Irrigation signals detected from SMAP soil moisture retrievals

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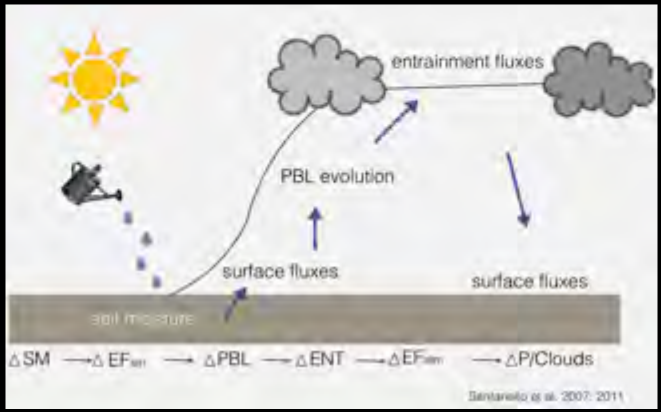
Motivation

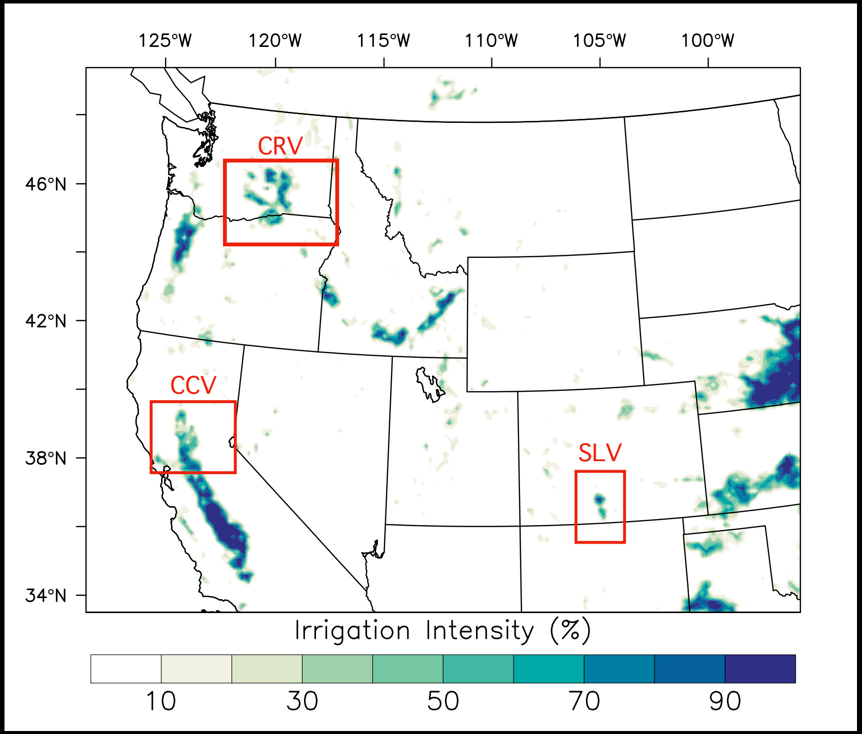
- Irrigation can influence weather and climate, but impacts of irrigation are poorly represented in models, if included at all.
- Satellite-based irrigation detection via soil moisture can help but has been limited to date (SMOS, AMSRE, ASCAT, etc.)
- This study explores the utility of the NASA's new Soil Moisture Active Passive (SMAP) satellite for identify irrigated regions and timing.



