

Satellite Irrigation Management Support with the Terrestrial Observation and Prediction System

Forrest Melton

forrest.s.melton@nasa.gov

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

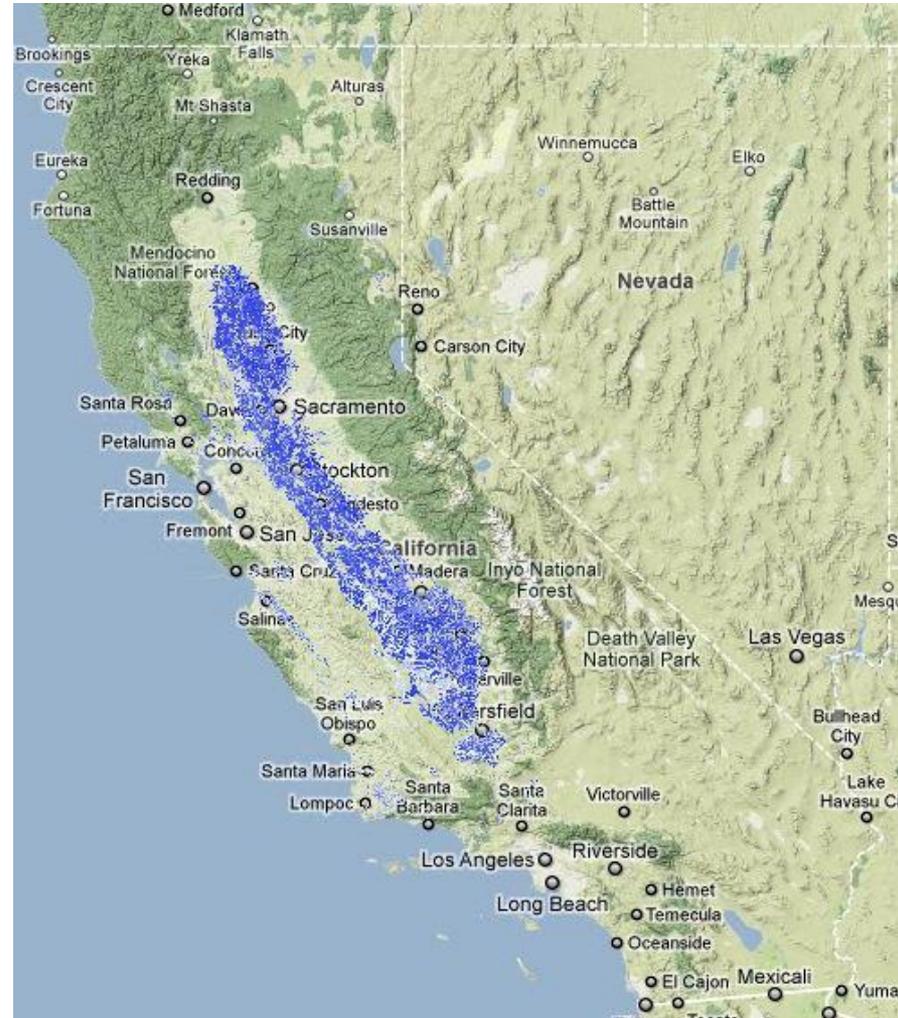
Farming D

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

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



Motivation: Benefits of Using Ag Weather Information in Irrigation Management

- Irrigation uses ~80% of water in CA
- During droughts, critical to optimize irrigation use
- California Department of Water Resources and UC Berkeley surveyed growers in 1990s
- Growers who utilized weather and ET_0 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%.



California Irrigation Management Information System

- Standard approach for incorporating weather information into irrigation management practices

$$ET_c = ET_o * K_c$$

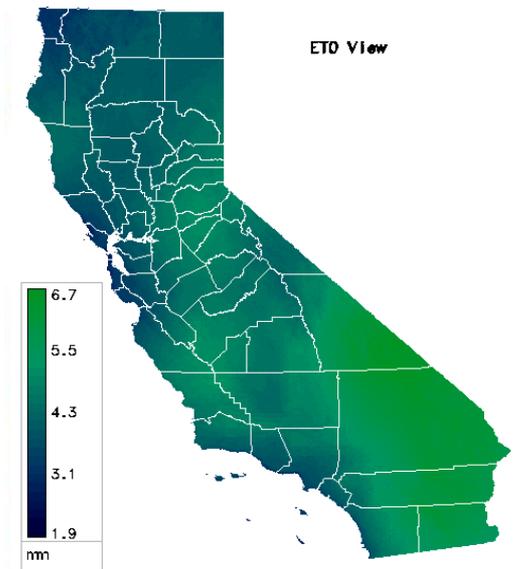


CIMIS, AgriMet, AZMET, CoAgMet

- 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

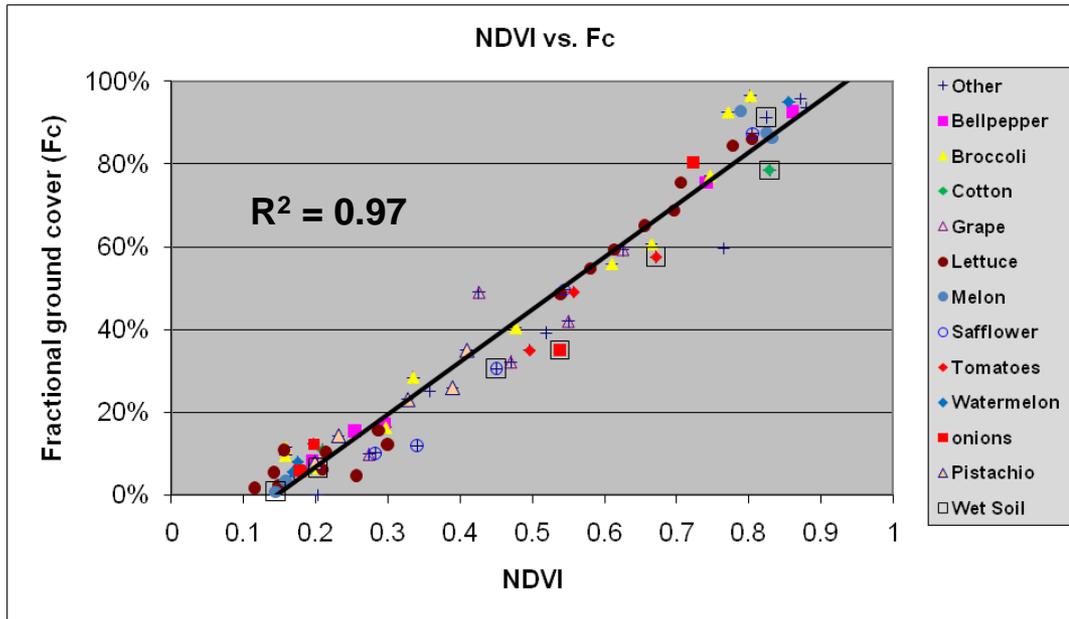


Photo credit: DWR CIMIS



Spatial CIMIS ET_o 16 Sept 2010

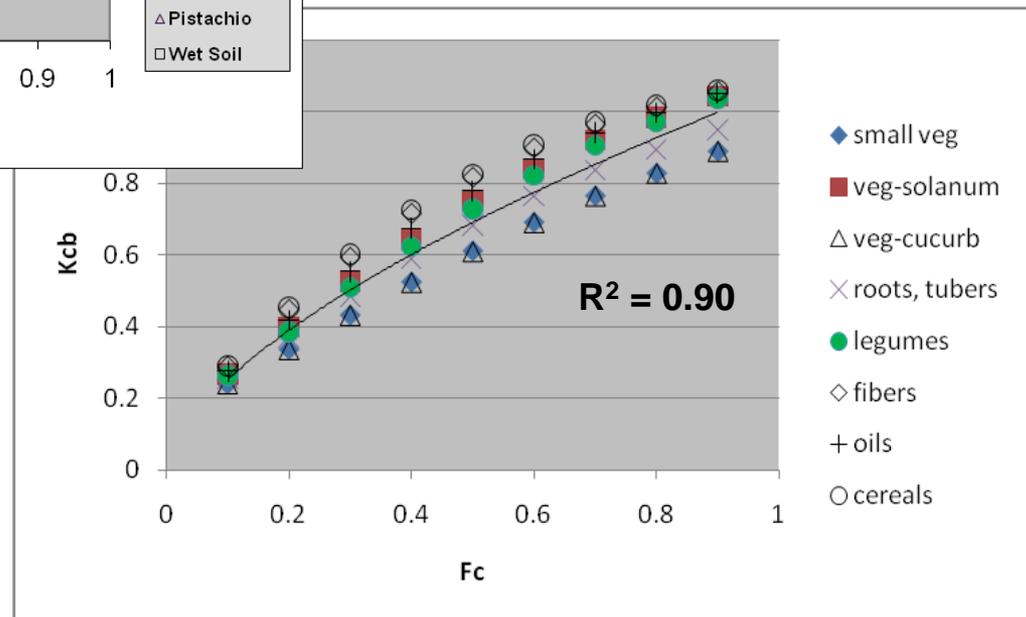
Approach: Mapping Crop Coefficients and Indicators of Crop Water Requirements from Satellite Data



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 K_{cb} 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

Satellite Data



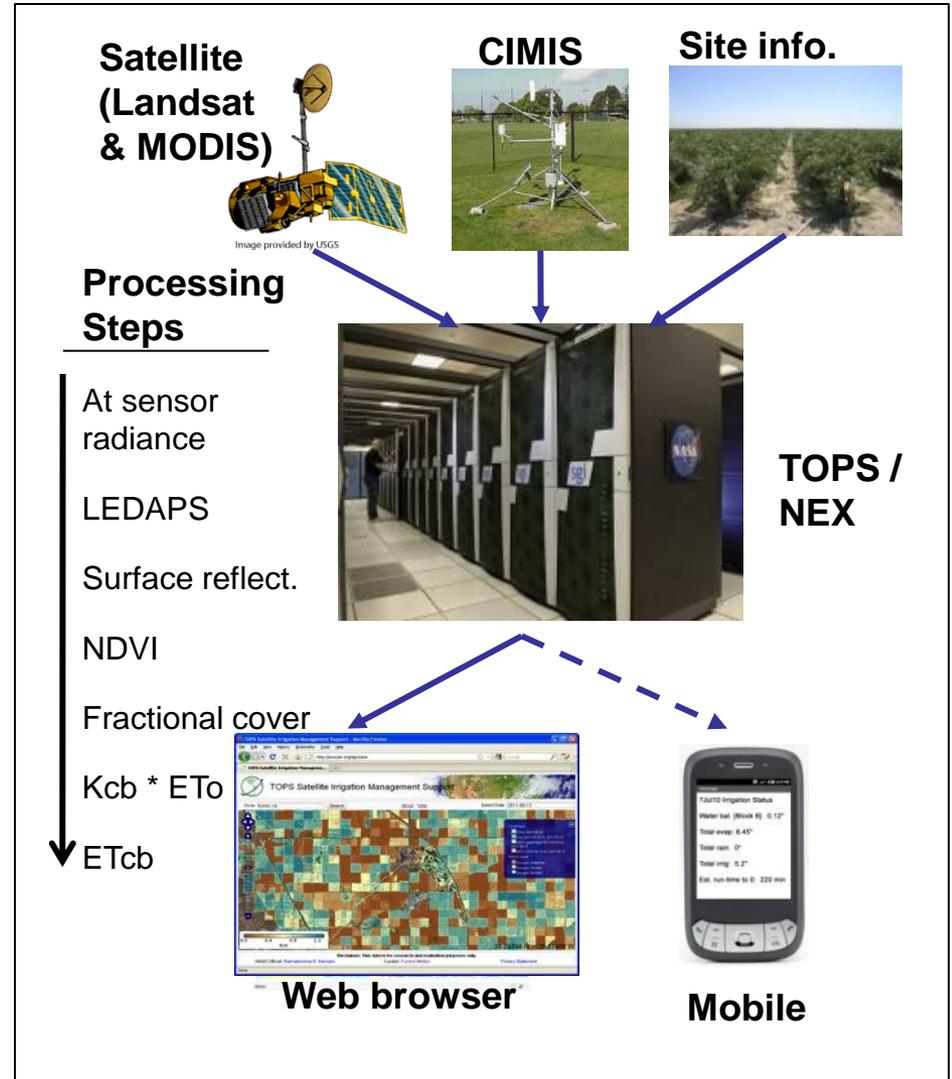
Landsat 5 and 7 (TM / ETM+)
(30m / 0.25 acres)



