ECOSTRESS Delta Project

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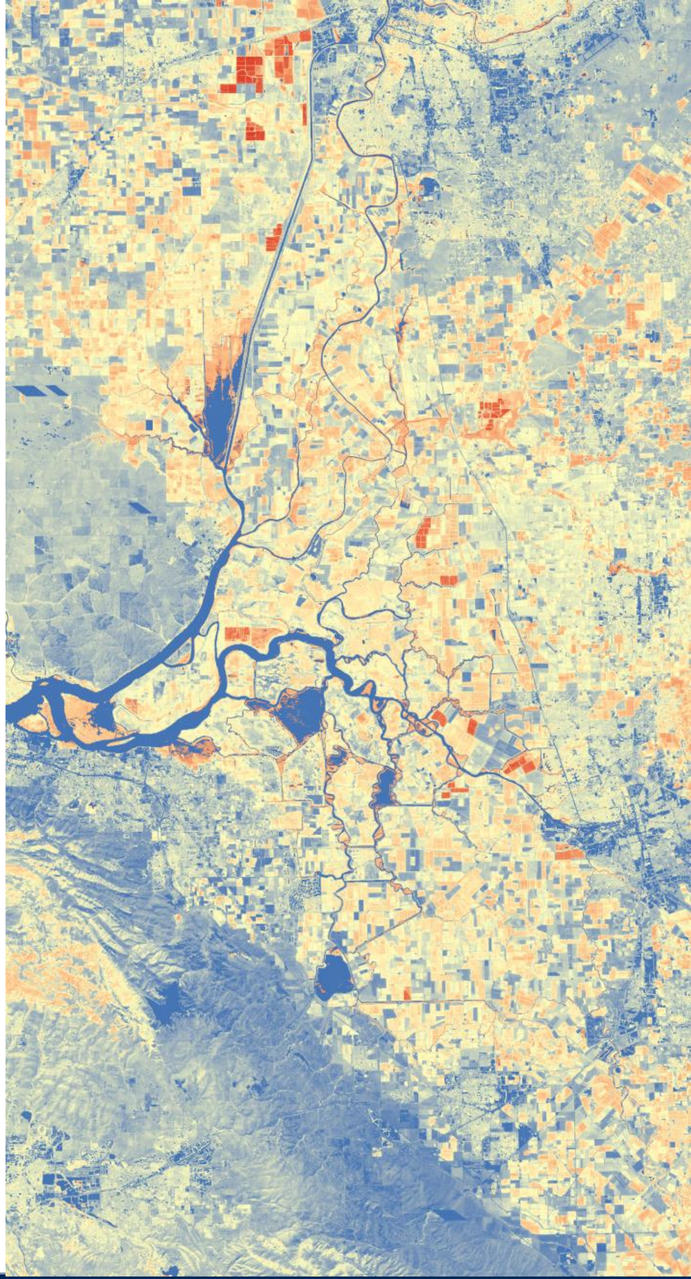
University of California, Davis

June 30, 2018.



ECOSTRESS

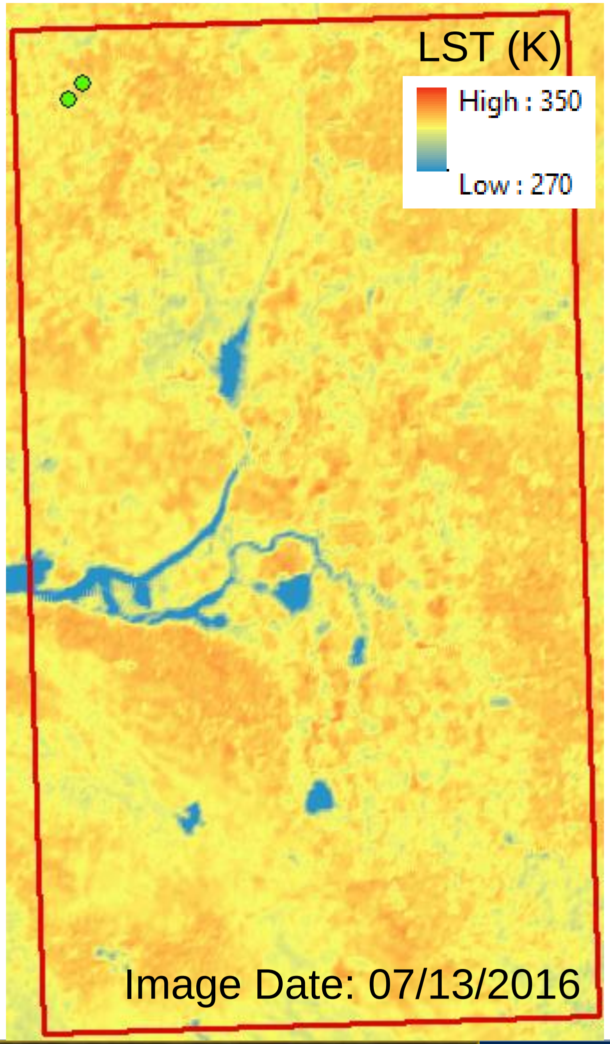
JPL · UCDAVIS

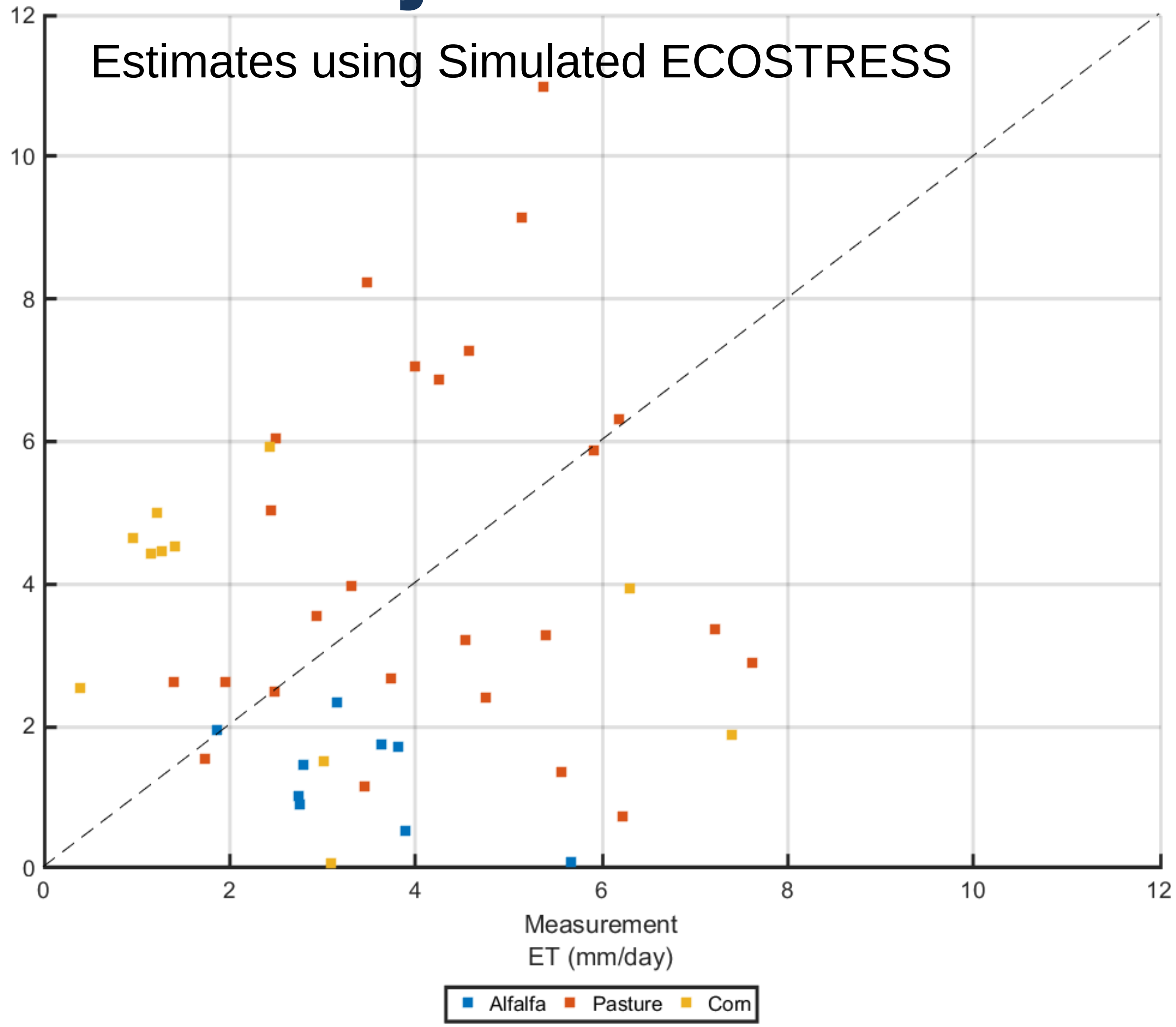
Original ECOSTRESS Delta Project

> Estimate ET using four remote sensing models, and simulated ECOSTRESS data.

> The simulation was not meant for quantitative analysis.

> QA/QC Russell Ranch radiation and ET data





Overview

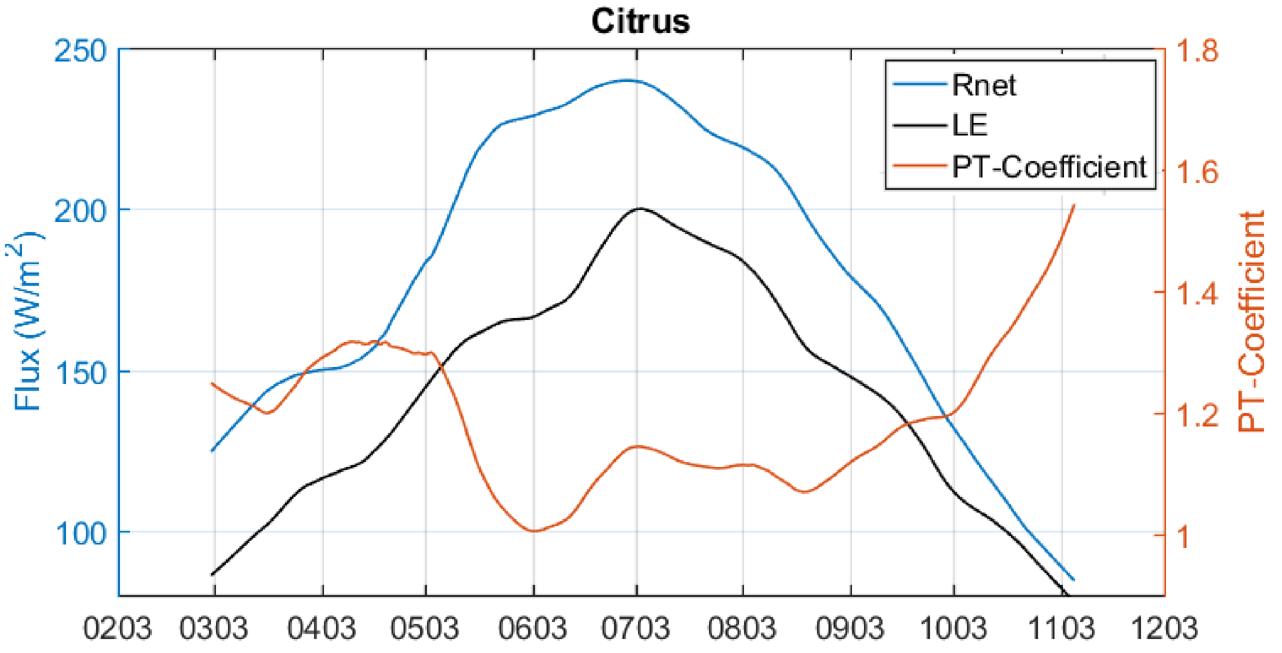
1. Priestley Taylor – UC Davis (PTUCD)
2. Field-scale Daily ET using Data Fusion and Sharpening
3. Improving Groundwater Budget Estimation using Remote Sensing ET

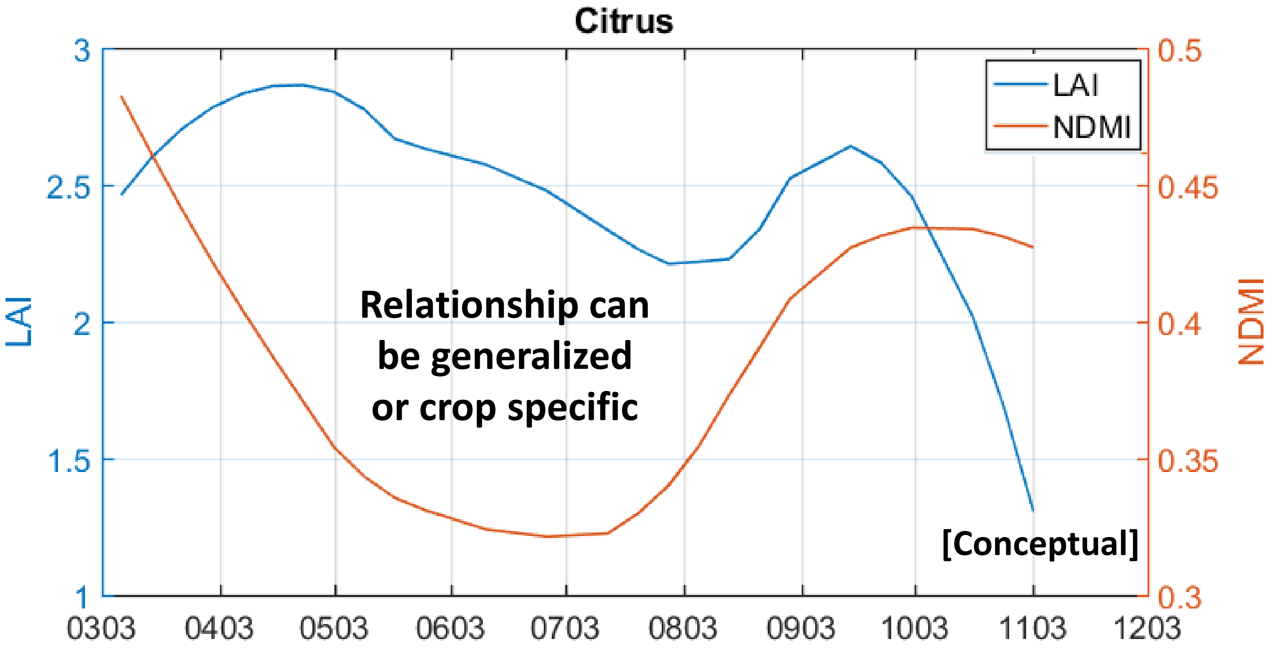
PTUCD: Key Equations and PT Coefficients

Priestley-Taylor (PT): $$\lambda E = \alpha \frac{\Delta(T_a)}{\Delta(T_a)+\gamma(T_a)}(R_{net} - G)$$

PT Coefficient: $$\alpha = [a * (1 - e^{-b*LAI} + c) + (d * NDMI + e) * f(T_a)]$$

