



C U P P L U S

DAILY SOIL WATER BALANCE PROGRAM



A Tool for Water Demand Planning

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2013 UC Statewide ANR Conference

Ontario, California

April 10, 2013

Objectives

- Improve the estimation of ET_c and ET_{aw} for irrigation planning
- Use daily weather data from CIMIS to compute ET_o
- Derive daily weather from monthly means from CIMIS to estimate ET_o and ET_c
- Study the impact of climate change on irrigation water needs using different scenarios

Input Data Requirements

- Weather Data
- Crop Information
- Soil Information

Output

- Daily and monthly weather and ETo
- Daily and monthly Kc, ETc, water balance, Espg, Re, and ETaw data
- Seasonal and annual total of ETo, ETc and ETaw
- A wide range of tables and charts that are useful for irrigation planning

California Weather Data

- Pan Evaporation Data
- CIMIS Weather Data
- ETo Zones Map

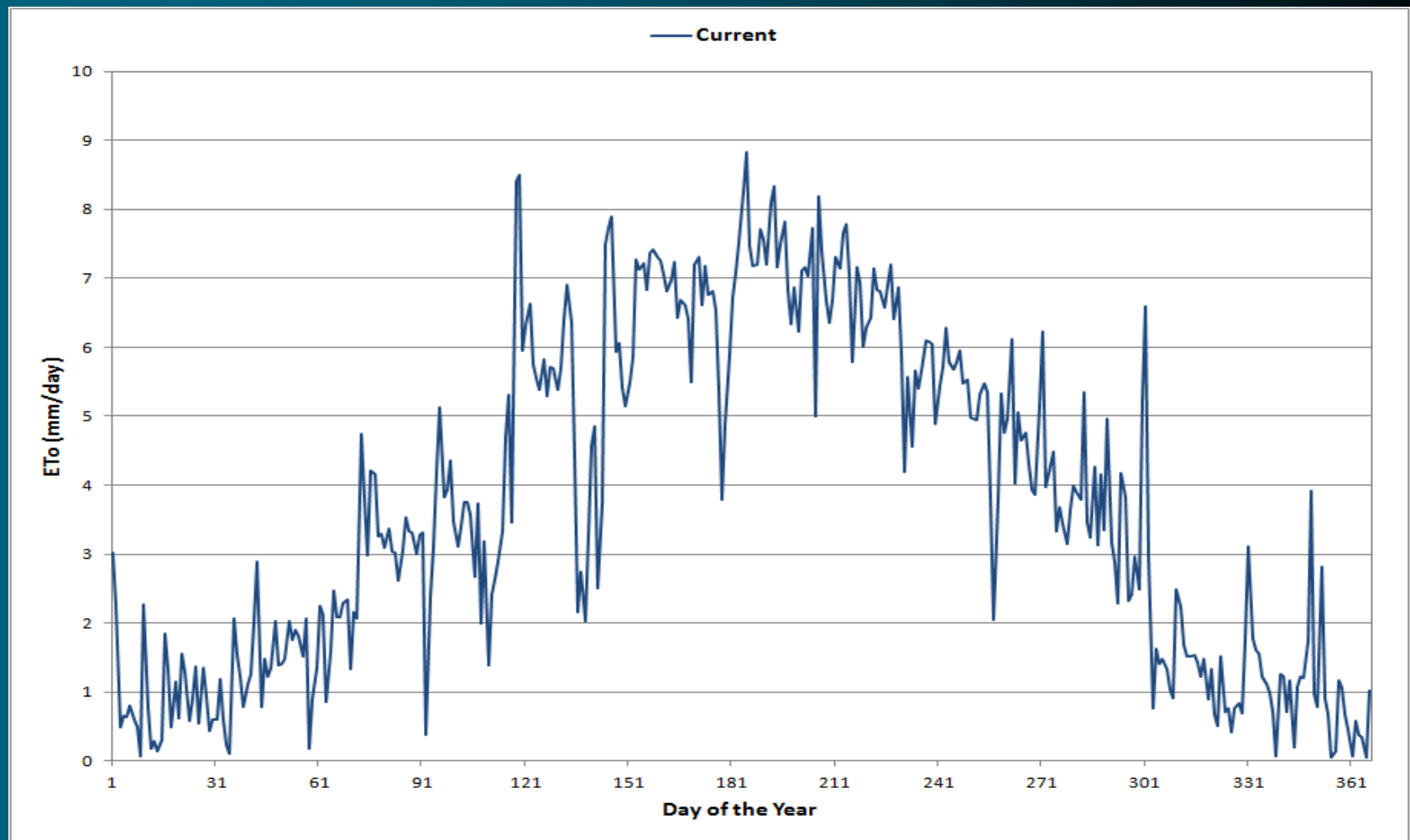
Reference Evapotranspiration (ET_o)

- Penman-Monteith
 - ◆ Daily equation
 - ◆ ASCE recommended
 - ◆ UN_FAO recommended
- Hargreaves-Samani Equation
- Pan evaporation (E_{pan})

