BUREAU OF RECLAMATION

Improvements to CalSim Reference Evapotranspiration

2024 CWEMF Annual Meeting, September 24, 2024

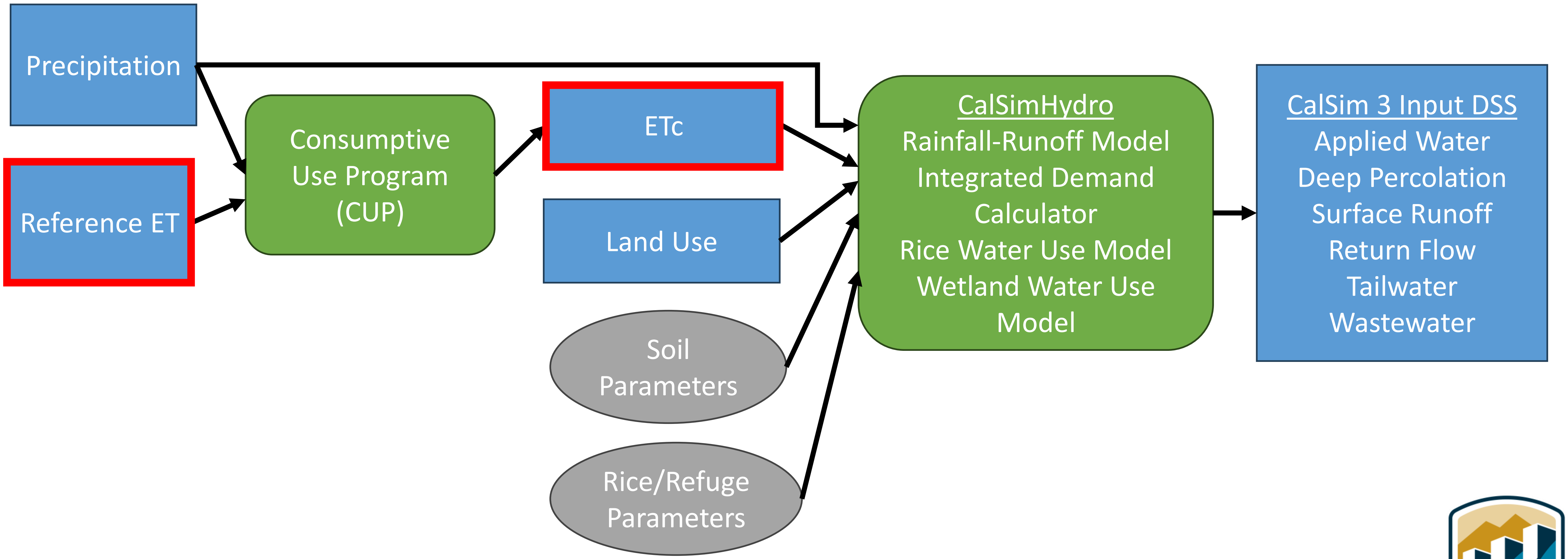
Presenter: Lauren Thatch

Collaborators: Justin Huntington (DRI), Chris Pearson (DRI)

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.

CalSimHydro Reference ET



Current CalSimHydro Reference ET Input

- Hargreaves-Samani equation

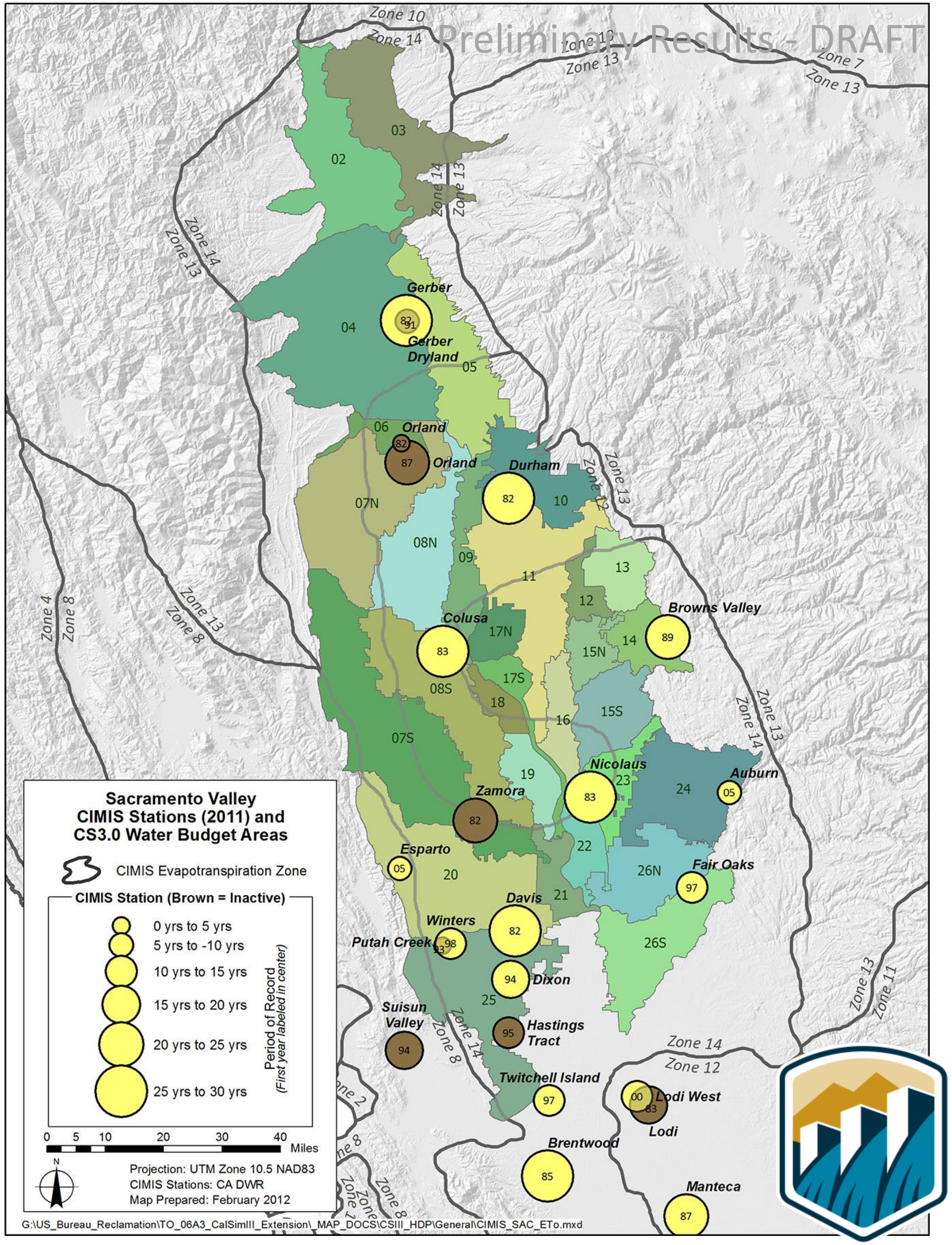
$$ET_o = 0.0023.R_a.(T_{max} - T_{min})^{0.5}.(T_m + 17.8)$$

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

$$f1 = \frac{ETO_{OBS}^{CIMIS}}{ETO_{HS}^{CIMIS}}$$

$$ETO_{HS}^{WBA} = ETO_{HS}^{CIMIS} * f1 * f2$$

$$f2 = \frac{ETO_{HS}^{WBA}}{ETO_{HS}^{CIMIS}}$$

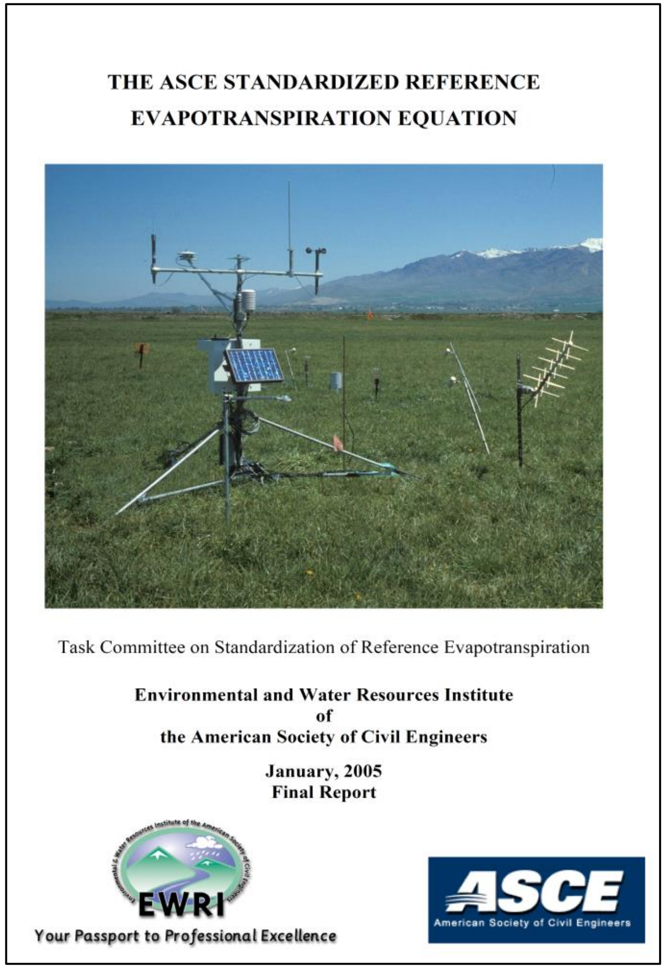


ASCE Standardized ETo Equation

- 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


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

Evaluate Reference ET Datasets for CalSim Applications

- Compare gridded weather datasets with station and existing CALSIM Potential ET datasets
- Identify best performing product for historical and future simulations
- Assess Penman-Monteith versus Hargreaves