Net Radiation: $$R_{net} = [(1 - Albedo)S_{\downarrow}] + [\varepsilon_s((1 + \mu * F^V) * \varepsilon_{clr})\sigma T_a^4 - (m\varepsilon_s\sigma T_s^4 + b)]$$

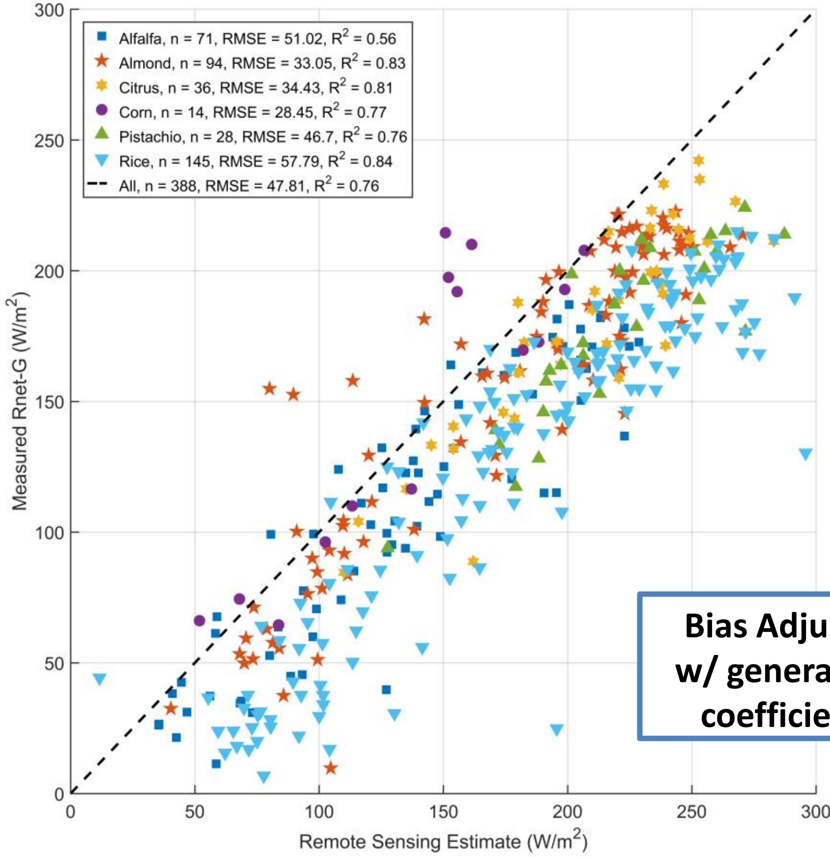




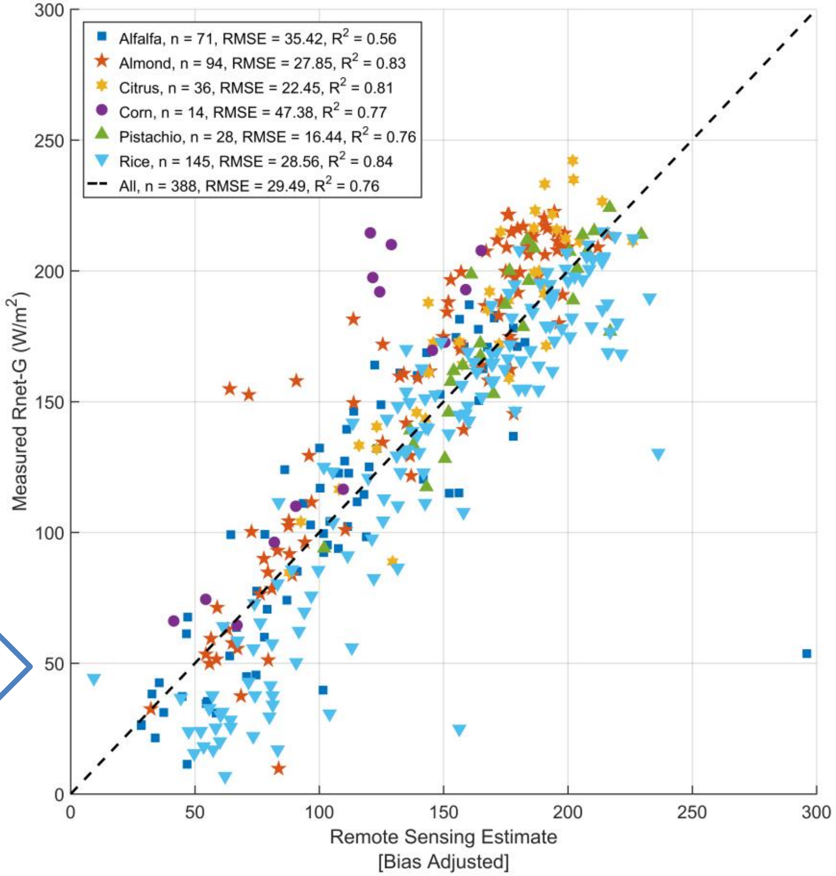
PTUCD: Mean Net Radiation

Net Radiation: $R_{net} = [(1 - Albedo)S_{\downarrow}] + [\varepsilon_s((1 + \mu * F^V) * \varepsilon_{clr})\sigma T_a^4 - (m\varepsilon_s \sigma T_s^4 + b)]$

(at 24hrs Time Step)

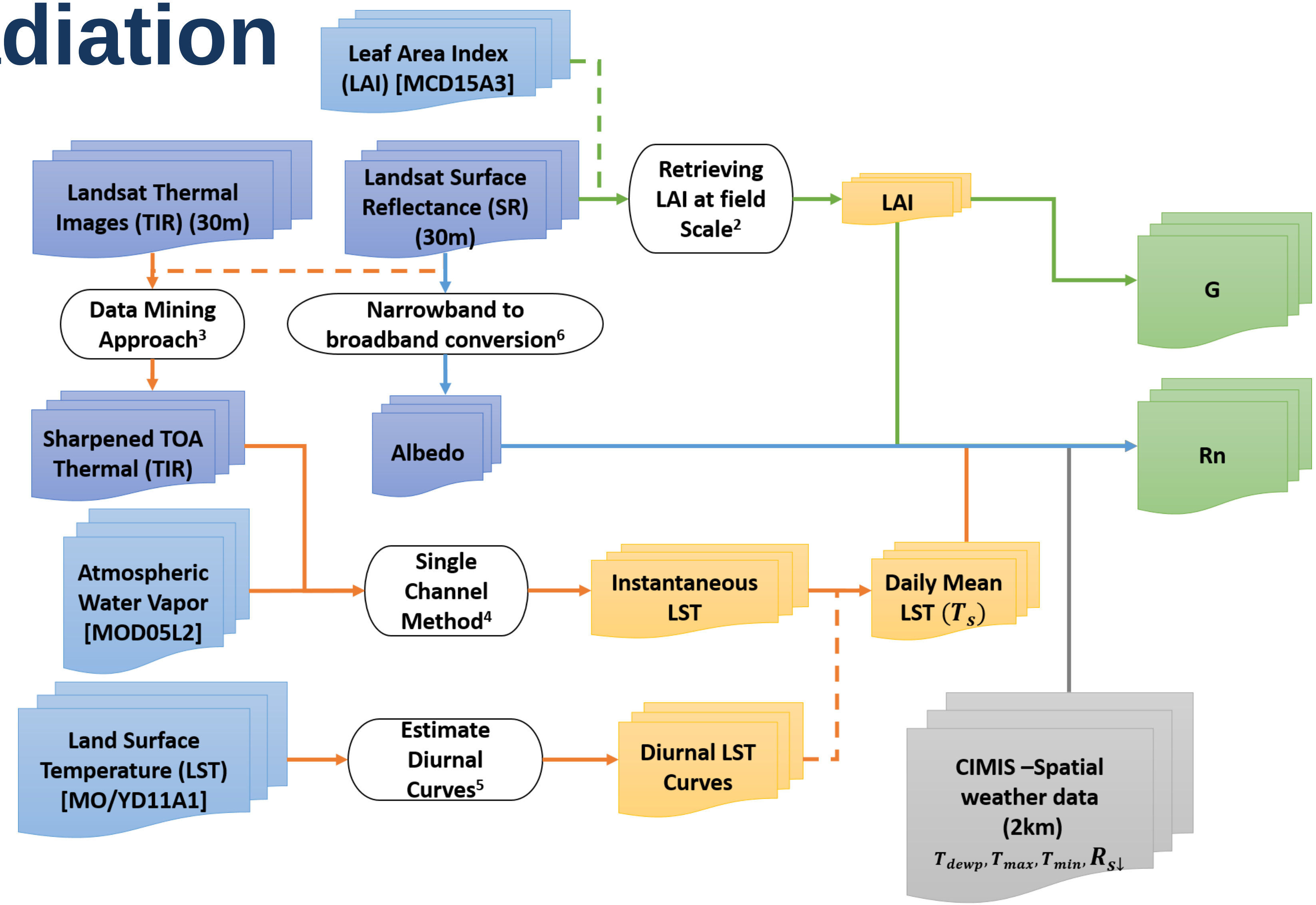


Bias Adjusted w/ generalized coefficients



All sky emissivity:
Duarte et al., 2006
Clear sky emissivity:
Prata, 1996

PTUCD: Net Radiation



2. Gao et. al. (2012a).
3. Gao et. al. (2012b).
4. Jimenez-Munoz et. al. (2014).
5. Jin et. al. (2011).
6. Liang, S. (2001).

PTUCD: 24hrs Mean LST

$$T_{S\,MODIS}(t) = T_{s\,MODIS\,daily} + A_T \cos\left(\pi \frac{(t - t_m)}{(t_m - t_{sunrise})}\right) \qquad for\ day\ time, t > t_{sunrise}$$

$$T_{S\,MODIS}(t) = T_{s\,MODIS\,daily} + A_T \sin\left(\pi + \pi \frac{(t - t_{sunset})}{2(24 + t_{sunrise} - t_{sunset})}\right) \qquad for\ night\ time, t < t_{sunrise}$$

modified from (Sun and Pinker, 2005)

$T_{s\,MODIS\,daily}$ and A_T are optimized per MODIS pixel using four instantaneous LST observations from MODIS MOD11A1 and MYD11A1 V006 products.

$$T_{S\,MODIS\,inst} = T_{S\,MODIS}(t = Landsat\ overpass)$$

24hrs Mean LST: $T_{s\,daily} = T_{s\,Landsat\,inst} * \frac{T_{s\,MODIS\,daily}}{T_{s\,MODIS\,inst}}$

PTUCD + ECOSTRSS

$$T_{S\,MODIS}(t) = T_{s\,MODIS\,daily} + A_T \cos\left(\pi \frac{(t - t_m)}{(t_m - t_{sunrise})}\right) \quad for\ day\ time, t > t_{sunrise}$$

… DIS da… $\frac{(t - t_{sunset})}{(24 + \ldots}$ … $for\ night\ time, t < t_{sunrise}$

from (Sun and Pinker, 2005)

t = ISS overpass

ECOSTRESS LST

ECOSTRESS Emissivity

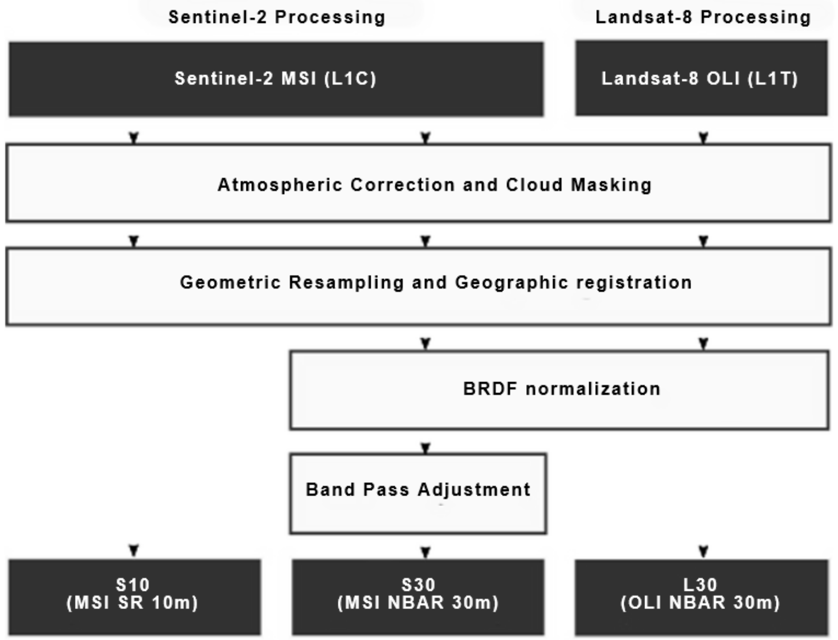
$T_{s\,MODIS\,daily}$ and A_T are optimized per MODIS pixel using four instantaneous LST observations from MODIS MOD11A1 and MYD11A1 V006 products.

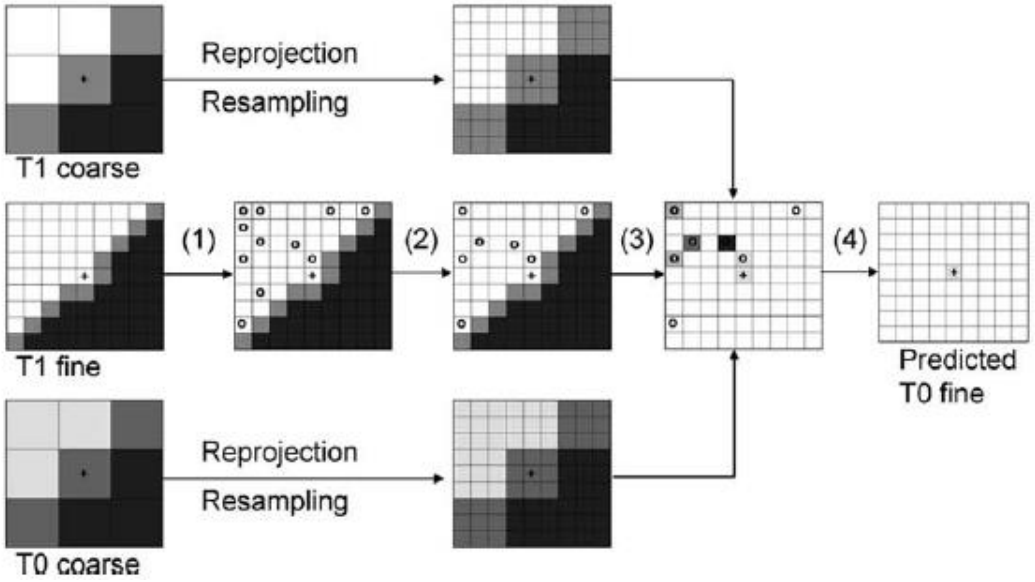
$$T_{S\,MODIS\,inst} = T_{S\,MODIS}(t = Landsat\ overpass)$$

24hrs Mean LST: $T_{s\,daily} = T_{s\,Landsat\,inst} * \frac{T_{s\,MODIS\,daily}}{T_{s\,MODIS\,inst}}$

PTUCD + ECOSTRSS: Surface Reflectance?