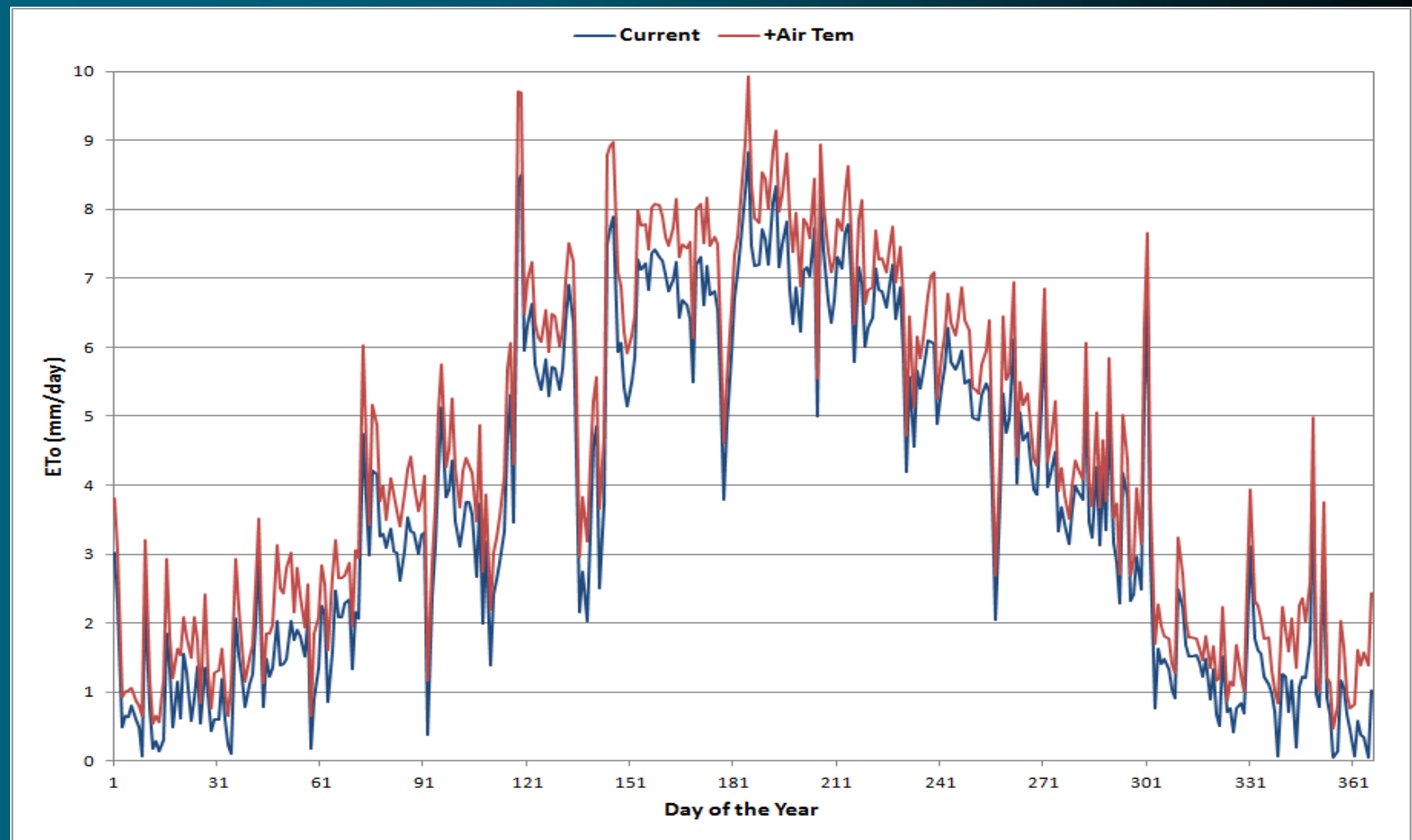
Climate Change

- Evaluate climate change
 - ◆ Solar Radiation, Clouds, and Fog (ETo)
 - ◆ Temperature (ETo)
 - ◆ CO₂ Concentration (ETo)
 - ◆ Rainfall Patterns (ETaw)

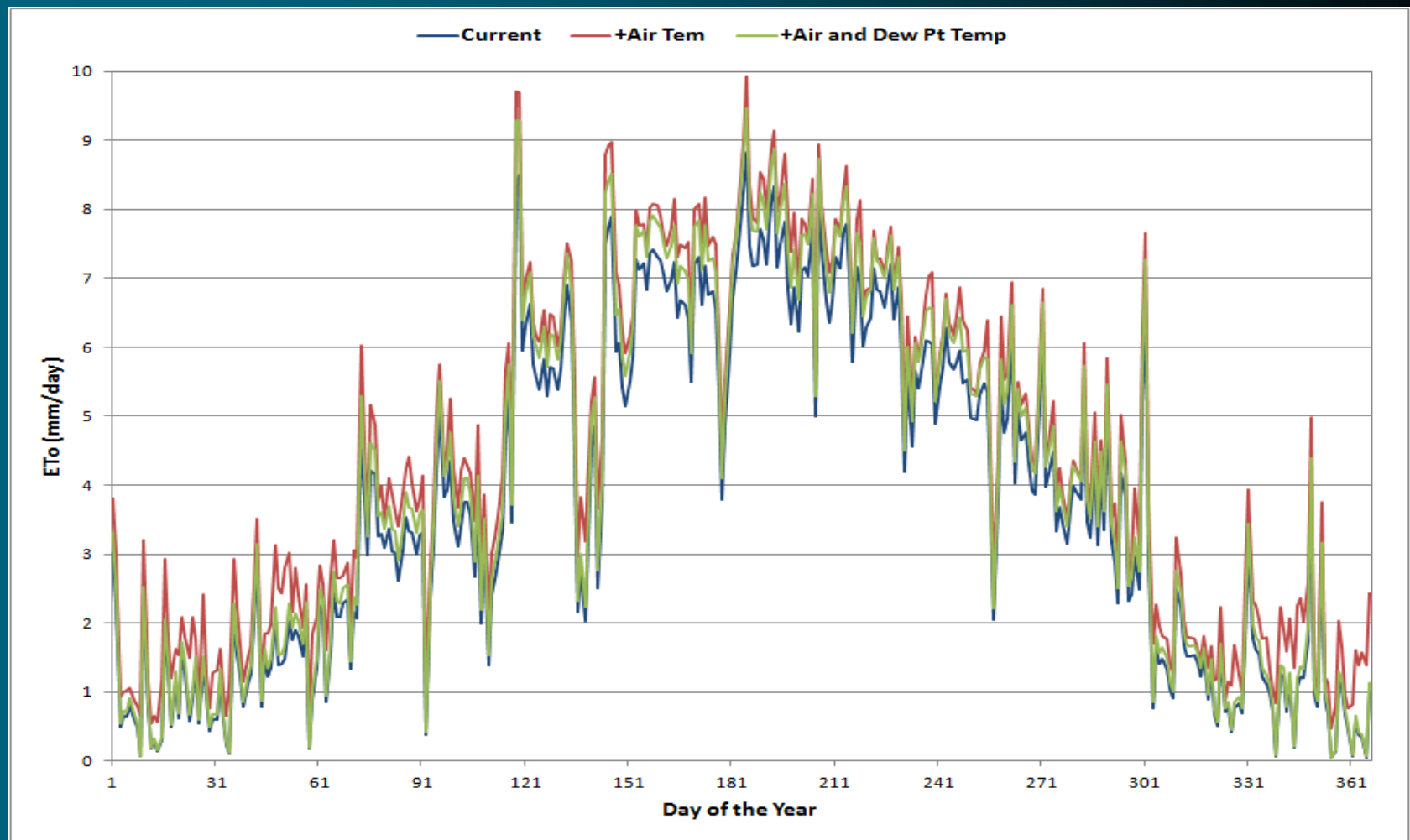
Calculated daily ETo for current conditions at Davis, California



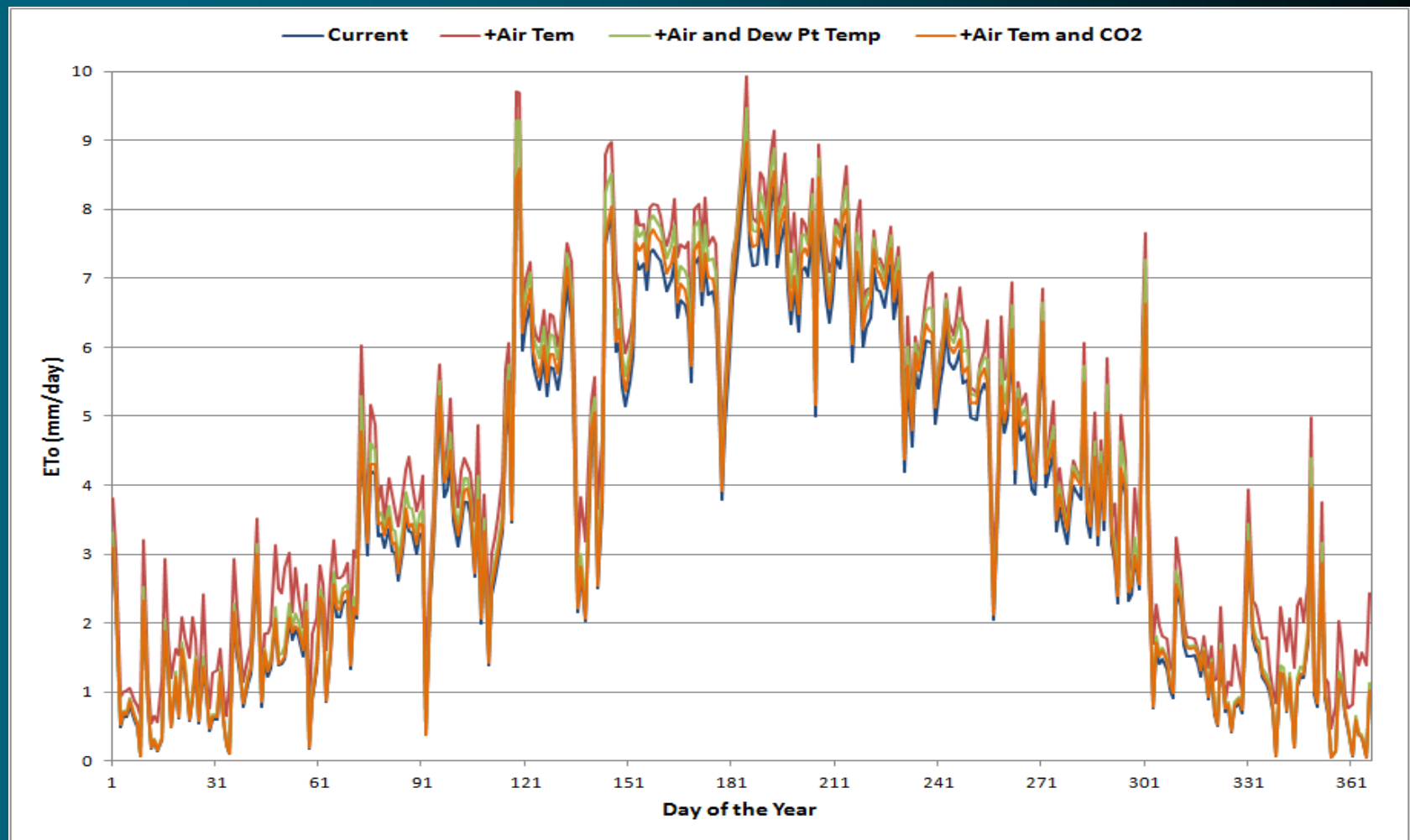
ETo comparison for current and climate change conditions at Davis, California