Santanello et al. 2011

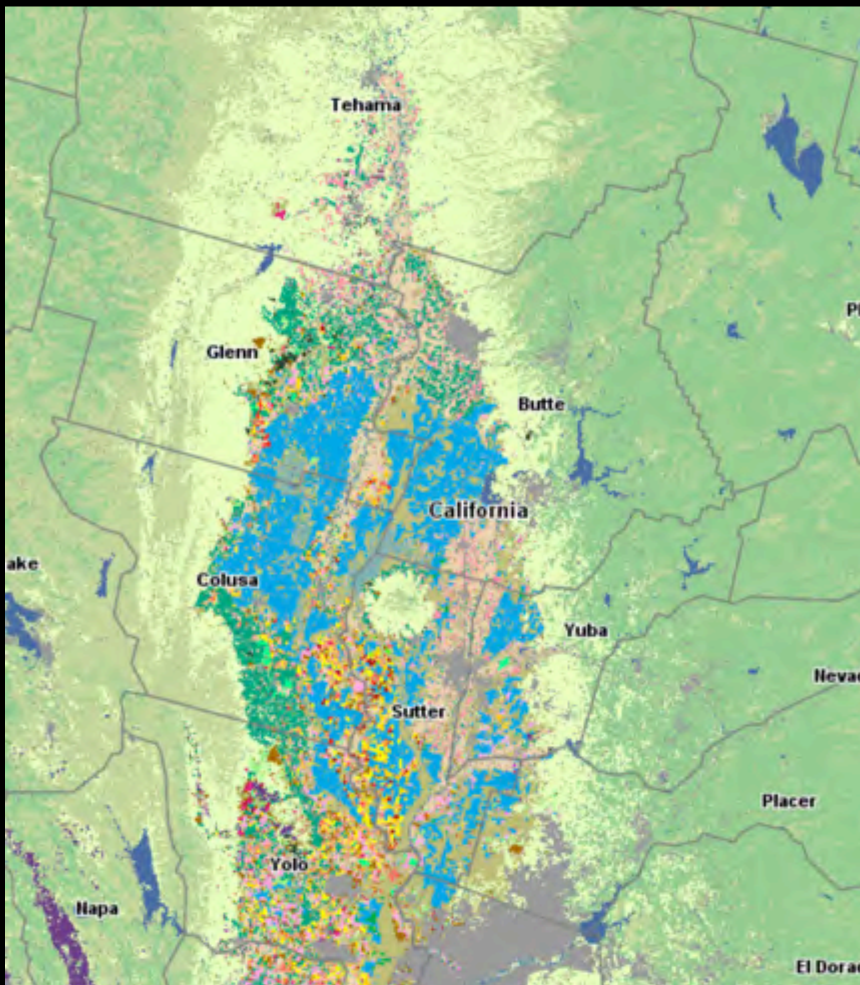
Data & Methods

- Three case study regions:
  1. Sacramento Valley, California (CCV)
  2. San Luis Valley, Colorado (SLV)
  3. Columbia River Valley (CRV)
- Datasets:
  1. SMAP Enhanced soil moisture
  2. NCEP Stage IV daily precipitation
  3. MODIS Terra true color reflectance
  4. US Dept of Ag crop bulletins
- Analyzed in three ways:
  1. Spatially in/out of growing season
  2. Temporally at irrigated/non-irrigated points
  3. Time integrated & normalized precip/soil moisture metric



From Salmon et al. (2013)

Case Study 1: Sacramento Valley



Credit: CropScape (USDA NASS)