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

Objectives

1. Develop near real-time information products from satellite data to support growers in optimizing irrigation: F_c , K_{cb} , ET_{cb} maps at field scale
2. 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. Integrate new capability into CA DWR CIMIS framework
4. Grower outreach and education in partnerships with Western Growers and other grower organizations



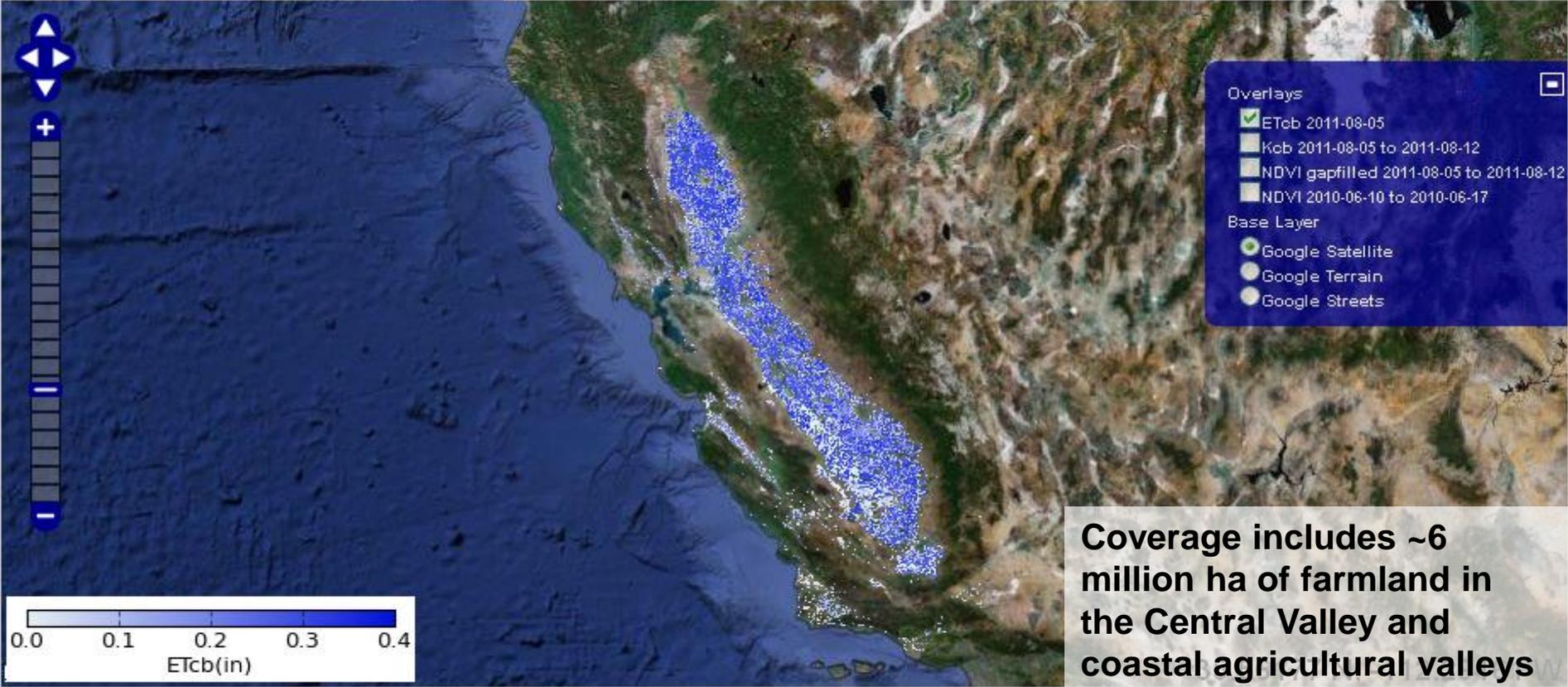


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Coverage includes ~6 million ha of farmland in the Central Valley and coastal agricultural valleys

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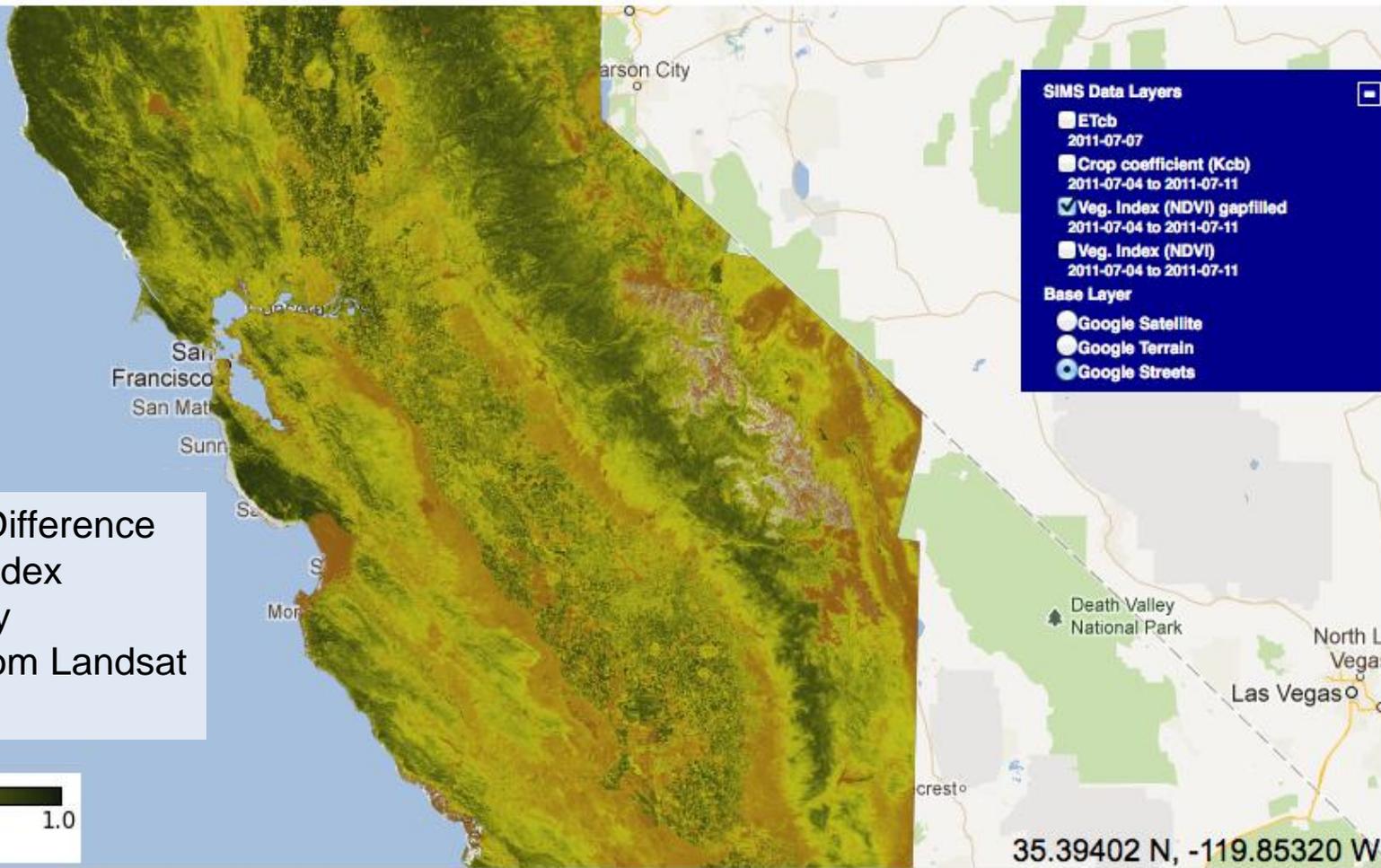
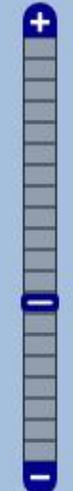
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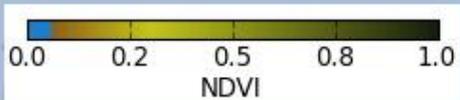
SIMS Data Layers

- 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

- Google Satellite
- Google Terrain
- Google Streets

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



35.39402 N, -119.85320 W

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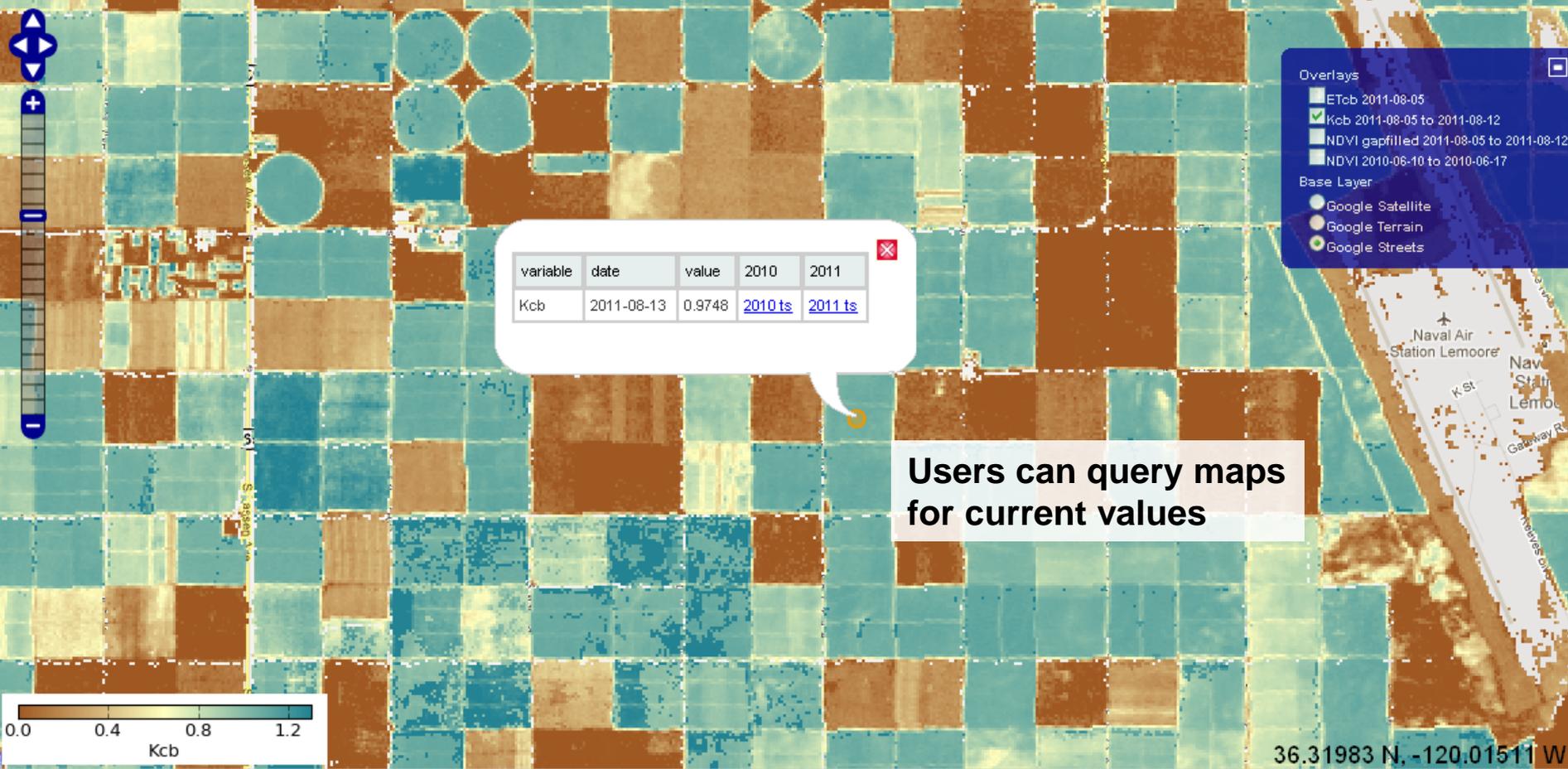
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Users can query maps for current values