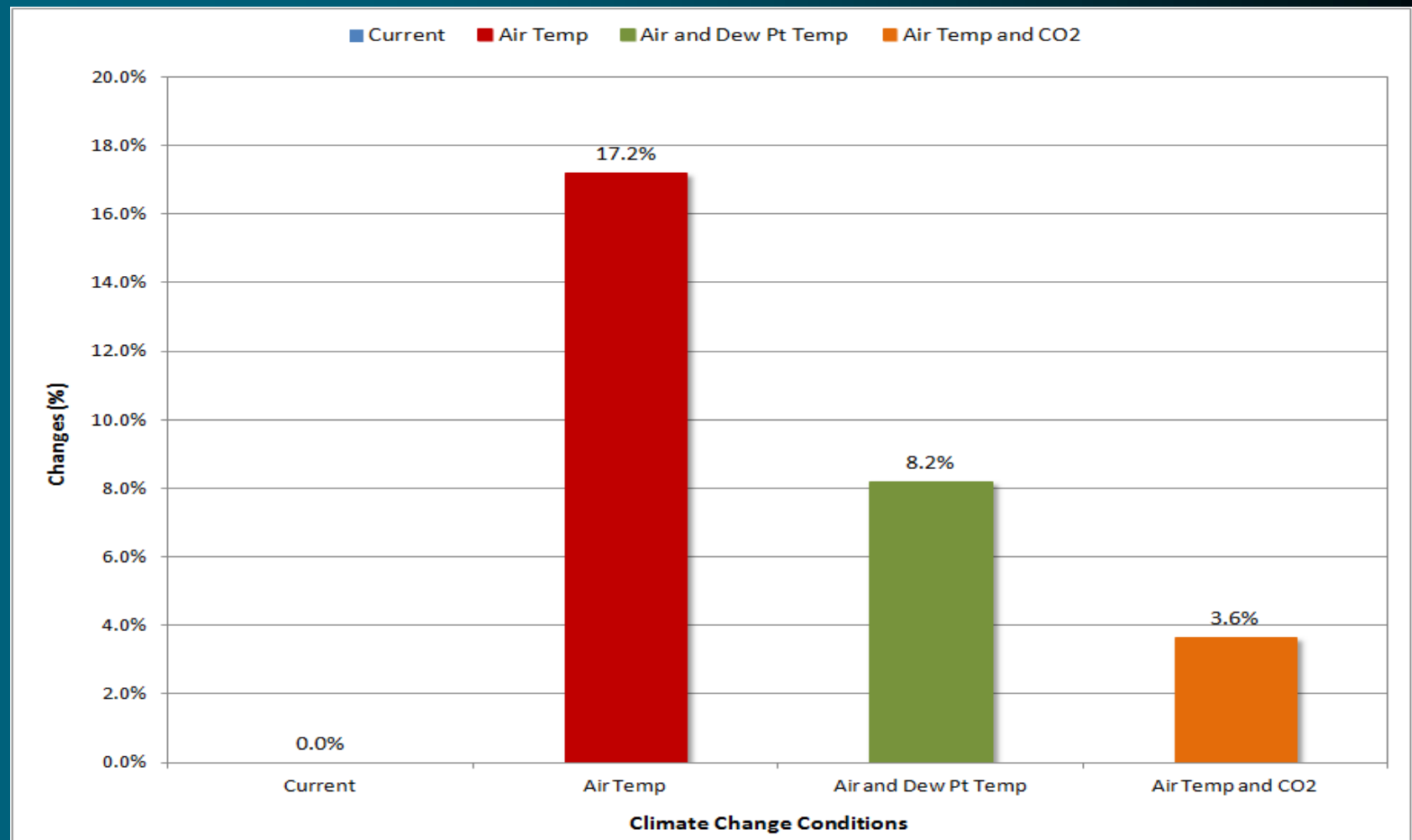
ET_o comparison for current and climate change conditions at Davis, California



ETo comparison for current and climate change conditions at Davis, California



Changes in ETo for current and climate change conditions at Davis, California



Crop & Soil Input

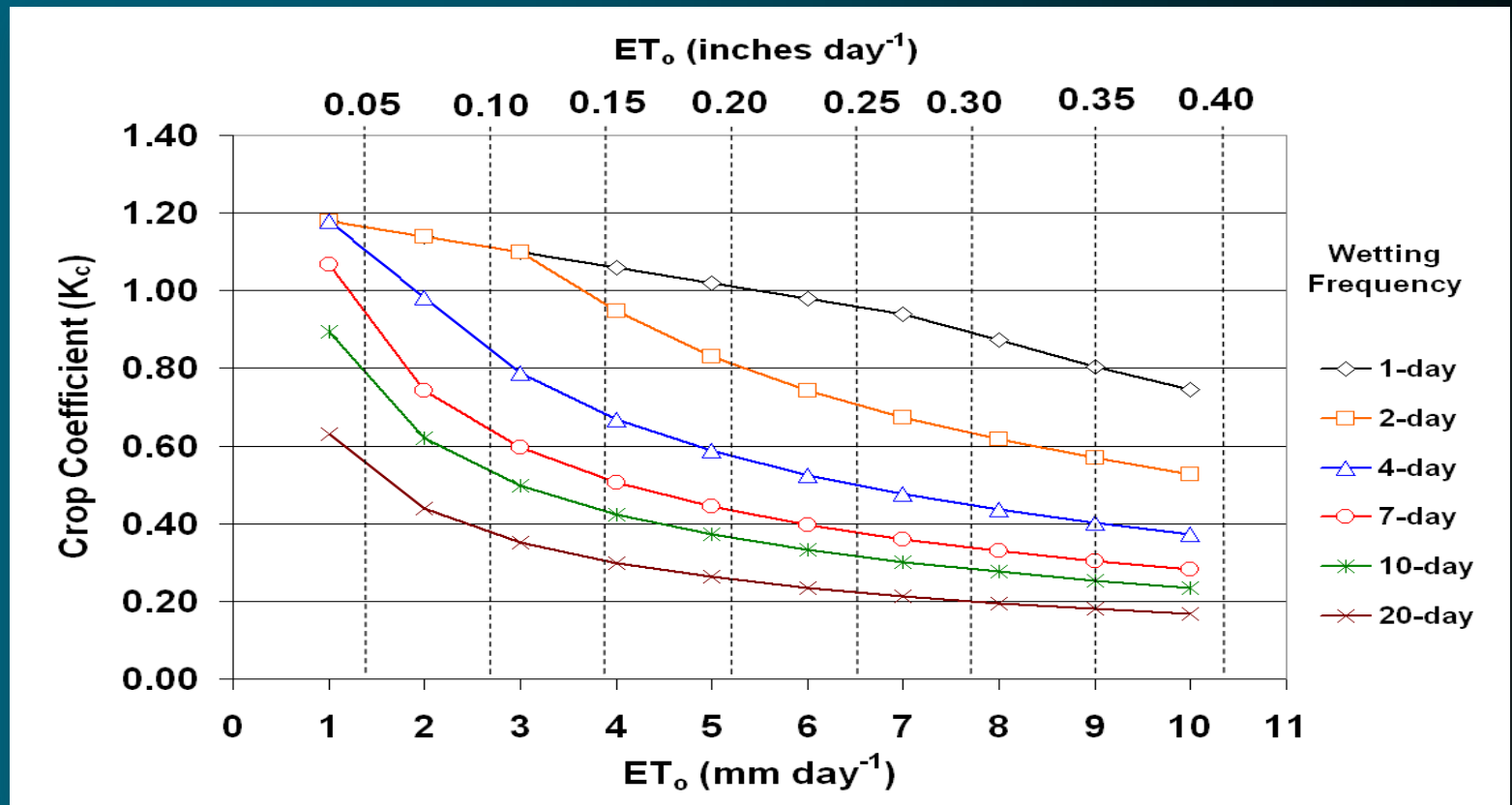
- Crop name
- Starting and ending date
- Wetting frequency during the initial growth period
- Presence of cover crops