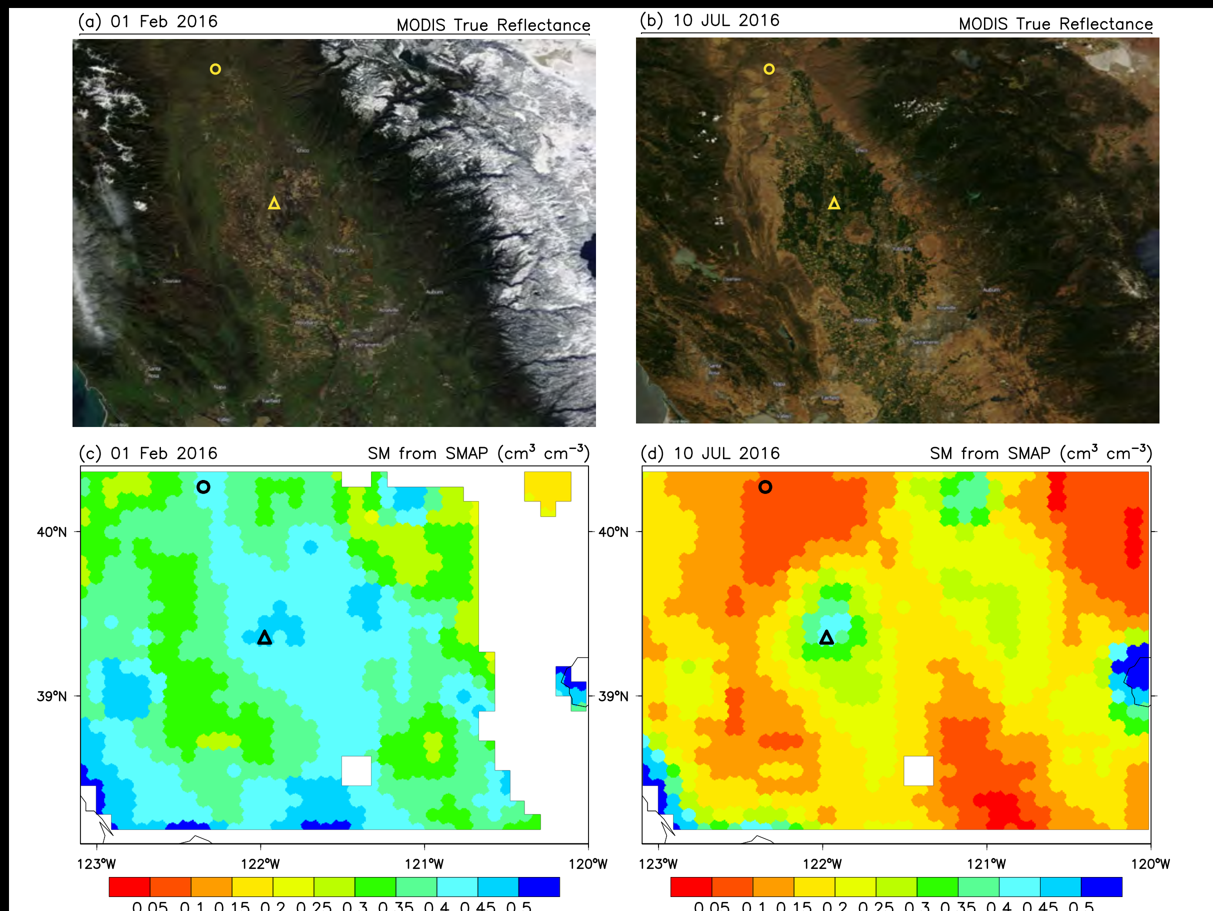
Credit: Cal Rice News

Results: Sacramento Valley

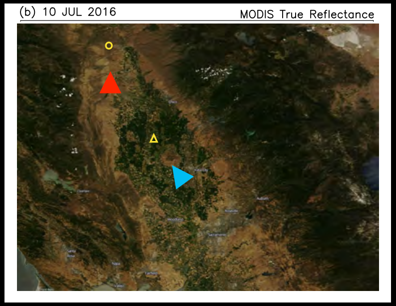
01 Feb 2016 | 10 July 2016

MODIS
True color
reflectance

SMAP
Soil Moisture

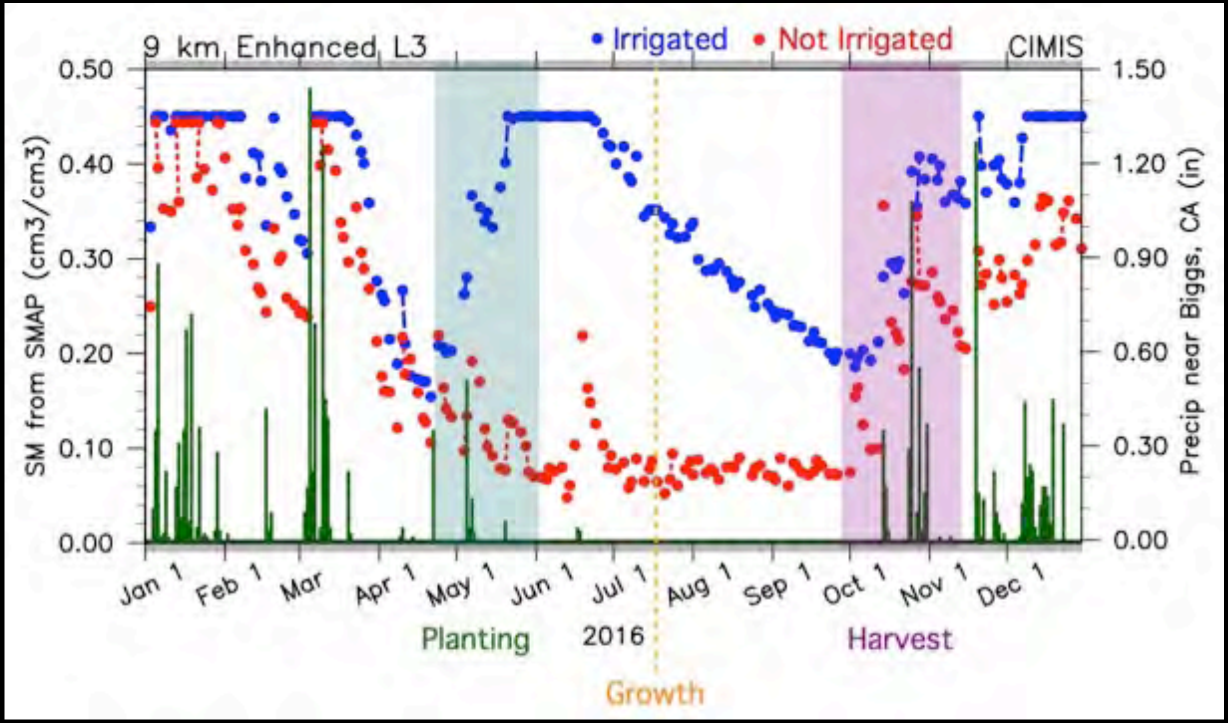


Results: Sacramento Valley



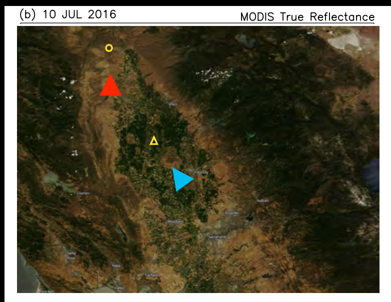
Irrigated

Not irrigated



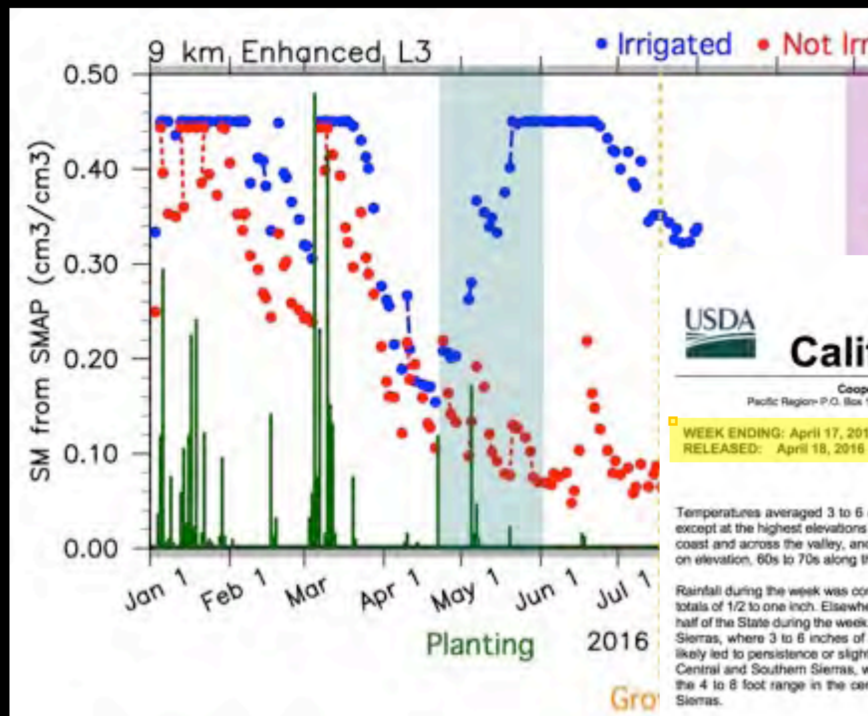
SMAP detects the onset of flood irrigation in May and sustained, elevated soil moisture in the flooded rice paddy in summer.

