.3	28.1	29.9	24.5	0.0	1.8	3.6	5.4
206	16-Jul-19	197		7.1	7.1		1.15	0.0	8.2	670	8.2																		
207	17-Jul-19	198		7.1	7.1		1.15	0.0	8.1	678	16.3																		
208	18-Jul-19	199		7.1	7.1		1.15	0.0	8.1	686	0.0	24.4	27.1	90			19.8	19	47	27.1	24.4	26.2	28.0	29.8	24.4	0.0	1.8	3.6	5.4
209	19-Jul-19	200		7.1	7.1		1.15	0.0	8.1	695	8.2																		
210	20-Jul-19	201		7.1	7.1		1.15	0.0	8.1	703	16.3																		
211	21-Jul-19	202		7.1	7.1		1.15	0.0	8.1	711	24.4																		

Title | Crop | CropRef | Climate | Sched | KcPlot | ETPlot | ET_Irrig | System | AppRate | OrigCropRef

Ready

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AF225 | =IF(ISNUMBER(U225),U225-AE225,"")

CROP = **Stone Fruits**

AR = **1.37** (mm h⁻¹) DU = **90** (%)

	Date da-mon-yr (10 Jun 11)	Day #	FRET ETo (mm)	Hist. ETo (mm)	Select ETo (mm)	Obs. Precip. (mm)	Est. Kc --	Effect. Precip. (mm)	Pred. ETc (mm)	Sum ETc (mm)	SWD LQ (mm)	Irrig. LQ (mm)	Appl. Water (mm)	Appl. Effic. (%)	Day of Week	Week Day #	ST=AW/AR Set Time (h)	Set Time (h)	(min)	AW (mm)	Applied by Quarter LQ (mm)	SQ (mm)	TQ (mm)	FQ (mm)	LQ SWD (mm)	Balance by Quarter LQB (mm)	SQB (mm)	TQB (mm)	FQB (mm)
5										sum 1257		sum 785	sum 872																
9										0	0.0	0.0																	
205	15-Jul-19	196		7.1	7.1		1.15	0.0	8.2	662	0.0	24.5	27.2	90			19.9	19	52	27.2	24.5	26.3	28.1	29.9	24.5	0.0	1.8	3.6	5.4
206	16-Jul-19	197		7.1	7.1		1.15	0.0	8.2	670	8.2																		
207	17-Jul-19	198		7.1	7.1		1.15	0.0	8.1	678	16.3																		
208	18-Jul-19	199		7.1	7.1		1.15	0.0	8.1	686	0.0	24.4	27.1	90			19.8	19	47	27.1	24.4	26.2	28.0	29.8	24.4	0.0	1.8	3.6	5.4
209	19-Jul-19	200	6.6	7.1	6.6		1.15	0.0	7.6	694	7.6				Fri	6													
210	20-Jul-19	201	6.6	7.1	6.6		1.15	0.0	7.6	702	15.2				Sat	7													
211	21-Jul-19	202	6.6	7.1	6.6		1.15	0.0	7.6	709	0.0	22.8	25.3	90	Sun	1	18.5	18	29	25.3	22.8	24.5	26.2	27.9	22.8	0.0	1.7	3.4	5.1
212	22-Jul-19	203	6.9	7.1	6.9		1.15	0.0	7.9	717	7.9				Mon	2													
213	23-Jul-19	204	7.1	7.0	7.1		1.15	0.0	8.1	725	16.1				Tue	3													
214	24-Jul-19	205	7.4	7.0	7.4		1.15	0.0	8.5	734	0.0	24.6	27.3	90	Wed	4	20.0	19	57	27.3	24.6	26.4	28.2	30.1	24.6	0.0	1.8	3.6	5.5
215	25-Jul-19	206	6.9	7.0	6.9		1.15	0.0	7.9	742	7.9				Thu	5													
216	26-Jul-19	207	7.3	7.0	7.3		1.15	0.0	8.4	750	16.3				Fri	6													
217	27-Jul-19	208	7.9	7.0	7.9		1.15	0.0	9.1	759	0.0	25.4	28.2	90	Sat	7	20.6	20	36	28.2	25.4	27.3	29.2	31.0	25.4	0.0	1.9	3.8	5.6
218	28-Jul-19	209	7.7	7.0	7.7		1.15	0.0	8.8	768	8.8				Sun	1													
219	29-Jul-19	210	7.2	7.0	7.2		1.15	0.0	8.3	776	17.1				Mon	2													
220	30-Jul-19	211	6.7	6.9	6.7		1.15	0.0	7.7	784	0.0	24.8	27.6	90	Tue	3	20.1	20	7	27.6	24.8	26.6	28.5	30.3	24.8	0.0	1.8	3.7	5.5
221	31-Jul-19	212		6.9	6.9		1.15	0.0	7.9	792	7.9																		
222	1-Aug-19	213		6.9	6.9		1.15	0.0	7.9	800	15.9																		
223	2-Aug-19	214		6.9	6.9		1.15	0.0	7.9	808	23.8																		
224	3-Aug-19	215		6.9	6.9		1.15	0.0	7.9	815	31.6																		
225	4-Aug-19	216		6.8	6.8		1.15	0.0	7.8	823	39.5																		