Crop & Soil Input

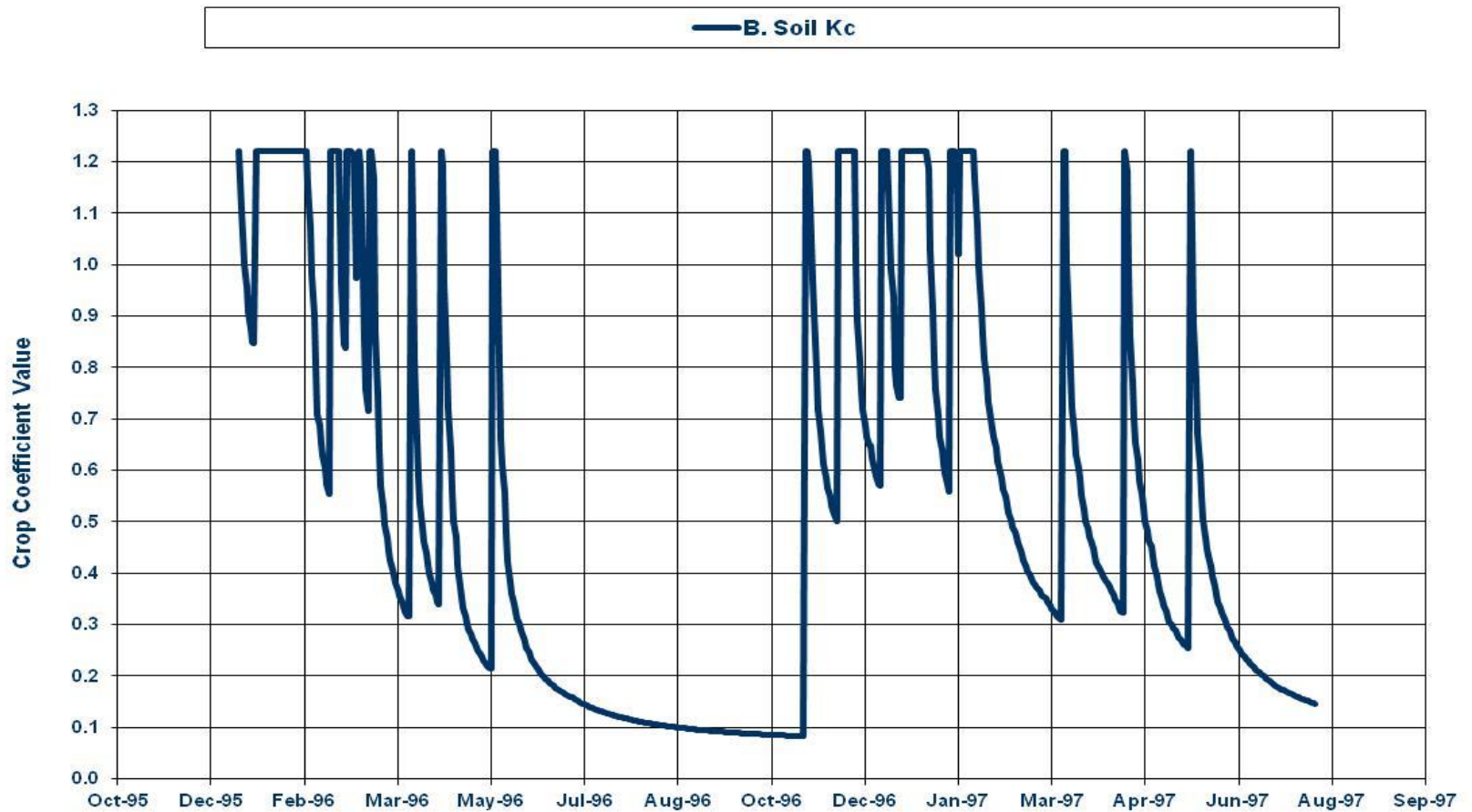
- Immaturity factors
- Maximum rooting depths
- Available water holding capacity (AWHC)
- Maximum soil depths (SDx)
- Allowable depletion (50%)