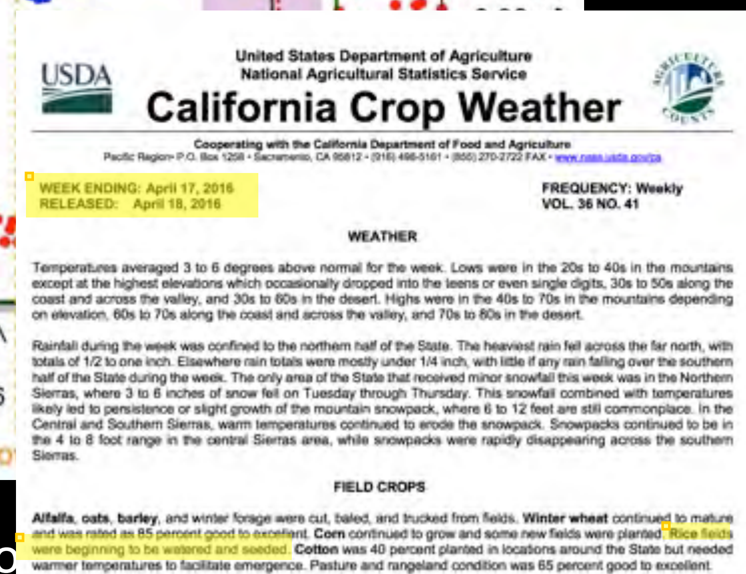
Results: Sacramento Valley



Irrigated

Not irrigated





United States Department of Agriculture
National Agricultural Statistics Service

California Crop Weather

Cooperating with the California Department of Food and Agriculture
Pacific Region- P.O. Box 1258 • Sacramento, CA 95812 • (916) 498-5161 • (855) 270-2722 FAX • www.nass.usda.gov/ca

WEEK ENDING: April 17, 2016
RELEASED: April 18, 2016

FREQUENCY: Weekly
VOL. 36 NO. 41

WEATHER

Temperatures averaged 3 to 6 degrees above normal for the week. Lows were in the 20s to 40s in the mountains except at the highest elevations which occasionally dropped into the teens or even single digits, 30s to 50s along the coast and across the valley, and 30s to 60s in the desert. Highs were in the 40s to 70s in the mountains depending on elevation, 60s to 70s along the coast and across the valley, and 70s to 80s in the desert.

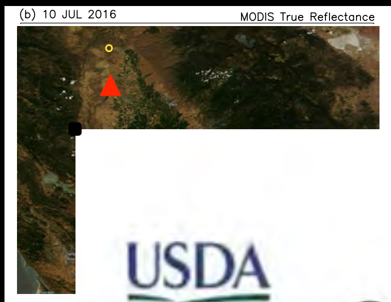
Rainfall during the week was confined to the northern half of the State. The heaviest rain fell across the far north, with totals of 1/2 to one inch. Elsewhere rain totals were mostly under 1/4 inch, with little if any rain falling over the southern half of the State during the week. The only area of the State that received minor snowfall this week was in the Northern Sierras, where 3 to 6 inches of snow fell on Tuesday through Thursday. This snowfall combined with temperatures likely led to persistence or slight growth of the mountain snowpack, where 6 to 12 feet are still commonplace. In the Central and Southern Sierras, warm temperatures continued to erode the snowpack. Snowpacks continued to be in the 4 to 8 foot range in the central Sierras area, while snowpacks were rapidly disappearing across the southern Sierras.

FIELD CROPS

Alfalfa, **oats**, **barley**, and winter forage were cut, baled, and trucked from fields. **Winter wheat** continued to mature and was rated as 85 percent good to excellent. **Corn** continued to grow and some new fields were planted. Rice fields were beginning to be watered and seeded. **Cotton** was 40 percent planted in locations around the State but needed warmer temperatures to facilitate emergence. Pasture and rangeland condition was 65 percent good to excellent.

SMAP detects the onset of flood irrigatio
elevated soil moisture in the flooded rice paddy in summer.

Results: Sacramento Valley



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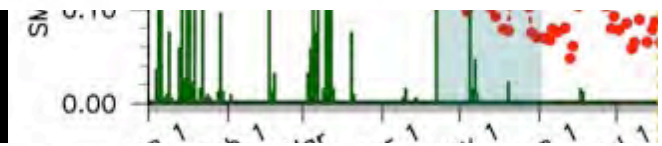

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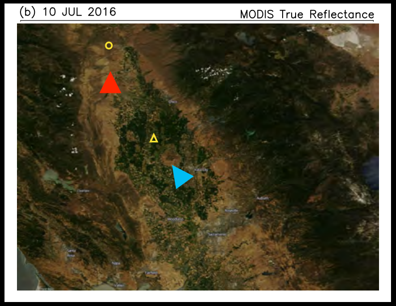
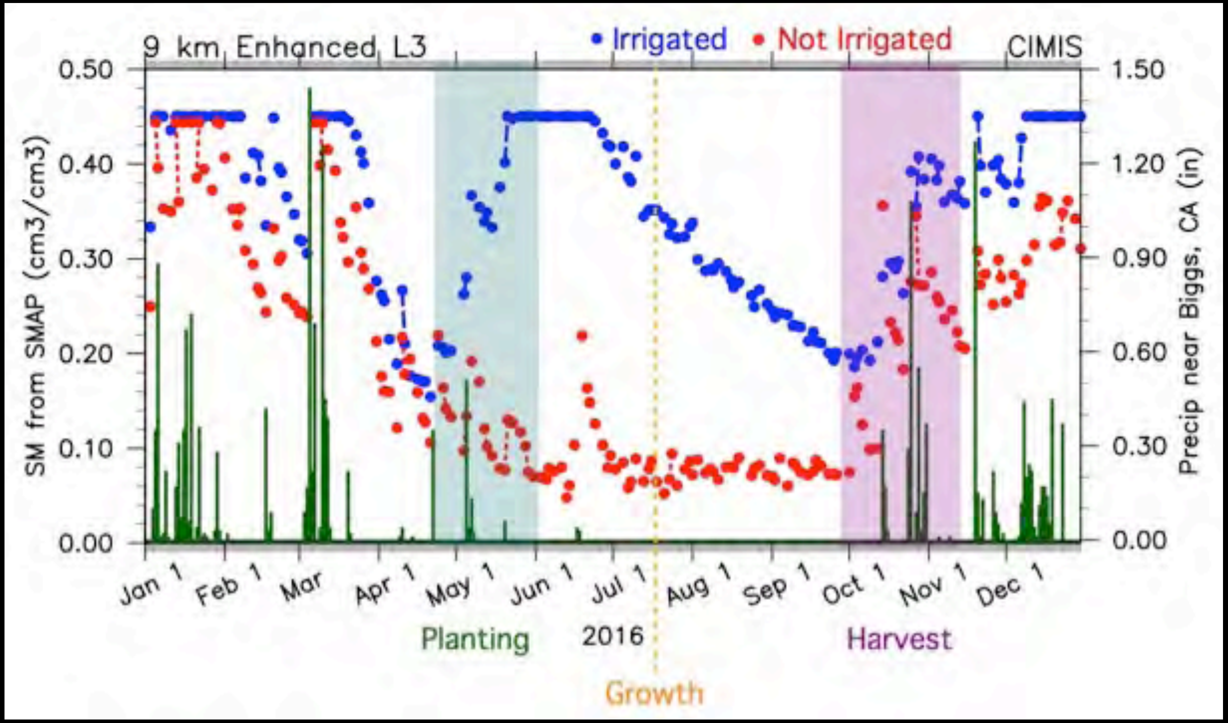


