Lessons Learned in Calculating Evapotranspiration in CalSim 3

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Objectives

- How reference ET and crop ET are calculated in CalSim 3.
- Sources of hydrologic variables temperature, precipitation, and solar radiation used in CalSim 3 ET modeling.
- Discuss and visualize ET variability in CalSim 3 by example through a study in which a potential future temperature timeseries is developed by removing the trend from the historical timeseries (from 1921 to 2015).

Challenges

- Lack of reliable long-term data records
  - Gage data largely unavailable for the early periods of the CalSim 3 modeling period (WY 1922 – 2015).
  - Simulated data for California available from PRISM and CIMIS
- Few methods for modeling ET with available data
  - Early 20th century data limited to maximum/minimum temperature and precipitation from PRISM.
  - Data constraints force using Hargreaves-Samani method for reference ET.

Method: Reference ET

- Step 1: Develop monthly correction factors for Hargreaves-Samani Equation using observed ETo data.
  - Compare CIMIS data and HS computed Eto for common period
  - Used CIMIS produced and PRISM data at station locations.
  - Computed Ra at each CIMIS location
- Step 2: Compute ETo for each CIMIS station using PRISM data for period 1921 - 2015

Method: Reference ET

- Step 3: Compute 30 year (1971-2000) monthly average ETo for each CIMIS station using HS equation and PRISM data.
- Step 4: Correct CIMIS ETo values from Step 2 using the monthly factors from Step 1.
- Step 5: Develop monthly factors for each WBA relating WBAs to nearest CIMIS station.
  - Obtain spatial PRISM average of monthly Tmax and Tmin for each WBA for 30 years (1971-2000)

$$ETo_{HS} = K_H R_a \sqrt{T_{max} - T_{min}} (T_{mean} + 17.8)$$

$$ETo_{HS}^{WBA} = K_H R_a \sqrt{T_{max}^{WBA} - T_{min}^{WBA}} (T_{mean}^{WBA} + 17.8)$$

$$K_H = 0.0023, ETo \text{ and } R_a \text{ in } mm/day$$

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

f1= Monthly mulitplication factor that corrects ETo computed by HS method using observed ETo values. In other words, this factor is one for each month, if HS computed monthly values match observed monthly values

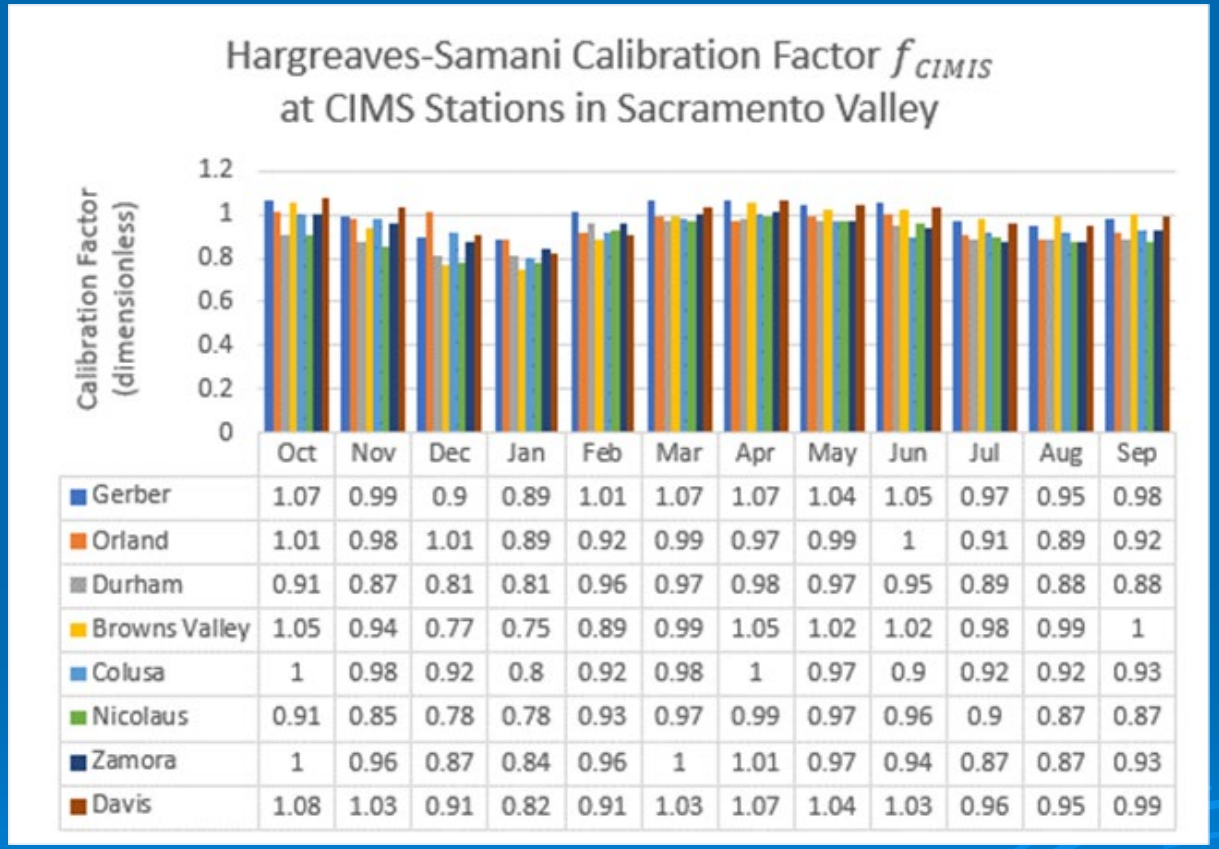
$$f1 = \frac{ETO_{OBS}^{CIMIS}}{ETO_{HS}^{CIMIS}}$$

