National Aeronautics and Space Administration

Satellite Remote Sensing for Agricultural Applications

Christopher Hain

May 5, 2020

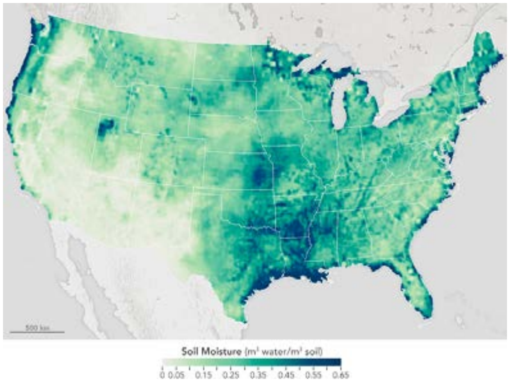
Training Outline

April 14, 2020

Overview of Agricultural Remote Sensing

https://eospso.nasa.gov/content/nasas-earth-observing-system-project-science-office

April 21, 2020



Soil Moisture for Agricultural Applications

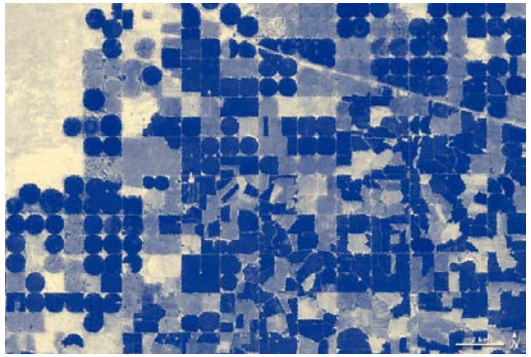
https://earthobservatory.nasa.gov/images/87036/soil-moisture-in-the-united-states

April 28, 2020

Earth Observations for Agricultural Monitoring

https://earthobservatory.nasa.gov/images/90095/satellites-eye-winter-cover-crops

May 5, 2020



Evapotranspiration & Evaporative Stress Index for Agricultural Applications

https://earthobservatory.nasa.gov/images/42428/water-use-on-idahos-snake-river-plain

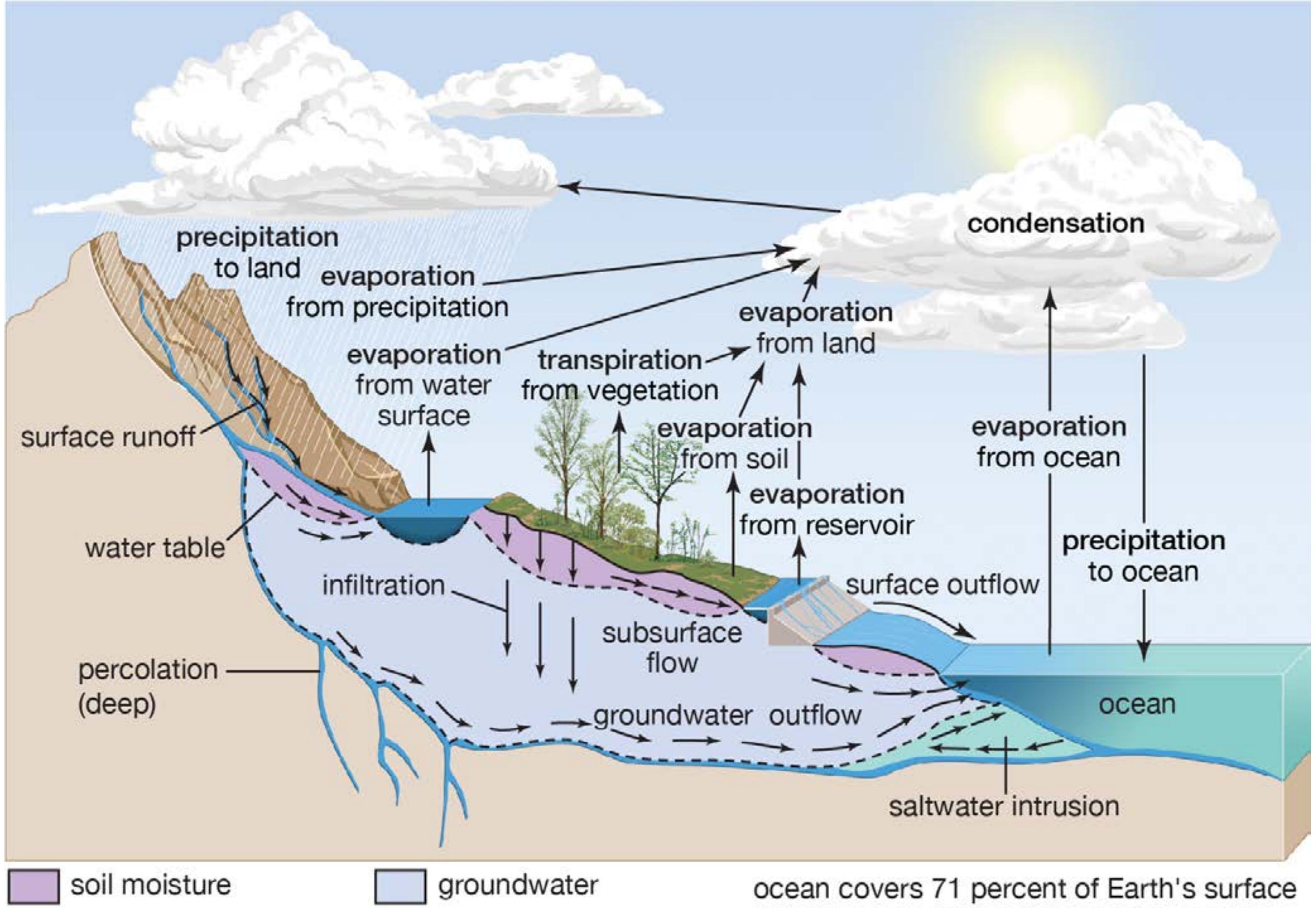
Homework and Certificate

- Homework Assignments found on the training page: https://arset.gsfc.nasa.gov/water/webinars/remote-sensing-for-agriculture-20
  – Answers must be submitted via Google Form
  – Due date: **May 12**
- A Certificate of Completion will be awarded to those who:
  – Attend all webinars
  – Complete all homework assignments
- You will receive a certificate approximately two months after the completion of the course from: marines.martins@ssaihq.com

Evapotranspiration for Agricultural Applications

What is Evapotranspiration?

- Evapotranspiration is the sum of evaporation from the soil surface, evaporation of water intercepted by the canopy, and transpiration from vegetation.



Atmospheric Controls on Transpiration from Plants

The amount of water that plants transpire varies greatly geographically and over time. There are a number of factors that can determine transpiration rates:

- **Temperature:** Transpiration rates go up as the temperature goes up, especially during the growing season when the air is warmer.
- **Atmospheric Moisture:** As the relative humidity of the air rises, the transpiration rate falls. It is easier for water to evaporate into dryer air than into more saturated air.
- **Wind:** Increased movement of the air around a plant will result in a higher transpiration rate, as turbulence can mix drier air near the plant surface.
- **Soil Moisture:** When moisture is lacking, plants can begin to senesce (premature aging, which can result in leaf loss) and transpire less water.

Why do we need to measure ET for Agricultural Applications?

- Irrigation management
- Monitoring drought and crop stress
- Yield prediction
- Water use accounting
- Crop water productivity (crop per drop)

How do we measure ET?… Observational Systems

Eddy Covariance:

- The most direct method of measuring evapotranspiration is with the eddy covariance technique, in which fast fluctuations of vertical wind speed are correlated with fast fluctuations in atmospheric water vapor density.

Lysimeter:

- One method for measuring evapotranspiration is with a lysimeter. The weight of a soil column is measured continuously and the change in storage of water in the soil is modeled by the change in weight.

How do we measure ET?... Models

Land Data Assimilation Systems: Land surface models (LSMs) predict energy, water, and momentum fluxes by solving the governing equations of the land-atmospheric medium. By constraining, LSMs with observed atmospheric boundary conditions and land surface states, estimates of evapotranspiration can be made.

Advantages:

- Can be made wherever adequate atmospheric forcing data is available.
- Provides high temporal resolution of ET estimates/Available at varying spatial resolutions.

Disadvantages:

- Errors in atmospheric forcing (e.g., precipitation) will lead to downstream effects on ET accuracy.
- Can experience "model drift" due to errors in atmospheric forcing or model physics.

Satellite Methods for Estimating ET

Crop Coefficient/Et_o Methods

- Evapotranspiration is estimated by computing a measure of reference ET (Et_o) from an agricultural weather station and applying a crop coefficient (K_c).
- One established method is the NASA Satellite Irrigation Management Support (SIMS) framework (Melton et al., 2012).
- SIMS uses Landsat NDVI to estimate crop fractional cover, along with estimates of crop height and stomatal control to estimate K_c.
- Limitations of methods such as this are less sensitivity to transitory ET decreases from intermittent deficit irrigation or ET increases from bare soil surfaces or shortly after precipitation events.

Satellite Methods for Estimating ET

Energy Balance Methods

- These methods for estimating ET are grounded in the theory behind the surface energy balance model, where available energy at the surface from shortwave and longwave radiation is balanced by fluxes from surface heating (e.g., sensible heat flux) and exchange of water vapor (e.g., latent heat flux).
- Energy balance models can be divided into two categories:
  - (1) Single-source energy balance models, where vegetation and soil are analyzed in a combined energy budget.
  - (2) Two-source energy balance models, where vegetation and soil energy budgets are analyzed separately.

