Satellite Irrigation Management Support with the Terrestrial Observation and Prediction System

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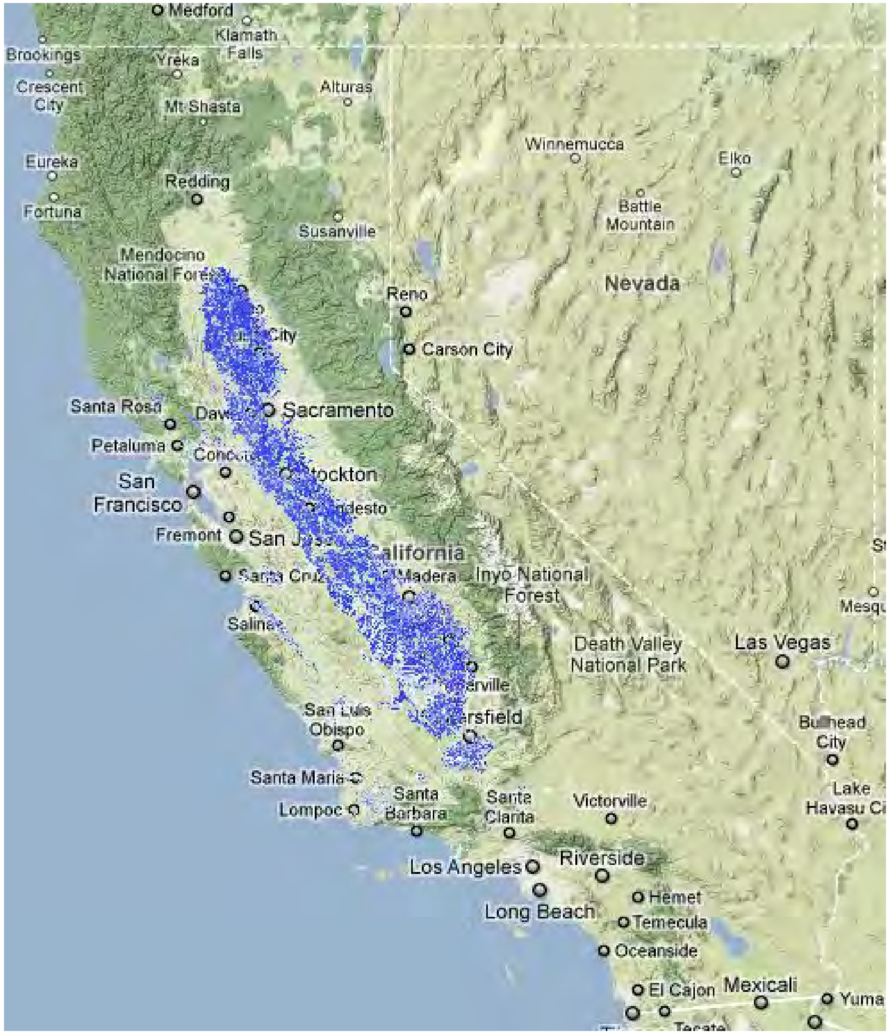
Project Team:
Ecological Forecasting Lab
CSU Monterey Bay & NASA ARC, Moffett Field, CA

Partners:
California Department of Water Resources
Western Growers Association
Center for Irrigation Technology, CSU Fresno
USDA Agricultural Research Service / NRCS
Univ. of California, Cooperative Extension
USGS
Booth Ranches
Chiquita
Constellation Wines
Del Monte Produce
Farming D
Fresh Express
Periera Farms
Ryan Palm Farms
Tanimura & Antle



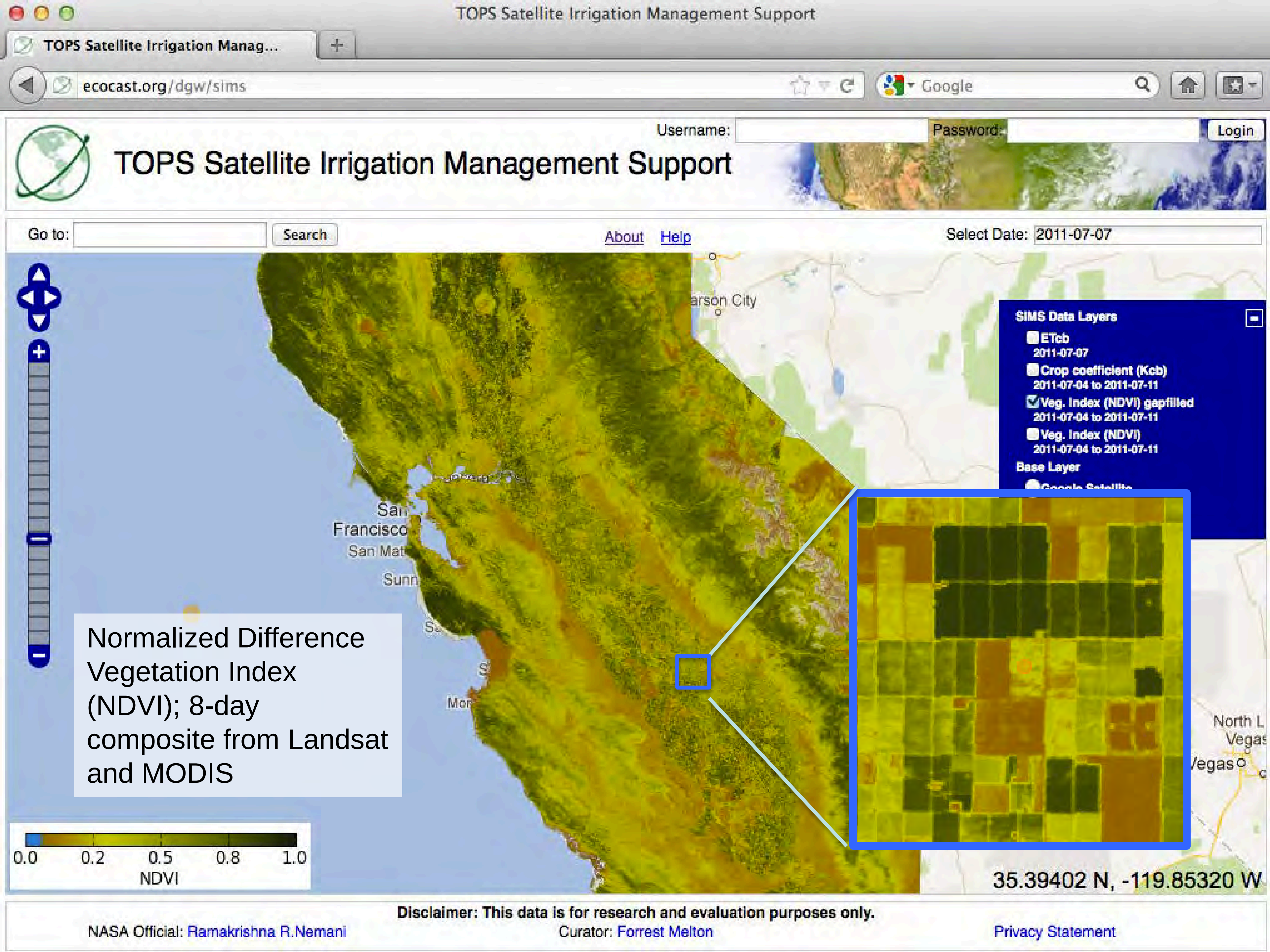
Support for this project provided by the NASA Applied Sciences Program, CSU Agricultural Research Initiative, CDFA

Remote Sensing of Western Water
San Diego, CA
Sept. 28, 2012

Satellite Data

Landsat (TM / ETM+)
(30m / 0.25 acres)

Terra / Aqua (MODIS)
(250m / 15.5 acres)



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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)
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NDVI
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Curator: Forrest Melton
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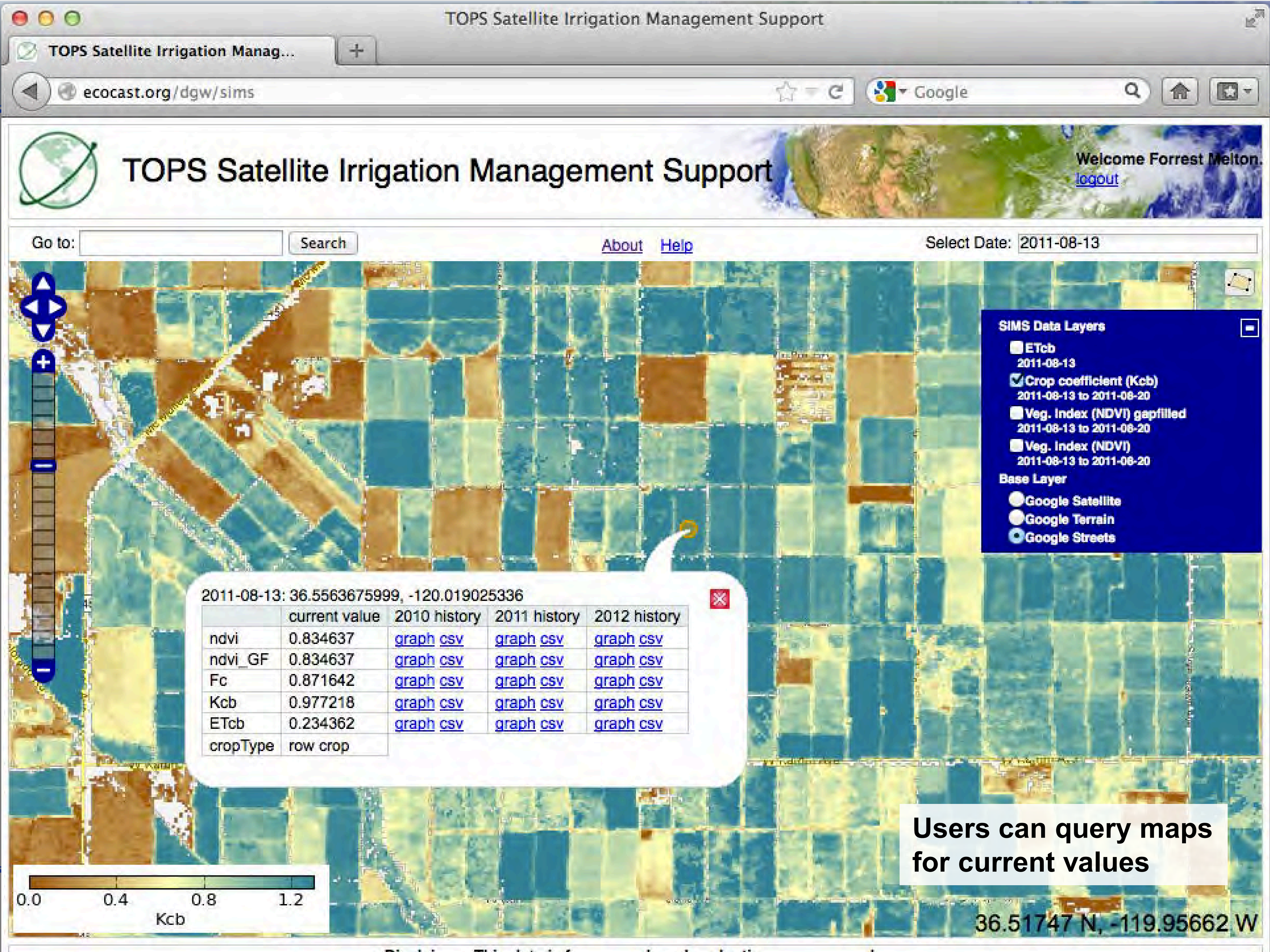
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2011-08-13
Crop coefficient (Kcb)
2011-08-13 to 2011-08-20
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Veg. Index (NDVI)
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Base Layer
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Kcb 0.977218 graph csv graph csv graph csv
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Kcb
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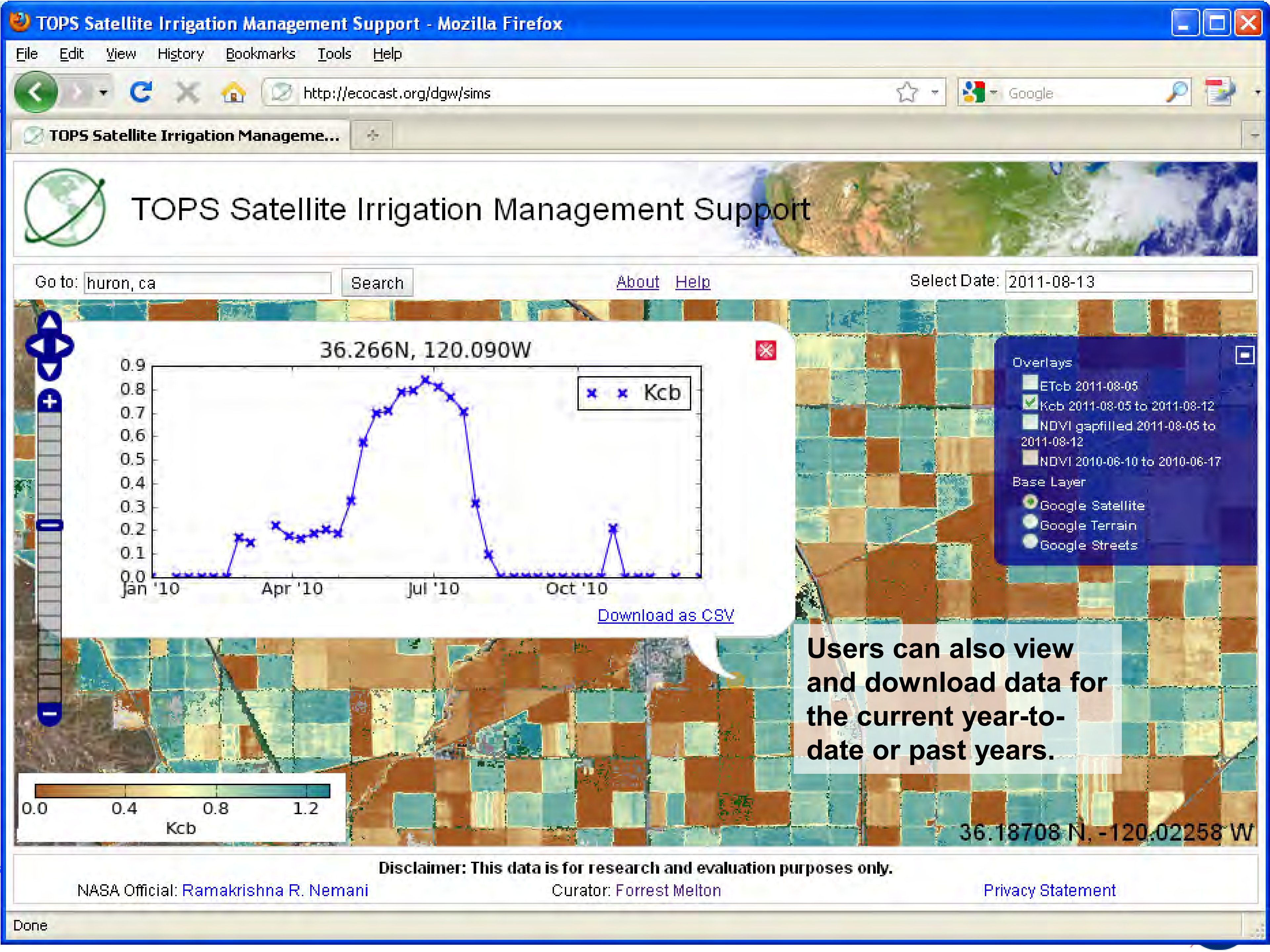
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Jan '10
Apr '10
Jul '10
Oct '10
Download as CSV
Overlays
ETcb 2011-08-05
Kcb 2011-08-05 to 2011-08-12
NDVI gapfilled 2011-08-05 to 2011-08-12
NDVI 2010-06-10 to 2010-06-17
Base Layer
Google Satellite
Google Terrain
Google Streets
Users can also view and download data for the current year-to-date or past years.
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0.4
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1.2
Kcb
36.18708 N, -120.02258 W
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Done