f2= Monthly factor that corrects for changes in climate between CIMIS location and spatially averaged PRISM data for WBA. In otherwords, this factor is one, if the CIMIS station is located at the centroid of the WBA: f2= PRISM_HS_ETO/CIMIS_HS_ETO

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

Method: Reference ET

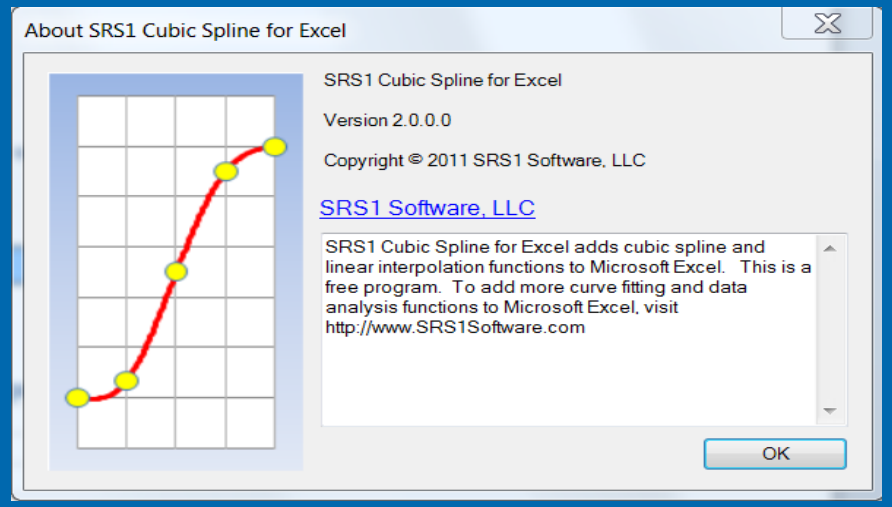
- Step 5 (continued):
  - Compute extraterrestrial radiation for each WBA
  - Compute ETo for each WBA (30 yr monthly avg)
  - Compare computed ETo values for each WBA (Step 5c) and CIMIS ETo values (Step 3) to obtain a second monthly factor.
- Step 6: Use monthly factors for each WBA (Step 5) to correct computed ETo (Step 4)



