SC-SIMETAW

(Historical Estimates of ET of Applied Water of Agricultural Crops and Urban Landscape in the South Coast Region)

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Introduction

The South Coast Simulation of Evapotranspiration of Applied Water (SC-SIMETAW) was specifically designed to estimate historical ET of applied water of agricultural crops and warm-season grass in the South Coast region for the Department's Surface Storage Program work. The work required modeling annual applied water demand at the existing (2004) and future (2030) levels of demand using historical period (water year 1922 to 2007) hydrology to provide input to allow the Department's Least-Cost Planning Simulation (LCPSIM) Model to better simulate regional urban water management operations in the South Coast Region. The application uses a weather generator to simulate daily weather data from monthly mean values from PRISM and to estimate daily soil water balance for surfaces within the South Coast region that account for evapotranspiration losses and water contributions from rainfall and irrigation. It computes daily reference evapotranspiration (ETo), crop coefficient factors (Kc), crop evapotraspiration (ETc), daily water balance, effective rainfall, evapotranspiration of applied water (ETaw), etc. for agricultural crops and warm-season grass within each of the 13 DAUs (Detail Analysis Unit) in the South Coast region for the water years 1922-2007. The water balance model is similar to that used in the Simulation of ET of Applied Water (SIMETAW) application program, which was also developed as a cooperative effort between the University of California (UC) and the Department of Water Resources (DWR). The main difference between the SIMETAW and SC-SIMETAW application programs is that SIMETAW is used to determine the daily water balance of individual fields of crops within a study area, whereas SC-SIMETAW is designed to use batch files of input data to compute daily water balance for all 16 land use categories over the period of record for each of 13 DAUs within the South Coast region having a range of evaporative demand and rainfall.

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Methodology

The SC-SIMETAW program is developed to use a weather generator to simulate many years of daily weather data from monthly mean values from PRISM and to estimate daily soil water balances for agricultural crops and warm-season grass within the South Coast region using the simulated weather data. The model uses a large database of weather, soil water holding capacities, and depths on a 4 km X 4 km grid over the entire South Coast region, which can be used to determine the weighted mean water holding capacity for soils on the DAU. The weather data include daily mean maximum and minimum air temperature and total precipitation by month from October 1921 to September 2007. The application uses batch processing to read (1) the temperature and precipitation data, (2) the surface/crop coefficient values, (3) growth dates to estimate annual curves, (4) soil information, (5) crop and irrigation information, and (6) the surface area of each land-use category on each of the 13 DAUs. The simulated daily temperature data were used to calculate daily ETo rates using the Hargreaves-Samani (HS) equation. Because the HS equation is based on temperature only, ETo from the HS equation were compared with CIMIS ETo at the same locations using available CIMIS data to determine correction factors to estimate CIMIS ETo from the HS ETo. GIS was used to obtain a spatial distribution of correction factors which in turn were used to convert HS ETo to CIMIS ETo. The currently accepted crop coefficients were then used to estimate daily crop water use by DAU. The result is a large data base of historical crop evapotranspiration that will be used to update inputs into the Department's LCPSIM model. The program computes daily ETo, Kc factors, ETc, daily water balance, effective rainfall, ETaw, etc. for every surface within each of the 13 DAU for the 85 year period. The application also accounts for seepage contributions to ETc and it estimates soil evaporation using a 2-stage soil evaporation model based on ETo and surface wetting frequency. SC-SIMETAW was specifically set up to analyze historical climate data, to account for spatial variability within the South Coast region and to compute ETaw for 16 land use categories that change from year-to-year.

Crop and Soil Data

To determine ETaw within a DAU, SC-SIMETAW also requires the crop and soil information for each DAU. The input data include as following:

- Land and use category name

- Planting and ending dates

- Weighted mean available water holding capacity

- Acreage planted

- Maximum soil depth

- Maximum effective rooting depth during growing season

- Allowable depletion (%)

- Pre-irrigation

- Initial growth wetting frequency
  Irrigation frequency is the number of days between irrigation events during the initial growth period. (30 days is the default value). If a value more frequent than 30 days is input, the input irrigation frequency will be used.

- Ground cover percentage on date B, C, D, and E, which are used to account for immaturity effect on Kc values for tree and vine crops. Values of '70%' or greater indicate that the tree or vine crop is mature.

- Cover crop dates
  If there is a cover crop for tree and vine crops, enter the beginning and ending dates. There can be two periods of cover crops during a year.

SC-SIMETAW is currently not designed to account for initial growth irrigation frequency, pre-irrigation information, immaturity factors, and presence of cover crops. This feature was not included because the data base of information is unavailable. The ability to account for these

factors can be easily added to the application program. Table 2 describes the variables contained in each row of the crop/soil file.

In SC-SIMETAW, seasonal Kc curves are used to estimate evapotranspiration for the 16 various crop categories. The crop coefficient factors (Kc) are multiplied by reference evapotranspiration (ETo) to estimate the ET of a particular crop category. We will use the symbol ETc, which is commonly used for crop evapotranspiration, as the symbol for evapotranspiration by the crop category. Therefore, the crop category evapotranspiration rate on any given day is calculated as:

$$ETc = ETo \times Kc \qquad (1)$$

Where, Kc is a factor to convert ETo to ETc.

Crop Categories

The SC-SIMETAW application uses 16 crop categories. Each category includes one or more crops. The crop categories and what they include vary depending on the source of the information (i.e. land-use survey, or California Agricultural Water Use Model). A sample of the crop category for water years 1922-1940 is shown in Table 1.

