Satellite Mapping of Crop Water Requirements for Irrigation Management Support

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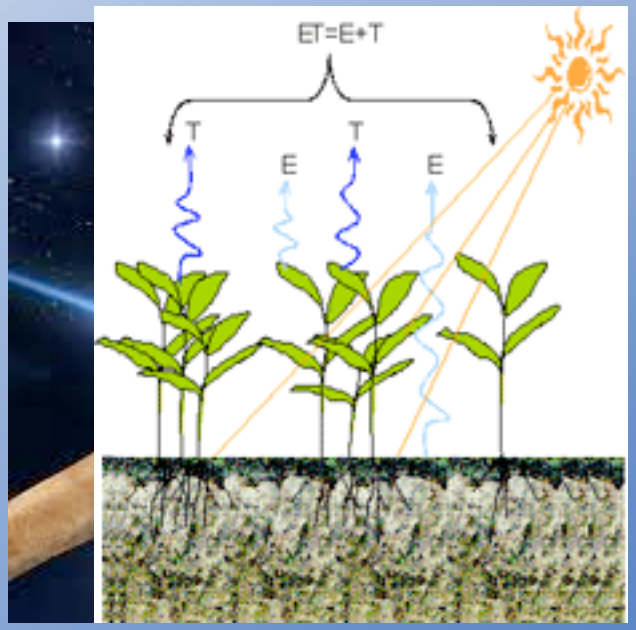
Partners:

CA Dept. of Water Resources, Western Growers Association, Center for Irrigation Technology / CSU Fresno, USDA ARS / NRCS, Univ. of California Cooperative Extension, USGS, Booth Ranches, Chiquita, Constellation Wines, Del Monte Produce, E & J. Gallo, Farming D, Fresh Express, Pereira Farms, Ryan Palm Farms, Tanimura & Antle

NASA + ET?



Evapotranspiration (ET): water consumed (lost to atmosphere) by combined processes of soil evaporation & plant transpiration

Basal ET (ETcb): ET for well-watered crop on a dry soil surface


Earth Science Missions in Operation
Aquarius
OSTM/Jason 2 (NOAA)
Jason
QuikSCAT*
TRMM
EO-1
Landsat-7 (USGS)
Aqua
ACRIMSAT
Terra
SORCE
GRACE (2)
Aura
CALIPSO
CloudSat
NPP
Landsat-8 (USGS)

Benefits of Using Ag Weather Information in Irrigation Management

- California Department of Water Resources and UC Berkeley surveyed growers in 1990s
- Growers who utilized weather and ET_o data reported an increase in yields of 8% and a decrease in applied irrigation of 13% (DWR, 1997)

Method Used by Farmers to Decide When to Irrigate, USDA Farm & Ranch Irrig. Survey, 2008

	Percent of Farmers	
Method	CA	US
Condition of Crop	66%	78%
Feel of soil	45%	43%
Personal calendar schedule	32%	25%
Soil moisture sensing device	14%	9%
Daily ET reports	**12%**	**9%**
Scheduled by water delivery org.	11%	12%
Commercial or government scheduling service	10%	8%
When neighbors irrigate	6%	7%
Other	6%	9%
Plant moisture sensing device	3%	5%

Growers may report more than one method, so total of all methods may exceed 100%.

Opportunity

Standard approach for incorporating information on weather / crop stage into irrigation management practices:

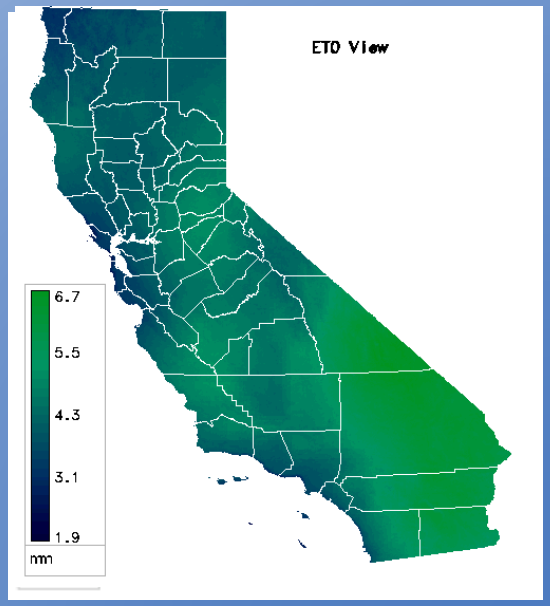
$$ET_c = ET_o * (K_{cb} + K_e)$$

CIMIS *Satellite*

Photo credit: DWR CIMIS

California Irrigation Management Information System (CIMIS)

- Operated by CA DWR since 1982
- >140 stations currently providing daily measurements of ET_o
- **Spatial CIMIS** data now available for CA; 2km statewide grid, daily
- Crop coefficient mapping identified by CA DWR as high priority need for CIMIS



Spatial CIMIS ET_0

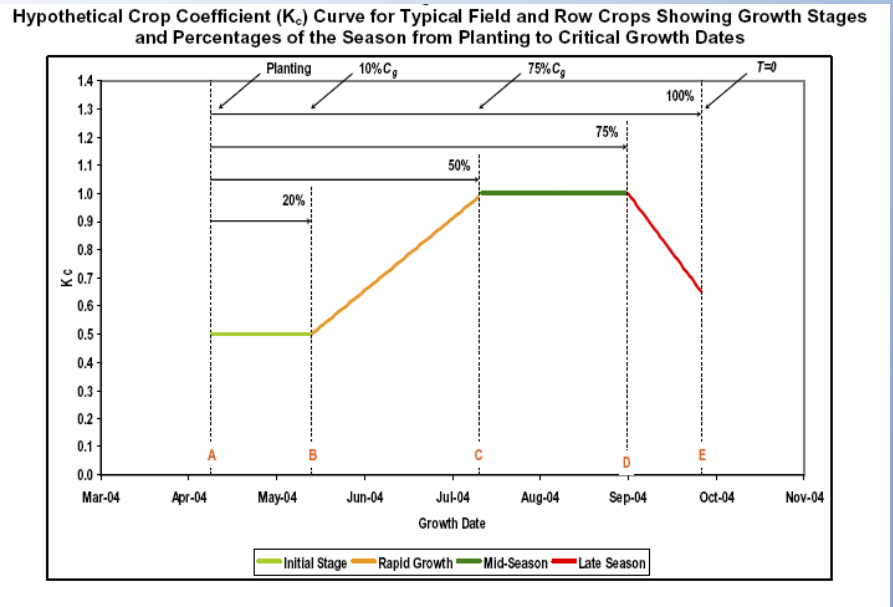
Combining Surface and Satellite Data: Mapping of Crop Water Requirements at Field Scales

$$ET_{cb} = ET_o * K_{cb}$$

CIMIS (AgriMet, AZMET, CoAgMet)

satellite

Standard K_c Profile (manual)



TOPS-SIMS K_{cb} Profile (Automated, Satellite-derived)

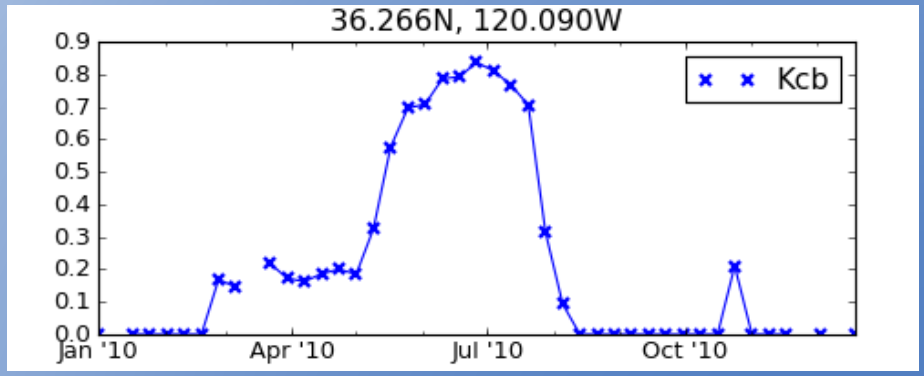


Figure credit: 2005 California Water Plan Update

Problem Statement

- Increased access to information on crop evapotranspiration can support California growers in improving on-farm water use efficiency

- Information must be:
  1. Timely and reliable
  2. Specific to individual fields
  3. Easy to access
  4. Easy to use
  5. Accuracy of data must be clearly defined

- Project philosophy:
  - Irrigation management is complex → growers are in the best position to determine their crop water needs, ***and,***
  - Better information leads to better decisions

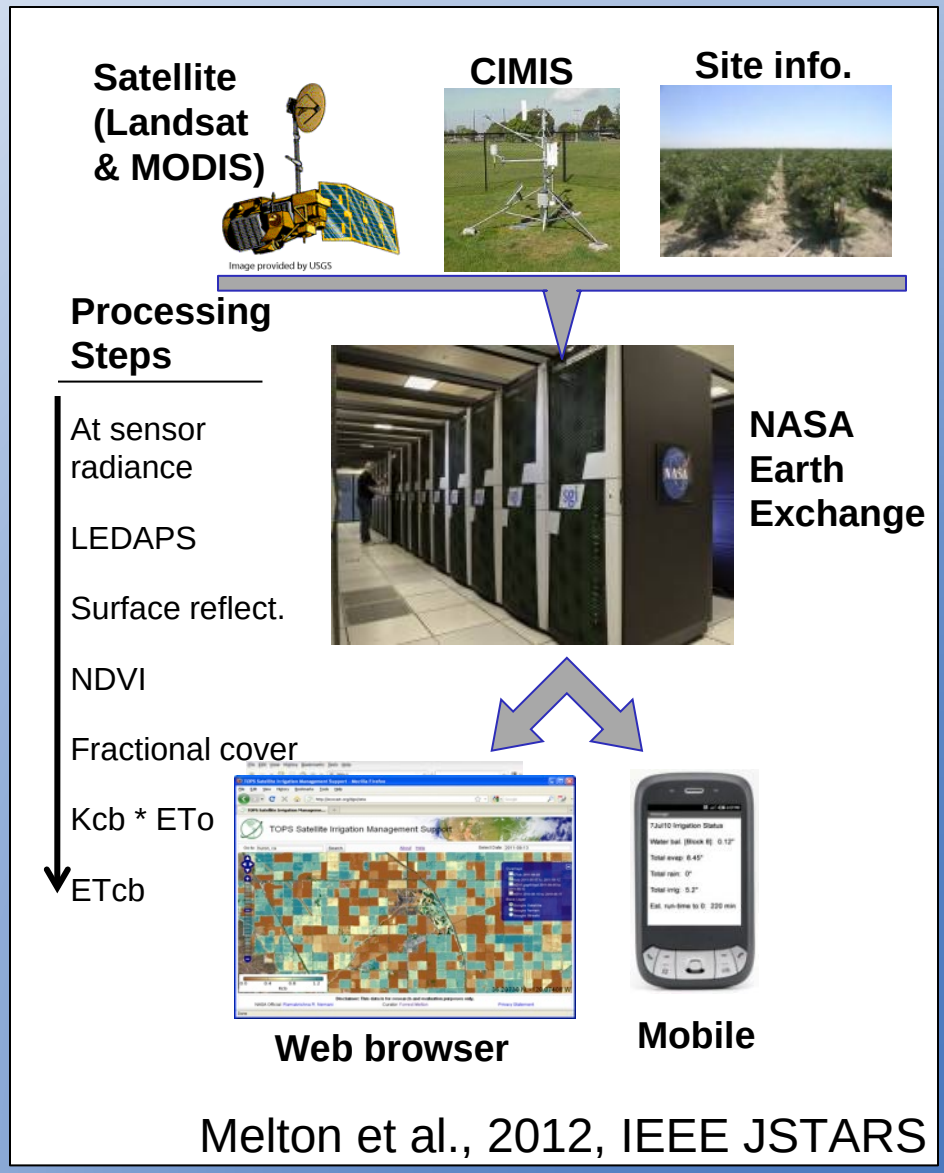
Satellite Irrigation Management Support (SIMS): Objectives