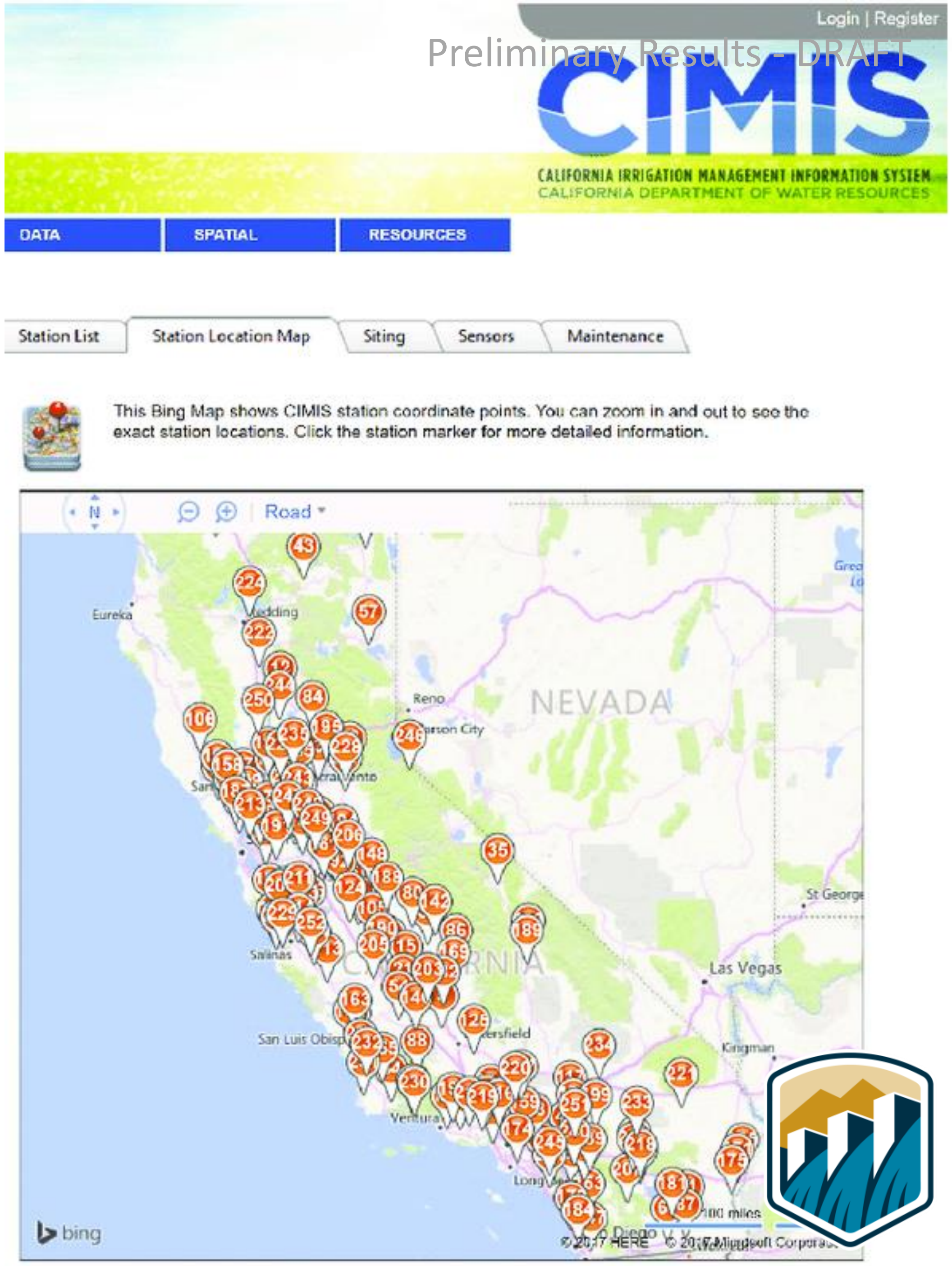
Gridded ETo Datasets:

- GridMET
- Spatial CIMIS
- RTMA
- ERA5-Land
- NLDAS
- CONUS 404
- OpenET GridMET
- PRISM*
- ERA5-Ag*

*Hargreaves PET

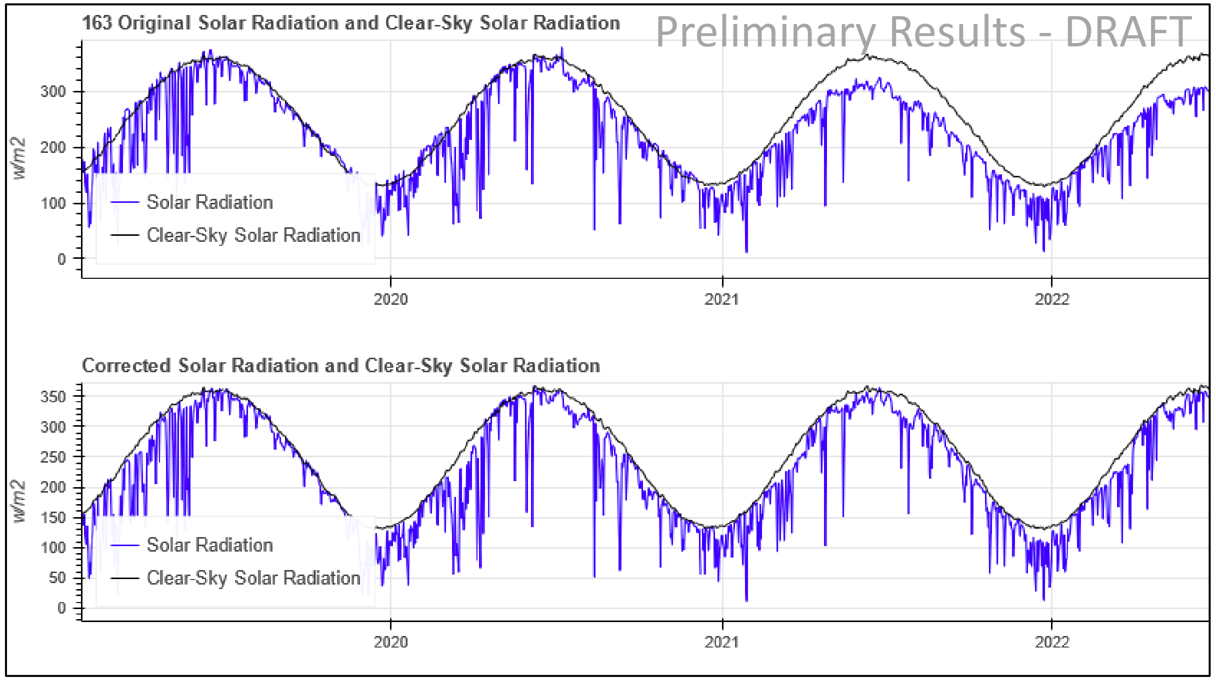
Selected CIMIS Locations

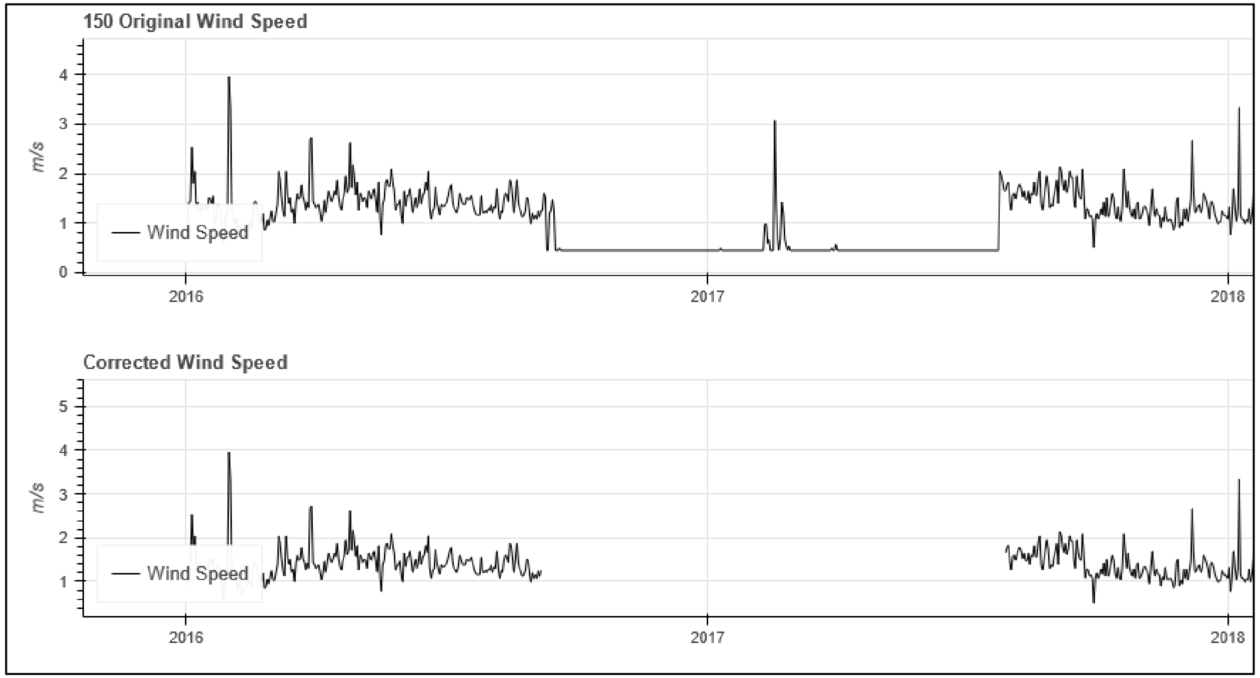
- Considered 147 CIMIS Weather Station Datasets for inclusion
- Selected 110 stations based on location and conditions
  - Reference Conditions
  - Uniform, stress-free vegetation growth
  - Relatively well-watered conditions (soil moisture >~50%)
  - Unobstructed wind and fetch
- 1994 to 2022
  - Average of 17.5 years of Reference ET per station