Table 1. An example of 27 rows of a soil and crop data file.

		Turf	Irrig							Irrig	Dry	Truck	Fresh	Process			
Crop		W-season	Pasture	Alfalfa	Field	Corn	Onion	Potato	Cucurb	Grains	Beans	Crops	Tomato	Tomato	Orchard	Vineyard	Sub Tropic
Code	Type	TU	PA	AL	FI	CO	ON	PO	CU	GR	BE	TR	TO	TO	OR	VI	SU
Number	#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Type		2	2	2	1	1	1	1	1	1	1	1	1	1	3	3	4
BD		1-Jan	1-Jan	1-Jan	1-Apr	1-Apr	1-Oct	1-Apr	1-Mar	1-Nov	15-Apr	1-Apr	1-Apr	1-Feb	1-Apr	1-Apr	1-Jan
ED		31-Dec	31-Dec	31-Dec	31-Jul	31-Aug	31-May	30-Sep	30-Jun	31-May	31-Jul	31-Aug	31-Aug	25-Jul	15-Nov	15-Oct	31-Dec
BD		1	1	1	92	92	275	92	61	306	106	92	92	32	92	92	1
ED		366	366	366	213	243	517	274	182	517	213	243	243	207	320	289	366
F		30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Kc1		0.6	0.95	1	0.21	0.2	0.8	0.8	0.8	0.33	0.2	0.37	0.3	0.3	0.55	0.45	0.85
Kc2		0.6	0.95	1	1.04	1.05	1	1.1	0.85	1.1	1	1.01	1.1	1.1	1.05	0.8	0.85
Kc3		0.6	0.95	1	0.57	0.6	0.75	0.7	0.85	0.15	0.1	0.38	0.65	0.65	0.8	0.35	0.85
a-b		25	0	0	19	20	10	20	19	20	24	14	25	25	0	0	0
a-c		50	33	33	44	45	26	45	47	45	40	31	50	50	49	25	33
a-d		75	67	67	76	75	75	78	85	75	91	92	80	80	75	75	67
SDx		1524	1524	1524	1524	1524	1524	1524	1524	1524	1524	1524	1524	1524	1524	1524	1524
RDx		1500	1219.2	1219.2	914.4	1371.6	609.6	762	914.4	1219.2	762	914.4	914.4	609.6	1219.2	1219.2	914.4
AW		0.16	0.16	0.16	0.16	0.16	0.16	0.22	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
AD %		50	50	50	55	60	25	40	35	55	45	50	40	40	50	45	50
GCB																	
GCC																	
GCD																	
BC1																	
EC1																	
BC2																	
EC2																	

The first 27 rows of the file includes the crop type number, the begin (BD) and end (ED) calendar dates and day of the year, the Kc values from dates a-b (Kc1), dates c-d (Kc2), and date E (Kc3), the percentages of the season from dates a-b, a-c, and a-d, the maximum soil depth

(SDx), the maximum root depth for the South Coast region, the available water holding capacity, and the allowable depletion (50%). Table 2 contains symbol definitions.

The Kc curves for the 16 land-use categories were determined as weighted means of the crop or other surface Kc curves within each category based on percentages that were observed in the land-use surveys.

Table 2. Symbols used in Table 1.

Symbol	Variable
BD	Beginning calendar date for the in-season period
ED	Ending calendar date for the in-season period
BD	Beginning day of the year for the in-season period
ED	Ending day of the year for the in-season period. Subtract 365 for bigger numbers.
F	Frequency of irrigation during initial growth of type 1 crops (default =30 days)
Kc1	Crop coefficient on date B and between dates A and B
Kc2	Crop coefficient between dates C and D
Kc3	Crop coefficient on date E
a-b	Percentage of the season from date A to B
a-c	Percentage of the season from date A to C
a-d	Percentage of the season from date A to D
SDx	Maximum soil depth (mm)
RDx_Lo	Maximum crop root depth in Delta lowlands (mm)
RDx_Up	Maximum crop root depth in Delta uplands (mm)
AW_Lo	Available water content in Delta lowland soil (mm)
AW_Up	Available water content in Delta upland soils (mm)
AD %	Allowable depletion of available water (%)

Detail Analysis Units (DAU)

DAUs are the geographic boundaries that are used for estimating water demand by agricultural crops and other surfaces for a region for planning studies. There are 13 DAUs within the South Coast region and are numbered that can be used to identify regions of similar reference evapotranspiration (ETo).

Calculating the Yield Threshold Depletion (YTD)

Soil water-holding characteristics, effective rooting depths, and irrigation frequency are used with rainfall and ETc data to calculate a daily water balance and determine effective rainfall and

ETaw, which is equal to the seasonal cumulative ETc minus the effective rainfall. Irrigations are timed so that the estimated soil water depletion (SWD) does not exceed the yield threshold depletion (YTD), which is calculated as the product of the allowable depletion and the plant available water content within the crop rooting depth. The plant available water content is computed as the product of the soil available water-holding capacity and the effective rooting depth. The allowable depletion is a crop and soil specific factor that defines the fraction (or percentage) of the available water content within a rooting zone that can be depleted between irrigation events. For many crop and soil combinations, an allowable depletion of 50% is adequate. In the off-season, the maximum soil water depletion (SWDx) is set equal to 50% of the available water content within the top 0.3 m. It is assumed that, without a crop, the soil in the top 0.3 m cannot lose more water than SWDx.

