Remote Sensing and Irrigation Scheduling

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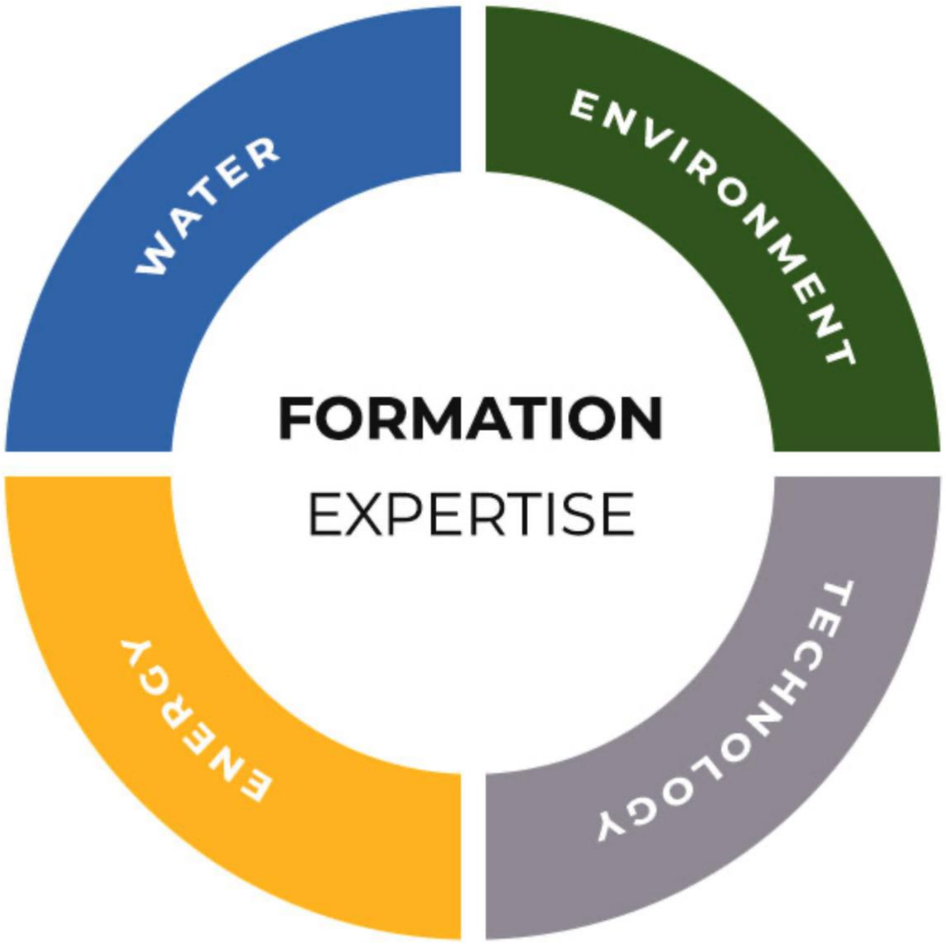
Formation Environmental

USGS - Louisville
December 12, 2019

Formation Environmental

Water Resources Engineers
Soil Scientists
Engineering Geologists
Hydrogeologists
Agricultural Engineers
ETa Analysts
Soil Technicians
Agronomists
Crop Scientists

Civil Engineers
LiDAR Analysts
Remote Sensing Analysts
Certified Arborists
Engineering Geologists
Statisticians
Meteorologists
Geological Engineers



Environmental Scientists
Environmental Engineers
Geologists
Chemists
Botanists
Risk Assessors
Aquatic Biologists
Ecotoxicologists
Restoration Ecologists

UAS Pilots
Aeronautical Engineers
LiDAR Analysts
GIS Analysts
Applied Physicists
IT Developers
Database Analysts
Data Scientists