Irrigated

Not irrigated



SMAP detects the onset of flood irrigation in May and sustained, elevated soil moisture in the flooded rice paddy in summer.

Soil Moisture/Rainfall Metric

- Concept: High soil moisture co-located with low precipitation may indicate irrigation
  - Analyze soil moisture and precipitation
- Method: For precip and SM in each study area

1) Accumulate values over time (June & July 2016):

$$\beta_{ji} = \sum_{t=0}^{n} x_{ji}(t)$$

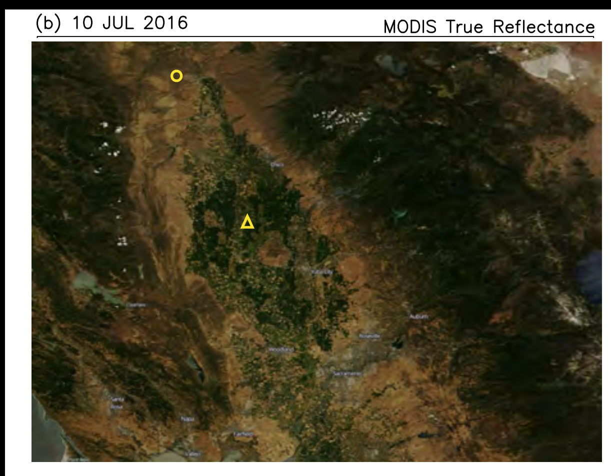
2) Normalize:

$$N_{ji} = \frac{\beta_{ji} - \min(\beta)}{\max(\beta) - \min(\beta)}$$

- Result: Relative (to each region and time period) measure of wettest/driest (SMAP) and rainiest/least rainy (precip) areas.