Satellite Methods for Estimating ET

Energy Balance Methods

Examples of these methods include:

(1) Surface Energy Balance Algorithm for Land (SEBAL; Bastiaanssen et al. 1998)

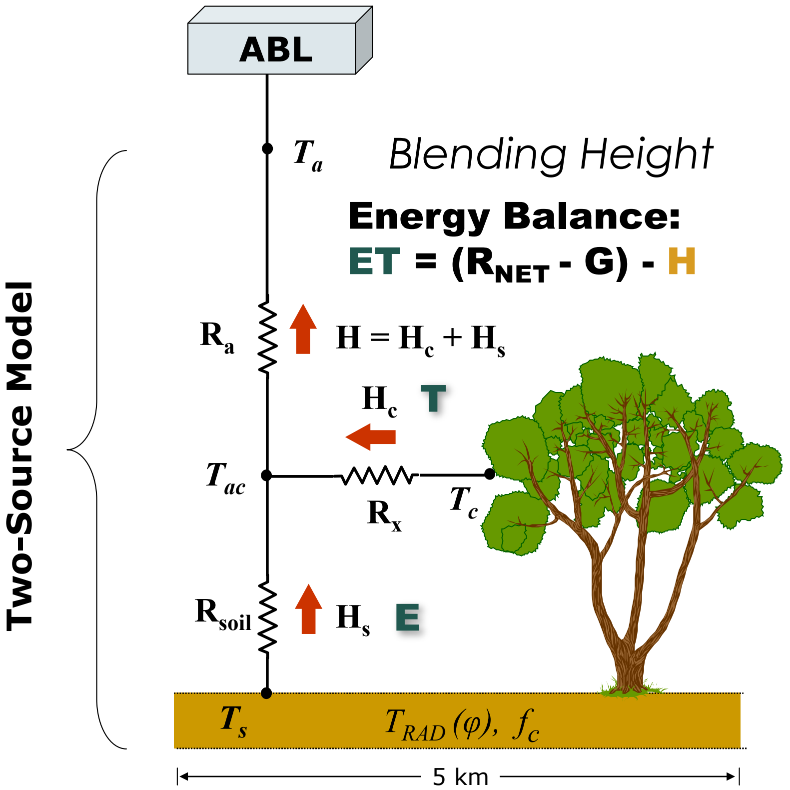
(2) Surface Energy Balance System (SEBS; Su 2002)

(3) Mapping Evapotranspiration at High Resolution with Internalized Calibration (METRIC; Allen et al. 2007)

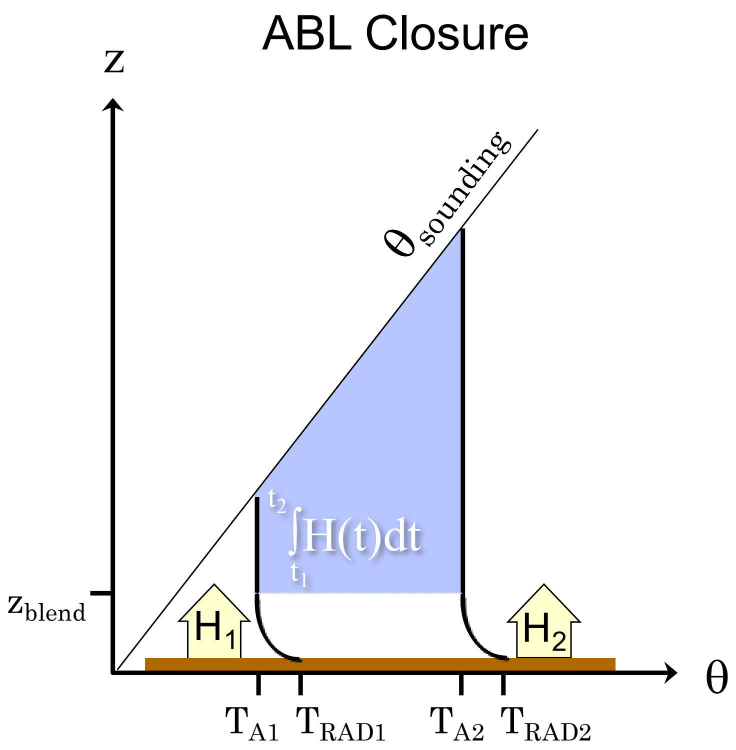
(4) Operational Simplified Surface Energy Balance (SSEBop; Senay et al. 2007, 2013)

(5) Atmosphere-Land Exchange Inverse (ALEXI) and DisALEXI (Anderson et al. 1997)

ALEXI: Atmosphere Land Exchange Inverse Model



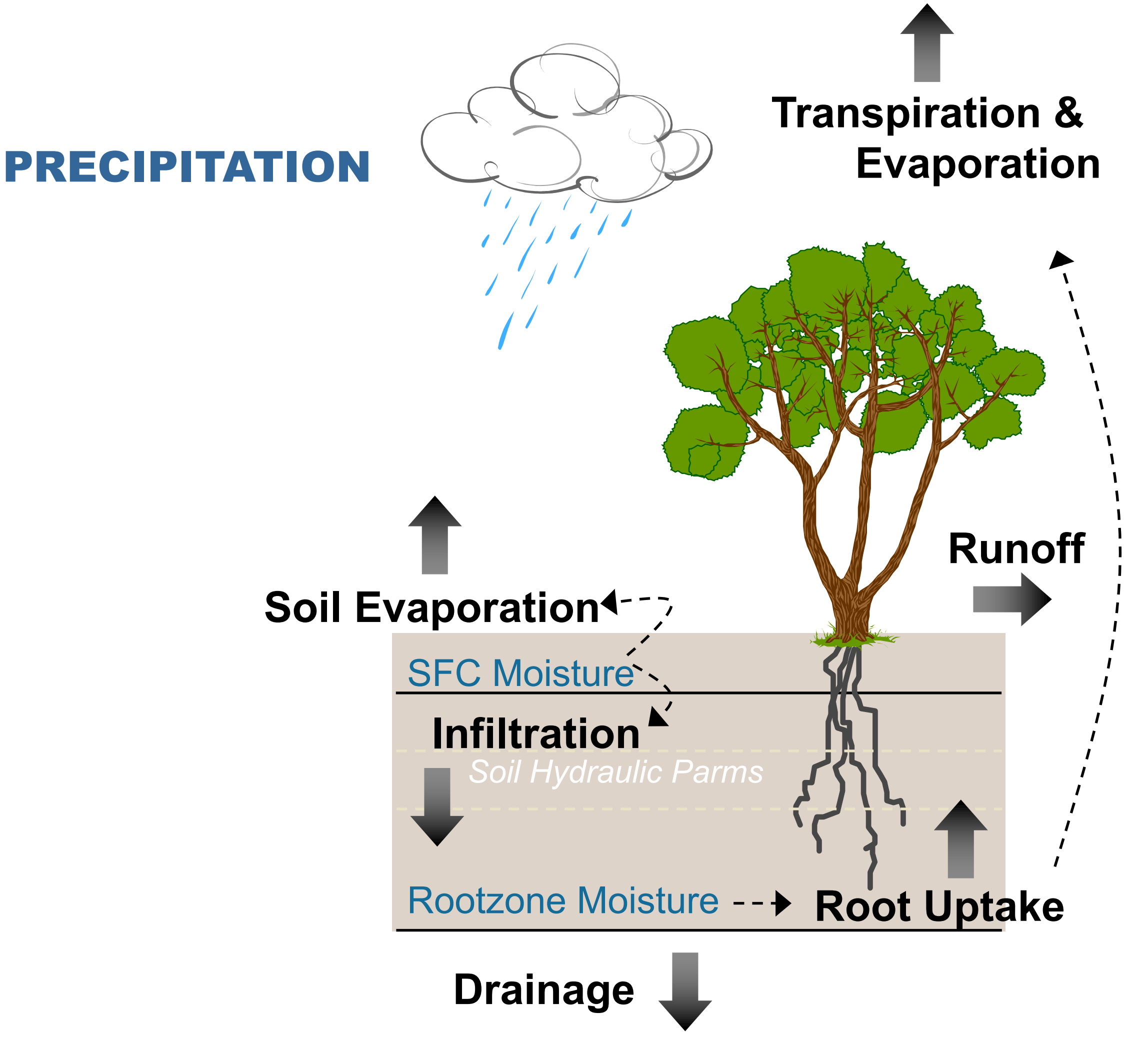
ALEXI
(Atmosphere-Land Exchange Inverse Model)



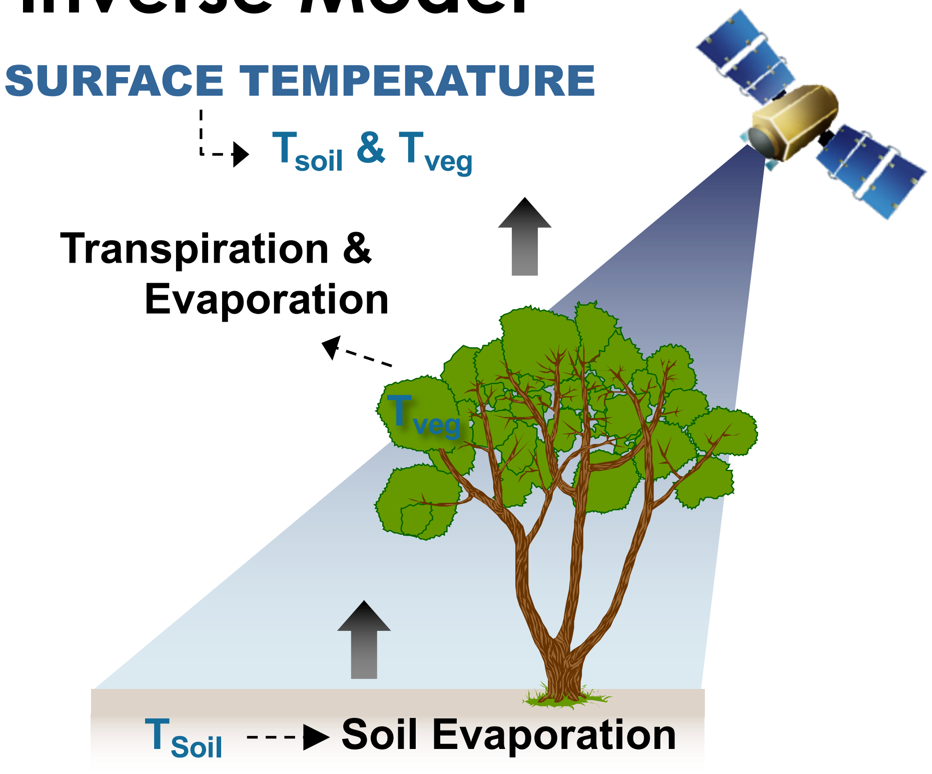
Regional Scale

Surface Temperature :	ΔT_{RAD}	- Geostationary
Air Temperature :	T_a	- ABL Model

ALEXI: Atmosphere Land Exchange Inverse Model



WATER BALANCE APPROACH
(Prognostic Modeling)