1. Sentinel 2 – Landsat Harmonized Surface Reflectance Product (https://hls.gsfc.nasa.gov/)
2. Non-Landsat/Sentinel 2 Overpassing day:
   Spatial and Temporal Adaptive Reflectance Fusion Model (STARFM) (Gao et.al 2006.)





PTUCD + Landsat

<table>
<tr><th>Day</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th></tr>
<tr><td>SR</td><td rowspan="2">Landsat 8</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="2">Landsat 8</td></tr>
<tr><td>LST</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

[Conceptual]

PTUCD + Landsat + Sentinel 2 + ECOSTRSS

<table>
<tr><th>Day</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th></tr>
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</table>

[Conceptual]

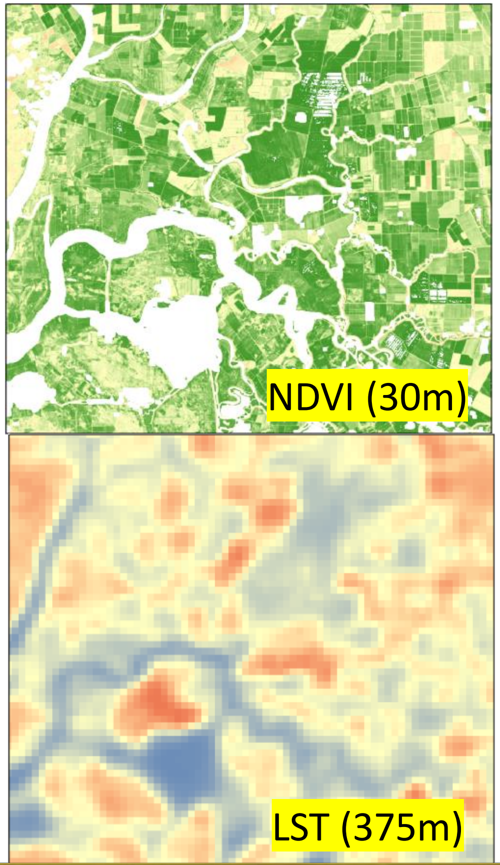
PTUCD + … + STARFM

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SR	Landsat 8	VIIRS (375m) - STARFM		Sentinel 2	VIIRS (375m) -STARFM									Sentinel 2	VIIRS (375m) - STARFM		Landsat 8
LST	Landsat 8		ECO STRESS		ECO STRESS			ECO STRESS									Landsat 8

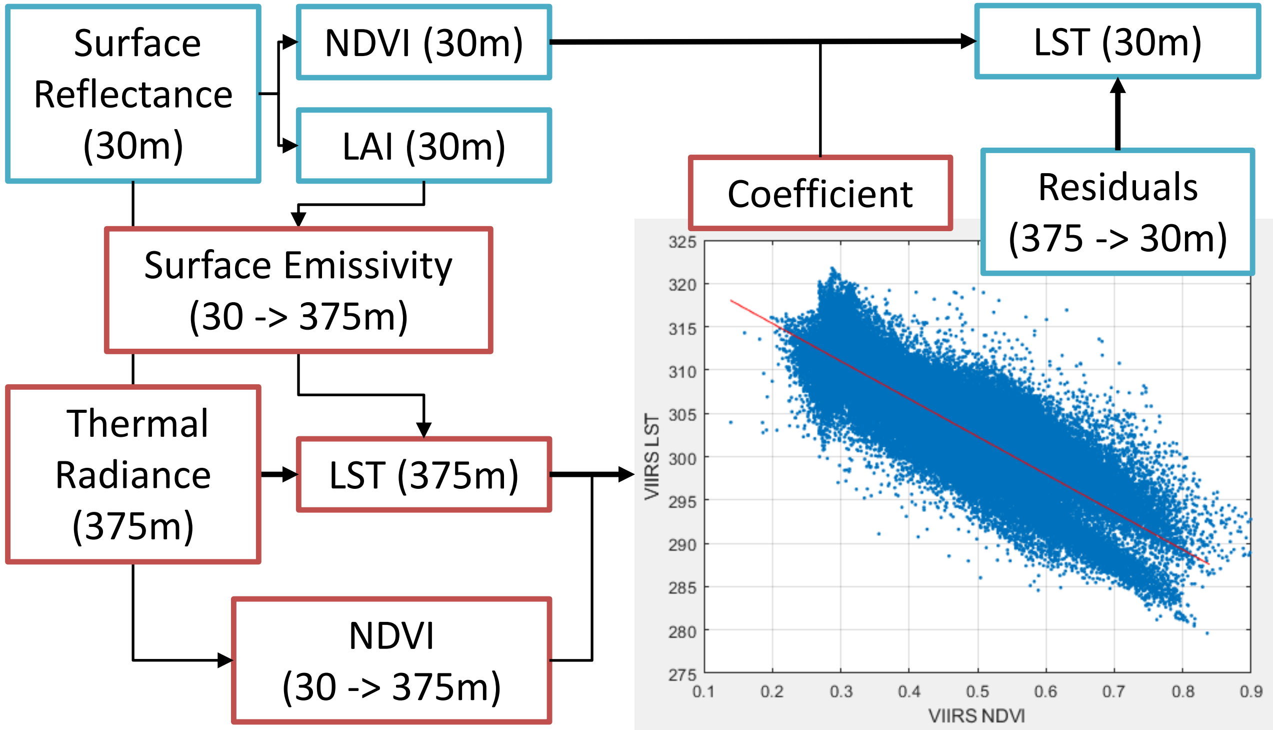
[Conceptual]

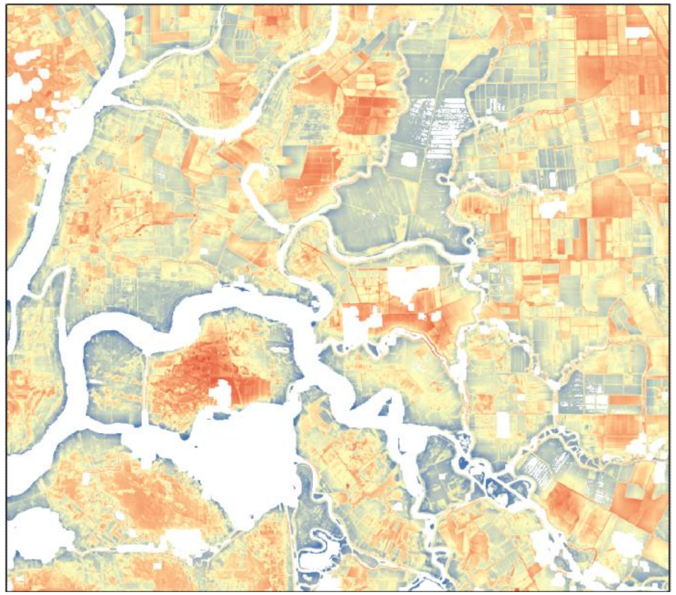
Estimating Daily ET with Thermal Sharpening

Sharpening VIIRS with Harmonized Sentinel-2 Landsat dataset



Thermal Sharpening (TS)

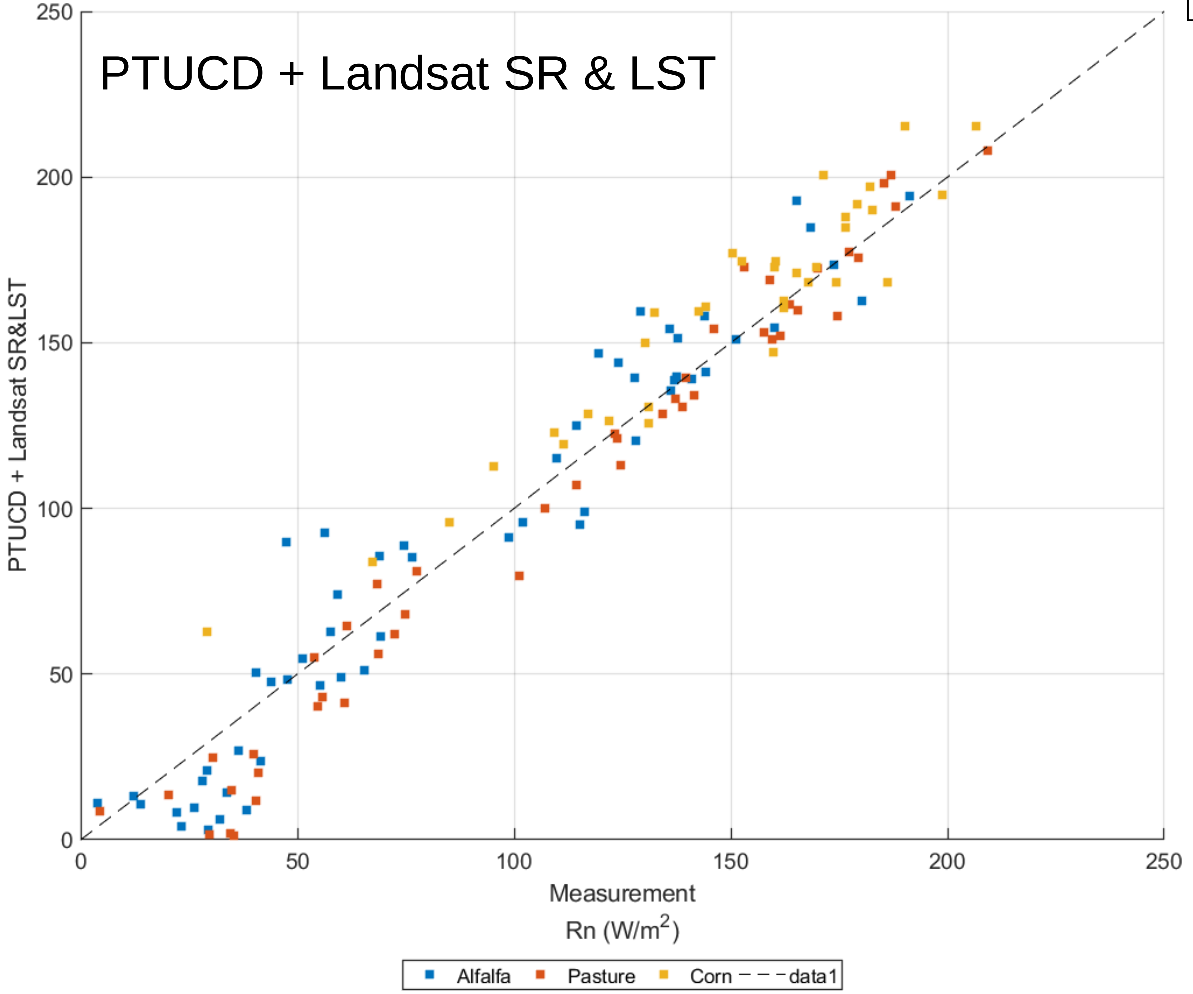


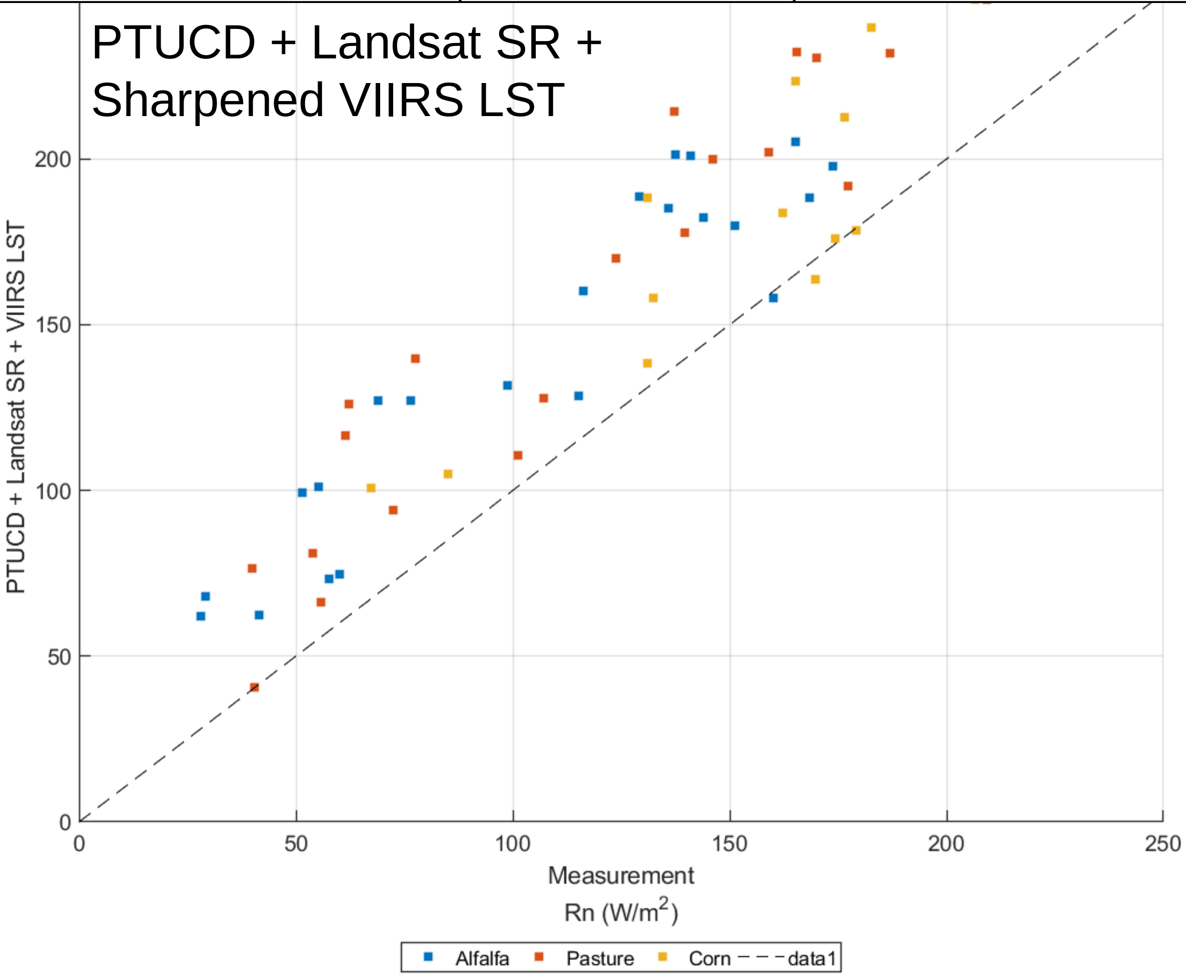


LST (30m)