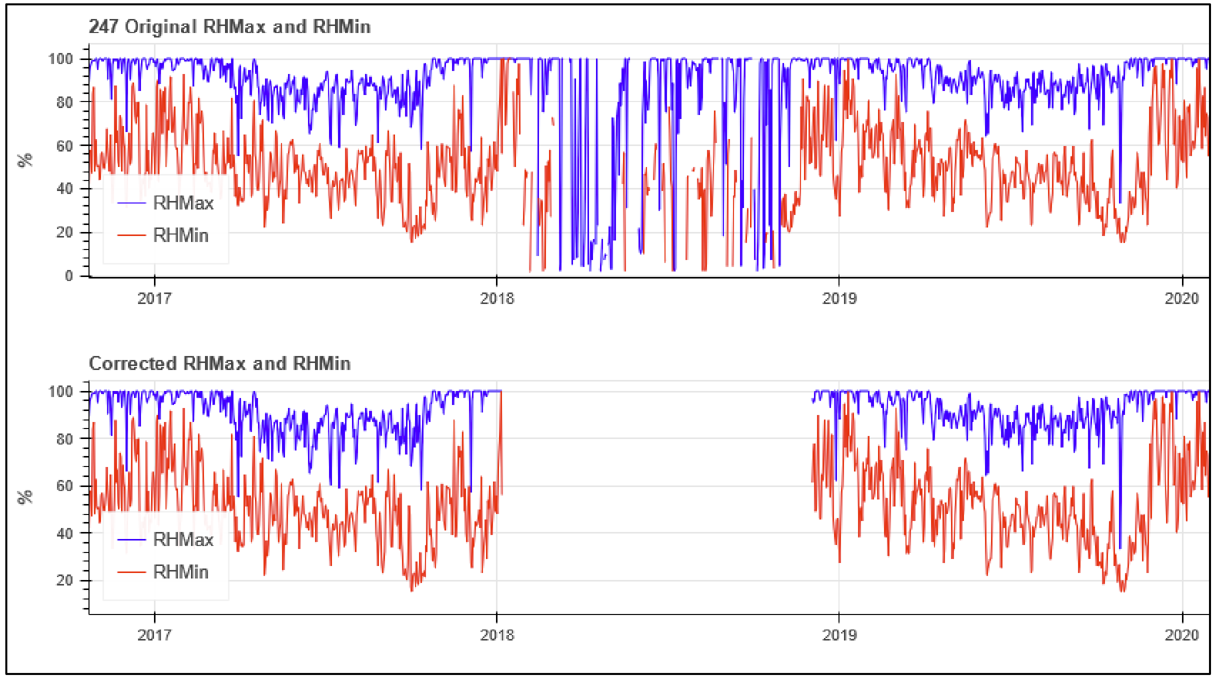


CIMIS Station QAQC

- Python AgWeather-QAQC routine







Python AgWeather-QAQC routine

- https://github.com/WSWUP/agweather-qaqc

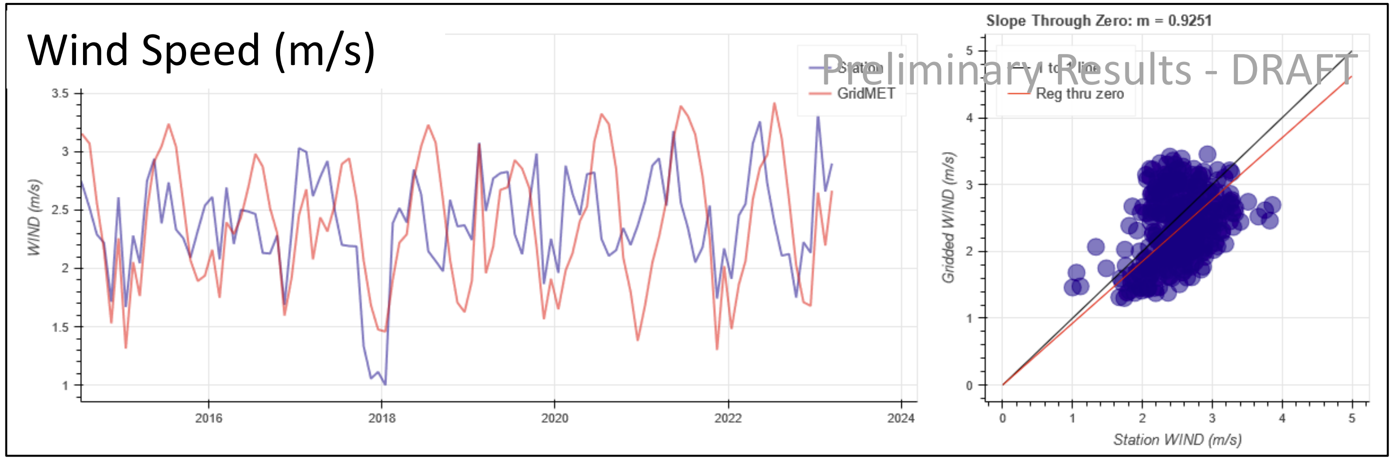
JOSS
The Journal of Open Source Software

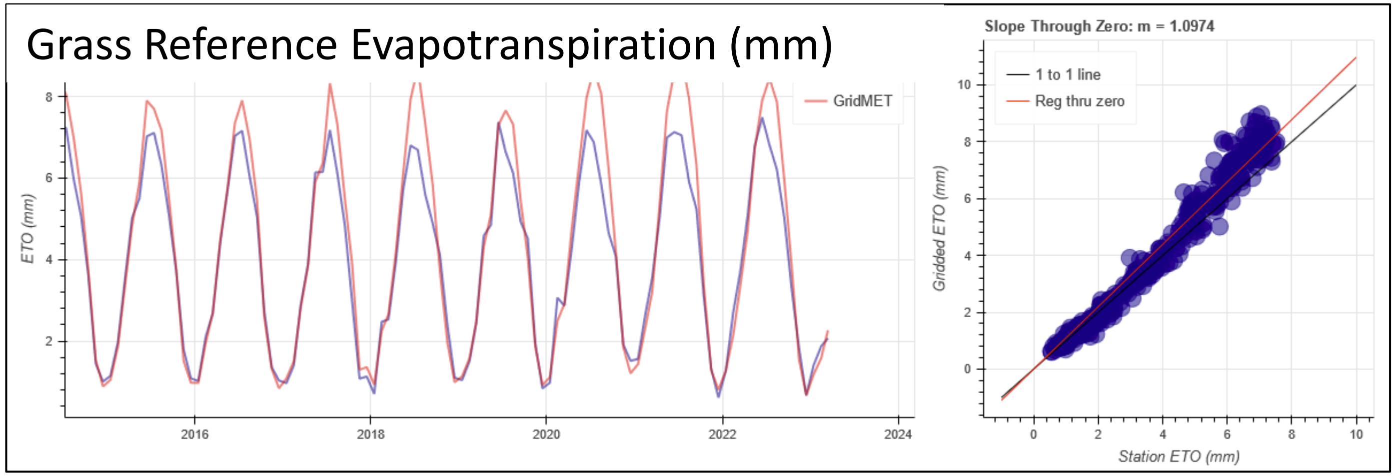
agweather-qaqc: An Interactive Python Package for Quality Assurance and Quality Control of Daily Agricultural Weather Data and Calculation of Reference Evapotranspiration

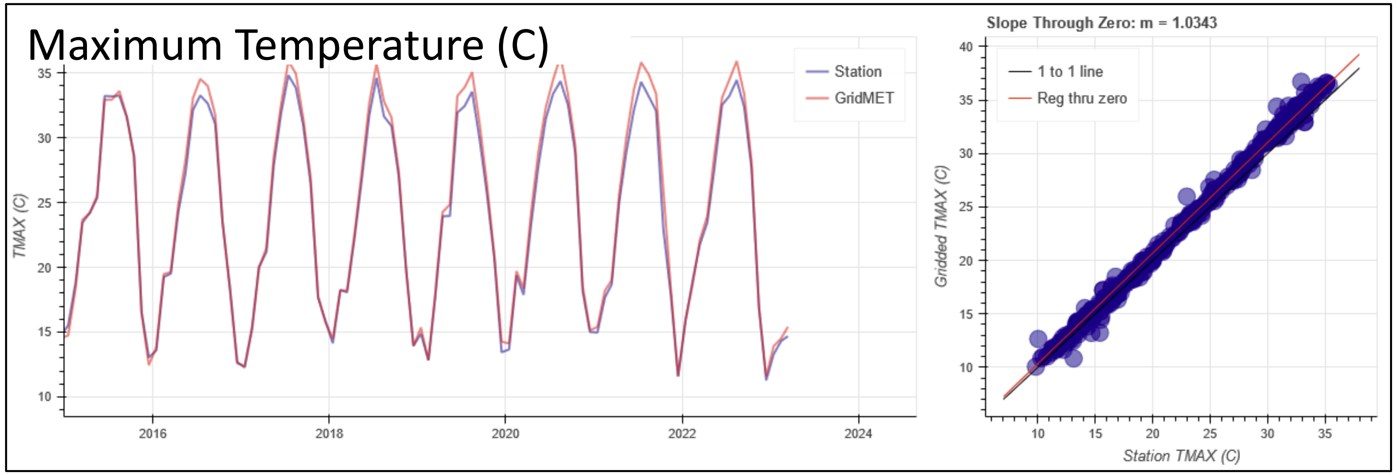
Christian Dunkerly[1¶], Justin L. Huntington[1], Daniel McEvoy[1,2], Asa Morway[3,4], and Richard G. Allen[5]