Crop Coefficients

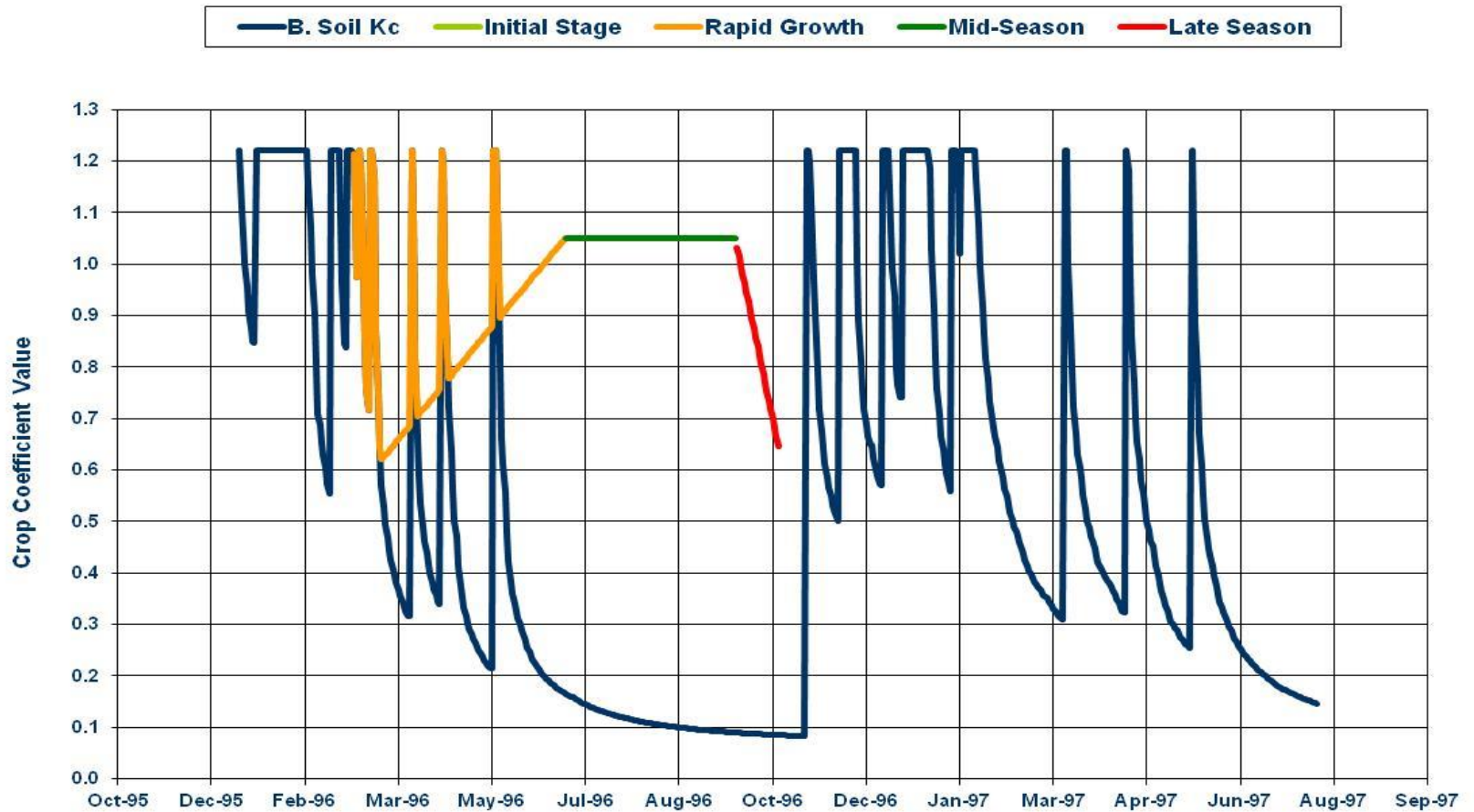
■ Off-season (bare soil) K_c



Crop Coefficients



Crop Coefficients



Crop Coefficients

- Adjustment of Initial K_c for Wetting Frequency
- Cover crop adjustment
- Immature crop adjustment

Daily Soil Water Balance

- Yield threshold depletion

$$YTD = AD \times PAW$$

- Plant available water

- I. If $SDx > RDx$ then $PAW = AWHC \times RDx$

- II. If $SDx < RDx$ then $PAW = AWHC \times SDx$

Daily Soil Water Balance

- Off-season maximum depletion
(50% of PAW in upper 30 cm)

- Soil water depletion

$$SWD = FC - SWC$$

Daily Soil Water Balance

- Effective rainfall
 - I. If $P > SWD$ then $R_e = SWD$
 - II. If $P < SWD$ then $R_e = P$
- Irrigate when $SWD > YTD$
- ET of Applied Water
$$ET_{aw} = \sum NA$$

Daily Soil Water Balance

- Pre-irrigation (start at FC at planting or leaf out)
- No pre-irrigation (start at FC on January 1)

Excel Worksheets

Help

This worksheet provides assistance how to use the CUP+ program for entering the input data requirements for calculating crop water requirements

CUP+ includes 28 Excel Worksheets

1. Disclaimer Worksheet:

Explains that California Department of Water Resources is not responsible for the accuracy, completeness, and quality of the program.

2. HelpAbout Worksheet:

Provides information about the program.

3. About CUP+ Worksheet:

Explains the CUP+ model.

4. Help Worksheet:

Explains the various components of the program and also provides step-by-step instructions on how to enter the input data requirements into the program.

5. ET_o Zones Map Worksheet:

Contains a California map showing 18 zones of similar ET_o data in mm / day.

6. ET_o Zones Worksheet:

Contains a table of monthly mean ET_o rates (mm.day) by ET_o zone.

7. Monthly Climate Input Worksheet:

Is used to input monthly mean ET_o, Epan, or weather data for calculating monthly mean ET_o (mm/day). Weather data include, solar radiation, maximum and minimum temperatures, dew point temperature, wind speed, monthly total precipitation, and number of rainy days per month.

8. Daily Weather Input Worksheet:

Is used to input daily measured weather data for calculating daily ET_o (mm/day). The weather data include, solar radiation, maximum and minimum temperatures, dew point temperature, precipitation, and wind speed.

Excel Worksheets

Monthly Input

CIMIS and Pan Site Description Input

Station Name:

Latitude (deg):

Elevation (m):

Pan Fetch (m):

albedo, α :

Atm. Press, (kPa) :

Solar Const. G_{SC} :

ϕ (latitude in radians) :

Stefan-B. Const., σ :

λ (MJ kg^{-1}) :

γ (kPa $^{\circ}C^{-1}$) :

Selected ET_o Data >>>

Input ET_o and/or Epan data or daily average weather data to calculate PM and/or HS ET_o

Month	R_s (MJ $m^{-2}d^{-1}$)	T_{max} ($^{\circ}C$)	T_{min} ($^{\circ}C$)	U_2 ($m s^{-1}$)	T_d ($^{\circ}C$)	Pcp (mm)	NRD (#)	ET_o (mm day^{-1})	E_{pan} (mm day^{-1})	PM (mm day^{-1})	HS (mm day^{-1})
Canopy Resistance ($s m^{-1}$) = 69								Use priority >>> 1 fetch 2 3			
1	6.5	12.7	3.6	2.6	5.4	102.6	8.6			1.01	1.17
2	10.4	16.0	5.0	2.7	6.6	107.3	6.5			1.70	1.87
3	15.9	19.0	6.0	2.7	7.2	69.6	5.8			2.74	2.92
4	21.5	22.8	7.8	3.0	6.9	17.8	1.7			4.41	4.27
5	25.5	26.3	10.4	3.0	9.2	19.0	1.5			5.56	5.42
6	28.8	30.1	12.7	3.0	10.8	6.0	0.6			6.82	6.42
7	29.0	32.9	13.7	2.7	12.7	3.3	0.3			7.13	6.87
8	26.0	32.5	13.2	2.5	11.5	2.3	0.1			6.52	6.13
9	20.9	30.8	12.1	2.4	10.2	7.4	0.7			5.37	4.82
10	14.8	26.3	9.6	2.4	7.6	17.6	1.5			3.86	3.13
11	9.4	18.4	5.4	2.4	5.3	35.7	3.5			2.11	1.71
12	6.5	12.8	2.7	2.7	4.3	60.8	4.9			1.15	1.10

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.01	1.70	2.74	4.41	5.56	6.82	7.13	6.52	5.37	3.86	2.11	1.15
PM	PM	PM	PM	PM	PM	PM	PM	PM	PM	PM	PM

List of Symbols and their Common Units

R_s - solar radiation (MJ $m^{-2}d^{-1}$)	T_d - dew point temperature ($^{\circ}C$)	NRD - # rainy days per month
T_{max} - maximum temperature ($^{\circ}C$)	U_2 - wind speed at 2 m height ($m s^{-1}$)	(with Pcp > 2 x daily ET_o)
T_{min} - minimum temperature ($^{\circ}C$)	Pcp - precipitation (mm)	E_{pan} - pan evaporation (mm/day)

