ECOSTRESS Delta Project

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June 30, 2018.
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

Image Date: 07/13/2016
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:
\[
\alpha = \left[a \ast (1 - e^{-b \ast LAI}) + c \right] + \left(d \ast NDMI + e \ast f(T_a)\right)
\]

Net Radiation:
\[
R_{net} = \left[(1 - Albedo)S_1\right] + \left[\varepsilon_S \left((1 + \mu \ast F^V \ast \varepsilon_{clr})\sigma T_a^4 - (m \varepsilon_S \sigma T_s^4 + b)\right)\right]
\]

Conceptual Relationship can be generalized or crop specific
PTUCD: Mean Net Radiation

Net Radiation: \( R_{\text{net}} = [(1 - \text{Albedo})S_1] + \left[ \varepsilon_s ((1 + \mu \ast F^V) \ast \varepsilon_{\text{clr}}) \sigma T_a^4 \right] - (m \varepsilon_s \sigma T_s^4 + b) \)

(at 24hrs Time Step)

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

2. Gao et. al. (2012a).
PTUCD: 24hrs Mean LST

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

\[ T_{S\text{ MODIS}}(t) = T_{S\text{ MODIS daily}} + A_T \sin \left( \pi \cdot \frac{(t - t_{\text{set}})}{2(24 + t_{\text{sunrise}} - t_{\text{set}})} \right) \quad \text{for night time, } t < t_{\text{sunrise}} \]

modified from (Sun and Pinker, 2005)

\[ T_{S\text{ MODIS daily}} \text{ and } A_T \text{ are optimized per MODIS pixel using four instantaneous LST observations from MODIS MOD11A1 and MYD11A1 V006 products.} \]

\[ T_{S\text{ MODIS inst}} = T_{S\text{ MODIS}}(t = \text{Landsat overpass}) \]

24hrs Mean LST: \[ T_{S\text{ daily}} = T_{S\text{ Landsat inst}} \cdot \frac{T_{S\text{ MODIS daily}}}{T_{S\text{ MODIS inst}}} \]
\[ T_{S\text{ MODIS}}(t) = T_{S\text{ MODIS daily}} + A_T \cos \left( \frac{\pi}{(t_m - t_{\text{sunrise}})} (t - t_m) \right) \]

for day time, \( t > t_{\text{sunrise}} \)

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PTUCD + ECOSTRASS: Surface Reflectance?


2. Non-Landsat/Sentinel 2 Overpassing day: Spatial and Temporal Adaptive Reflectance Fusion Model (STARFM) (Gao et.al 2006.)
# PTUCD + Landsat

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[Conceptual]
## PTUCD + … + STARFM

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<td>VIIRS (375m) - STARFM</td>
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[Conceptual]
Estimating Daily ET with Thermal Sharpening

Sharpening VIIRS with Harmonized Sentinel-2 Landsat dataset

Thermal Sharpening (TS)

- Surface Reflectance (30m)
- NDVI (30m)
- LAI (30m)
- Surface Emissivity (30 -> 375m)
- Thermal Radiance (375m)
- LST (375m)
- NDVI (30 -> 375m)
- LST (30m)

Coefficient

Residuals (375 -> 30m)

LST (30m)
PTUCD w/ “Simulated” data: Rn

<table>
<thead>
<tr>
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<th>PTUCD + Landsat (n=138)</th>
<th>PTUCD + Landsat + VIIRS (n=55)</th>
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<tbody>
<tr>
<td>RMSE (W/m²)</td>
<td>14.96</td>
<td>40.78</td>
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<tr>
<td>R²</td>
<td>0.94</td>
<td>0.87</td>
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<tr>
<td>Absolute Bias (W/m²)</td>
<td>11.93</td>
<td>35.6</td>
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PTUCD + Landsat SR & LST

PTUCD + Landsat SR + Sharpened VIIRS LST
PTUCD w/ “Simulated” data: ET

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<th>PTUCD + Landsat (n=131)</th>
<th>PTUCD + Landsat + VIIRS (n=55)</th>
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</thead>
<tbody>
<tr>
<td>RMSE (mm/day)</td>
<td>0.88</td>
<td>1.15</td>
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<tr>
<td>$R^2$</td>
<td>0.83</td>
<td>0.83</td>
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<tr>
<td>Absolute Bias (mm/day)</td>
<td>0.68</td>
<td>0.96</td>
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PTUCD + Landsat SR & LST

PTUCD + Landsat SR + Sharpened VIIRS LST
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.
Motivation

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**Toxic Taps**

*The California Drought Isn’t Over* - Sinking Land Causes California Water Chokepoint


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

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

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.

More investigation and modification are needed.

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

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<tr>
<td>RMSE (AF/Acre)</td>
<td>0.16</td>
<td>0.21</td>
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<tr>
<td>$R^2$</td>
<td>0.5</td>
<td>0.36</td>
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<tr>
<td>Absolute Bias (AF/Acre)</td>
<td>0.09</td>
<td>0.15</td>
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Archived PVHM (Calibrated Estimates)

PVHM + PTUCD (Uncalibrated Estimates)
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.

Legend:
- 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)
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.
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 feedback/validation to further improve the models.
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Thank you!