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CalSim Hydro Input Development

CWEMF Annual Meeting , April 2023
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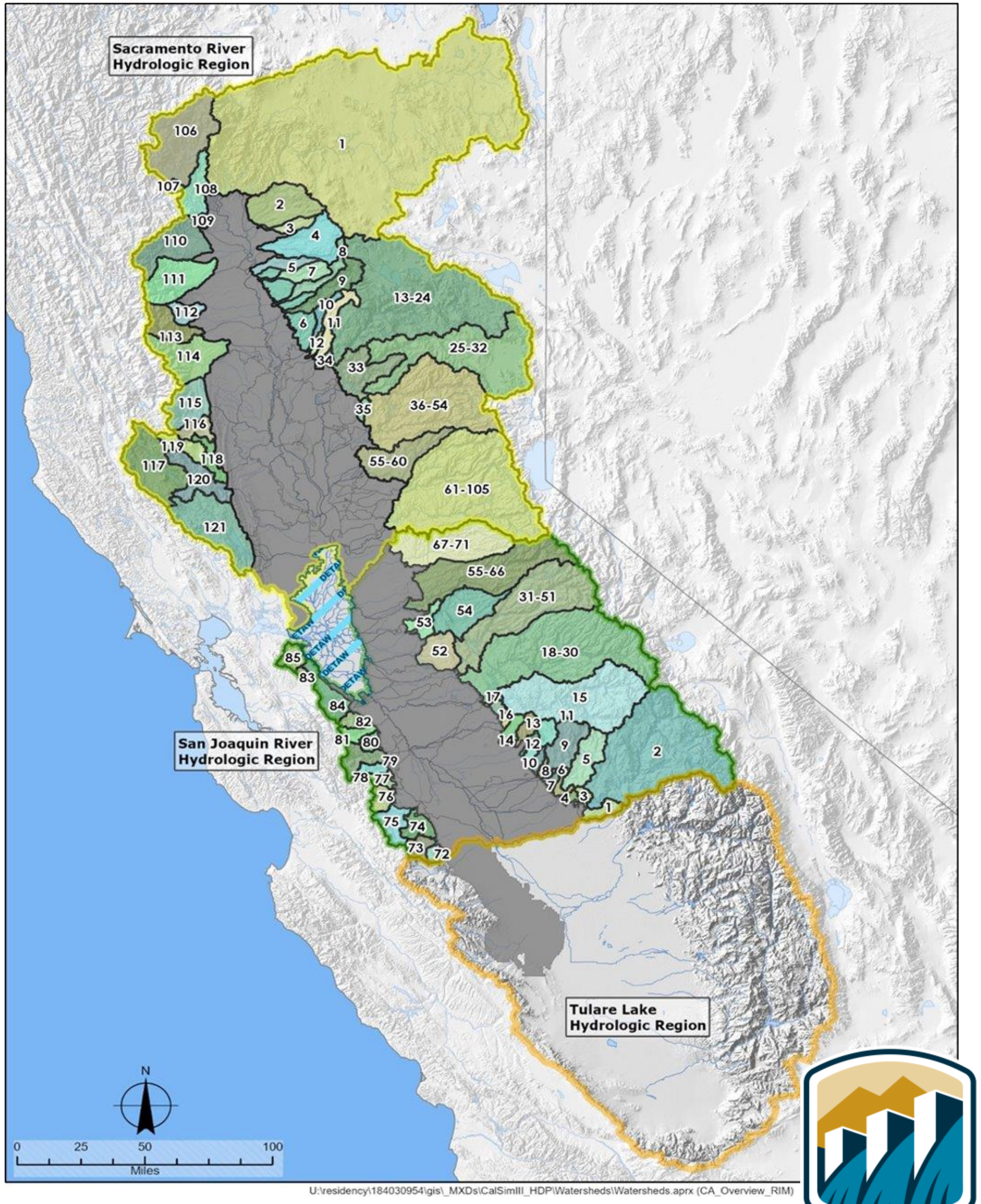
Modeling Division, Bay Delta Office

Presentation Overview

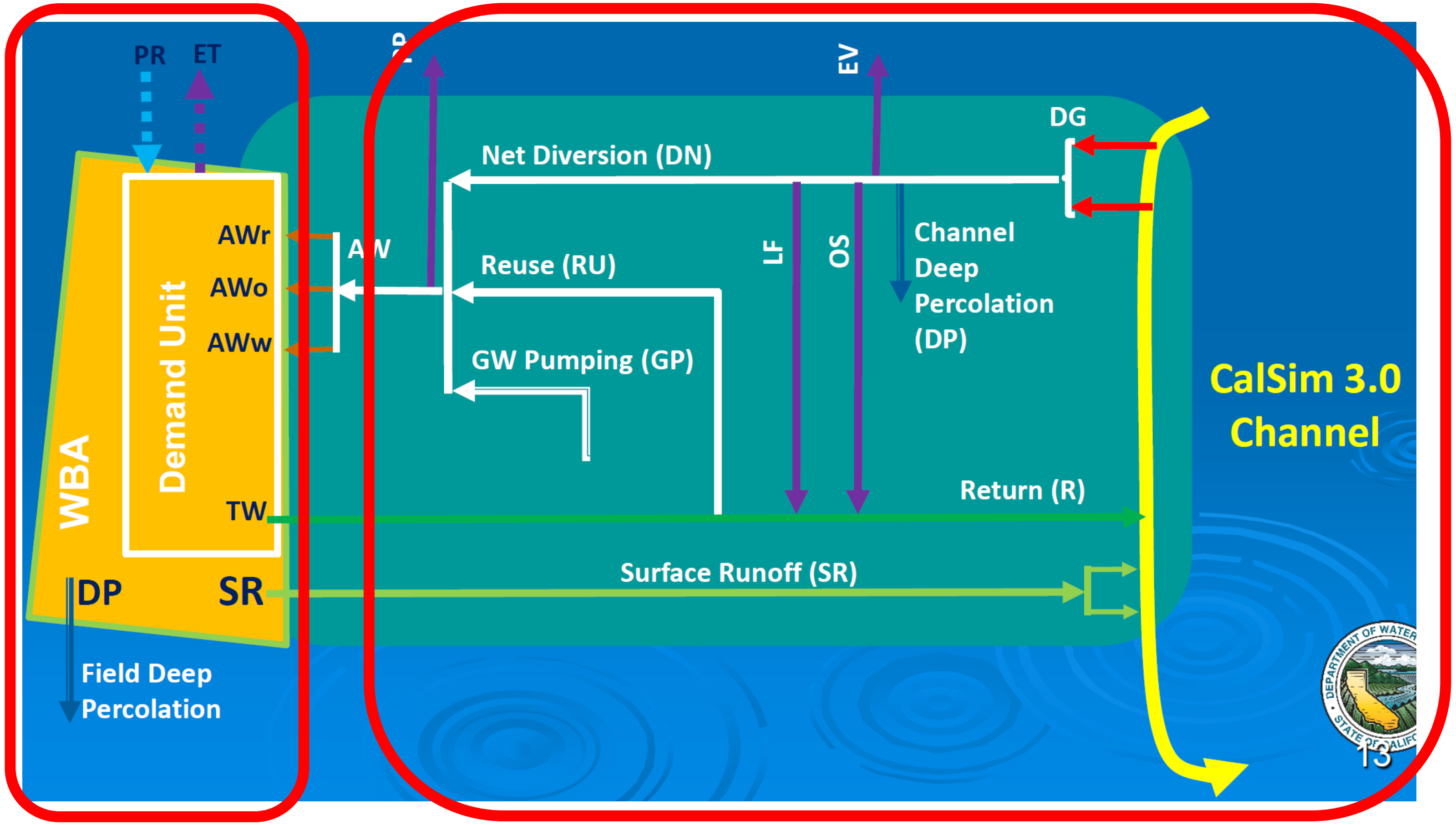
- CalSim Hydro Background
- Project goals
- Comparison of existing and proposed methods
  - Reference ET
    - Hargraves - Semani
    - Penman Monteith
  - Crop ET
    - CUP Model
    - ET Demands
- Summary of Future Work

Preprocessed Surface Hydrology for CalSim 3.0

- Separate approaches for different regions
  - Rim Watershed Hydrology
  - Valley Watershed Hydrology



CalSim 3.0 Valley Watershed Hydrology



CalSimHydro
preprocessed

CalSim
Dynamically Simulated


CalSimHydro
Diagnose
SV
Daily CN Runoff Model
Integrated Demand Calculator
Rice Water Use Model
Refuge Water Use Model
Data Aggregator and SV File Generator
Hydrologic Water Balance Diagnose Utility

Project Goals

- Improve representation of applied water demands.
- Leverage the best available datasets and methods to refine modeled applied water demands.
- Captures year-to-year variations in the applied water demands and better emulate changes in farming practices with climate changes.