Formation Environmental Science Team

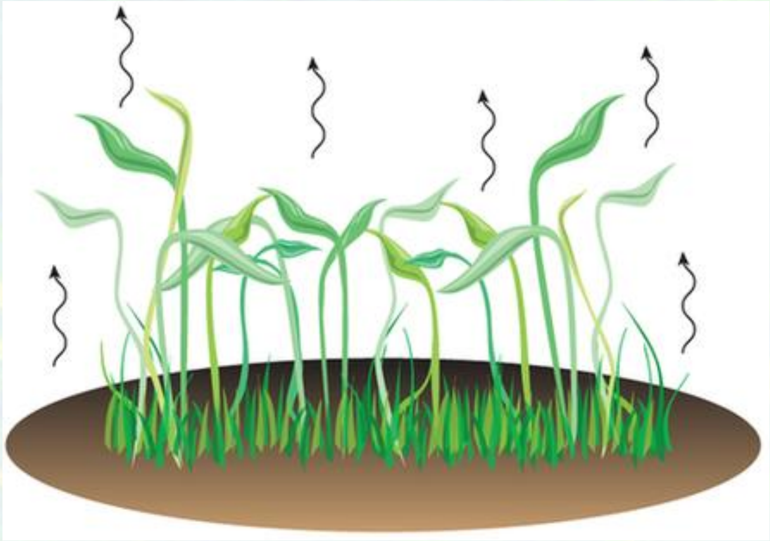
- George Paul, PhD – Agronomist/Agricultural engineer
- Chuan-Shin Chong – Electrical engineer
- Sushant Mehan, PhD – Agricultural engineer
- Ben Cheng, PhD – Remote sensing hydrologist
- Clint Kellar – GIS and web developer
- Macall Teague, Yuri Walsh, & Cameron Gurley – data support

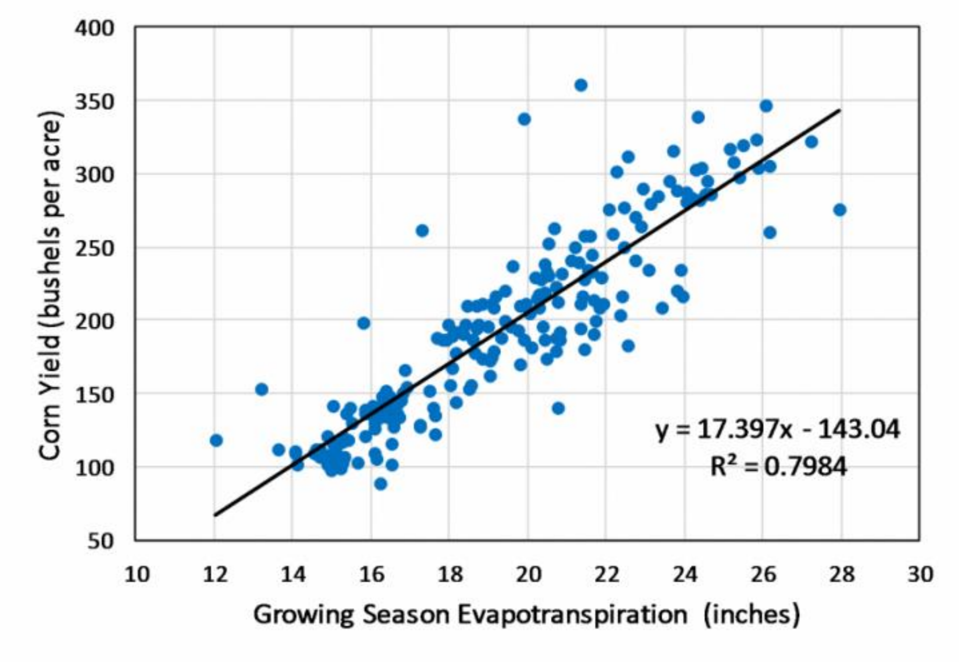
Scope of Today's Discussion

- Evapotranspiration – fundamental to irrigation scheduling
- Considerations for irrigation scheduling
- Fundamentals of irrigation scheduling
- Sensor based irrigation scheduling
- Irrigation scheduling and remote sensing; CA and KY