1) Develop near real-time estimates of crop water requirements from satellite data to assist growers in managing irrigation, and water managers in improving estimates of agricultural water requirements

2) Provide web and mobile data interfaces to increase the ability of the agricultural community to access and use satellite data in irrigation management and crop monitoring

Satellite Irrigation Management Support (SIMS) Framework

1. Integration of satellite and surface measurements
2. Prototyping accelerated by NASA high end computing resources
3. Integration with irrigation management tools (CropManage, VSIM)
4. Freely available data
5. Outreach and education through partnerships with Western Growers and agricultural extension services



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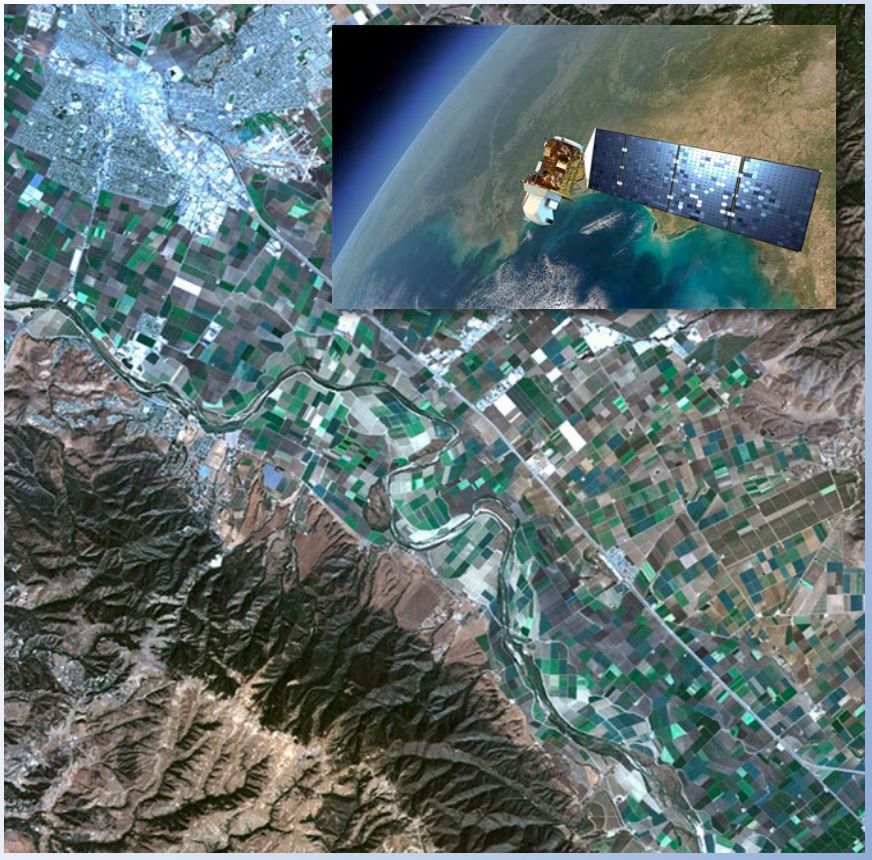
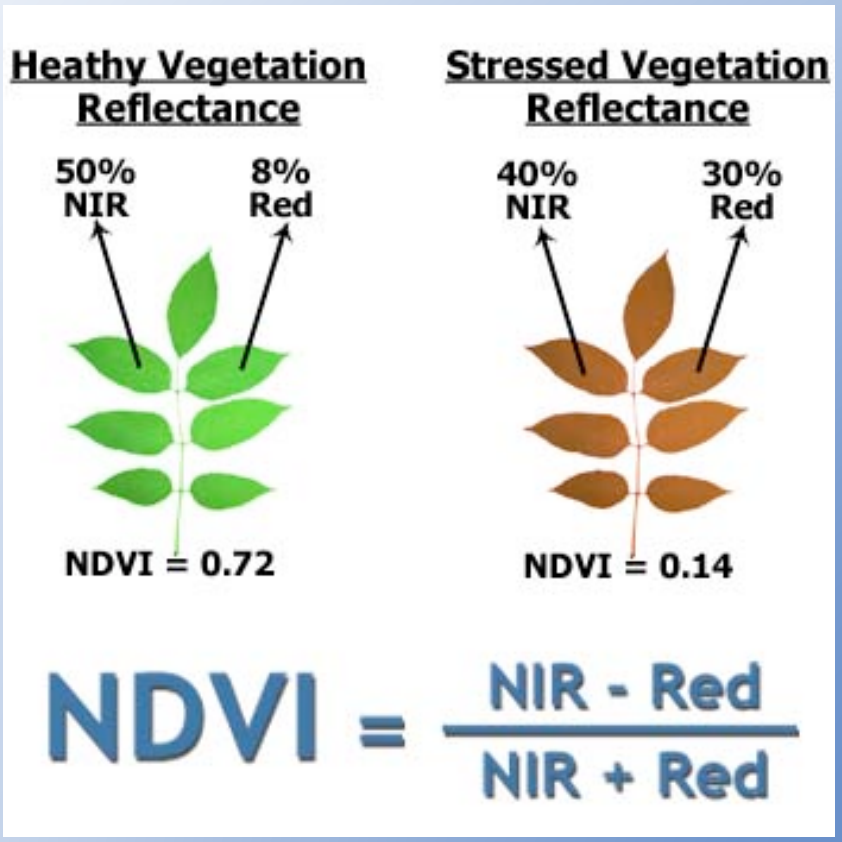
Satellite Data



Landsat (TM / ETM+ / OLI)
30m / 0.25 acres
Overpass every 8-16 days

Terra / Aqua (MODIS)
250m / 15.5 acre
Daily overpass

Normalized Difference Vegetation Index



Credit: ODIS

Commonly used remote sensing index of vegetation condition

Username: Password: Login

TOPS Satellite Irrigation Management Support

Go to: Search About Help Select Date: 2011-07-07

SIMS Data Layers
- ETcb 2011-07-07
- Crop coefficient (Kcb) 2011-07-04 to 2011-07-11
- Veg. Index (NDVI) gapfilled 2011-07-04 to 2011-07-11
- Veg. Index (NDVI) 2011-07-04 to 2011-07-11

Base Layer

Normalized Difference Vegetation Index (NDVI); 8-day composite from Landsat and MODIS

0.0 0.2 0.5 0.8 1.0
NDVI

35.39402 N, -119.85320 W

Disclaimer: This data is for research and evaluation purposes only.
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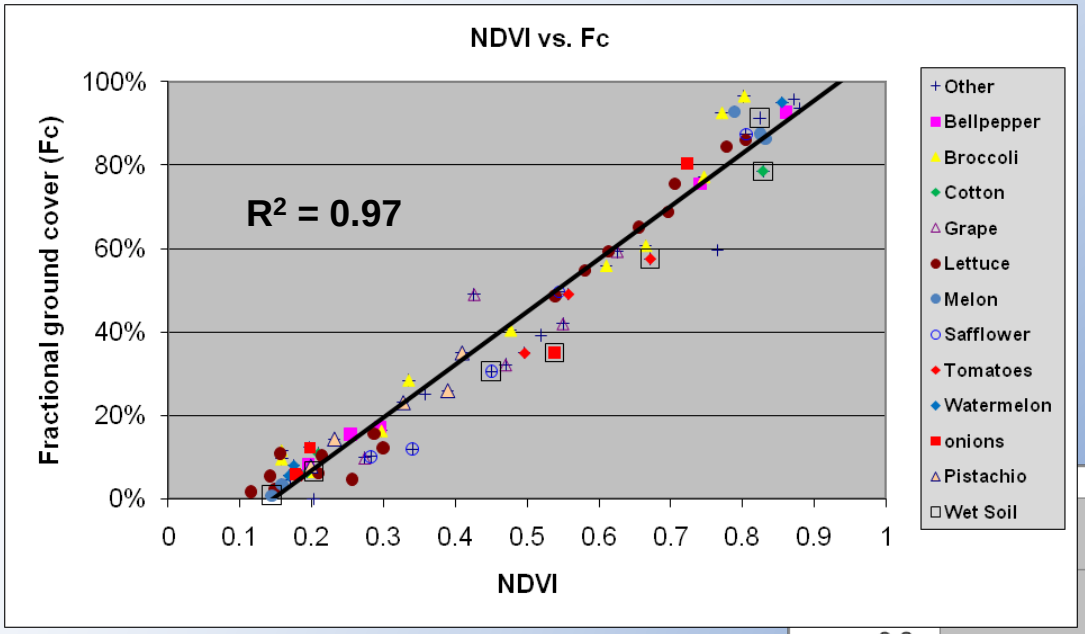
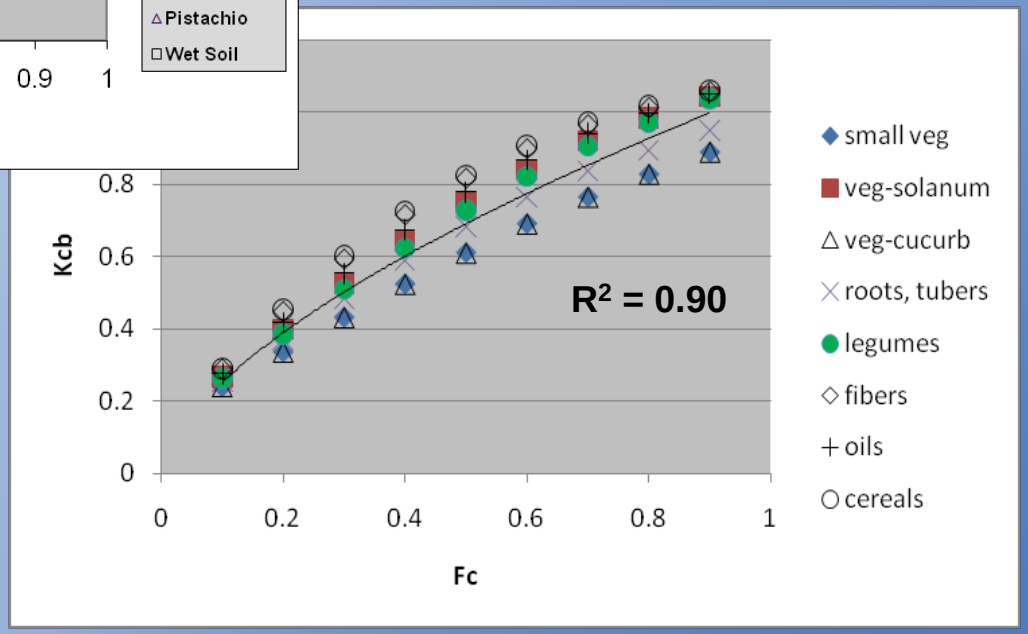
Approach: Mapping Crop Coefficients and Indicators of Crop Water Requirements from Satellite Data



Trout et al., 2008; Johnson & Trout, 2011

USDA studies provide basis for linking satellite vegetation indices (NDVI) to fractional cover.