Current CalSimHydro Reference ET Input

- Hargreaves-Samani equation

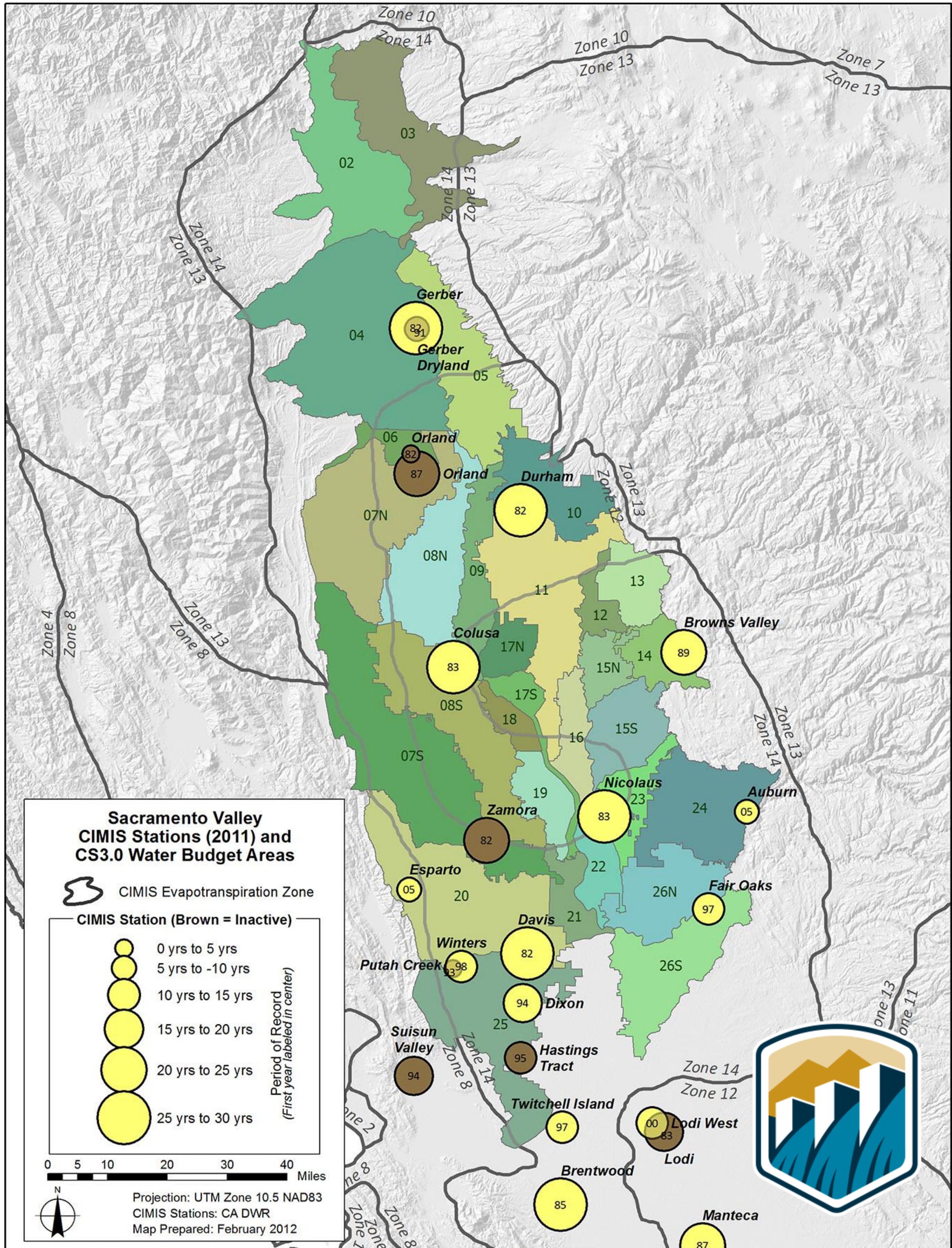
$$ET_o = 0.0023.R_a.\ (T_{max} - T_{min})^{0.5}.(T_m + 17.8)$$

- Temperature data provided by PRISM daily and monthly data
- Monthly Correction Factors based on CIMIS Stations

$$f1 = \frac{ETO^{CIMIS}_{OBS}}{ETO^{CIMIS}_{HS}}$$

$$ETO^{WBA}_{HS} = ETO^{CIMIS}_{HS} * f1 * f2$$

$$f2 = \frac{ETO^{WBA}_{HS}}{ETO^{CIMIS}_{HS}}$$

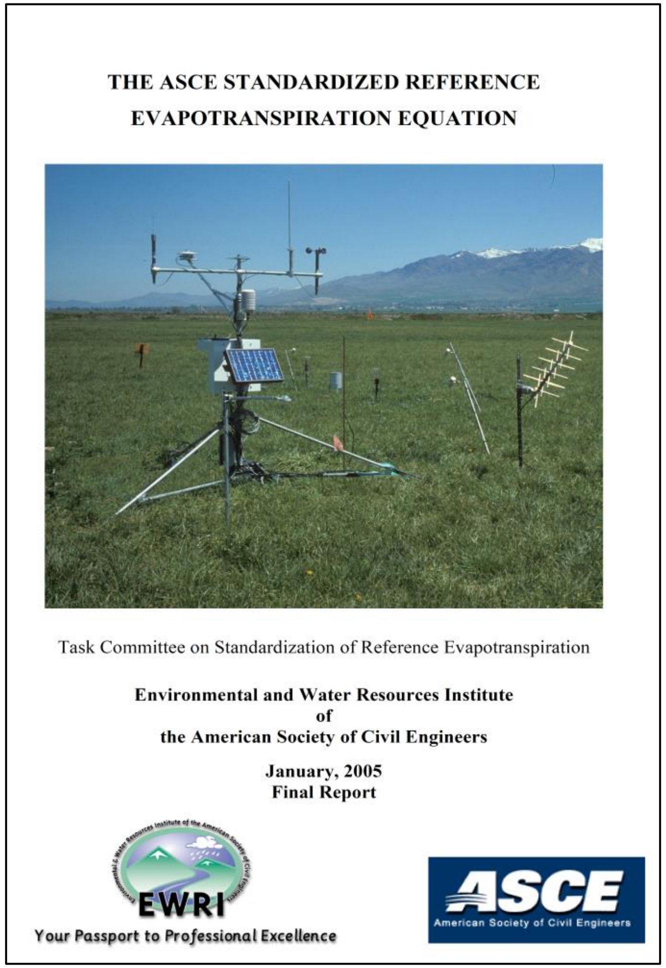


ASCE Standardized ETo Equation

- ASCE adopted FAO Irrigation and Drainage Paper No. 56 Penman Monteith Combination Method in 2005
- Combined energy balance and mass transfer

$$ET_{sz} = \frac{0.408\,\Delta(R_n - G) + \gamma \dfrac{C_n}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + C_d\, u_2)}$$

- Primary inputs: temperature, solar radiation, humidity and wind speed
- Solar radiation and humidity (can be estimated using min/max daily air temperature)


THE ASCE STANDARDIZED REFERENCE EVAPOTRANSPIRATION EQUATION

Task Committee on Standardization of Reference Evapotranspiration

Environmental and Water Resources Institute
of
the American Society of Civil Engineers

January, 2005
Final Report

EWRI
Your Passport to Professional Excellence

ASCE
American Society of Civil Engineers

Evaluation of ASCE-PM ETo

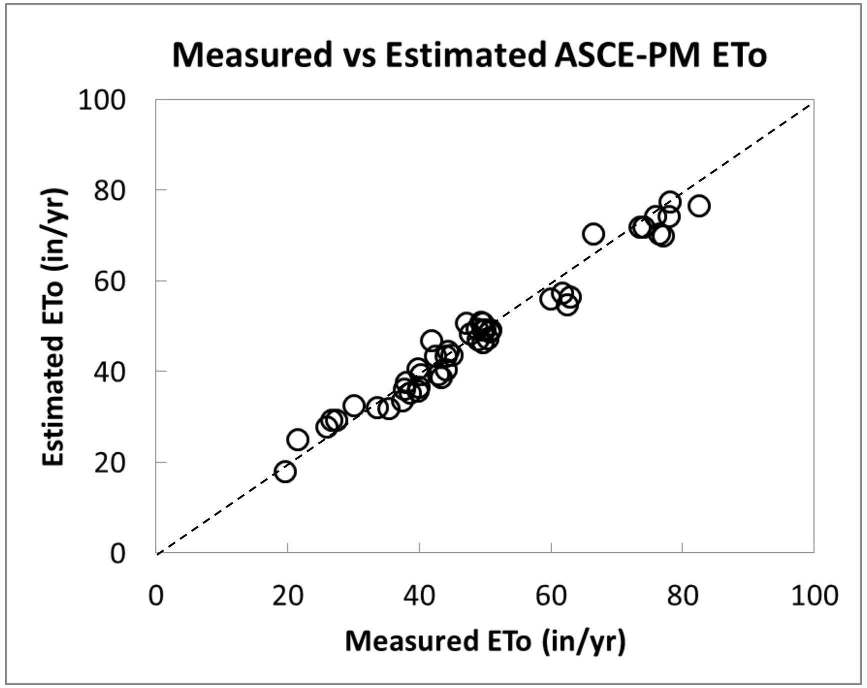
- Compared estimated ASCE-PM reference ET (ETo) to measured ETo at ***50*** agricultural weather station – COOP/NWS station pairs
  - Estimated ETo used daily T_{max} and T_{min} to estimate solar radiation, and mean monthly spatially distributed dewpoint and windspeed
- Estimated ETo is robust at annual and monthly time scales when compared to measured agricultural station ETo