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

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

CIMIS → ET_o
(AgriMet, AZMET, CoAgMet)

satellite → K_{cb}

Standard K_c Profile (manual)

Hypothetical Crop Coefficient (K_c) Curve for Typical Field and Row Crops Showing Growth Stages and Percentages of the Season from Planting to Critical Growth Dates

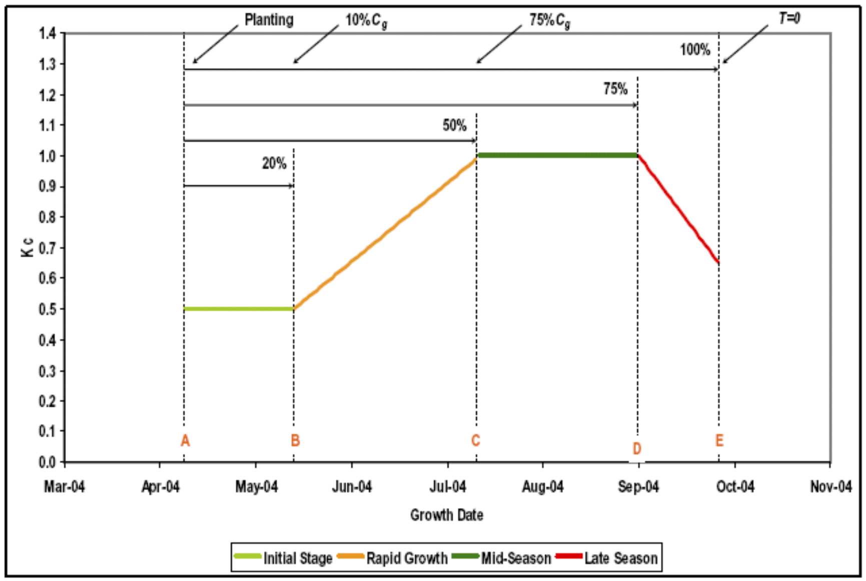
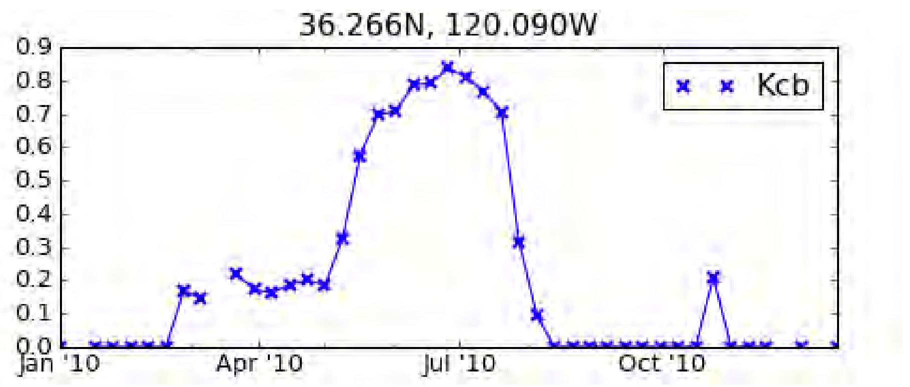
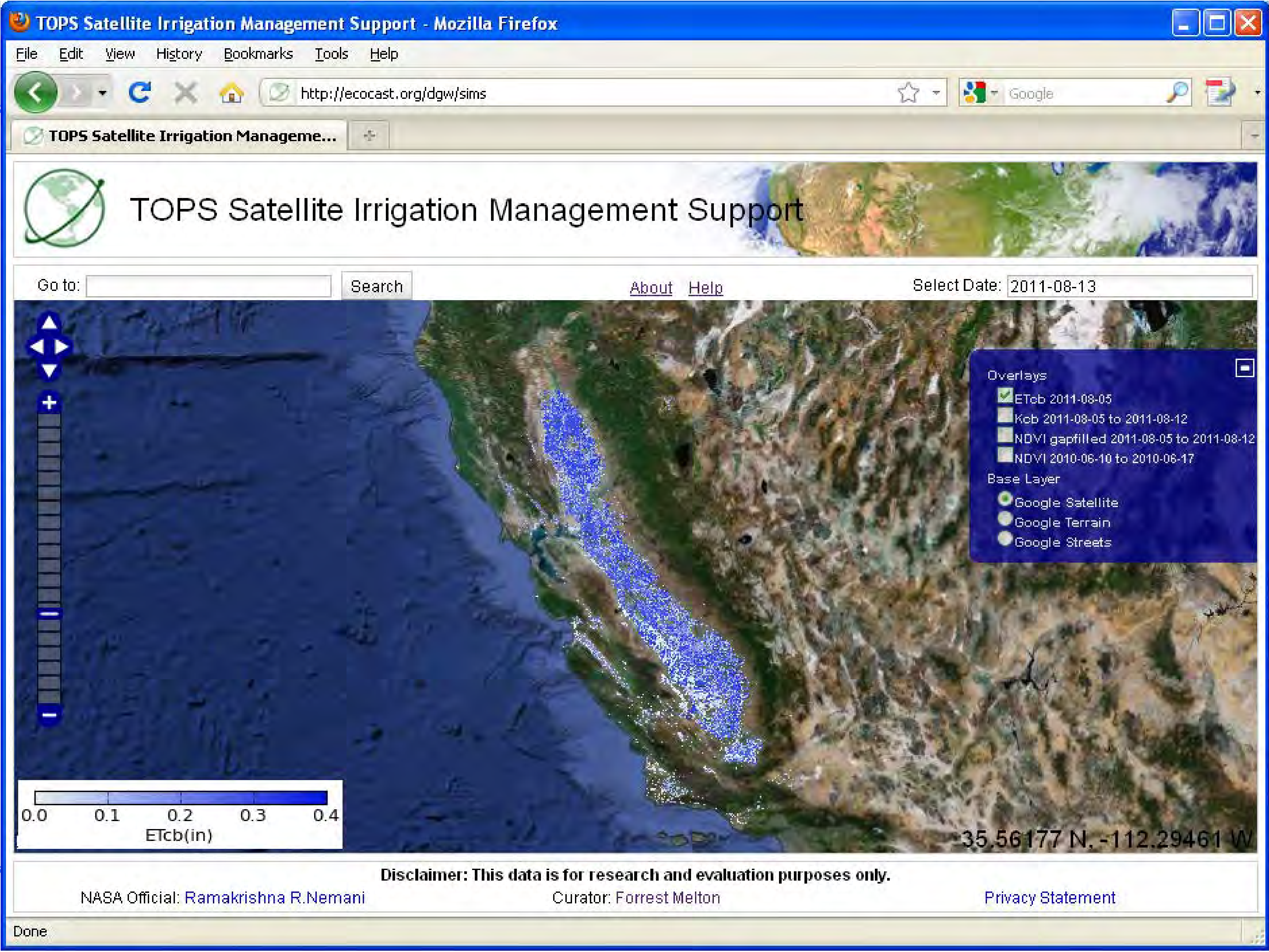