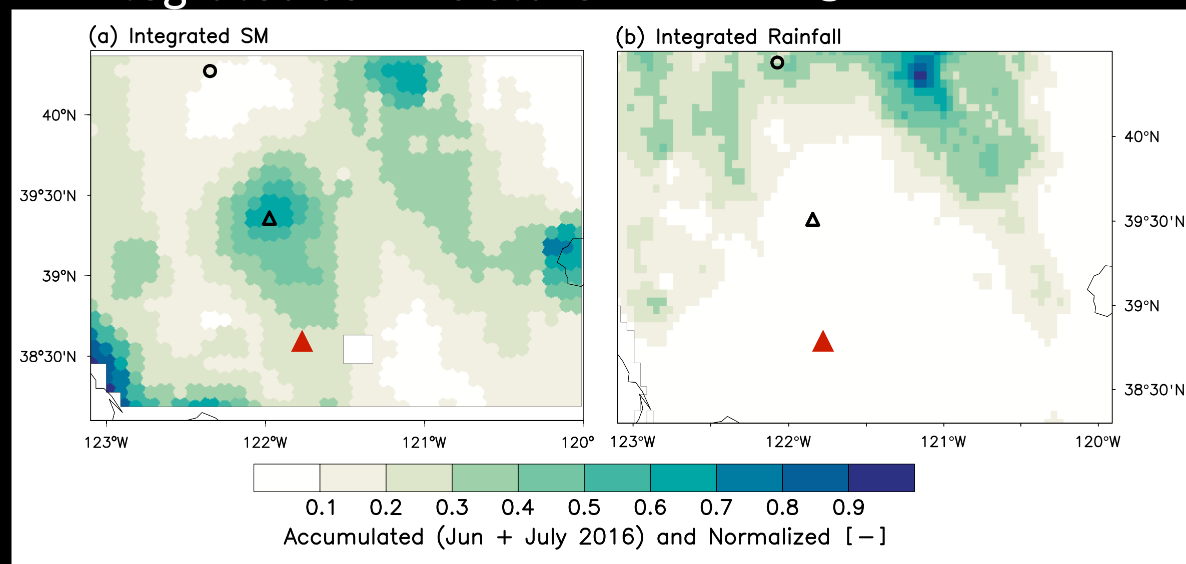
Results: Sacramento Valley

MODIS True color reflectance



Integrated soil moisture

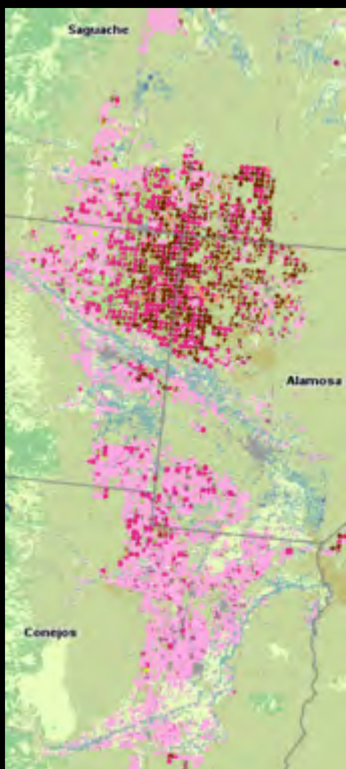
Integrated rainfall



Relatively high soil moisture…

But local minimum in precipitation

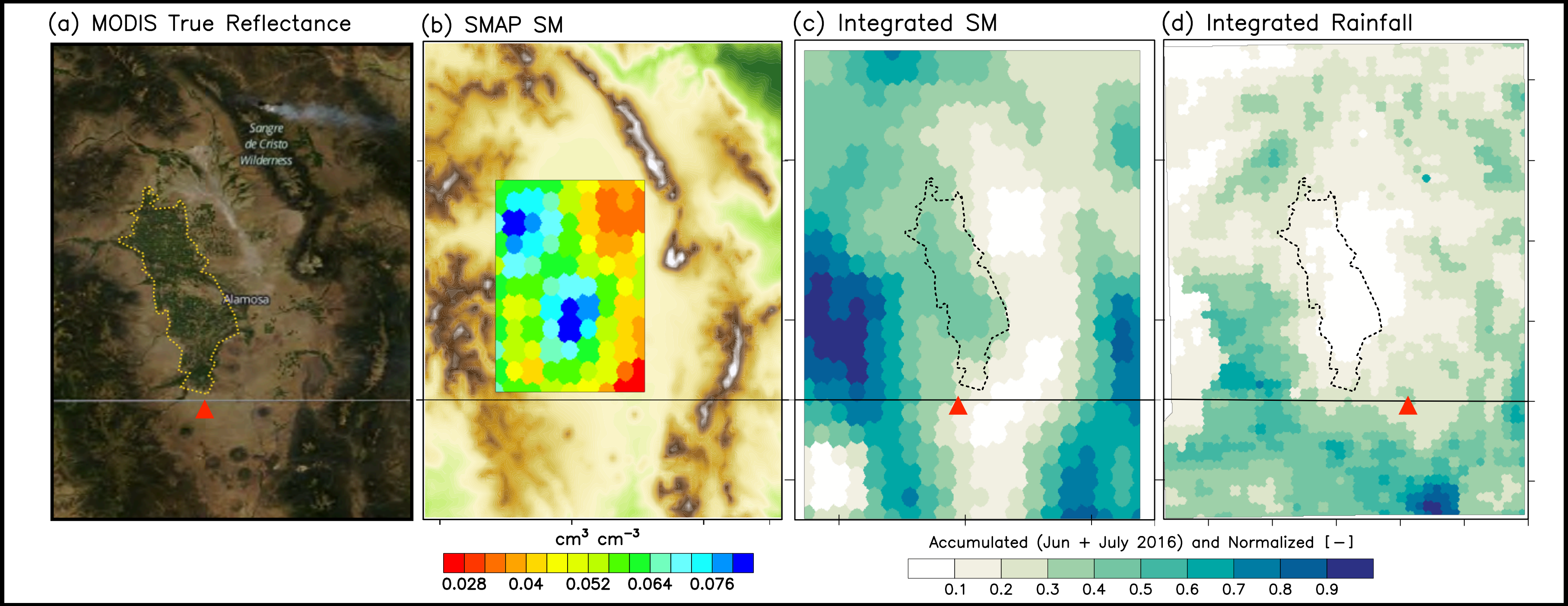
Case Study 2: San Luis Valley



Credit: Alamosa.org

Credit: USDA NASS

Results: San Luis Valley



Irrigation in the valley

Relatively high soil moisture…

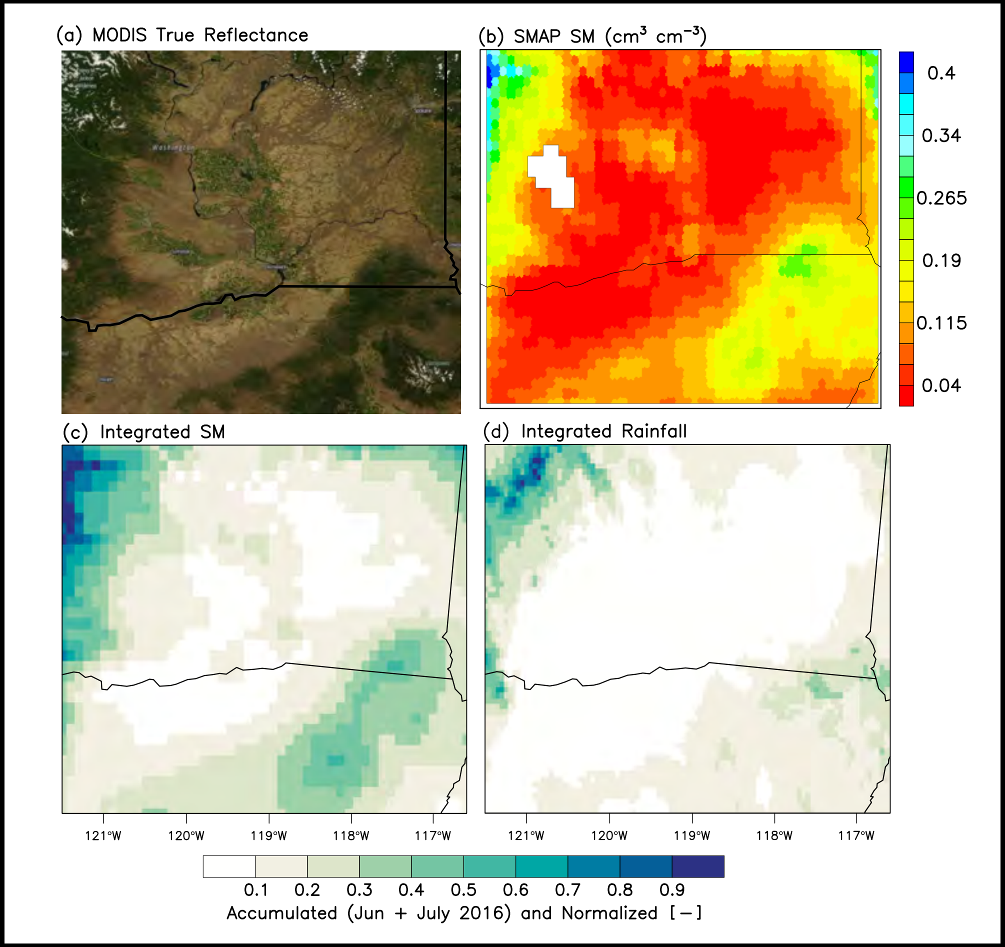
But local minimum in precipitation

Case Study 3: Columbia River Valley

Credit: John Clement

Credit: CropScape (USDA NASS)

Results: Columbia River Valley



A complicating factor in this region is the proximity to rivers and lakes which could contaminate the SMAP signal.

Conclusions

- In three semi-arid regions, SMAP is able to detect the bulk seasonal timing and spatial signal of irrigation via elevated soil moisture relative to adjacent non-irrigated regions
- Flood irrigation is easiest to detect
- Limitations apply
- Future work will apply apply these approaches globally and will use SMAP-Sentinel downscaled 1 km soil moisture

Poster C-5

Irrigation Signals Detected from SMAP Soil Moisture Retrievals

Patricia M. Lawston[1,2], Joseph A. Santanello, Jr.[2], Sujay V. Kumar[2]
[1]University of Maryland ESSIC, College Park, Maryland, USA; *patricia.m.lawston@nasa.gov*
[2]NASA-GSFC Hydrological Sciences Lab, Greenbelt, Maryland, USA

MOTIVATION:

- Irrigation can influence weather and climate, but the timing, spatial extent, and land-atmosphere coupling impacts of irrigation are poorly represented in models, if included at all.
- Satellite remote sensing of irrigation impacts to soil moisture is a promising method for obtaining needed observations routinely, but so far, irrigation detection from passive microwave satellites has proven difficult.
- **This study explores the utility of the new Soil Moisture Active Passive (SMAP) satellite for identifying irrigated regions and timing.**

DATA & METHODS:

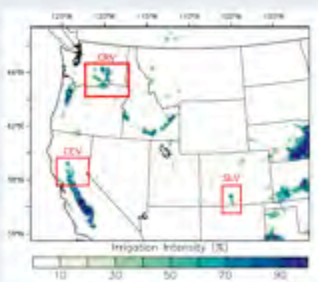


Figure 1. Percent of areas equipped for irrigation (Salmon et al., 2015) and case study regions.

- **Three case studies** are investigated in the western U.S.
  1. Sacramento Valley, California (CCV)