Annuals



Recent studies by Allen & Pereira (2009) and others provide basis for linking fractional cover to K_{cb} for a range of crops.

Also see Bryla et al., 2010; Grattan et al., 1998; Hanson & May, 2006; Lopez-Urrea et al., 2009

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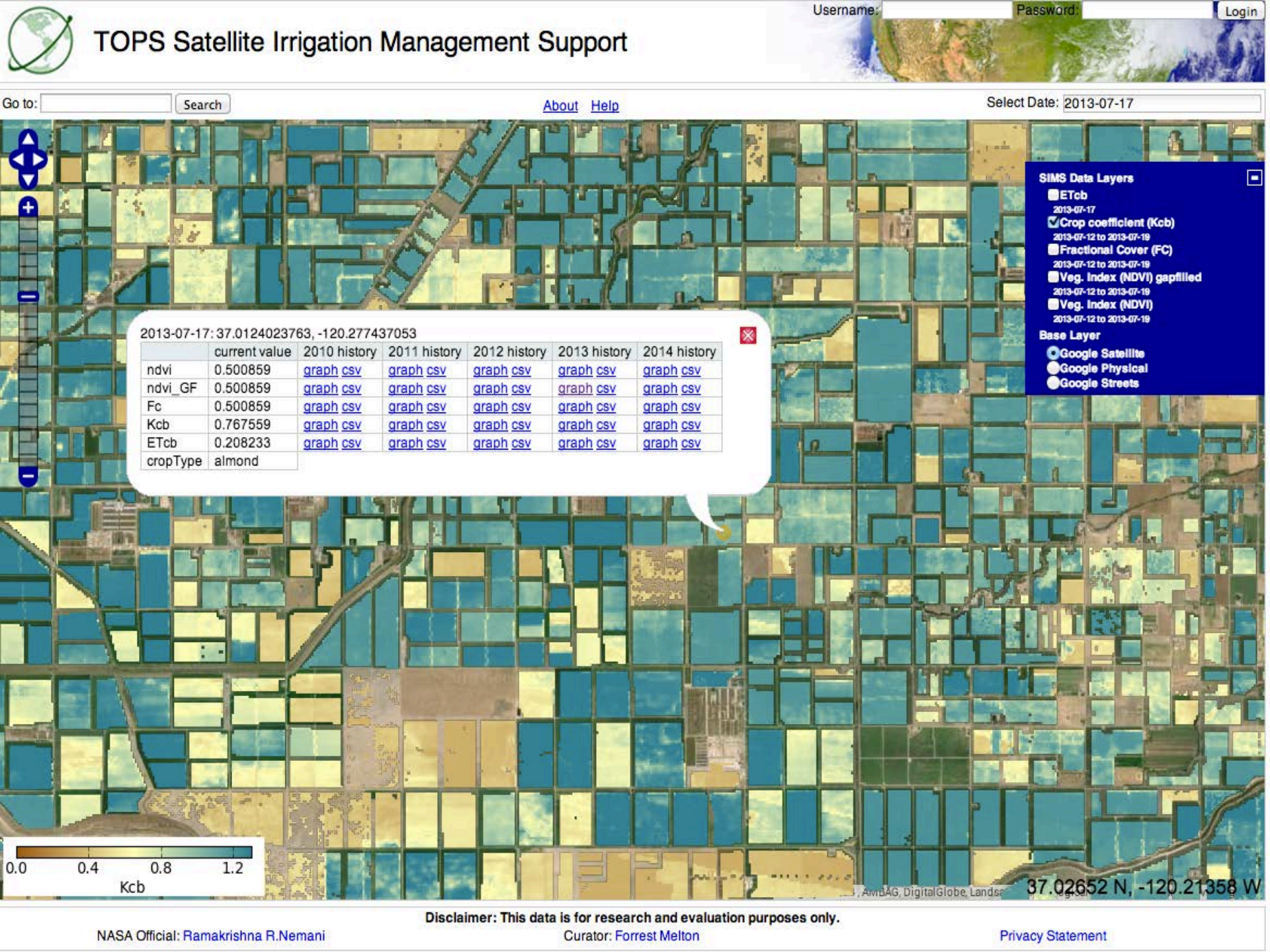
TOPS Satellite Irrigation Management Support
Username:
Password:
Login
Go to:
Search
About
Help
Select Date: 2013-07-17
SIMS Data Layers
ETcb
2013-07-17
Crop coefficient (Kcb)
2013-07-12 to 2013-07-19
Fractional Cover (FC)
2013-07-12 to 2013-07-19
Veg. Index (NDVI) gapfilled
2013-07-12 to 2013-07-19
Veg. Index (NDVI)
2013-07-12 to 2013-07-19
Base Layer
Google Satellite
Google Physical
Google Streets
2013-07-17: 37.0124023763, -120.277437053
current value
2010 history
2011 history
2012 history
2013 history
2014 history
ndvi 0.500859 graph csv graph csv graph csv graph csv graph csv
ndvi_GF 0.500859 graph csv graph csv graph csv graph csv graph csv
Fc 0.500859 graph csv graph csv graph csv graph csv graph csv
Kcb 0.767559 graph csv graph csv graph csv graph csv graph csv
ETcb 0.208233 graph csv graph csv graph csv graph csv graph csv
cropType almond
0.0
0.4
0.8
1.2
Kcb
37.02652 N, -120.21358 W
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Curator: Forrest Melton
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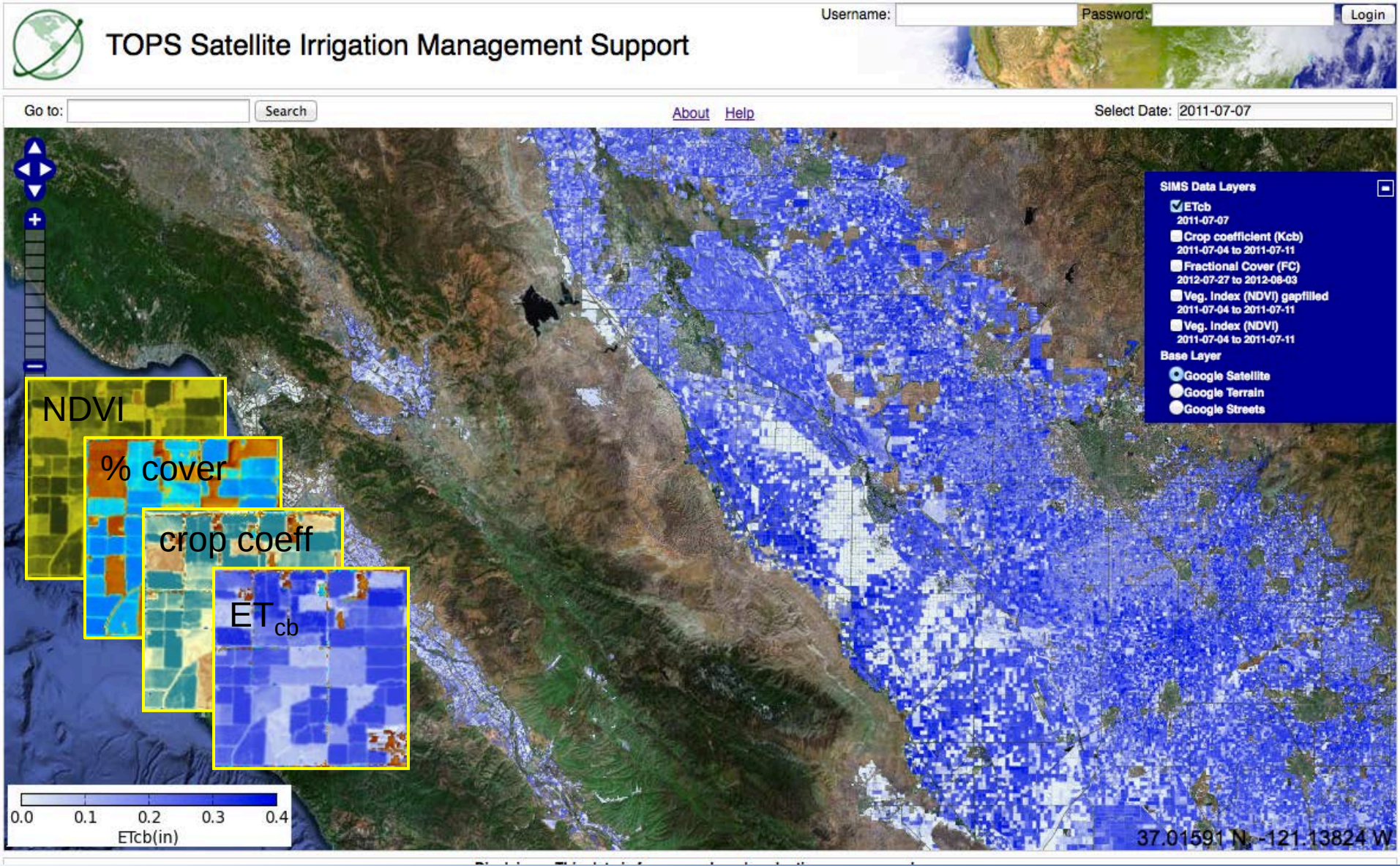
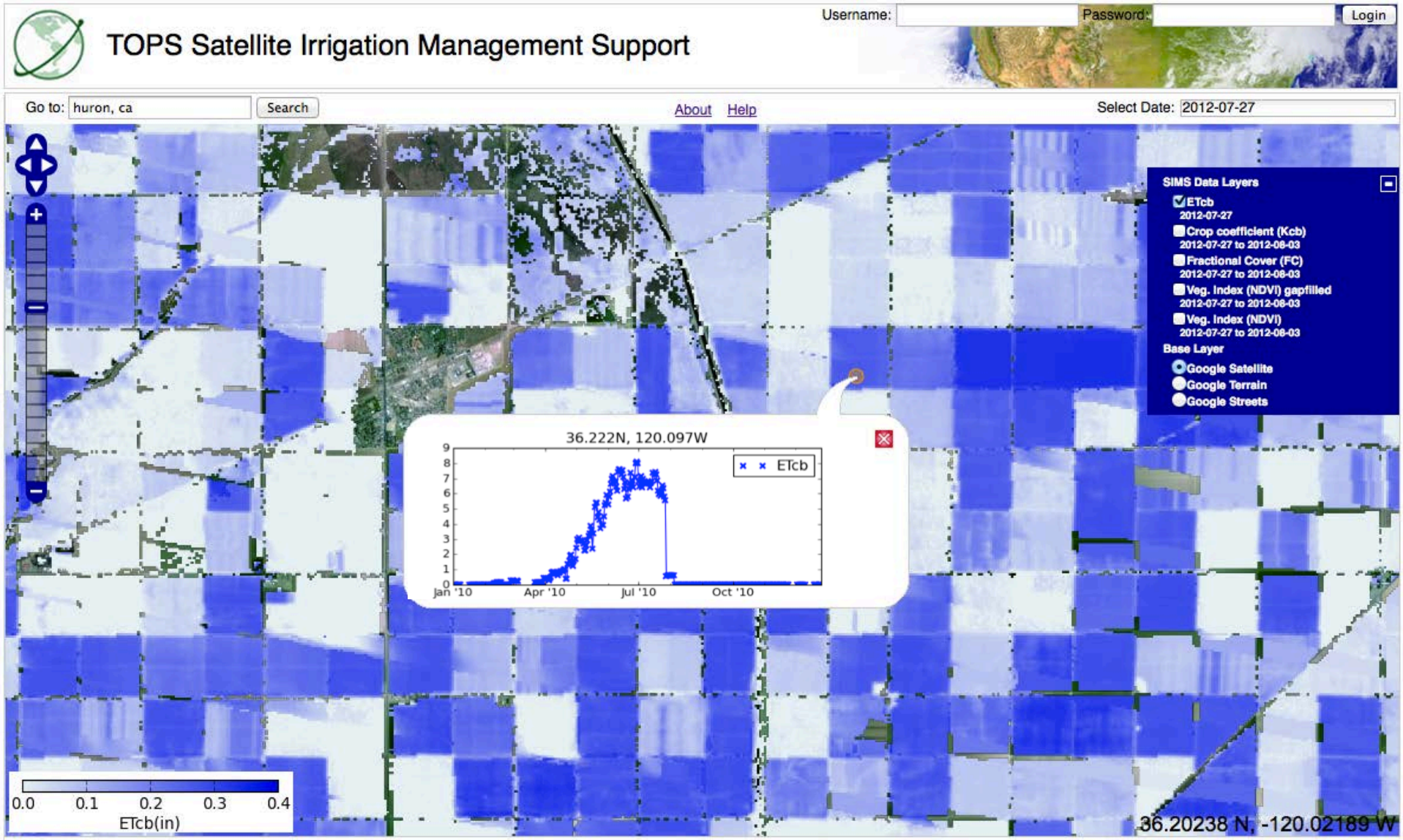
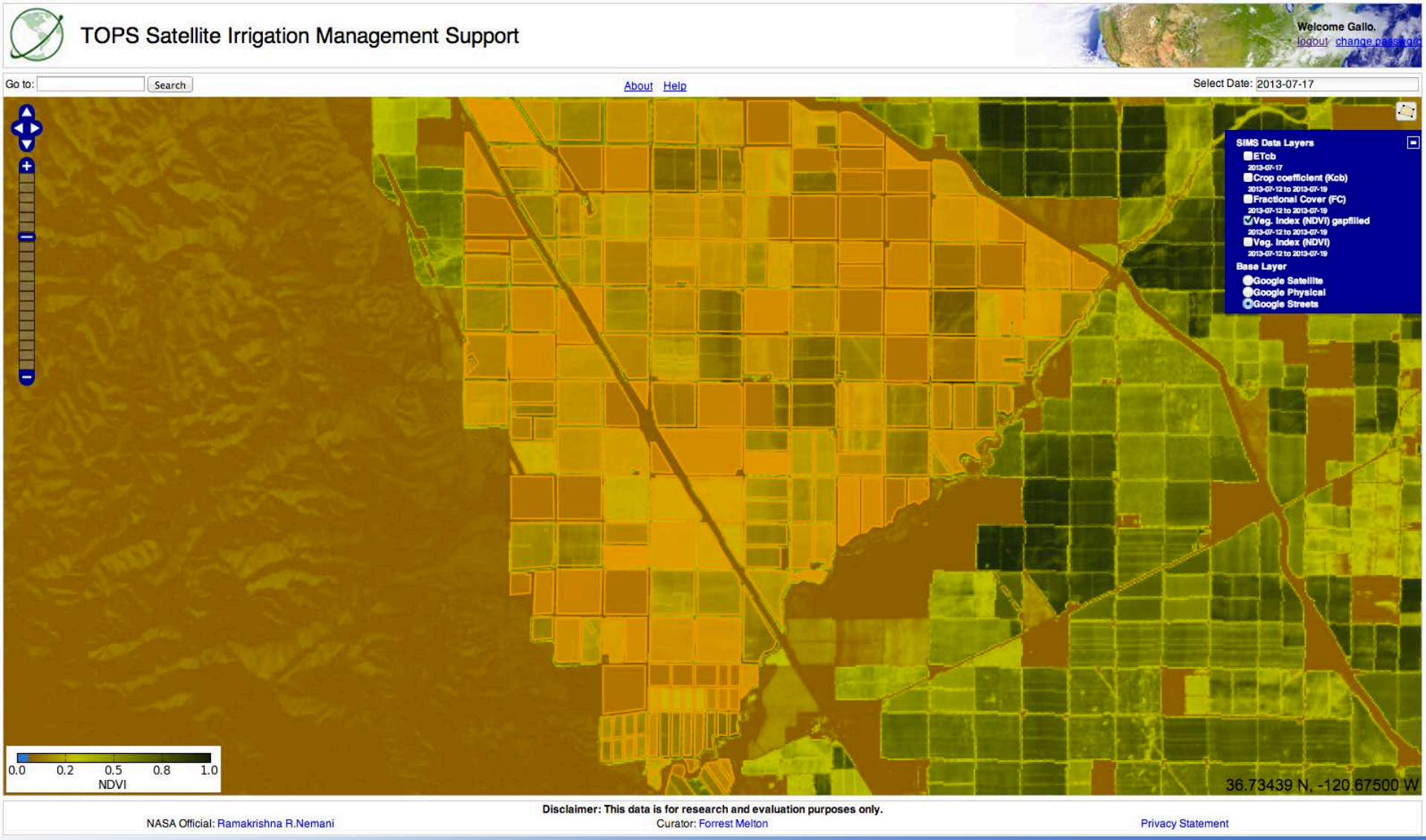
Satellite Irrigation Management Support (SIMS) Framework