1 Desert Research Institute **2** Western Regional Climate Center **3** Huntington Hydrologic **4** Battle Born Homeschool Co-op **5** University of Idaho (ret.) ¶ Corresponding author

Davis (#006) vs. GridMET



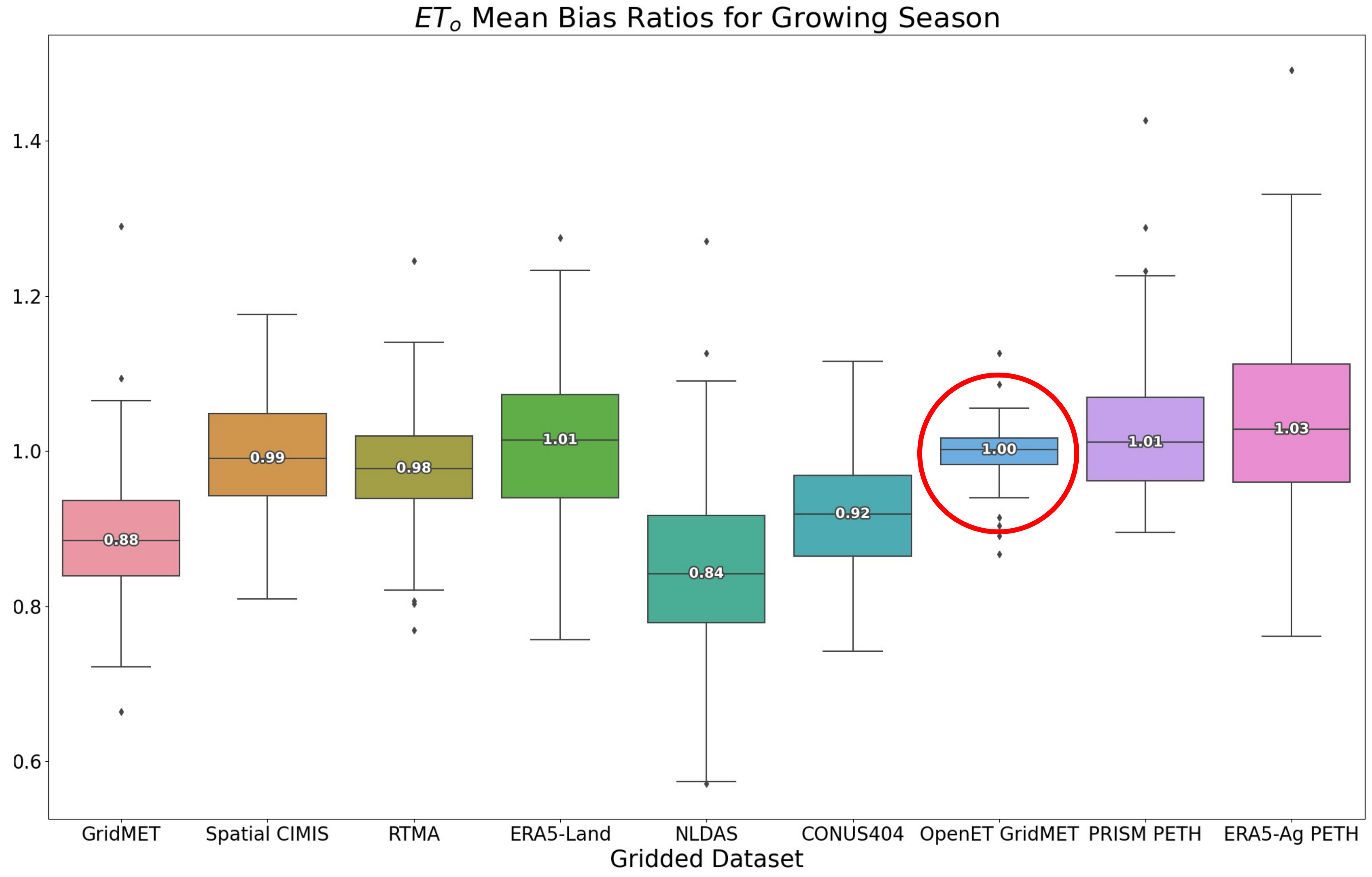




Gridded Data Comparisons

$$\frac{\text{CIMIS Station } ET_o}{\text{Gridded Dataset } ET_o}$$

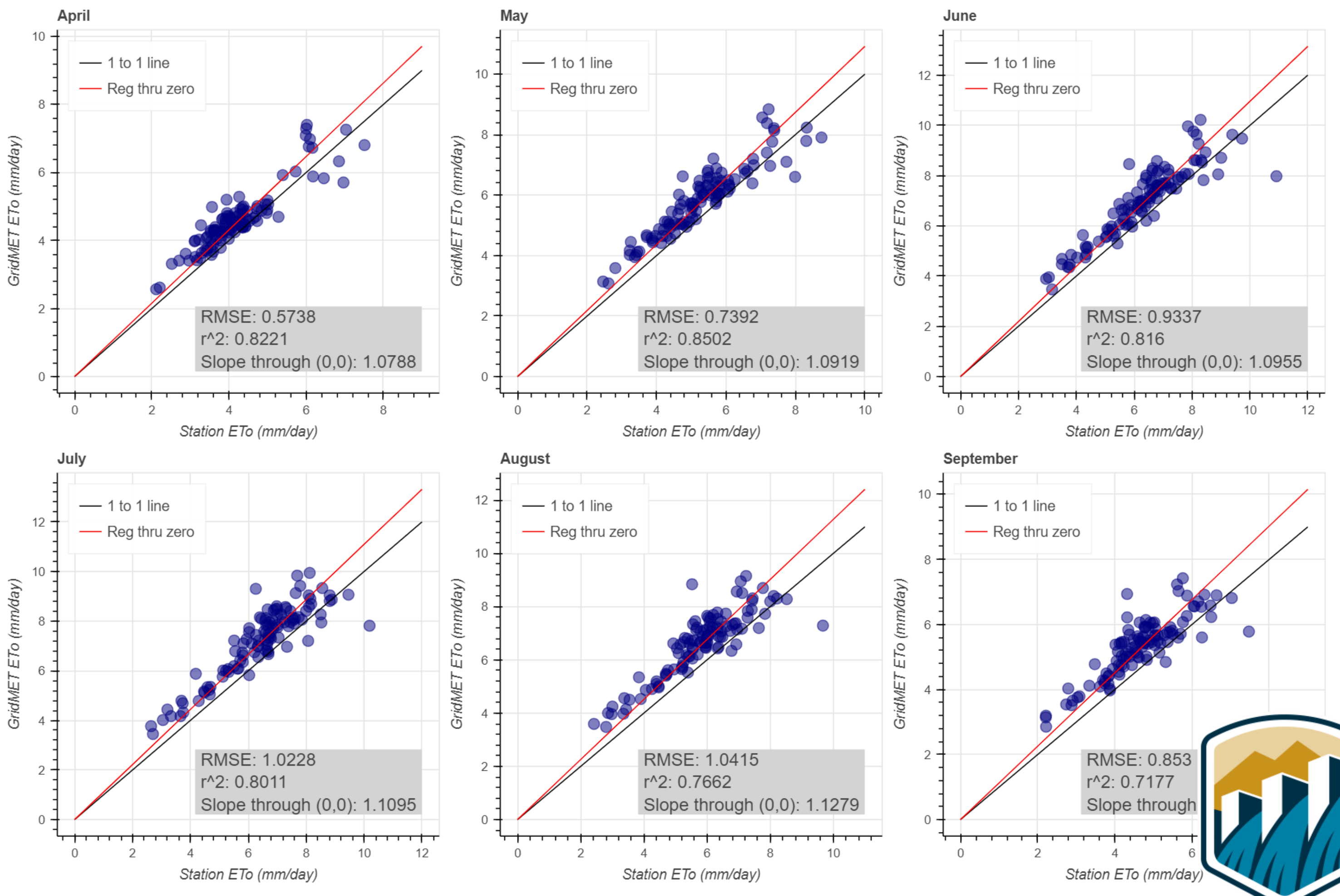
> 1: underpredicted ETo
< 1: overpredicted ETo



OpenET GridMET (bias-corrected GridMET)

- Bias corrected reference ET based on station data
- Agricultural stations only
- Adjust for evaporative cooling effects not represented in gridMET