Figure credit: 2005 California Water Plan Update

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

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Overlays
ETcb 2011-08-05
Kcb 2011-08-05 to 2011-08-12
NDVI gapfilled 2011-08-05 to 2011-08-12
NDVI 2010-06-10 to 2010-06-17
Base Layer
Google Satellite
Google Terrain
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0.0 0.1 0.2 0.3 0.4
ETcb(in)
35.56177 N, -112.29461 W
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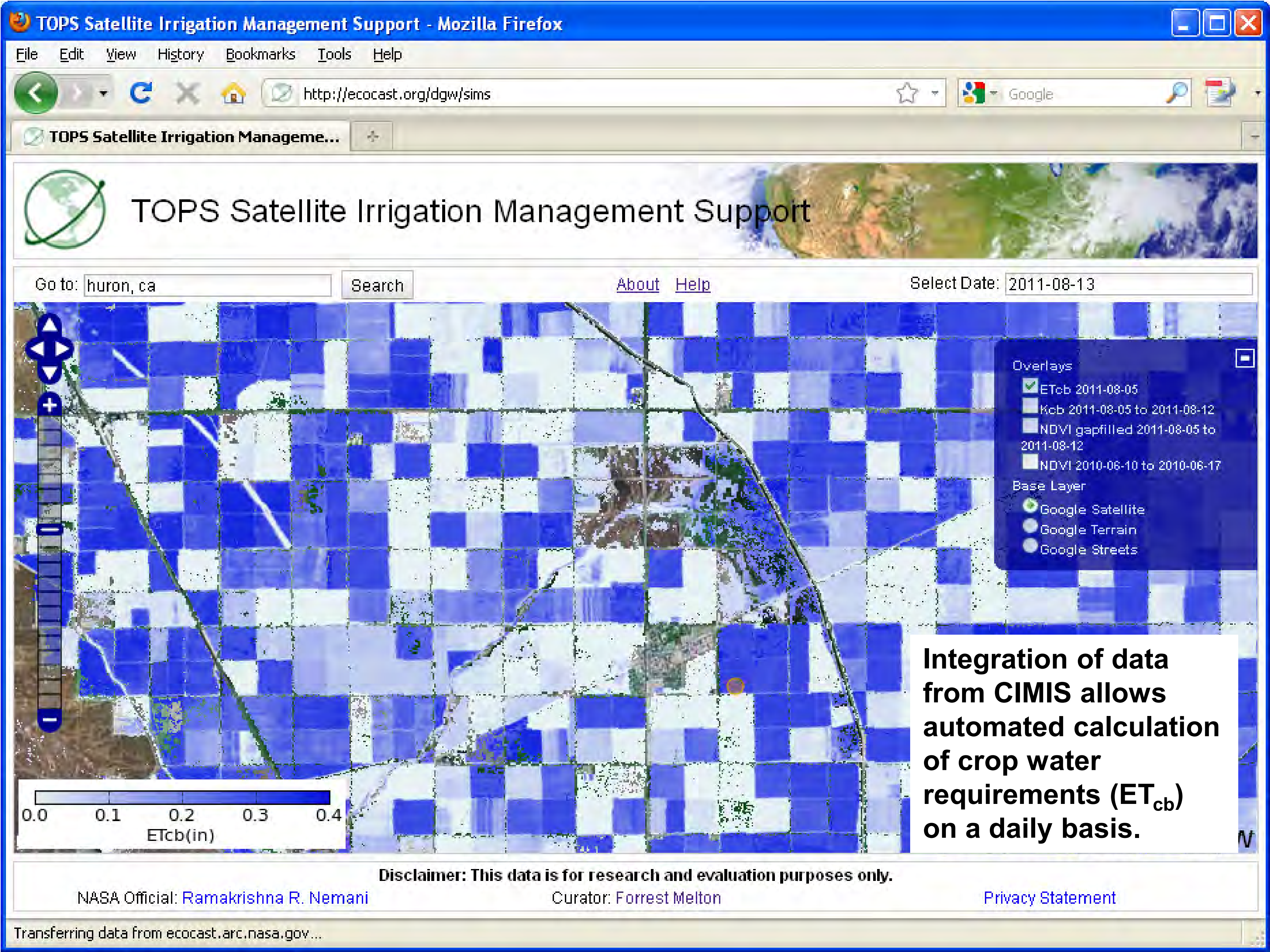
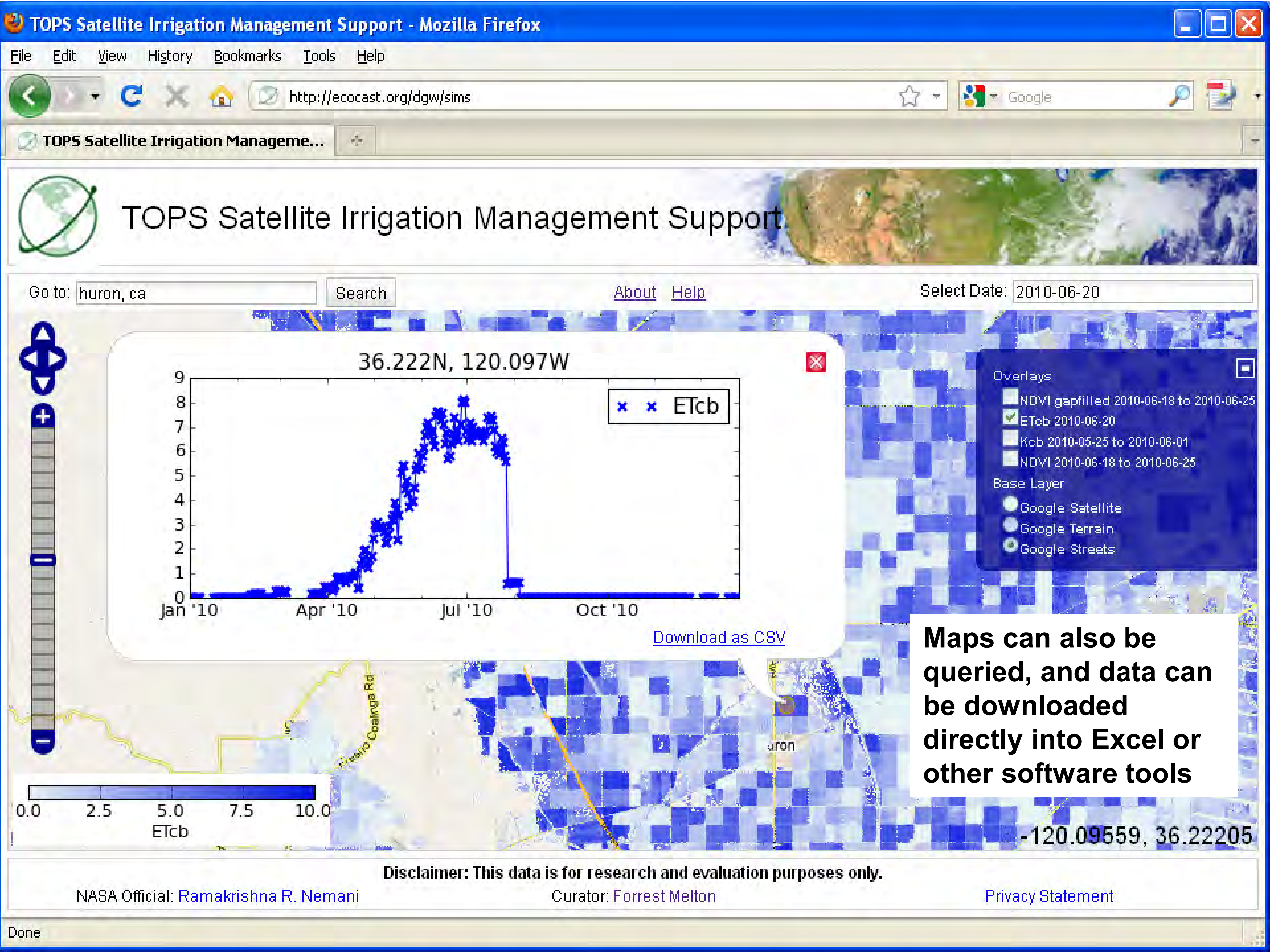
Done



Integration of data from CIMIS allows automated calculation of crop water requirements (ET_{cb}) on a daily basis.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36.222N, 120.097W
ETcb
Jan '10
Apr '10
Jul '10
Oct '10
Download as CSV
Overlays
NDVI gapfilled 2010-06-18 to 2010-06-25
ETcb 2010-06-20
Kcb 2010-05-25 to 2010-06-01
NDVI 2010-06-18 to 2010-06-25
Base Layer
Google Satellite
Google Terrain
Google Streets
Maps can also be queried, and data can be downloaded directly into Excel or other software tools
0.0
2.5
5.0
7.5
10.0
ETcb
-120.09559, 36.22205
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Done

Motivation

- Across the western U.S., depletion of groundwater, growing urban populations, and drought are constraining water supplies for irrigated agriculture
- Need for "win-win" solutions to assist growers in optimizing water use
- Satellite data + agricultural weather networks can be used to map crop water requirements
- Easily accessible data can assist growers in tuning irrigation to match weather conditions / crop growth stage

Benefits of Using Ag Weather Information in Irrigation Management

Water, Yield and Total Benefits to Farmers from CIMIS				
Crop	Water $US +	Yield++ $US	Total $US	**Benefit/Hectare $US**
Trees and Vines Sample				
Almonds	246,000	2,426,500	2,672,500	**408**
Apples	900	13,900	14,800	**366**
Avocados	-141,350*	738,000	596,500	**760**
Grapes	100,850	1,336,500	1,437,3500	**730**
Pistachios	370,150	6,755,000	7,125,000	**630**
Plums	556	12,445	13,000	**402**
Vegetable Sample				
Artichoke	2,500	326,200	328,700	**160**
Broccoli	2,750	106,100	108,850	**730**
Cauliflower	5,750	334,100	339,850	**870**
Celery	3,350	345,750	349,100	**1700**
Lettuce	26,000	1,361,000	1,387,000	**920**
Field Crop Sample				
Alfalfa	47,790	325,700	373,500	**100**
Cotton	345,300	810,500	1,155,800	**110**

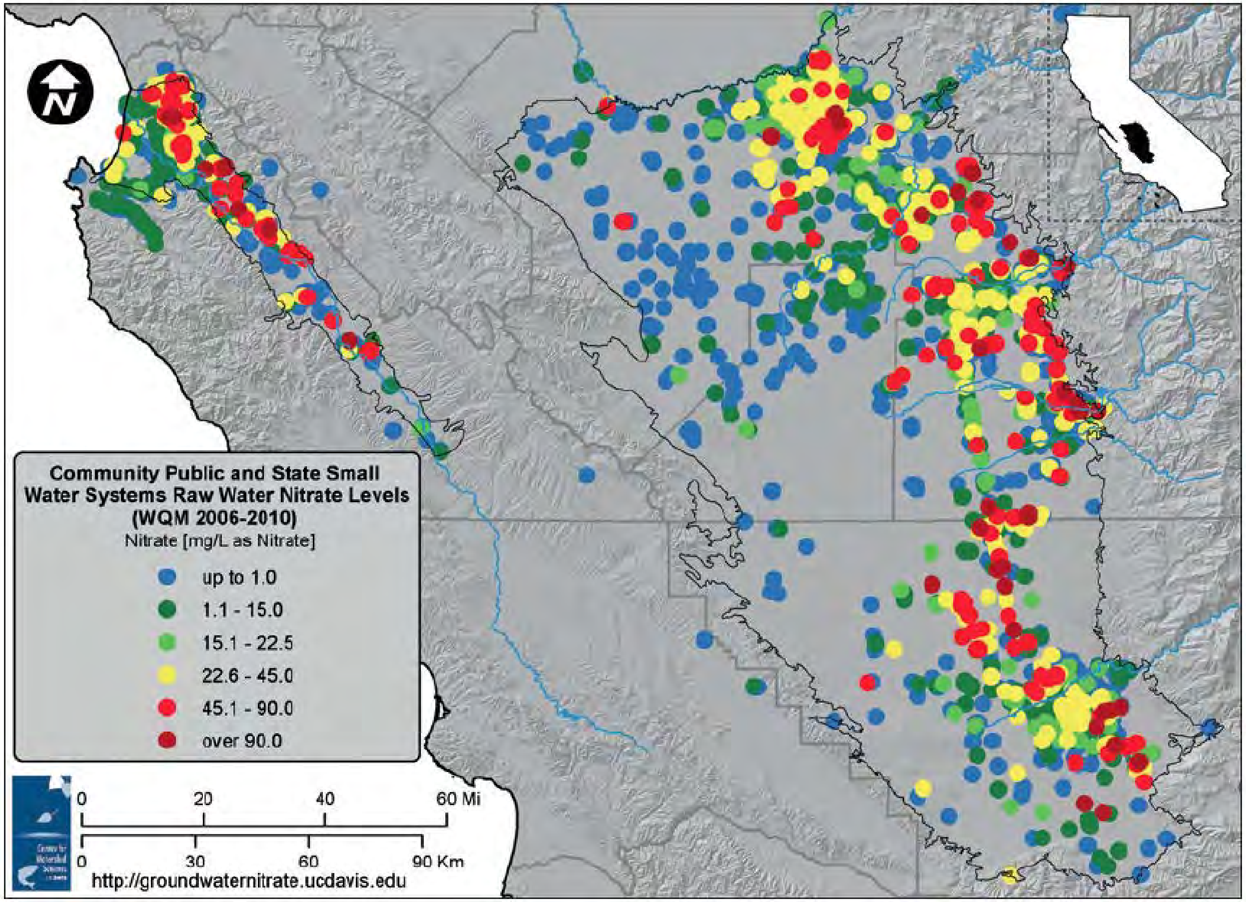
Source: Parker et al. (1996); http://www.cimis.water.ca.gov/cimis/resourceArticleOthersTechRole.jsp

+Money saved due to reduced water bill resulting from using CIMIS.
++Increased income from increased yield resulting from using CIMIS.
*Negative number indicates increased water use with CIMIS.