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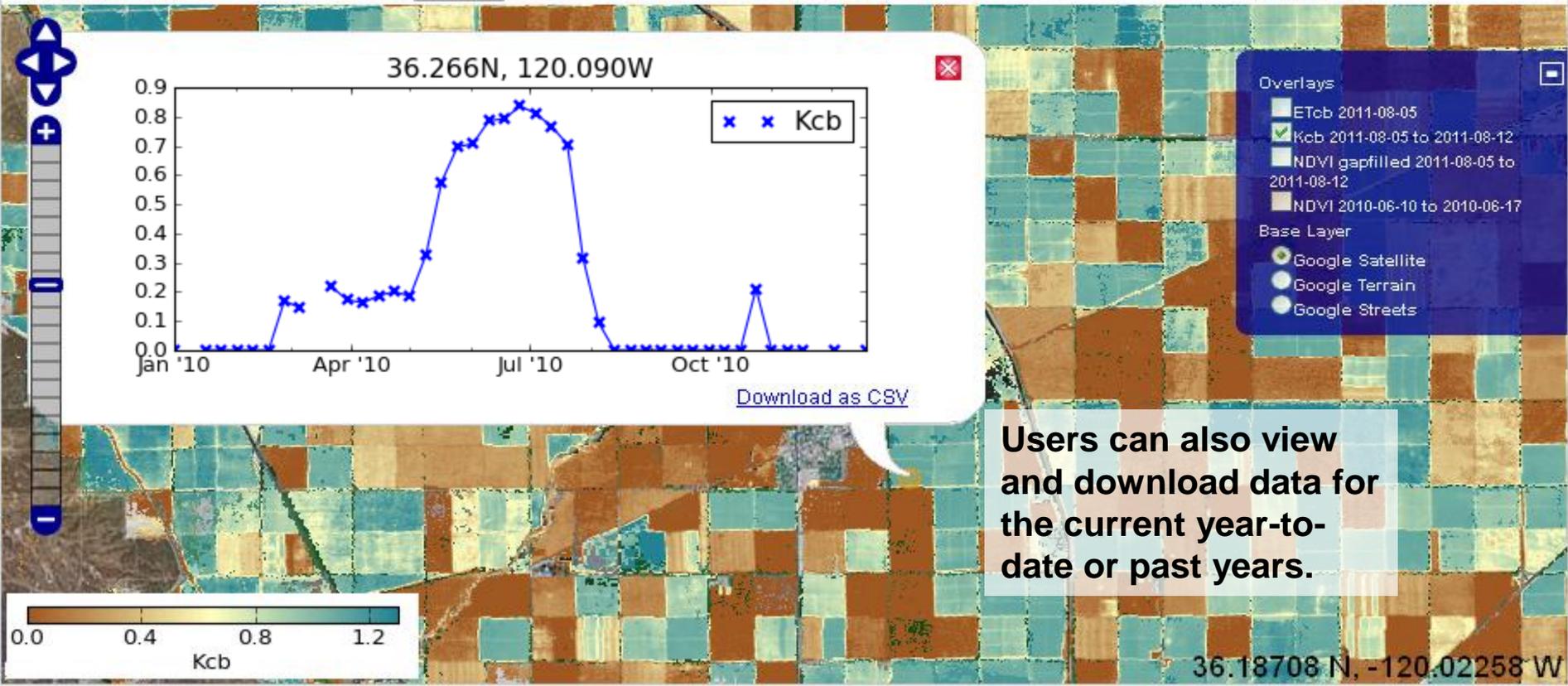


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Users can also view and download data for the current year-to-date or past years.

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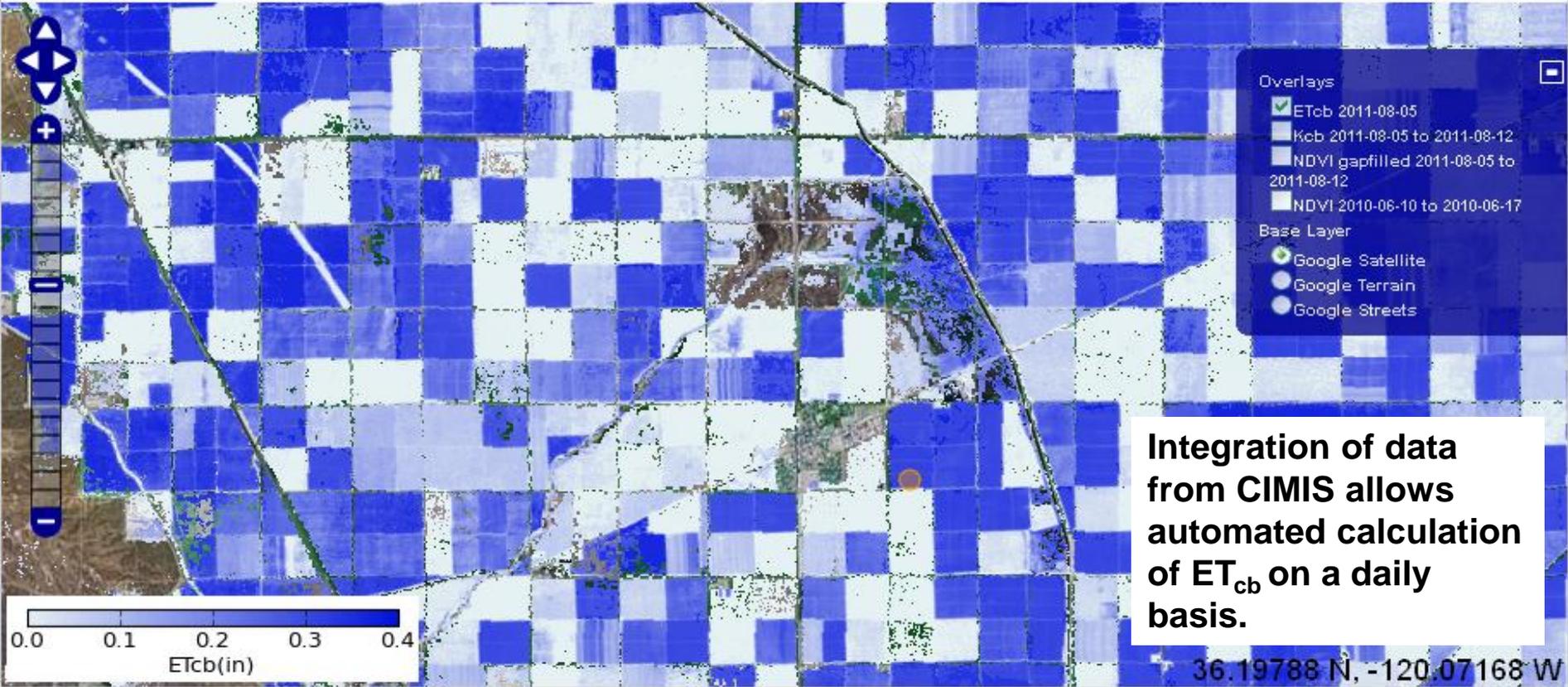


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Integration of data from CIMIS allows automated calculation of ET_{cb} on a daily basis.

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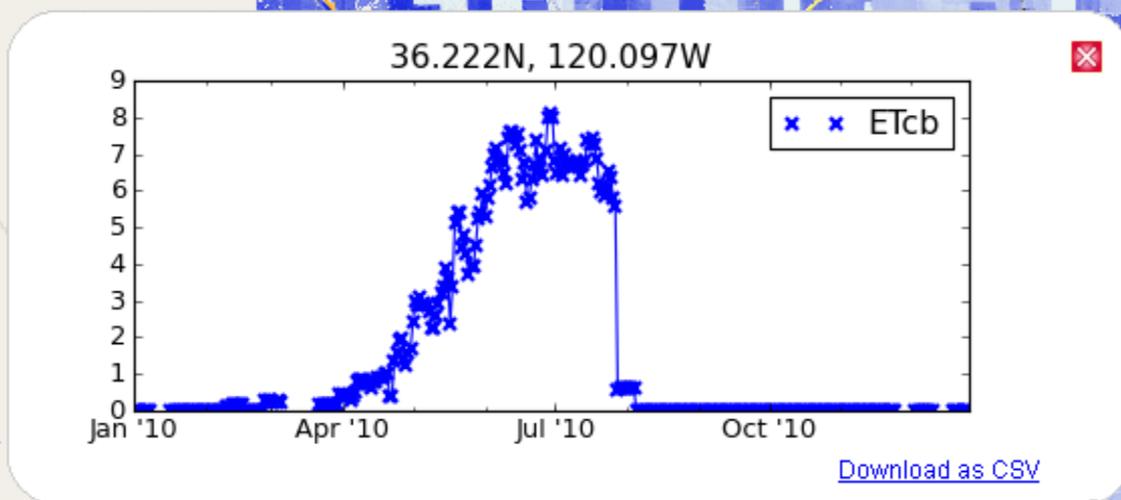
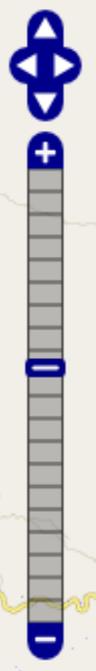
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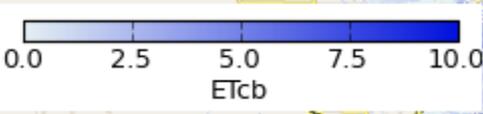


Overlays

- 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



ET_{cb} maps can also be queried, and data can be downloaded directly into Excel or other software tools