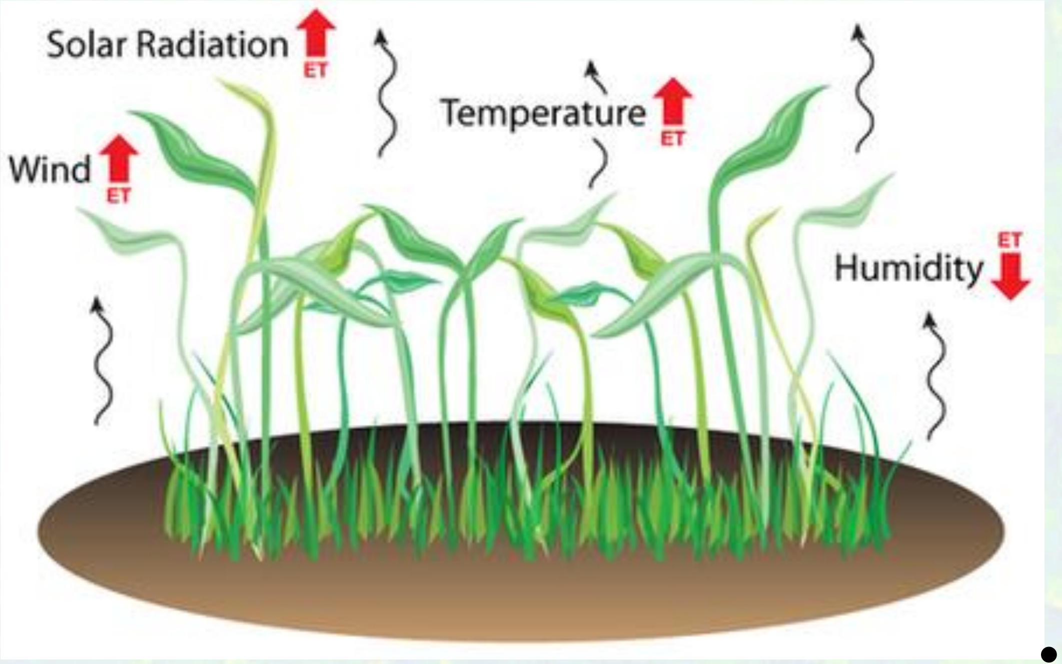
Evaporation and Transpiration
aka Evapotranspiration or ET

Evaporation – of water from soil and plant leaves to the atmosphere
Transpiration – water moving through a plant due to atmospheric demand
Combined – ET is what is required to keep a plant alive and productive!





Atmospheric Drivers of ET



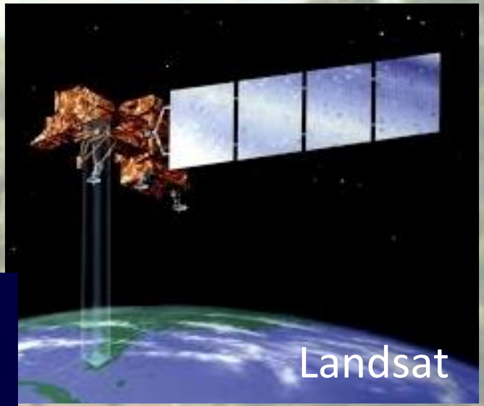
- Sunlight – more sunlight, higher ET
- Temperature – higher temperature, higher ET
- Wind – higher wind, higher ET and
- Humidity – higher humidity, lower ET

Constrainers of ET

- In adequate soil water
- Nutrient deficiency
- Salt toxicity
- Ion toxicity
- Pests and diseases

Remote Sensing of ET
(thermal imaging)

Net Radiation (Rn)
(energy in from the sun)