Ratio of ***Annual*** Estimated to Measured ETo:

- Range = 0.86 -1.15
- Average = 1.03
- STD = 0.06

Ratio of ***Monthly*** Estimated to Measured ETo:

- Range = 0.84 -1.37
- Average = 1.03
- STD = 0.16



Crop Evapotranspiration, ET_c

- Single Crop Coefficient (most commonly used):

$$ET_c = ET_o * K_c$$

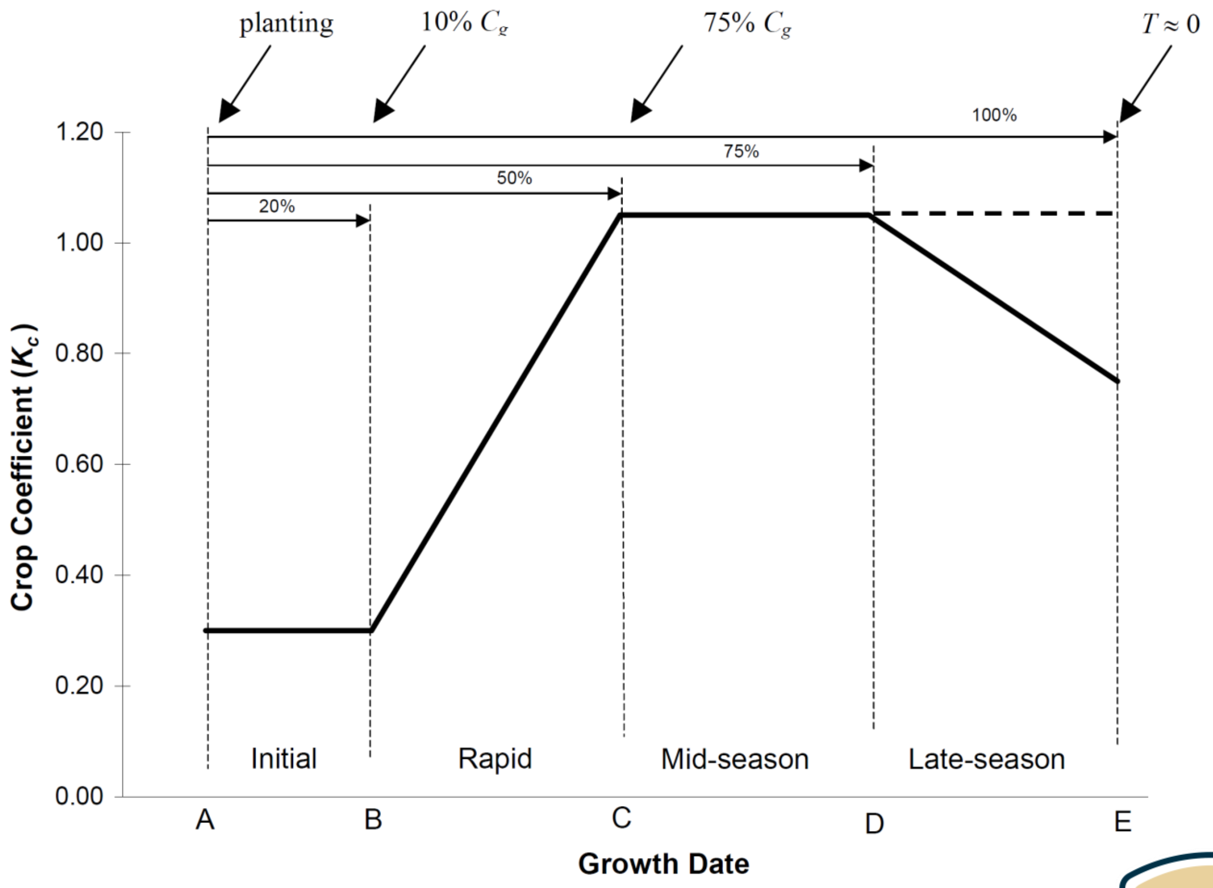
- Dual Crop Coefficients:
  - Allows for simulation of specific wetting events
  - Combination of a transpiration (basal) coefficient (Kcb) and an evaporation coefficient (Ke)

$$ET_c = ET_o * (K_{cb} + K_e)$$

  - A stress coefficient (Ks) can also be applied to reduce Kcb under low soil moisture conditions (no or deficit irrigation practices)

Consumptive Use Program

- Used to develop ETc for CalSimHydro
- Single Crop Coefficient model
- Season is separated into growth periods
- Deciduous trees, vines, orchard crops can be adjusted using percentage of ground cover
- Growing season is a fixed input



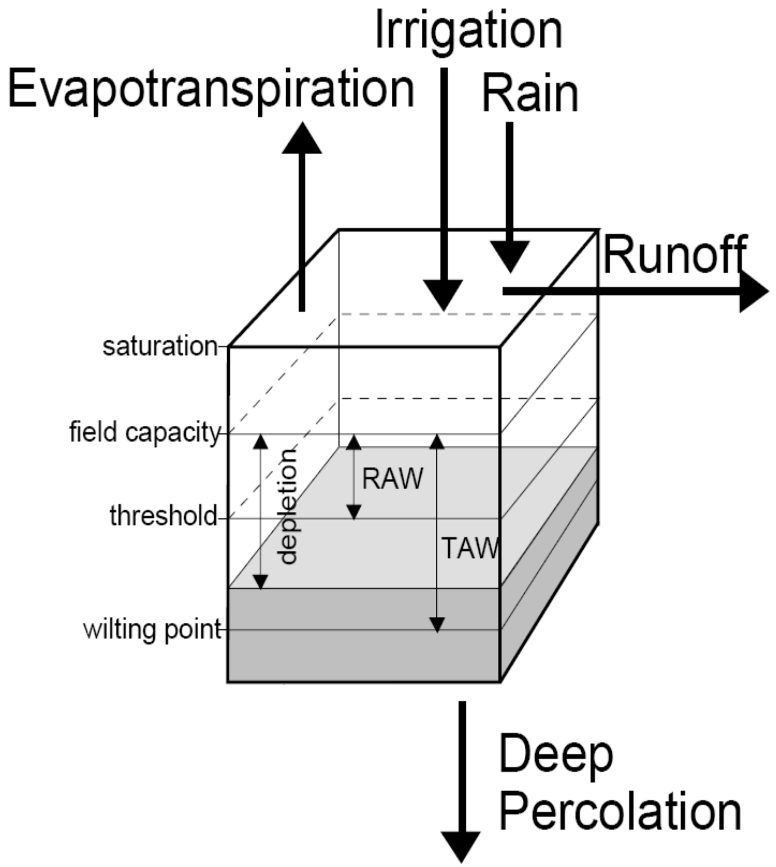
(Orang et al. 2009)

CUP+ Crop Coefficients and Seasons

Lengths of Crop Development Stages for Various Crops													
Crop Number	Crop Name	% season B	% season C	% season D	K_c AB	K_c CD	K_c E	Planting Month	Planting Day	Harvest Month	Harvest Day	Planting Date	Harvest Date
3.01	Almonds	0	50	90	0.51	1.10	0.60	3.00	1.00	10.00	15.00	1-Mar-15	15-Oct-15
3.02	Apple	0	50	75	0.51	1.06	0.74	4.00	1.00	11.00	15.00	1-Apr-15	15-Nov-15
3.03	Wine Grapes	0	25	75	0.41	0.74	0.32	4.00	1.00	11.00	1.00	1-Apr-15	1-Nov-15
3.04	Table Grapes	0	25	75	0.32	1.01	0.74	4.00	1.00	11.00	1.00	1-Apr-15	1-Nov-15
3.05	Raisin Grapes	0	25	75	0.32	1.01	0.74	4.00	1.00	11.00	1.00	1-Apr-15	1-Nov-15
3.06	Kiwifruit	0	22	67	0.32	1.01	0.74	5.00	1.00	10.00	31.00	1-May-15	31-Oct-15
3.07	Stone fruits	0	50	90	0.51	1.10	0.60	3.00	1.00	10.00	15.00	1-Mar-15	15-Oct-15
3.11	Walnuts	0	50	75	0.51	1.10	0.74	4.00	1.00	11.00	15.00	1-Apr-15	15-Nov-15
3.09	Peach	0	50	90	0.51	1.10	0.60	3.00	1.00	10.00	15.00	1-Mar-15	15-Oct-15
3.12	Figs	0	50	90	0.51	1.104	0.60	3.00	1.00	10.00	15.00	1-Mar-15	15-Oct-15
3.10	Plum-Prune	0	50	90	0.51	1.06	0.60	3.00	1.00	10.00	15.00	1-Mar-15	15-Oct-15
4.01	Avocado	0	50	90	0.92	0.92	0.92	1.00	1.00	12.00	31.00	1-Jan-15	31-Dec-15
4.02	Grapefruit	0	33	67	0.92	0.92	0.92	1.00	1.00	12.00	31.00	1-Jan-15	31-Dec-15
4.03	Lemon	0	33	67	0.83	0.83	0.83	1.00	1.00	12.00	31.00	1-Jan-15	31-Dec-15
4.06	Olives	0	33	67	0.83	0.83	0.83	1.00	1.00	12.00	31.00	1-Jan-15	31-Dec-15
4.07	Orange	0	33	67	0.92	0.92	0.92	1.00	1.00	12.00	31.00	1-Jan-15	31-Dec-15
3.08	Pistachio	0	33	78	0.64	1.06	0.46	3.00	1.00	11.00	26.00	1-Mar-15	26-Nov-15