-120.09559, 36.22205

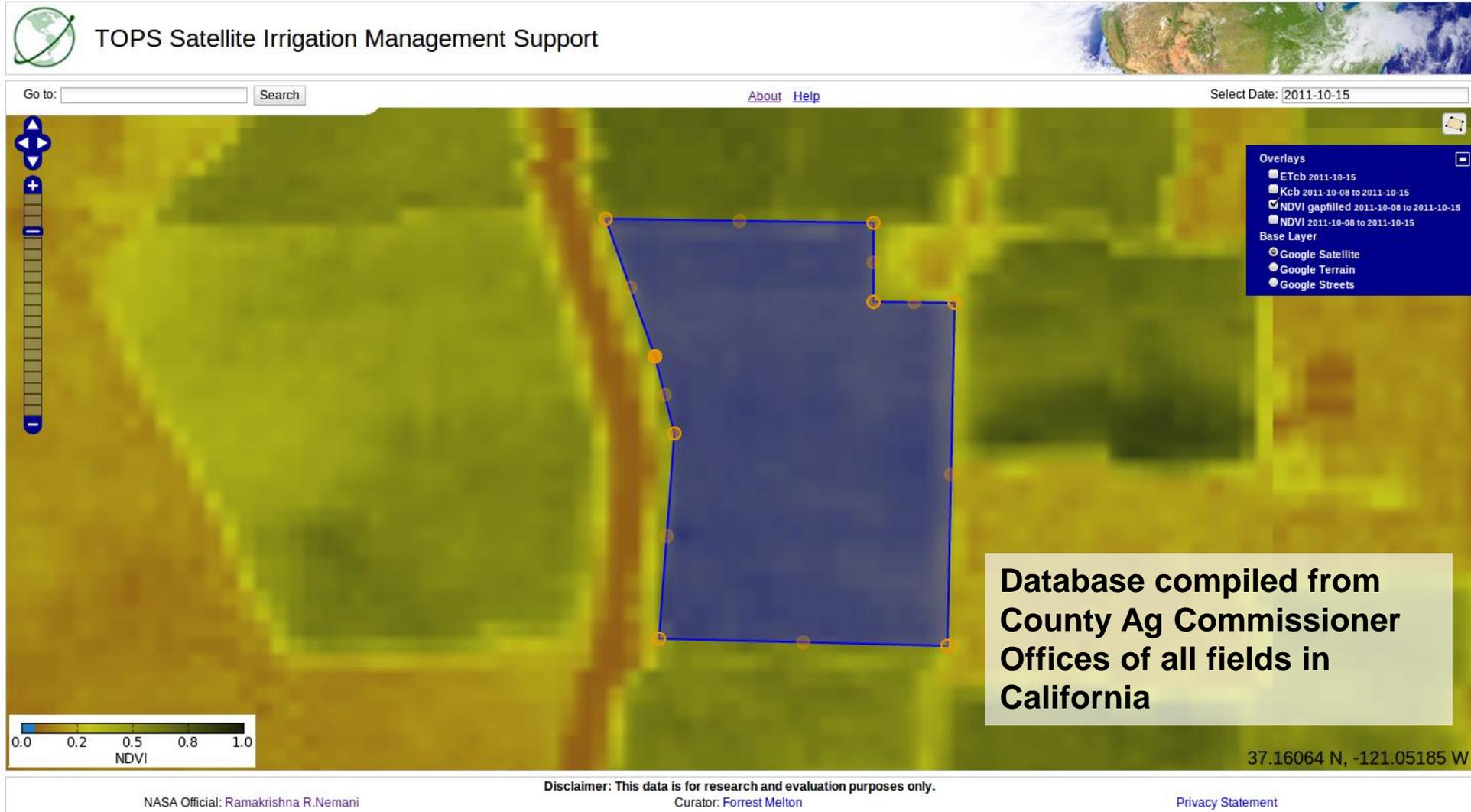
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Customized Reporting: Field Level Summaries

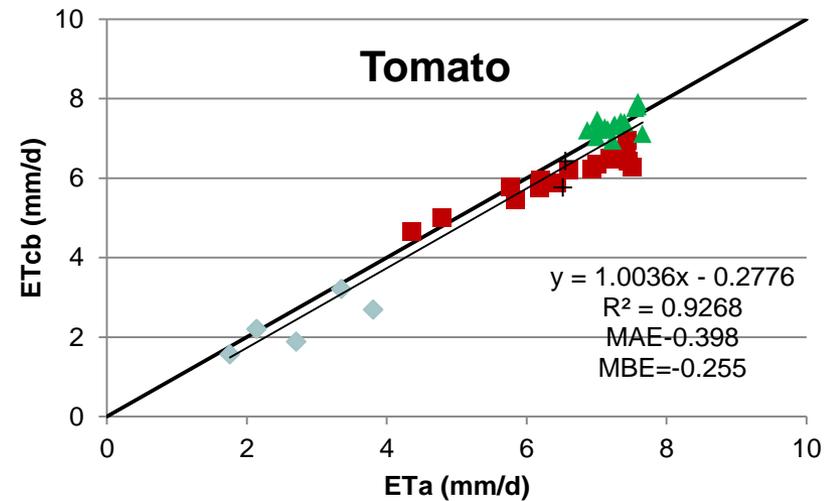
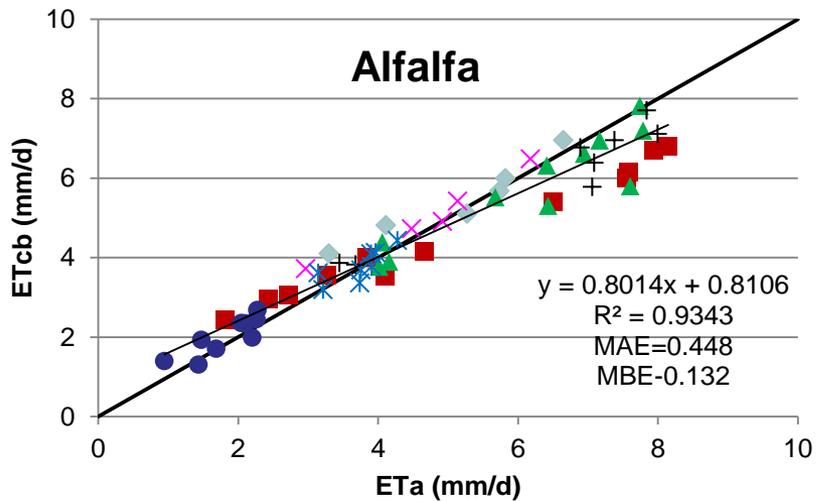
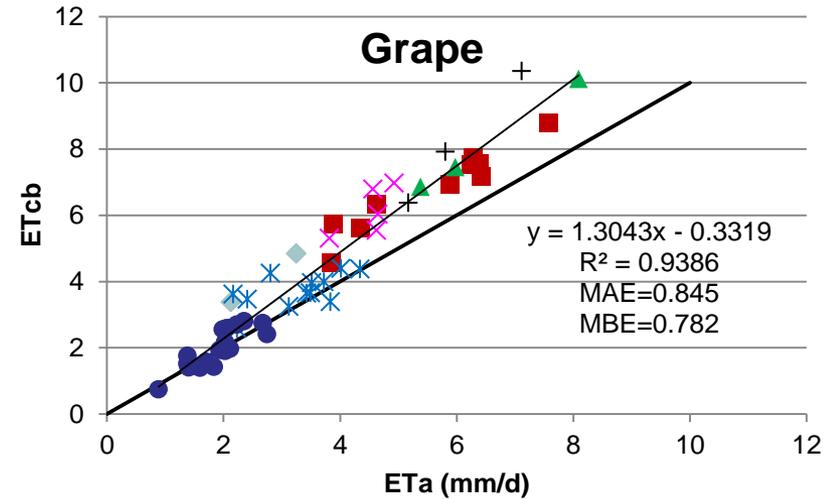
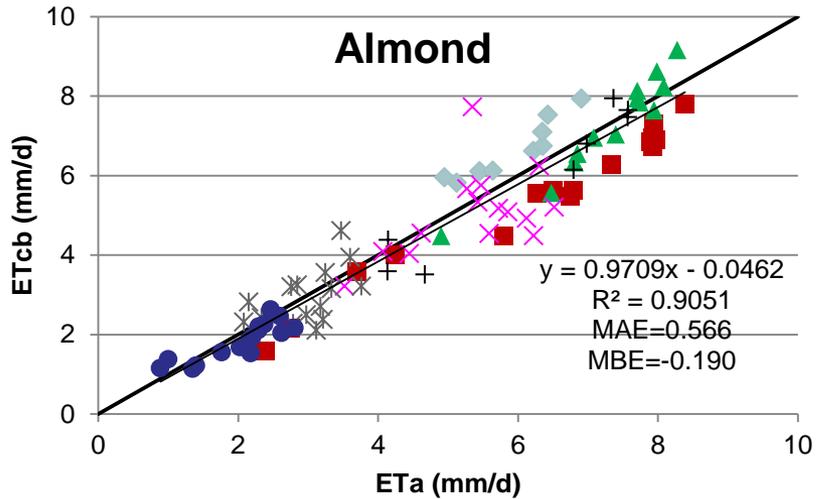


Approach: System Validation and Accuracy Assessment

- 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

Satellite ET Mapping

TOPS SIMS (Automated) vs SEBAL (Manual)



- ◆ 23-Apr
- 25-May
- ▲ 26-Jun
- + 28-Jul
- × 29-Aug
- ✱ 30-Sep
- 1-Nov
- 1:1 line

SIMS: Field Sensor Network Components

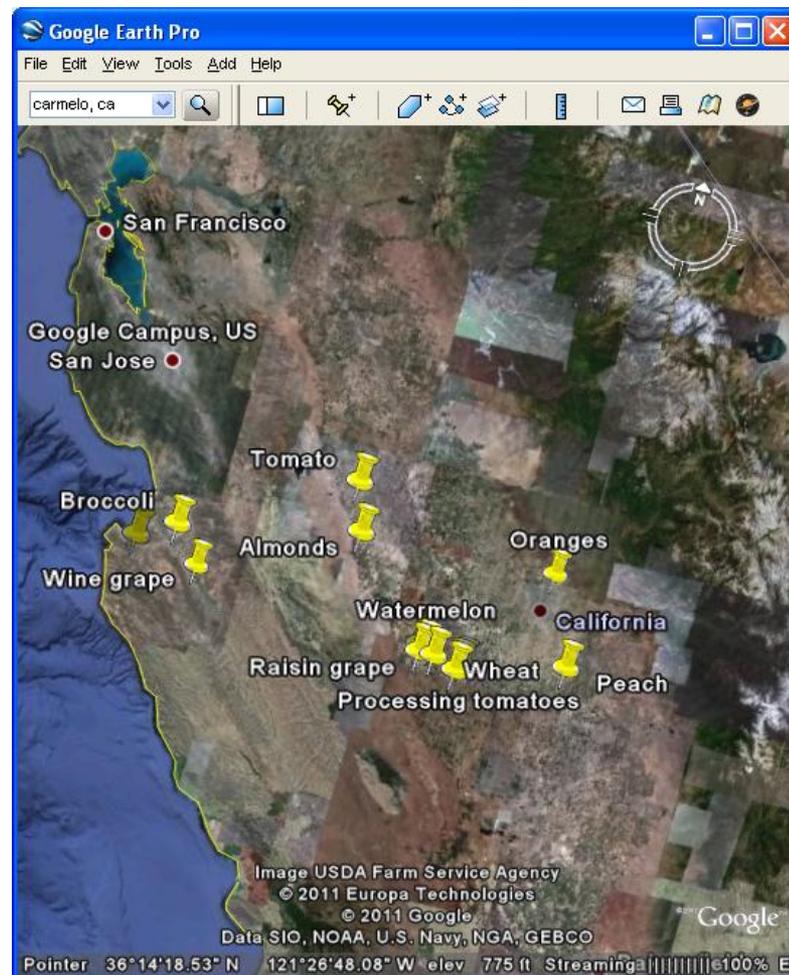


- 1) Surface renewal instrumentation for measuring ET
- 2) Volumetric water content at 8-12 points at four depths (10HS)
- 3) Soil water potential at 8 points at one depth (MPS-1)
- 4) Deep drainage at two points (Gee passive capillary lysimeter)
- 5) Flow measurements at two irrigation standpipes (Badger)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