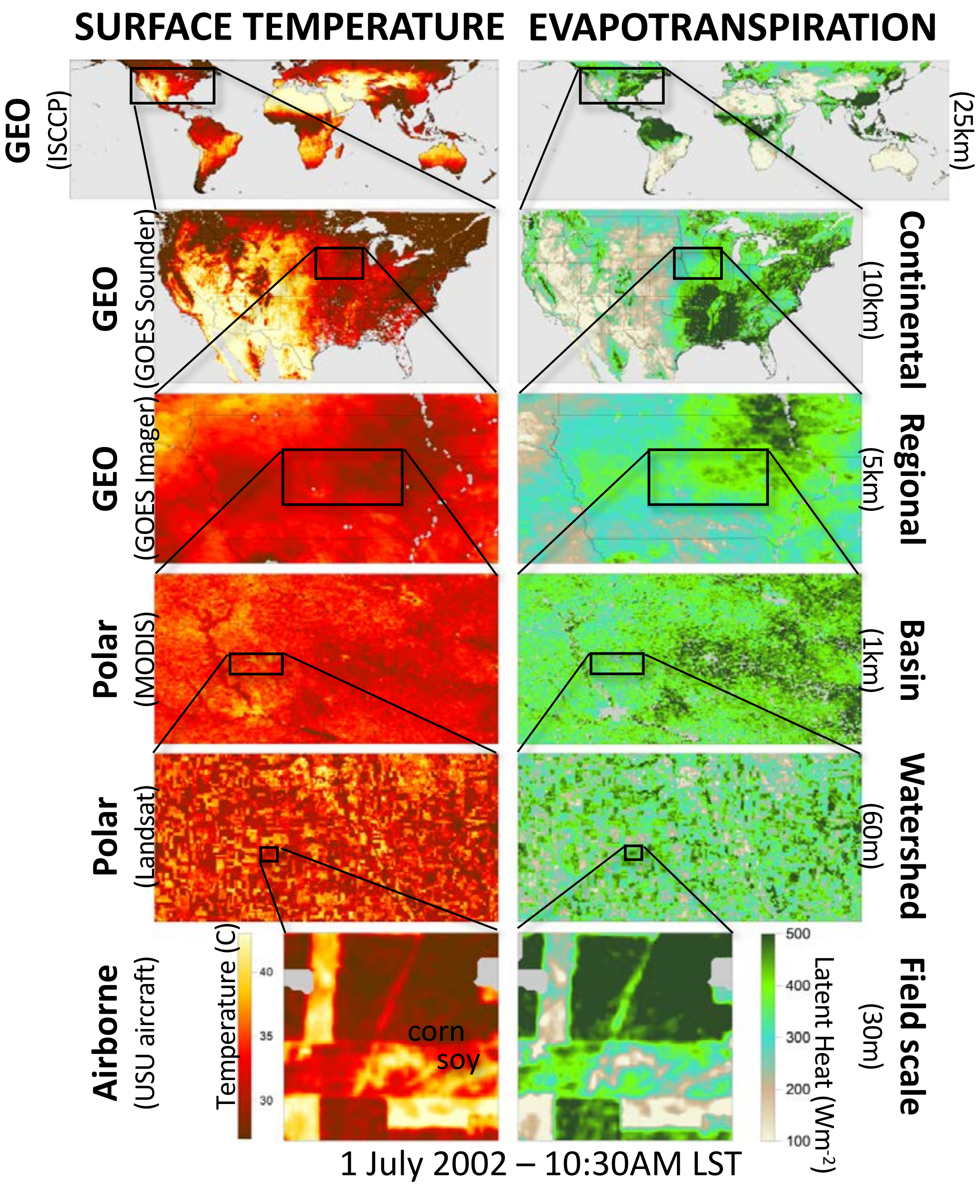


Given known radiative energy inputs, how much water loss is required to keep the soil and vegetation at the observed temperatures?

ENERGY BALANCE APPROACH
(Diagnostic Modeling)

ALEXI: Atmosphere Land Exchange Inverse Model

MULTI-SENSOR/MULTI-SCALE ET MAPPING

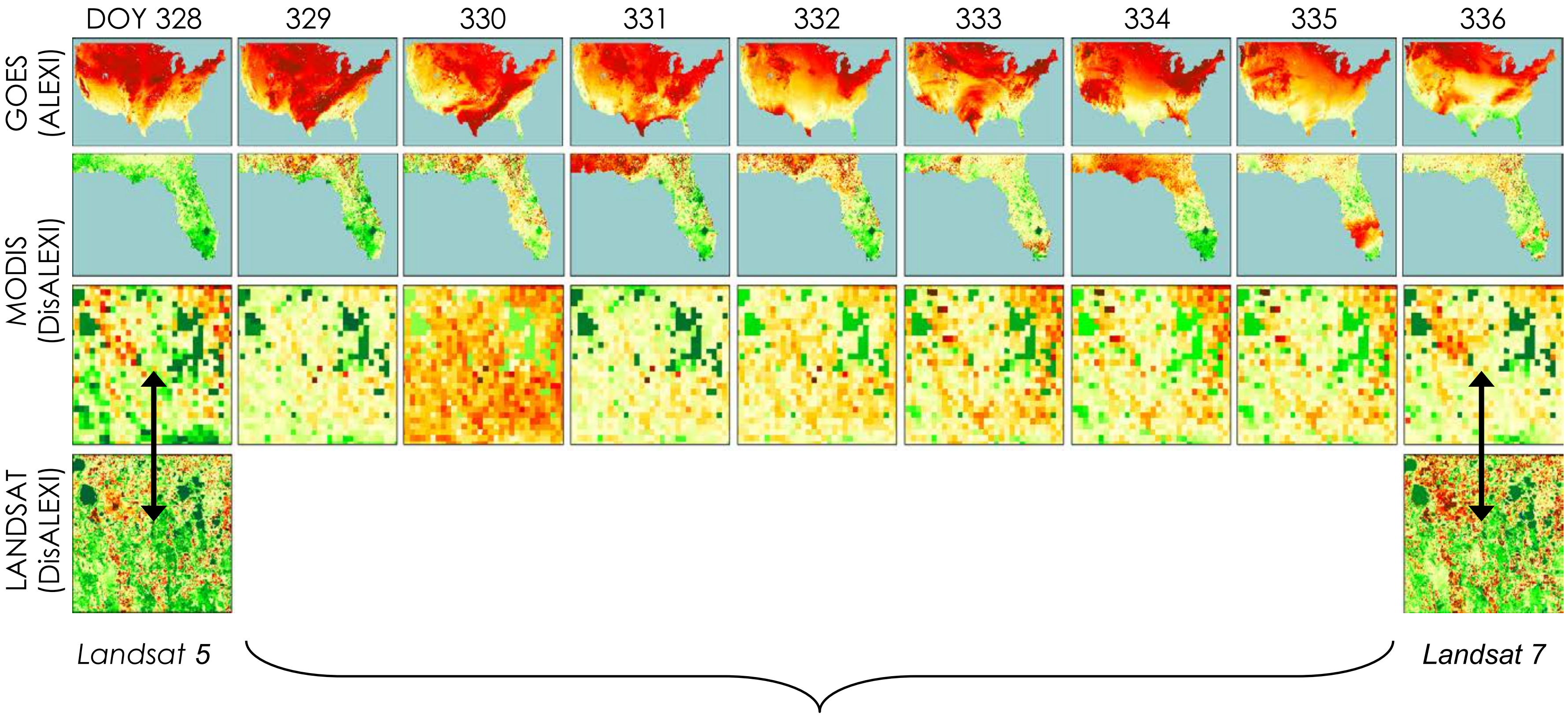


Hourly

Daily

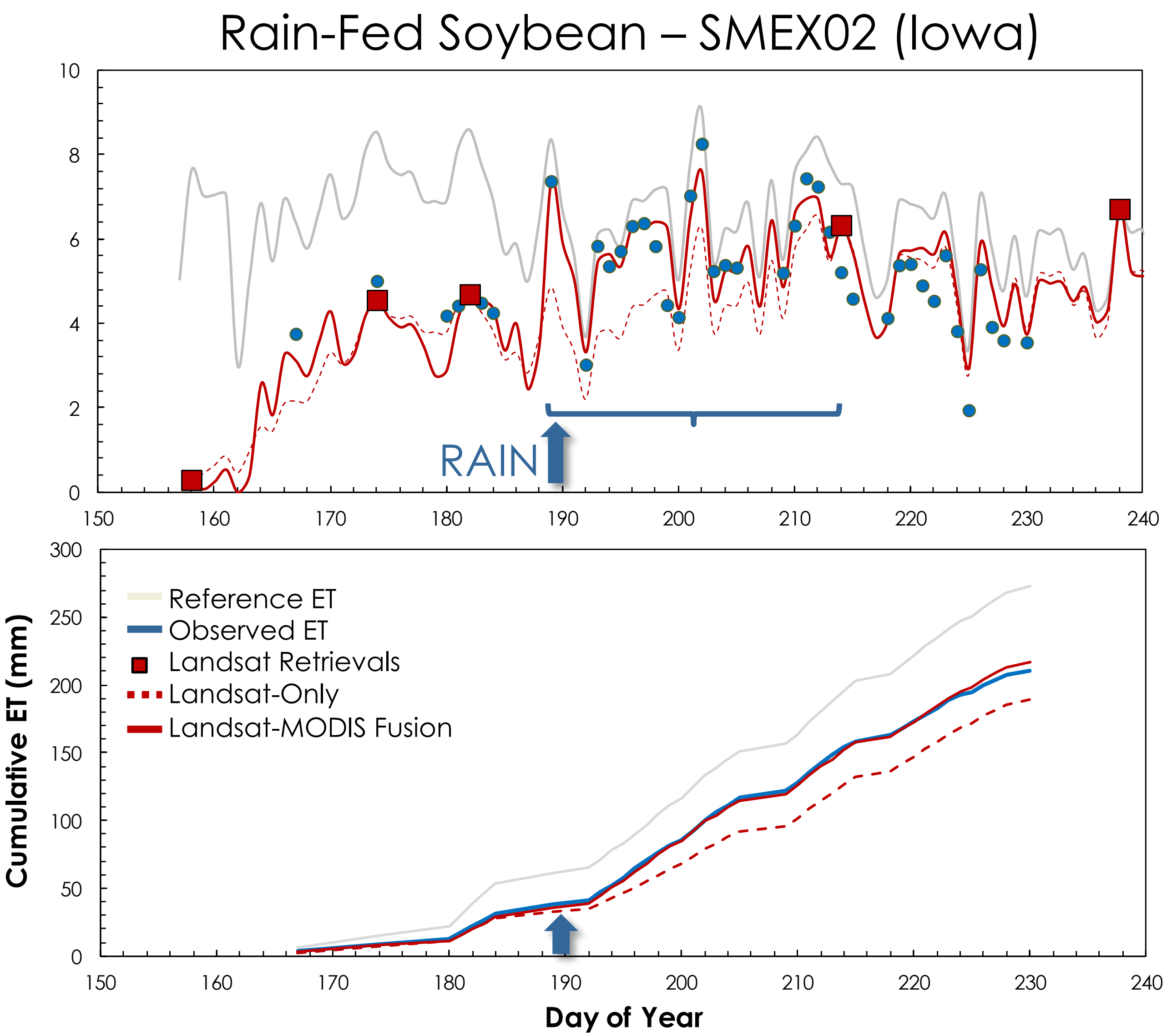
Integration of Moderate-Resolution LST into ALEXI/DisALEXI