PTUCD w/ “Simulated” data: Rn

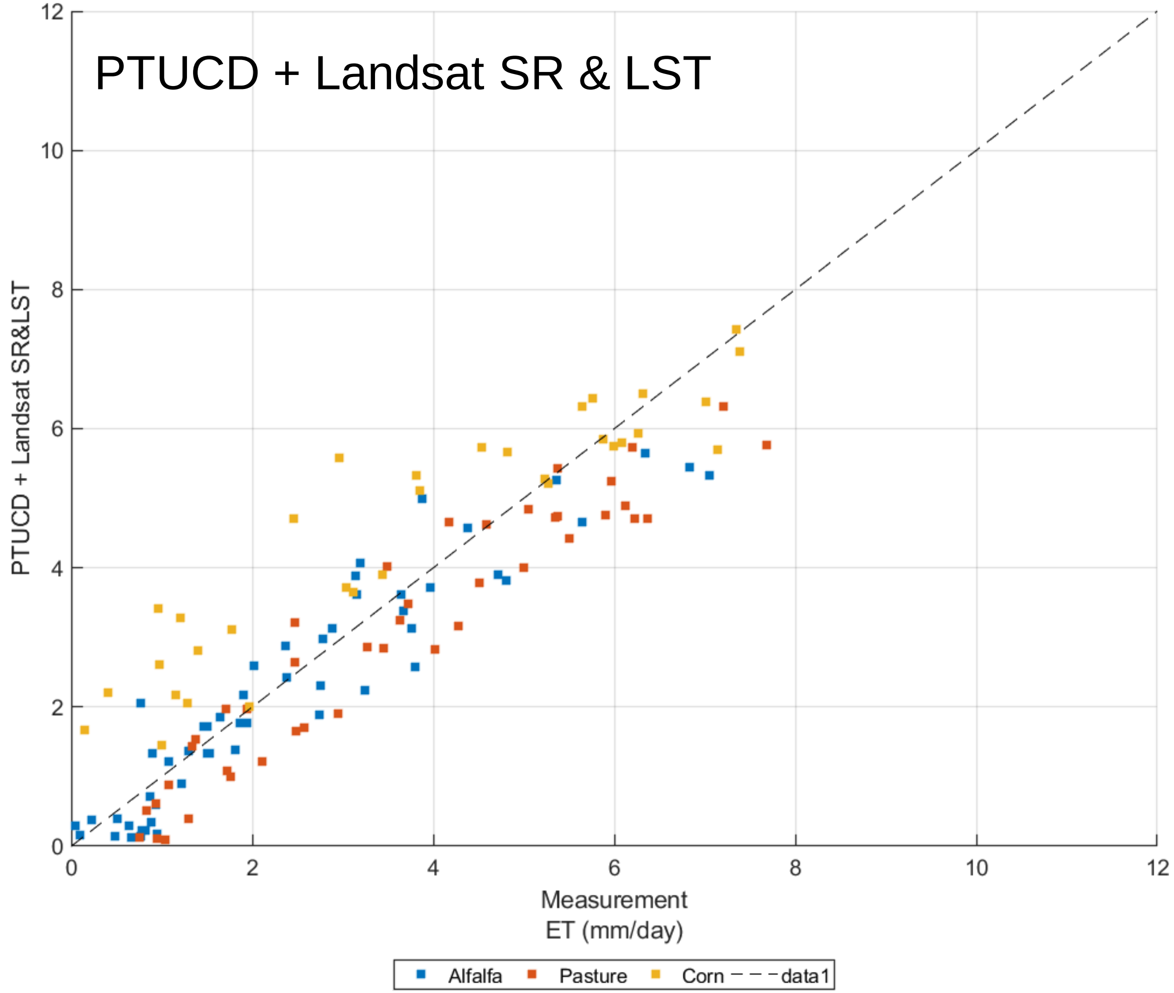
	PTUCD + Landsat (n=138)	**PTUCD + Landsat + VIIRS** (n=55)
RMSE (W/m^2)	**14.96**	**40.78**
R^2	**0.94**	**0.87**
Absolute Bias (W/m^2)	**11.93**	**35.6**

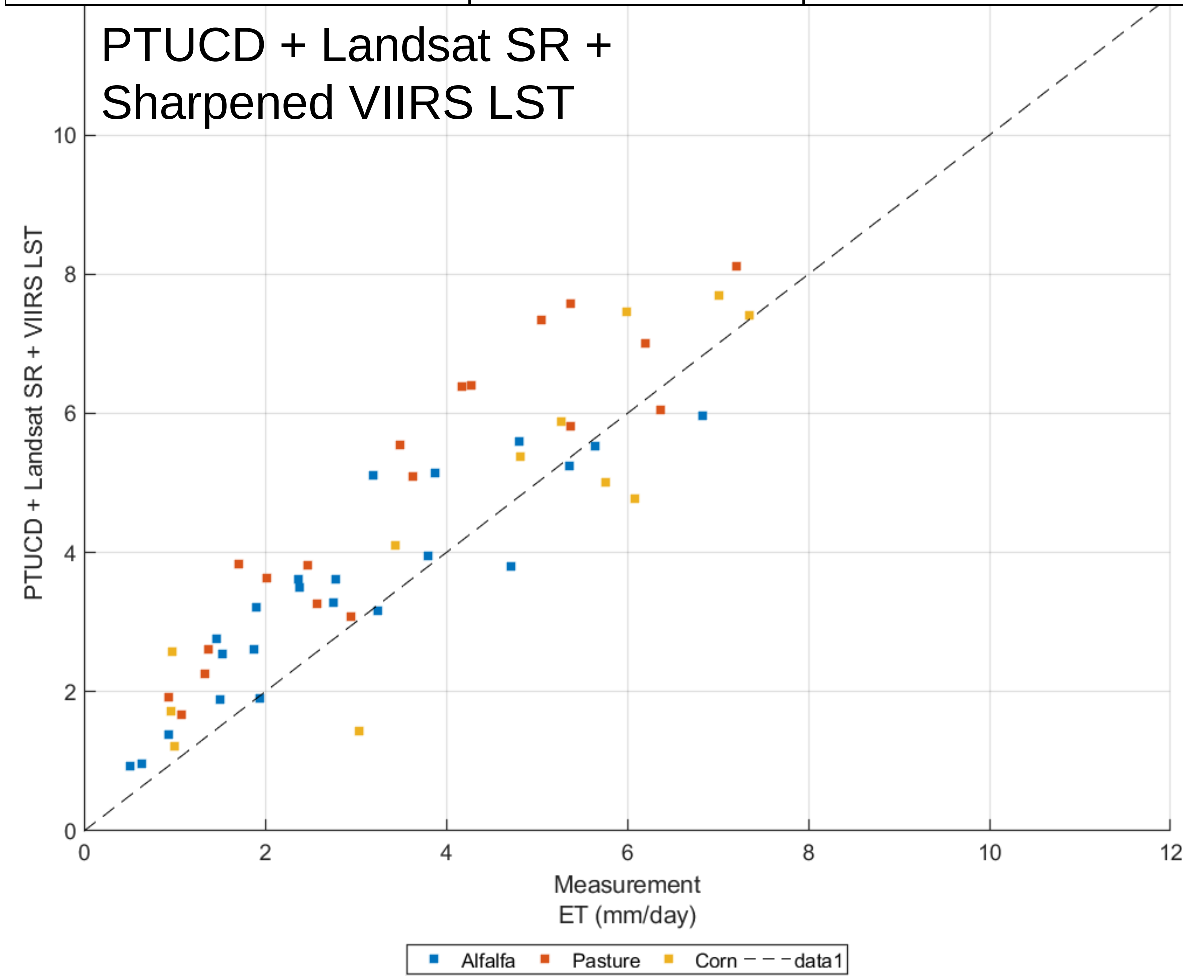




PTUCD w/ “Simulated” data: ET

	PTUCD + Landsat (n=131)	PTUCD + Landsat + VIIRS (n=55)
RMSE (mm/day)	**0.88**	**1.15**
R^2	**0.83**	**0.83**
Absolute Bias (mm/day)	**0.68**	**0.96**





Upcoming Works

1. Validate thermal sharpening with ECOSTRESS LST product and Russell Ranch tower measurements
2. Investigate on thermal sharpening bias issue
3. Estimate ET on Sentinel overpassing dates
4. Implement STARFM
5. Replace Emissivity method
6. Overcome NaN stripes in the VIIRS data
7. Request harmonized SR data for the entire Delta

Motivation

California produces nearly half of the fruit, nuts, and vegetables grown in our nation.
> 25% of which are produced in the Central Valley, including 40% of the nation's fruit and nuts.

California overdrafts 1-2 MAF of groundwater per year.
> 1.2-1.8 MAF per year occurs in the San Joaquin Valley.

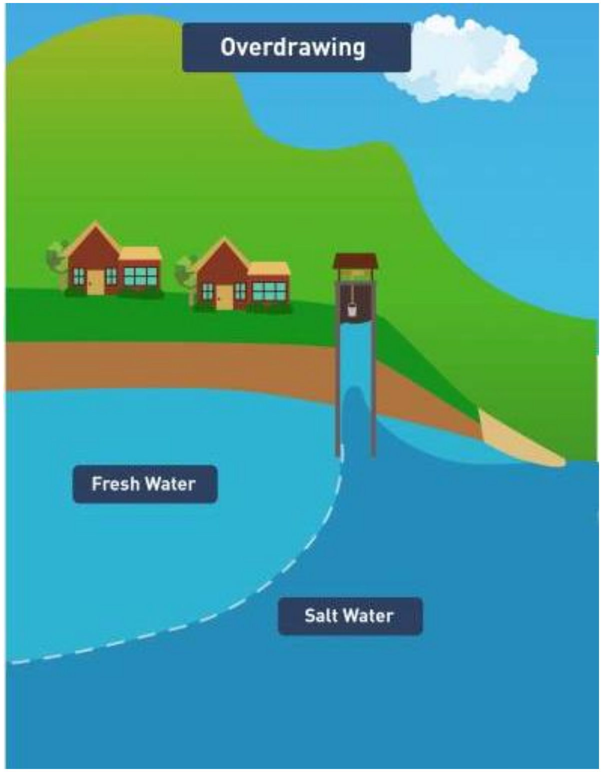
Toxic Taps

The California Drought Isn't Over, It Just Went Underground

Drought conditions continue for thousands of rural residents in the San Joaquin valley who rely on groundwater. And the race to dig deeper wells is a losing game for small communities and those on private wells.

WRITTEN BY Mark Grossi | PUBLISHED ON July 5, 2017 | READ TIME Approx. 5 minutes

TOXIC TAPS
The fight for water, health and equity in California's Central Valley and beyond.



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Sustainable Groundwater Management Act (SGMA)

Toxic Taps

The California Drought Isn't Over

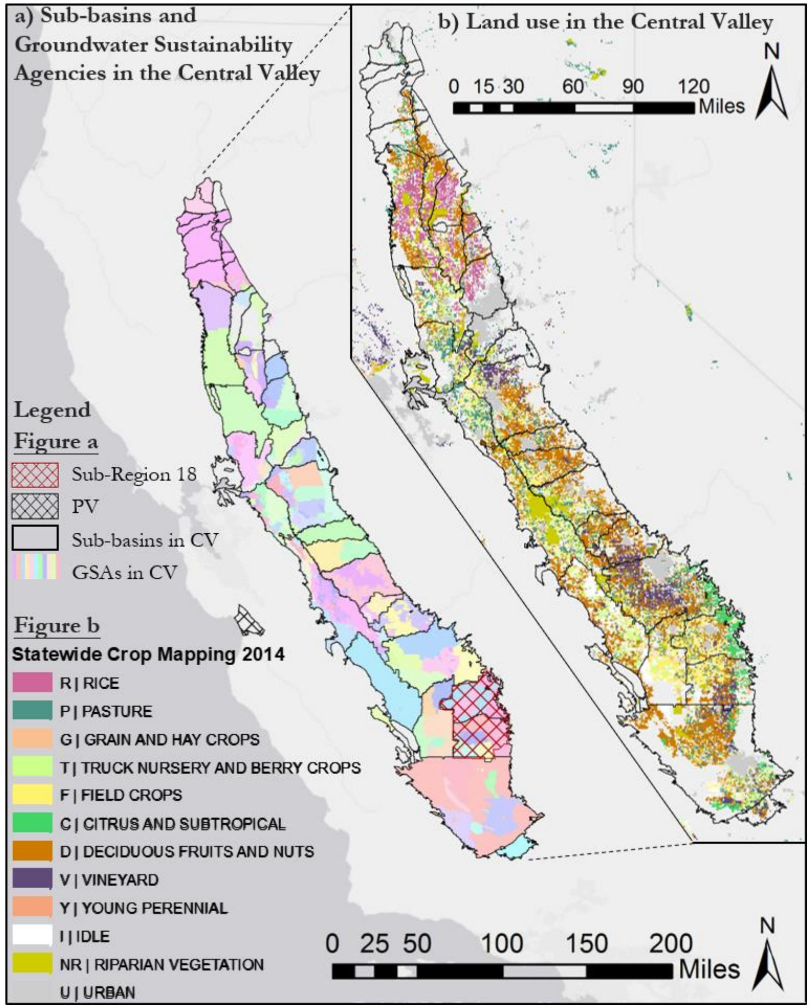
Sinking Land Causes California Water Chokepoint

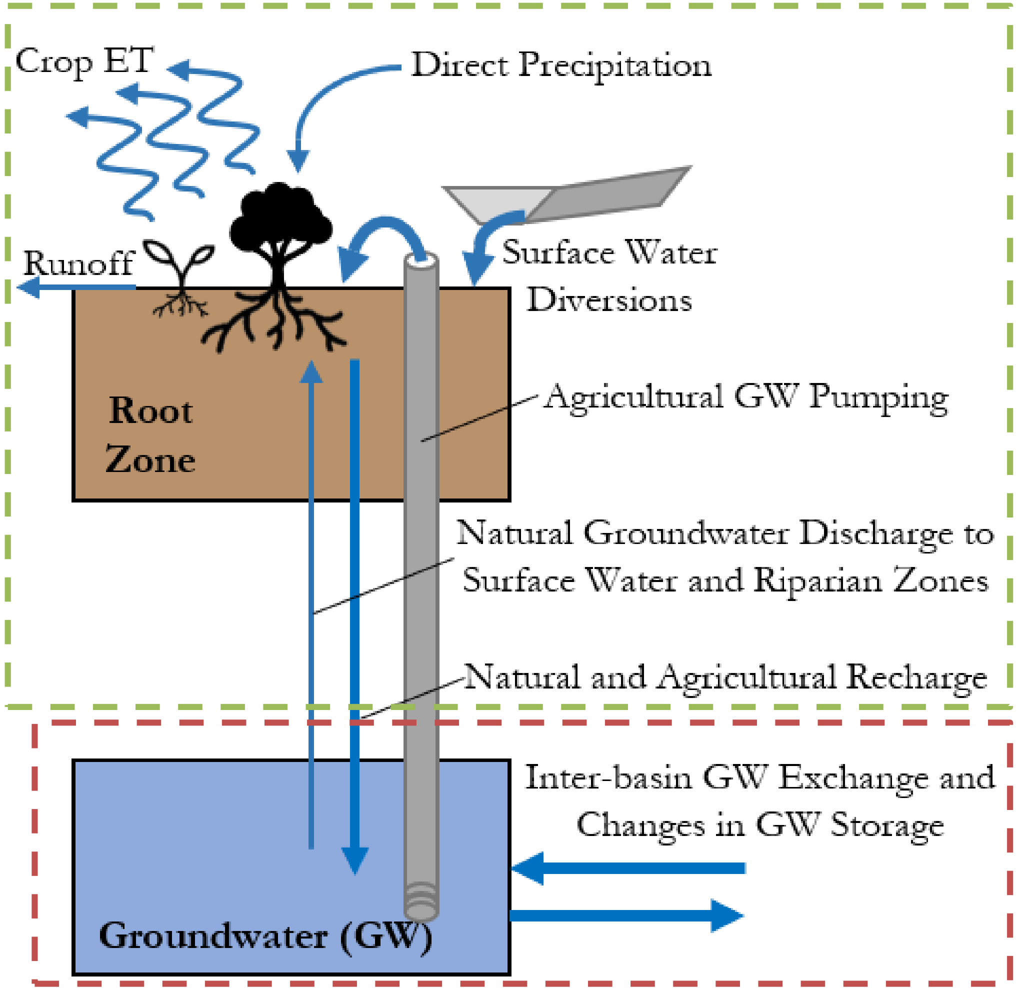
February 10, 2017 / in Infrastructure, Water Management, Water News / by Brett Walton

Buckled canals, damaged because of groundwater pumping, impair state's ability to deliver water and control floods.