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Gerber	1.07	0.99	0.9	0.89	1.01	1.07	1.07	1.04	1.05	0.97	0.95	0.98
Orland	1.01	0.98	1.01	0.89	0.92	0.99	0.97	0.99	1	0.91	0.89	0.92
Durham	0.91	0.87	0.81	0.81	0.96	0.97	0.98	0.97	0.95	0.89	0.88	0.88
Browns Valley	1.05	0.94	0.77	0.75	0.89	0.99	1.05	1.02	1.02	0.98	0.99	1
Colusa	1	0.98	0.92	0.8	0.92	0.98	1	0.97	0.9	0.92	0.92	0.93
Nicolaus	0.91	0.85	0.78	0.78	0.93	0.97	0.99	0.97	0.96	0.9	0.87	0.87
Zamora	1	0.96	0.87	0.84	0.96	1	1.01	0.97	0.94	0.87	0.87	0.93
Davis	1.08	1.03	0.91	0.82	0.91	1.03	1.07	1.04	1.03	0.96	0.95	0.99

Method: Crop Evapotranspiration

- Partial use of the CUP+ Model.
- DWR currently generates daily ETo for each WBA by disaggregating the ETo by WBA outlined in previous slides for direct input into the CUP+ Model.
- Daily disaggregation achieved using the SRS1 Cubic Spline routine for Excel.
- Daily precipitation for each WBA is also provided to the CUP+ Model by DWR.



CUP+ Model

CUP PLUS (CONSUMPTIVE USE PROGRAM PLUS) MODEL - Version 3.0

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ABSTRACT

A user-friendly Microsoft Excel application program "Consumptive Use Program +" or "CUP+" was developed to help growers and water agencies determine reference evapotranspiration (ET_o), crop coefficient (K_c) values, crop evapotranspiration (ET_c), and evapotranspiration of applied water (ET_{aw}), which provides an estimate of the net irrigation water diversion needed to produce a crop. CUP+ computes ET_o from monthly means of solar radiation, maximum and minimum temperature, dew point temperature, and wind speed using the Penman-Monteith and Hargreaves-Samani equations. The program uses a curve fitting technique to derive one year of daily weather and ET_o data from the monthly data. In addition to using monthly means of weather data, it uses daily measured data to estimate daily ET_o. Daily rainfall data are used to estimate bare soil evaporation as a baseline for in-season Kc as a function of mean of ETo and wetting frequency in days. A bare soil Kc value is calculated to estimate the off-season evapotranspiration and as a baseline for in-season Kc calculations. CUP+ accounts or the influence of orchard cover crops on Kc values and it accounts for immaturity effects on Kc values for tree and vine crops. Further, the program computes and applies all ETo and Kc values on a daily basis to determine crop water requirements by month, by season, by year. The application also can be used to study the impact of climate change on evapotranspiration and irrigation water needs.

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CUP+ Model: Pros and Cons

- The CUP+ model has been a standard tool for DWR for the recent past.
- DWR has written routines (VBA) within a version of the CUP+ model to automate the model running through all WBA/DUs and all years.
- CUP+ model is slow. Running through 100 years of ETc generation takes approximately 5-7 days of continuous running on an 11th Gen Intel(R) Core(TM) i7-11850H @ 2.50GHz 2.50 GHz with 32 GB RAM.
- Difficult to get access to the VBA-based code for the core CUP+ routines.