GridMET **without** bias correction



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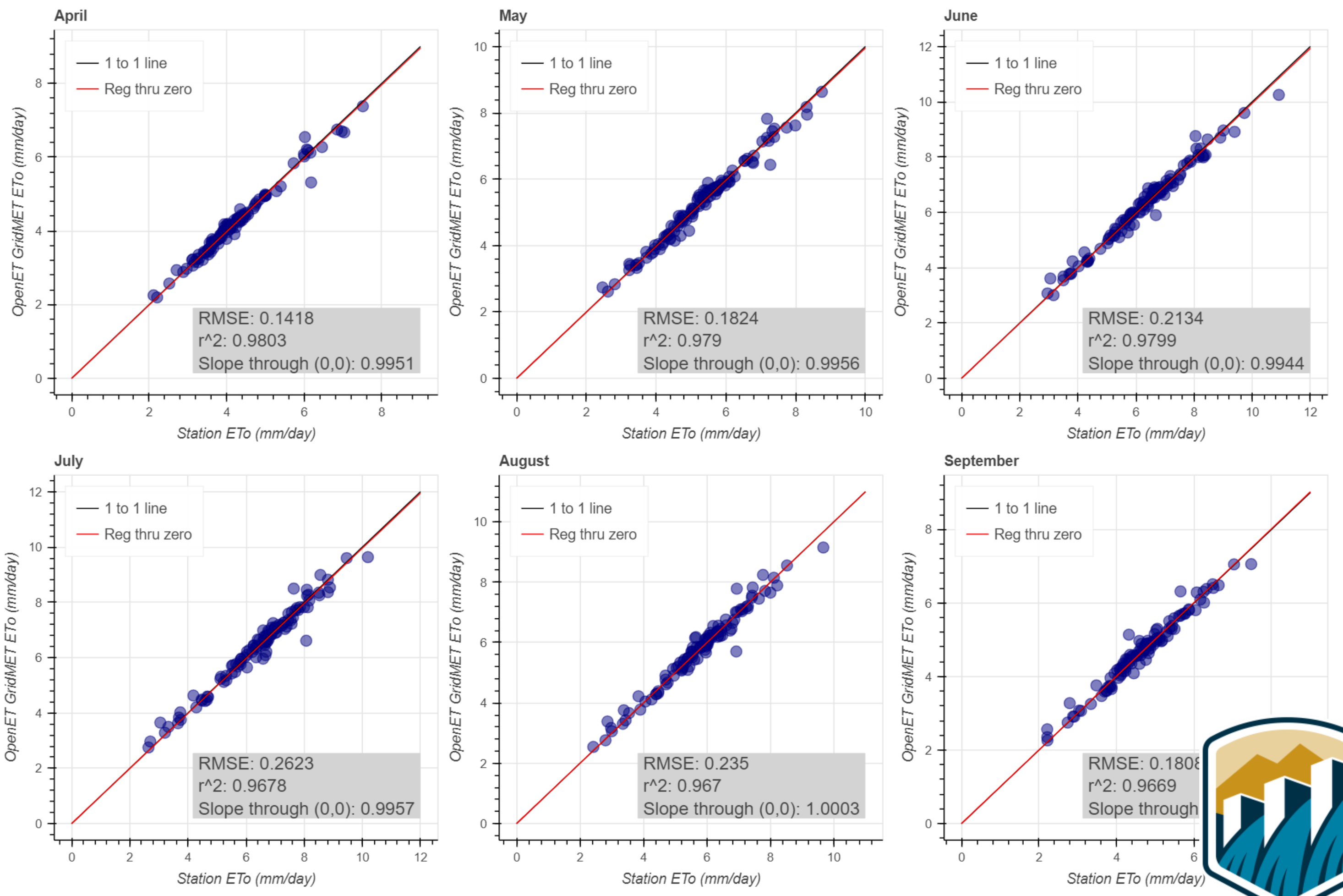
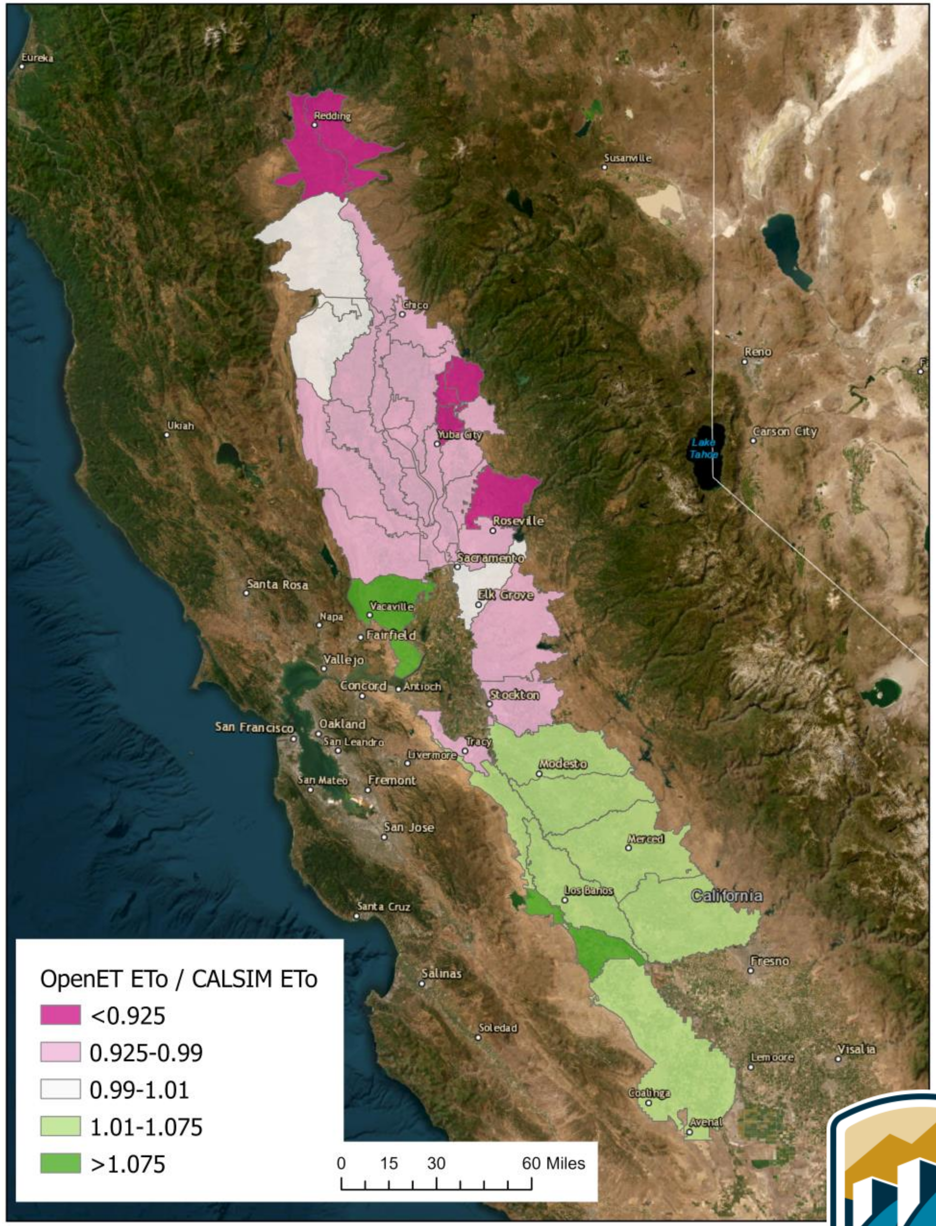


Comparison with Existing Reference ET

- OpenET gridMET ETo / CALSIM ETo
- July Average ETo
  - High Bias in Northern CA
  - Low Bias in Southern CA
- Similar patterns to spatial CIMIS

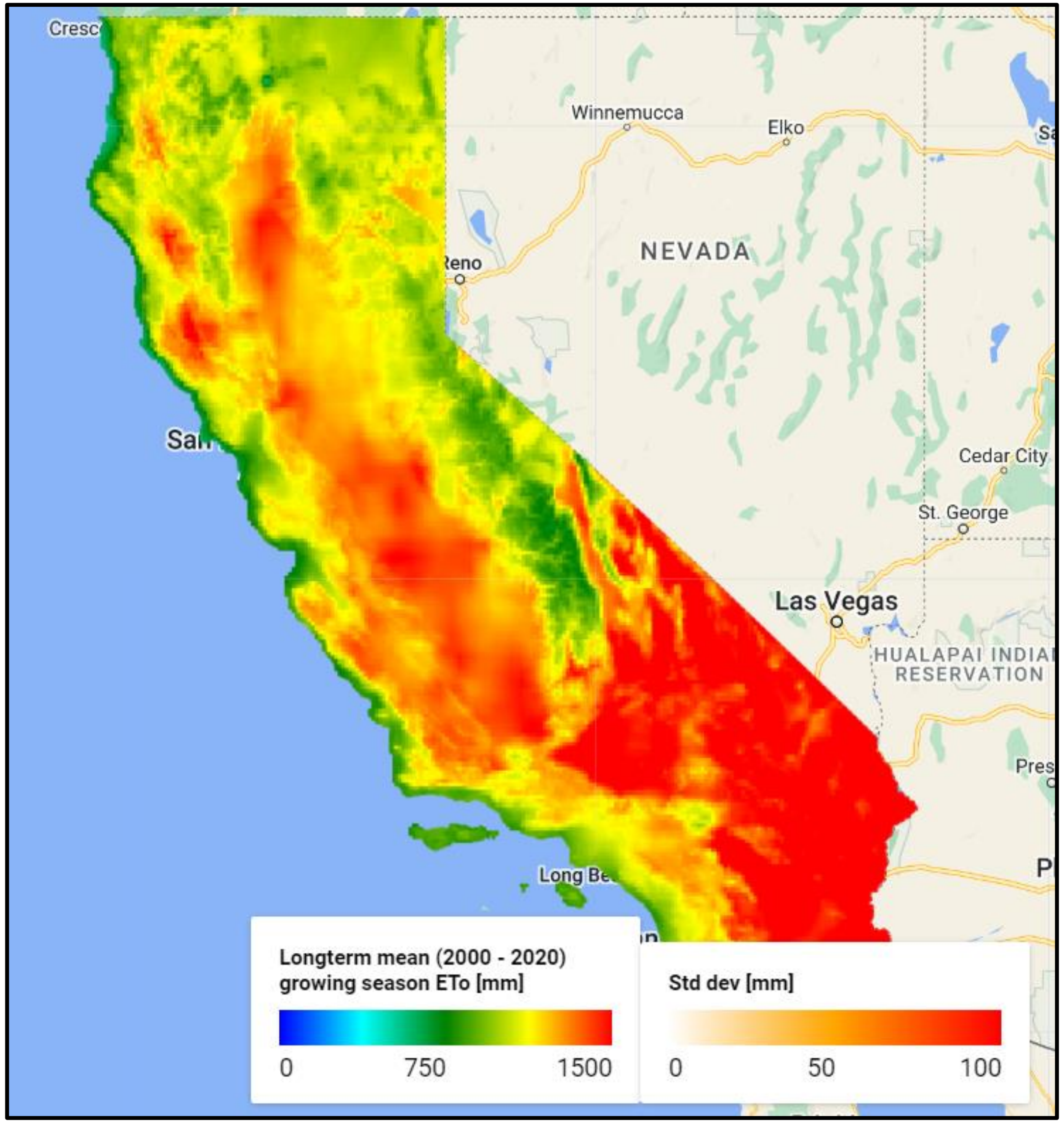
>1: CalSim underpredicts ETo
< 1: CalSim overpredicted ETo