WRITTEN BY	PUBLISHED ON	READ TIME
Mark Grossi	July 5, 2017	Approx. 5 minutes

SGMA and Groundwater Model Applications





Groundwater Model Applications:

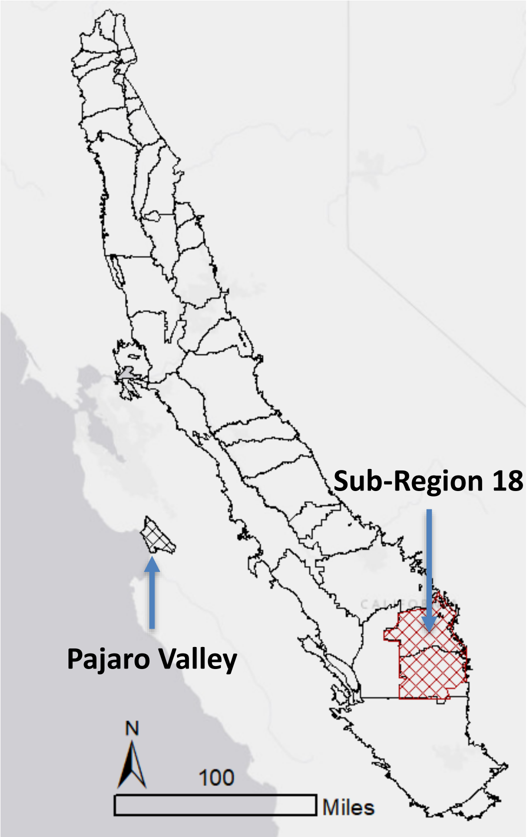
> Synthesize best available data

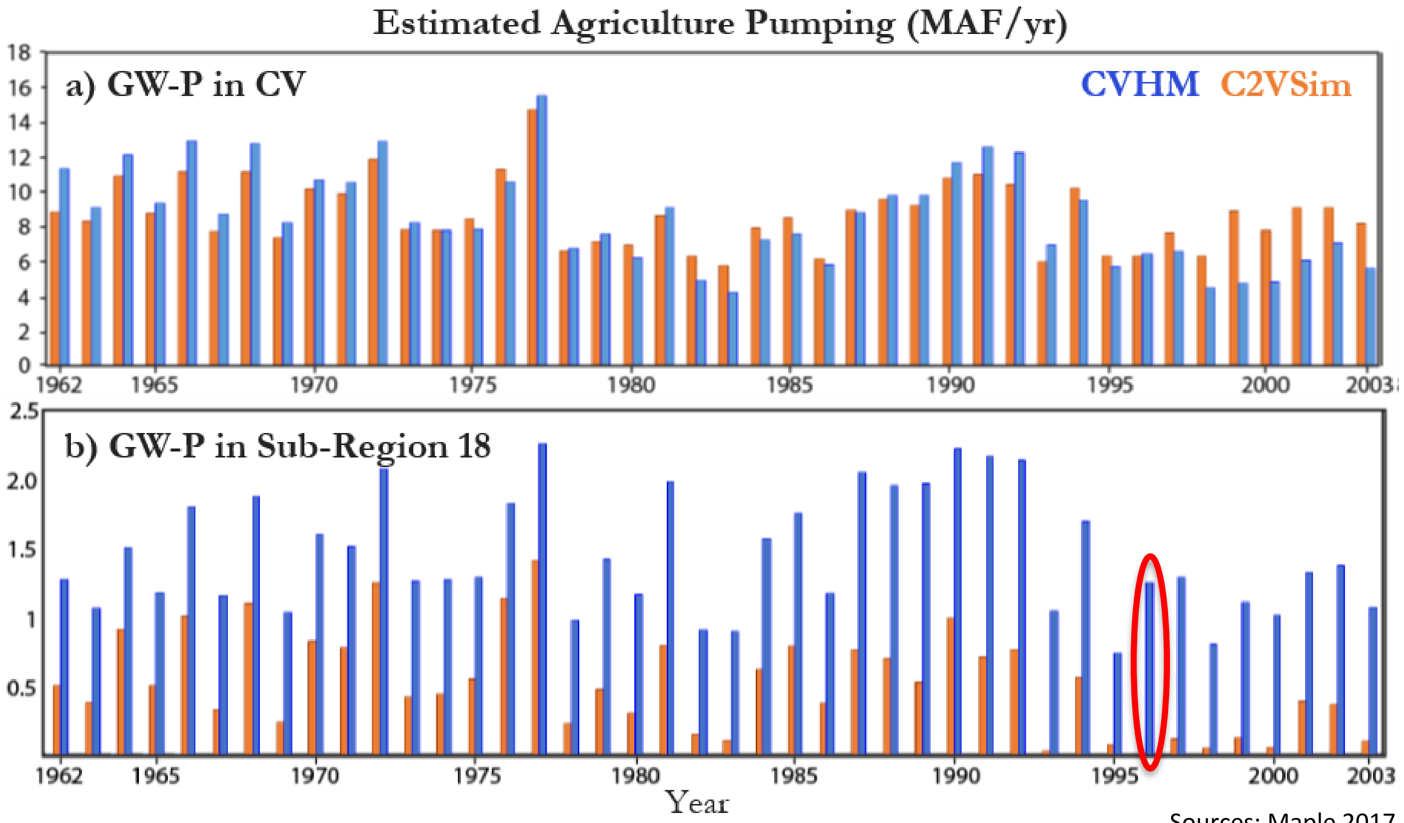
> Estimate water budget

> Simulate future scenario and management policy

Discrepancies in Groundwater Models

Difference in pumpage estimates are driven by how the two models conceptualize and simulate the crop evapotranspirative requirements.





Sources: Maple 2017

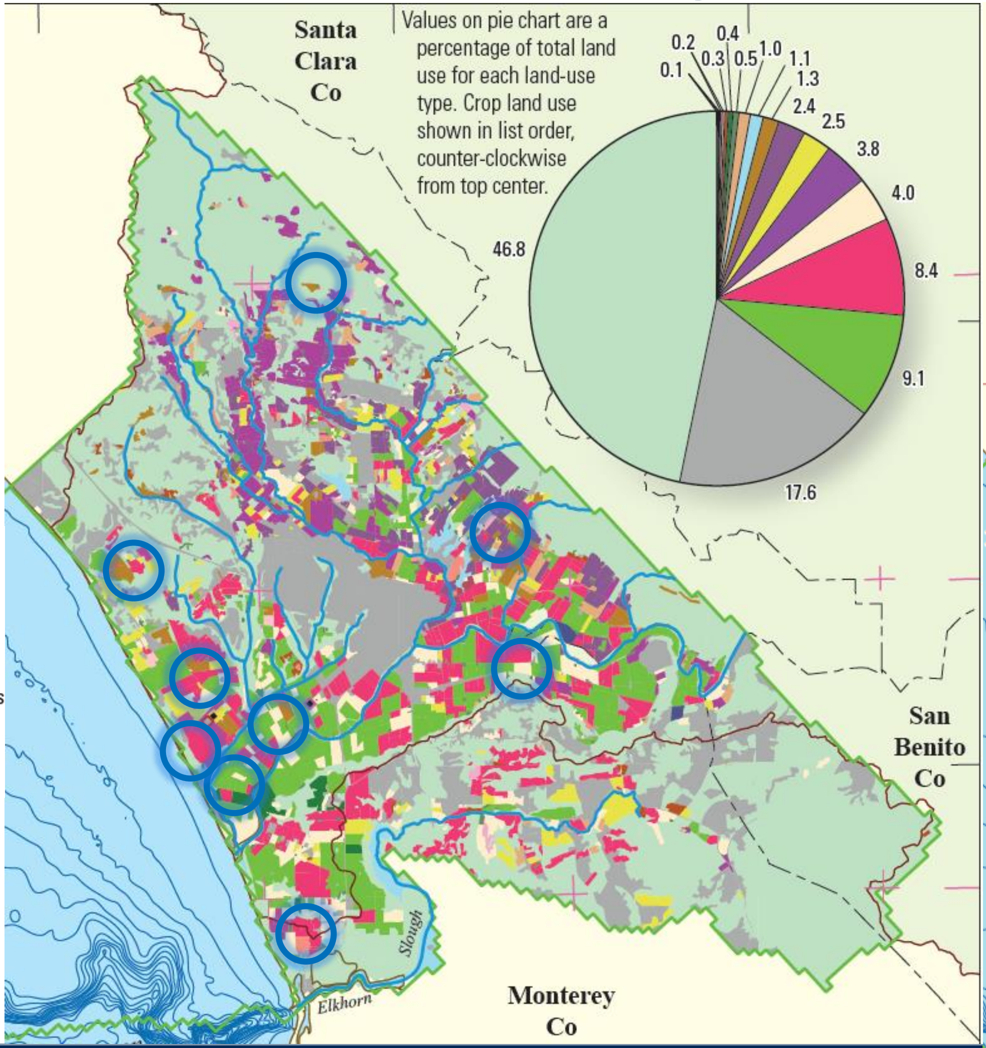
Pajaro Valley Hydrological Model (PVHM)

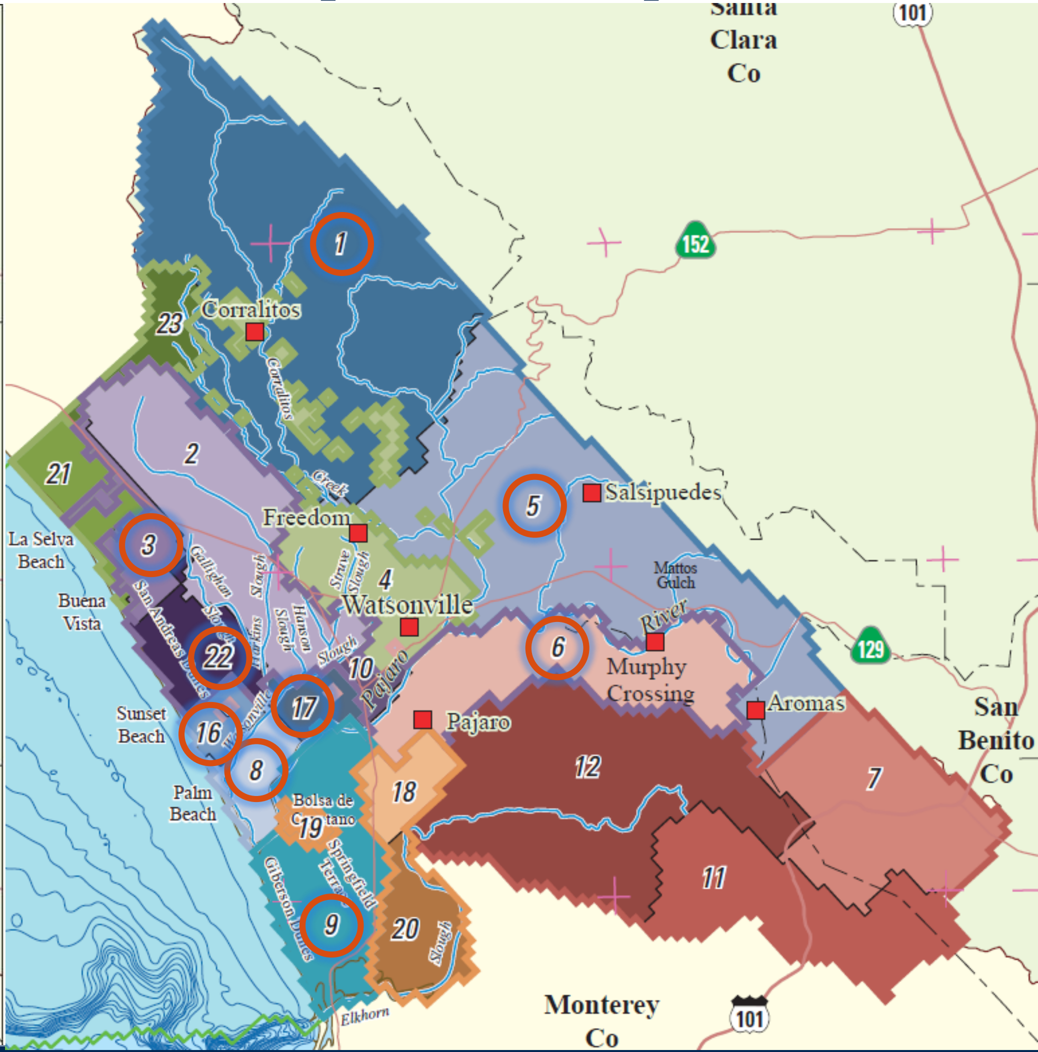
Focus on

Water Balance Sub-regions:

1,3,5,6,8,9,

16,17,22

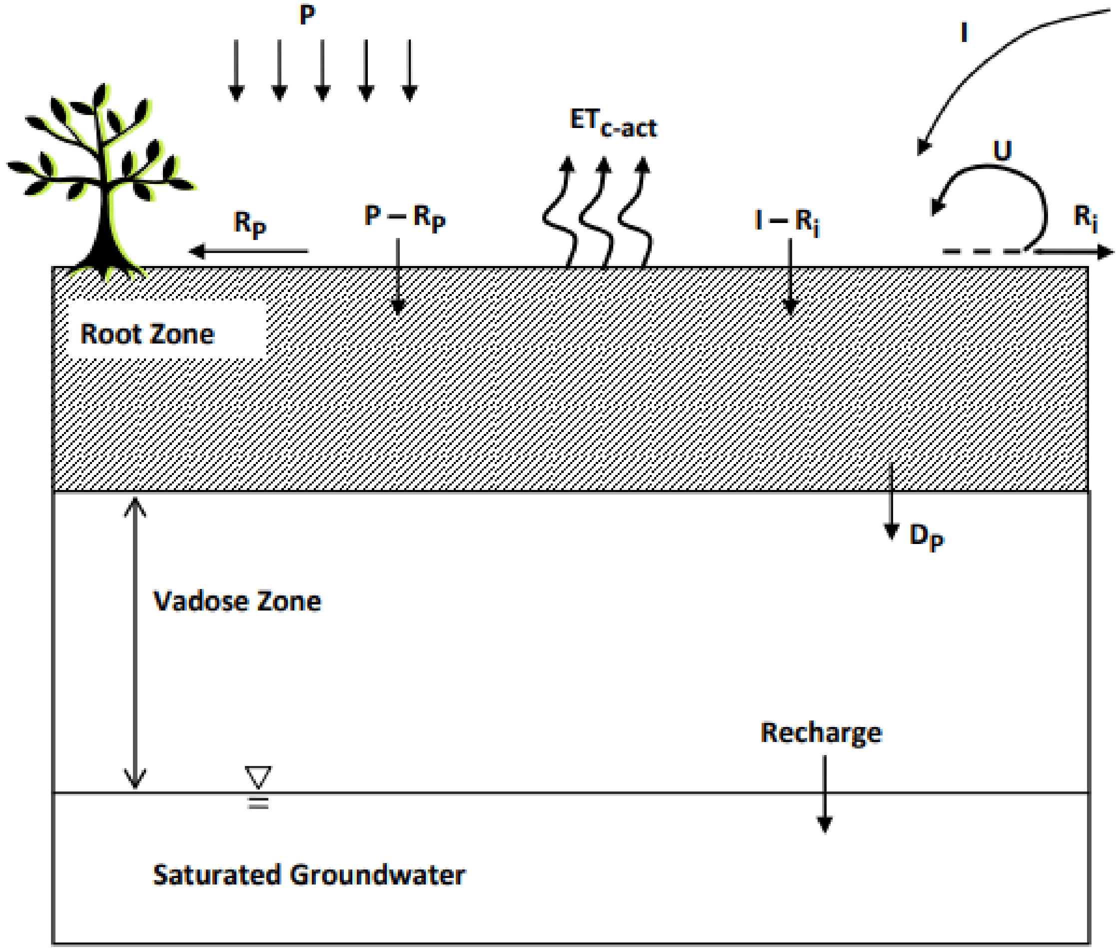




From ET to Pumpage in Concept

Pumpage = I – Surface Water Supply

Conceptually, I+P = ETa / Efficiency.