Title | Crop | CropRef | Climate | Sched | KcPlot | ETPlot | ET_Irrig | System | AppRate | OrigCropRef

Ready

SetTime.xlsx - Excel

Irrigation system ending times for given irrigation system starting and set times. Find the required system set time in the left-hand column go to the right to find the desired time t
irrigation system on the next day. Then, go upwards to the top row to find the approximate time to start the irrigation system on the current day.

Set	Irrigation System Starting Time																									
Time	**12:00**	**12:15**	**12:30**	**12:45**	**13:00**	**13:15**	**13:30**	**13:45**	**14:00**	**14:15**	**14:30**	**14:45**	**15:00**	**15:15**	**15:30**	**15:45**	**16:00**	**16:15**	**16:30**	**16:45**	**17:00**	**17:15**	**17:30**	**17:45**	**18:00**	**18:15**	**18:30**
18:00	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30
18:15	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45
18:30	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00
18:45	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15
19:00	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30
19:15	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45
19:30	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00
19:45	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15
20:00	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15	14:30
20:15	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45
20:30	8:30	8:45	9:00	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45	15:00
20:45	8:45	9:00	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45	15:00	15:15
21:00	9:00	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45	15:00	15:15	15:30
21:15	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45	15:00	15:15	15:30	15:45
21:30	9:30	9:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45	15:00	15:15	15:30	15:45	16:00
21:45	9:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45	15:00	15:15	15:30	15:45	16:00	16:15
22:00	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45	15:00	15:15	15:30	15:45	16:00	16:15	16:30
22:15	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45	15:00	15:15	15:30	15:45	16:00	16:15	16:30	16:45
22:30	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45	15:00	15:15	15:30	15:45	16:00	16:15	16:30	16:45	17:00
22:45	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45	15:00	15:15	15:30	15:45	16:00	16:15	16:30	16:45	17:00	17:15
23:00	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45	15:00	15:15	15:30	15:45	16:00	16:15	16:30	16:45	17:00	17:15	17:30
23:15	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45	15:00	15:15	15:30	15:45	16:00	16:15	16:30	16:45	17:00	17:15	17:30	17:45
23:30	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45	15:00	15:15	15:30	15:45	16:00	16:15	16:30	16:45	17:00	17:15	17:30	17:45	18:00
23:45	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45	15:00	15:15	15:30	15:45	16:00	16:15	16:30	16:45	17:00	17:15	17:30	17:45	18:00	18:15
24:00	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45	15:00	15:15	15:30	15:45	16:00	16:15	16:30	16:45	17:00	17:15	17:30	17:45	18:00	18:15	18:30