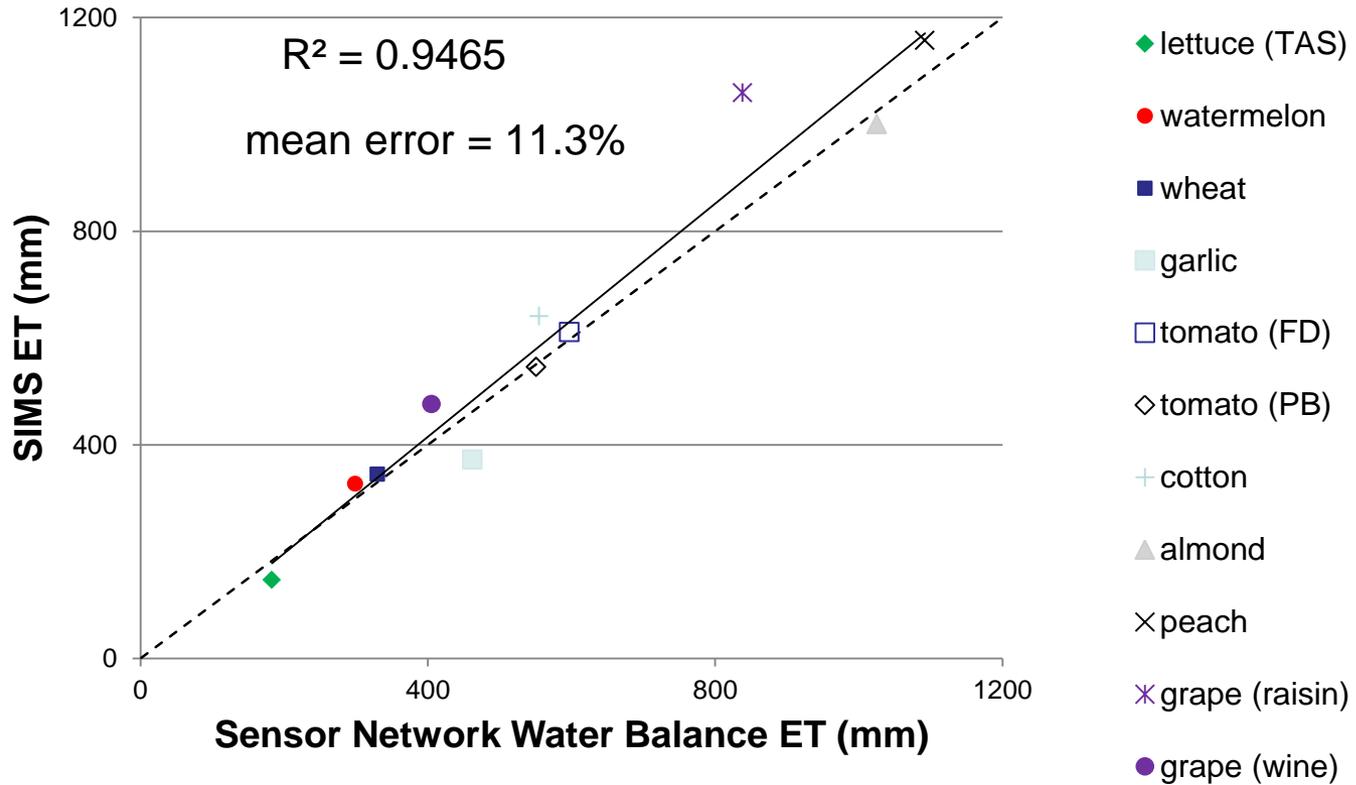
Sensor Network Installations

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 Verification Results (2011)



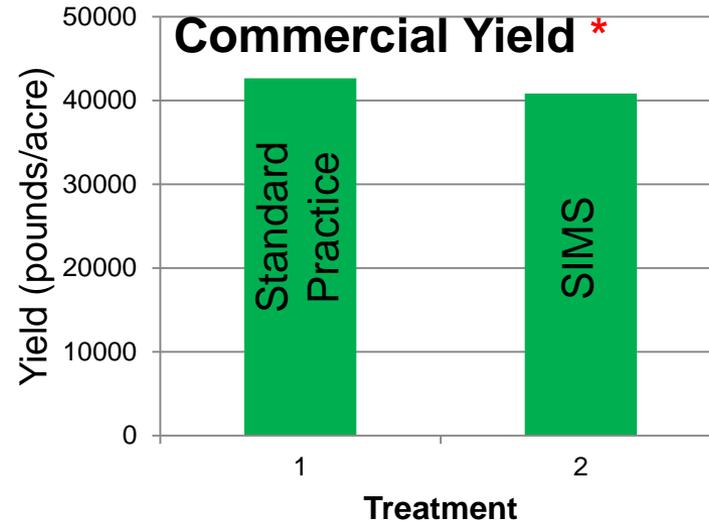
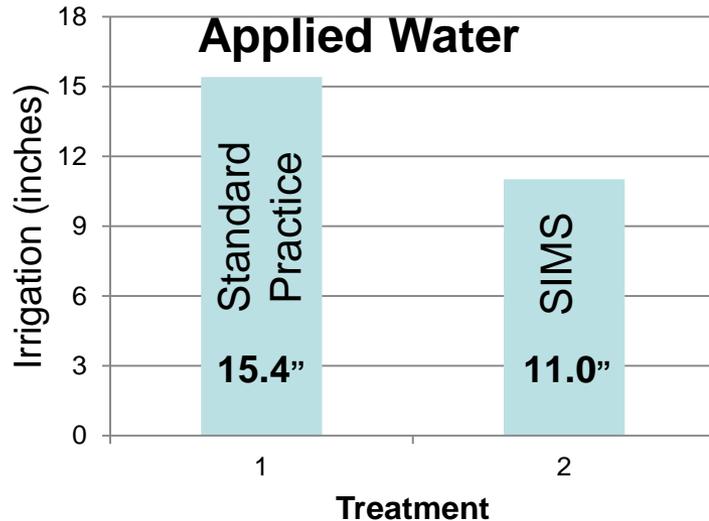
Impacts: Benefits of Using Ag Weather Information in Irrigation Management

Specialty Crop Irrigation Trials

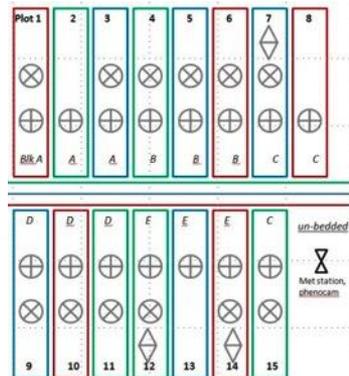
Research Partners: CSUMB/NASA, USDA-Ag Research Service, UC Cooperative Extension

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*



Quantifying 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: <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 \geq \$100/ha:
Increasing use of ET
from 12% to 22% has
value of ~\$60m/yr**

Next Steps (FY13)

- **Integration of data from SPOT and Landsat Data Continuity Mission**
- **Complete analysis of additional surface renewal data collected by CA DWR + 2012 data**
- **Completion of field-level reporting tools and integration with mobile-optimized interface**
- **Developing plans for formal system verification with CA DWR**
- **Initiation of operational trials with partner growers**
- **Finalize plans for outreach and education program with Western Growers and NRCS**
- **Integration of satellite-driven energy balance models in collaboration with Desert Research Institute**

Questions?



Back-up Slides

Summary

- **Information on evapotranspiration (ET) can be used to support optimization of irrigation and nutrient management**
- **SIMS: Application of NASA satellite and computing technologies to develop new information products to support U.S. growers working to maximize the benefit of available water supplies**
- **Prototype system developed for California and currently being tested in collaboration with partner growers in 2012**
- **System validation on-going, initial results are highly encouraging**
- **Partnerships with CA DWR, Western Growers Association, USDA ARS, and individual growers / irrigation consultants in the California Central Valley and Salinas Valley are key to project success**

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

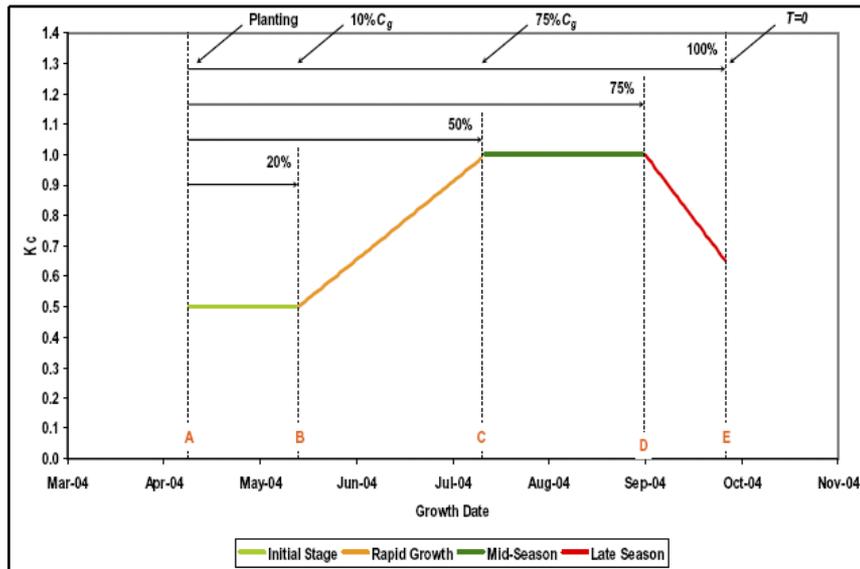
Combining Weather and Satellite Data: Mapping of Crop Coefficients at Field Scales

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

CIMIS
(AgriMet, AZMET, CoAgMet)
satellite

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



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

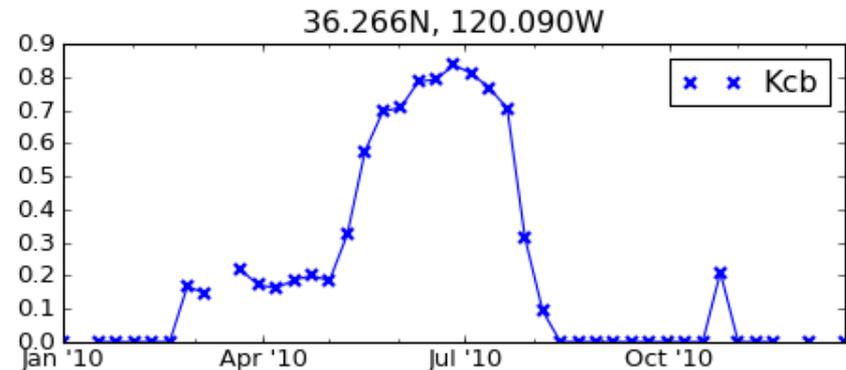
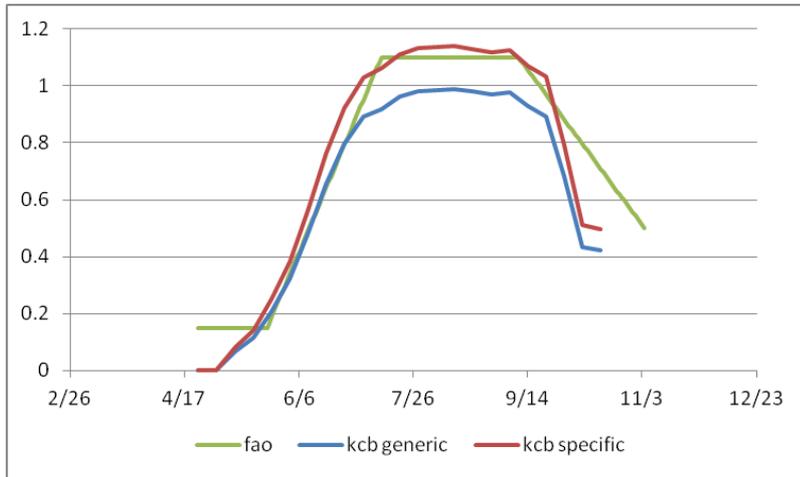