Daily Evapotranspiration – Orlando, FL, 2002

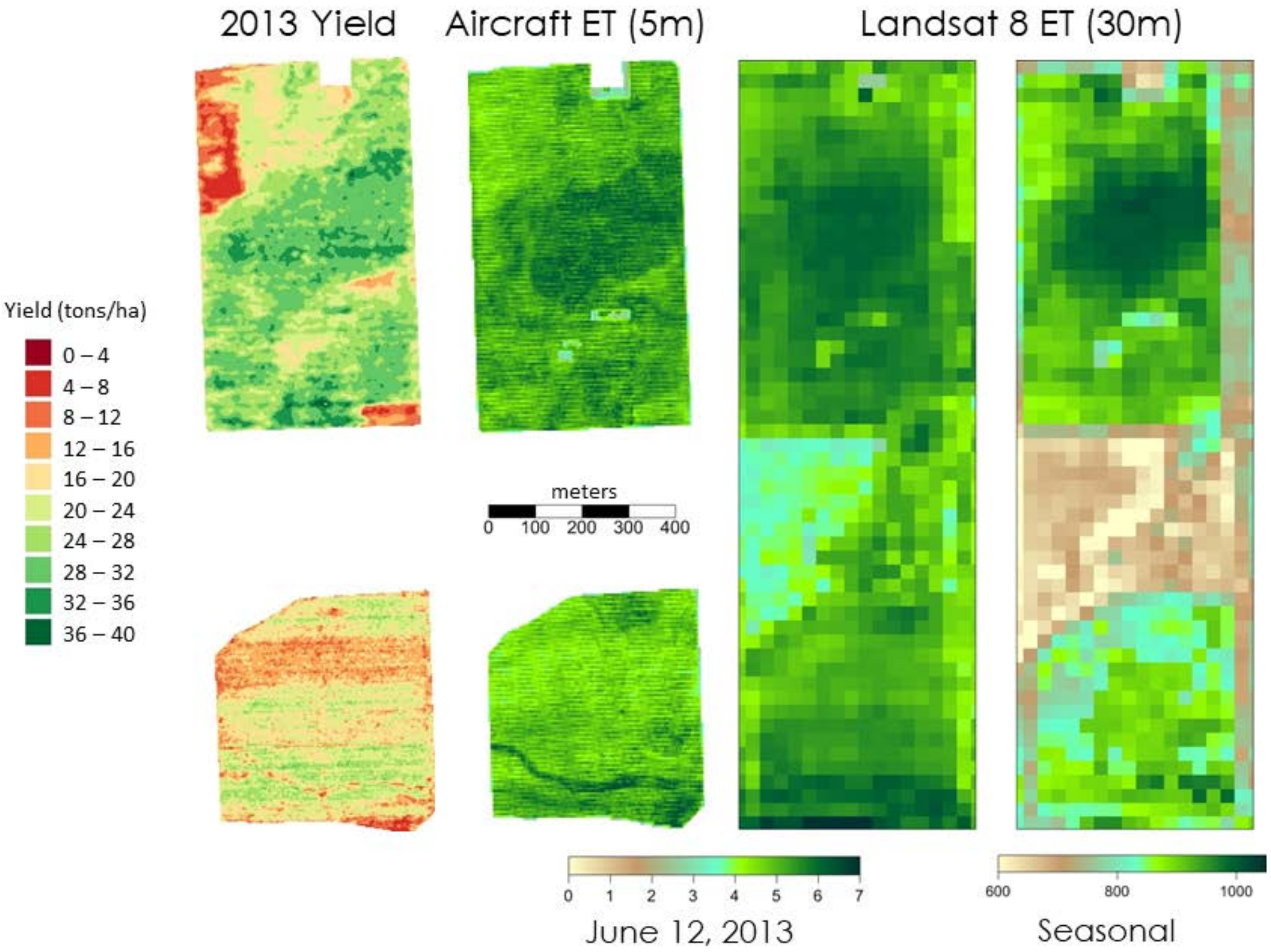


Spatial Temporal Adaptive
Reflectance Fusion Model (STARFM)

Integration of Moderate-Resolution LST into ALEXI/DisALEXI

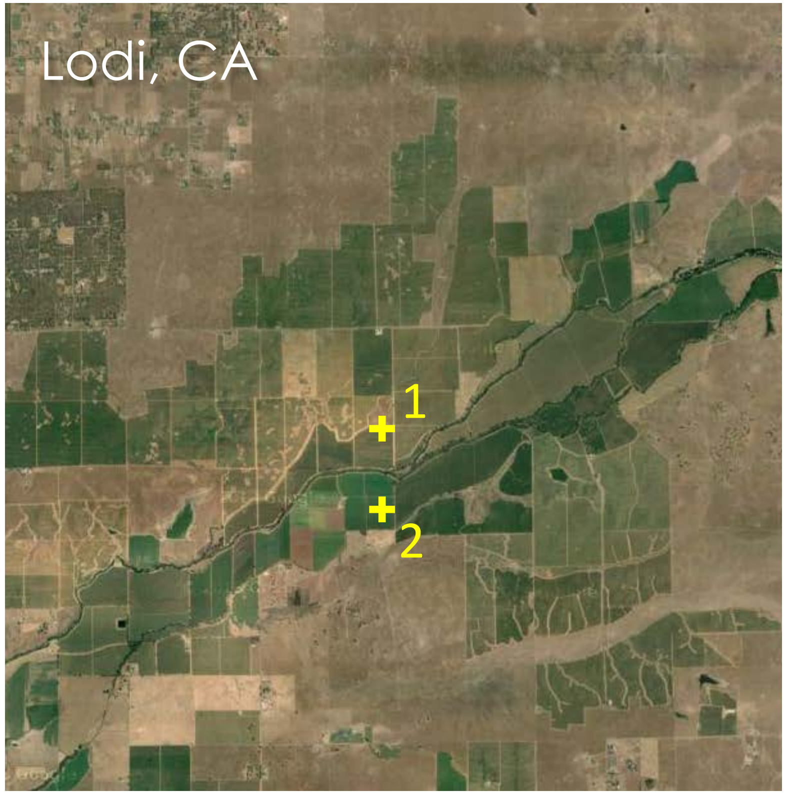


ALEXI Intra-field ET variability



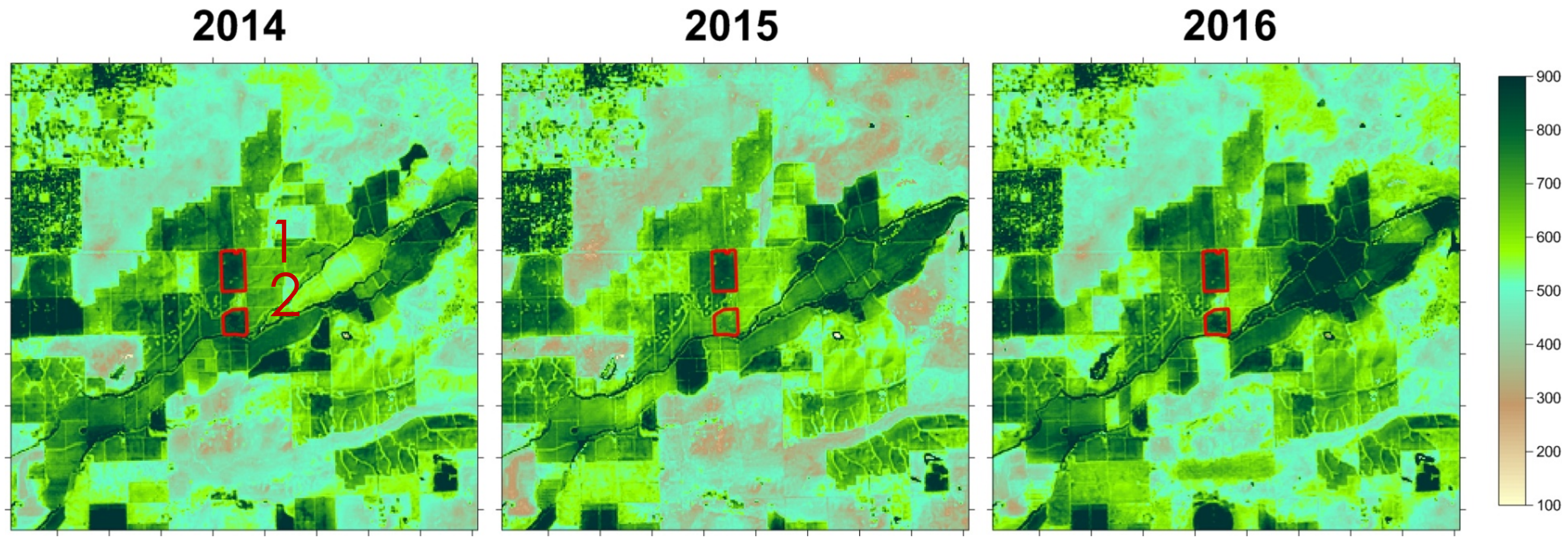
Case Study for Grape Production in the Central Valley

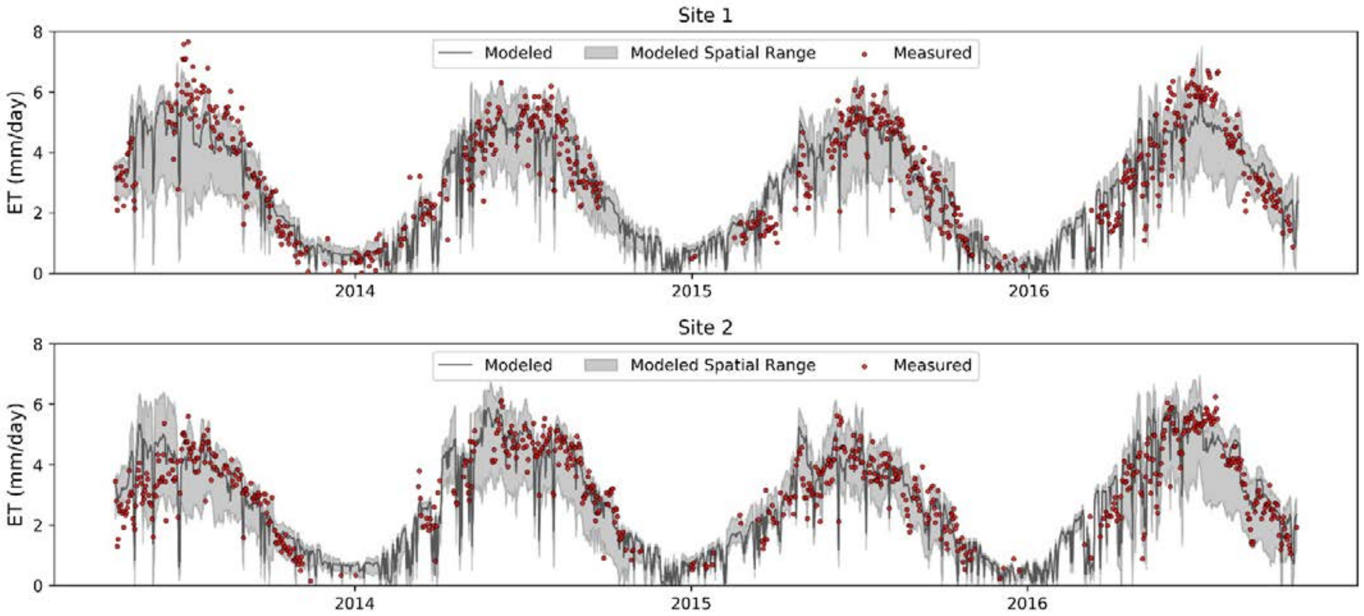
Grape Remote sensing Atmospheric Profile and Evapotranspiration eXperiment (GRAPEX)