Crop rooting depth, maximum soil depth, and water holding characteristics are used to calculate the yield threshold depletion (YTD), which is used to make a crop and soil specific irrigation schedule. The available water holding capacity of the soil value is multiplied by the smaller of the rooting depth or the soil depth to determine the plant available water (PAW) within the soil reservoir at the maximum rooting depth for the crop. The YTD is calculated as the product of the allowable depletion (expressed as a fraction) and the PAW. In reality, the rooting depth and PAW increase as the roots grow, but, because of the additional complexity, this is ignored in the SC-SIMETAW model. The maximum rooting depths vary depending whether the DAU is in the South Coast region and on the land-use category. The available soil water holding capacities and depths on a 4Km X 4Km grid over the entire South Coast region were determined from SURRGO (Soil Survey Geographic Database).

Reference Evapotranspiration (ETo)

Reference evapotranspiration (ETo), an estimate of the evapotranspiration from a well-watered, improved pasture, is technically defined as the ET from a short 12 cm tall vegetation of large extent and not lacking for water. In practice, ETo is approximately equal to the ET of a 12 cm tall, cool-season pasture grass. The SC-SIMETAW application program uses ETo and crop coefficients to estimate crop ET (ETc) assuming no water or salinity stress.

Climate data

To estimate ETo, SC-SIMETAW uses the Hargreaves-Samani (HS) equation and daily maximum and minimum temperatures, on a 4×4 km grid spacing over the South Coast, from the USDA PRISM climate database for the period of record. Calibration factors to convert from the HS estimates of ETo to the standardized Penman-Monteith (PM) daily (24-hour) ETo were determined by comparing ETo calculated using the PM equation using daily solar radiation, maximum and minimum temperature, the mean dew point temperature, and mean wind speed with HS ETo calculated from daily maximum and minimum temperature. The data for calculating PM ETo came from CIMIS stations and the data for calculating HS ETo came from nearby NCDC stations. The procedure to develop conversion factors from HS to PM ETo is explained below.

PRISM

PRISM is a data base that was developed by the USDA to spatially estimate climate variables from climate data and to account for elevation. The PRISM software generates gridded estimates of climatic parameters (e.g. precipitation and temperature). It uses a moving-window regression of climate values from nearby climate stations versus elevation or climatology for each grid cell. A spatial climate knowledge base weights data in the regression function according to their physiographic similarity to the target grid cell. PRISM accounts for spatial variations in climate due to: (1) elevation, (2) terrain orientation (rain shadows), (3) terrain profile (enhancement of precipitation), (4) moisture regime (exposure to moisture sources), (5) coastal proximity, (6) two layer atmosphere (inversion layer and free atmosphere), and (7) topographical position (susceptibility to cool air pooling). The monthly PRISM data were masked and then reprojected to obtain an equal area raster map for California on a 4×4 km grid for the period 1920 through 2007 for maximum temperature (Tx), minimum temperature (Tn), and significant precipitation (Pcp). Precipitation was considered significant if the precipitation was twice the mean daily HS ETo rate.

ETo Correction Factors

NCDC stations were paired with neighboring CIMIS stations from the time when the CIMIS station came on-line. Corresponding data for the paired stations were selected from the UC IPM site (http://ipm.ucdavis.edu). The PM equation was used to calculate reference evapotranspiration (ETo) using daily CIMIS data and the HS equation was used to calculate ETo (ETHS) using daily Tx and Tn data. The calculation methods for PM and HS are given in Appendix A. The correction factor (CF) was calculated as:

$$C_F = \frac{ET_o}{ET_{HS}}$$

Spatial interpolation was completed using ARC GIS and a 4 km gridded raster map for CF was produced (Fig. 2). The CF values fell within 15% of 1.0.

The CF values were archived for each 4×4 km grid area, and the grid areas were stored in files designated by the DSA number (e.g. DSA003GA.csv for DSA 3.

Weather Simulation

Weather simulation models are often used in conjunction with other models to evaluate possible crop responses to environmental conditions. One important response is crop evapotranspiration (ETc). Crop evapotranspiration is commonly estimated by multiplying reference evapotranspiration by a crop coefficient. In SC-SIMETAW, daily data are used to estimate reference evapotranspiration. Rainfall data are then used with estimates of ETc to determine ETaw. SC-SIMETAW uses simulated daily data for the calculations.

Simulation Accuracy

Monthly PRISM weather data (October 1921 to September 2007) from PRISM grid 99-62 were

Used in the model to simulate 30 years of daily weather data. The weather data consist of daily T_{max}, T_{min}, and total rainfall by month. The simulated weather data from SC-SIMETAW were compared with the data from CIMIS at Davis, California. Figures 1, 2, 3, and 4 show that T_{max}, Tmin, rainfallm, and ETo values predicted from SC-SIMETAW were well correlated with those values obtained from CIMIS. Similar results were observed for other CIMIS sites.