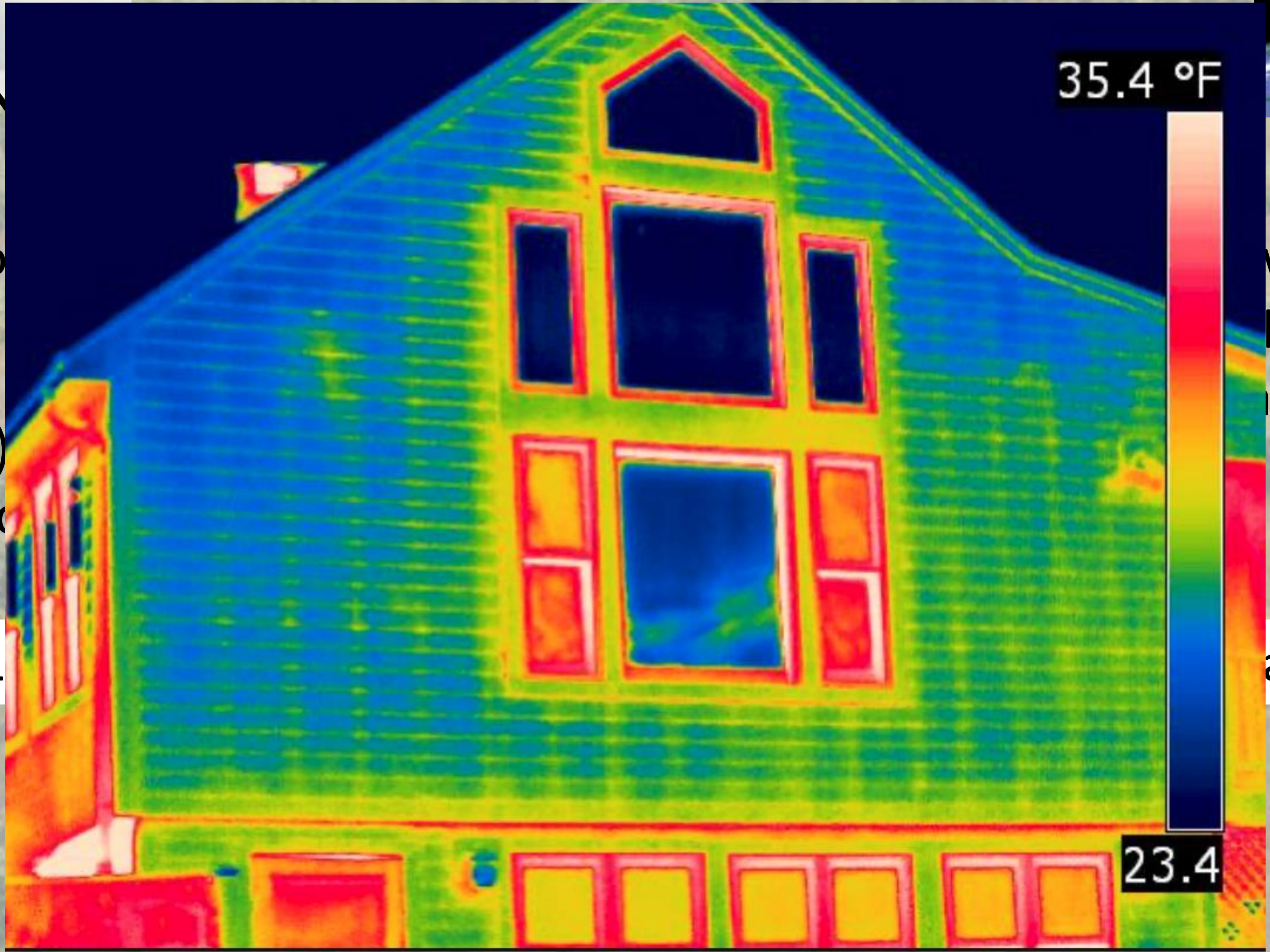
Evapotranspiratio

Soil Heat Flux (G)
(warms the grounc

ET (L

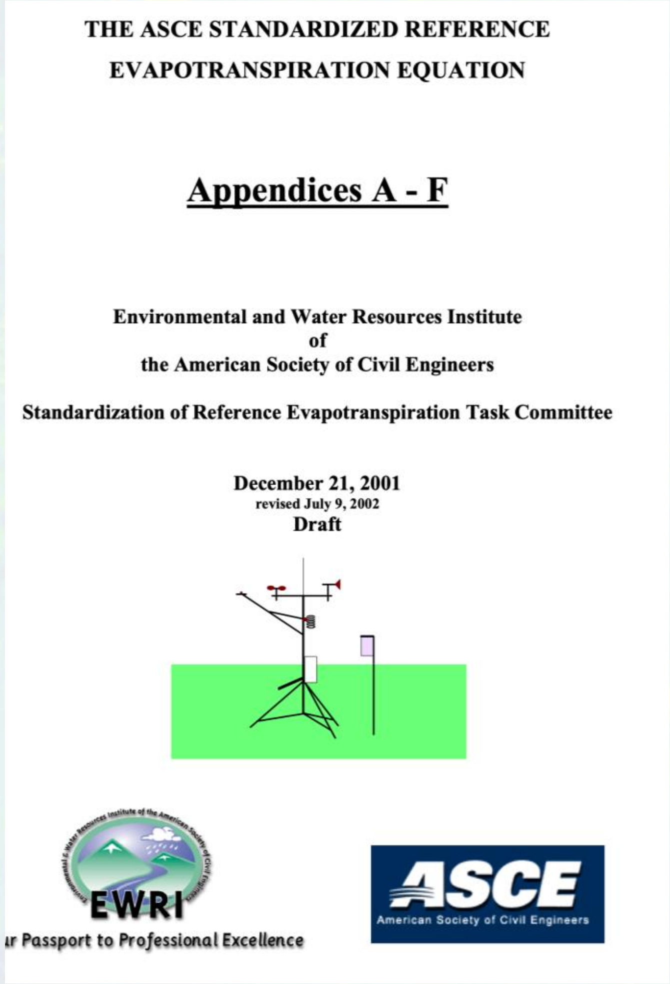
warm the air
le Heat Flux (H)
rms the air)
rmal imager

arm the air (H)



Ground-based Data

Weather Station and Penman-Monteith Equation


THE ASCE STANDARDIZED REFERENCE EVAPOTRANSPIRATION EQUATION

Appendices A - F

Environmental and Water Resources Institute
of
the American Society of Civil Engineers

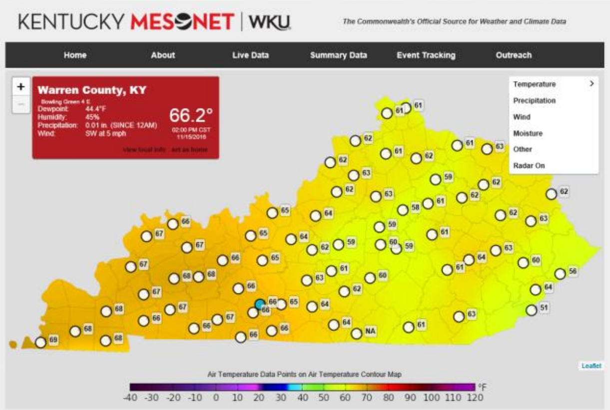
Standardization of Reference Evapotranspiration Task Committee

December 21, 2001
revised July 9, 2002
Draft

EWRI
ır Passport to Professional Excellence

ASCE
American Society of Civil Engineers

- ASCE standard equation.
- Referenced to **grass** or alfalfa.
- Weather inputs used to calculate a time-based reference value.



Available Data

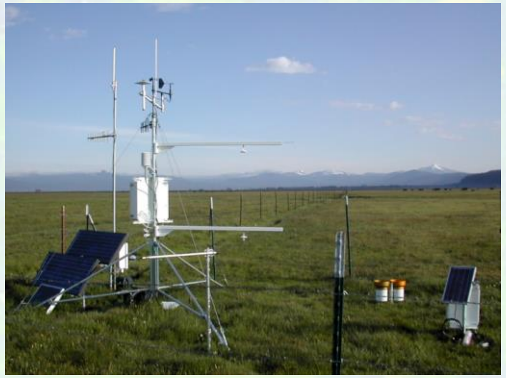
- Air Temperature
- Relative Humidity
- Solar Radiation
- Wind Speed
- Dew Point Temperature
- Precipitation
- Wind Direction