Data Limitations

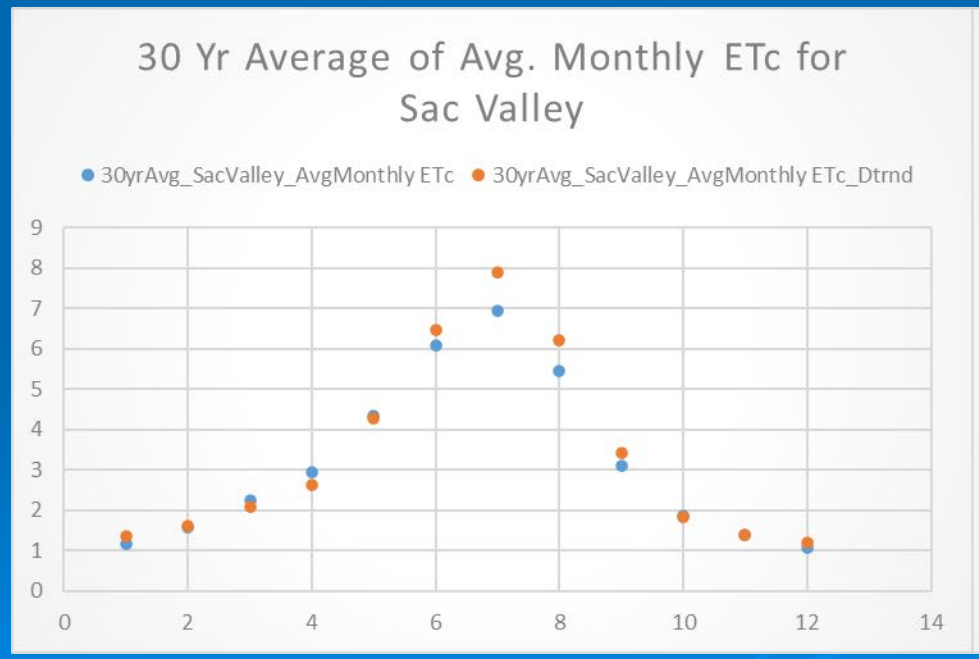
- Ideally, ETo would be computed using the Penman-Monteith equation
  - Requires wind speed measurements, which are largely unavailable for the modeling domain and time period.
  - DWR has attempted to estimate missing data and calculate ETo using P-M; however, the effort showed that results were not better than H-S estimated ETo.
- Main data source for 1921 – 2015 data is PRISM, which models monthly data for California for min/max temperature and precipitation.
  - Ideally, daily data would be used for the modeling time period, but daily data is only available after 1981.
  - Since daily data is needed, a monthly approximation of H-S is applied then disaggregated to daily.
- A secondary source of data is the CIMIS station network
  - Has estimates of ETo using P-M method, but for a limited time window.
  - DWR incorporates CIMIS data into calculations.

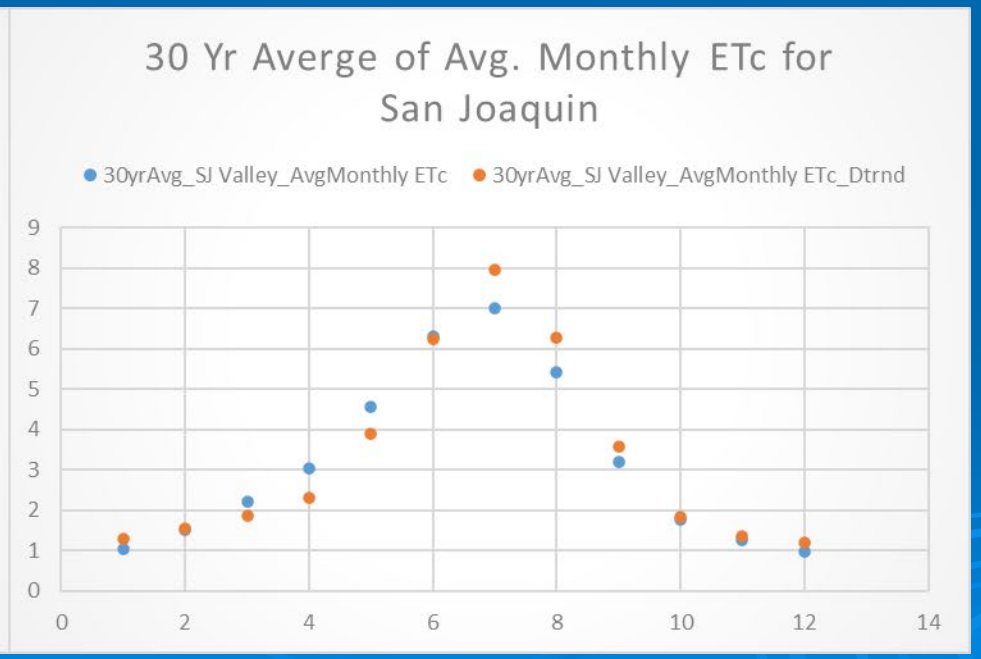
Future Possibilities

- The Livneh data repository
  - Daily Precipitation from 1915 – 2018
  - Daily min/max temperature from 1915 – 2018
  - Daily wind speed from 1948 – 2018
  - DWR is parsing the Livneh data and will compare with existing datasets and methods.