Average reduction in total applied water: 13%
Average increase in yields: 8%

Benefit of ≥ $100/ha: 4 million ha of irrigated land in CA → potential benefit of >$400m

Water Quality: Groundwater and Nitrates

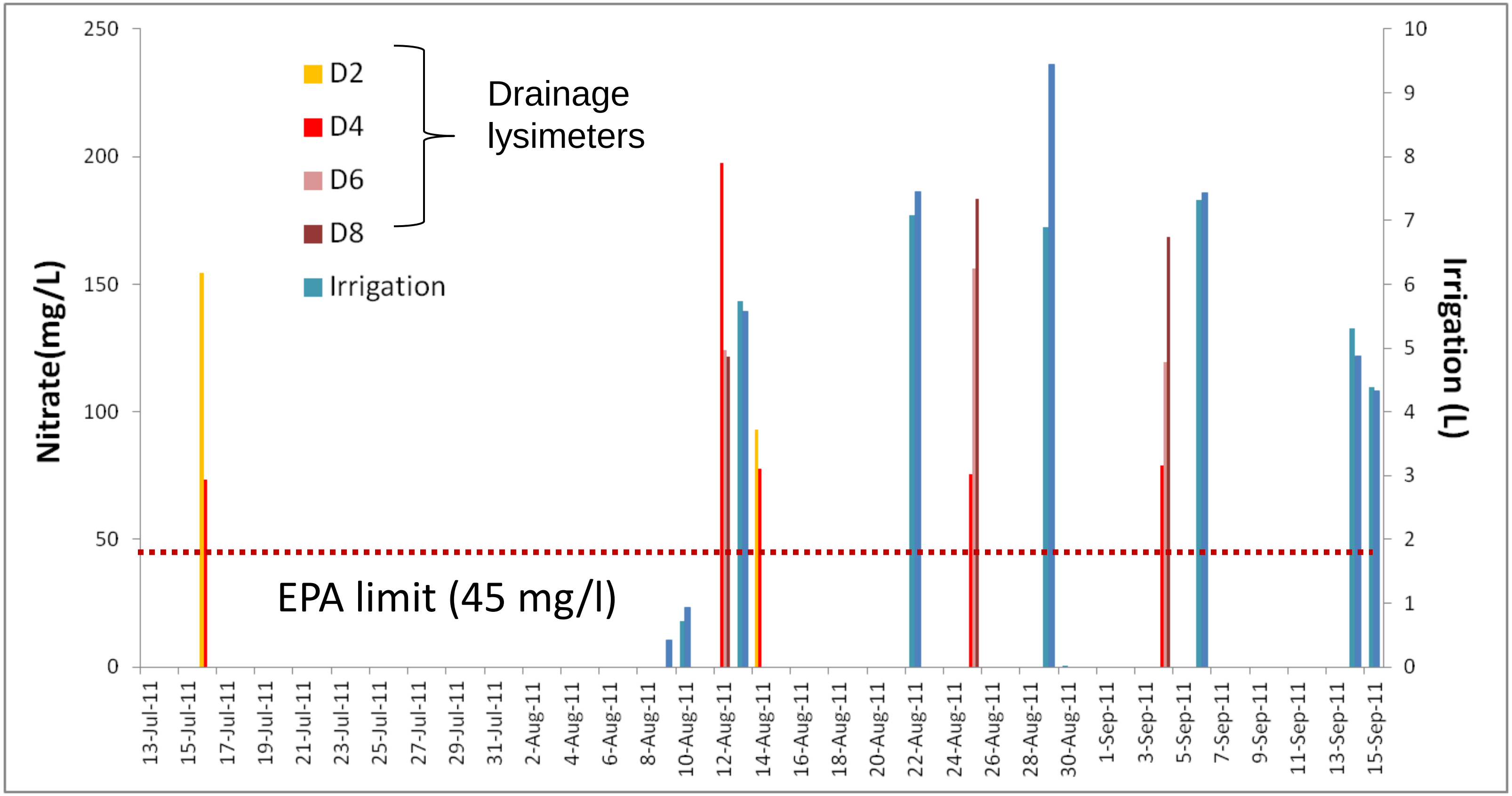


Maximum reported raw-level nitrate concentration in community public water systems and state-documented state small water systems, 2006-2010 (Harter et al., 2012)

Nitrate Concentrations in Drainage

Measured Nitrate Concentration in Drainage Below the Root Zone

(Lettuce, preliminary results)



California State University Monterey Bay

NASA

California Irrigation Management Information System

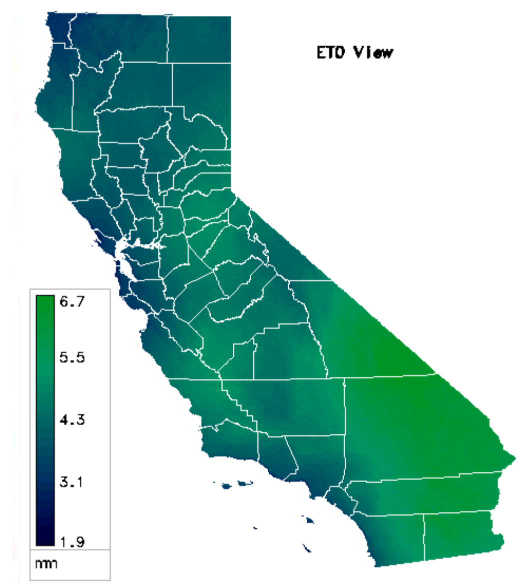
- Standard approach for incorporating weather information into irrigation management practices

$$ET_c = ET_o * K_c$$

CIMIS, AgriMet, AZMET, CoAgMet

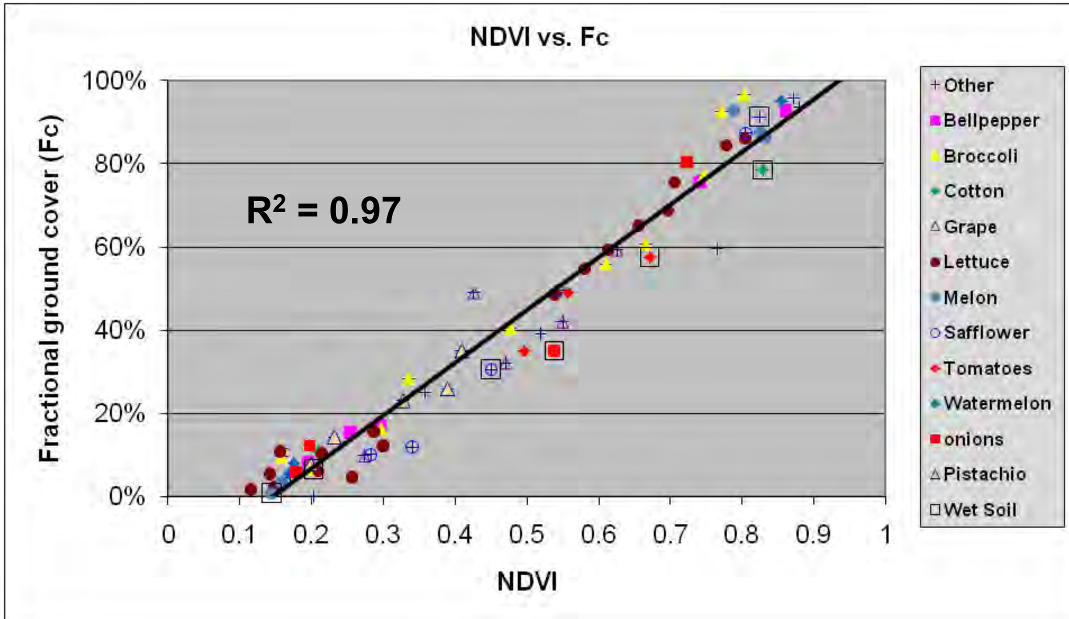
- California Irrigation Management Information System (CIMIS)
  - Operated by CA DWR since 1982
  - More than 139 stations currently providing daily measurements of ET_o
  - **Spatial CIMIS** data now available for CA; 2km statewide grid, daily

Photo credit: DWR CIMIS



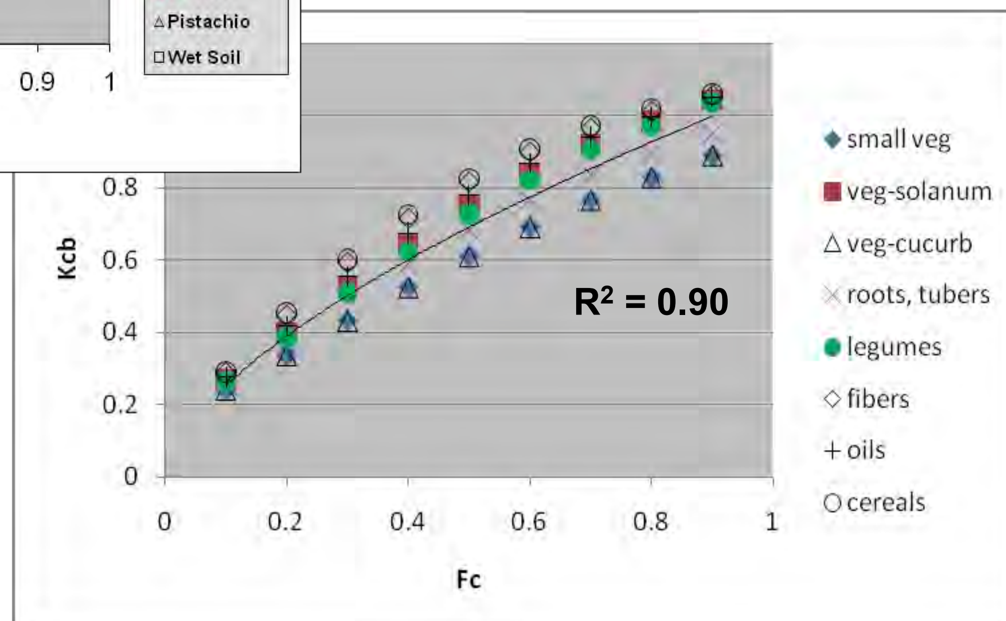
Spatial CIMIS ET_0 16 Sept 2010

Approach: Mapping Crop Coefficients and Indicators of Crop Water Requirements from Satellite Data



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

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



Recent studies by Allen & Pereira (2009) and others provide basis for linking fractional cover to Kcb for a range of crops. *Additional studies ongoing in collaboration with CSU Fresno and UC West Side Research & Extension Center*

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

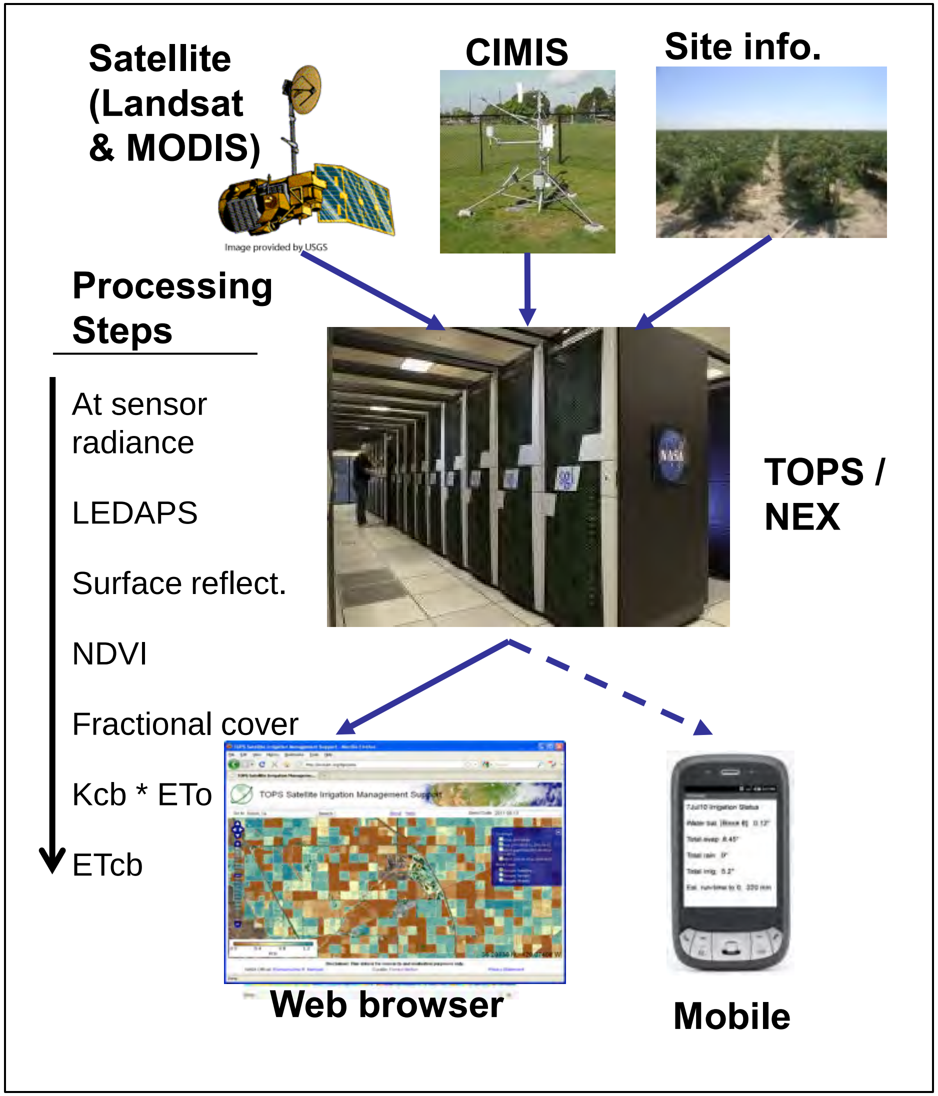
Data Analysis and Modeling Frameworks: Terrestrial Observation and Prediction System and NEX

1. Data for growers: Develop near real-time information products from satellite data to support growers in optimizing irrigation: NDVI, F_c, K_{cb}, ET_{cb} maps at field scale

2. New technology: Build data processing systems required to combine data from satellites and surface observation networks in real-time to map crop coefficients and crop water requirements

3. Transition to operations: Integrate new capability into CA DWR CIMIS framework

4. Outreach: Grower outreach and education in partnerships with Western Growers and other grower organizations



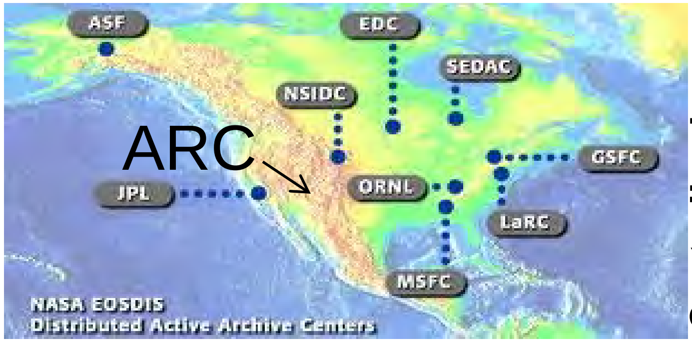
Melton et al., IEEE JSTARS (*in press*)