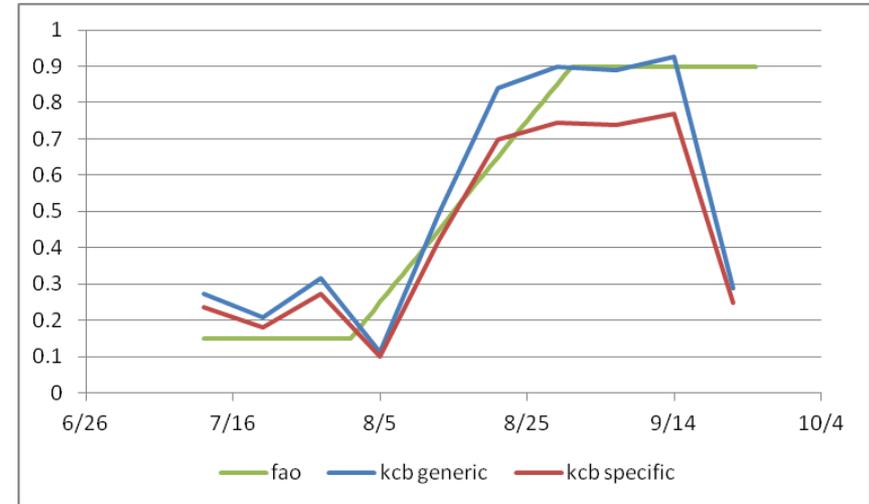
Figure credit: 2005 California Water Plan Update

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

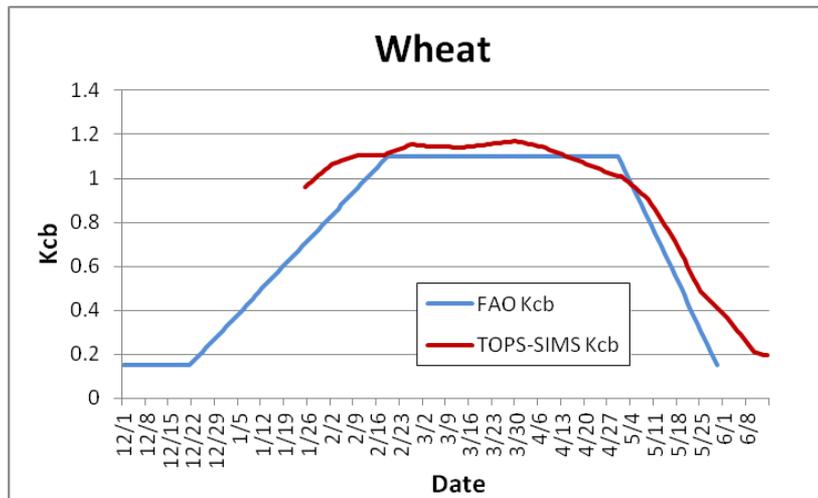
Cotton (Huron)



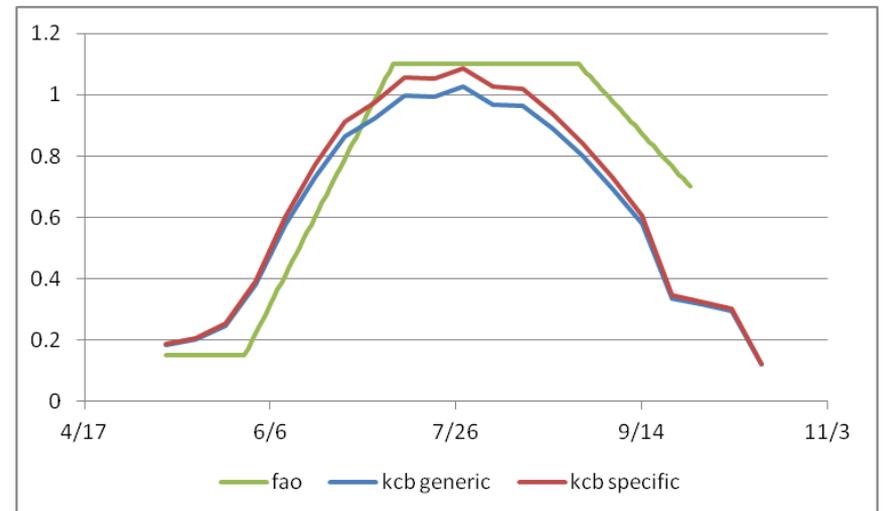
Lettuce (Salinas)



Wheat (Huron)

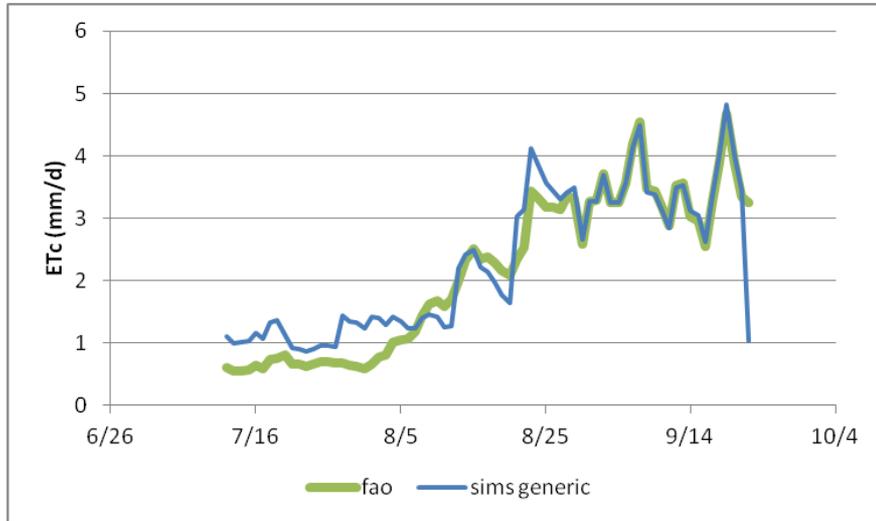


Tomato (Los Banos)

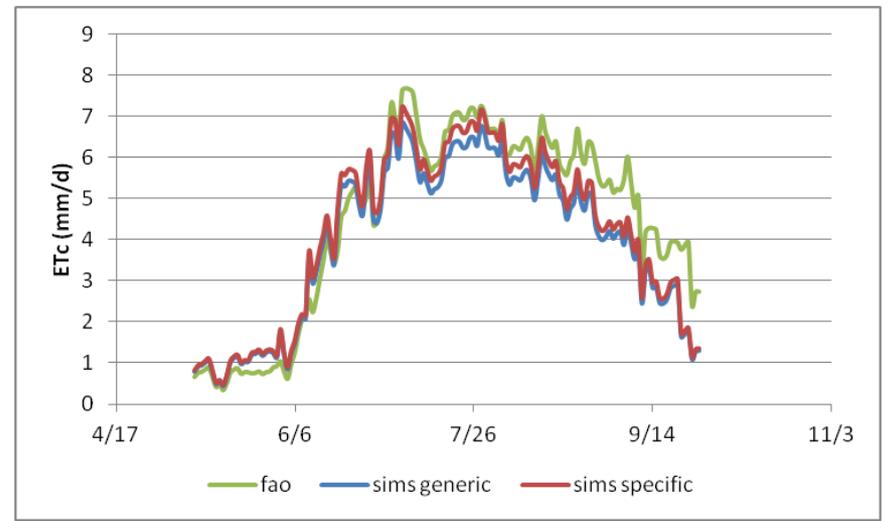


ET_{cb}: SIMS vs FAO-56

Lettuce (Salinas)



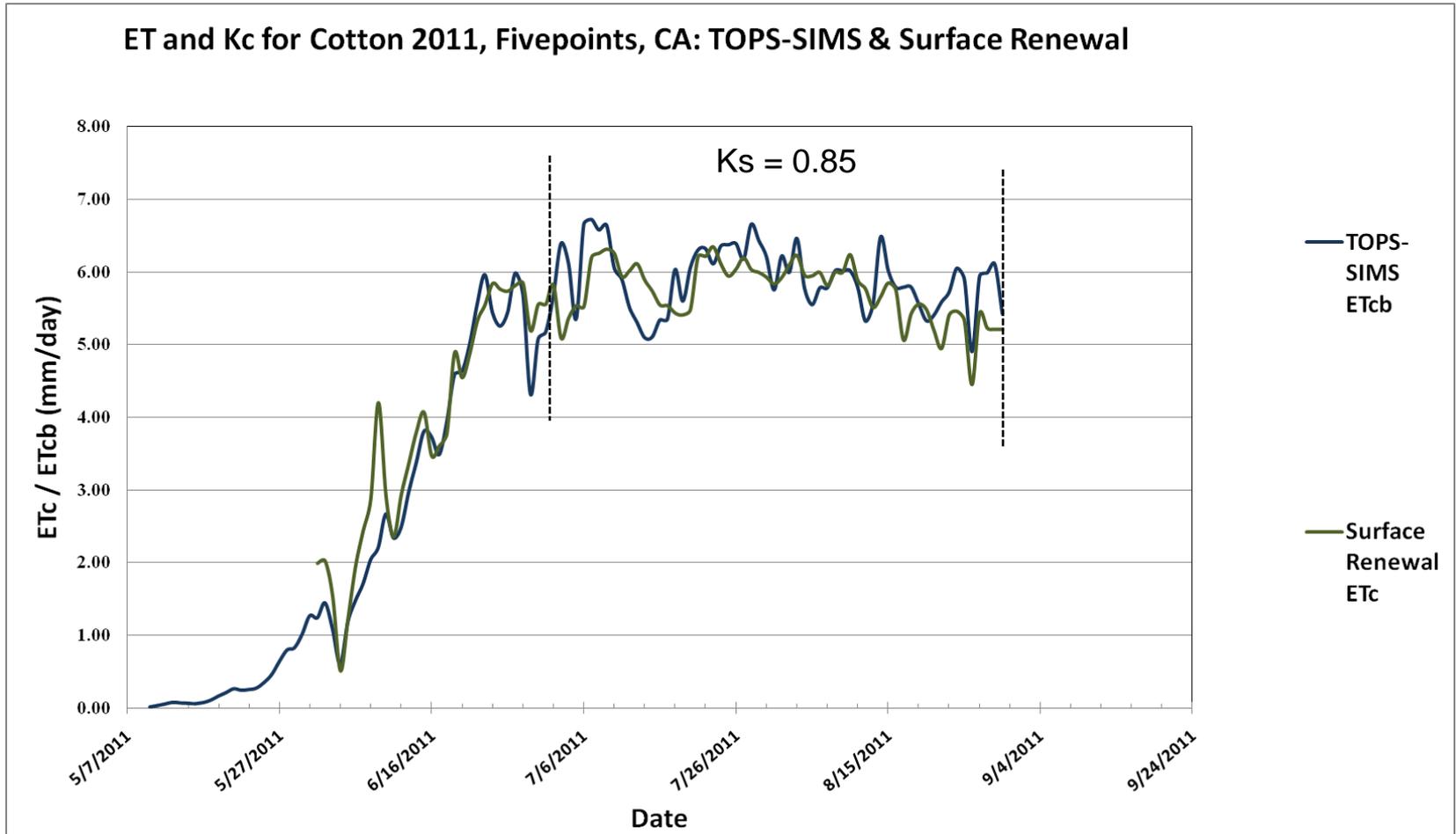
Tomato (Los Banos)



Watermelon (Huron)