Excel Worksheets

Daily Weather Input

CIMIS Site Description Input		Input daily raw weather data to calculate PM and/or HS ET ₀								
Station Name is:	Colusa	Date #	DOY #	R _s MJ m ⁻² d ⁻¹	T _{max} °C	T _{min} °C	U ₂ m s ⁻¹	T _d °C	Pcp mm	ET ₀ mm
Latitude (deg) is:	39.20	1/1/1996	1	8.73	21.00	9.30	3.70	5.50	0.00	3.01
Elevation (m) is:	17.00	1/2/1996	2	8.82	20.10	10.30	3.30	8.30	0.00	2.28
Canopy Resistance (s/m):	69.35012827	1/3/1996	3	3.46	13.10	6.20	1.40	9.30	0.00	0.50
r _s (s/m):	208.00	1/4/1996	4	5.96	14.30	6.10	1.10	8.60	0.00	0.66
albedo, α:	0.23	1/5/1996	5	5.01	14.00	5.60	1.30	8.60	0.00	0.63
Atm. Press. (Kpa):	101.10	1/6/1996	6	9.08	16.80	3.10	0.90	7.10	0.00	0.80
Solar Const. G ₉₀₀ :	0.08	1/7/1996	7	6.14	13.60	4.20	0.90	7.80	1.00	0.59
φ (rad):	0.68	1/8/1996	8	4.24	12.20	4.50	0.90	8.00	0.00	0.50
Stefan-B. Const., σ:	0.00	1/9/1996	9	0.86	9.90	7.10	2.30	8.50	2.00	0.06
λ (MJkg ⁻¹):	2.45	1/10/1996	10	9.59	17.70	5.90	4.50	6.10	0.00	2.27
γ (Kpa °C ⁻¹):	0.067	1/11/1996	11	5.70	14.60	1.80	1.30	6.40	0.00	0.77
r _d /r _s :	0.333414	1/12/1996	12	2.85	7.10	1.50	1.30	5.50	0.00	0.18
		1/13/1996	13	2.94	6.70	4.30	1.30	5.70	0.00	0.29
		1/14/1996	14	1.64	6.20	4.40	1.60	5.30	1.00	0.15
		1/15/1996	15	2.42	10.40	5.90	4.10	7.90	4.00	0.31
		1/16/1996	16	5.62	19.80	5.90	4.60	9.80	20.00	1.86
		1/17/1996	17	8.99	13.00	3.40	2.00	2.50	0.00	1.32
		1/18/1996	18	1.64	12.20	3.50	3.20	6.90	11.00	0.48
		1/19/1996	19	9.51	15.50	1.40	1.80	5.20	0.00	1.16
		1/20/1996	20	3.72	12.60	2.30	4.30	7.10	7.00	0.63
		1/21/1996	21	9.68	14.50	5.60	2.30	4.20	0.00	1.55
		1/22/1996	22	10.72	11.10	0.10	2.40	0.90	0.00	1.27
		1/23/1996	23	2.59	7.10	3.70	5.50	4.00	1.00	0.59
		1/24/1996	24	5.01	14.20	6.80	5.90	9.30	4.00	0.92
		1/25/1996	25	10.98	13.80	1.30	1.60	1.20	0.00	1.37
		1/26/1996	26	3.72	8.30	-0.10	1.00	3.00	5.00	0.54
		1/27/1996	27	7.61	15.50	3.50	5.20	7.60	15.00	1.35
		1/28/1996	28	8.82	14.10	0.70	1.10	5.00	0.00	0.93
		1/29/1996	29	3.72	9.40	1.90	1.00	5.90	0.00	0.44
		1/30/1996	30	3.54	10.00	6.60	2.70	7.20	5.00	0.60
		1/31/1996	31	3.63	12.80	6.80	2.70	9.10	6.00	0.61
		2/1/1996	32	11.24	16.30	2.70	1.50	7.20	0.00	1.19
		2/2/1996	33	3.72	12.20	8.30	1.30	9.40	0.00	0.60

Symbols and their Common Units

R _s - solar radiation (MJ m ⁻² d ⁻¹)
T _{max} - maximum temperature (°C)
T _{min} - minimum temperature (°C)
T _d - dew point temperature (°C)
U ₂ - wind speed at 2 m height (m s ⁻¹)
Pcp - precipitation (mm)
ET ₀ - reference evapotranspiration (mm d ⁻¹)

Excel Worksheets

Input_Output

Summary of Input Data

Plant Year:	1996
Select an Input Data File:	Weather
Select a path for ETo:	Daily
Choose a Crop Type:	Deciduous
Choose a Crop:	Apple
Crop Number is:	3.02
Crop is:	Apple
Enter Starting Date:	
Default Starting Date:	1-Apr-96
Enter End Date:	
Default Ending Date:	15-Nov-96
AWH Capacity (mm/mm):	0.15
Max. Soil Depth (mm):	1500
Max. Root Depth (mm):	1500
Allow. Depl. (%):	50

Enter 1st Cover Crop (mon/day)

Start Date (mon/day):

End Date (mon/day):

Enter 2nd Cover Crop (mon/day)

Start Date (mon/day):

End Date (mon/day):

Enter Ground Cover in Percentage (%)

C

D


CUP^{plus} - Version 4.0

Calculated ETo, ETc, and ETaw (mm/month) and weighted mean Kc values


Month:	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Kc ():	0.73	0.82	0.95	1.10	1.15	1.14	1.01	0.88
ETo (mm):	115.22	163.80	199.62	225.58	191.39	144.88	105.87	22.12
ETc (mm):	82.06	131.92	188.51	248.43	220.10	164.76	105.78	19.50
ETaw (mm):	38.45	99.42	188.88	249.85	221.52	166.14	76.28	
Seasonal ETo (mm):	1,168.47			Seasonal ETc (mm):			1,161.06	
Seasonal ETaw (mm):	1,040.54			Annual ETaw (mm):			1,075.38	

Monthly Total Values of ETo, ETc, and ETaw (mm mon-1) for Apple

Developed by Land and Water Use, California Department of Water Resources
 And
 Department of Land, Air and Water Resources, University of California, Davis
 Morteza N. Orang, Richard L. Snyder



CALIFORNIA
DEPARTMENT OF WATER RESOURCES



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Excel Worksheets

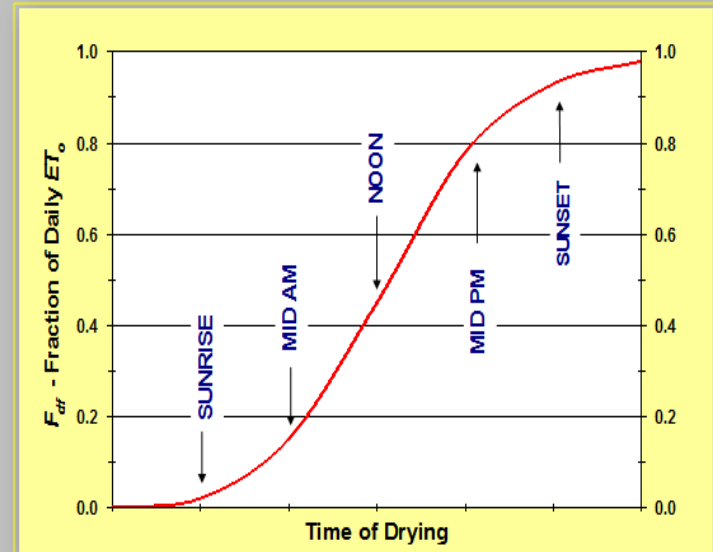
Seepage; Fog; Dew Input

Input seepage, fog interception, and dew contributions to evapotranspiration

Month	ET _o	Fog & Dew Contribution	F _{df}	Seepage Contribution	E _{sdf}
	mm	mm H ₂ O per day		mm H ₂ O per day	
1	0.9	0.10	0.09	0.40	0.49
2	1.4	0.10	0.14	0.40	0.54
3	2.8	0.10	0.28	0.40	0.68
4	3.8	0.10	0.38	0.40	0.78
5	5.3	0.10	0.53	0.40	0.93
6	6.7	0.10	0.67	0.45	1.12
7	7.3	0.10	0.73	0.45	1.18
8	6.2	0.10	0.62	0.45	1.07
9	4.8	0.10	0.48	0.45	0.93
10	3.4	0.10	0.34	0.40	0.74
11	1.3	0.10	0.13	0.40	0.53
12	0.9	0.10	0.09	0.40	0.49

Data Source: Daily Weather Input

Typical seepage range: 0.00 to 0.35 mm d⁻¹



Use the figure on the top to estimate fog and/or dew contributions

Using the approximate time of day that the plants dry off from overnight dew and fog interception, select the fraction (F_{df}) of daily ET_o. Enter the F_{df} coefficient in the table above by month. The Fog & Dew contribution is automatically calculated by month from the daily ET_o rates.