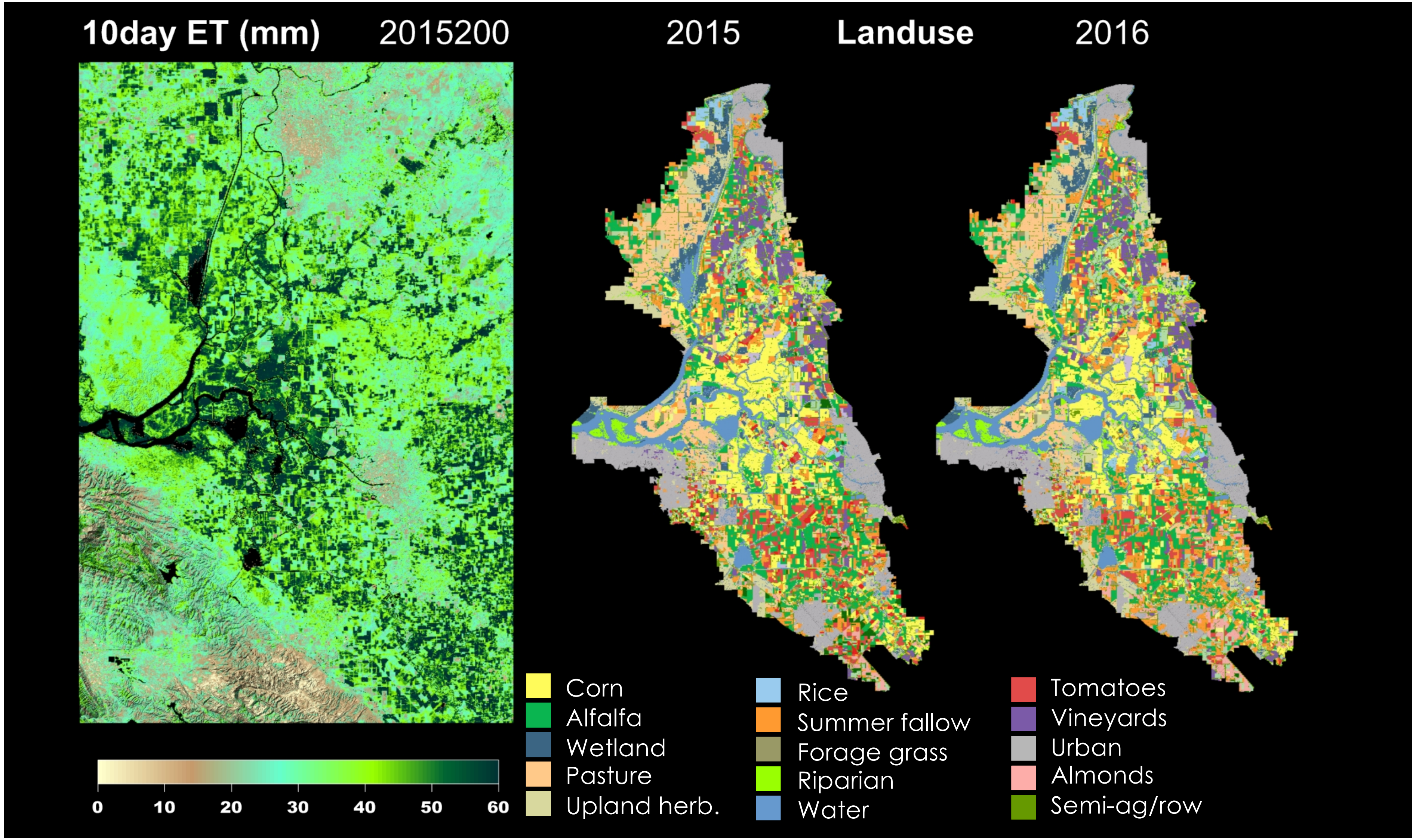
2013 - Present

Case Study for Grape Production in the Central Valley

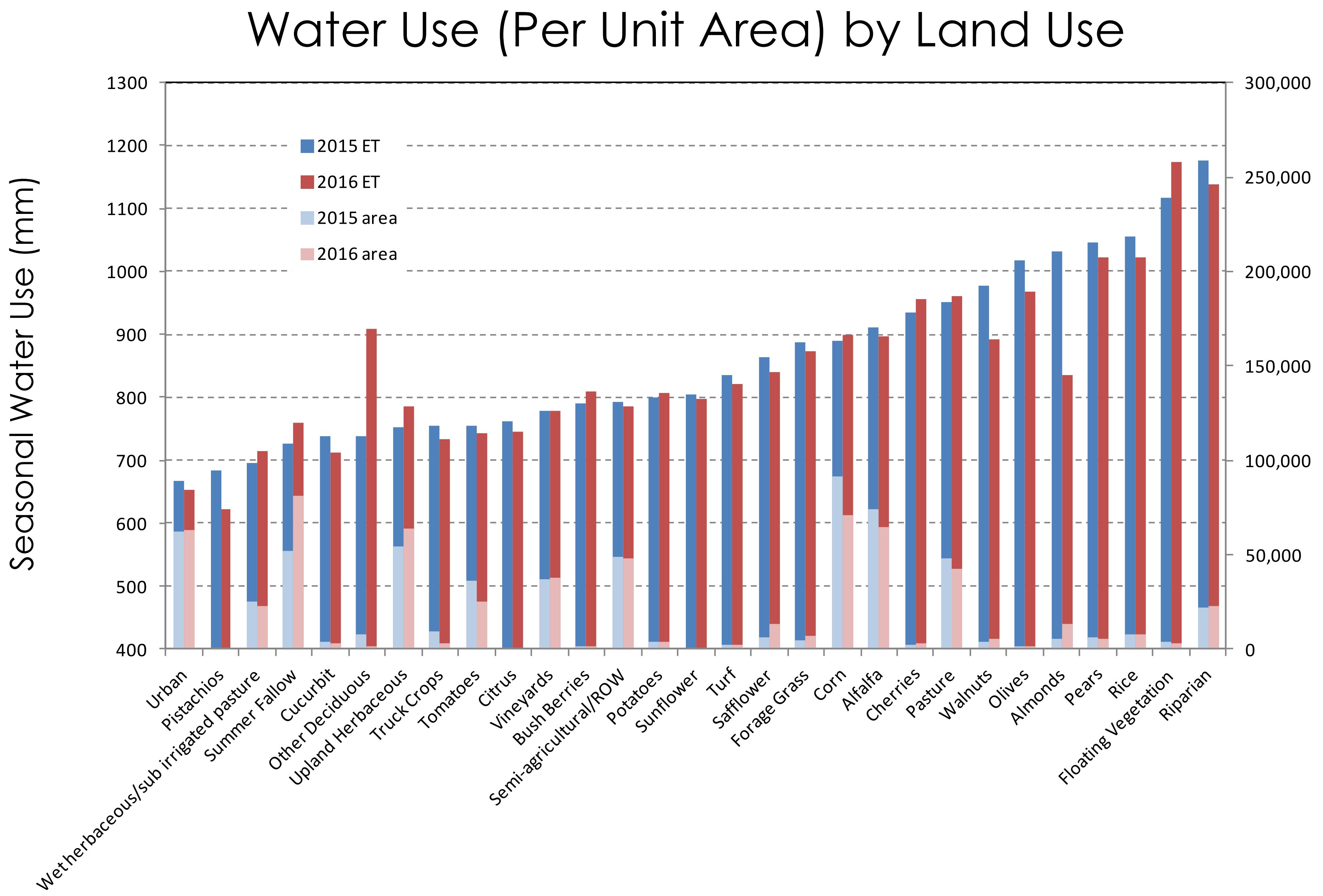




ALEXI Water Accounting Case Study



ALEXI Water Accounting Case Study



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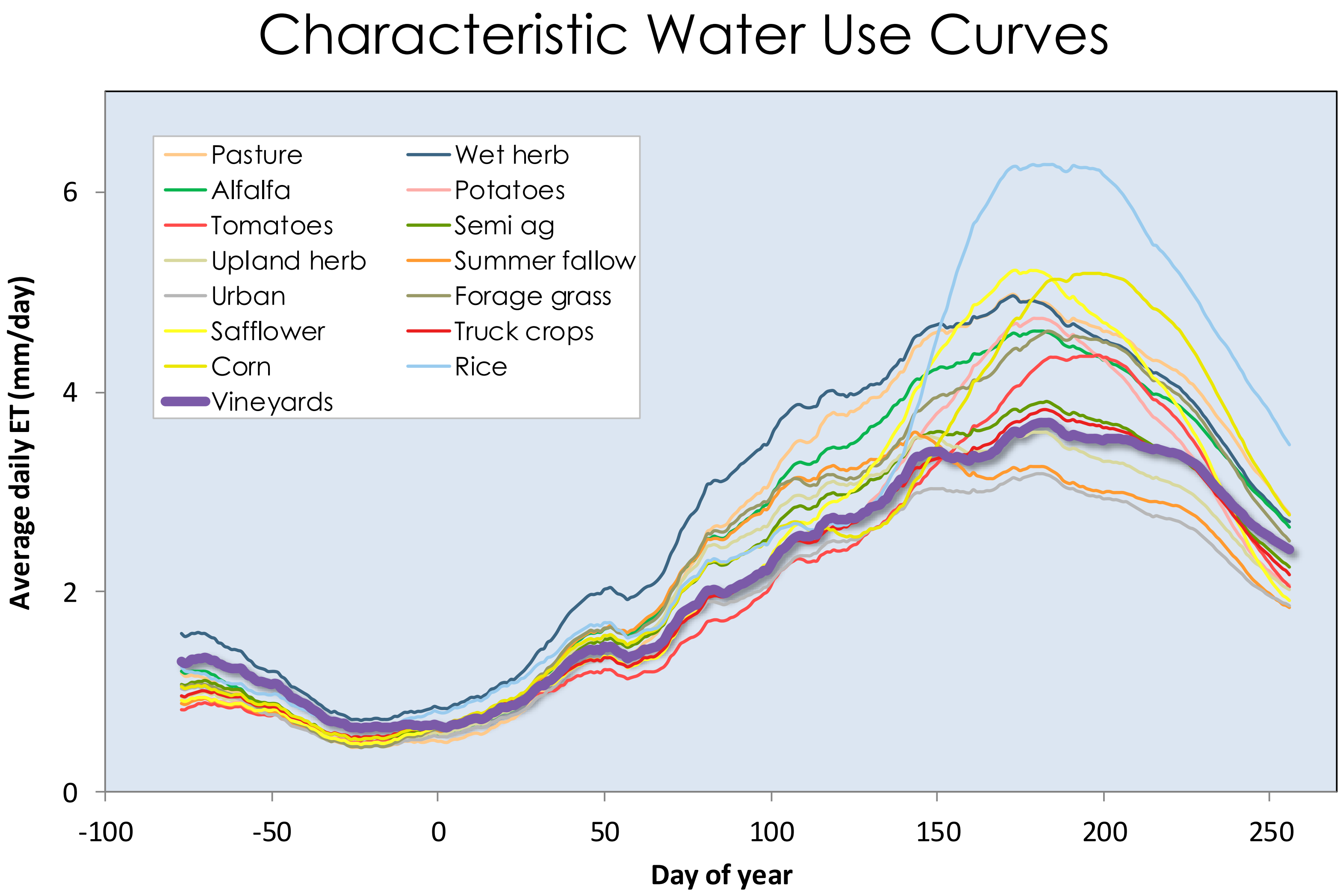
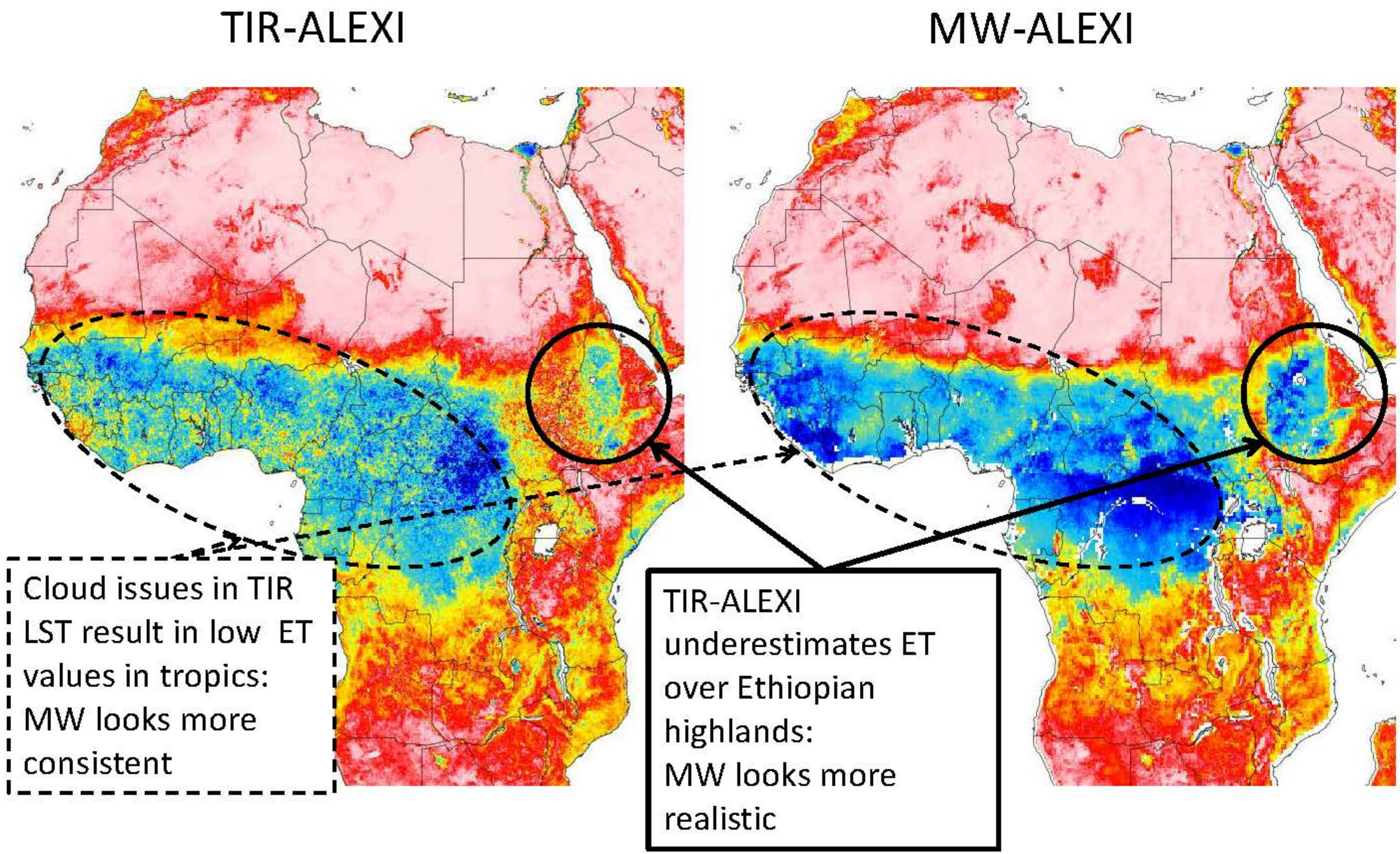