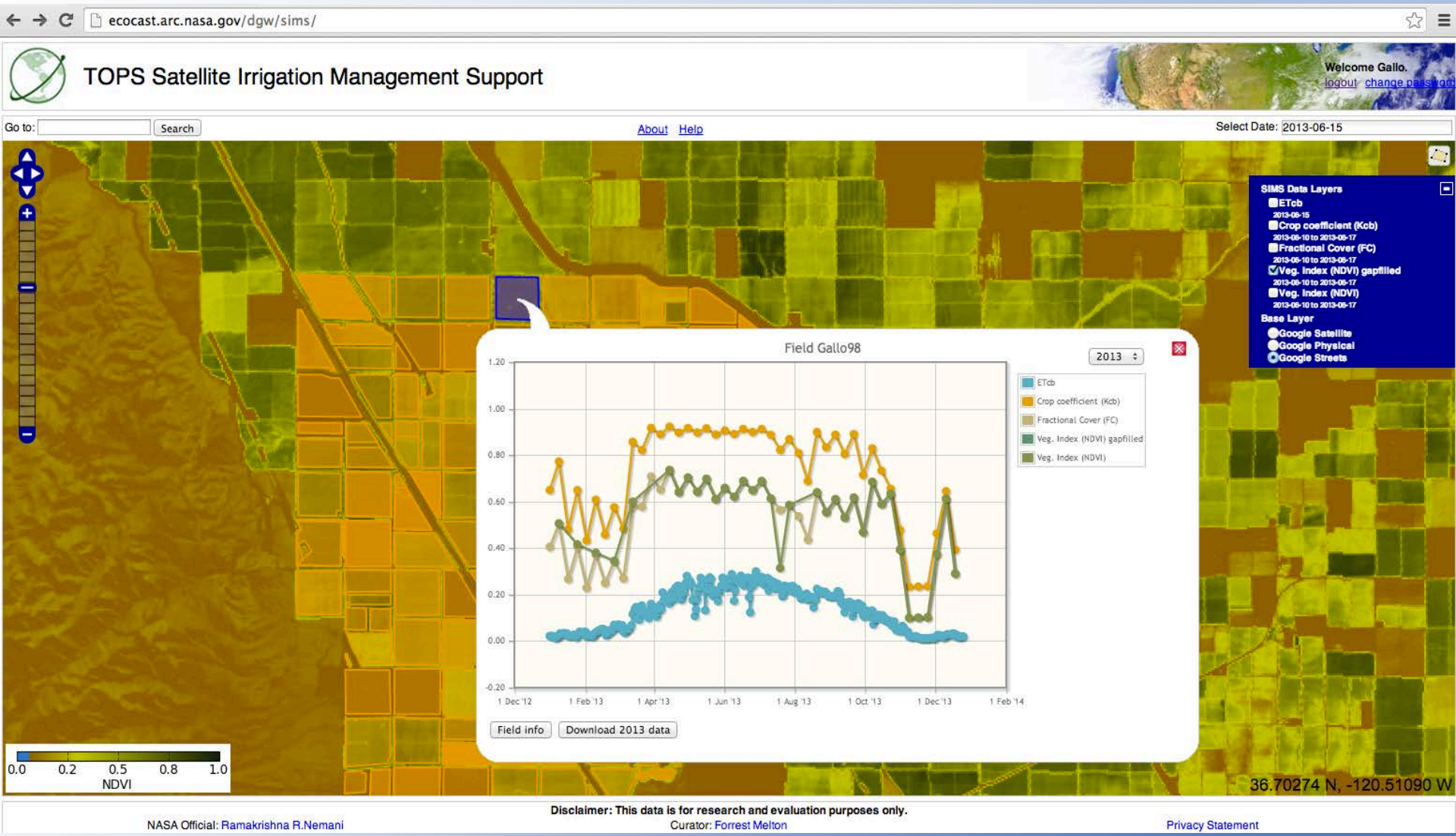
Satellite Irrigation Management Support (SIMS) Framework