  2. San Luis Valley, Colorado (SLV)
  3. Columbia River Valley, Washington/Oregon (CRV)
- The following datasets are used:
  1. SMAP Enhanced soil moisture retrievals
  2. NCEP Stage IV quantitative precipitation estimates
  3. MODIS Terra true color images
  4. US Department of Agriculture crop bulletins
- The sensitivity of **SMAP soil moisture to irrigation is analyzed in three ways:**
  1. Spatially during and outside of the growing season
  2. Temporally at irrigated and non irrigated points
  3. By using a regional, time-integrated and normalized metric of SM and precipitation

RESULTS:

Sacramento Valley (CCV)

- SMAP realistically senses seasonal soil moisture characteristics, including elevated soil moisture due to irrigated rice paddy agriculture at the center of the Valley.

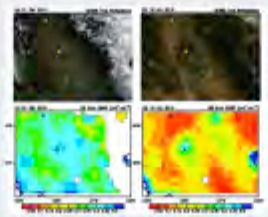


Figure 2. MODIS true color reflectance images in (a) Feb and (b) July 2016. SMAP soil moisture in (c) Feb and (d) May 2016.

- SMAP detects the onset of flood irrigation in May and sustained, elevated soil moisture in the flooded rice paddy in the summer (Fig. 3 blue dots).

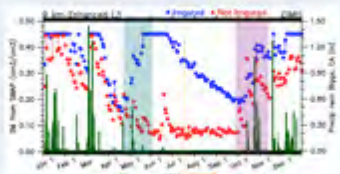


Figure 3. SMAP soil moisture (left axis) at an irrigated and non-irrigated site and daily rainfall (right axis)

- The irrigated valley stands out as one of the wettest locations in the region in June and July in terms of soil moisture (Fig 4a), despite receiving relatively little rainfall (Fig. 4b)

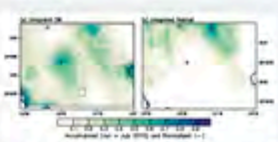


Figure 4. Time integrated and normalized soil moisture (a) and precipitation (b)

RESULTS (cont'd):

San Luis Valley (SLV)

- The scale of irrigation in the San Luis Valley is likely close to a practical minimum required for SMAP-based detection.

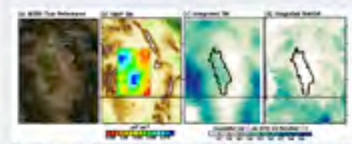


Figure 5. (a) MODIS Terra image, (b) SMAP soil moisture, time integrated and normalized (c) soil moisture and (d) rainfall

Columbia River Valley (CRV)

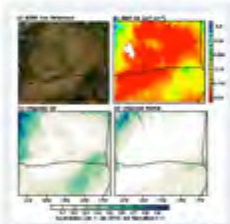


Figure 6. As in Fig. 5, but for the CRV

A complicating factor in this region is the proximity to rivers and lakes which could contaminate the SMAP signal. Nevertheless, the bulk, seasonal timing is of irrigation is apparent in the spatial plots and integrated metrics.