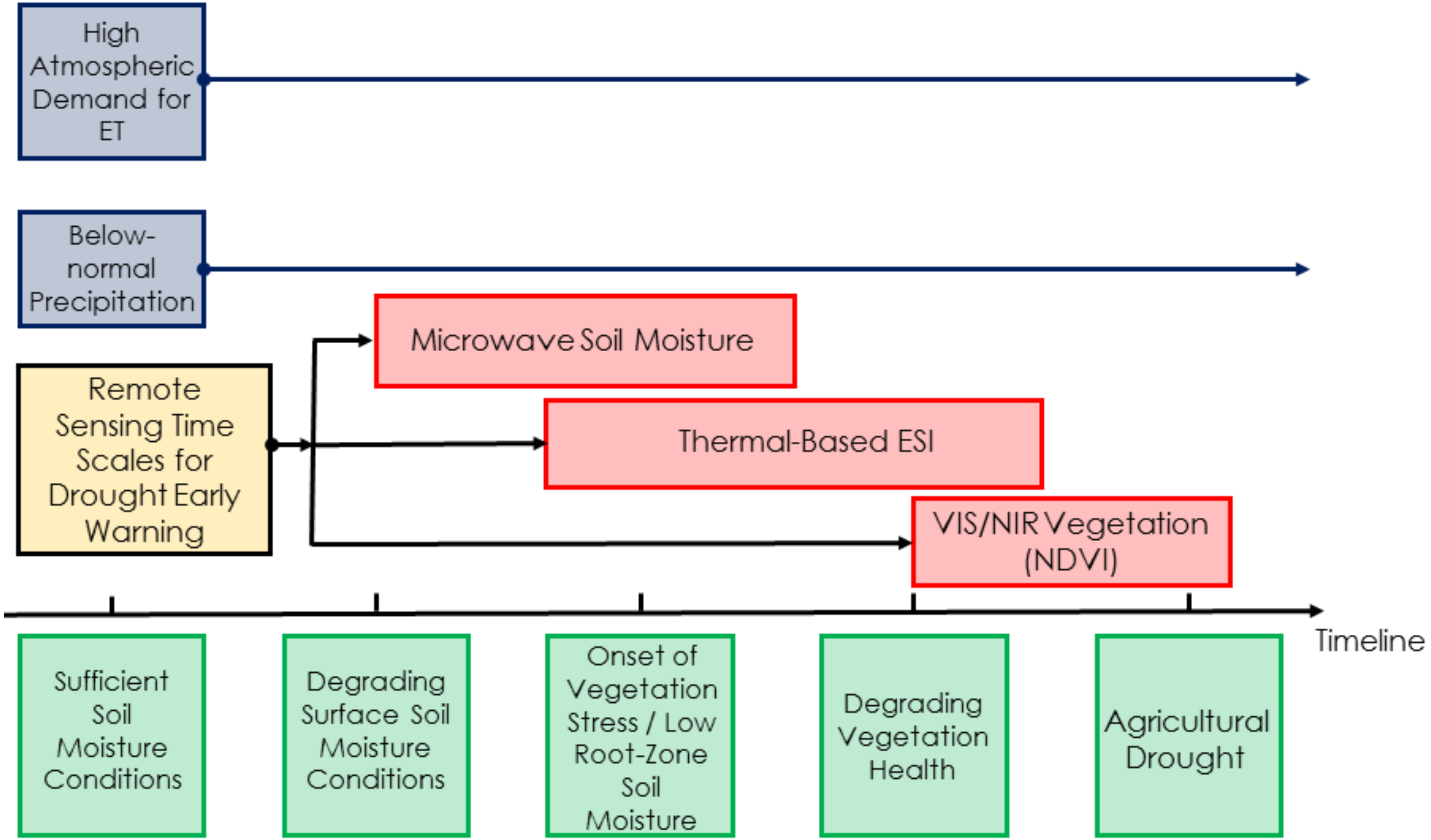
Integration of Microwave LST into ALEXI

- The synergy between Thermal Infrared (TIR) and Microwave (MW) observations is further being exploited by the development of Land Surface Temperature (LST) observations from MW observations (Ka-band).
- The integration of MW LST into a coupled TIR/MW ALEXI system will allow for retrieval of surface fluxes under cloud cover (where TIR-only retrievals are not possible).
- This capability fills in a significant gap in a TIR-only system over tropical equatorial regions where clear-sky retrievals may only be possible 1 to 3 times per month, particularly during the wet season.

Integration of Microwave LST into ALEXI



Evolution of Agricultural Drought



Evaporative Drought Demand Index (EDDI)

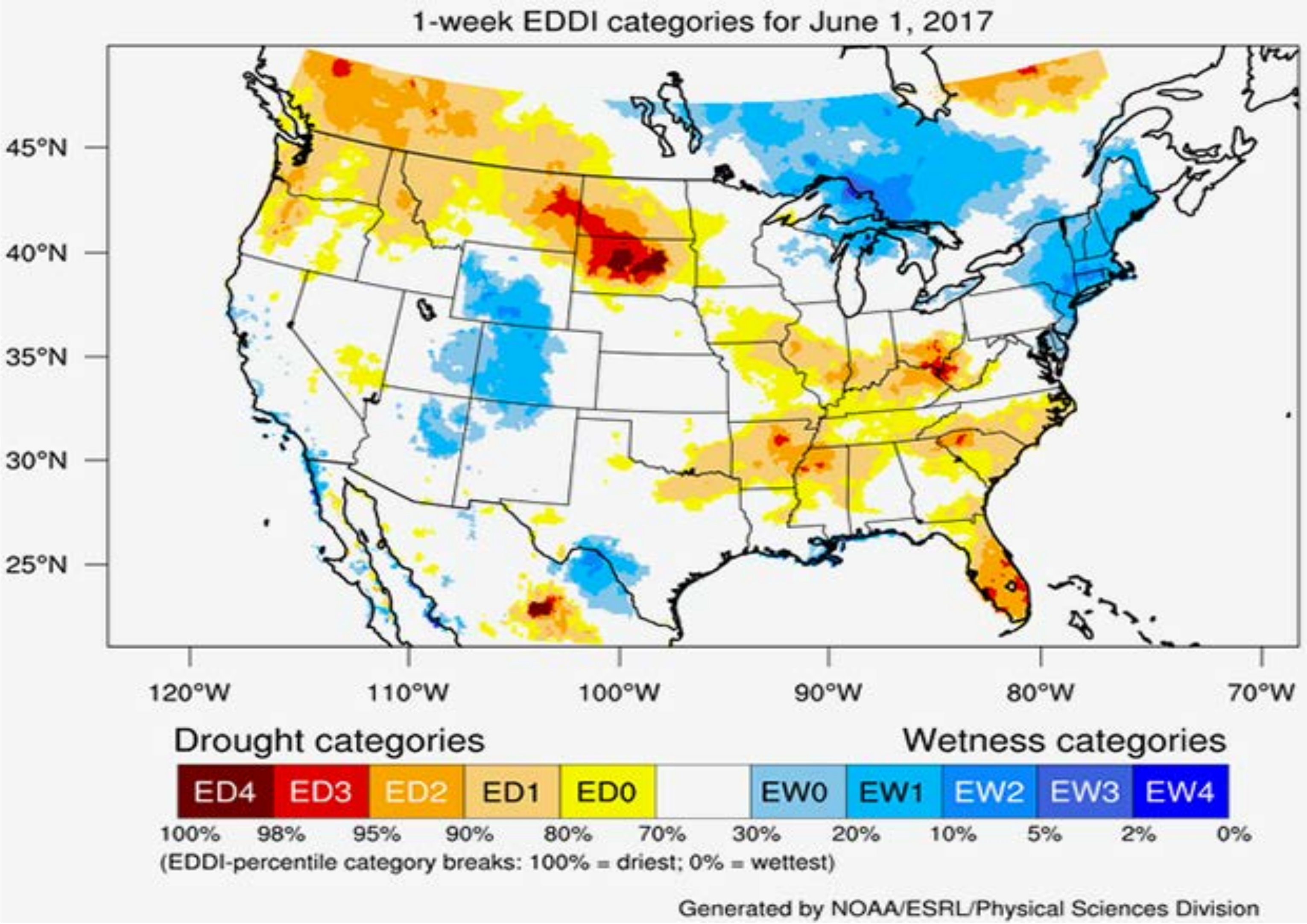
https://www.esrl.noaa.gov/psd/eddi/

- EDDI exploits the strong physical relationship between evaporative demand and actual loss of water from the land surface through ET.
- Evaporative demand can be explained as the "thirst of the atmosphere," estimated by the amount of water that would evaporate from the land surface under well-watered conditions.
- EDDI measures the signal of potential for future drought by using information on the rapidly evolving (e.g., daily timescales) conditions of the atmosphere to estimate the "potential" impact on the land surface.
- EDDI has no physical tie to actual land surface conditions, thus can only show "potential" for the development of drought, and it can not show "actual" drought conditions in isolation.