From ET to Pumpage in FMP2

Explanation: P – Precipitation; I – Irrigation; U – Re-use of irrigation water; DP – Deep percolation; R_p – Returnflow related to precipitation; R_i – Returnflow related to irrigation; $ET_{c\text{-}act}$ – Actual crop evapotranspiration.

Pumpage = I – Surface Water Supply

The FMP model is much more complex:

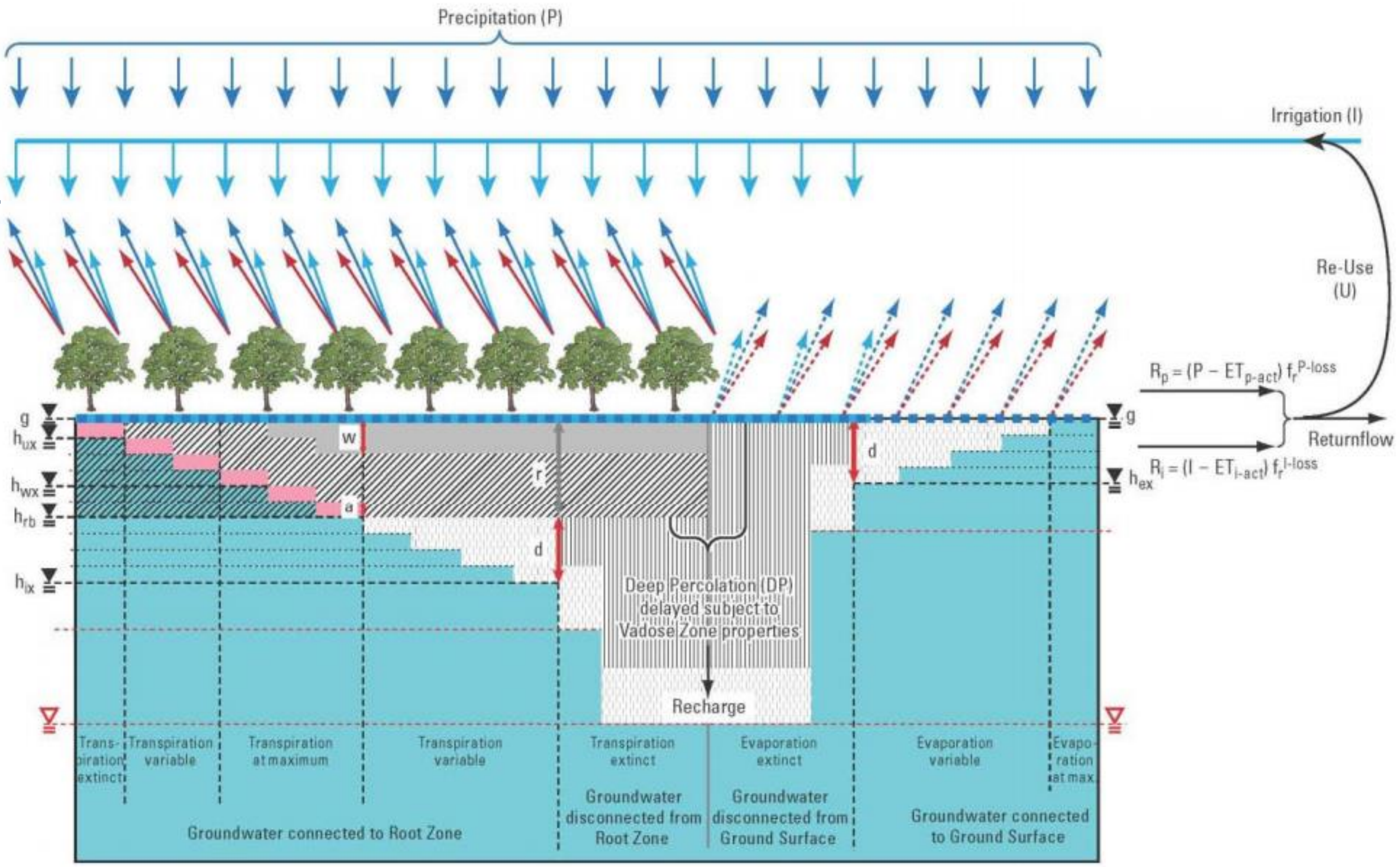
Crop ET = Crop Coefficient x Reference ET

Crop ET is further adjusted by season

Partition ET to 6 components.

The components are further adjusted according to

a) Vegetation root and soil properties,
b) Water table, and
c) Precipitation



Calibration in FMP2 for PVHM

In PVHM, the following parameters in FMP2 are calibrated using pumpage measurement：

1. Scale factors for seasonal crop coefficient
2. Fractions of total precipitation
3. Runoff from inefficient losses from precipitation and irrigation for selected crop and natural vegetation
4. Seasonal scale factors for irrigation efficiencies

Integrating Remote Sensing ET in FMP2

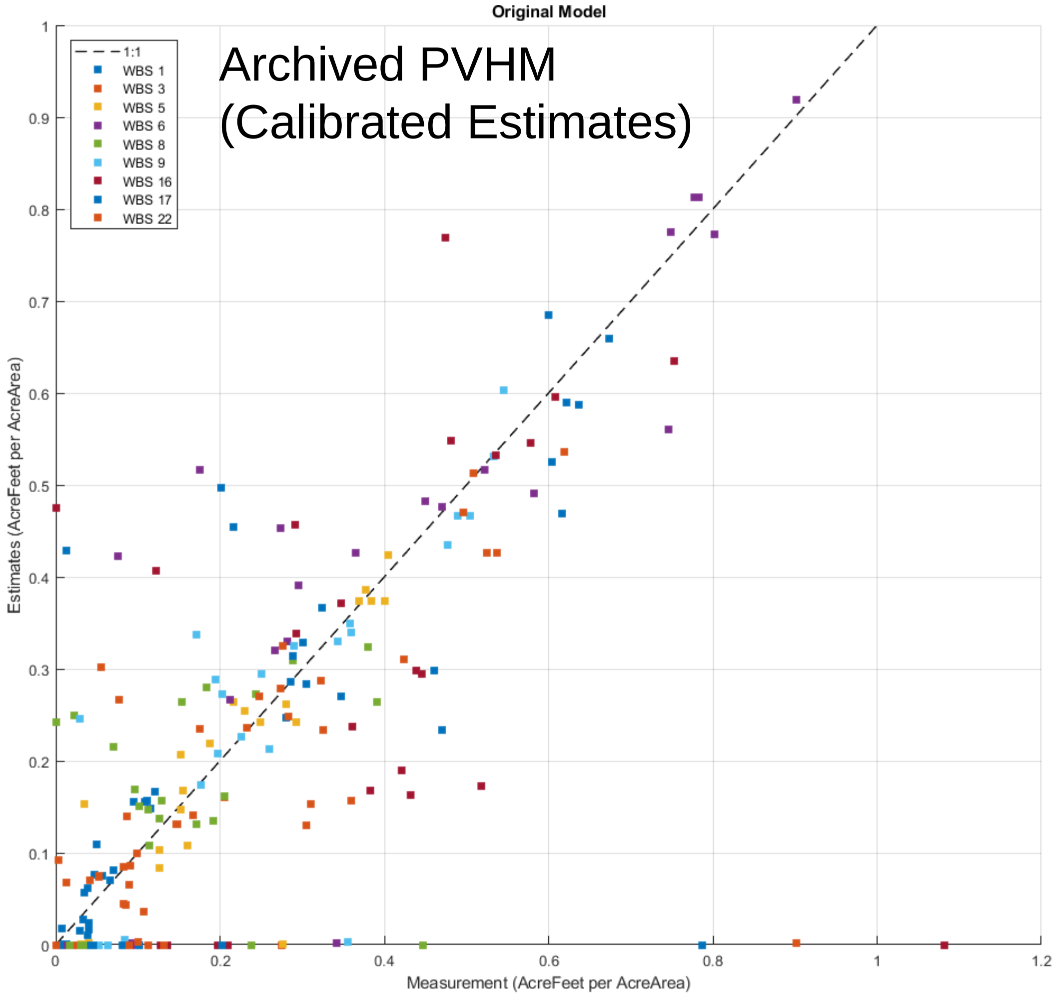
1. Rewrite ETo files with aggregated – generalized PTUCD ET value for 2003 Mar to 2009.
2. Change crop specific crop coefficient to 1.
3. Change regional and seasonal crop coefficient factors to 1
4. Remove PVHM's ETo bias correction factor.
5. Remove seasonal scale factor for irrigation efficiency.
6. Use actual precipitation files for 2006-2009.
7. Use actual ETo/ Remote Sensing ET files for 2006.

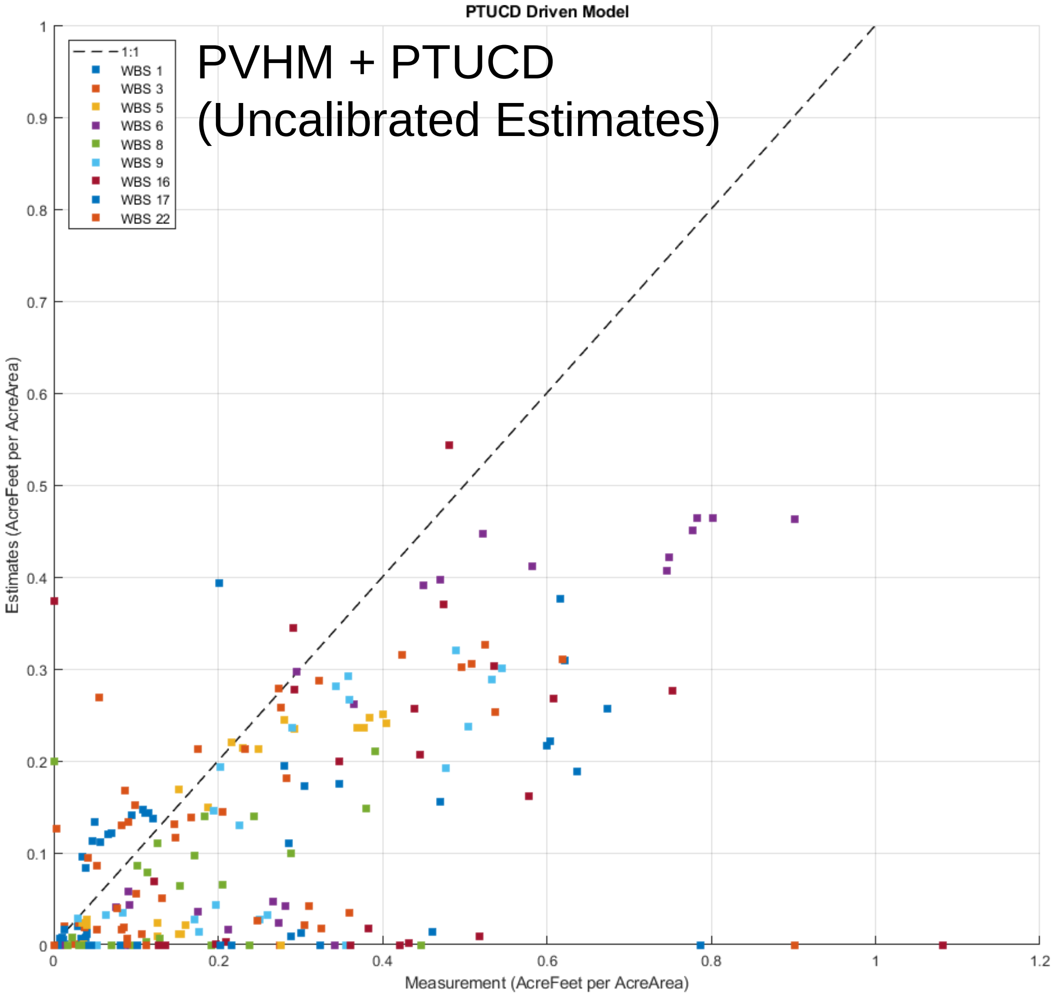
More investigation and modification are needed.

Goal: Use the integrated remote sensing ET + FMP2 to estimate pumpage without calibration.