NASA Earth Exchange

9PB of on-line storage
50PB of tape storage
512 CPUs readily accessible, 180,000 total

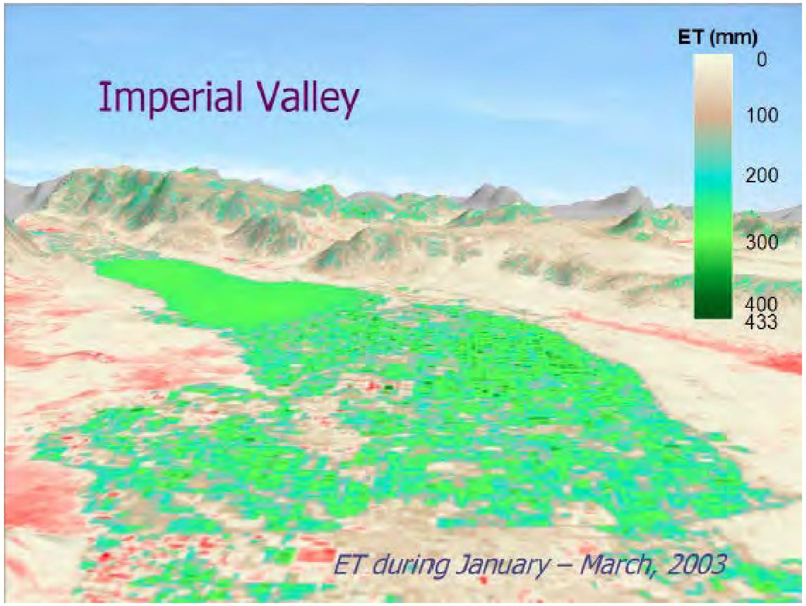
COLLABORATION
(over 250 members)

COMPUTING
(9PB, 180,000 cores)

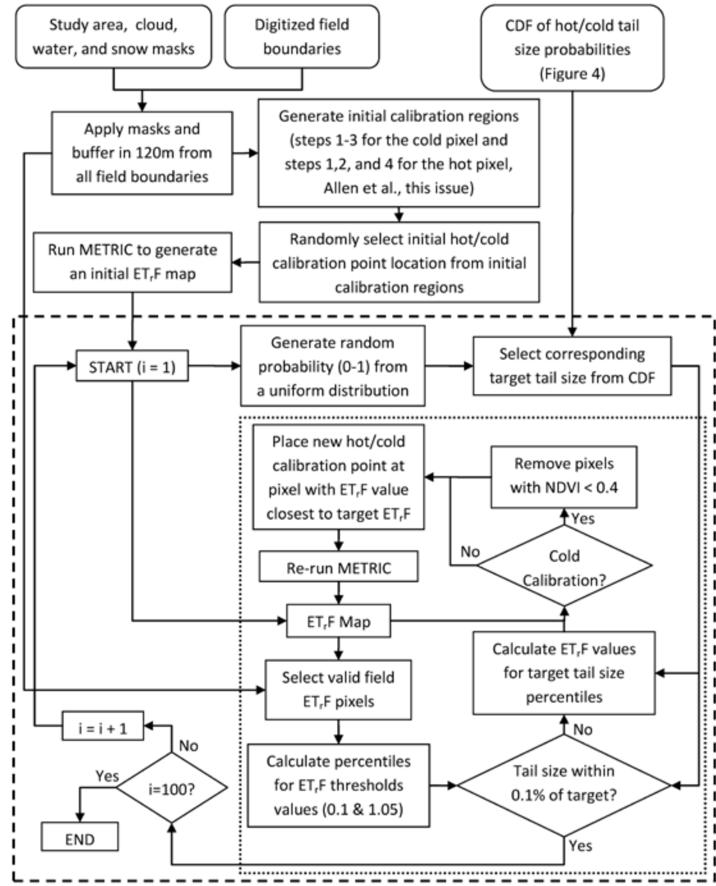


Centralized Data Repository
(over 400 TB of data)

Applying NEX to Support ET Models: METRIC



ET for the Imperial Valley from METRIC (R. Allen)

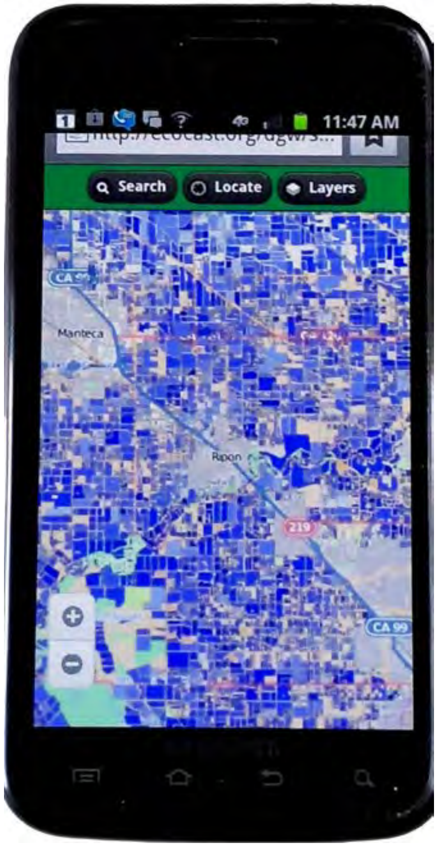


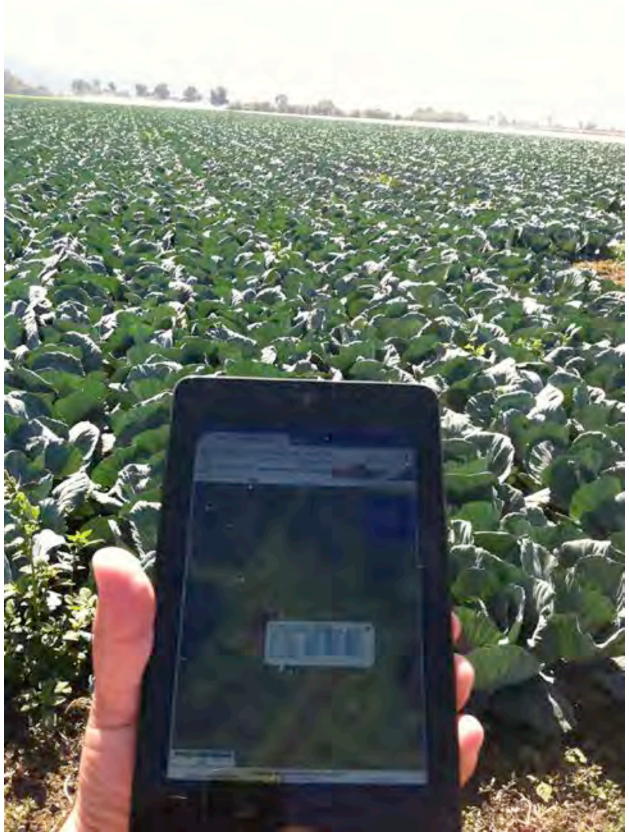
Sample workflow for METRIC automation (J. Huntington, C. Morton)

Goal: Near real-time, cost effective concurrent mapping of potential ET (crop water requirement from SIMS) and actual ET (consumptive from METRIC) use at field scale

PI: J. Huntington

Mobile Interfaces





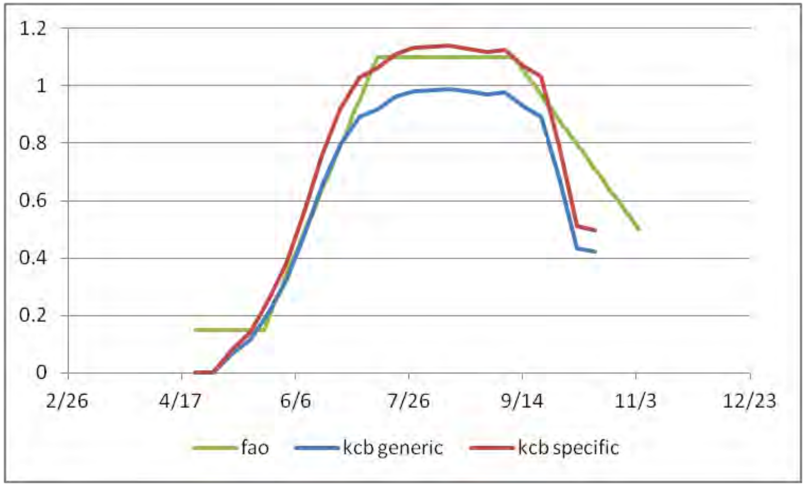
Mobile-based interfaces important for accelerating adoption by agricultural community

Approach: System Validation and Accuracy Assessment

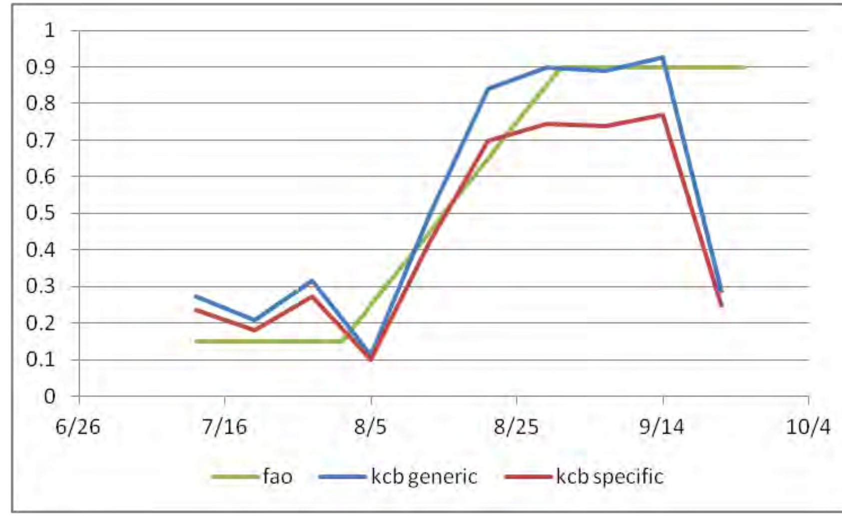
- Comparison with standard practices and other previously validated models
- Comparison against measurements from soil moisture sensor networks installed in collaboration with partner growers
- Comparison against measurements of evapotranspiration on commercial farms

Crop Coefficients (K_{cb}): SIMS vs FAO-56

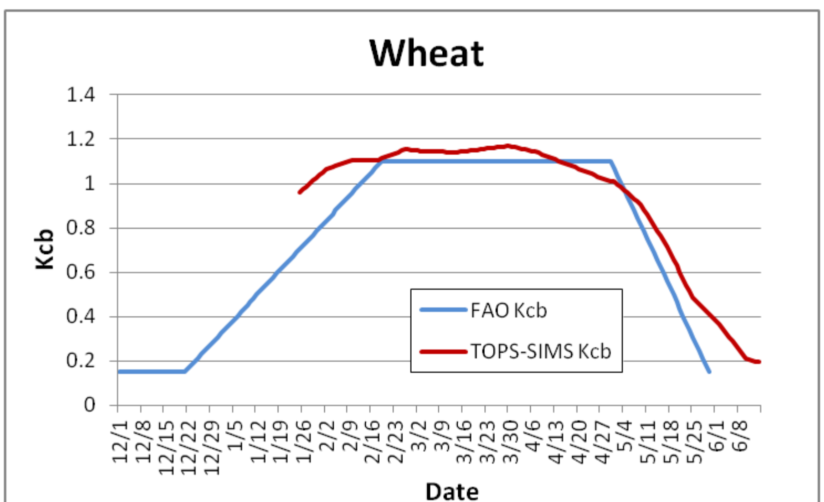
Cotton (Huron)



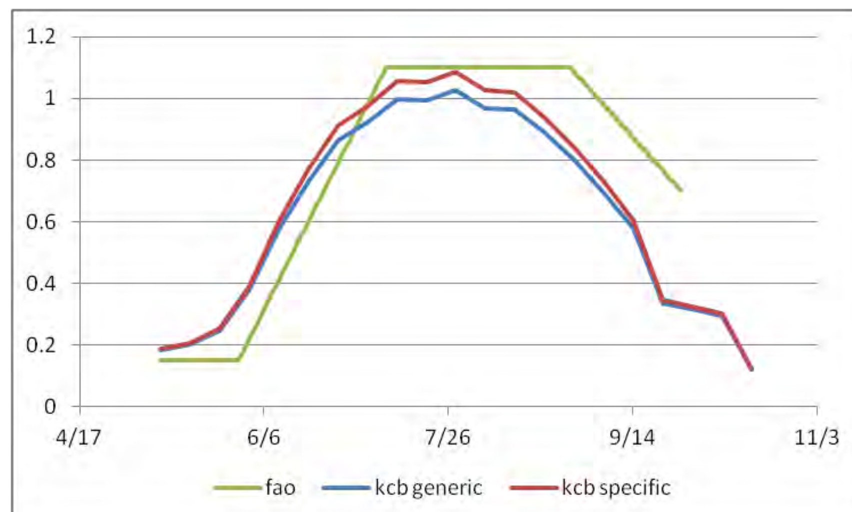
Lettuce (Salinas)