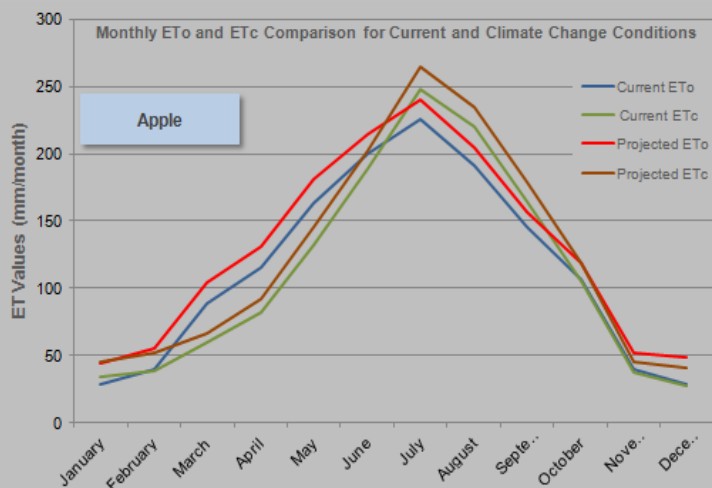
Excel Worksheets

Climate Change

Create climate change scenarios to determine its impacts on evapotranspiration rates

Data Requirements for Climate Change Scenario

Enter New CO ₂ Concentration Value (ppm)	550.00
Enter Percentage of Current Solar Radiation:	
Change Maximum Temperature (°C) by Degrees:	3.00
Change Minimum Temperature (°C) by Degrees:	3.00
Change Dew Point Temperature (°C) by Degrees:	



ET_o and ET_c Using Current and Climate Change Data (mm/month)

Year	Month	ET _o -Current	ET _c -Current	ET _o -Projected	ET _c -Projected
1996	January	28.62	33.59	43.69	45.54
1996	February	39.62	38.65	55.38	51.33
1996	March	88.08	59.05	104.09	66.56
1996	April	115.22	82.06	130.49	91.45
1996	May	163.80	131.92	180.76	145.76
1996	June	199.62	188.51	214.19	202.33
1996	July	225.58	248.43	240.65	265.02
1996	August	191.39	220.10	204.26	234.90
1996	September	144.88	164.76	157.05	178.62
1996	October	105.87	105.78	118.52	118.45
1996	November	40.01	37.60	51.63	44.99
1996	December	28.71	27.59	48.57	40.60
Annual	Jan-Dec	1371.40	1338.05	1549.29	1485.57

Annual variations in ET due to climate change factors:

↑ 11.5% ↑ 9.9%

Reference evapotranspiration (ET_o) and crop evapotranspiration (ET_c) calculations for current and climate change conditions