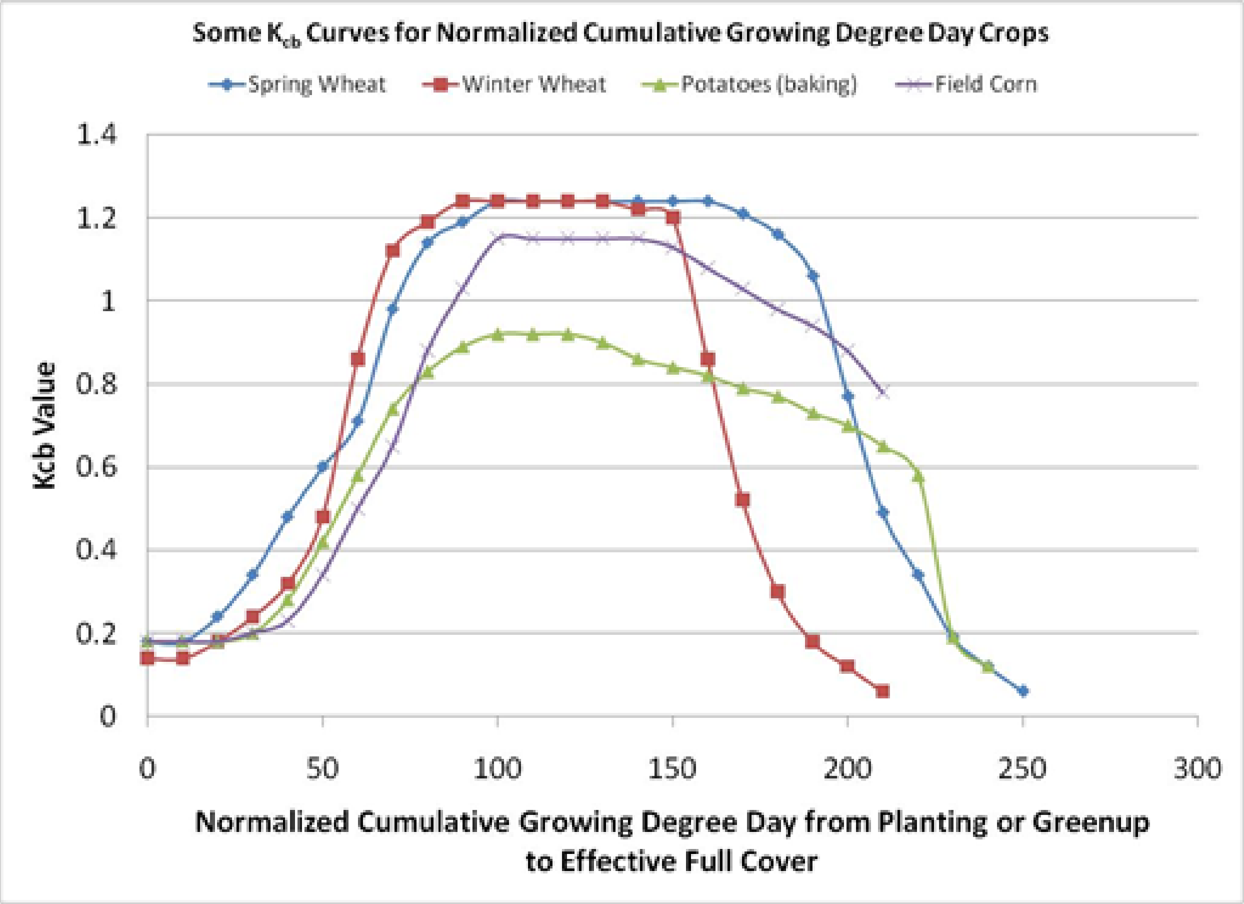
ETDemands Model

- Developed collaboratively by Reclamation, the Desert Research Institute and the University of Idaho
- Based on the American Society of Civil Engineers (ASCE) Standardized Reference Evapotranspiration (ET) Equation (ASCE-EWRI, 2005) and the Dual Crop Coefficient Model (Allen and Robison, 2009; Huntington and Allen, 2010)
- Temperature-based daily crop coefficient calculation allows for modeling longer growing seasons due to climate change



Basal Crop Coefficient, Kcb

- Based on 30-day average air temperature (T30), cumulative growing degree days (CGDD) and killing frost air temperatures
- T30 and GDD thresholds control planting, green-up and development
- Geographic-specific calibrations are required for Kcb estimation
- End dates are based on killing frost or harvest schedule



Evaporative Crop Coefficient, Ke

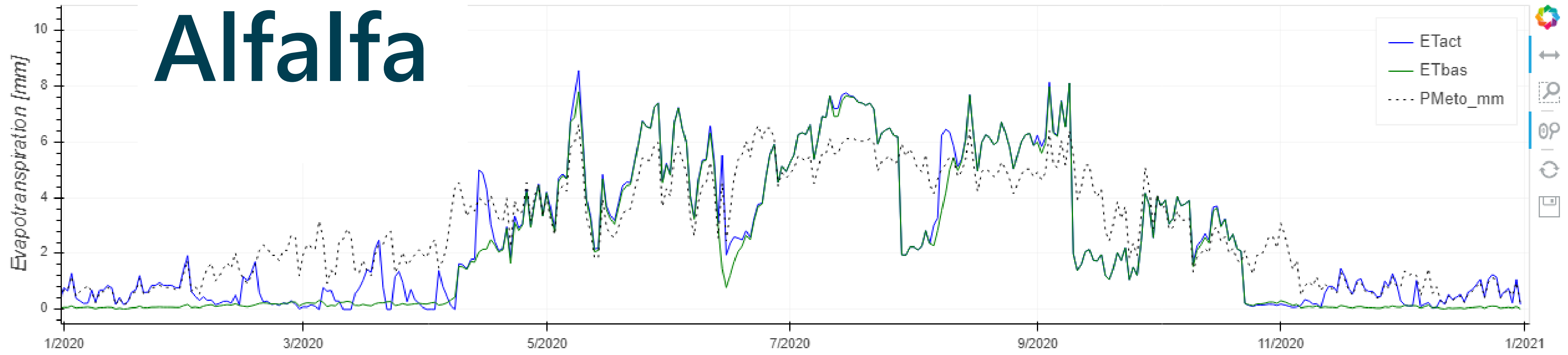
- Estimated based on the soil moisture content in the top 0.1-meter of the soil profile with large increases following precipitation and irrigation events
- For crops with an open canopy such as orchards where all or most of the ground surface is effectively exposed to evaporative energy the wetted surface is assumed equal to that exposed to solar radiation, and because of this, a portion of evaporation is compensated for by increased Kcb
- ET Demands includes Kcb curve options to simulate orchards with or without groundcover

Soil Moisture Balance and Irrigation

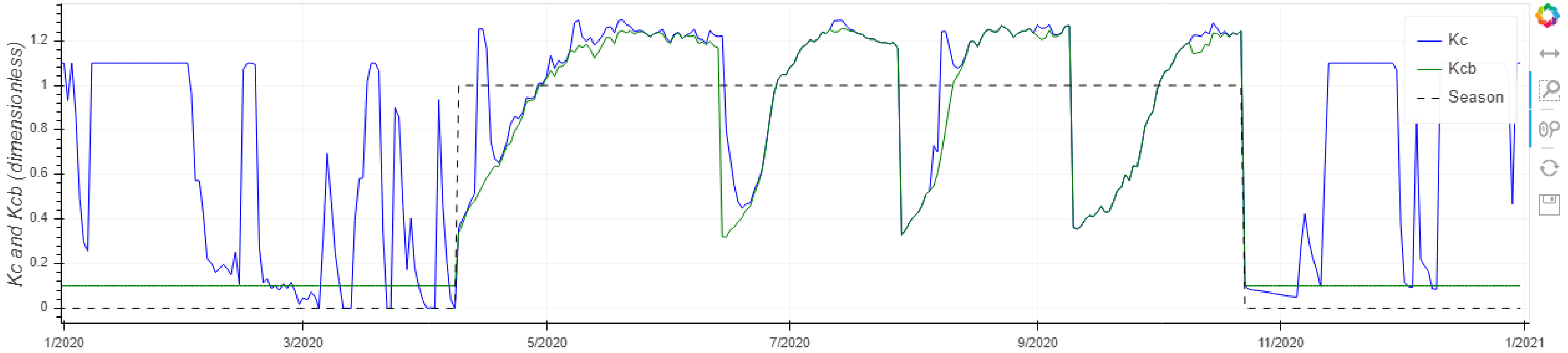
- Daily soil moisture balance, estimated as a function of:
  - antecedent soil moisture,
  - precipitation, irrigation,
  - runoff and deep percolation.
- Irrigation events are either
  - triggered automatically based on the soil moisture balance when maximum allowable depletion occurs, or
  - set manually to model irrigation schedules and water shortage scenarios