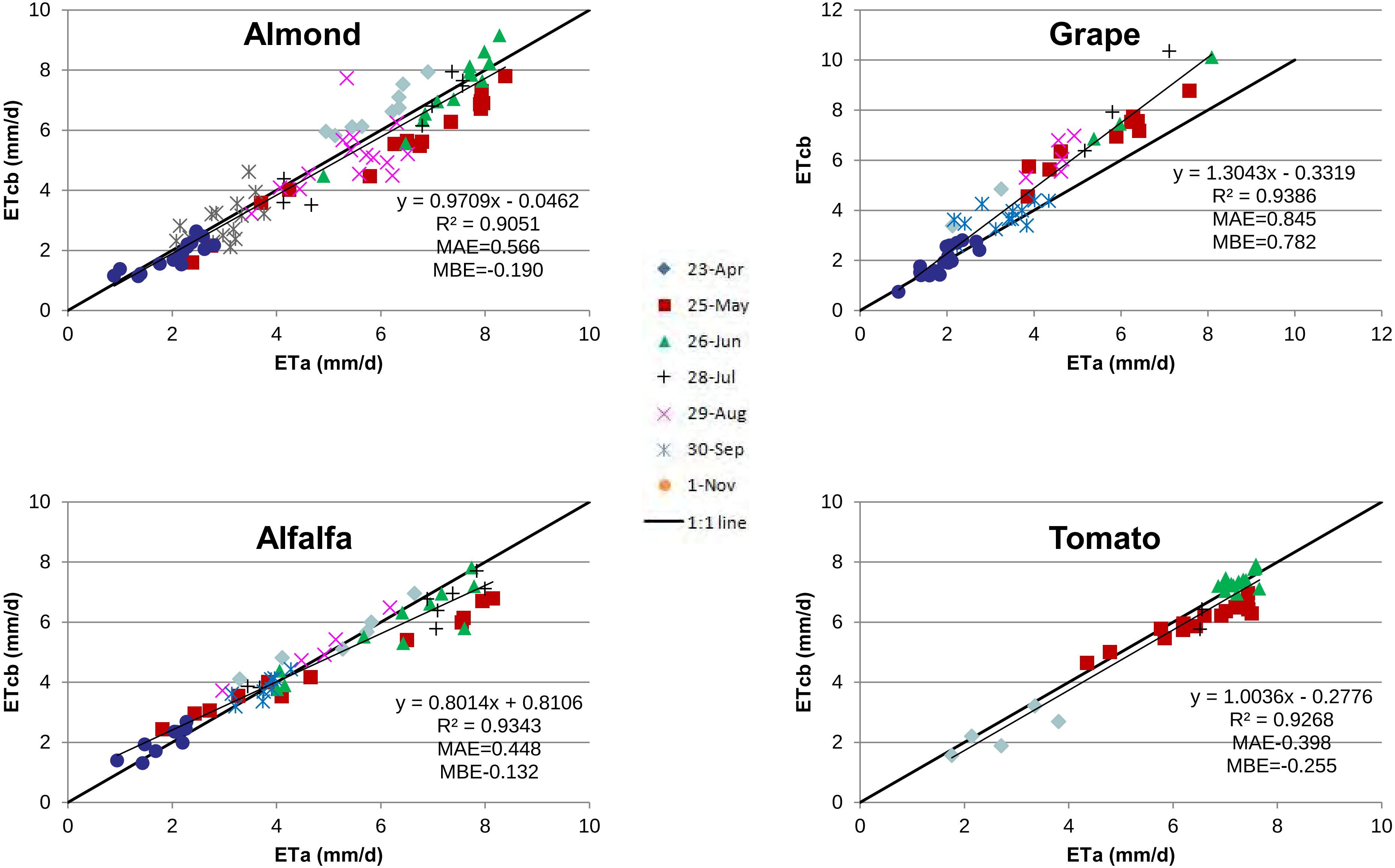
Wheat (Huron)



Tomato (Los Banos)



Satellite ET Mapping
TOPS SIMS (Automated) vs SEBAL (Manual)



SIMS: Field Sensor Network Components

1) Surface renewal instrumentation for measuring ET
2) Volumetric water content at 8-12 points at four depths (10HS)
3) Soil water potential at 8 points at one depth (MPS-1)
4) Deep drainage at two points (Gee passive capillary lysimeter)
5) Flow measurements at two irrigation standpipes (Badger)
6) Meteorological data (RH, T, P, wind speed, solar radiation)

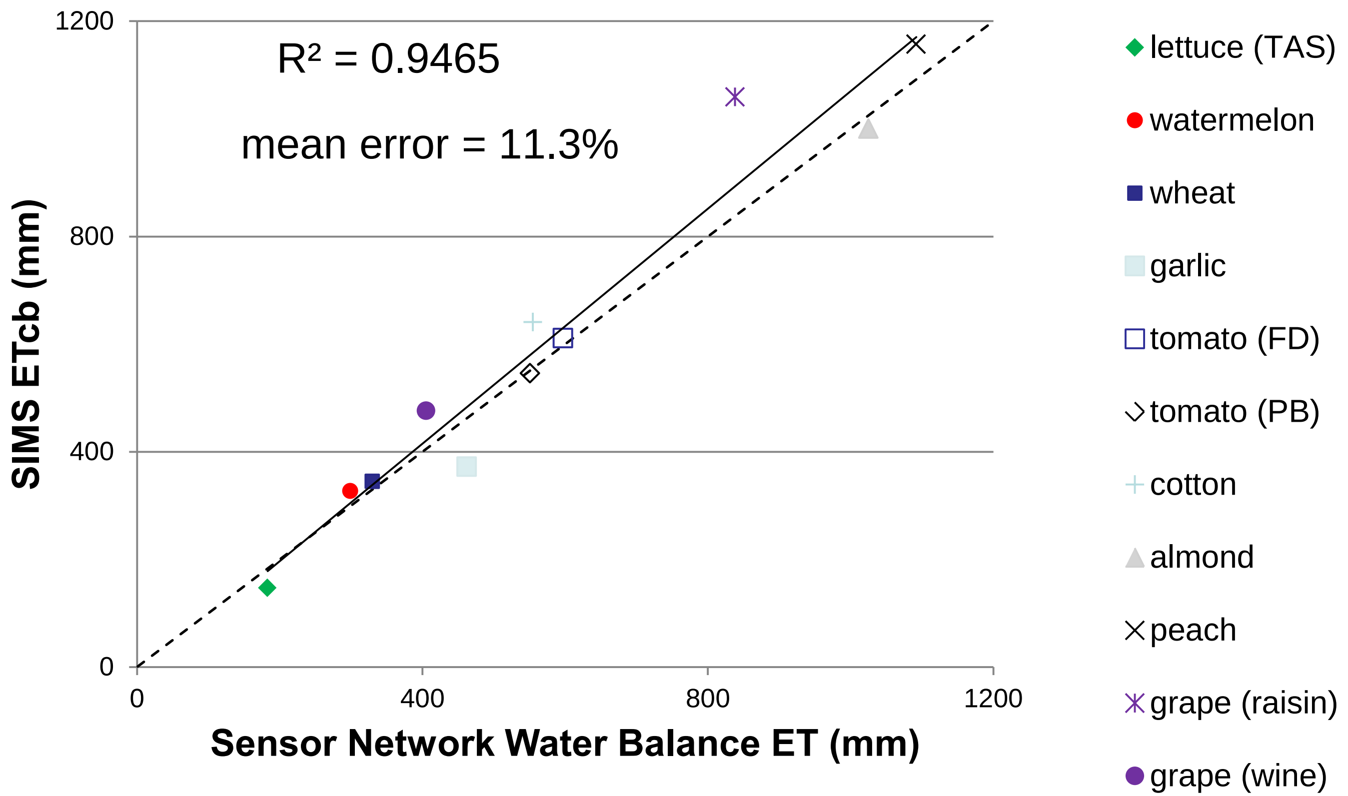
Support from CSU Agricultural Research Initiative and Oreggia Family Foundation

Sensor Network Installations

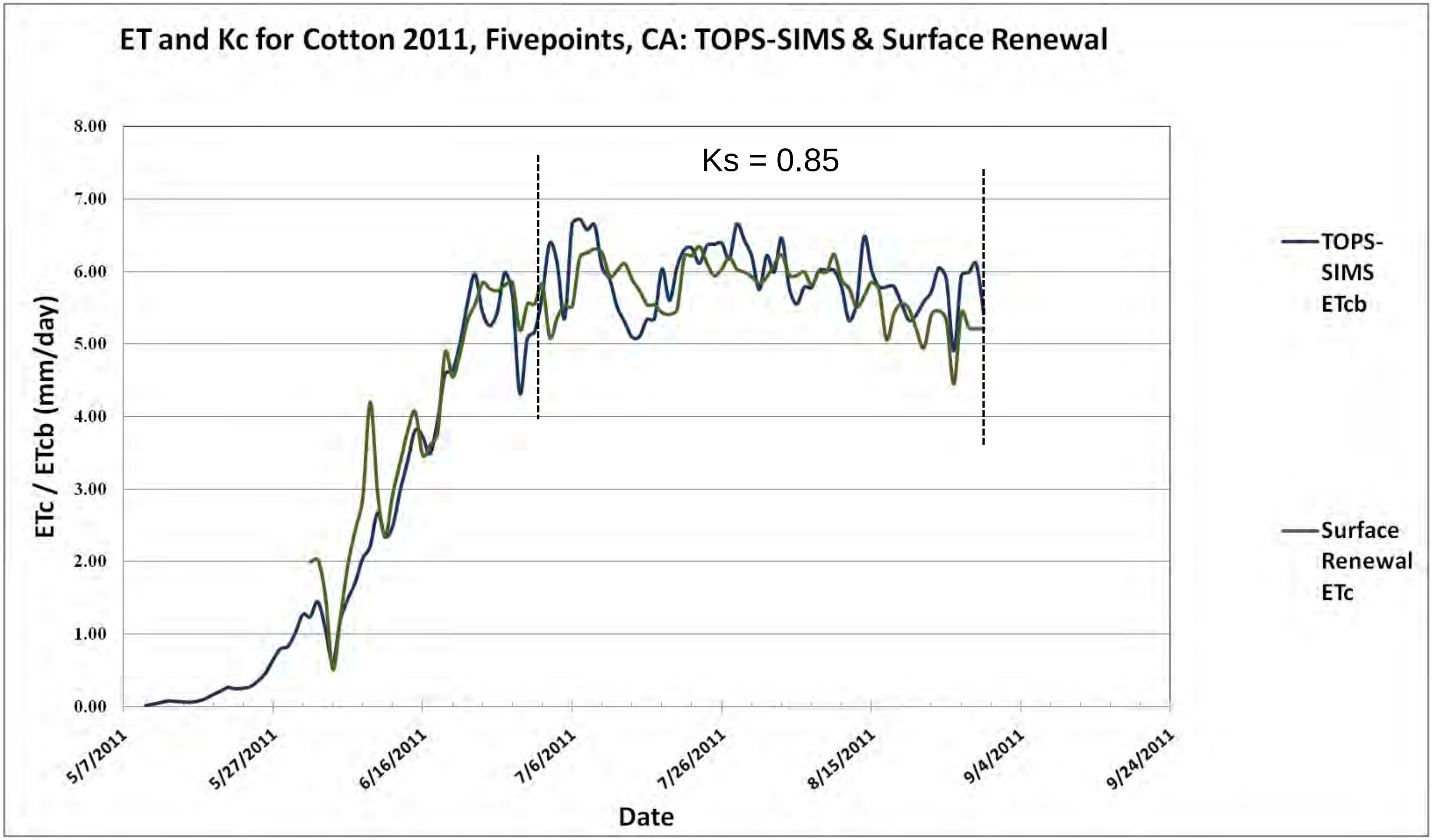
Crop Type	Crop	Location
Grain	Corn*	CSU Fresno
Grain	Wheat	San Joaquin Valley
Row	Garlic	San Joaquin Valley
Row	Lettuce*	SJ & Salinas Valley
Row	Broccoli	Salinas Valley
Row	Cauliflower	San Joaquin Valley
Row	Tomato(2)*	San Joaquin Valley
Row	Cotton (drip)*	San Joaquin Valley
Vine	Melon	San Joaquin Valley
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.**

SIMS ETcb vs Sensor Network ET (2011)