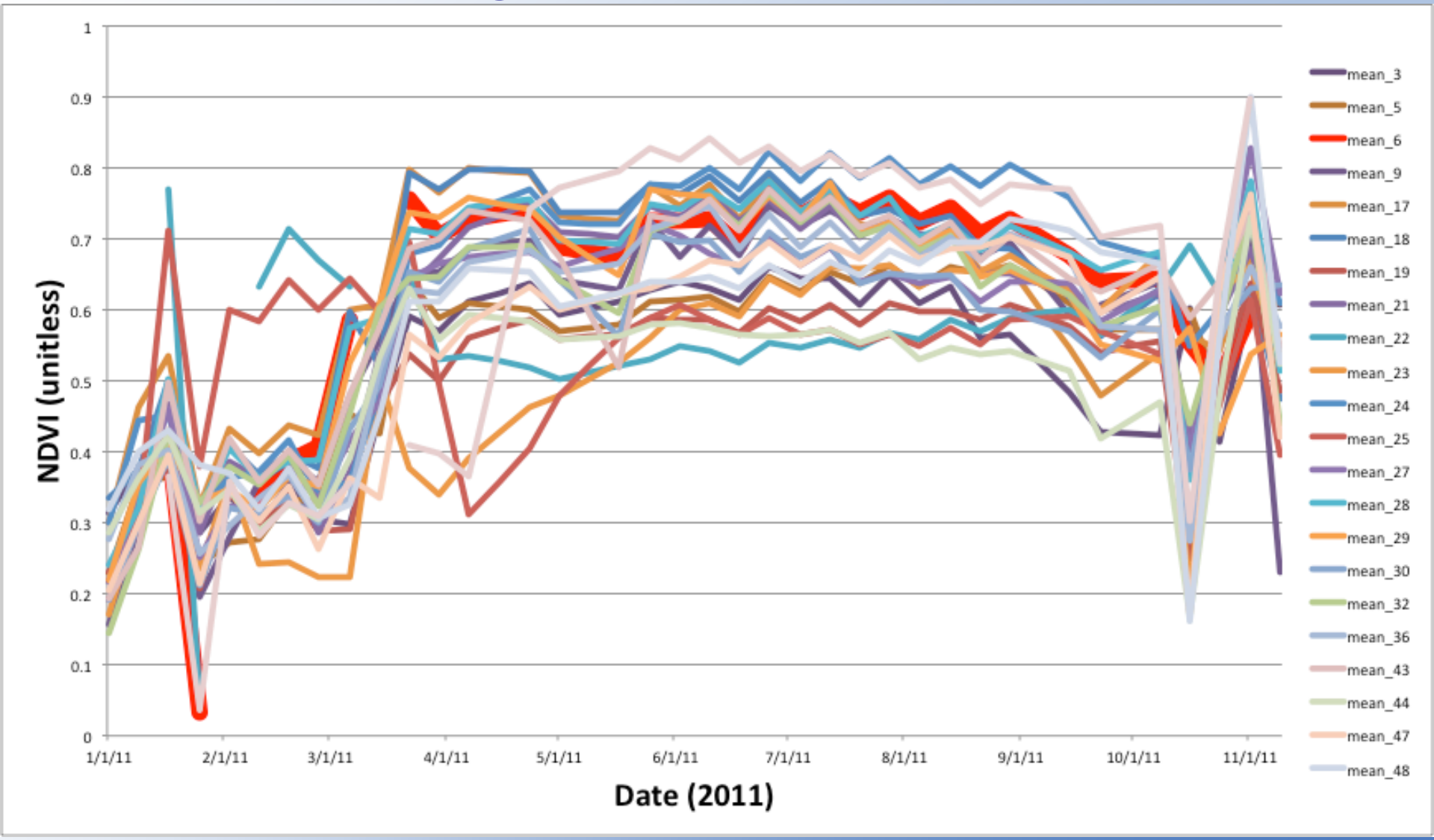
Tracking Conditions Across Fields



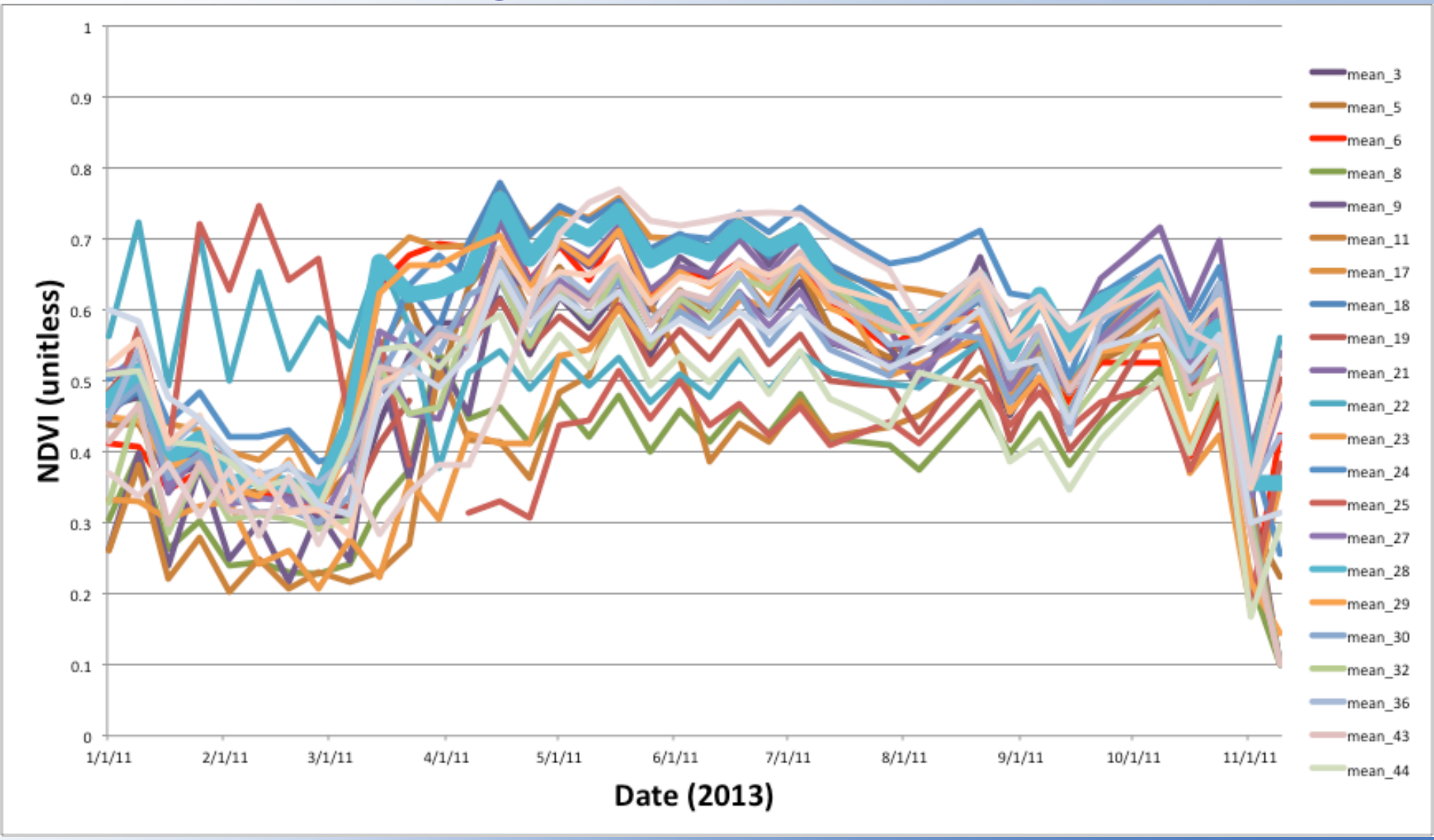
Tracking Conditions Across Fields



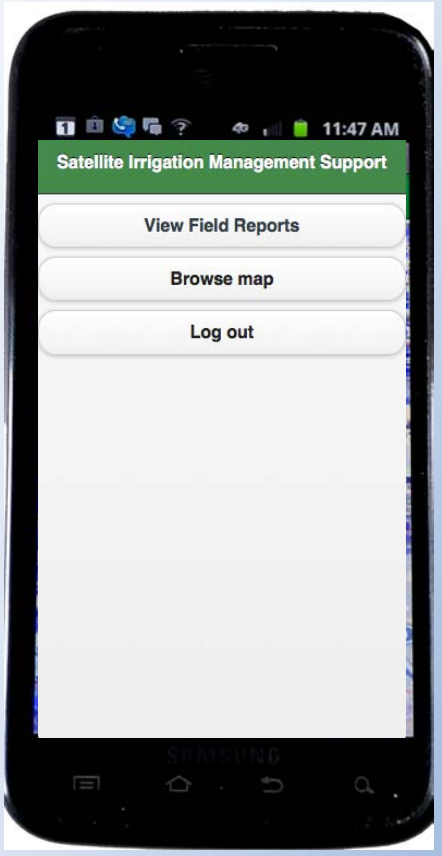
Tracking Conditions Across Years

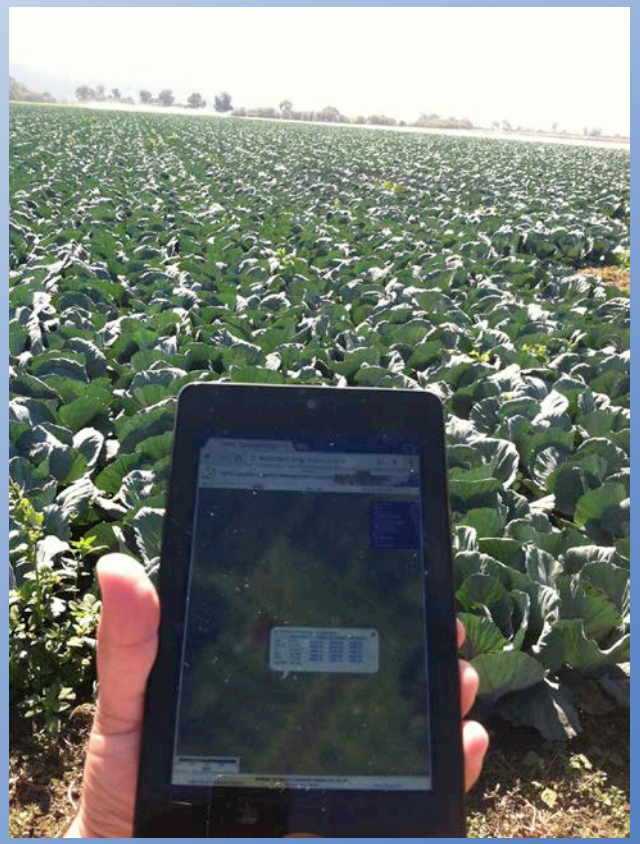


Tracking Conditions Across Years



Delivering Data to the Field: Mobile Interfaces





Mobile-based interfaces important for enhancing access to data

Field Validation Strategy

Goal: Calculate daily ET for a wide range of crops and growth forms (graminoids, short forbs, tall forbs, vines, and trees) using two cost-effective and independent approaches at each site.