Alfalfa

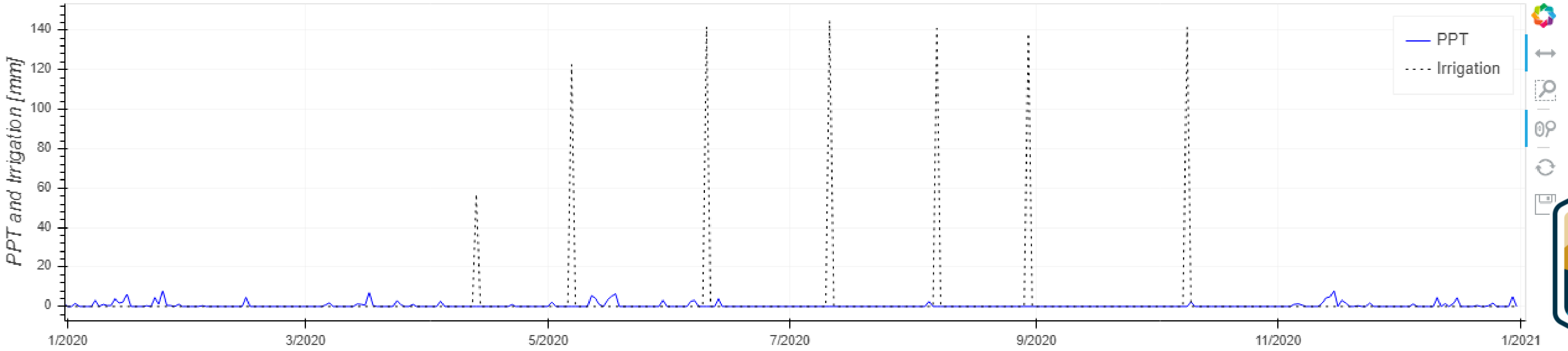
ET_o, ET_{act}, & ET_{bas}



K_c, K_{cb}, & Season



PPT & Irrigation



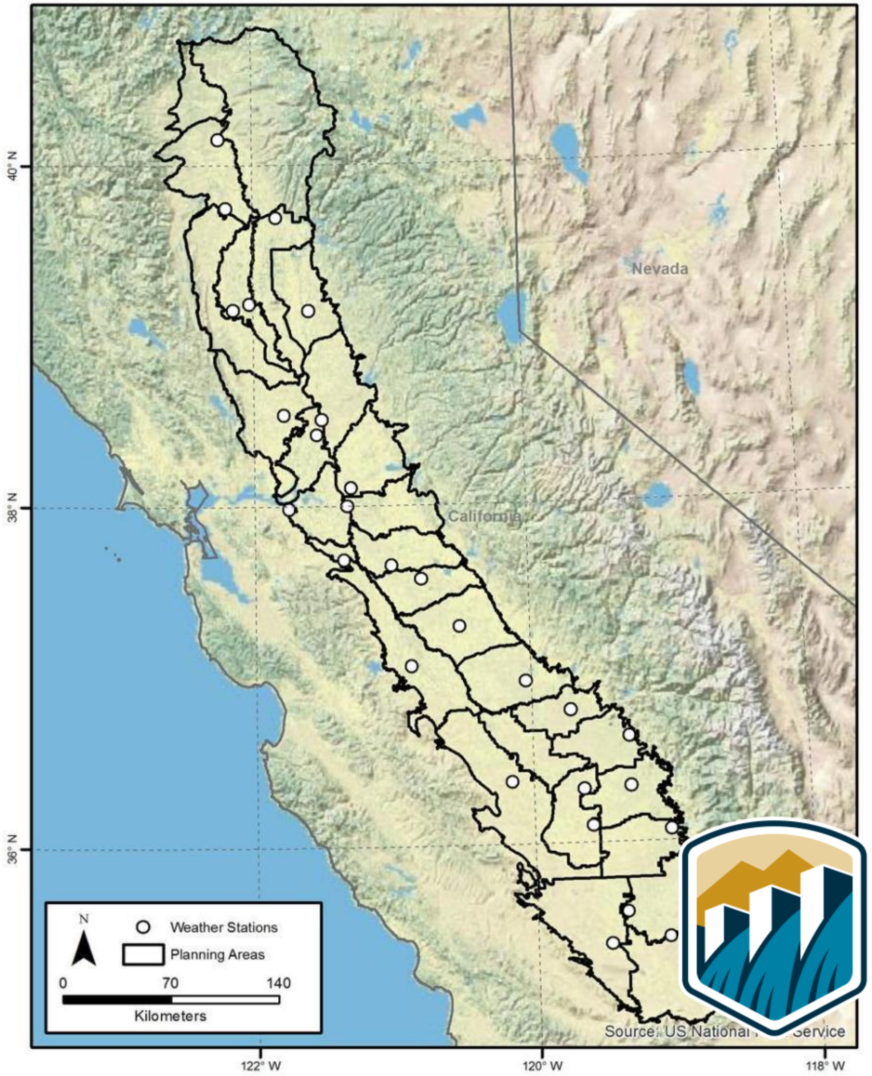
Application of the ET Demands Model

- ET Demands can be run with spatially varying climate and crop information for regional water use assessments and planning.
- Utilizes spatial soil and crop layers and gridded climate datasets
- Simulates each crop and climate grid cell combination separately
- Spatially varying calibration accounts for varying management and crop phenology
- Previous Applications:
  - Upper Colorado River Basin
  - Klamath River Basin
  - Nevada Net Irrigation Water Requirement Planning
  - Westwide Climate Assessment

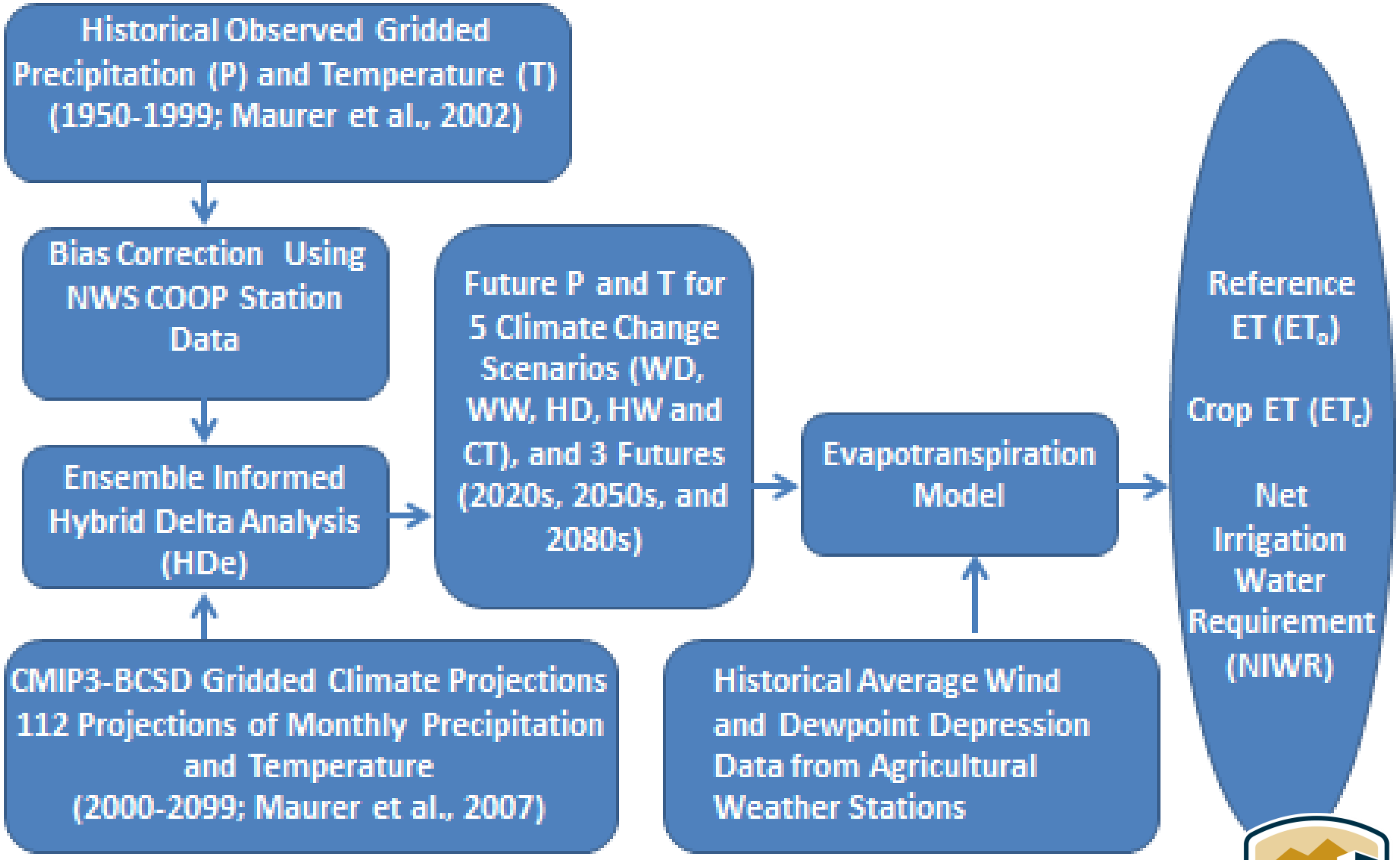
West-Wide Climate Risk Assessments:

Irrigation Demand and Reservoir Evaporation Projections

- SECURE Water Act authorizes Reclamation to evaluate the risks and impacts of climate change in each of the eight major Reclamation river basins
- WWCRAs will provide projections of future changes in water supplies, water demands, and river system operations that could result from changes in climate

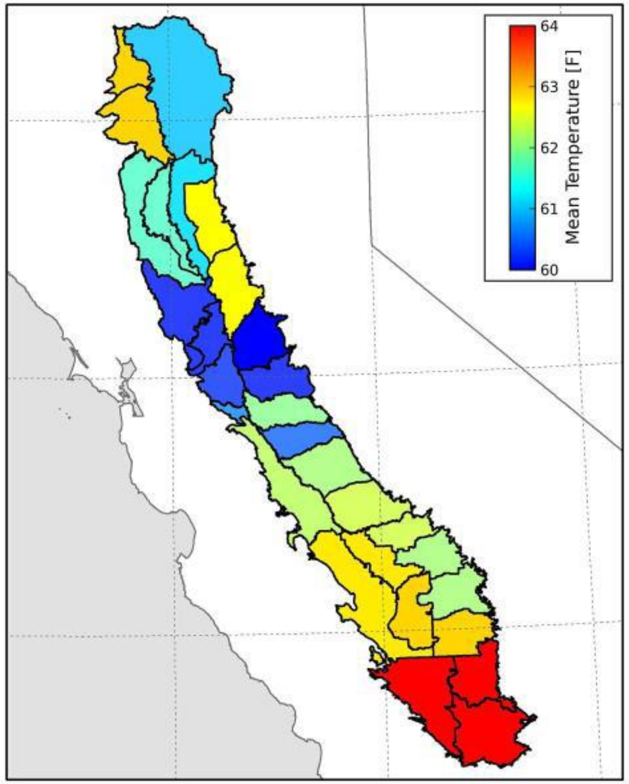


Process for estimating future water demands

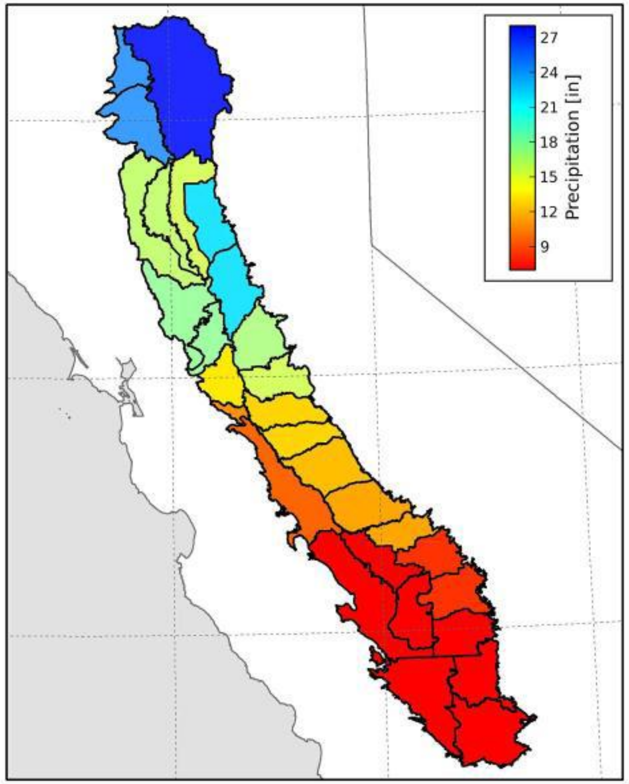


Model Inputs

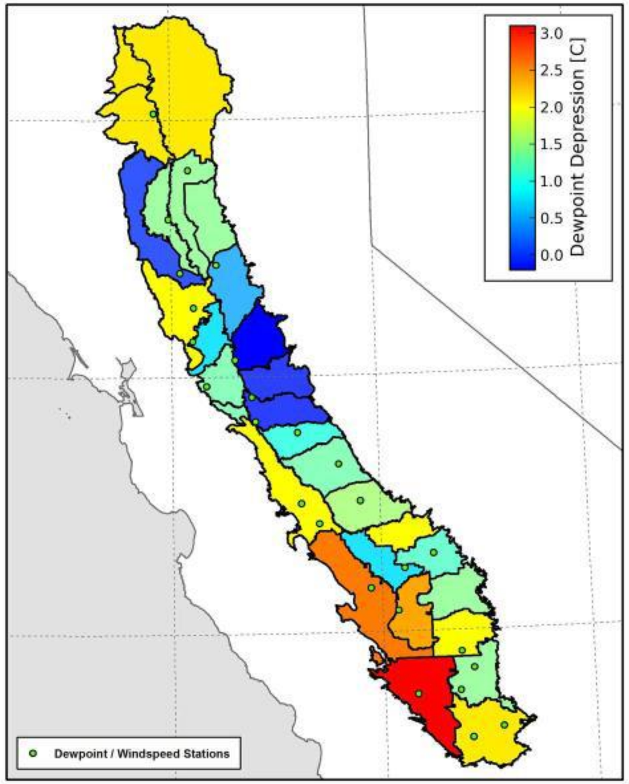
Mean Temp



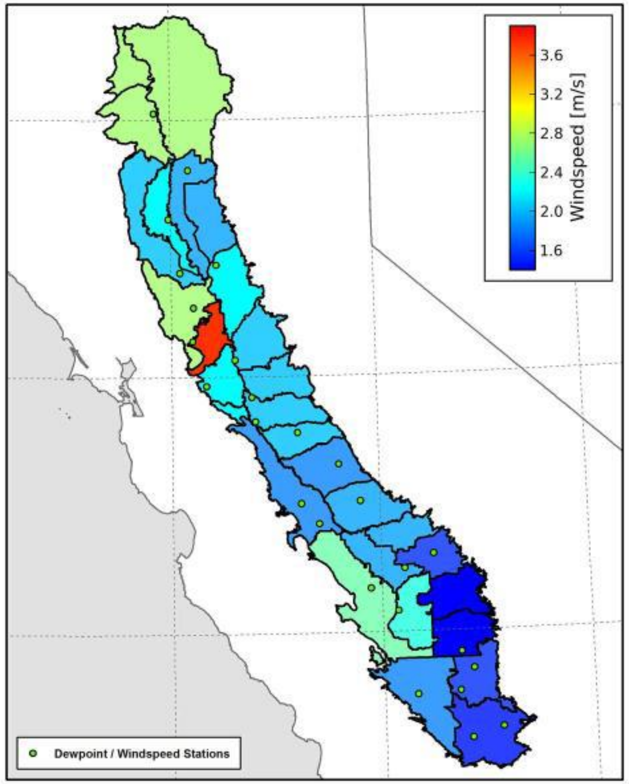
Precipitation



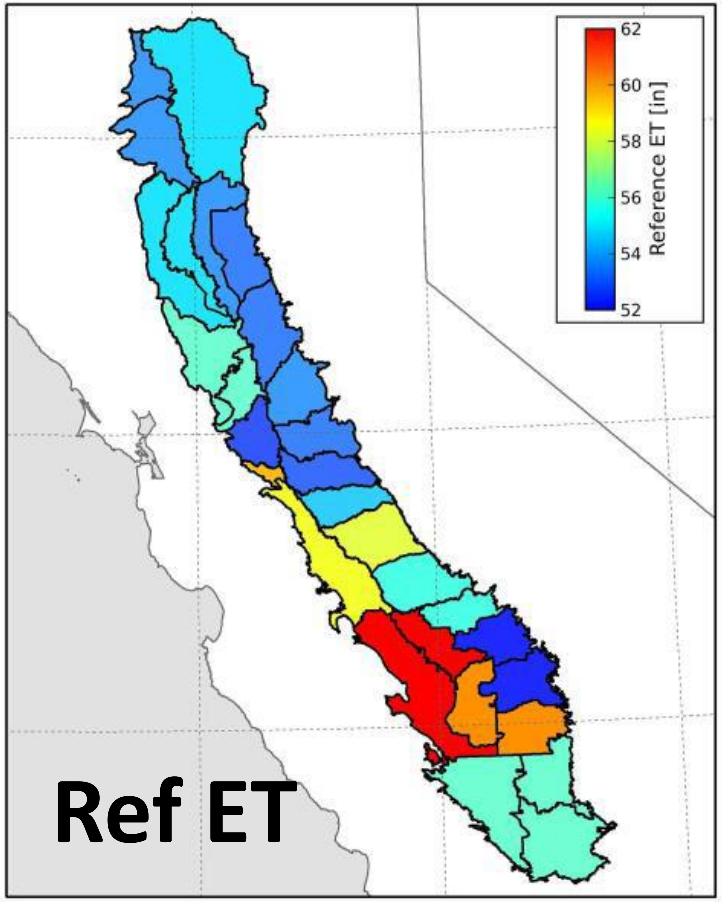
Dewpoint Depression

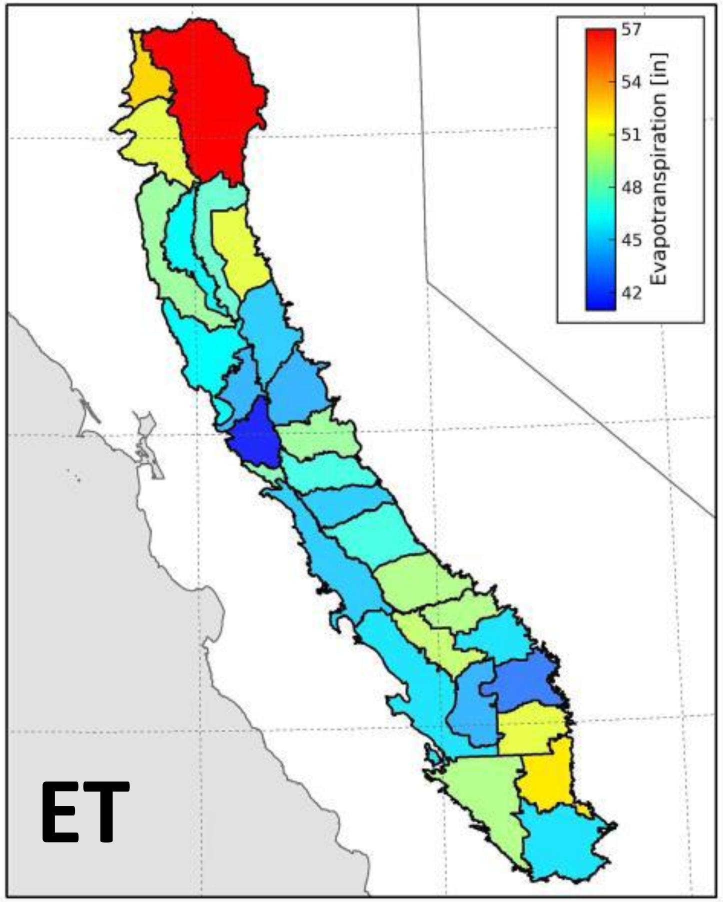


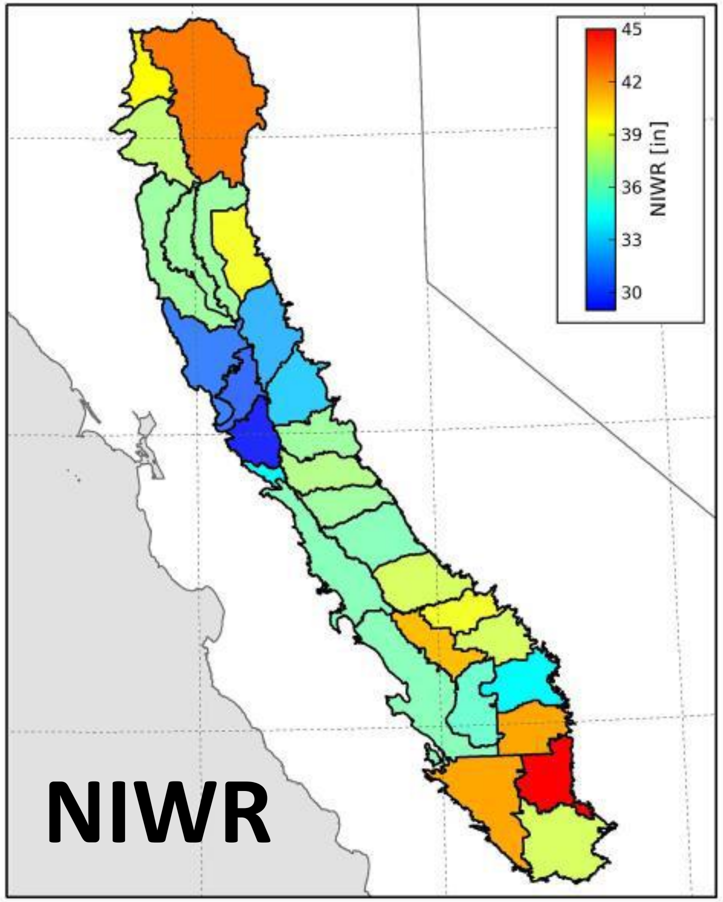
Windspeed

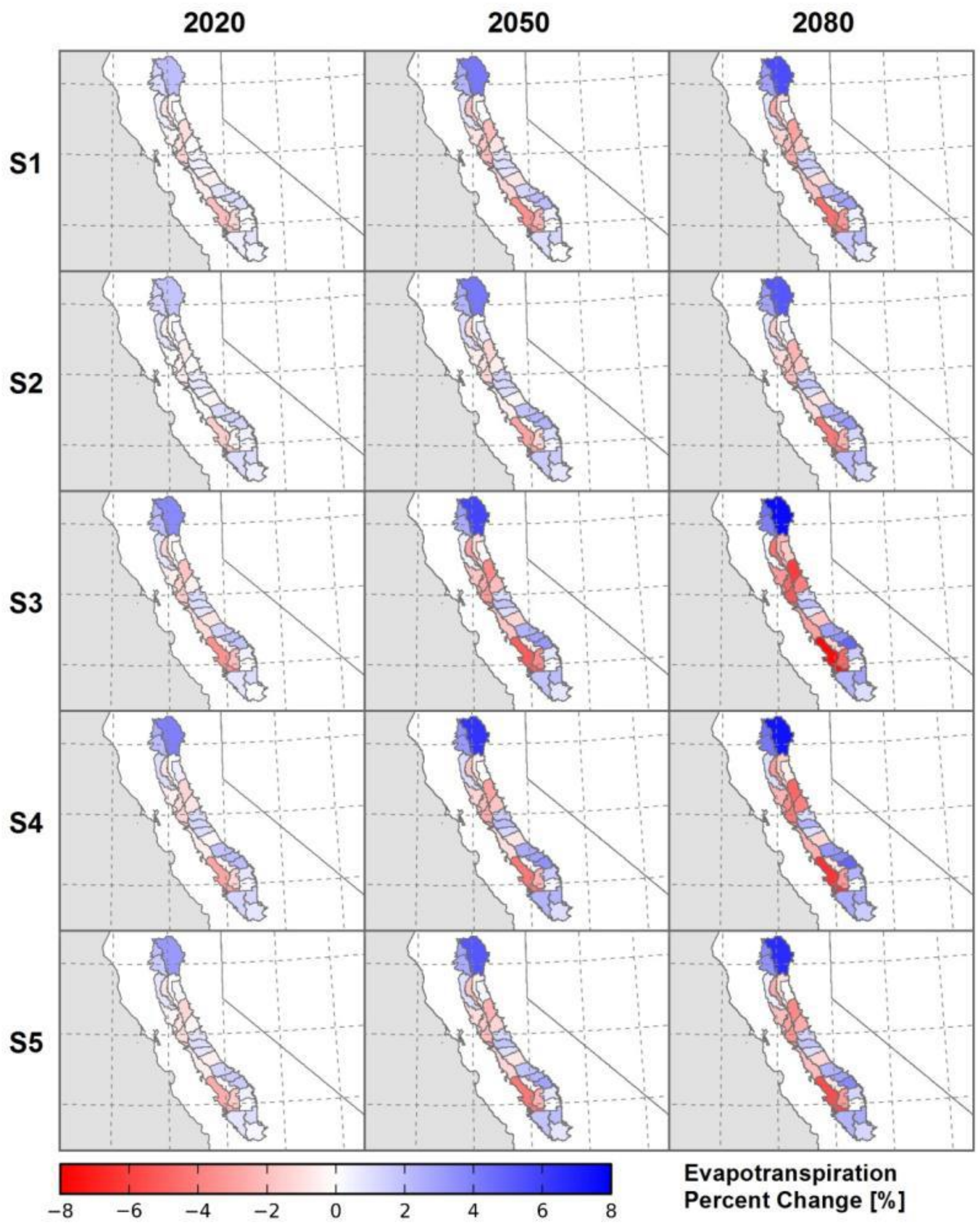


Model Results







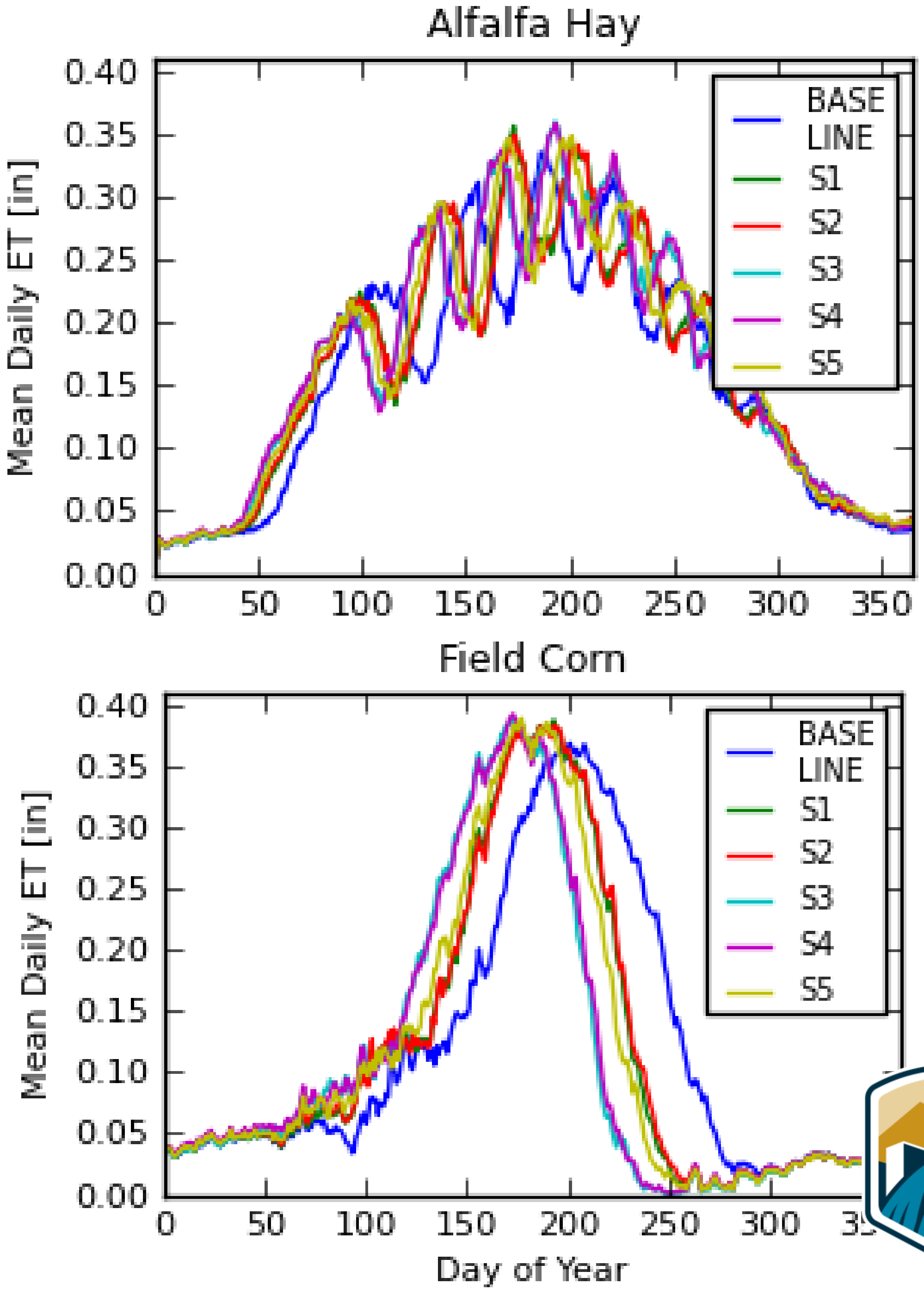


Changes in ET with Climate Change

- Ran 5 different climate projections
  - S1 – WD
  - S2 - WW