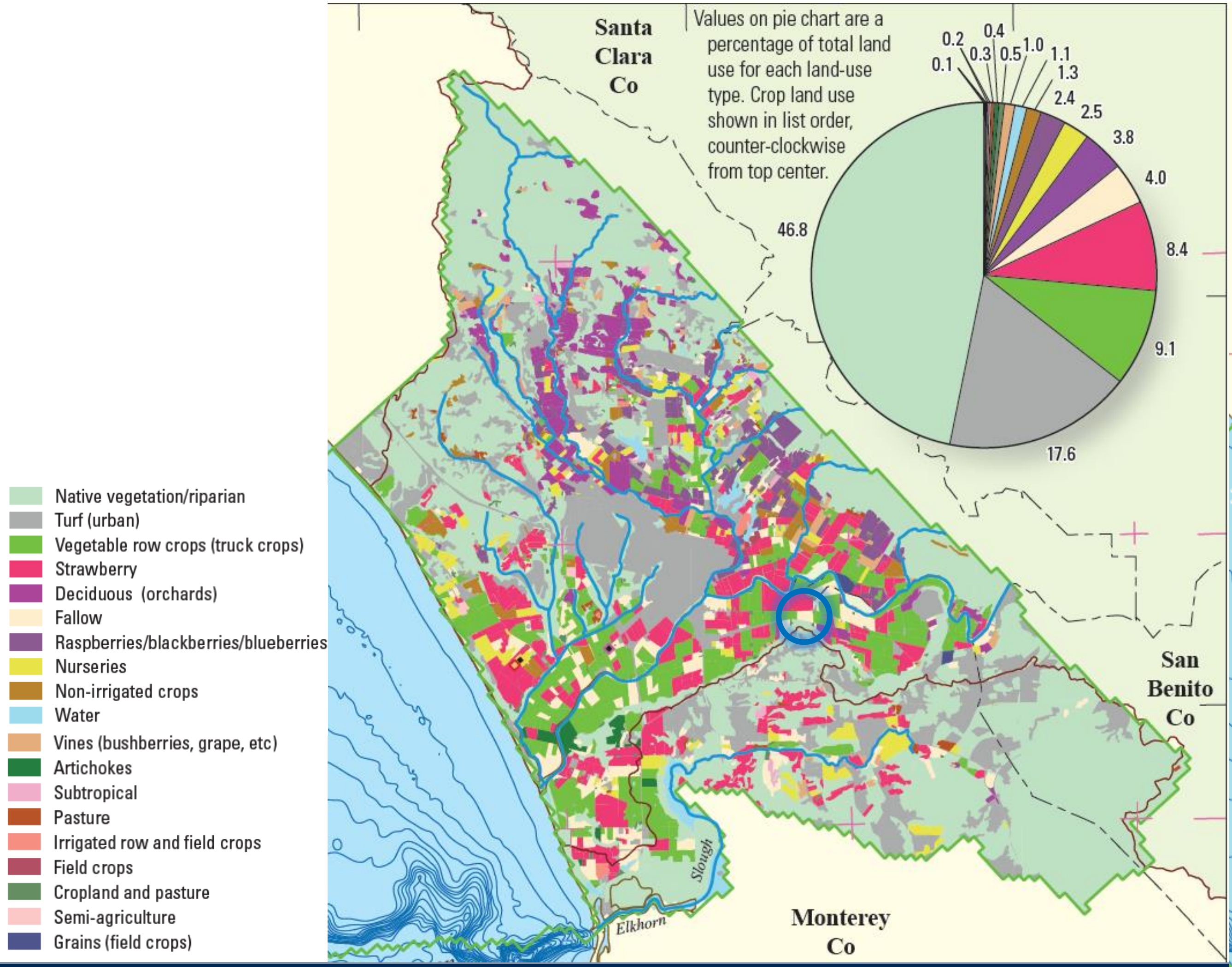
PVHM + PTUCD

	PVHM	PVHM + PTUCD
RMSE (AF/Acre)	**0.16**	**0.21**
R^2	**0.5**	**0.36**
Absolute Bias (AF/Acre)	**0.09**	**0.15**

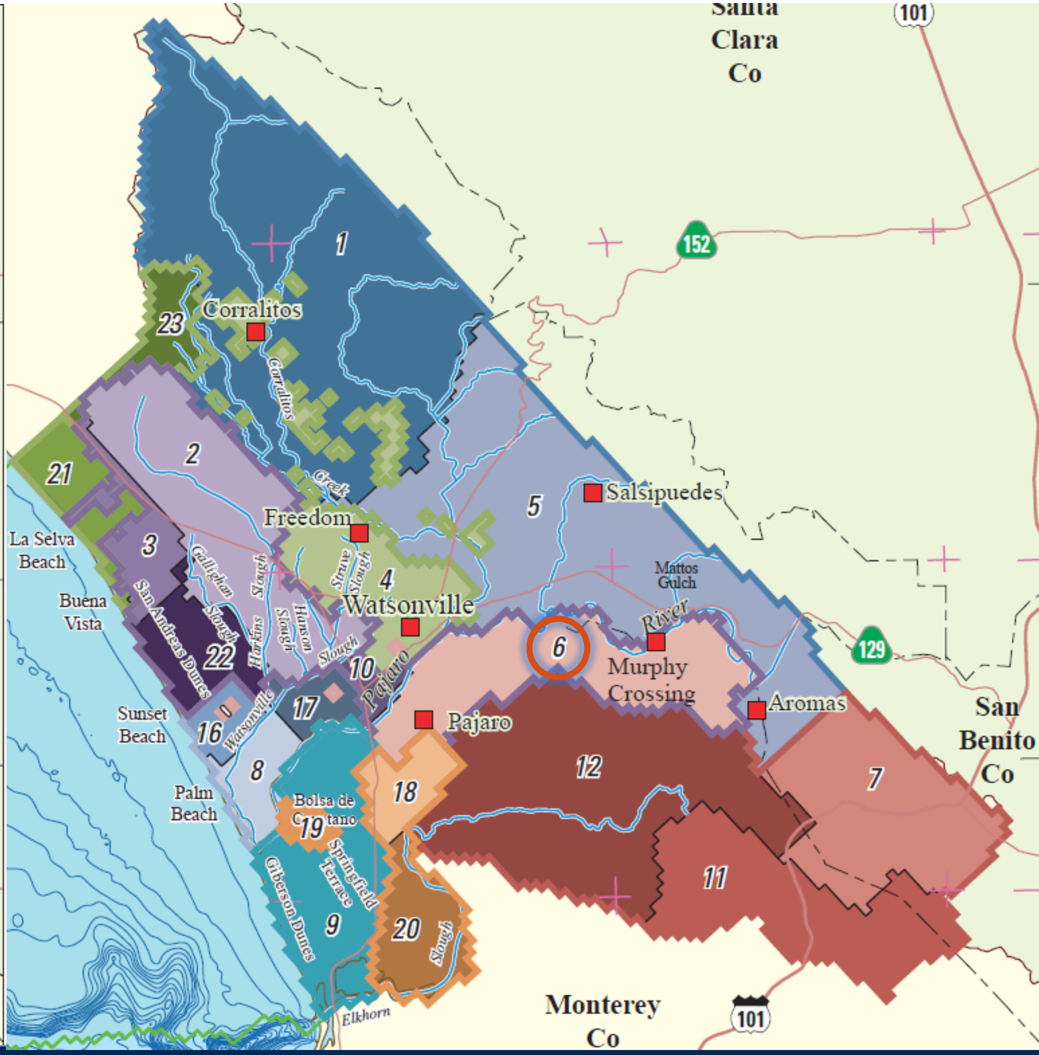




WBS 6



Santa Clara Co
Values on pie chart are a percentage of total land use for each land-use type. Crop land use shown in list order, counter-clockwise from top center.
0.1
0.2
0.3
0.4
0.5
1.0
1.1
1.3
2.4
2.5
3.8
4.0
8.4
9.1
17.6
46.8
San Benito Co
Monterey Co
Elkhorn
Slough
Native vegetation/riparian
Turf (urban)
Vegetable row crops (truck crops)
Strawberry
Deciduous (orchards)
Fallow
Raspberries/blackberries/blueberries
Nurseries
Non-irrigated crops
Water
Vines (bushberries, grape, etc)
Artichokes
Subtropical
Pasture
Irrigated row and field crops
Field crops
Cropland and pasture
Semi-agriculture
Grains (field crops)



Santa Clara Co
101
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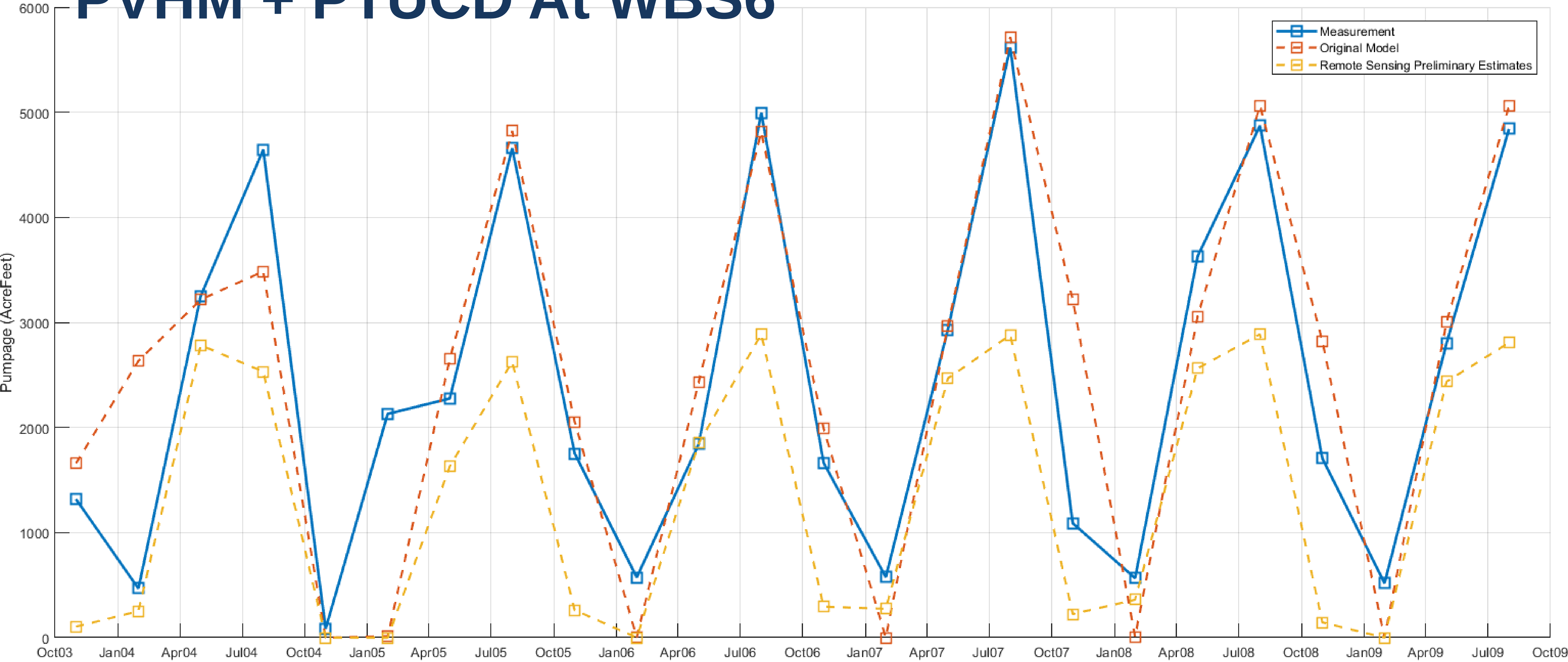
23
Corralitos
Freedom
Salsipuedes
Mattos Gulch
Watsonville
Murphy Crossing
Aromas
Pajaro
River
La Selva Beach
Buena Vista
Sunset Beach
Palm Beach
Bolsa de Chitano
San Andreas Dunes
Gibberson Dunes
Springfield Terrace
San Benito Co
Monterey Co
Elkhorn
Slough

PVHM + PTUCD At WBS6

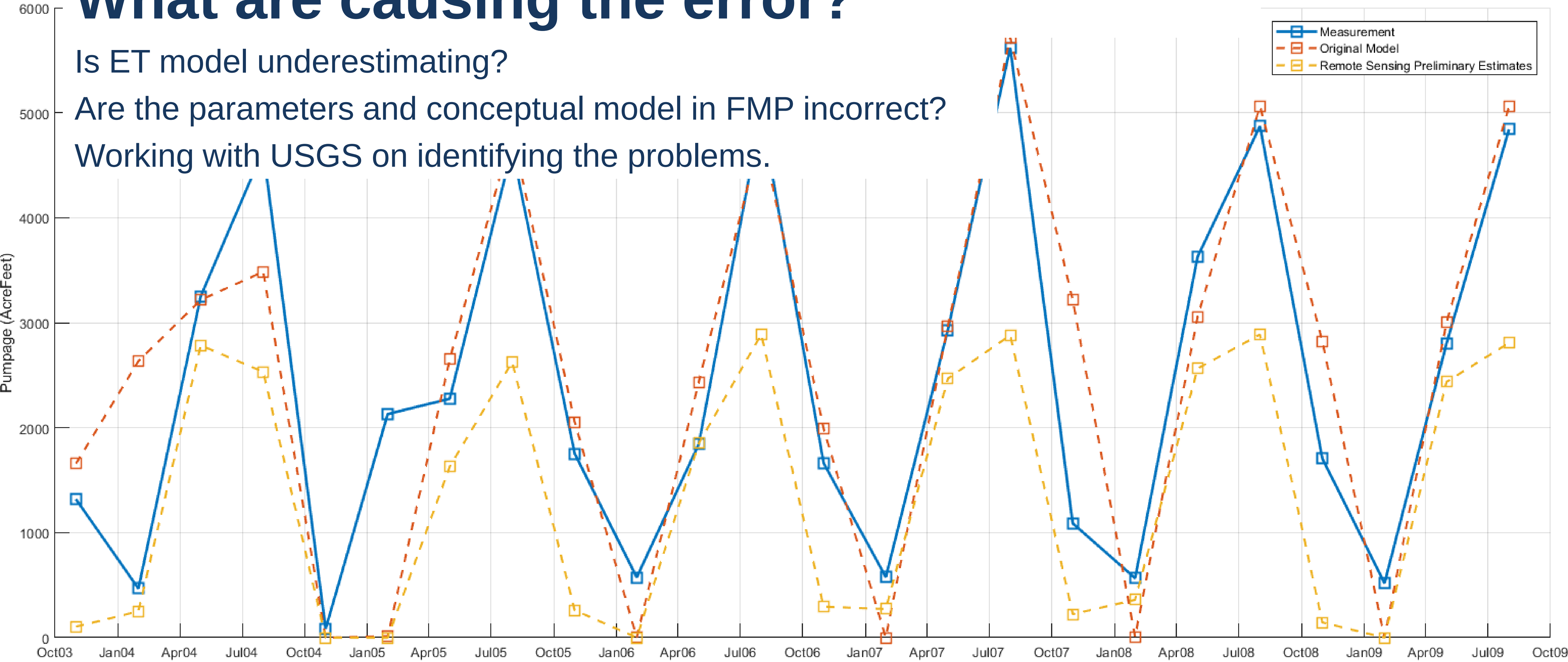


What are causing the error?

Is ET model underestimating?

Are the parameters and conceptual model in FMP incorrect?

Working with USGS on identifying the problems.