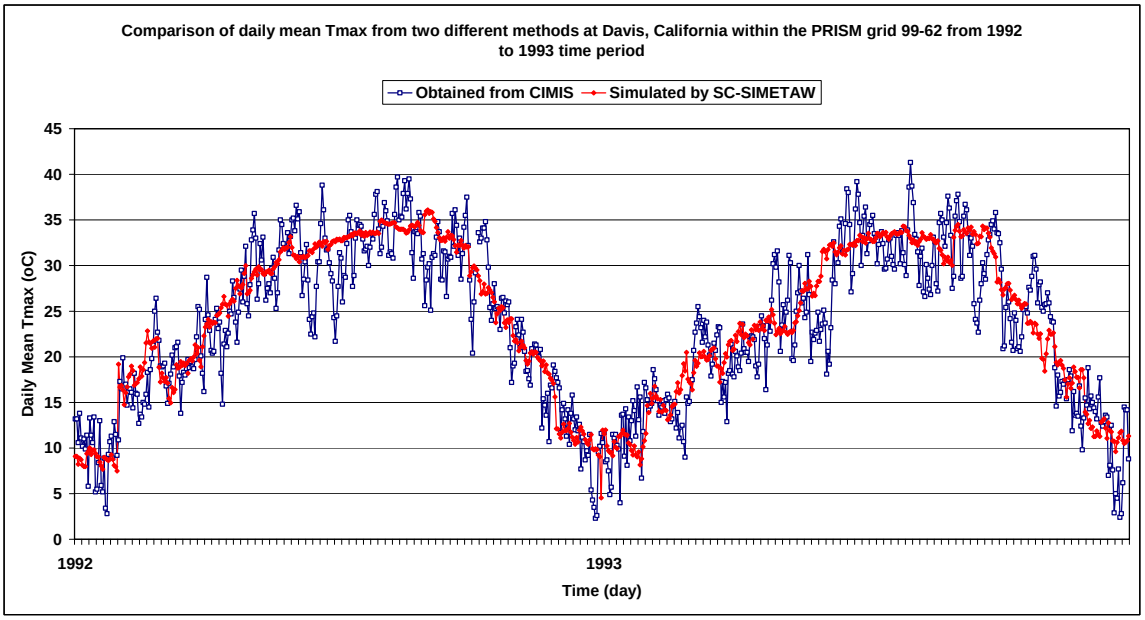

Figure 1. Comparison of daily Tmax from two different methods at Davis, California within the PRISM grid 99-62 from 1992 to 1993 time period.

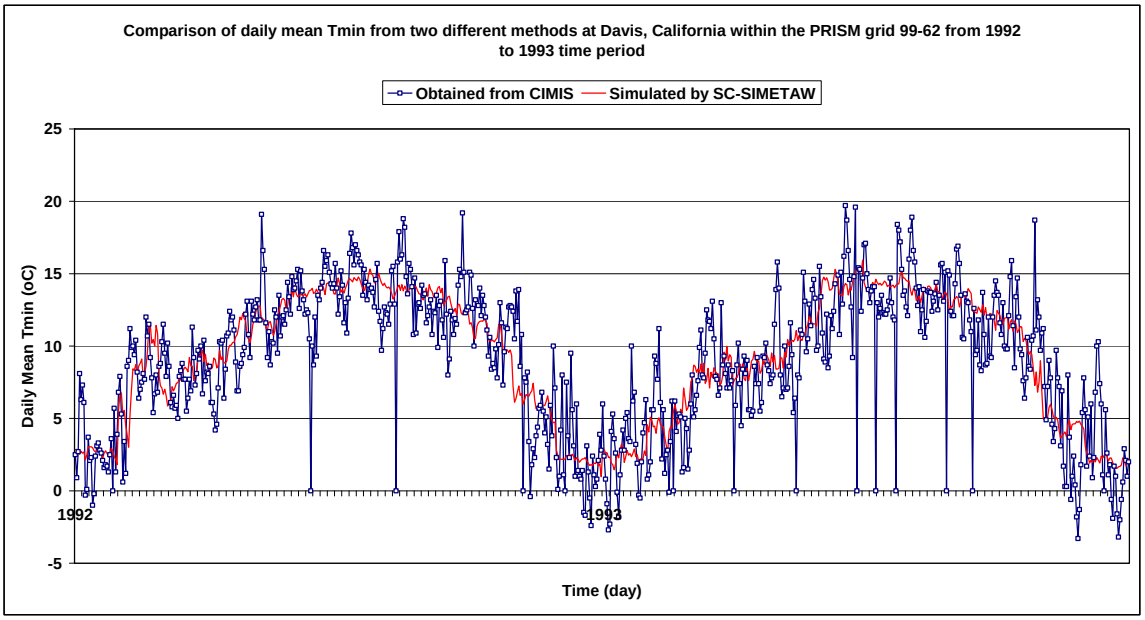

Figure 2. Comparison of daily Tmin from two different methods at Davis, California within the PRISM grid 99-62 from 1992 to 1993 time period.