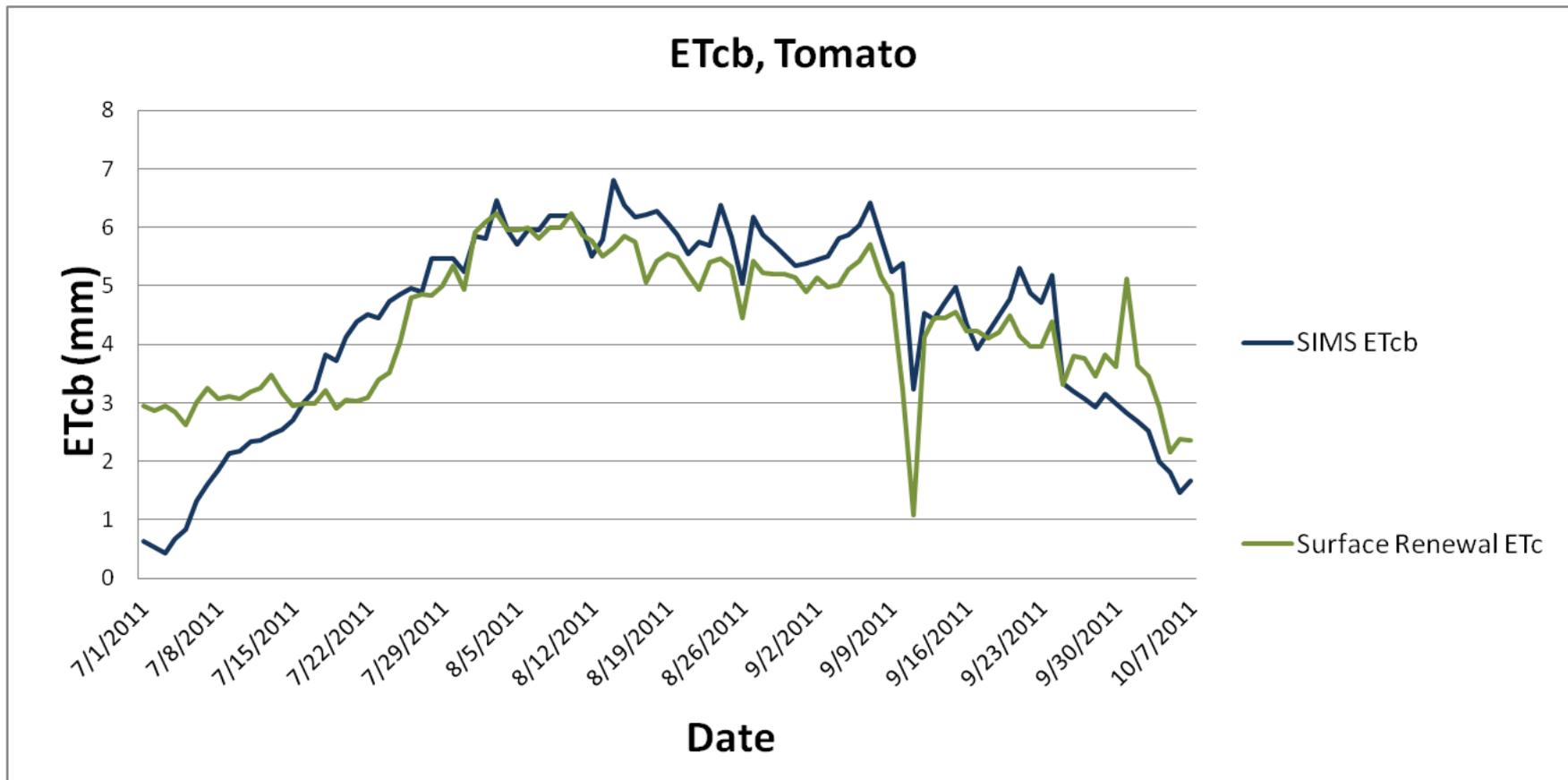


TOPS SIMS ETcb vs Surface Renewal (Cotton)

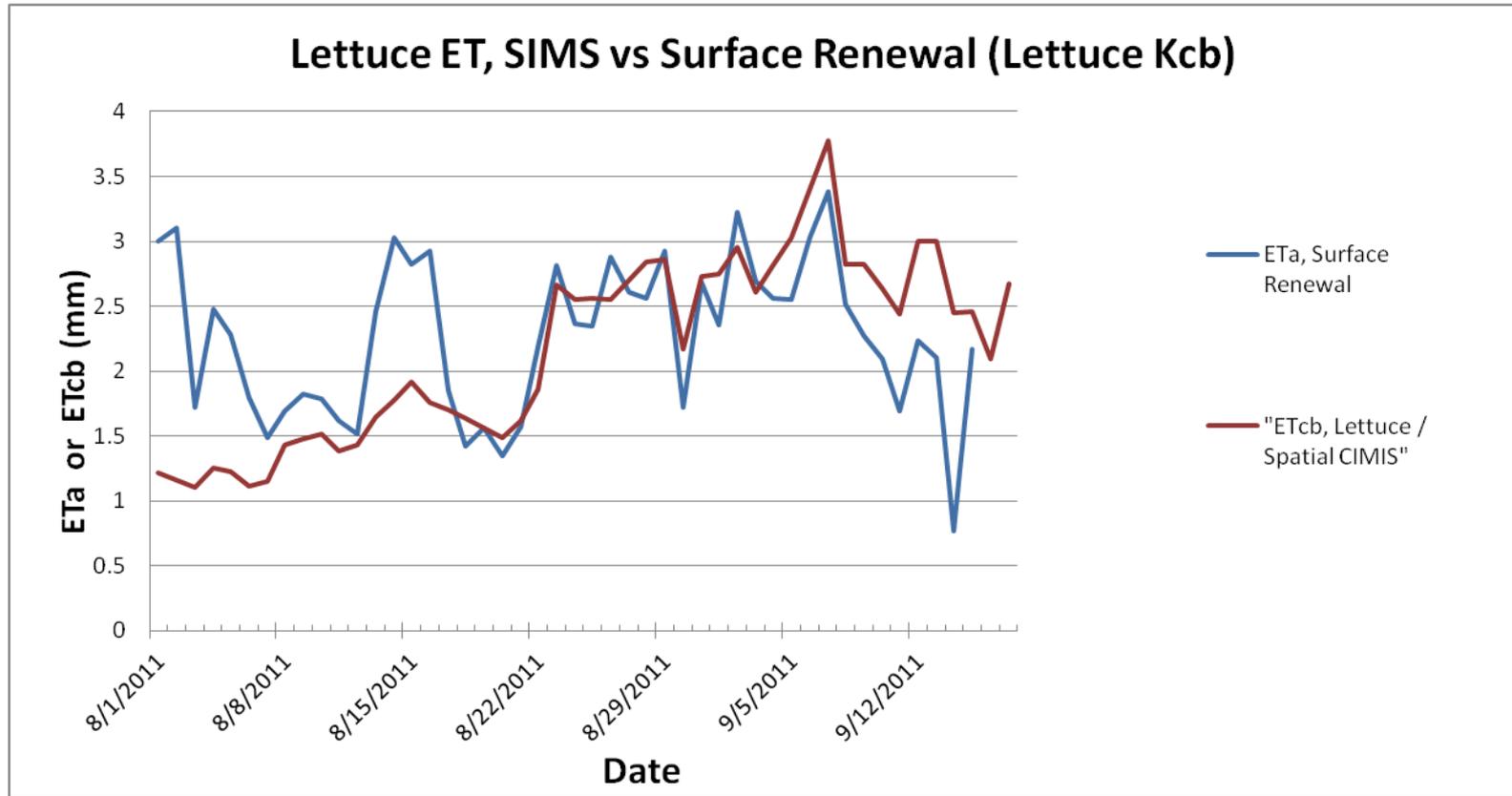


Use of a crop stress coefficient of 0.85 after July 1 reduces MAE to 0.38 mm / day

TOPS SIMS ETcb vs Surface Renewal (Tomato)



SIMS ETcb vs Surface Renewal ETa (Lettuce)



Upcoming Features: Field-Level Summary Reports

TOPS-SIMS Field Summary (Example)

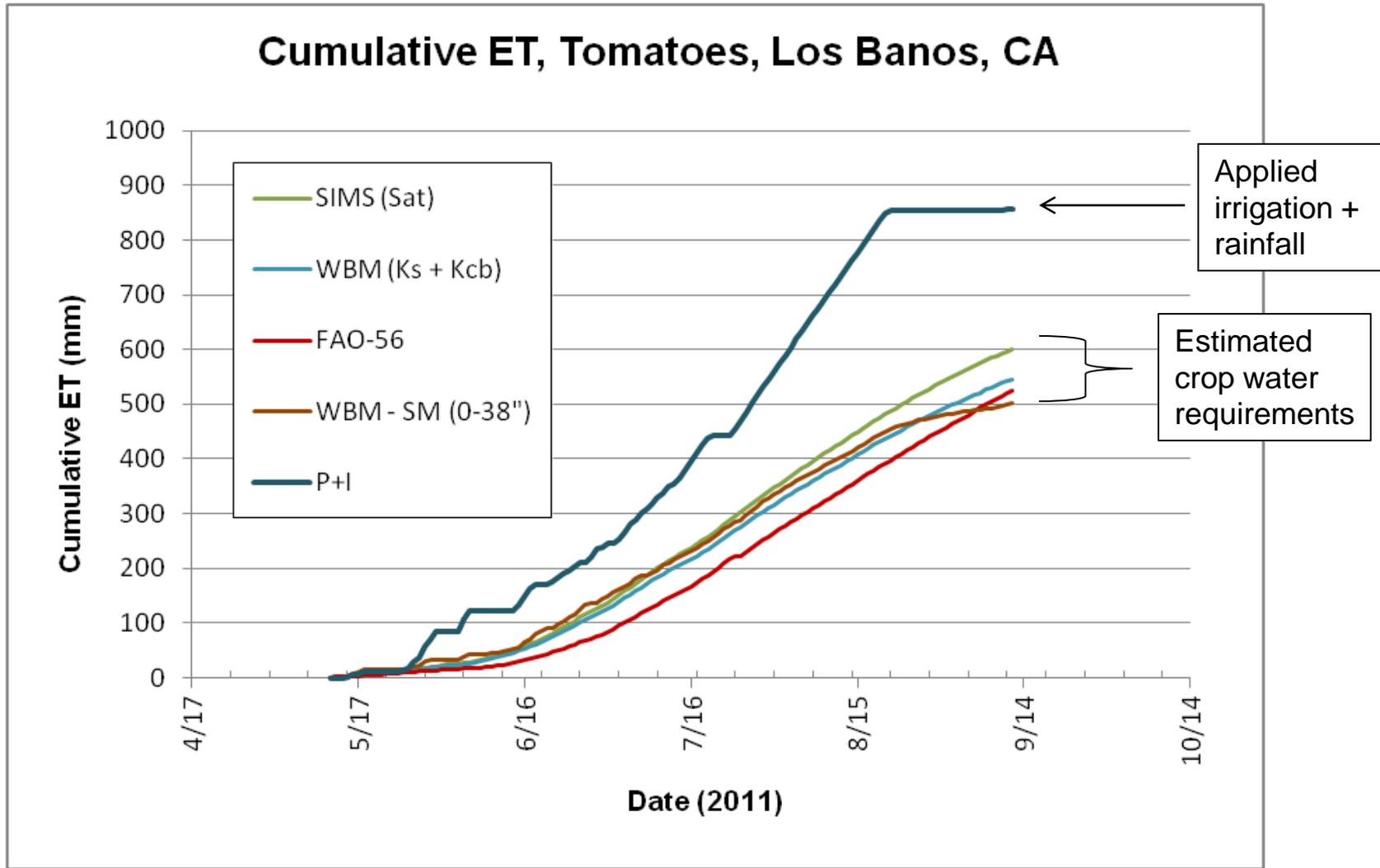
ETo = reference ET (in.), ETcb = crop water use (in.), Kcb = basal crop coefficient, SWB = soil water balance (in.), Runtime = estimated irrigation runtime (hrs.) to restore neutral soil water balance

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	--
...											