Approach 1) Water Balance: $ET = P + I - D - \Delta S$

Where ET is evapotranspiration, P is precipitation, I is irrigation, D is drainage below the root zone, and ΔS is change in volumetric water content

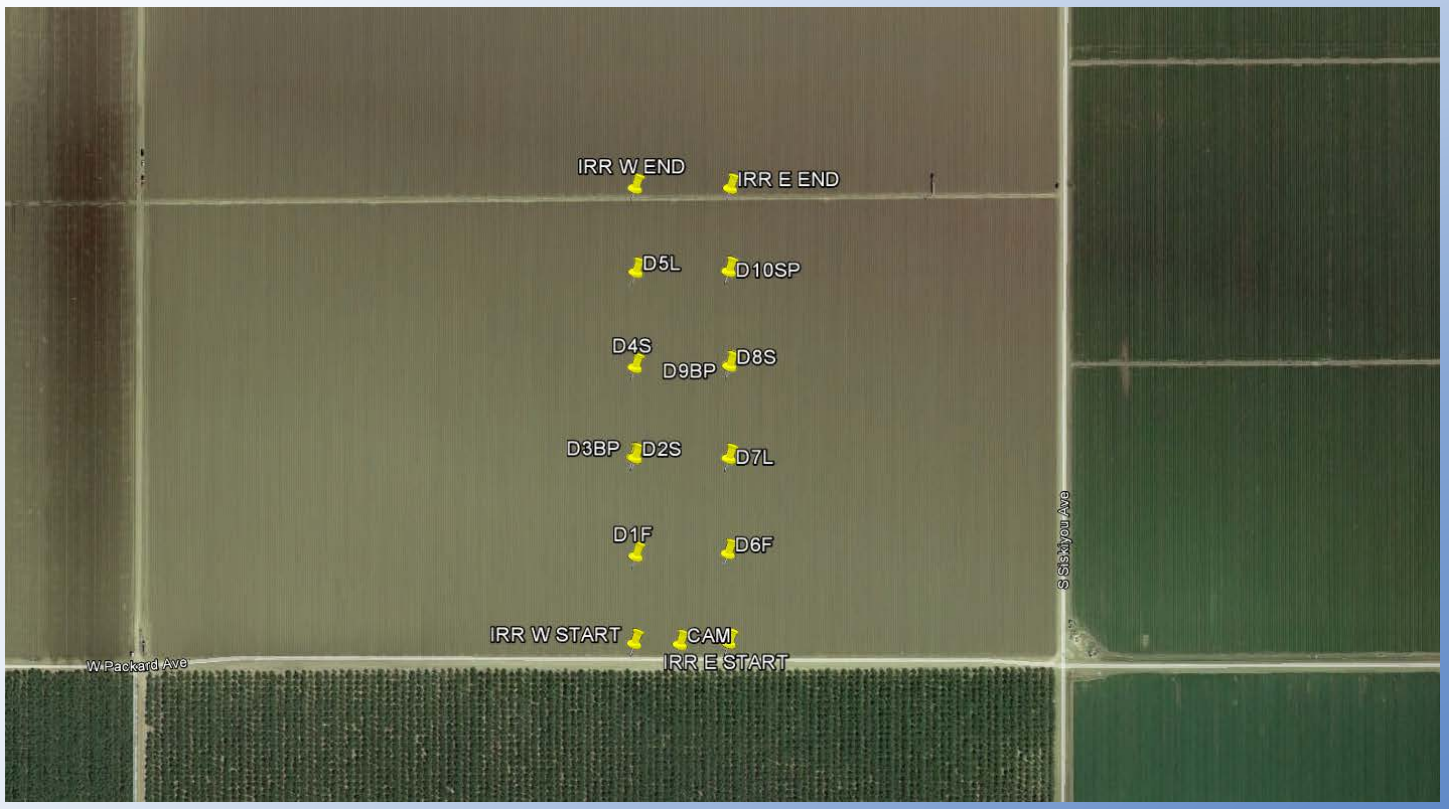
Approach 2) Surface Renewal Energy Balance:

$$ET = R_n - H - G$$

Where ET is evapotranspiration, R_n is net radiation, H is sensible heat flux, and G is ground heat flux

Verification and Validation: Sensor Networks

Instrumentation Layout



Point configuration (10):

- P1 10HS 0-4”
- P2 10HS 12-16”
- P3 10HS 24-28”
- P4 MPS-1 14”
- P5 10HS 36-40” / G3 Passive Capillary Lysimeter 44”

Other Instruments:

- SR station
- MET station
- In-line flow meter

Site Info:

- Block #4
- Bed Width: 60”
- Furrow: 20”
- Between plants 20”
- Transplant-Double row
- 12” emitter spacing
- South to North flow

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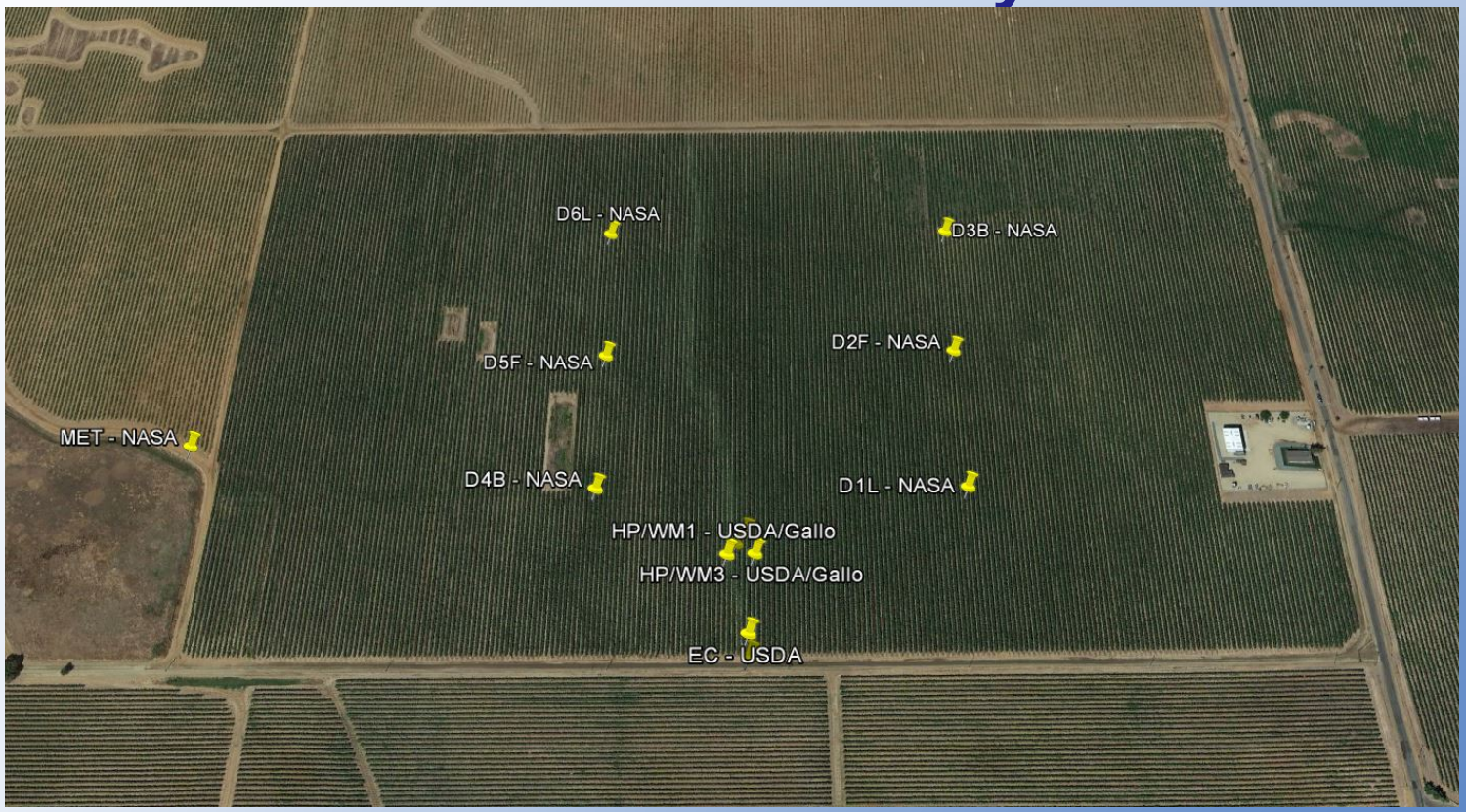
Instrumentation Layout

S



N

Point configuration (8):

- P1 10HS 0-4”
- P2 10HS 16-22”
- P3 10HS 32-36”
- P4 MPS-1 18”
- P5 10HS 48-52” / G3 Passive Capillary Lysimeter

Other Instruments:

- USDA Eddy Covariance
- MET station
- In-line flow meter

Site Info:

- Row Width: 130”
- Vine spacing: 60”
- Dimensions: Aisle CC12”
- Cover crop: grass