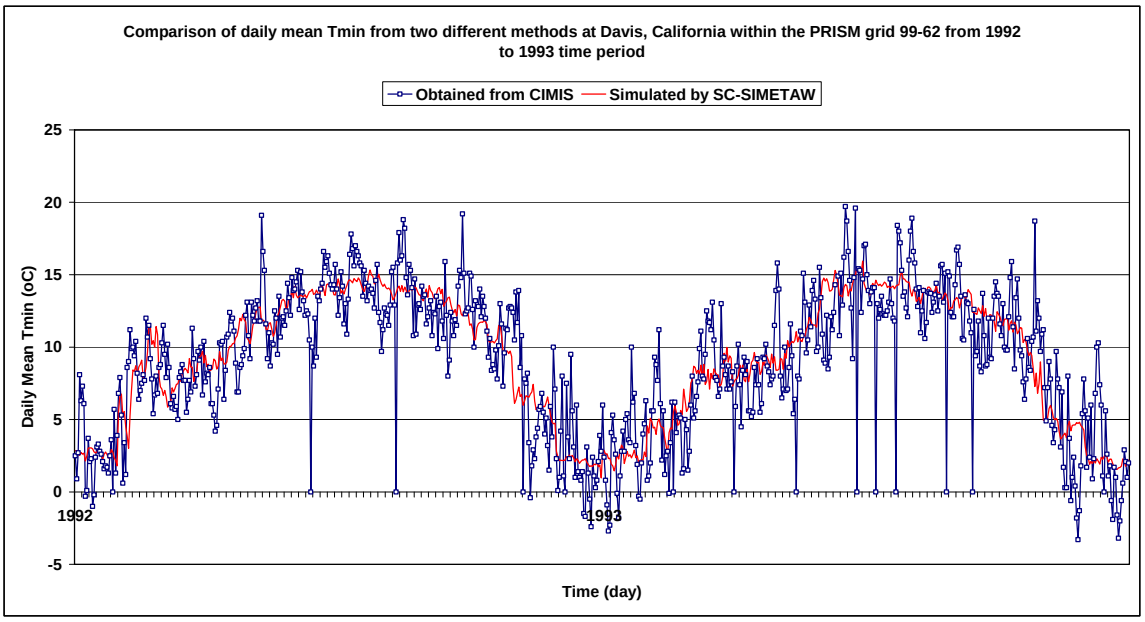

Figure 3. Comparison of daily Tmin from two different methods at Davis, California within the PRISM grid 99-62 from 1992 to 1993 time period.

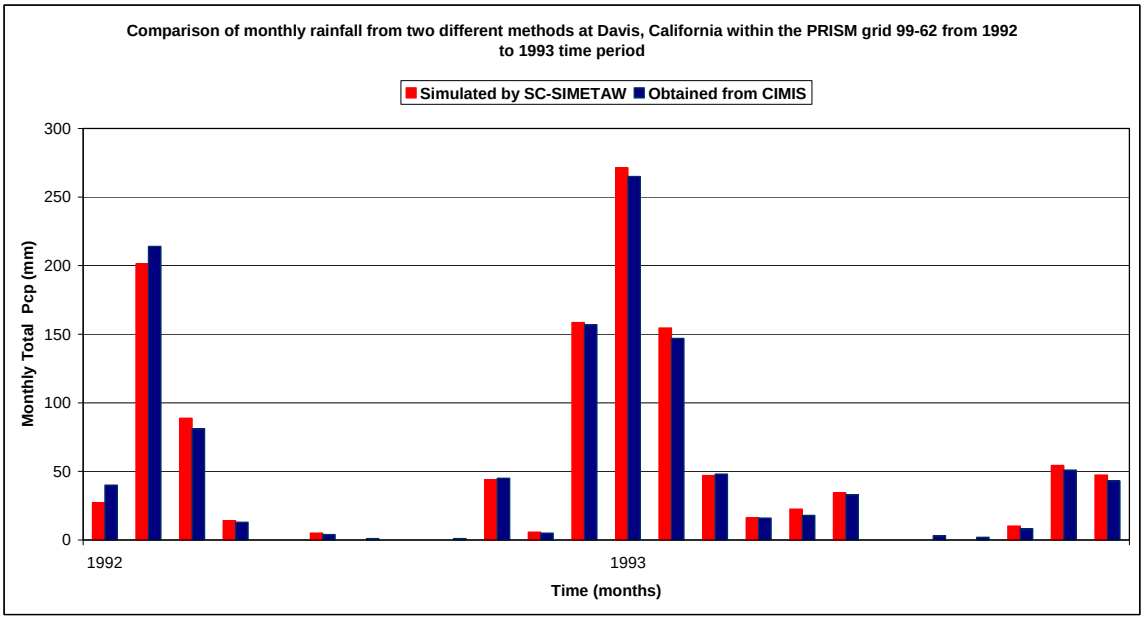

Figure 3. Comparison of monthly total of rainfall from CIMIS and SC-SIMETAW at Davis, California within the PRISM grid 99-62 from 1992 to 1993 time period.