CONCLUSIONS:

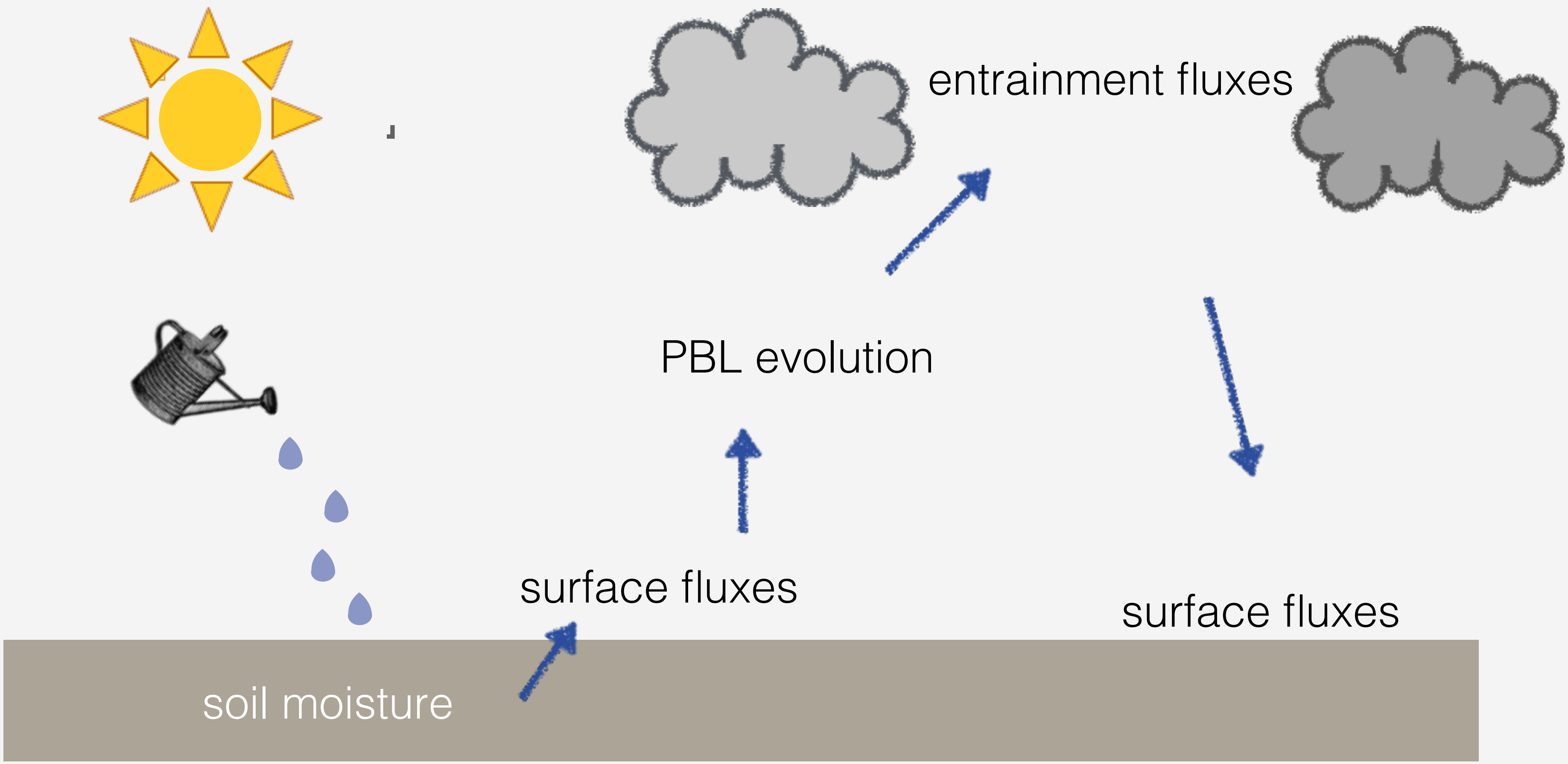
- In these semi-arid regions, SMAP is able to detect the bulk seasonal timing and spatial signature of irrigation via elevated soil moisture relative to adjacent non irrigated regions.
- Future work will apply these approaches globally, and will explore in a similar fashion the recently released SMAP-Sentinel downscaled 1 km soil moisture product.

ACKNOWLEDGEMENTS:

This study was supported by NASA grant NNH15ZDA001N-SUSMAP. Travel support generously provided by NOAA Climate Prediction Office.

Lawston et al. 2017: Irrigation signals detected from SMAP soil moisture retrievals. *Geophysical Research Letters*, 44 (23).

Science Motivation



SM → EF_{sm} → PBL → ENT → EF_{atm} → P/Clouds

Santanello et al. 2007; 2011

Can SMAP detect irrigation?

Concept:

- In these known irrigated areas, low precipitation consistently co-located with high soil moisture may indicate irrigation

  → Compare precipitation (Stage IV analysis) and SMAP soil moisture

Method:

For precip and SM in each study area:

1) Accumulate values over time (June & July 2016):

$$\beta_{ji}=\sum_{t=0}^{n} x_{ji}(t)$$

2) Normalize:

$$N_{ji}= \beta_{ji} - \min(\beta) / \max(\beta) - \min(\beta)$$

Result:

Relative (to each region and time period) measure of wettest/driest (SMAP) and rainiest/least rainy (precip) areas.

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