*Índice de Sequía por Demanda Evaporativa

Evaporative Drought Demand Index (EDDI)

https://www.esrl.noaa.gov/psd/eddi/



Evaporative Stress Index (ESI)

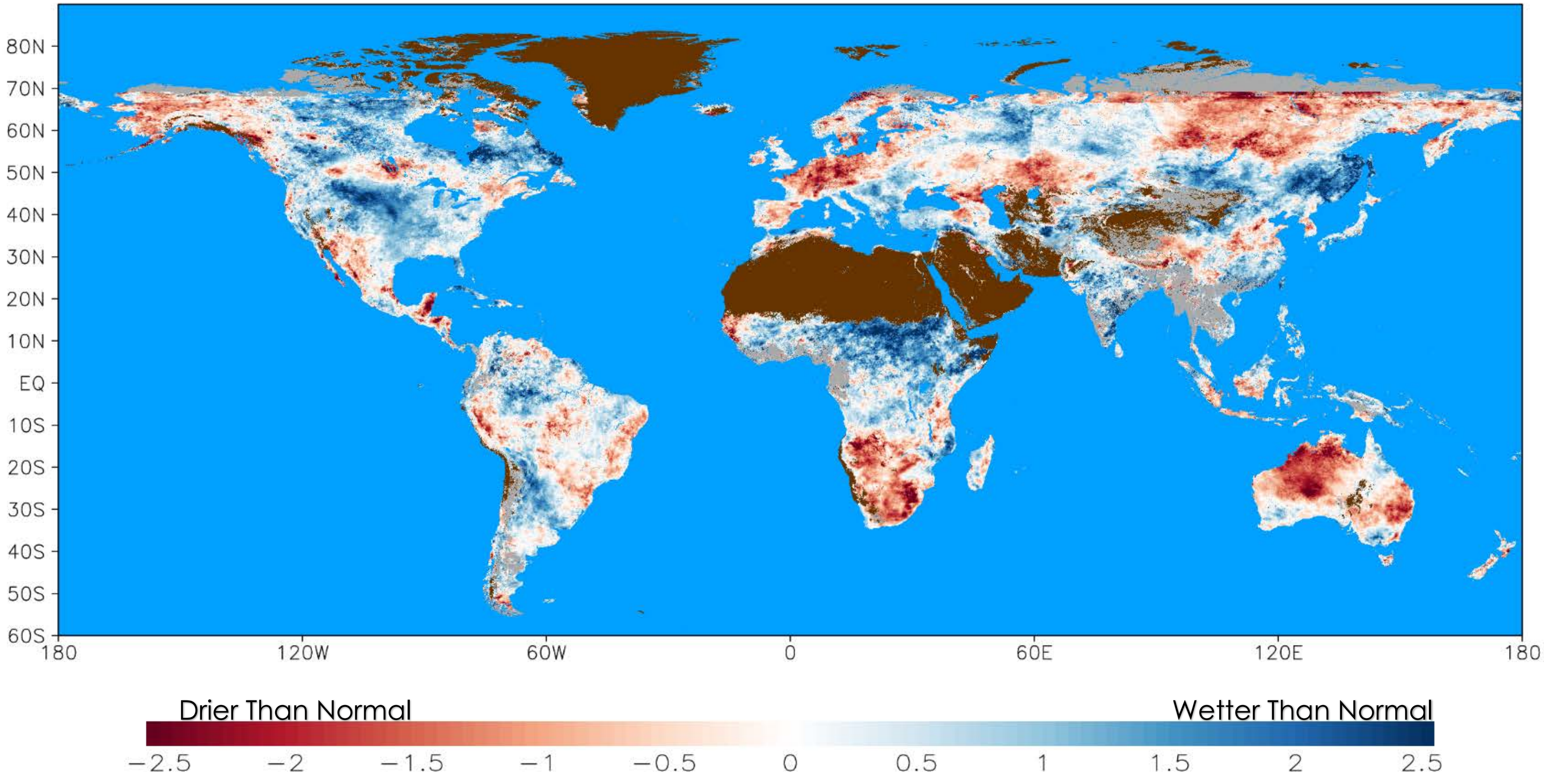
ALEXI ESI represents temporal anomalies in the ratio of actual ET to potential ET.

- ESI does not require precipitation data, ***the current surface moisture state is deduced directly from the remotely sensed LST.*** Therefore, it may be more robust in regions with minimal in-situ precipitation monitoring.

- Signatures of vegetation stress are manifested in the LST signal before any deterioration of vegetation cover occurs, for example as indicated in NDVI, so TIR-based indices such as ESI can provide an effective early warning signal of impending agricultural drought.

- ALEXI ESI inherently includes non-precipitation related moisture signals (such as irrigation, vegetation rooted to groundwater, and lateral flows) that need to be modeled a priori in prognostic LSM schemes.

Evaporative Stress Index (ESI)

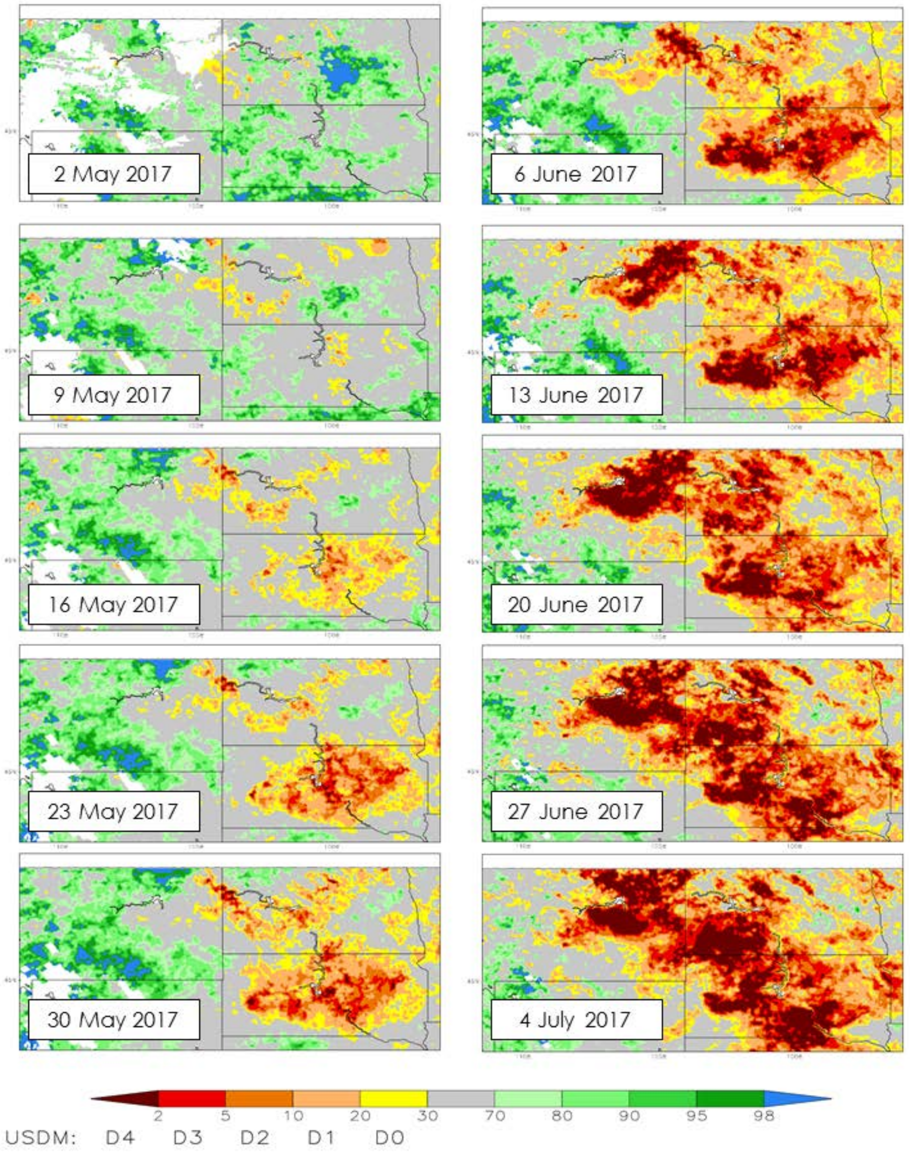


ESI and “Flash Droughts”

Las sequías repentinas son eventos de inicio
Flash droughts are rapid onset events typically driven by:

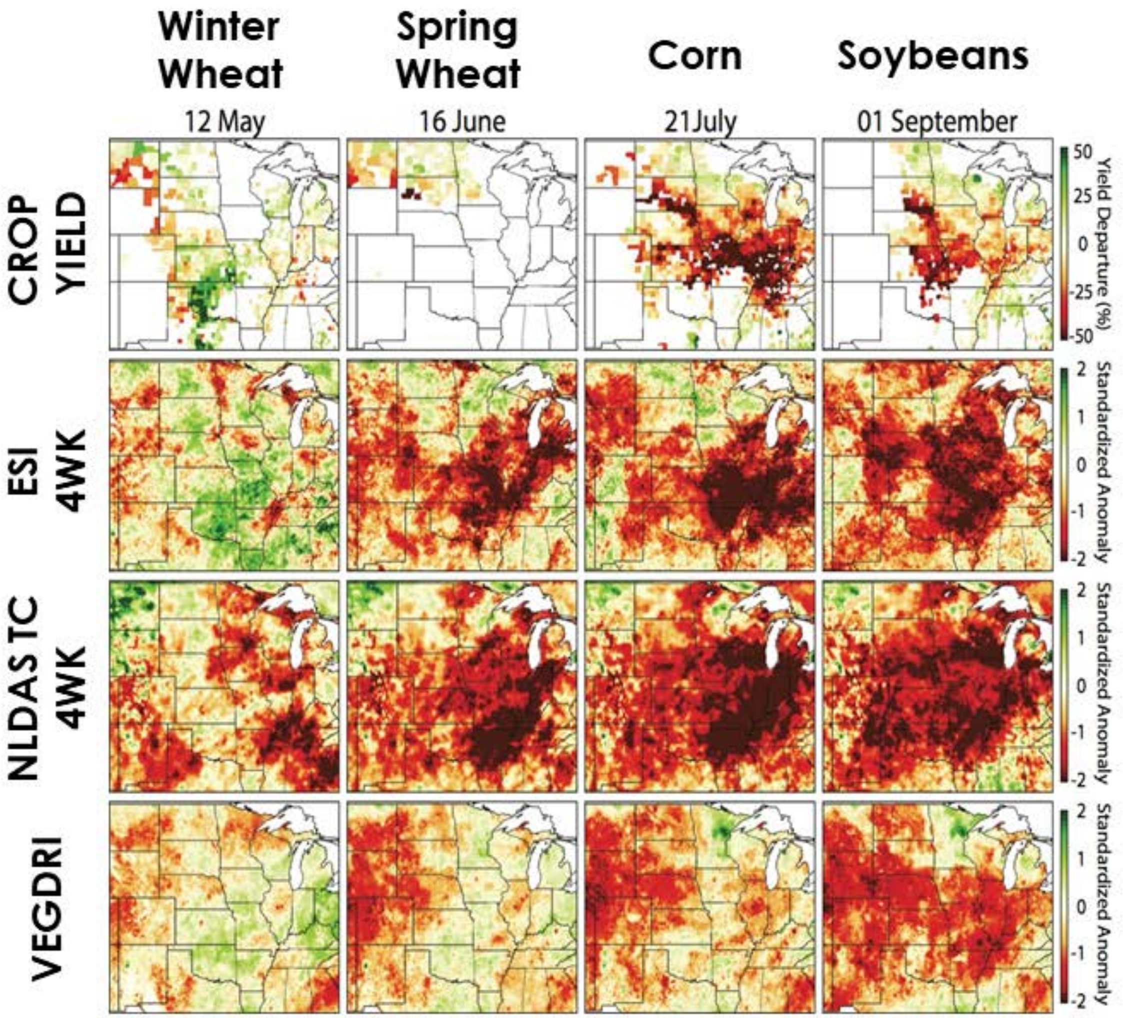
1) Precipitation deficits
2) High temperature anomalies
3) Strong winds
4) Anomalous incoming solar radiation

- ESI has the potential to provide an early warning for such events, since water stress is detectable in the LST signal before degradation in the vegetation health occurs.
- It can do so while providing information about actual vegetation stress and not just the potential for vegetation stress (e.g., PET-driven drought indicators).



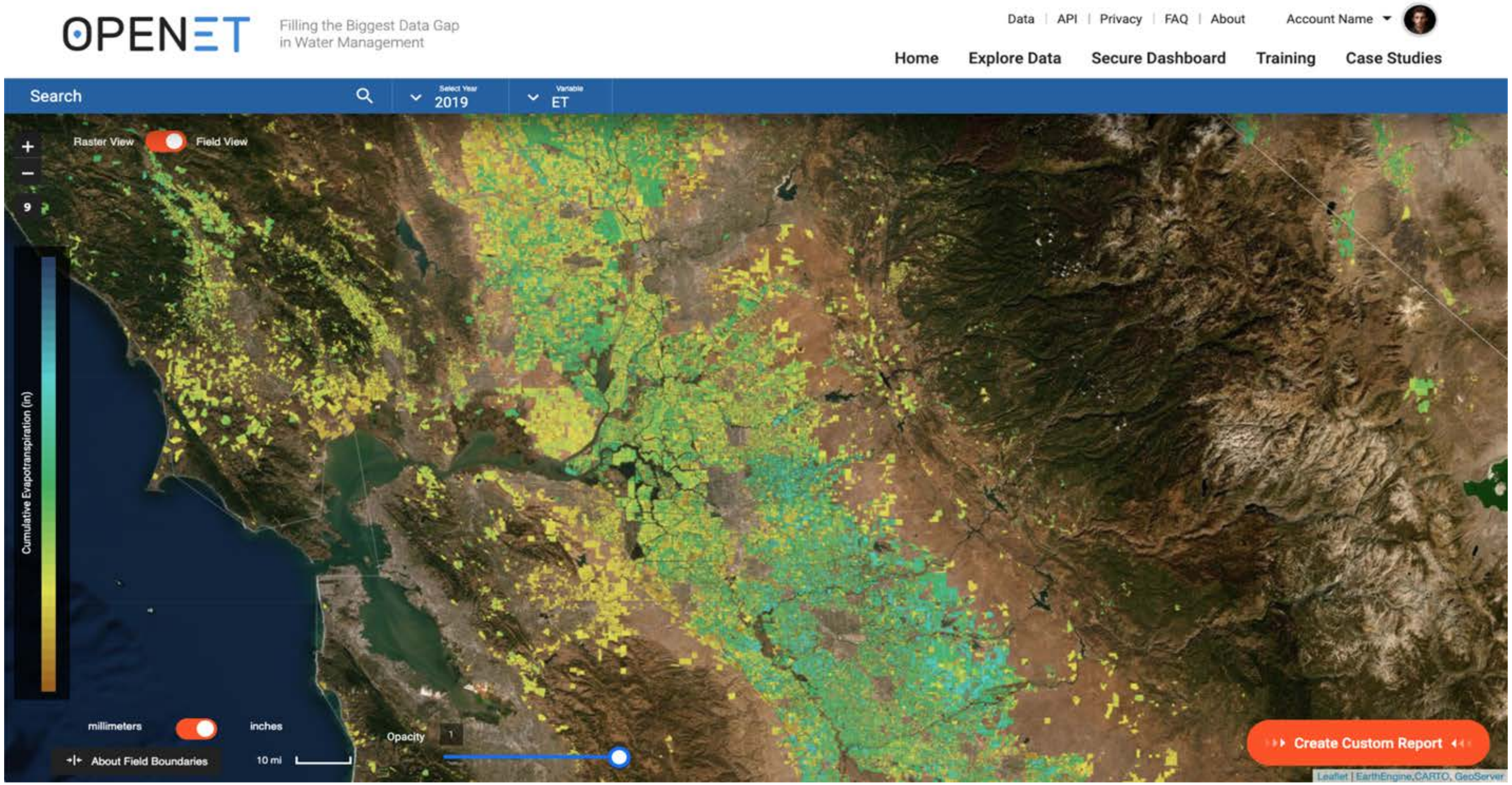
ESI and Prediction of Crop Yield Anomalies

- Examines drought conditions during critical crop stages
- Strong relationship between wheat yield and the ESI and VegDRI during critical crop stages
- NLDAS has strong (weak) relationship to corn/soybeans (wheat) yield
- ESI had strongest correlation to the wheat, corn, and soybean yield departures



OpenET: A Google Earth Engine ET Monitoring System

https://etdata.org/



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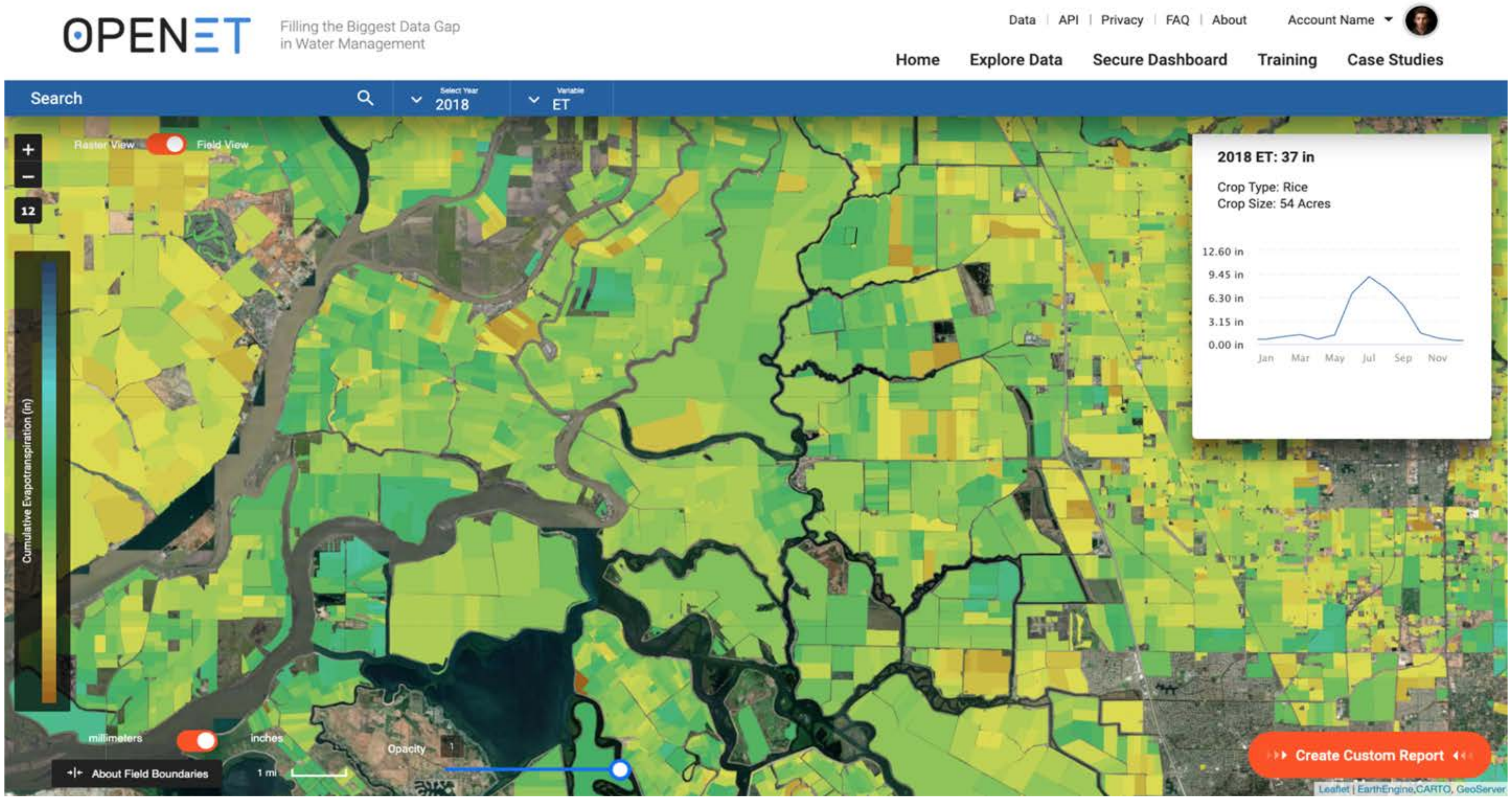

Question & Answer Session

- Please enter your questions in the Q&A box.
- We will post the questions and answers to the training website following the conclusion of the course:

  https://arset.gsfc.nasa.gov/water/webinars/remote-sensing-for-agriculture-20

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