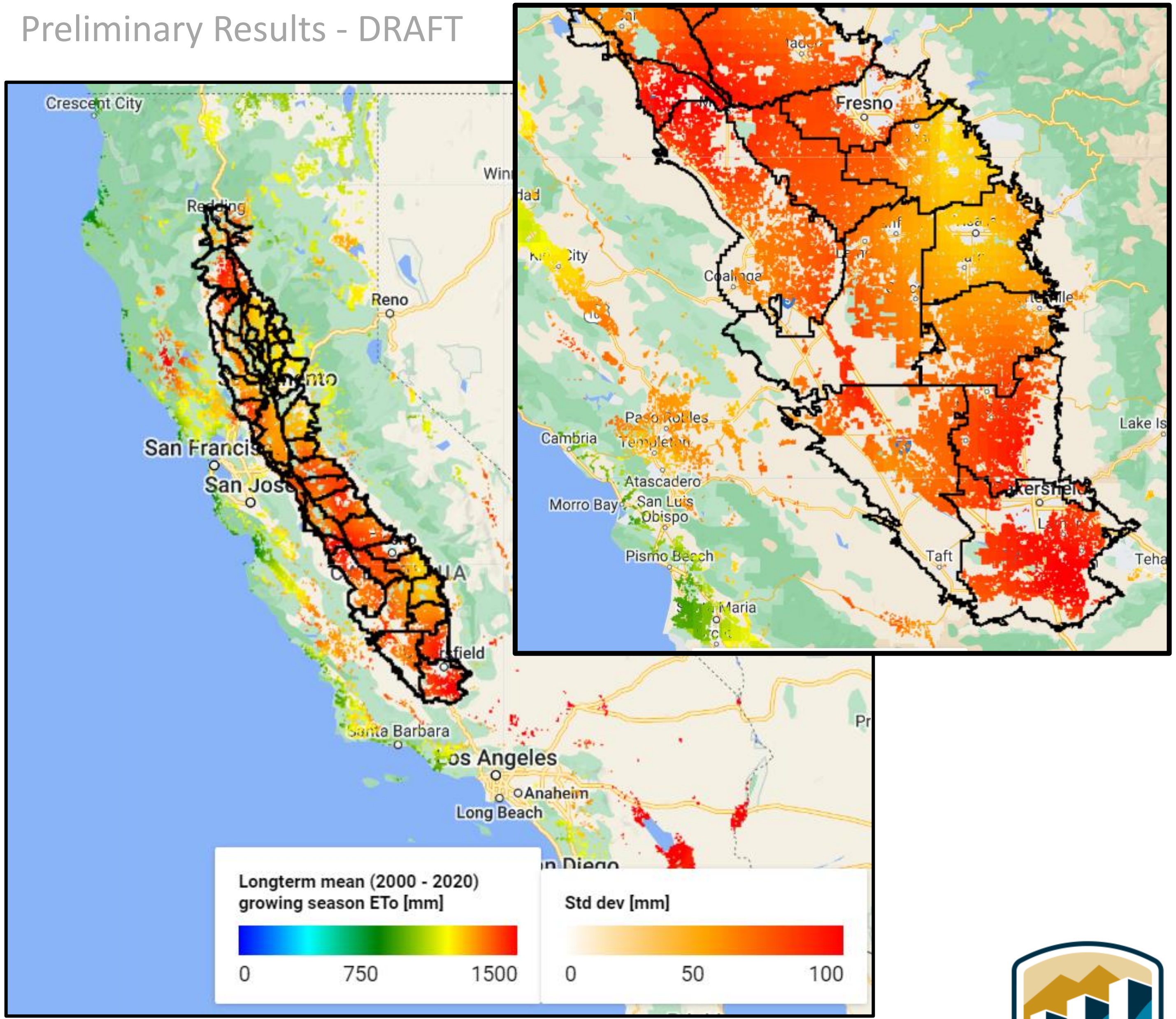


Recommendation –OpenET GridMET ETo

- Pros
  - Lowest bias and spread relative to station ETo
  - Natively pairs with:
    - OpenET Remotely Sensed ET products
    - Multivariate Adaptive Constructed Analogs Future Projections (MACA)
    - Downscaled GCMs trained with historical gridMET
  - Readily available: 1979-present (2-day lag)
- Cons
  - GridMET's Future: May be updated or discontinued in the next 5-10 years