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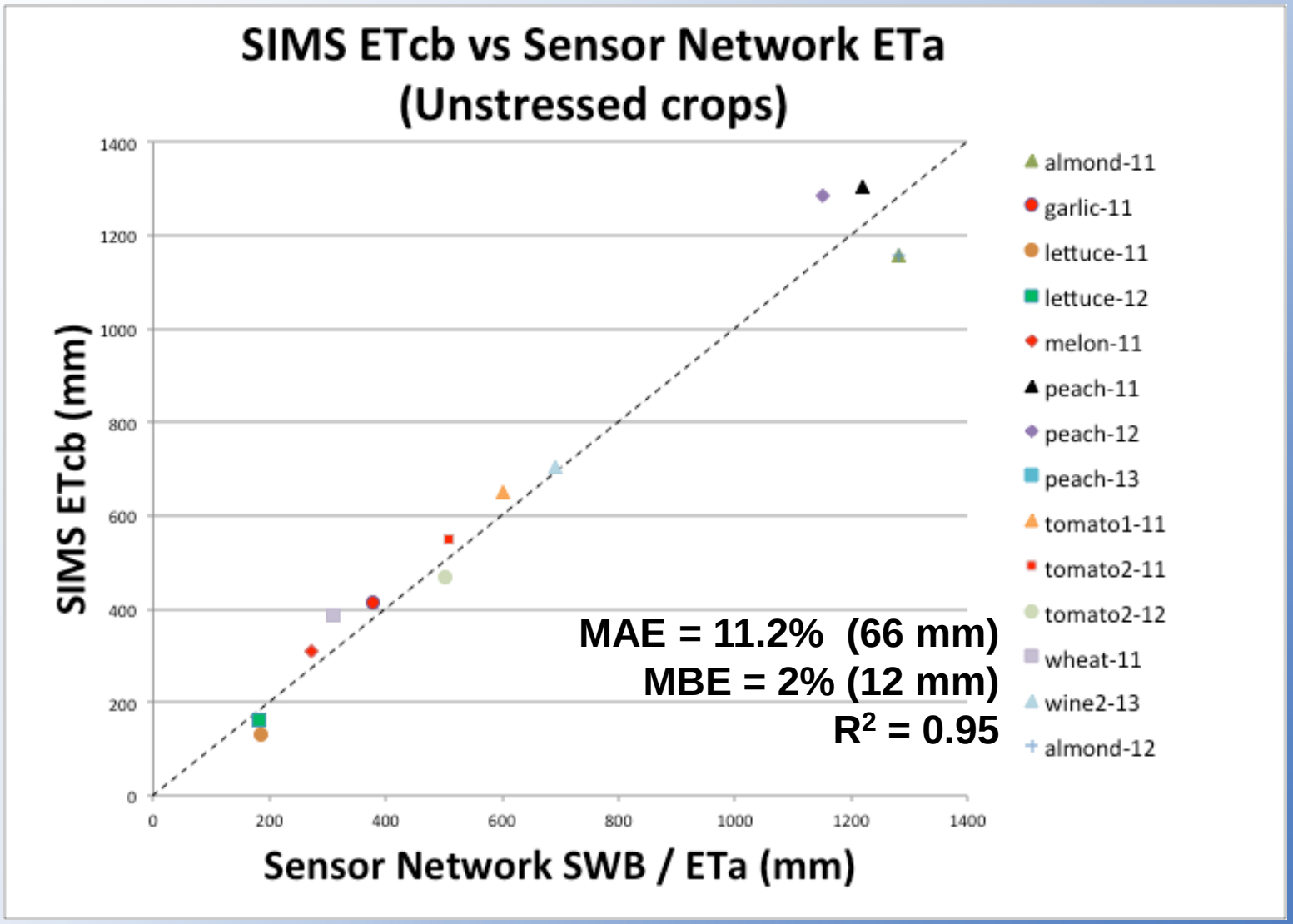
Sensor Network Installations

Crop Type	Crop	Location
Grain	Corn*	CSU Fresno
Grain	Wheat	San Joaquin Valley
Row	Garlic	San Joaquin Valley
Row	Lettuce*	SJ & Salinas Valley
Row	Broccoli*	Salinas Valley
Row	Cauliflower	San Joaquin Valley
Row	Tomato(2)*	San Joaquin Valley
Row	Cotton (drip)*	San Joaquin Valley
Vine	Melon	San Joaquin Valley
Vine	Wine grapes*	Salinas Valley
Vine	Raisins*	San Joaquin Valley
Tree	Peach*	San Joaquin Valley
Tree	Almond*	San Joaquin Valley
Tree	Orange*	San Joaquin Valley

***Surface renewal instrumentation.**

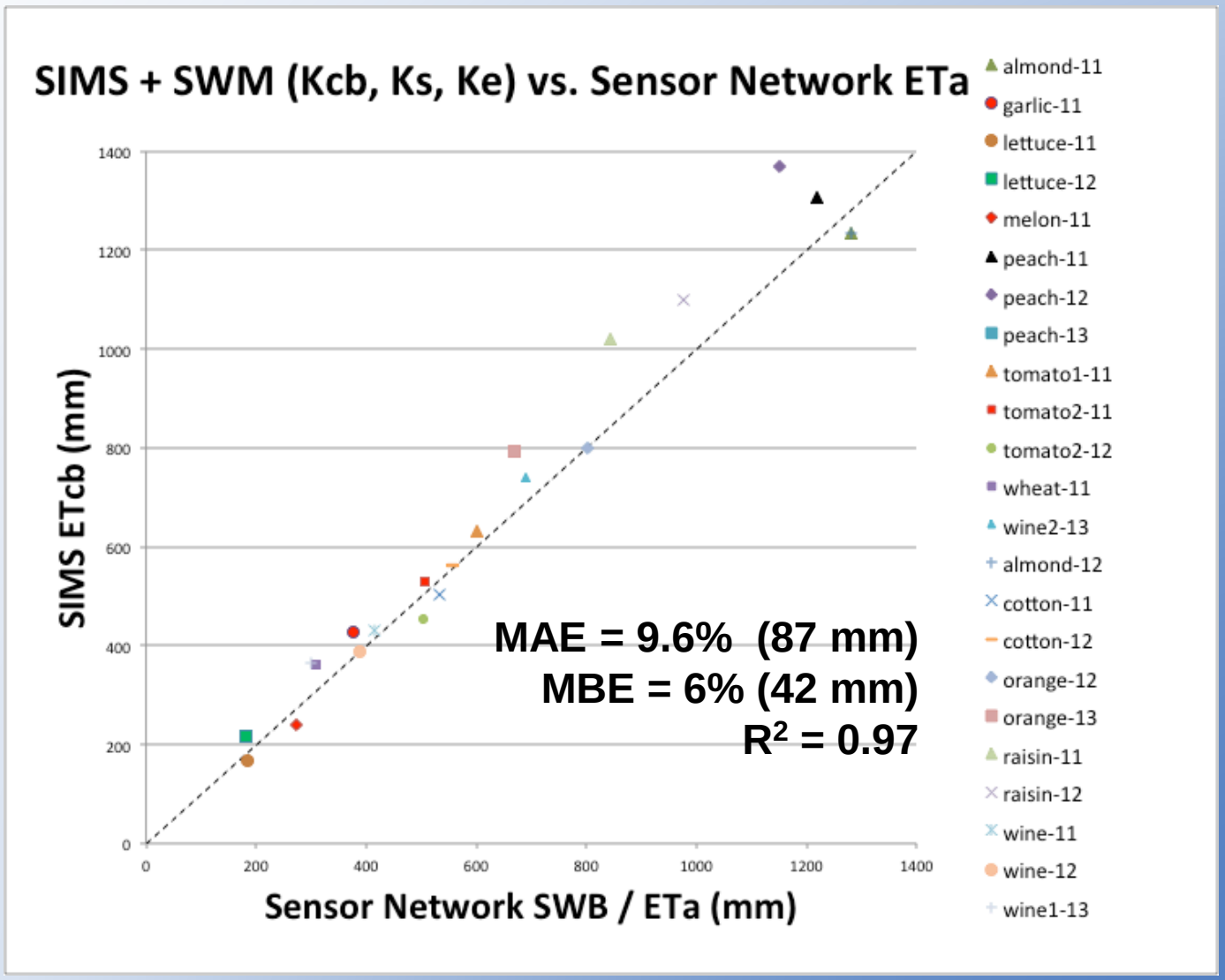
Chris Lund, Kirk Post NASA ARC/CSUMB

Verification and Validation: Results to date



Comparison of seasonal ET totals from SIMS and the sensor network for sites instrumented in 2011-2013, excluding intentionally stressed crops (wine grapes, raisins, cotton, oranges).

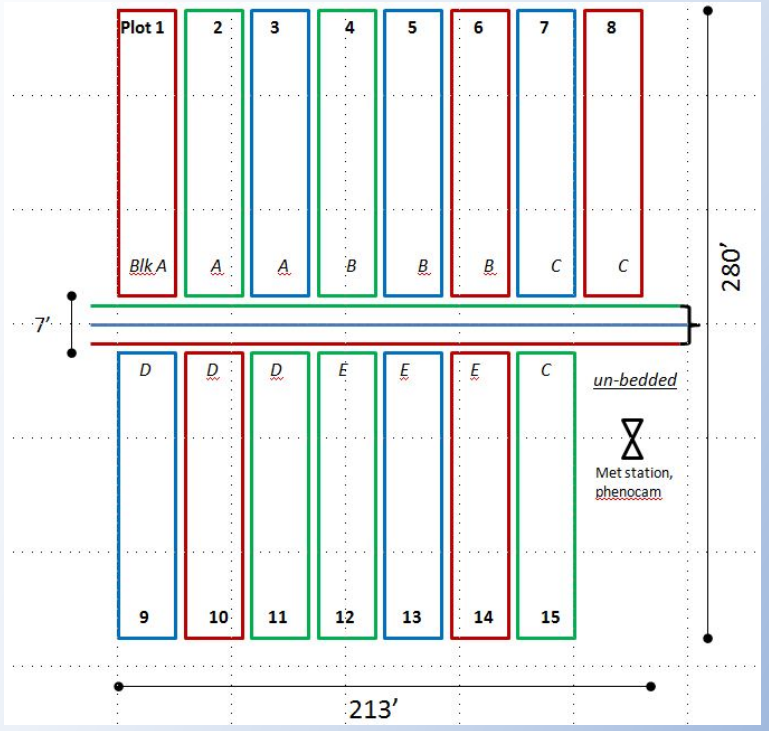
Verification and Validation: Results to date



Comparison of seasonal ET totals from SIMS and the sensor network for sites instrumented in 2011-2013. Ke and Ks coefficient via a soil water balance model based on FAO-56 (Allen et al., 1998).

Yield Trials

Lettuce & Broccoli
USDA ARS, Spence Road, Salinas



Treatments:

- Standard practice
- SIMS
- CropManage

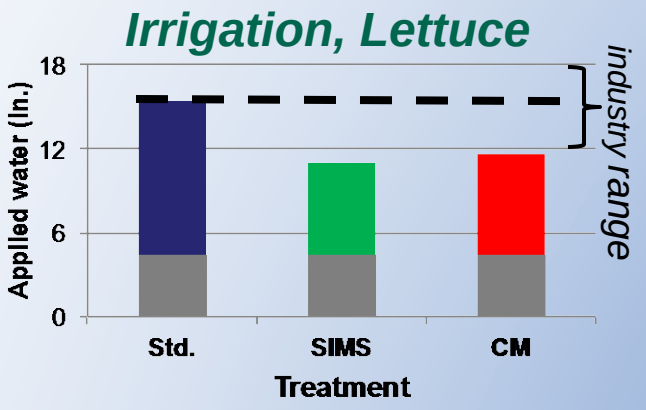
- **3 tmts, 5 reps, block randomized design**
- **Total area: ~1.4ac (0.57 ha)**
- **Two years of data: 2012 & 2013**

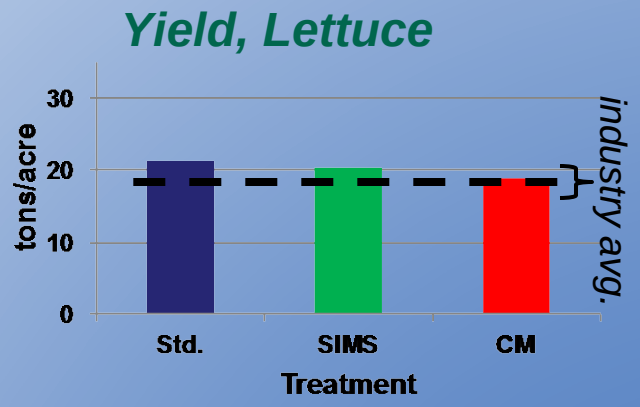
PI: Lee Johnson; Co-I: Michael Cahn
Collaboration with UCCE, USDA ARS, Fresh Express, Tanimura & Antle