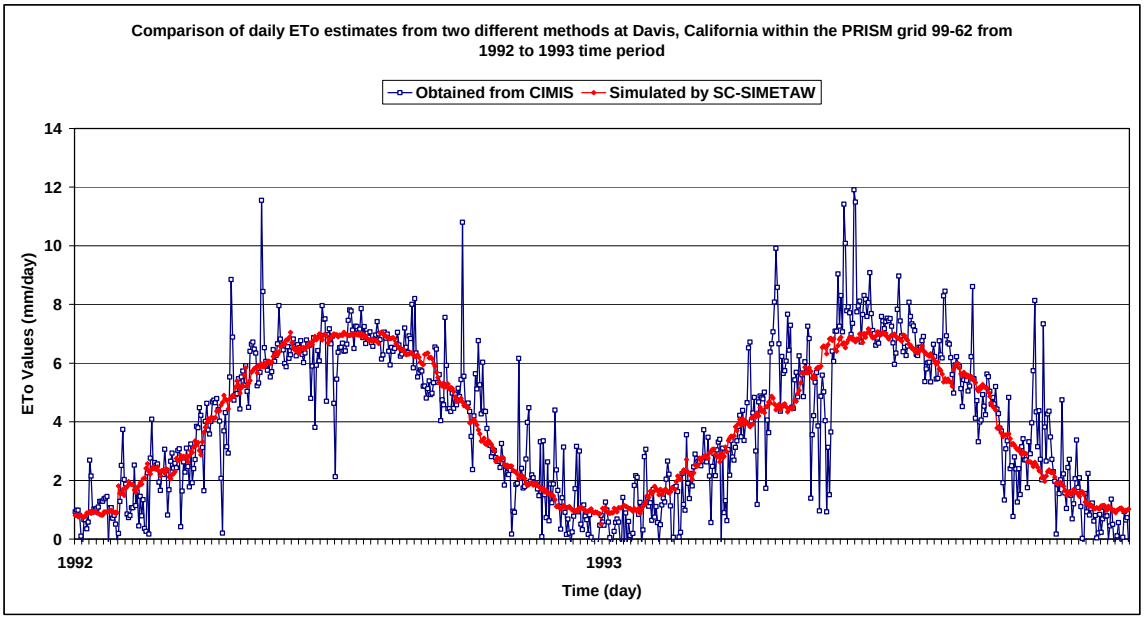

Figure 4. Comparison of daily calculated ETo from CIMIS and SC-SIMETAW at Davis, California within the PRISM grid 99-62 from 1992 to 1993 time period.

Soil Information

The available soil water holding capacity (AW) and maximum soil depth (SDx) database was developed from the USDA-NRCAS Soil Survey Geographical Database (SSURGO Ver. 2.2), which covers California on a 4×4 km grid. The AW was computed as the mean available soil water holding capacity over the SDx for each soil within a 4×4 km grid area. The weighted mean AW was then calculated over all soils within the grid area and the results were archived by grid area. Note that the AW content is unitless (mm/mm). The AW and SDx for each DAU were computed as the means over grid areas falling within the DAU. The values for AW and SDx were archived by crop category for the 13 DAU files that contain crop and soil information.

Daily Water Balance

The daily change in soil water content is calculated as Dsw = ETc – Er for agricultural crops and warm-season grass, where ETc is the crop evapotranspiration, and Er is the effective rainfall. ETc on every day of the year is computed as the product of ETo and Kc value, which equals the higher of the off-season (Okc) and in-season (IKc) crop coefficient on the same date. The OKc values are computed as a function of the ETo rate and soil wetting frequency. It is assumed that the Kc value on any given date cannot be lower than the OKc value. Effective rainfall (Er) is calculated from the precipitation (Pcp) and the soil water depletion. If the soil water depletion is greater than Pcp, then Er = Pcp. Otherwise, Er = SWD, the soil water depletion. Then the soil water depletion adjusted for seepage is calculated as SWD’ = SWD – Er, which could be zero or some positive number if the ETc is greater than the rainfall.

On every day of the year, the soil water depletion is calculated as SWD = SWDp + Dsw, where SWDp is the soil water depletion from the previous day and Dsw is the change in the soil water depletion on the current day. Irrigation dates and amounts are determined by comparing the SWD with the management allowable depletion.

Growers use a management allowable depletion (MAD) to help determine when and how much to irrigate. This is the amount of water that they want to deplete from the soil before irrigating, and it can depend on many crop, soil, and management factors. It is impossible for one to know how growers determine their MAD, but a main factor in

determining a MAD is to estimate the yield threshold depletion (YTD), where the YTD is the soil water depletion that should not be exceeded to avoid yield reductions due to water stress. In SC-SIMETAW, the YTD is estimated as 50% of the available soil water content in the crop root zone. The smaller of the maximum rooting depth and maximum soil depth is used to identify the effective rooting depth for a particular crop and soil combination. Then, the plant available water content for the effective rooting depth is calculated as the product of the effective rooting depth and the available water holding capacity. The plant available water content is computed and multiplied by 0.50 to obtain the YTD from the end of the crop rapid growth period to the end of the season. During initial growth period of field crops, the root depth is fixed at 0.3 m, but it increases to the maximum depth at the end of the initial growth. DETAW uses the YTD as the MAD except it is adjusted slightly to force the last irrigation to be applied so that the soil water content is low at the end of the season. In the program output, the column with the heading SWDx contains the MAD data that are used for scheduling

When scheduling irrigation, if SWDp + Dsw > SWDx, then the net application is NA = SWDp + Dsw. Otherwise, NA =0. On each date, the soil water depletion is calculated as SWD = SWDp + Dsw – NA, so the SWD returns to SWD = 0 on an irrigation date. This procedure is followed throughout the in-season period.

During the off-season, there is no irrigation and, therefore, NA = 0 on all off-season dates. However, Dsw and SWD are computed in the same manner all year. During the off-season, the soil water depletion cannot exceed 50% depletion of the soil water content within the upper 0.3 m depth of soil (i.e., the off-season SWDx). After the last day of the season, if SWD already exceeds SWDx, the SWD will not increase. The SWD can decrease, however, if Dsw is negative as the result of seepage and/or rainfall. Once the SWD is less than the off-season SWDx, it can increase again, but it cannot exceed the off-season maximum. Commonly, in California, the winter rainfall will decrease the SWD back to zero. Thus, the SWD prior to the next season is often close to field capacity.

ET of Applied Water (ETaw)

ETaw is the sum of the net irrigation applications to a crop during its growing season, where each net irrigation application (NA) is equal to the product of the gross application (GA) and an application efficiency fraction (AE), i.e., NA = GA × AE. The gross application is equivalent to the applied water, and the application efficiency is the fraction of GA that contributes to crop evapotranspiration (ETc). Three possible methods to determine ETaw are explained below using the example of a tomato crop grown in Sub-area 104, Acker Island, in the Sacramento – San Joaquin River Delta. The ETo, ETc, and Kc values for two sample years are shown in Figure 5.