Preliminary Results - DRAFT





https://openet.earthengine.app/view/histograms-of-eto-by-wba

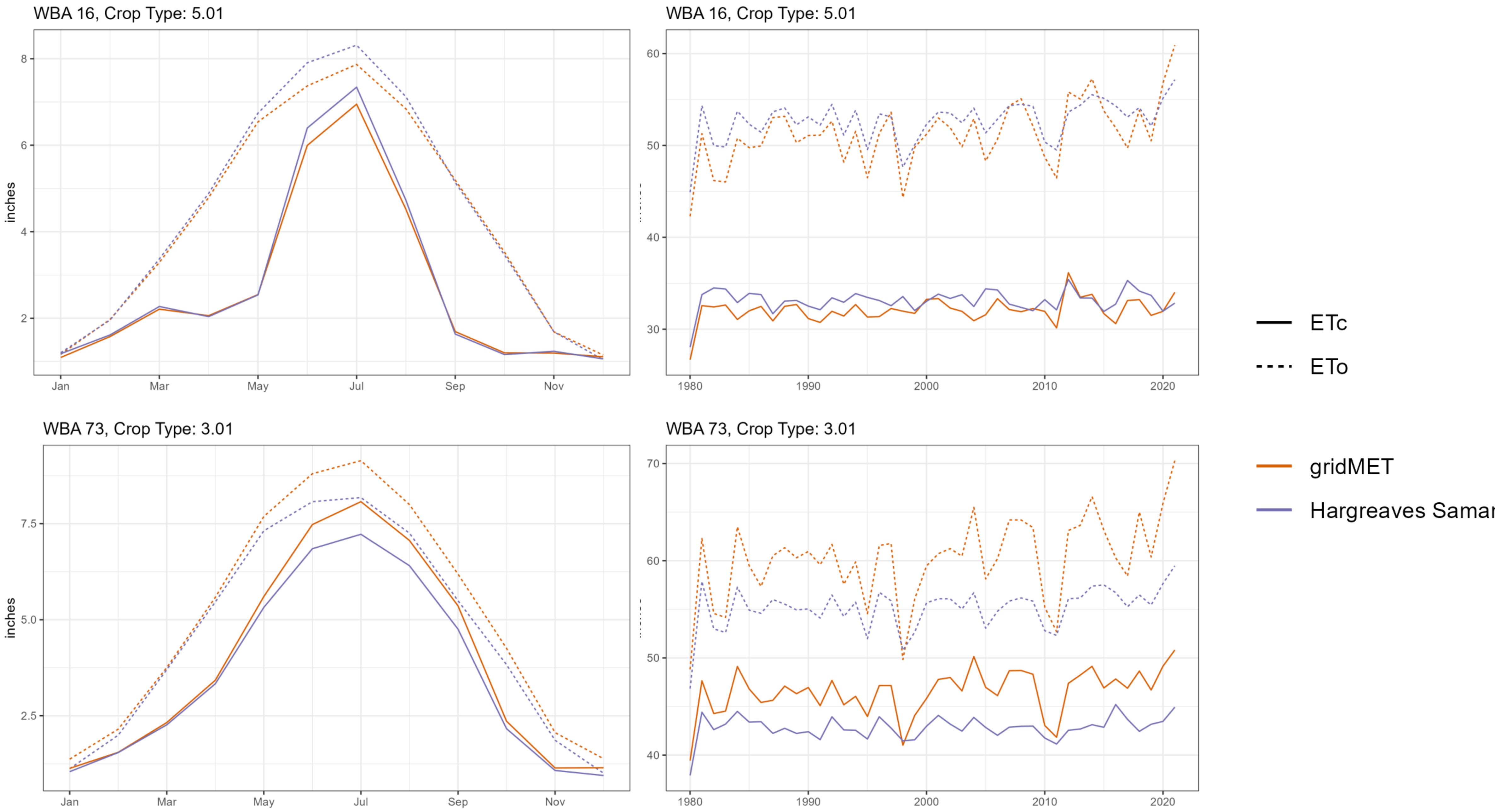
Preliminary Results - DRAFT

Monthly Average

Total Annual

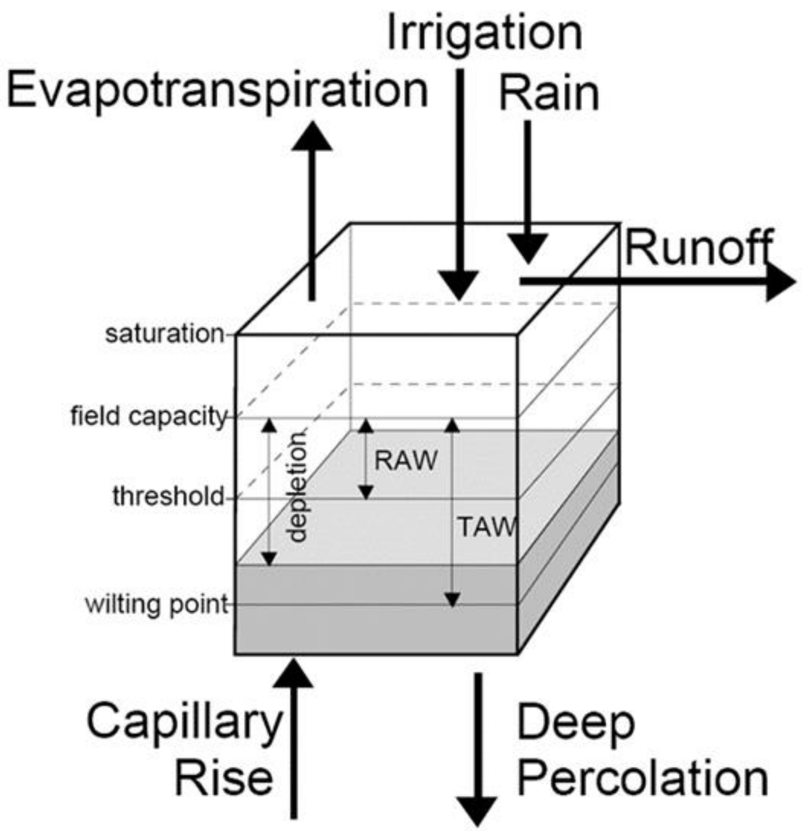
WBA 16, Tomatoes

WBA 73, Almonds



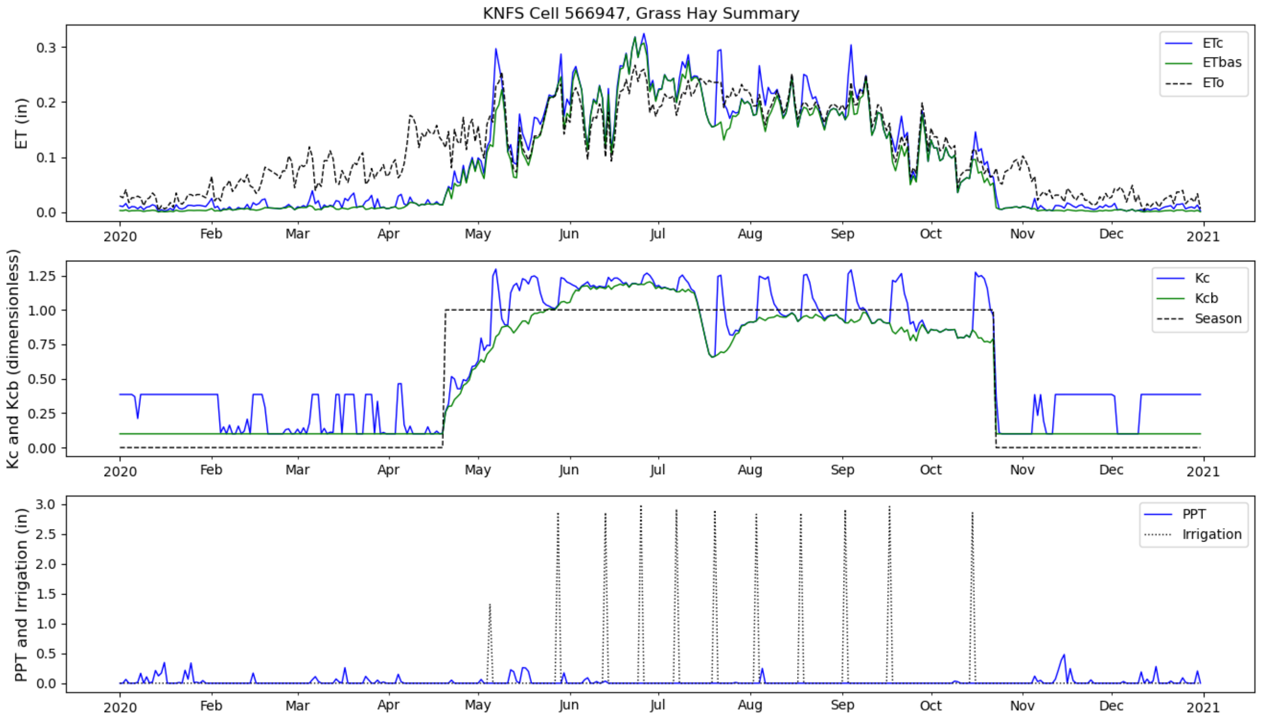
Next Steps

- Extension back to 1921
  - Combined Hargreaves-Samani and Bias-Corrected GridMET approach
- Calculate ETc using the ET Demands Model
  - Daily Crop ET
    - ASCE Standardized PM Reference ET
    - FAO-56 Dual Crop Coefficient Method
    - Daily soil water balance
  - Previous Applications:
    - West-wide Climate Risk Assessments, Upper Colorado River Basin Oregon, Klamath Natural Flow Study, Nevada, Idaho
  - https://github.com/WSWUP/et-demands



ET Demands – Modeling Methodology

- Crop Growth and ET Simulation
  - Temperature based model
  - Green Up: T30 or CGDD
  - Effective Full Cover: CGDD or Time
  - Harvest/Killing Frost: CGDD, Time, KF
- Irrigation Scheduling
  - MAD thresholds, irrigation occurs when MAD < Threshold
- Each crop, grid cell combination is simulated separately.



ET Demands - Calibration

- Crop specific calibrations
- NDVI comparisons using Landsat and HLS imagery
- Adjust Kc curve timing based on NDVI phenology
- Leverage typical growing season start and end dates
- Goal is to capture average signal and interpolate throughout the entire study area.

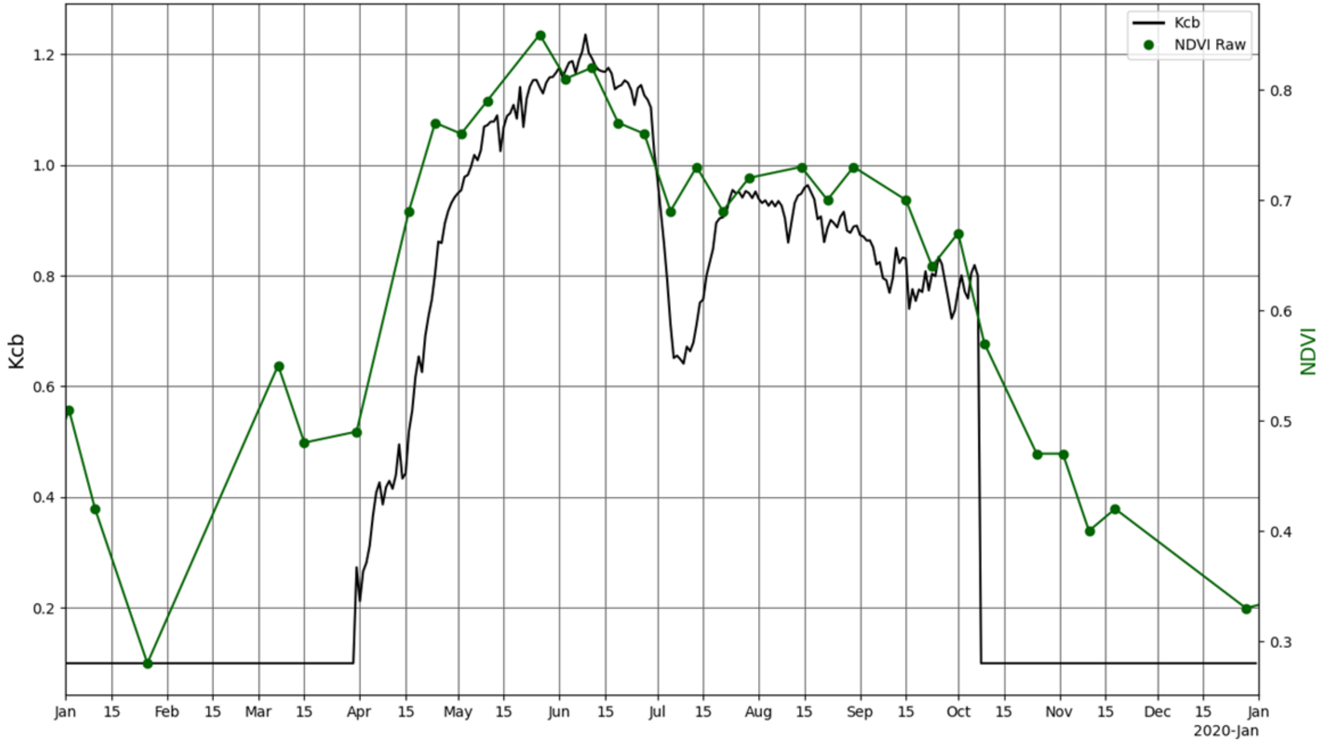


Figure: Time series comparison of Landsat derived NDVI and ET Demands simulated Kcb for grass hay crop in grid cell 564161 near Copoco Lake, CA.