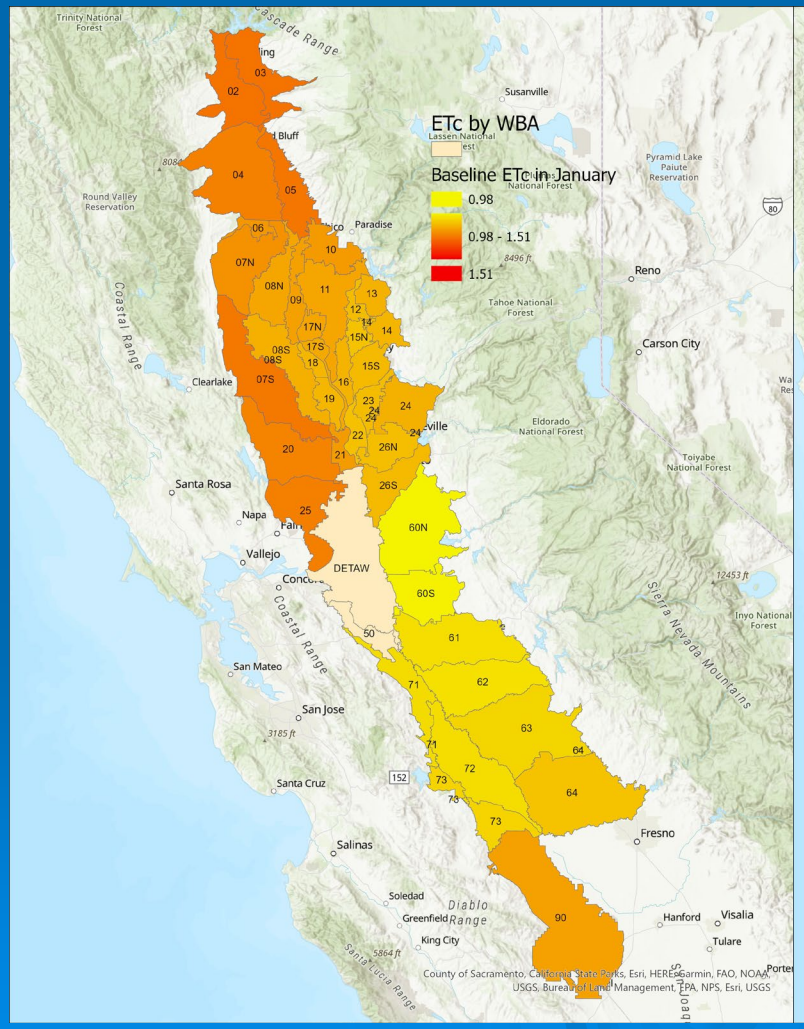
Study: Modeling future conditions using detrended temperature data

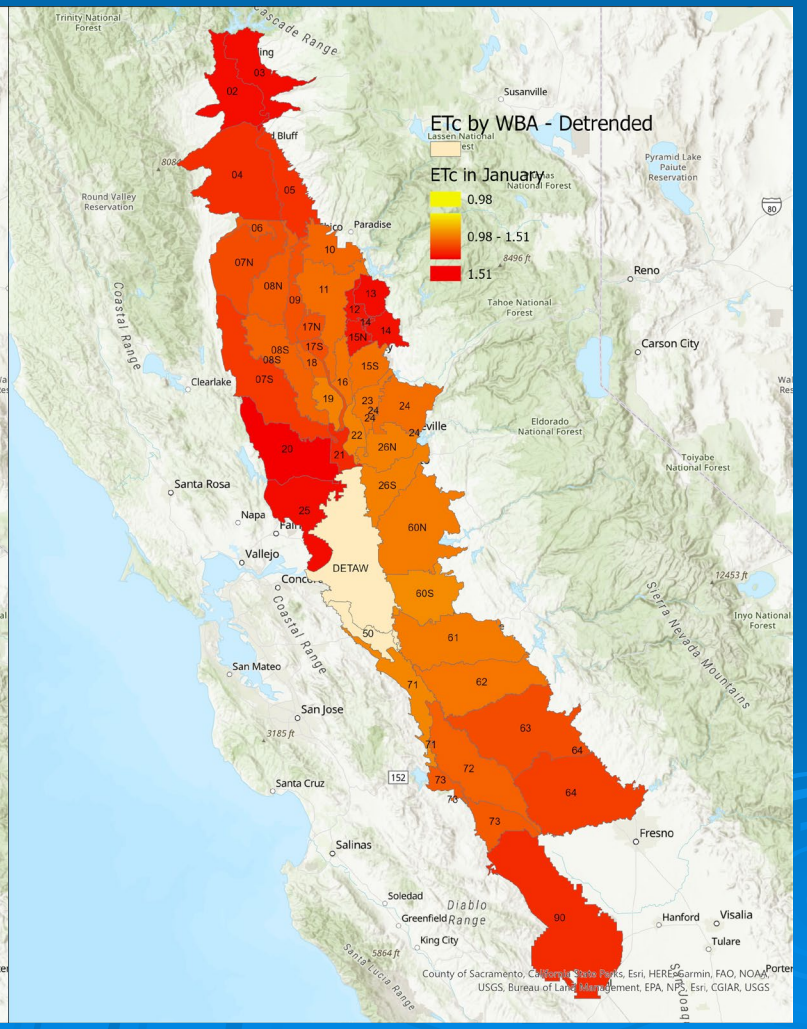
- ETc and ETo developed using timeseries of detrended temperature (provided by Jacobs) and adjusted precipitation (calculated by DWR).