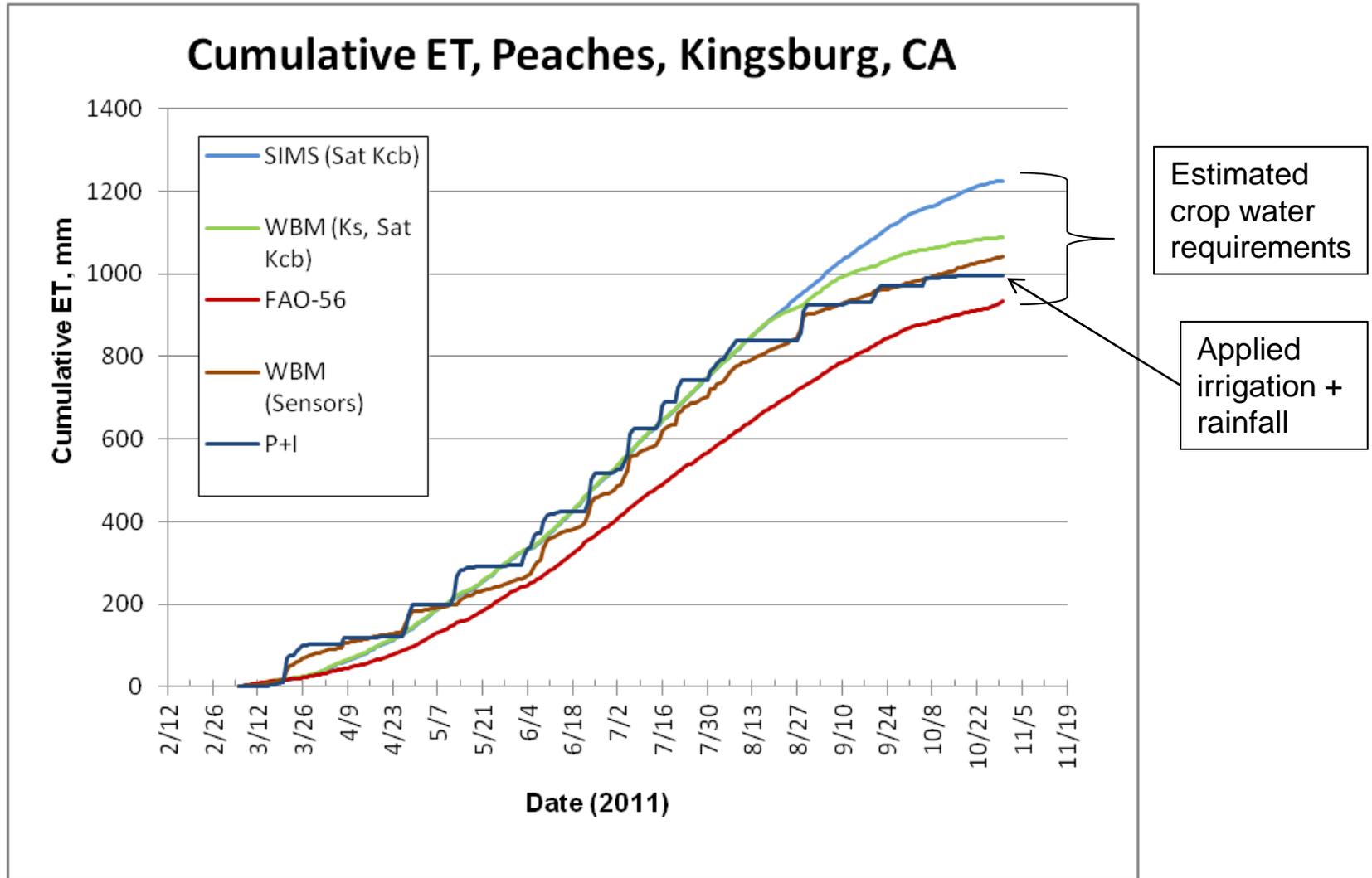


- Considers weather, soil texture, crop type, root depth, precipitation, prior irrigation amounts, method of application, and application rate.
- Parameters to include measures of within-field variability.
- Summary reports planned for delivery via text messages / PDFs sent to mobile devices.

Using ET to Evaluate Irrigation Management Strategies



Using ET to Evaluate Irrigation Management Strategies

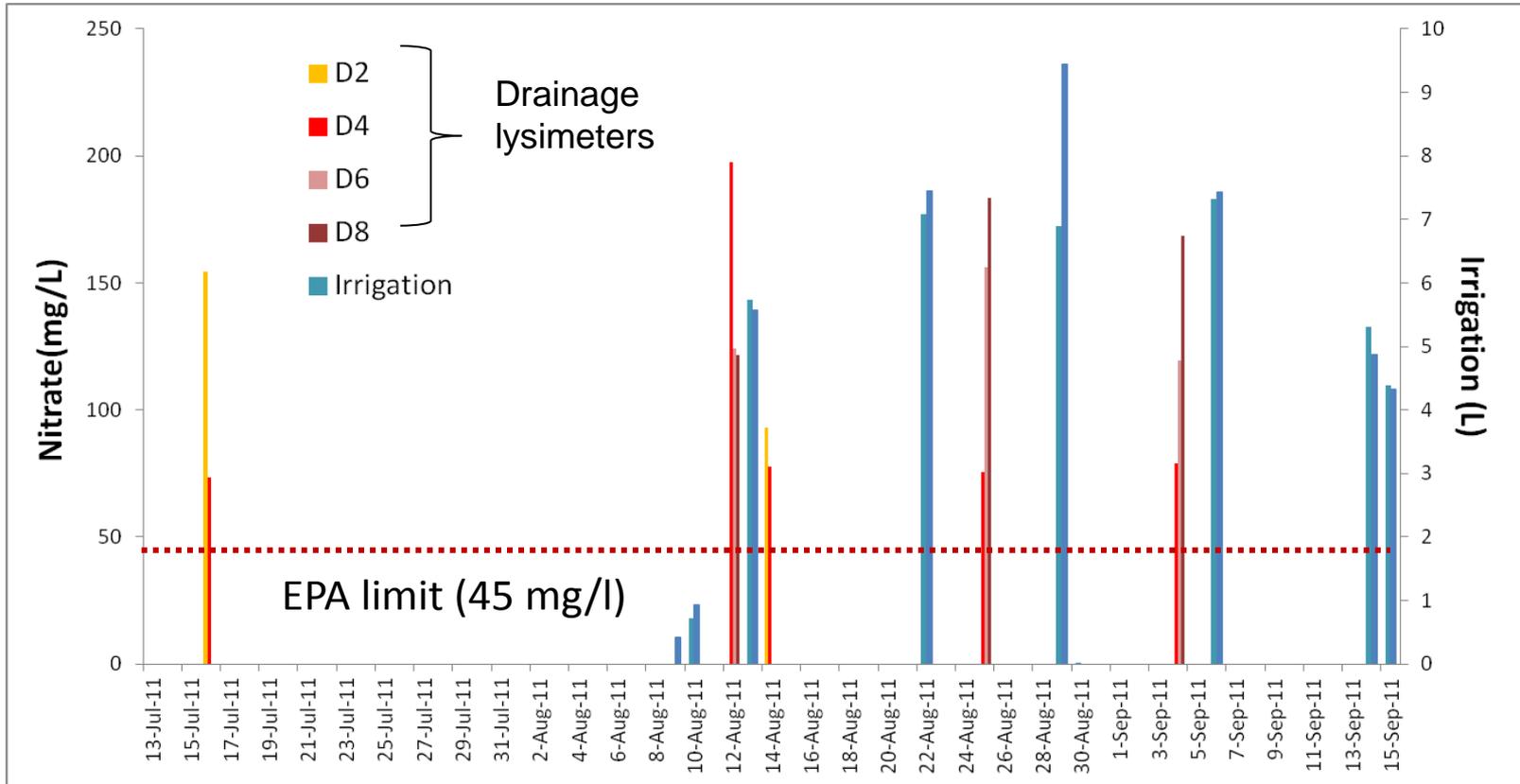


Estimated crop water requirements

Applied irrigation + rainfall

Nutrient Management, Nitrates, and ET

Measured Nitrate Concentration in Drainage Below the Root Zone (Lettuce, preliminary results)



ET data can potentially be used to minimize leaching and improve retention of fertilizer in the root zone

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/>

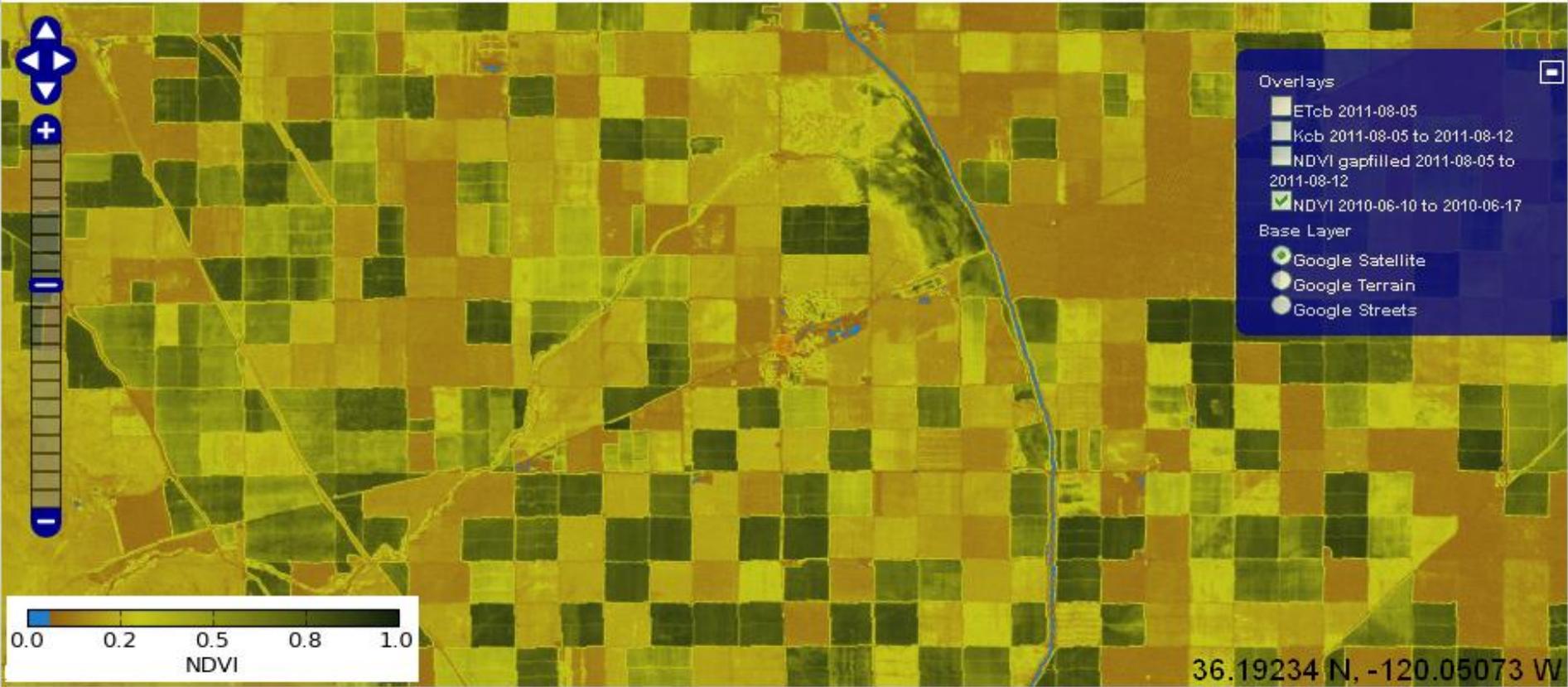


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