Sheet1

FRETmicro.xlsx - Excel

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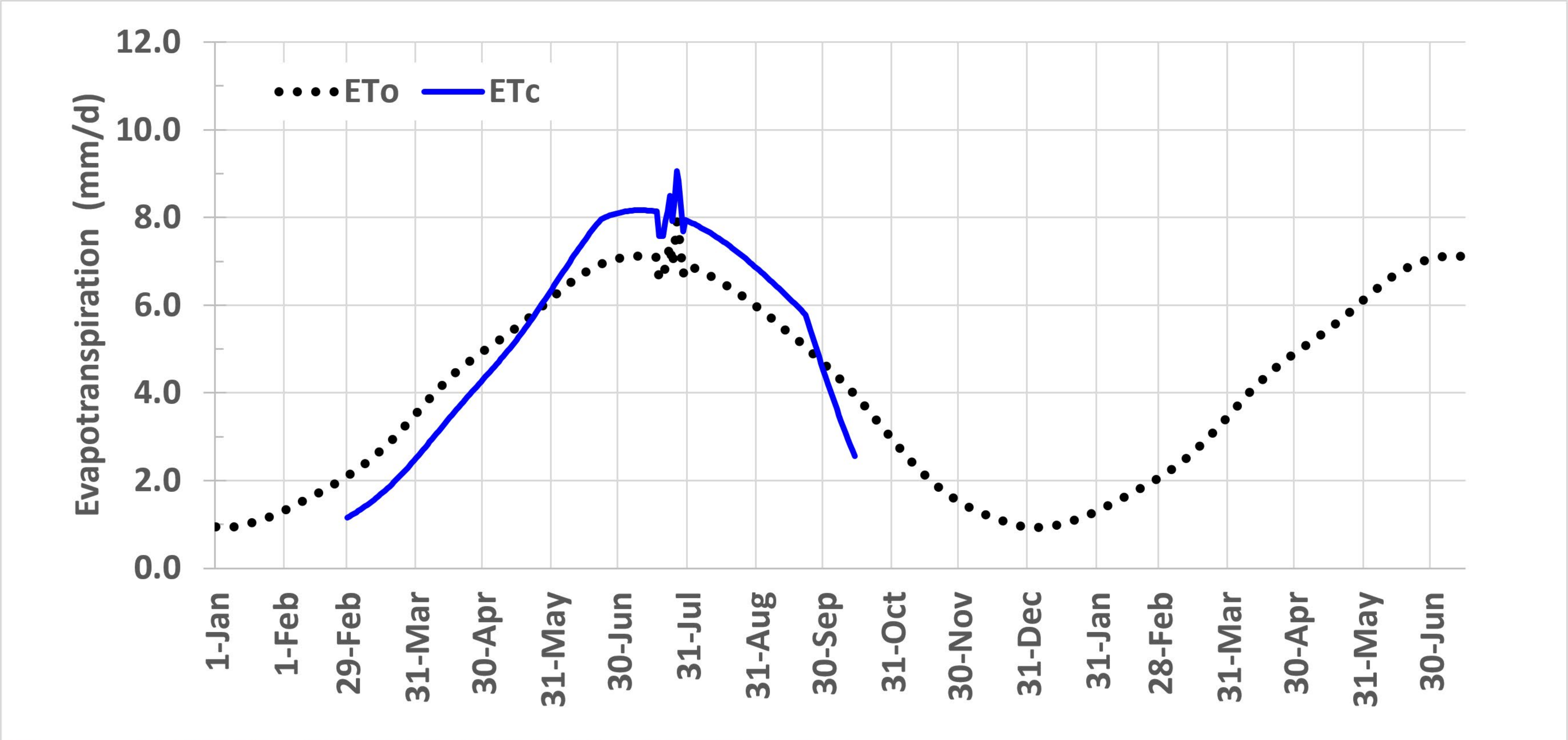
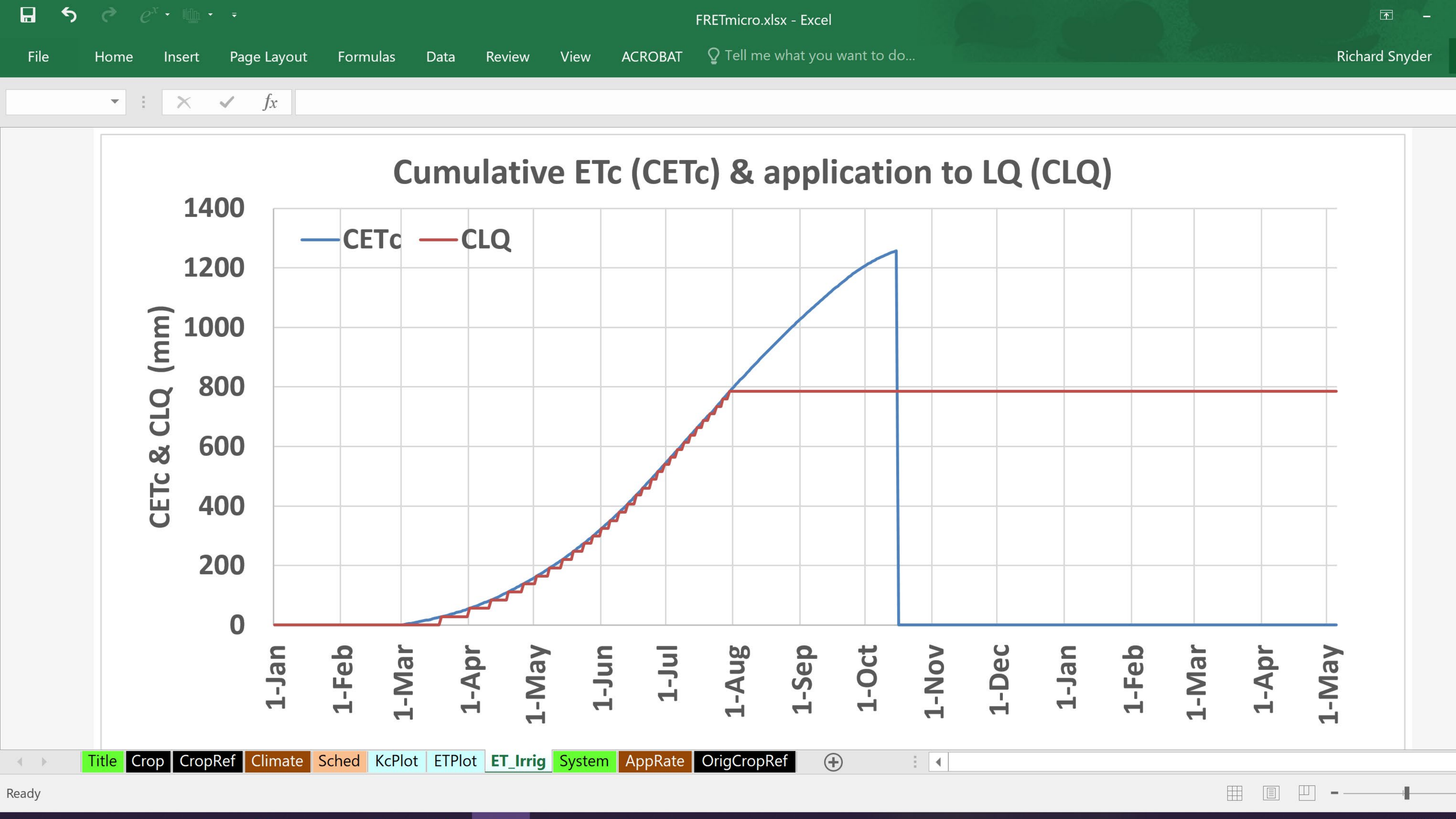


Title Crop CropRef Climate Sched KcPlot ETPlot ETPlot (2) ET_Irrig System AppRate OrigCropR ...

Ready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Tell me what you want to do...
Richard Snyder
Cumulative ETc (CETc) & application to LQ (CLQ)
CETc
CLQ
CETc & CLQ (mm)
1400
1200
1000
800
600
400
200
0
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
Title
Crop
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Ready

Conclusions

1. FRET offers irrigators the ability to plan up to one week in advance for irrigation water and labor needs.
2. A properly designed and operated network of weather stations is needed to validate FRET accuracy especially in climates where it has not been tested.
3. FRET is especially useful in urban locations where good weather station sites are scarce and in countries where funding for stations is limited.

Conclusions

4. FRET is more likely to be adopted because it comes from a more trusted weather forecast service; not a water agency.
5. The methodologies to determine forecast ET_o and to schedule irrigation are presented in application programs.
6. FRET can be used with low cost ET measurements, e.g., surface renewal, to estimate crop and landscape coefficients in locations with variable microclimates and in mixed vegetation on small farms and urban settings.

Questions

THANKS!

http://biomet.ucdavis.edu