Contact Info

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Input Data

Climate

- gridMET
  - Daily estimates at 4 km resolution
  - Tmin, Tmax, RH, Windspeed, Solar Radiation, Precipitation

ASCE Standardized PM Reference ET

- Grass Reference ET, ETo
- Bias corrected to station data using OpenET bias correction layer

Soil

- Average 0-150cm available water capacity
- Hydrologic Group – A, B, C
- Sand, Silt, Clay Fraction
- Adding GNATSGO functionalit

Crop Type

- USDA Cropland Data Layer (2008-2020)
- LandIQ (2014, 2016, 2018-2022)

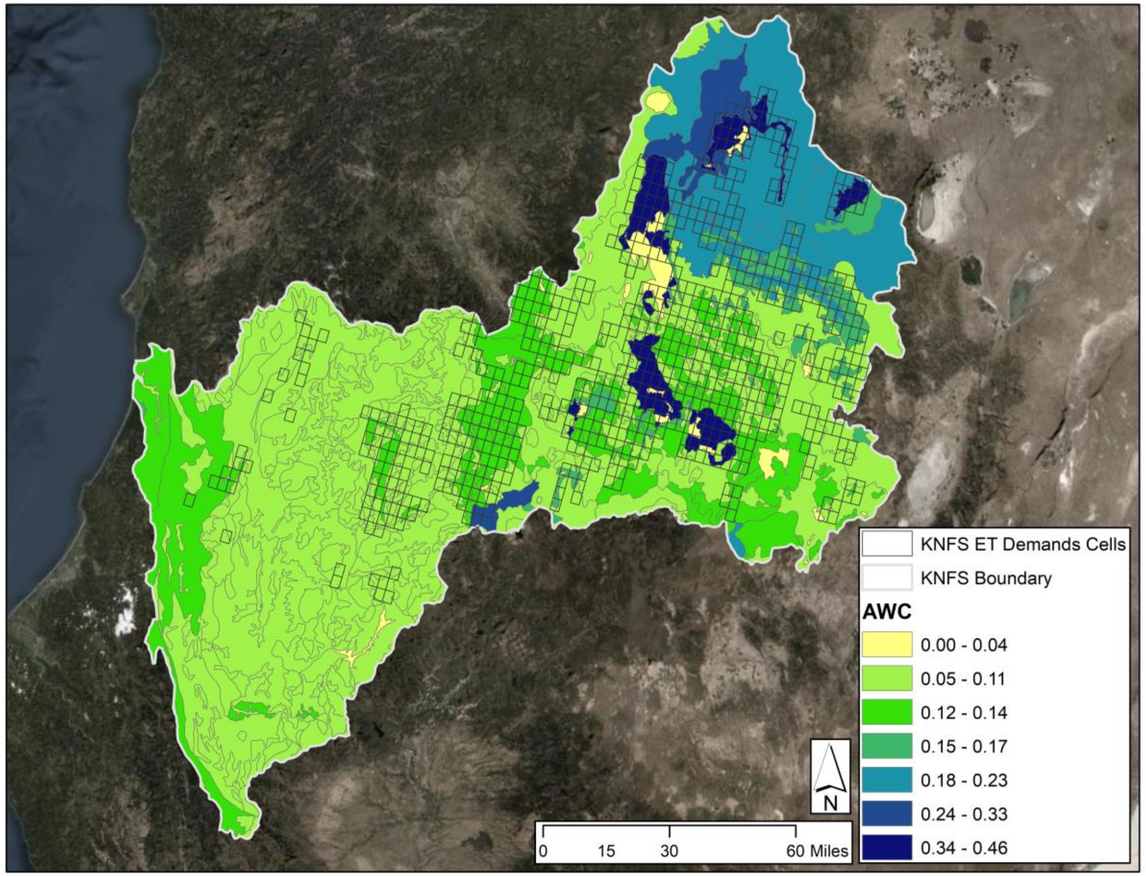


Figure: Example soil available water capacity from SSURGO/STATSGO dataset for the Klamath Basin.

ET Demands Model

Daily Crop ET and NIWR Estimates

- Crop ET
  - ASCE Standardized PM Reference ET
  - FAO-56 Dual Crop Coefficient Method
    - Kc = Kcb + Ke
- Daily Soil Water Balance
  - Effective Precipitation
    - P_rz = Amount of PPT available for both E and T
    - Pe = PPT - Runoff - Deep Percolation
  - Deep Percolation
    - Drainage below the crop root zone
    - Soil Water Content > Field Capacity
  - Runoff
    - USDA NRCS CN Approach
  - NIWR
    - ETc - Pe

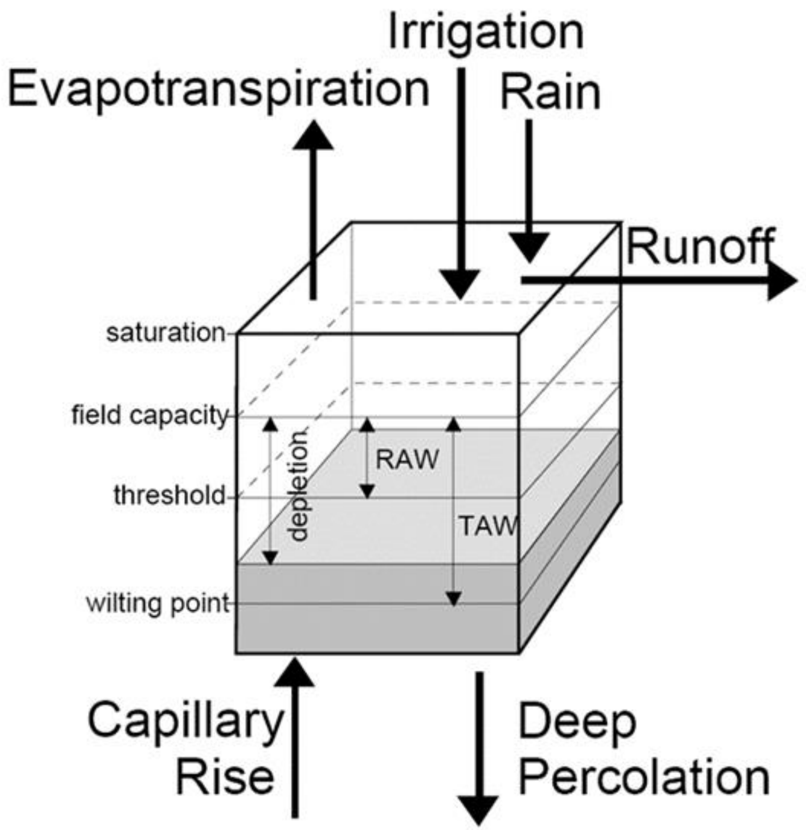


Figure: Conceptual diagram of the FAO-56 daily soil water balance utilized within ET Demands (modified from Allen et al., 2006).

Model Purpose

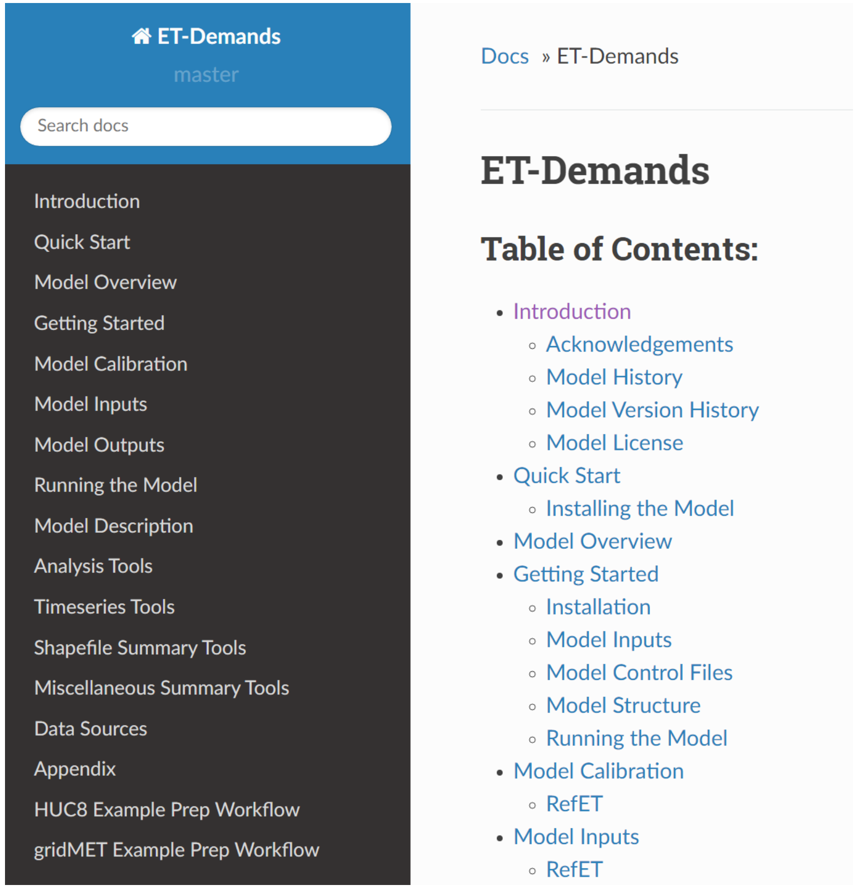
ET Demands Effective Precipitation

- The eeMETRIC model provides estimates of total ET
- Total ET = ETprecipitation + ETirrigation

Effective precipitation is defined as the amount of precipitation that is available for ET (Bos et al., 2009).

ET Demands provides estimates of daily Crop ET (ETc) and Pe using a daily soil water balance approach

- Previous Applications:
    - Upper Colorado River Basin
    - Oregon
    - Klamath Natural Flow Study
    - Nevada
    - Idaho
    - West-wide Climate Risk Assessments



<u>Model code and documentation:</u>
https://github.com/WSWUP/et-demands