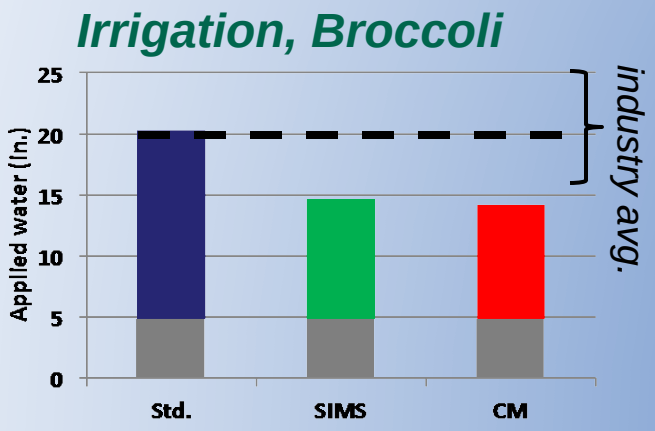
Yield Trials: Results to Date

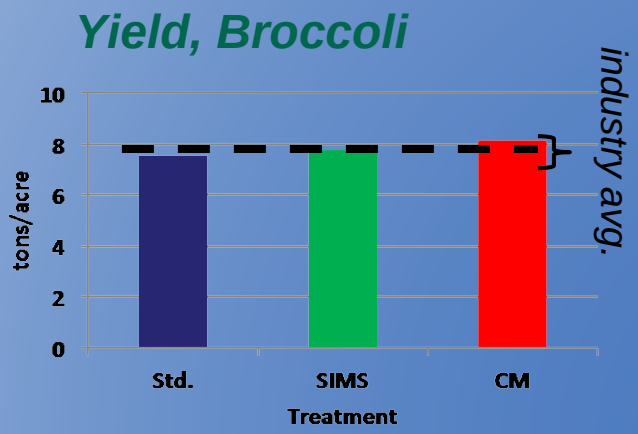
- Results to date confirm savings in applied water of 22-33% without reductions in yield or quality

Standard practice
SIMS
CropManage









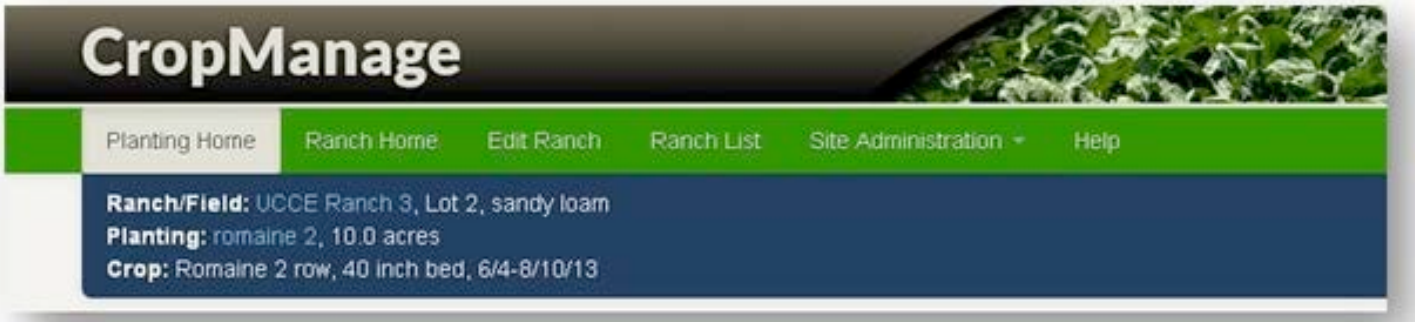
Next Steps

1. Yield vs irrigation trials at demonstration sites with interested growers → results for lettuce and broccoli encouraging

2. Completion of API for integration with CropManage, Vineyard Soil Irrigation Model (VSIM), and other irrigation scheduling tools

3. Development of additional data interfaces
   - CSV/Excel?
   - Field summaries for mobile devices (key stats and satellite imagery)?
   - Are crop coefficients and ET enough, or are irrigation system run times required?

API for Integration with Other Web-based Tools



Irrigation Summary

Show / Hide Columns | Reset Column Order | Show Previous Columns | Show Next Columns

Water Date	Irrigation Method	Recommended Irrigation Interval (days)	Recommended Irrigation Amount (inches)	Recommended Irrigation Time (hours)	Irrigation Water Applied (inches)	Kc	Canopy Cover (%)	Average Reference ET (inches/day)	Total Crop ET (inches)
6/4/13	Germination Sprinkler	N/A	N/A	N/A	0.75 in	0.00	0	0.00	0.00
6/5/13	Germination Sprinkler	1.6	0.22 in	0.72 hrs	0.45 in	1.00	0	0.14	0.14
6/7/13	Germination Sprinkler	1.9	0.36 in	1.18 hrs	0.30 in	0.70	0	0.17	0.23
6/9/13	Germination Sprinkler	1.7	0.39 in	1.29 hrs	0.45 in	0.70	0	0.18	0.25
6/12/13	Sprinkler	3.1	0.28 in	0.95 hrs	0.30 in	0.48	1	0.15	0.21
6/16/13	Sprinkler	2.9	0.40 in	1.33 hrs	0.45 in	0.37	1	0.20	0.30
Totals			1.64 in	5.47 hrs	2.70 in				1.13 in

New Watering | View Rainfall Data

First Previous 1 Next Last

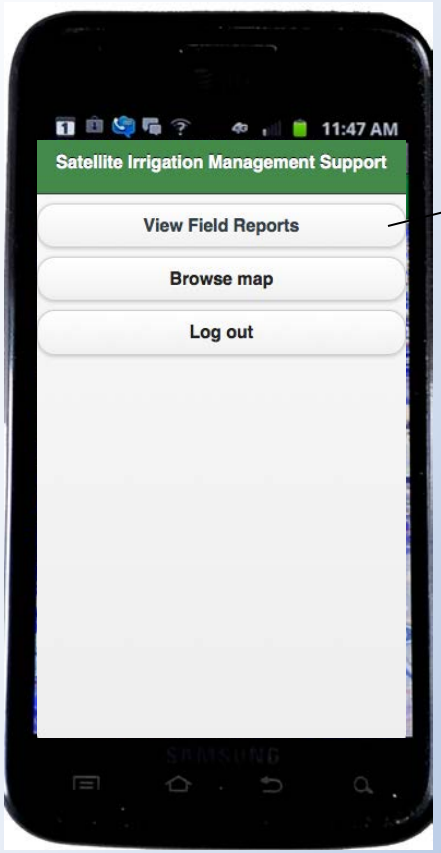
Show All Rows

Automated Daily Summaries for Individual Fields/Lots/Blocks/Ranches

Mean Evapotranspiration

	Block Name							
Date	001-01	001-02	001-03	001-04	001-05	001-06	001-07	001-08
2014-01-01-00	0.012044	0.00799	0.014516	0.017353	0.017395	0.010055	0.013572	0.013572
2014-01-02-00	0.01126	0.007469	0.013571	0.016223	0.016262	0.009401	0.012688	0.012688
2014-01-03-00	0.011418	0.007574	0.013761	0.016451	0.01649	0.009532	0.012866	0.012866
2014-01-04-00	0.010703	0.0071	0.0129	0.015421	0.015457	0.008936	0.012061	0.012061
2014-01-05-00	0.013896	0.009218	0.016748	0.020021	0.020069	0.011601	0.015659	0.015659
2014-01-06-00	0.011302	0.007497	0.013621	0.016283	0.016322	0.009436	0.012735	0.012735
2014-01-07-00	0.010154	0.006736	0.012238	0.014629	0.014664	0.008477	0.011442	0.011442
2014-01-08-00	0.012152	0.008061	0.014646	0.017508	0.01755	0.010145	0.013693	0.013693
2014-01-09-00	0.013172	0.012813	0.008339	0.024133	0.015088	0.01341	0.010982	0.016723
2014-01-10-00	0.017201	0.016732	0.010889	0.031515	0.019703	0.017511	0.014342	0.021839
2014-01-11-00	0.011829	0.011506	0.007488	0.021673	0.01355	0.012042	0.009863	0.015018
2014-01-12-00	0.01158	0.011264	0.007331	0.021217	0.013265	0.011789	0.009655	0.014702
2014-01-13-00	0.01193	0.011605	0.007553	0.021858	0.013666	0.012146	0.009947	0.015147
2014-01-14-00	0.012204	0.011872	0.007726	0.022361	0.01398	0.012425	0.010176	0.015495
2014-01-15-00	0.014323	0.013933	0.009068	0.026243	0.016407	0.014582	0.011942	0.018185
2014-01-16-00	0.014937	0.01453	0.009456	0.027368	0.017111	0.015207	0.012454	0.018965
2014-01-17-00	0.019621	0.012992	0.013451	0.029915	0.017275	0.017275	0.02506	0.02346
2014-01-18-00	0.019687	0.013036	0.013496	0.030015	0.017333	0.017333	0.025144	0.023538
2014-01-19-00	0.019485	0.012902	0.013358	0.029708	0.017155	0.017155	0.024886	0.023297
2014-01-20-00	0.019709	0.013051	0.013512	0.030049	0.017352	0.017352	0.025173	0.023565

Mobile Interface for Irrigators?



Field Ryan Palm, Peach

ETcb	2013-12-26: **0.022316**
Crop coefficient (Kcb)	2013-12-19: **0.508576**
Veg. Index (NDVI)	2013-12-19: **0.413906**
Veg. Index (NDVI) gapfilled	2013-12-19: **0.413906**
Fractional Cover (FC)	2013-12-19: **0.423514**

Back to my fields

- Add summary by date range
- Add latest satellite image for field
- Convert ET to runtimes?

Questions

1) What tools are growers currently using to schedule irrigation?

2) With training support, is there capacity to move beyond hard copy irrigation schedules?

3) Is ET sufficient, or are irrigation run-times required?

4) Is it better to target tools toward irrigators or irrigation consultants and growers?

5) Are new tools needed, or is integration with existing or emerging tools a better strategy?

6) Other advice or recommendations?

Project Team

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Partners:

CA Dept. of Water Resources, Western Growers Association, Center for Irrigation Technology / CSU Fresno, USDA ARS / NRCS, Univ. of California Cooperative Extension, USGS, Booth Ranches, Chiquita, Constellation Wines, Del Monte Produce, E & J. Gallo, Farming D, Fresh Express, Pereira Farms, Ryan Palm Farms, Tanimura & Antle

Interagency and public-private partnerships are critical to addressing major water management challenges in California.

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Thank you

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