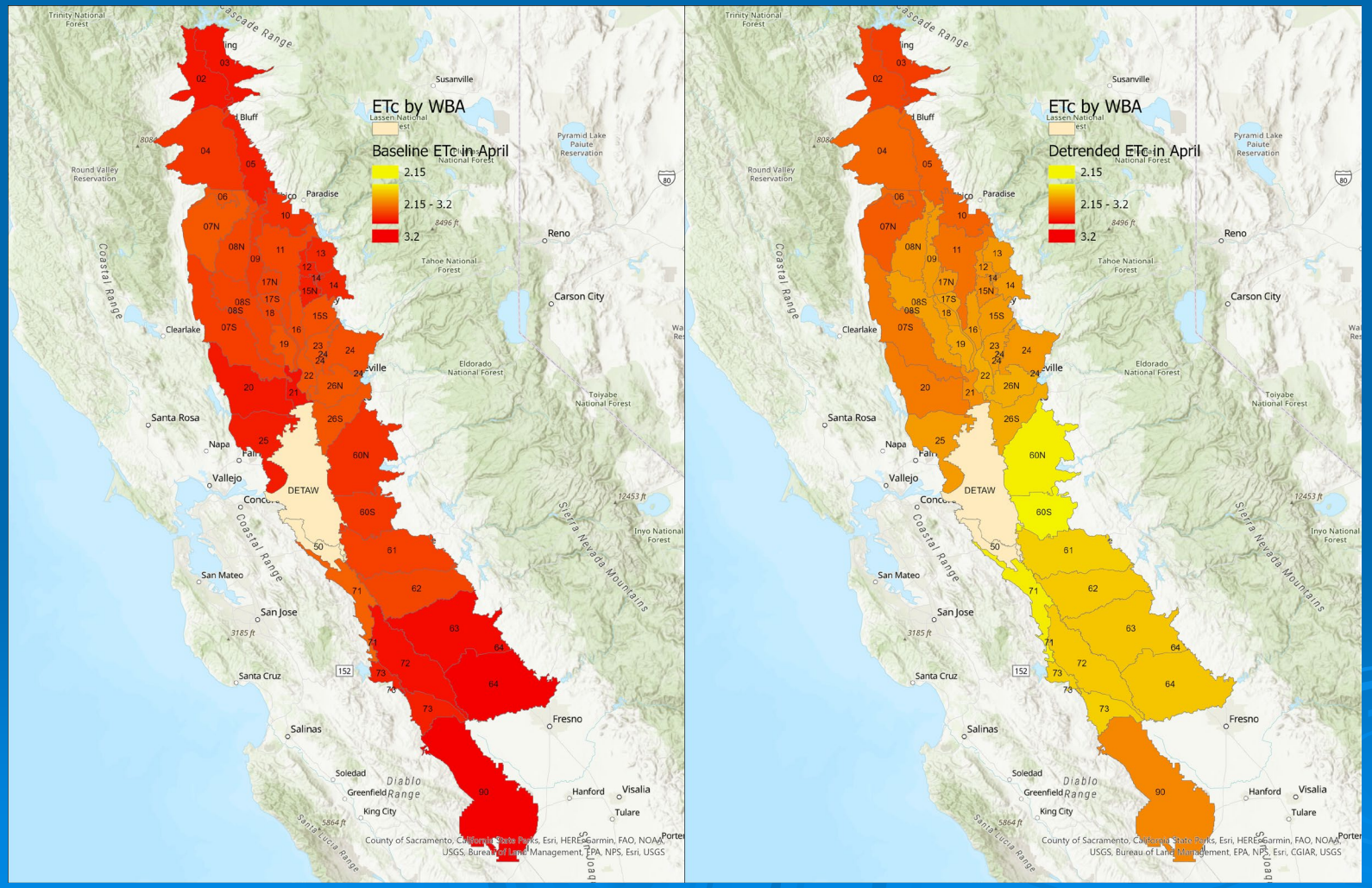


Results: ETc in January

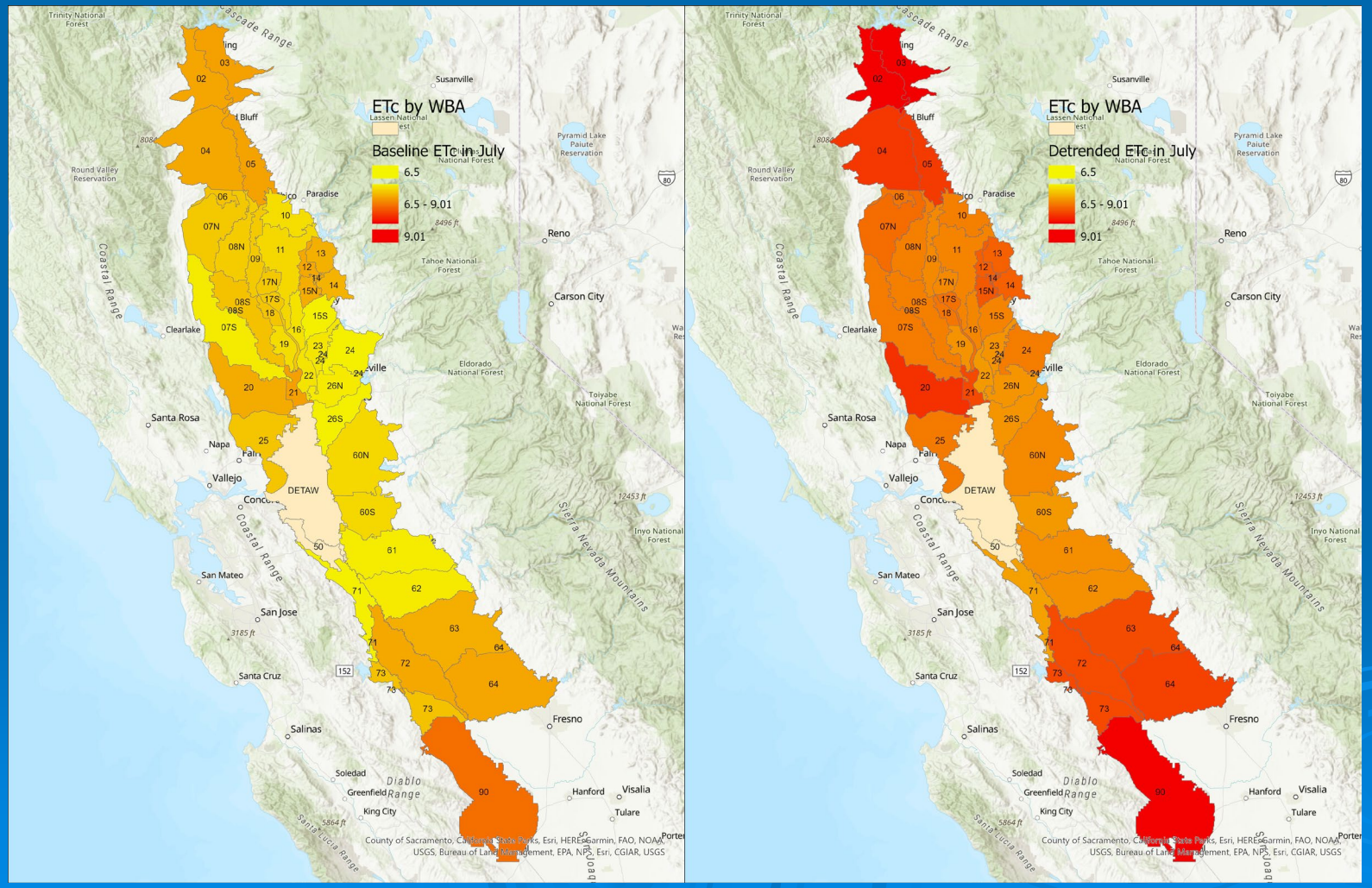