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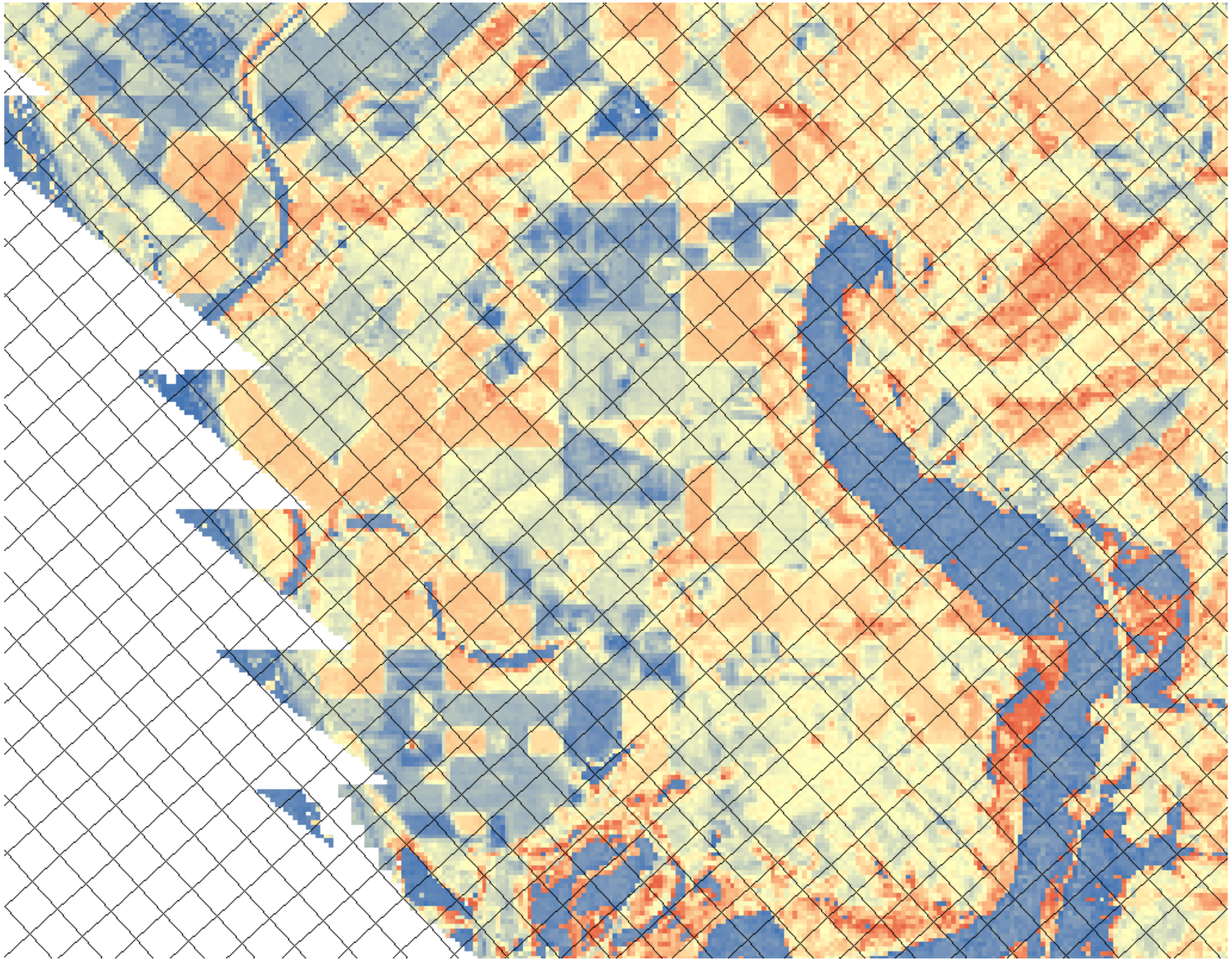
Next Steps

Remove sea shore NaN data artifact

Turn off actual ET adjustment (e.g. anoxia and wilting reduction)

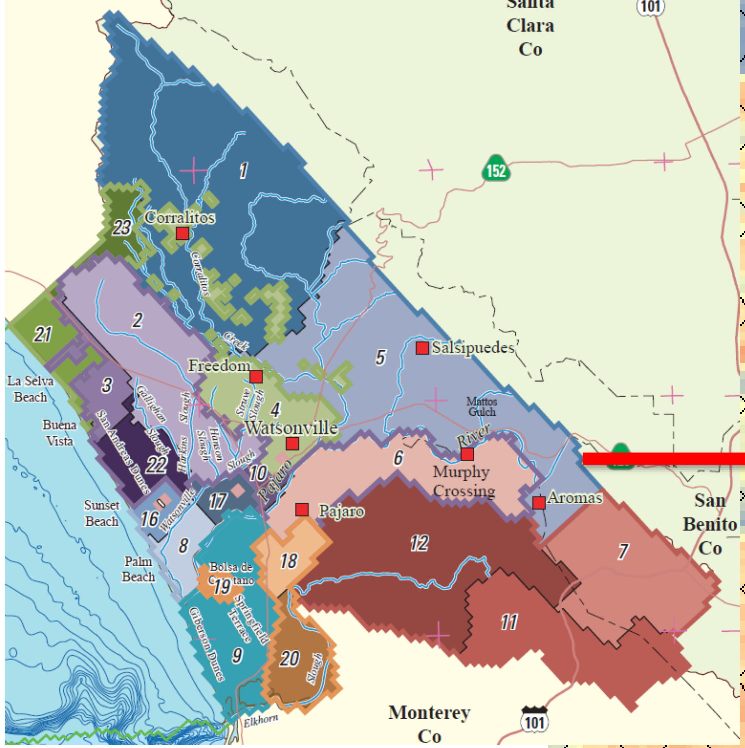
Reduce uncertainty in monthly ET estimates by data fusion and crop specific optimization

Comparing PTUCD with site measurements and ECOSTRESS L3 products in the Pajaro Valley.

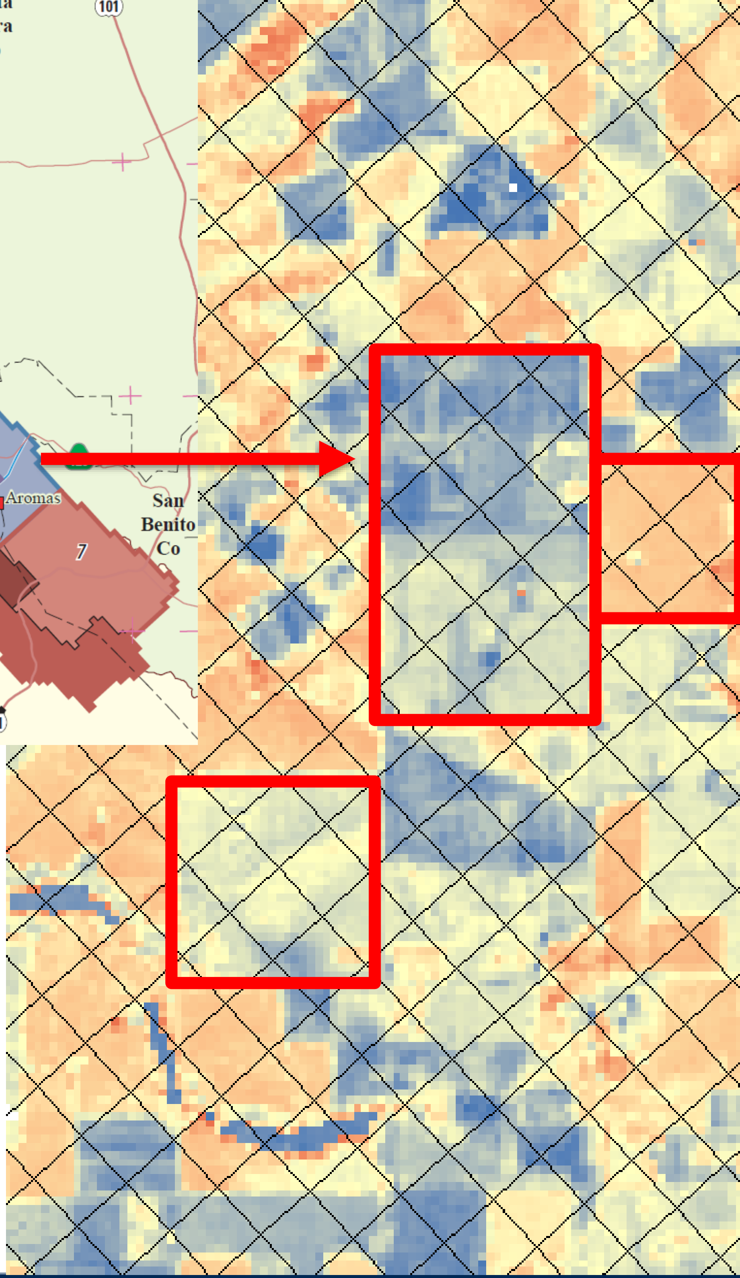


Vision

> Irrigation and pumpage estimates in
arid area where pumping are not metered



> Grid at field scale resolution,
delineate water balance sub-regions by farms,
operates by GSAs or irrigation district

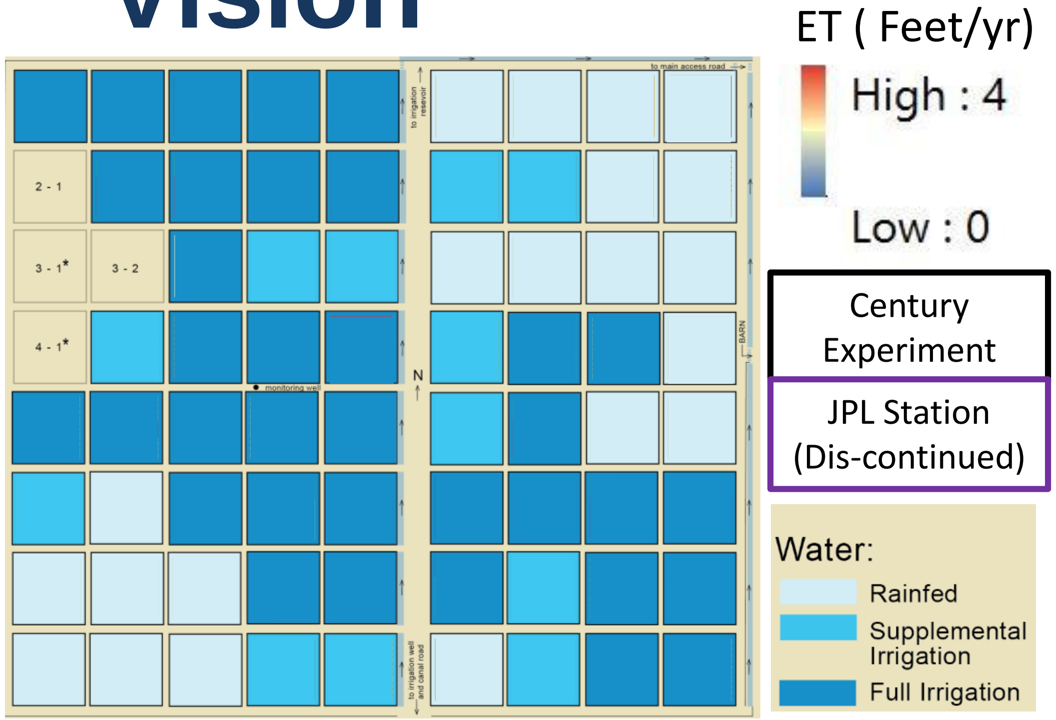


> A near real time water budget and used for monitoring progress

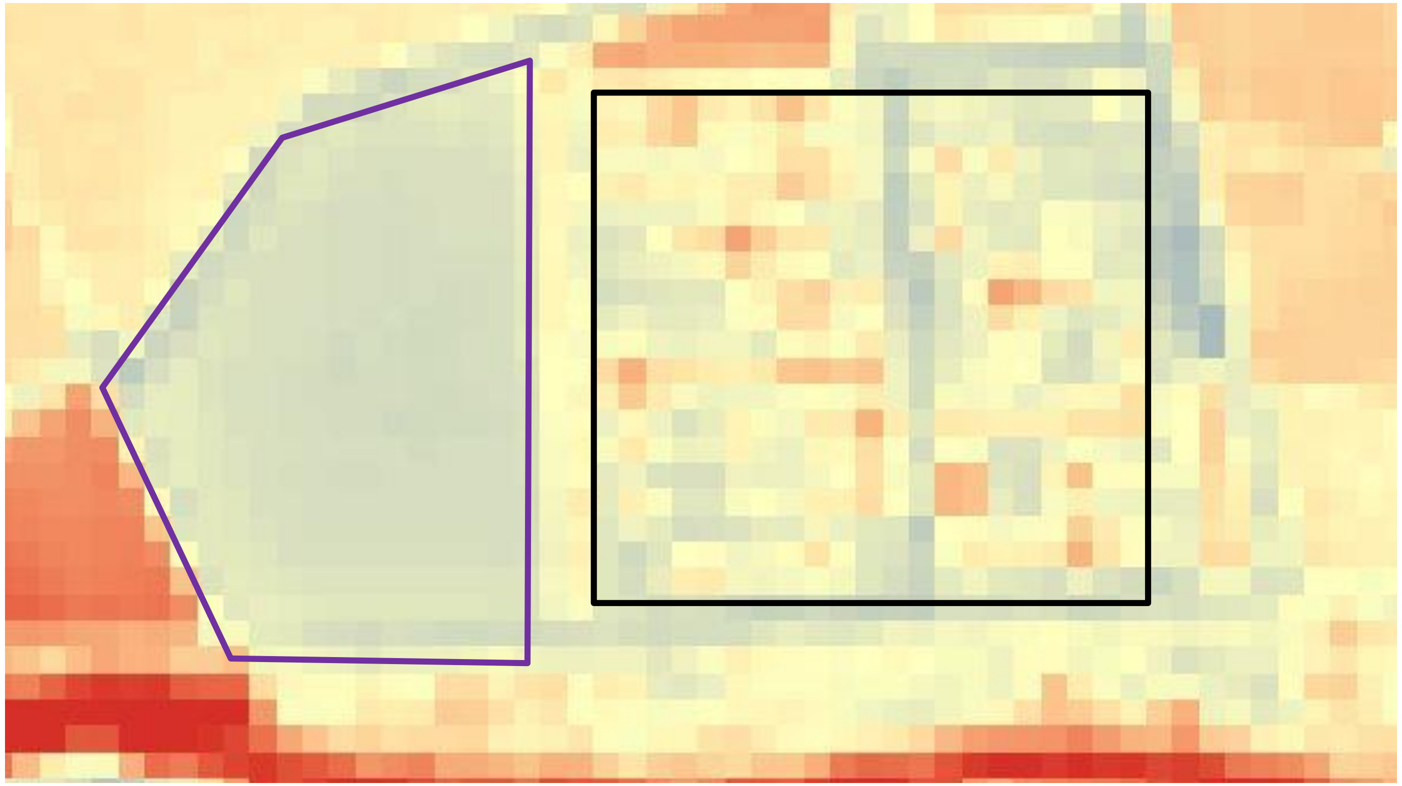
> A web portal where farmers can
1. view the estimated ET, irrigation, and pumpage of their lands,
2. identify rapid crop stress and over irrigation in their fields,
3. provide feed back / validation to further improve the models.

UCDAVIS

Vision



WY 2015 Russell Ranch Area



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Thank you!