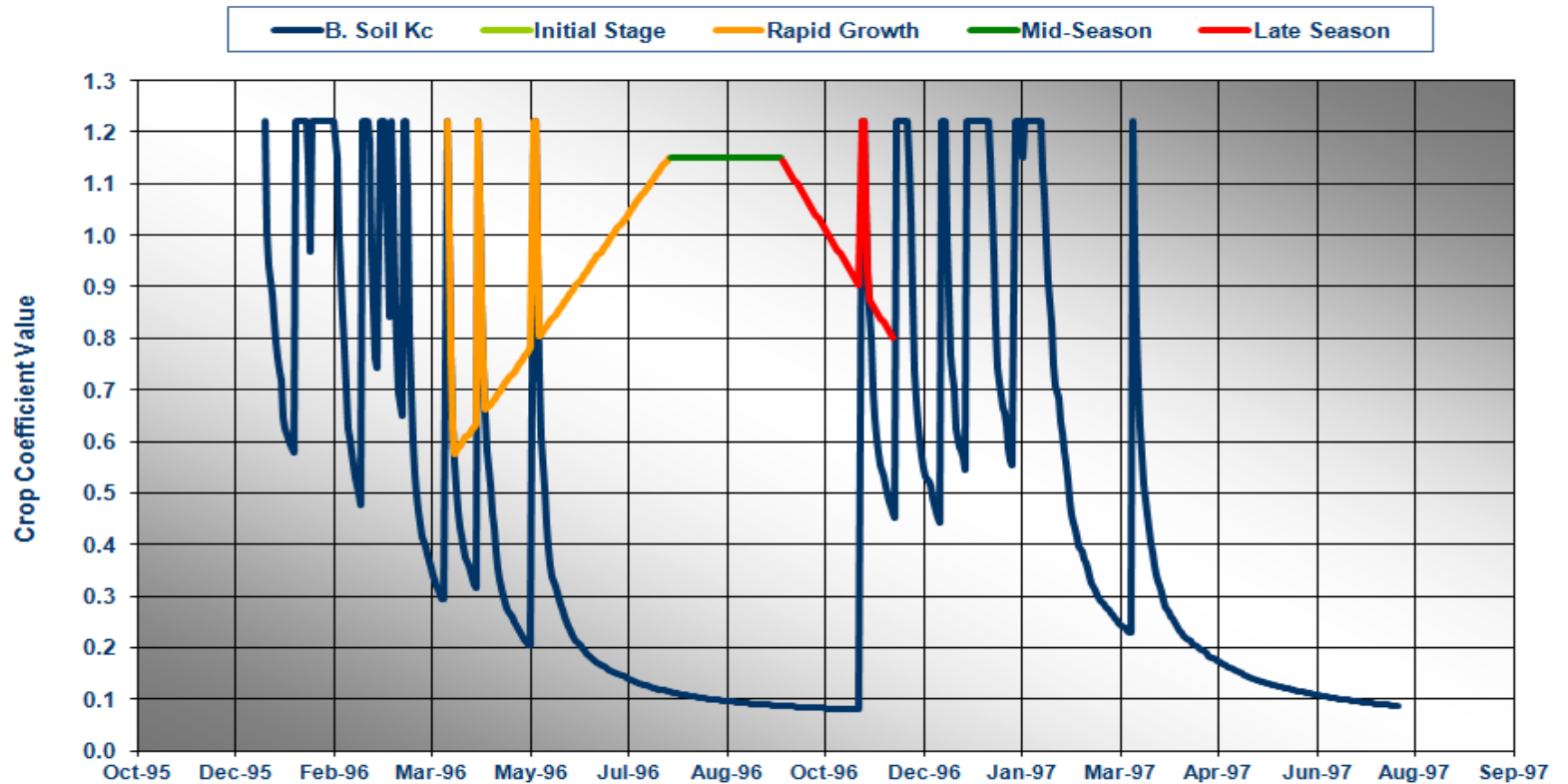
Data Source: Daily Weather Input

Excel Worksheets

Kc Chart

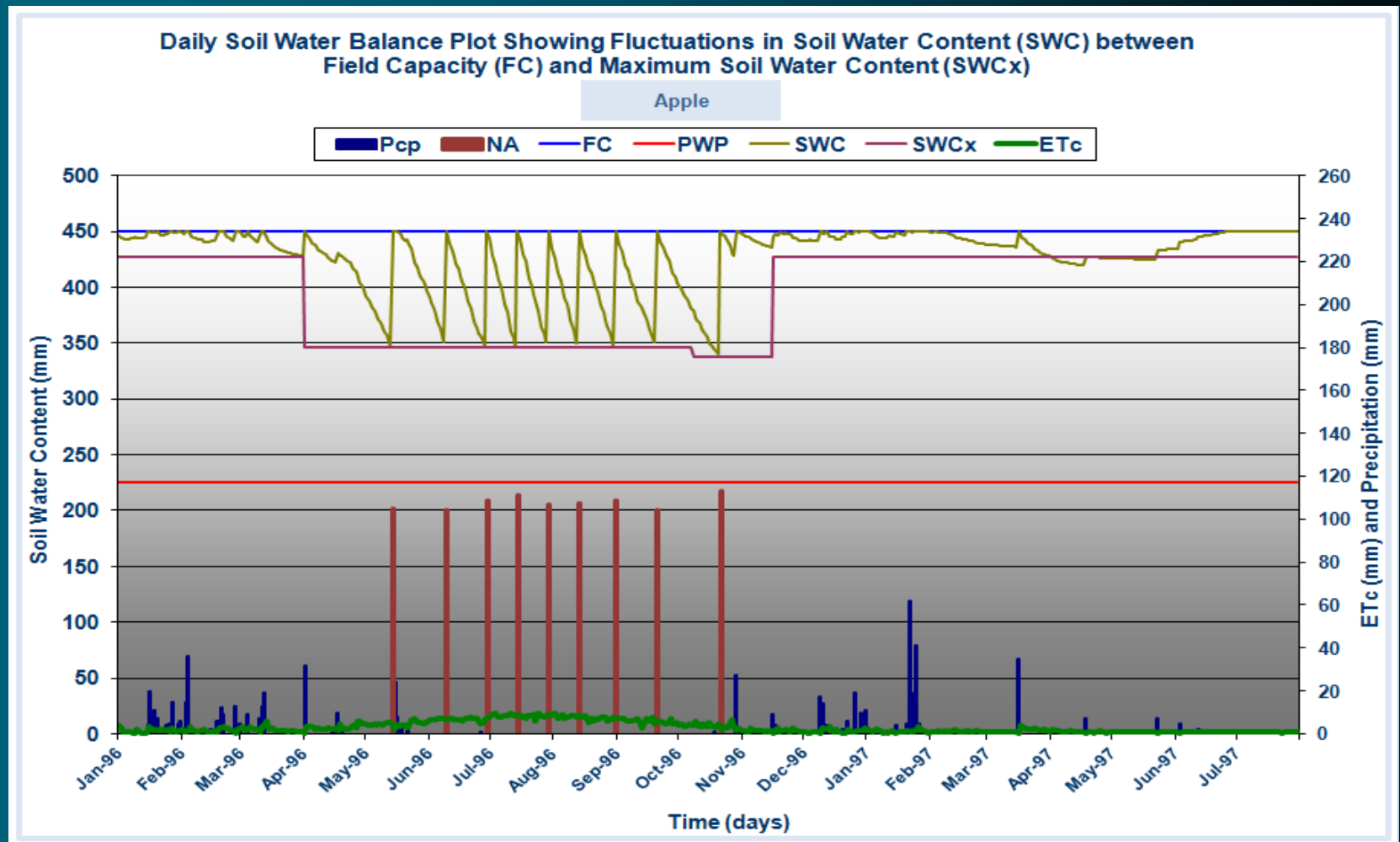
Bare soil K_c value is used as a baseline for estimating crop coefficient values during the off season

Apple



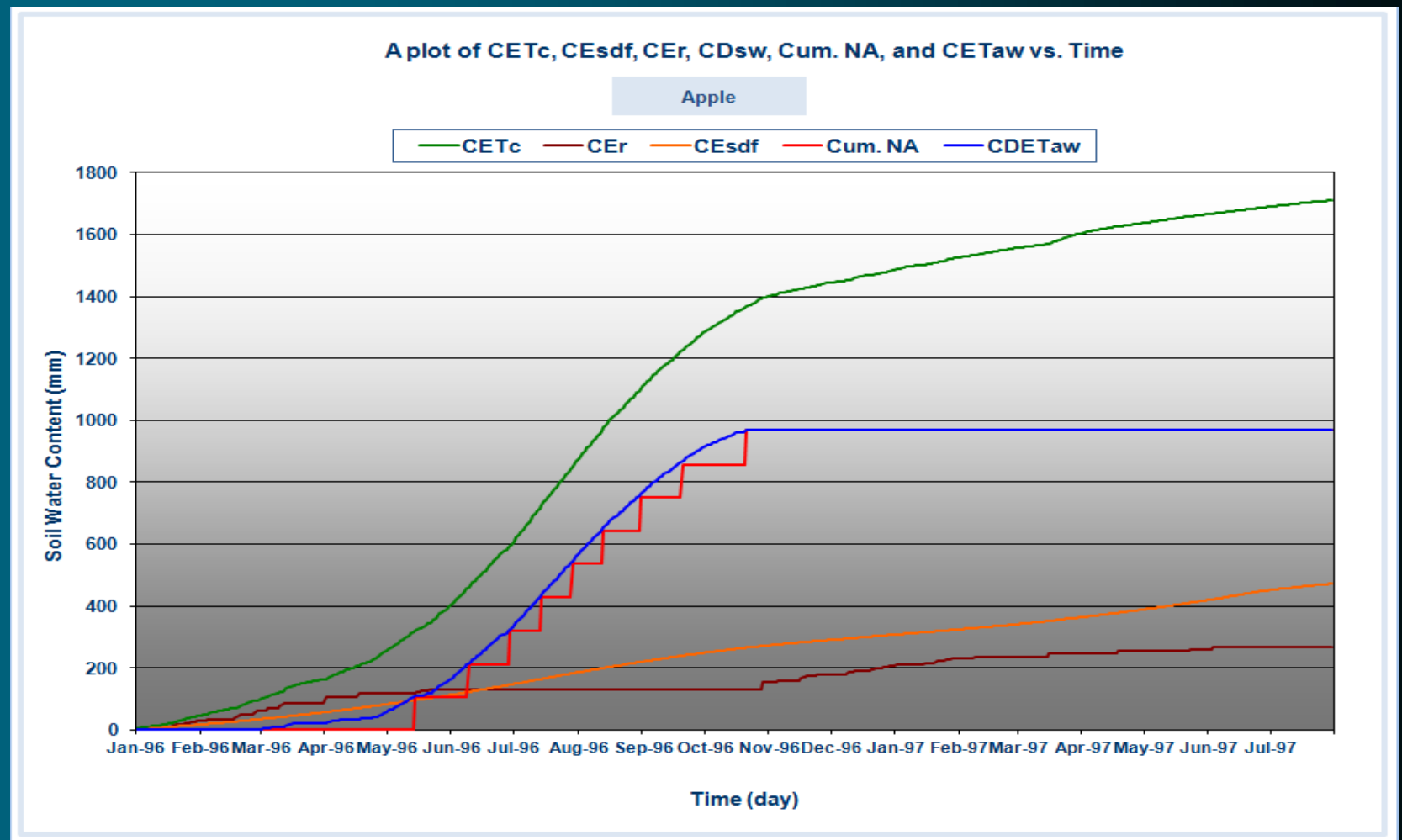
Excel Worksheets

WB Chart



Excel Worksheets

CETaw Plot



Additional Features

- Allows easy input of weather, crop, and soil information
- Outputs a wide range of tables and charts that are useful for irrigation planning
- View the output values as they are created
- User Friendly

The End

Questions