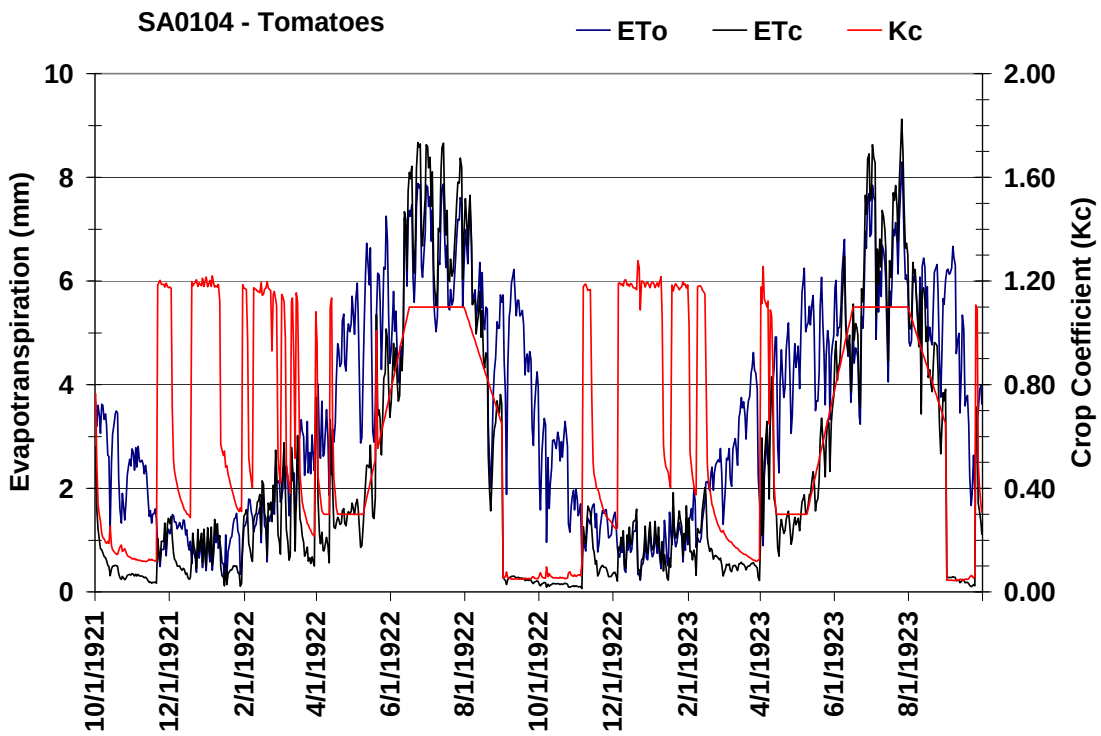

Figure 5. Crop (ETc) and reference (ETo) evapotranspiration and crop coefficient factors for 1921 – 1922 water years for a tomato crop grown in Sub-area 104 of the Delta.

For all surfaces except open water and riparian vegetation, daily water balance calculations start with the soil water content on the previous day (SWCo). Then the water losses to ETc are subtracted to determine the soil water content on the current day as SWC1=SWCo – ETc. This is the soil water depletion adjusted for ETc. Next, the effective seepage (Espg) contribution to the water balance is computed by comparing the

seepage (Spg) with SWC1. If Spg < SWC1, then Espg = Spg, otherwise, Espg = SWC1. Then the soil water content based on ETc and effective seepage is calculated as SWC2 = SWC1 + Espg. Then the soil water content is adjusted for effective rainfall by comparing the precipitation (P) with SWC2. If P < SWC2, then the effective rainfall is calculated as Er = P. Otherwise, Er = SWC2. Then the soil water content based on ETc, effective seepage, and effective rainfall is calculated as SWC3 = SWC2 + Er. Therefore, the final estimate of soil water content without considering irrigation, is given in terms of the daily change in soil water content (Dsw) as

$$\mathrm{SWC_3} = \mathrm{SWC_o} - \mathrm{Dsw} = \mathrm{SWC_o} - (\mathrm{ETc} - \mathrm{Espg} - \mathrm{Er})$$

Irrigation is applied whenever the soil water content on a given day would fall below the management allowable depletion (MAD) set for that date. The net application (NA) amount is the depth of water needed to raise the soil water content (SWC3) back to field capacity (FC) on the irrigation date. On each irrigation date, the NA is equal to SWC3, so the actual soil water content on each day of the season is calculated as

$$\mathrm{SWC} = \mathrm{SWCo} - \mathrm{Dsw} + \mathrm{NA}$$

Where SWCo is the soil water content on the previous day, NA is the net application, which is zero on non-irrigation days, and Dsw is the daily change in soil water content expressed as

$$\mathrm{Dsw} = \mathrm{ETc} - \mathrm{Espg} - \mathrm{Er}.$$

By definition, ETaw is the amount of applied irrigation water that contributes to ETc; therefore, ETaw is the sum of the net irrigation applications during a cropping season. Thus, ETaw for n irrigation events is calculated as:

$$ET_{aw} = NA_1 + NA_2 + \cdots + NA_n .$$

Alternatively, ETaw can be calculated as the seasonal total evapotranspiration (CETc) minus the cumulative effective seepage contribution (CEspg) minus the cumulative effective rainfall contribution (CEr) minus the difference in soil water content (ΔWC)

from the beginning to the end of the season (Figure 1). The cumulative change in daily oil water (Dsw) curve is, by definition calculated as

$CD_{sw} = CET_c - CE_{spg} - CE_r$. Therefore, the ETaw can also be expressed as

$ET_{aw} = CD_{sw} - \Delta WC$. Figure 1 illustrates how one can determine ETaw from CETc, CEspg, CEr, CDsw, and ΔSW. The ΔSW is unknown until the end of the season, so ETaw cannot be computed until the end of a cropping season using this method. The ETaw can be computed as the sum of the net applications after the last NA is applied. This is the method used to determine the ETaw in DETAW.