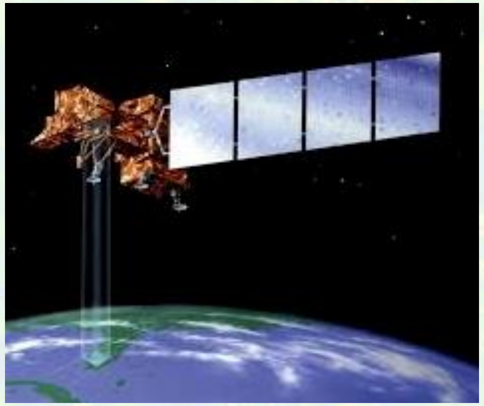
Reference ET (ETo)
California Dept. of Water Resources

- Daily publication of ETo maps at a 2km scale.
- Growers and urban agencies use data for irrigation scheduling.
- Free but requires an account

Spatial, Temporal, and Cost of Methods of Measuring ET

Method	Resolution		Cost
	Spatial	Temporal	
Research			
Weighing lysimeter	very low	very high	very high
Eddy covariance	very low	high	very high
Surface renewal	very low	high	very high
Applied			
Field water balance	low	high	very high
Weather data	low	high	low
Remote sensing	high	high	low





Accuracy of ET Measurement Methods

Table 2
Error, expressed as one standard deviation from the true mean value, expected for various types of ET measurement or retrieval systems.

Method	Typical error, %	Error for an experienced expert, trained and steeped in the physics of the process, %	Error for a novice or a person working outside their specialty area, %	Additional error caused by physical or equipment malfunction, %
Lysimeter	5–15	5	20–40	5–40
Soil water balance	10–30	10	20–70	10–40
Bowen ratio	10–20	10	20–50	5–40
Eddy covariance	15–30	10–15	30–50	10–40
Remote sensing energy balance	10–20	5–15	30–40	5–10
Remote sensing using vegetation indices	15–40	10–30	20–40	5–10
Sap flow	15–50	10–40	40–200	20–100
Scintillometers[a]	10–35	10–15	20–50	5–30

[a] Scintillometers measure sensible heat flux, only, and require estimating ET as a residual of the energy balance ($\lambda E = R_n - G - H$).

Source: R.G. Allen et al, 2011. Evapotranspiration information reporting: I. Factors governing measurement accuracy. Agricultural Water Management (98) 899-920.

Irrigation Scheduling Considerations

- ET varies by crop, time-of-year, and location.
- Meeting a crop's yield potential requires adequate soil water content.
- Coupling ET demand to soil water content is required to ensure adequate soil water.
- Field variability can be significant, and knowledge of the variation is essential for maximizing uniformity of irrigation and fertilizer application.