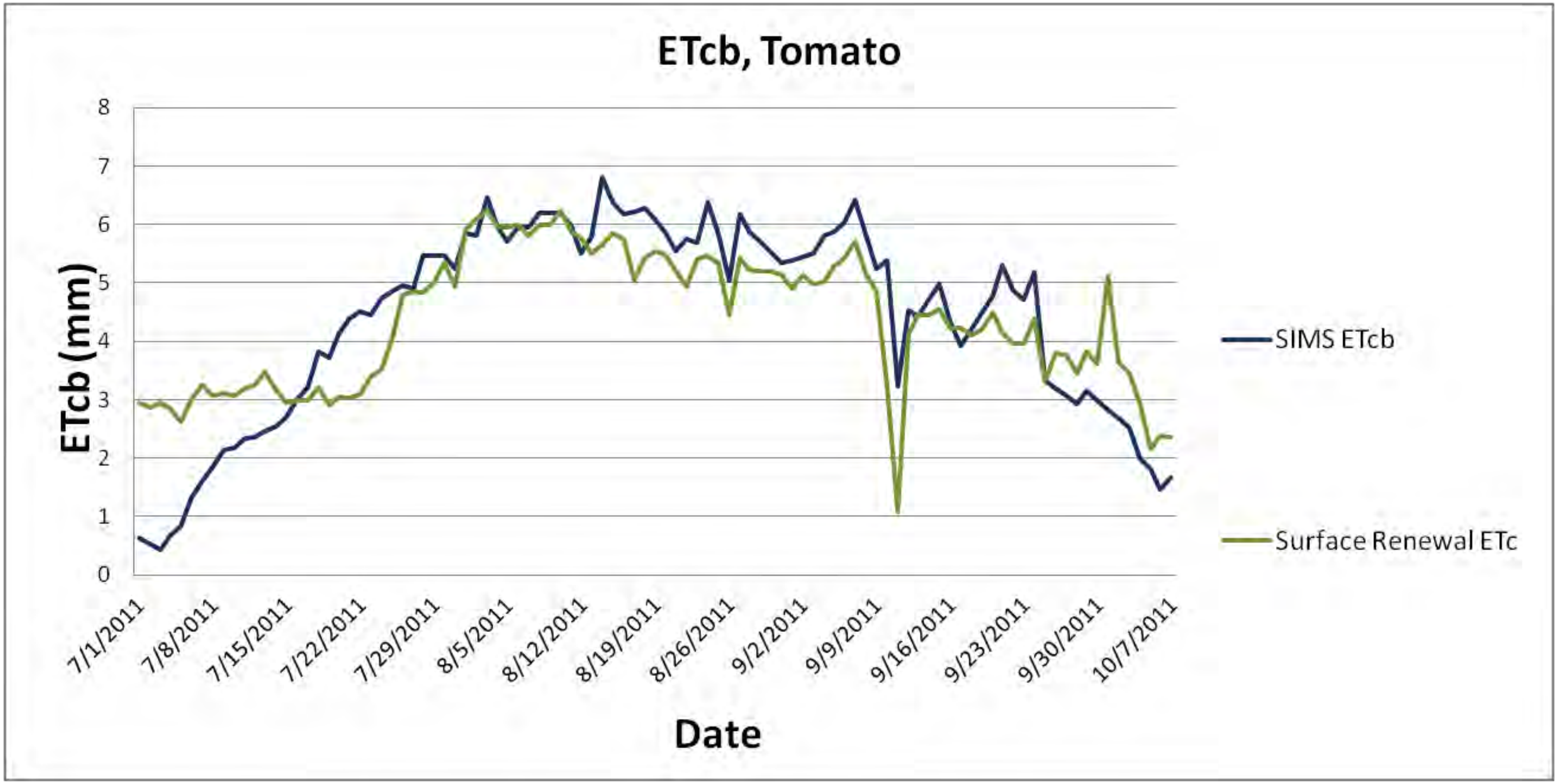


TOPS SIMS ETcb vs Surface Renewal (Cotton)



Use of a crop stress coefficient of 0.85 after July 1; MAE of 0.38 mm / day

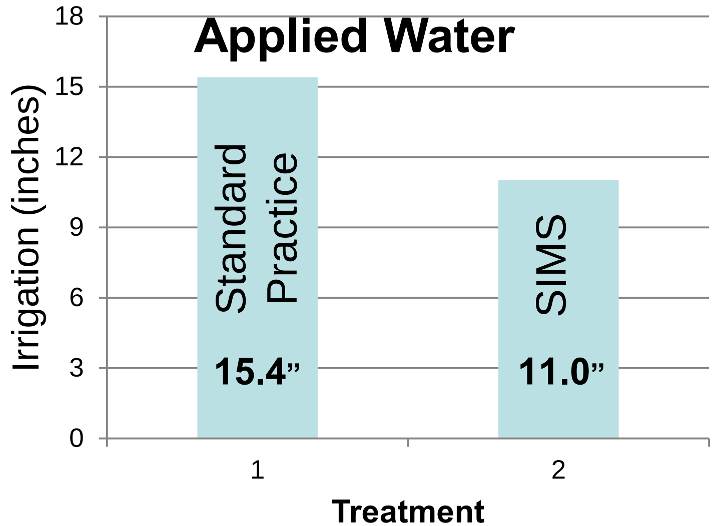
TOPS SIMS ETcb vs Surface Renewal (Tomato)

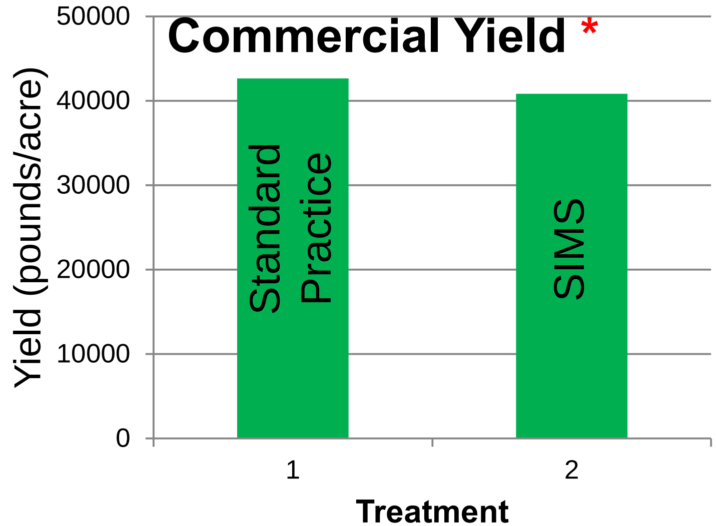


Field Demonstrations of Irrigation Savings

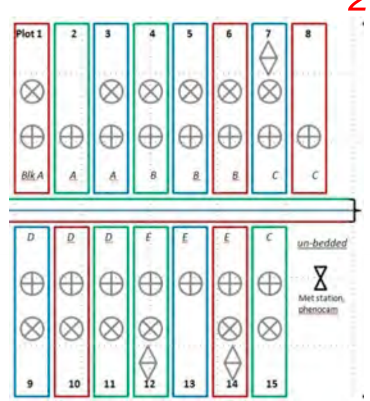
Specialty Crop Irrigation Trials

Research Partners: CSUMB/NASA, USDA-Ag Research Service, UC Cooperative Extension
Commercial Cooperators: Chiquita/Fresh Express, Inc., Tanimura & Antle, Inc.
Sponsor: Calif. Dept. Food & Agriculture





*no significant difference in yields despite 28.6% less applied water



PI: L. Johnson


Questions?

Back-up Slides






Motivation: Benefits of Using Ag Weather Information in Irrigation Management

- Irrigation uses ~80% of water in CA
- California Department of Water Resources and UC Berkeley surveyed growers in 1990s
- Growers who utilized ET_o data reported an increase in yields of 8% and a decrease in applied irrigation of 13% (DWR, 1997)
- Use of ET data in irrigation scheduling still not widespread; majority of growers rely on the condition of the crop and the feel of the soil as primary guides in scheduling irrigation

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

Method	Percent of Farmers 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%.

Upcoming Features: Field-Level Summary Reports

TOPS-SIMS Field Summary (Example)

ETo = reference ET (in.), ETcb = crop water use (in.), Kcb = basal crop coefficient, SWB = soil water balance (in.), Runtime = estimated irrigation runtime (hrs.) to restore neutral soil water balance

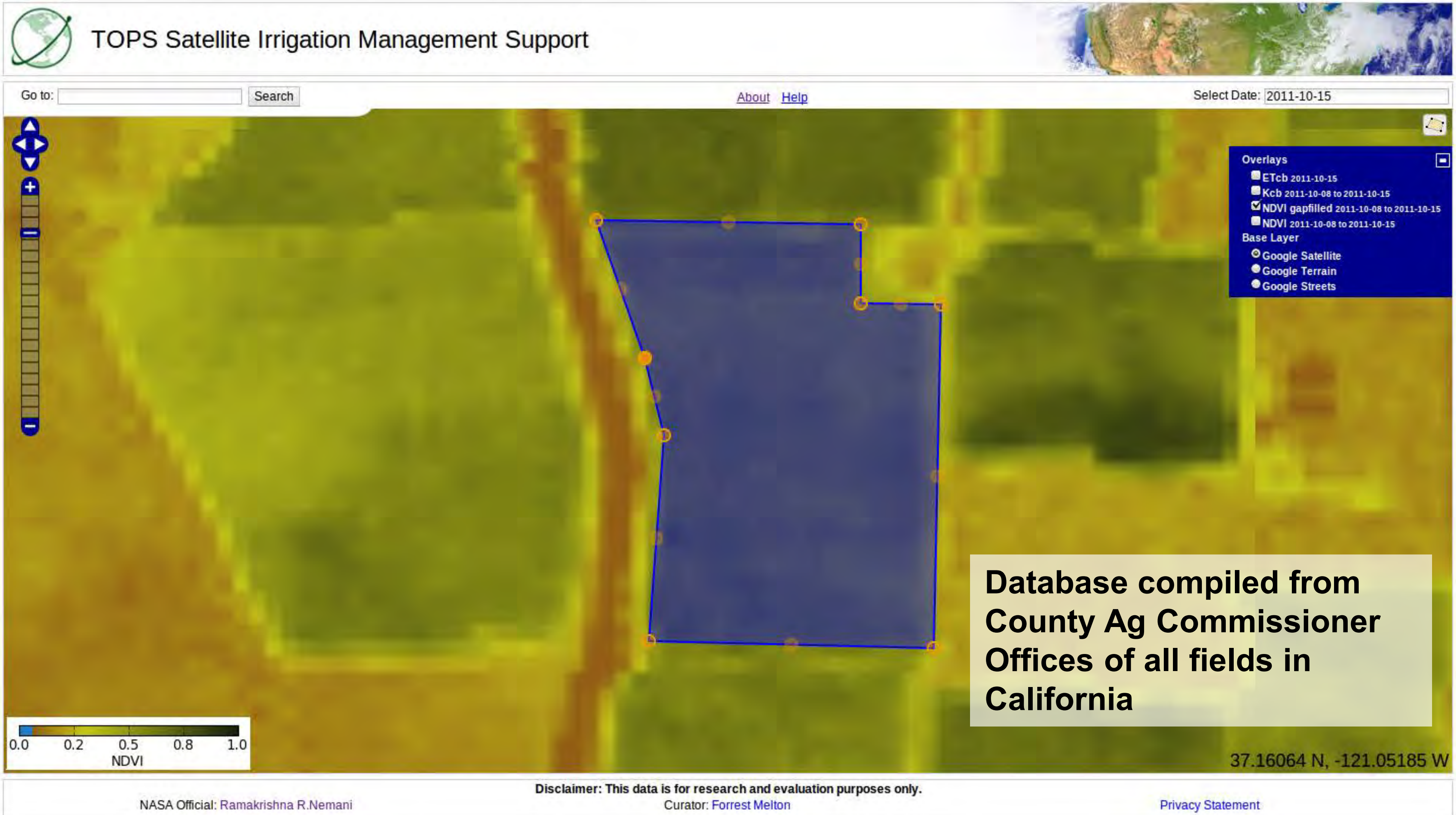
Past 3 days:								Next 3 days:			
Field	ETo	Kcb mean	Kcb max	Kcb min	ETcb	SWB	**Runtime 8/8/2010**	ETo	ETcb	SWB	**Runtime 8/11/2010**
F-01	0.83	1.05	1.09	0.95	0.87	+0.30	--	0.79	0.83	-0.53	**2.5**
F-02	0.83	0.97	1.04	0.91	0.81	-0.12	**1**	0.79	0.77	-0.77	**4**
F-03	0.83	1.09	1.12	1.02	0.90	+1.14	--	0.79	0.86	0.28	--
...											

- Considers weather, soil texture, crop type, root depth, precipitation, prior irrigation amounts, method of application, and application rate.

- Parameters to include measures of within-field variability.

- Summary reports planned for delivery via text messages / PDFs sent to mobile devices.