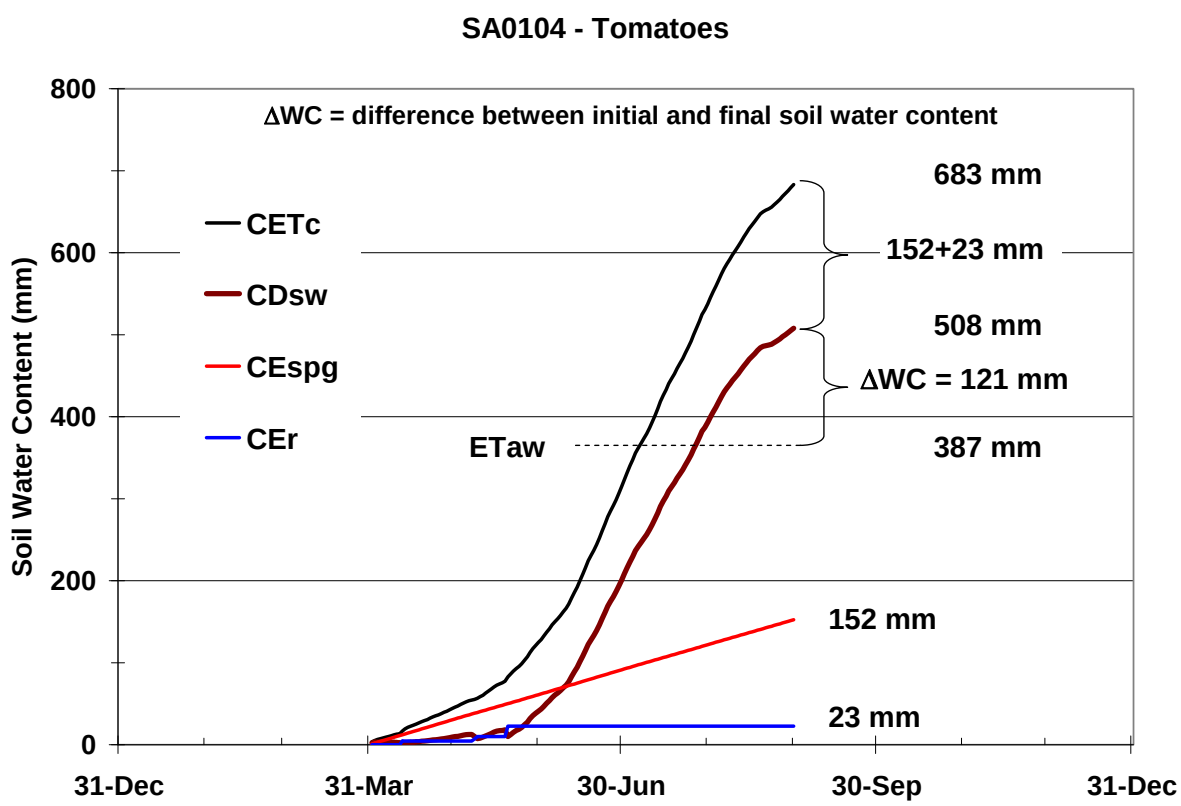

Figure 1. A plot of CET_c, CE_{spg}, CE_r, and CD_{sw} versus time for a tomato crop using data from the 1922 growing season.

The general form of consumptive use equation is

$$ETc = Kc \times ETo \quad (1),$$

where the Kc factor is an empirically determined crop coefficient relating ETc to reference evapotranspiration (ETo), which is a measure of evaporative demand that is only affected by the weather. Theoretically, ETo is the ET of a 12-cm tall vegetative surface of large extent with a fixed canopy resistance and an aerodynamic resistance that is inversely proportional to the wind speed. ETo, however, is approximately equal to the ET of a 12 cm tall, cool-season pasture grass, with no shortage of water to limit transpiration.

The daily change in soil water content, without considering irrigation, is calculated as

$$Dsw = ETc - Espg - Er \quad (2),$$

where Espg is the effective water contribution from seepage, Er is the effective rainfall, and DSW represents the increase in soil water depletion (or decrease in water content) each day. Therefore, when there is no irrigation, the soil water depletion (i.e., the difference between field capacity and the soil water content) on any given day is calculated as

$$SWD = SWDP + DSW \quad (3),$$

where SWDP is the soil water depletion on the previous day. Equation 3 is used for all non-irrigated surfaces except open water. For irrigated land-use surfaces, the net irrigation application (NA) is subtracted from the soil water depletion to estimate the SWD following an irrigation event using the equation

$$SWD = SWDP + DSW - NA \quad (4).$$

For riparian vegetation, wetland vegetation, water surfaces, native vegetation, and non-irrigated grain crops there is no irrigation, so NA always equals zero and there is no ETaw. For urban surfaces, the irrigated portion of the land area is estimated to determine the ETaw.

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