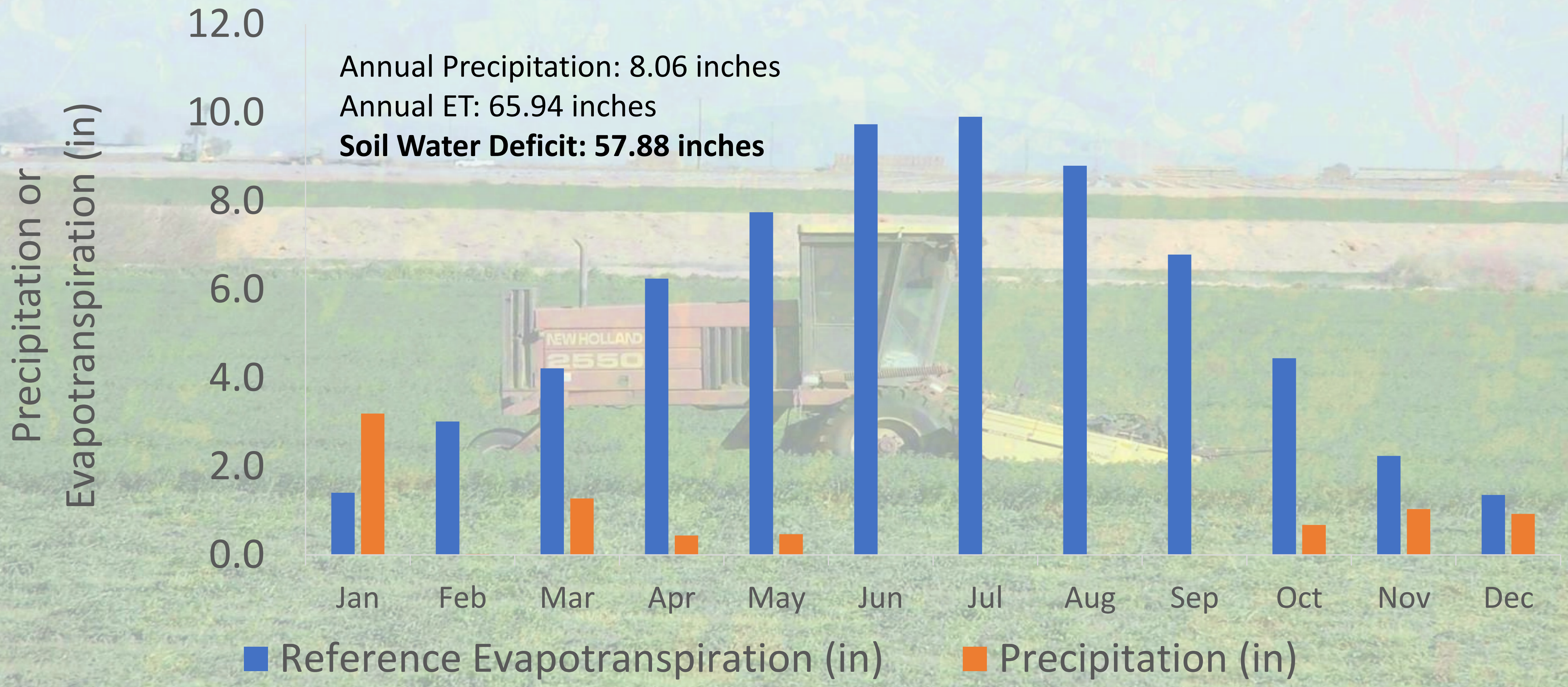
Irrigation Scheduling Considerations

- Providing water for irrigation requires pumping, supply lines, and a method of irrigating (i.e. drip, pivot, sprinkler, or furrow).

- Purchasing, constructing, and operating pumping plants, supply lines, and irrigation systems is expensive and should be sized to minimize cost and maximize profit.

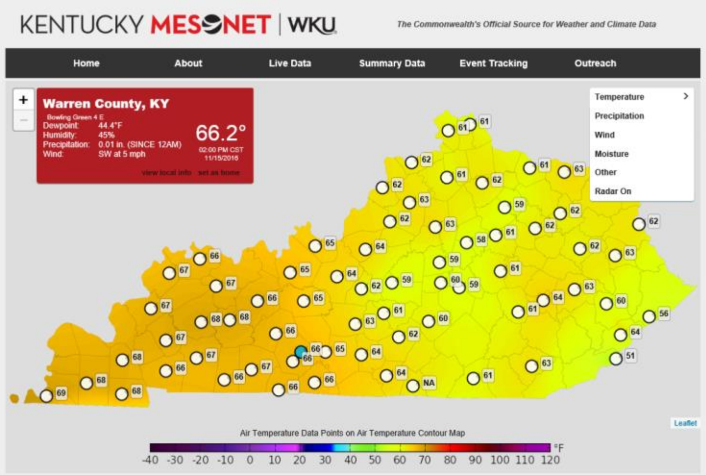
- Take-home message is that you need ET demand information to support irrigation scheduling.