Customized Reporting: Field Level Summaries



Database compiled from County Ag Commissioner Offices of all fields in California

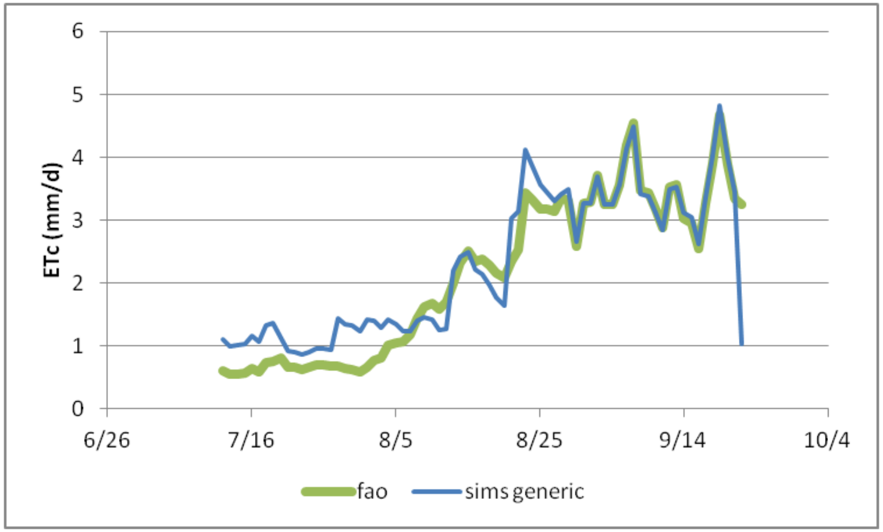
California Agriculture

- Significant ag production, $38.5B in cash farm receipts in 2010 from 81,700 farms
- Major domestic/international supplier of specialty crops
- Half of US-grown fruits, nuts, vegetables
- Diversity of crops

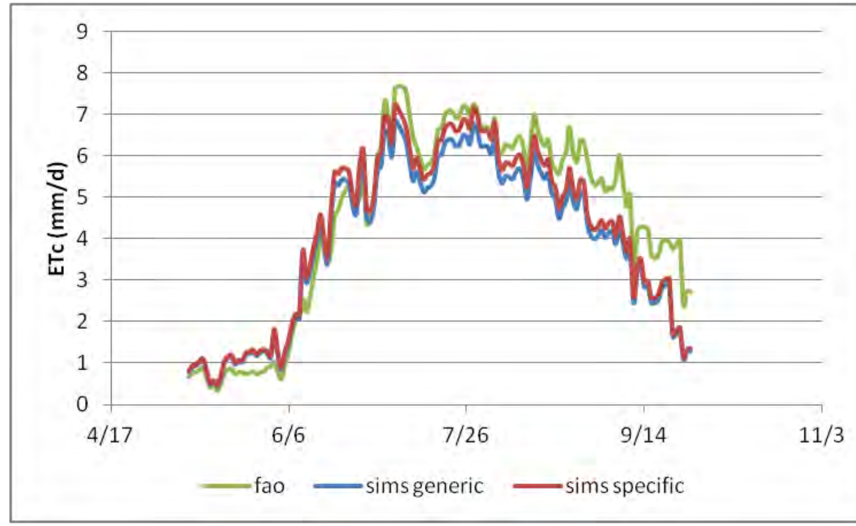
Source: Calif. Dept. Food & Agriculture

ET_{cb}: SIMS vs FAO-56

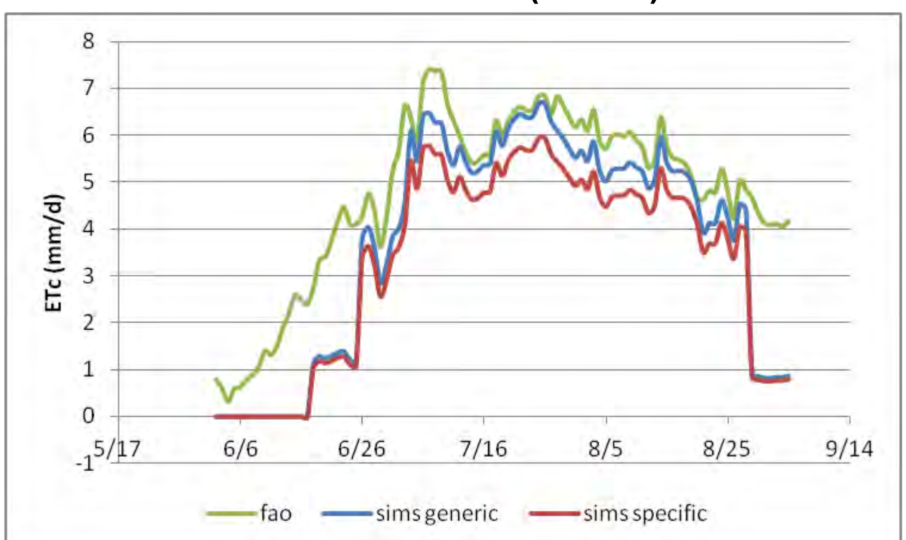
Lettuce (Salinas)



Tomato (Los Banos)

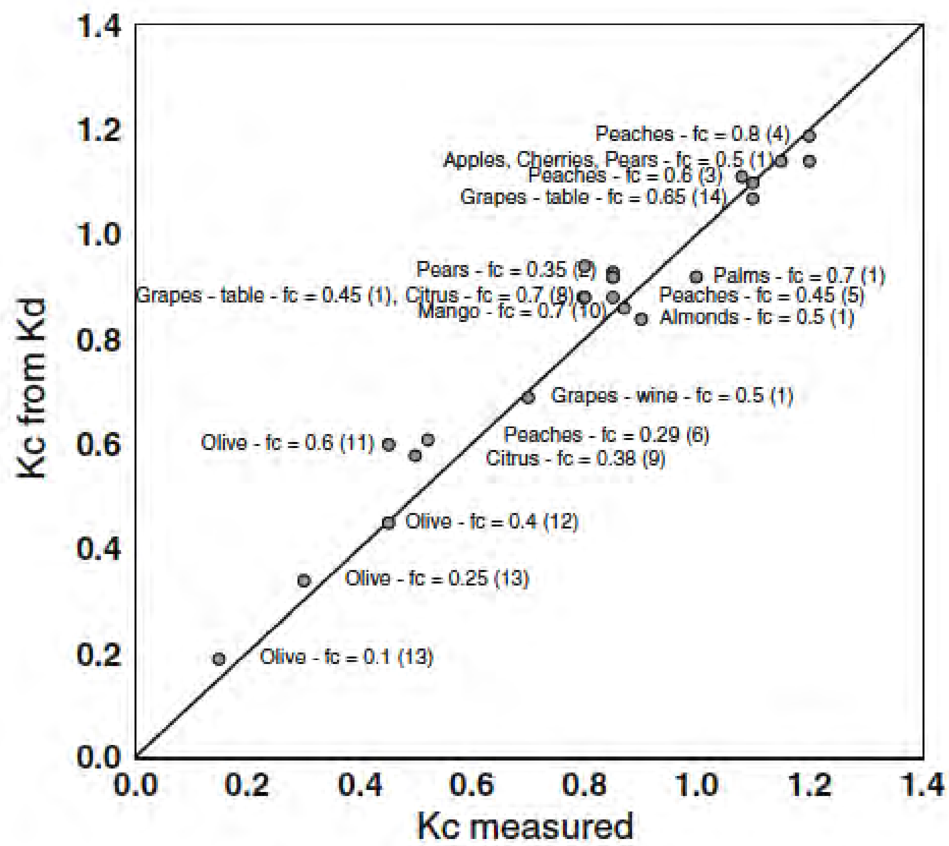


Watermelon (Huron)



Improved Mapping of Kc for Perennial Crops

Allen and Pereira (2009), Method for estimating crop coefficients from fraction of ground cover and height:



$$K_d = \min\left(1, M_L f_{c\,eff}, f_{c\,eff}^{\left(\frac{1}{1+h}\right)}\right)$$

K_d = density coefficient

M_L = multiplier on fc to account for effect of canopy density on shading

$f_{c\text{-}eff}$ = effective fraction of ground cover

h = mean height of vegetation

Water Resource Management Challenges

- Drought impacts
- Competing demands
- Water quality and impaired water bodies
- Aging water conveyance infrastructure
- Groundwater overdraft
- Population growth and climate change

Credit: Jose Phillip

Calif. Water Plan 2009

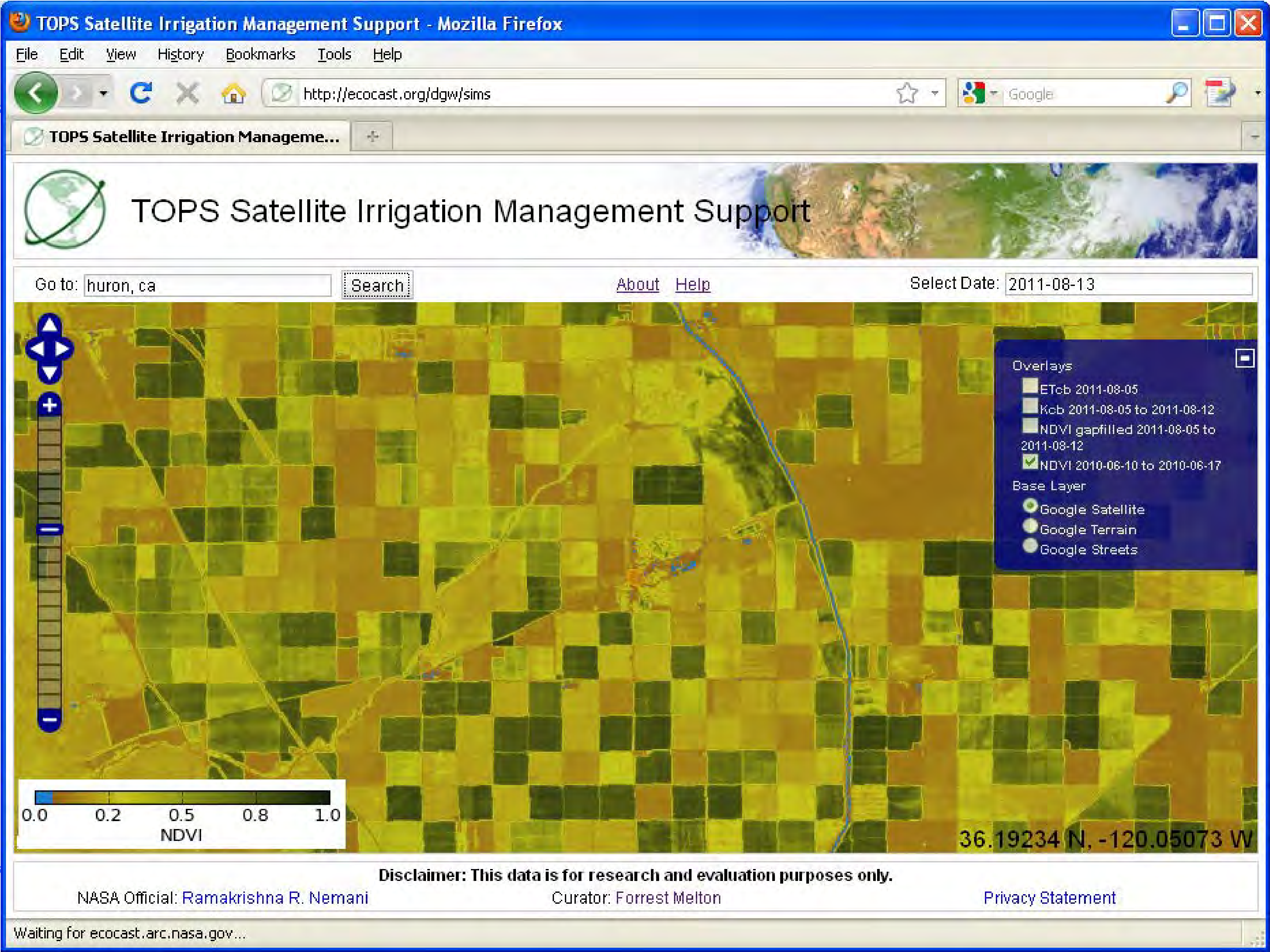
Additional Information and Resources

NASA Satellite Irrigation Management Support Project:
http://ecocast.arc.nasa.gov/sims/

CIMIS: http://wwwcimis.water.ca.gov/cimis/welcome.jsp

Crop coefficients: http://wwwcimis.water.ca.gov/cimis/infoEtoCropCo.jsp, or http://biomet.ucdavis.edu/irrigation_scheduling/bis/BIS.htm

NASA Applied Sciences Program:
http://science.nasa.gov/earth-science/applied-sciences/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Google
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Select Date: 2011-08-13
Overlays
ETcb 2011-08-05
Kcb 2011-08-05 to 2011-08-12
NDVI gapfilled 2011-08-05 to 2011-08-12
NDVI 2010-06-10 to 2010-06-17
Base Layer
Google Satellite
Google Terrain
Google Streets
0.0 0.2 0.5 0.8 1.0
NDVI
36.19234 N, -120.05073 W
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