Results: ETc in April



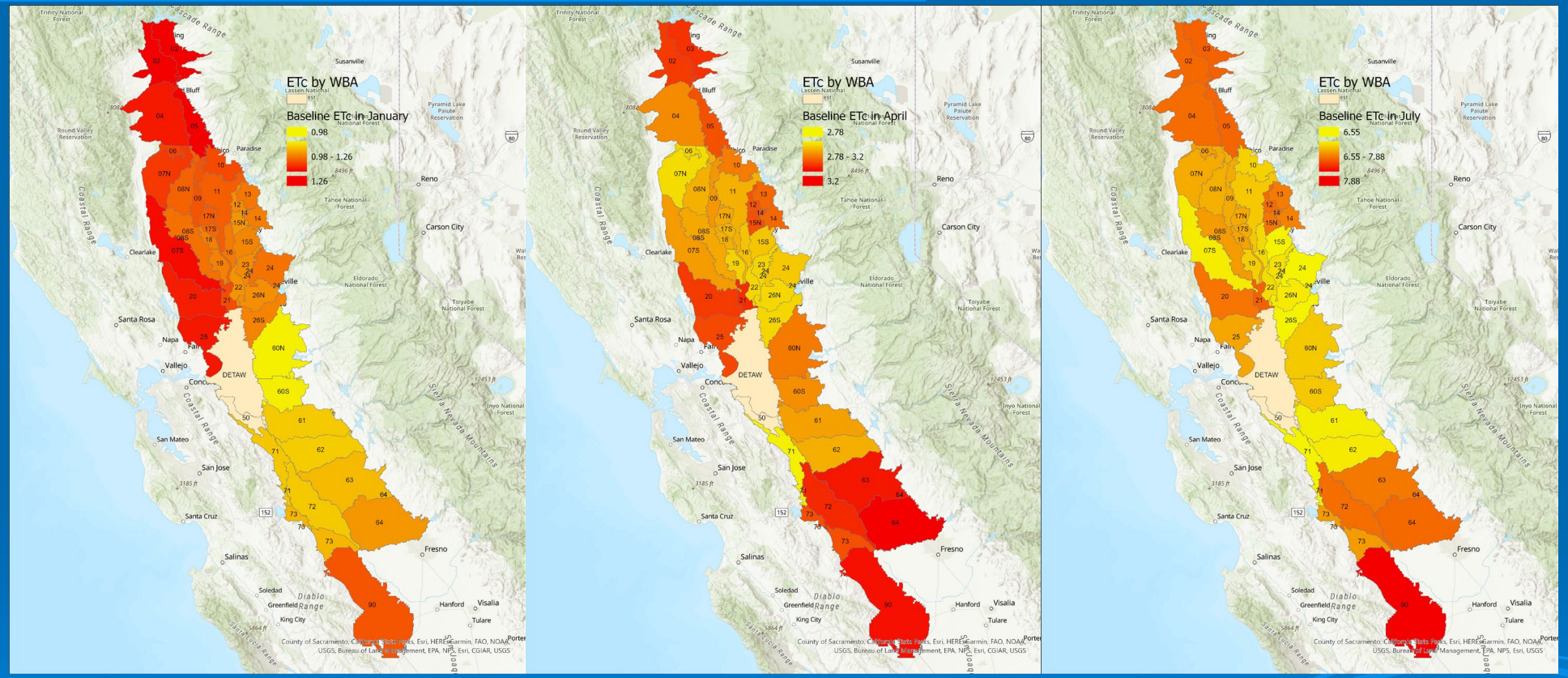
Results: ETc in July



Thank you!

and questions?

Results: Baseline ETc



Results: Detrended ETc