  - S3 - HD
  - S4 – HW
  - S5 - CT
- Spatially variable changes in ET
- Larger percent changes in 2080s

Climate Change Impacts on ET Timing

- 5 Climate Scenarios
  - S1 – WD
  - S2 - WW
  - S3 - HD
  - S4 – HW
  - S5 - CT
- By 2080, significant shifts in growing-season length, crop development, and cutting cycles.

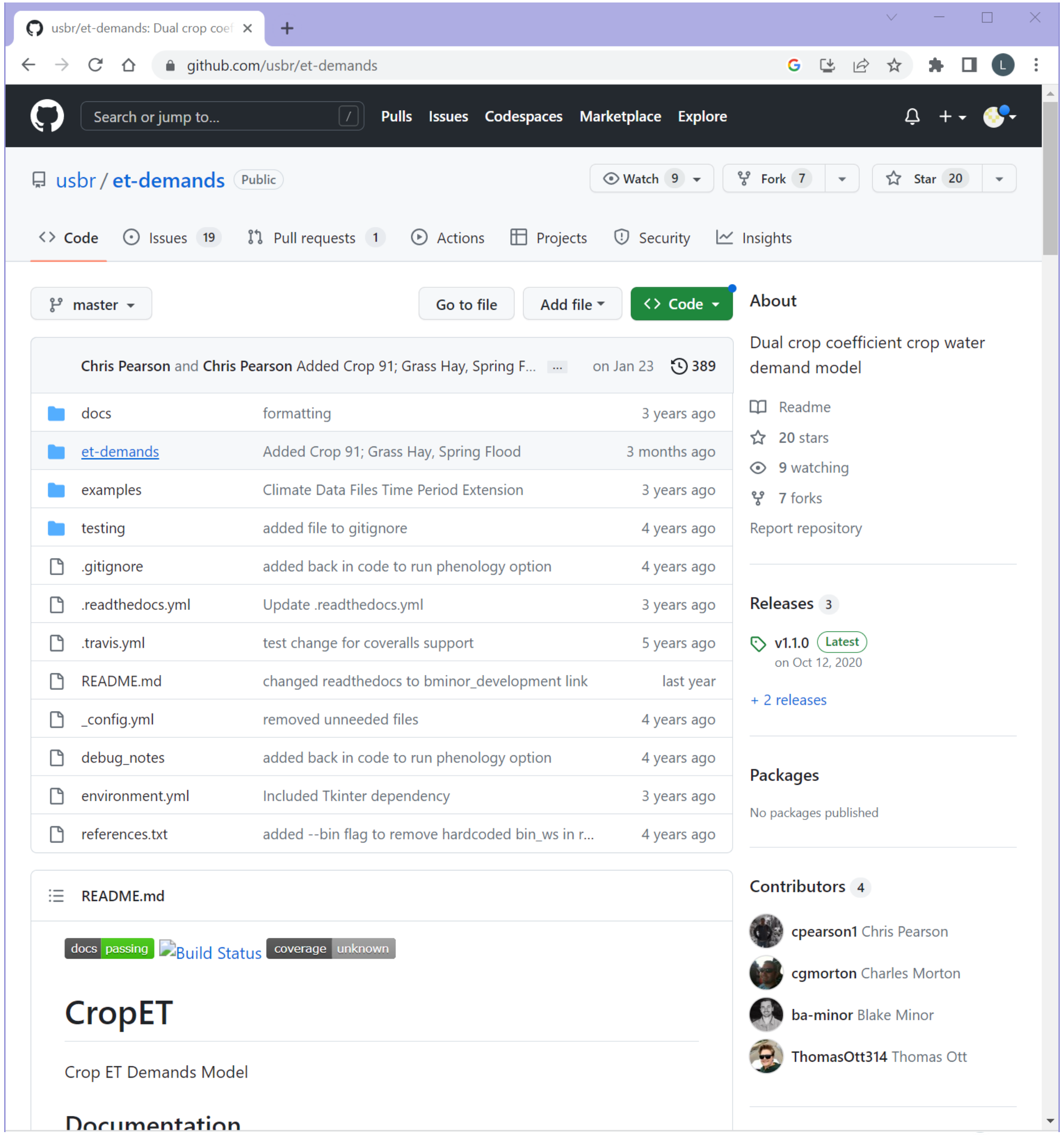


Evaluation of ET Demands Crop ET

- Huntington and Allen (2010) - Truckee-Carson – crop ET
- Ratio of estimated annual to measured: Average = 1.04, STD = 0.12
- Allen et al. (2005) - Imperial Valley, CA – crop ET
- ± 6% uncertainty at the 95% confidence level when compared to project wide water balance
- Burt et al. (2002) - Central Valley, CA – crop ET
- ± 14% at the 95% confidence level when considering uncertainty in model parameters
- Burt et al. (2005) – Central Valley, CA – bare soil
- Ratio of average mean daily FAO-56 modeled evaporation to 'measured' evaporation was 0.98, with an average percent different in cumulative study period totals of 4.7%
- Allen (2011) – Kimberly, ID – bare soil
- Within 15% of study period cumulative evaporation when compared to Kimberly lysimeter

ETDemands Code

- Github.com/usbr/et-demands
- Originally written with Visual Basic for Windows – ported to non-versioned python



Future Work

- Development of ASCE-PM Standardized Reference ET Dataset
  - Leverage Spatial CIMIS (available in 2003)
  - Develop monthly correction factors between CIMIS Stations and Spatial CIMIS for pre 2003
- Development of ETDemands estimated crop ET
  - Spatially Variable Calibration to estimate Crop growth curves (crop coefficients), large data needs
    - Number of cuttings
    - Average planning (green-up) date for each crop type
    - Average harvest (end) date for each crop
    - Average time from planning to full cover
- Updating CalSimHydro using the updated IWFM IDC which includ wetlands and refuges.

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