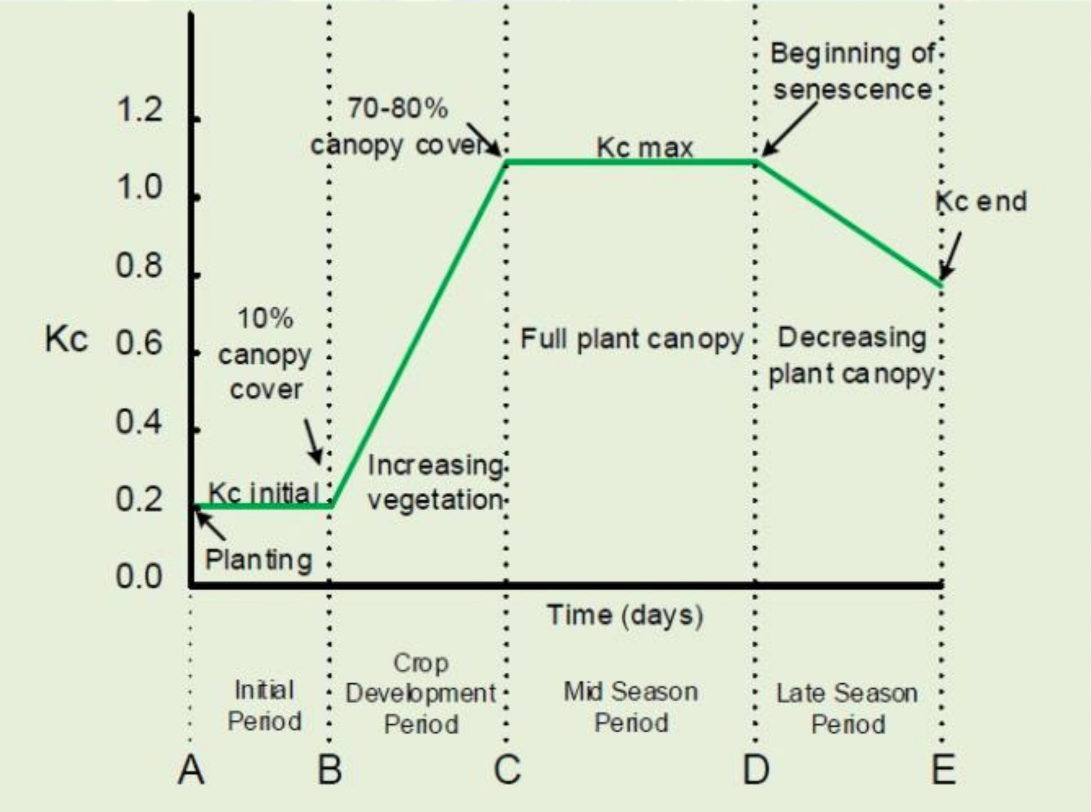
Fundamentals of Irrigation Scheduling
Matching demand and supply



Fundamentals of Irrigation Scheduling
Crop ET demand using crop coefficients

Crop ET demand (ETc) = ETo (Reference) * Crop Coefficient (Kc)





Irrigation Scheduling Approaches

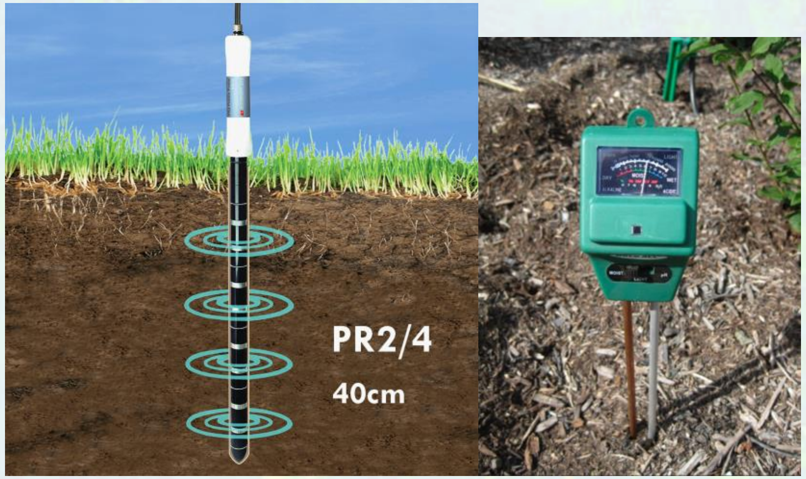
- Experience (sound, crop appearance)
- Rotation (water availability)
- Equipment (cutters, bailers, rakes)
- Demand and soil water content

Sensor Based Irrigation Scheduling

tensiometer

surface renewal

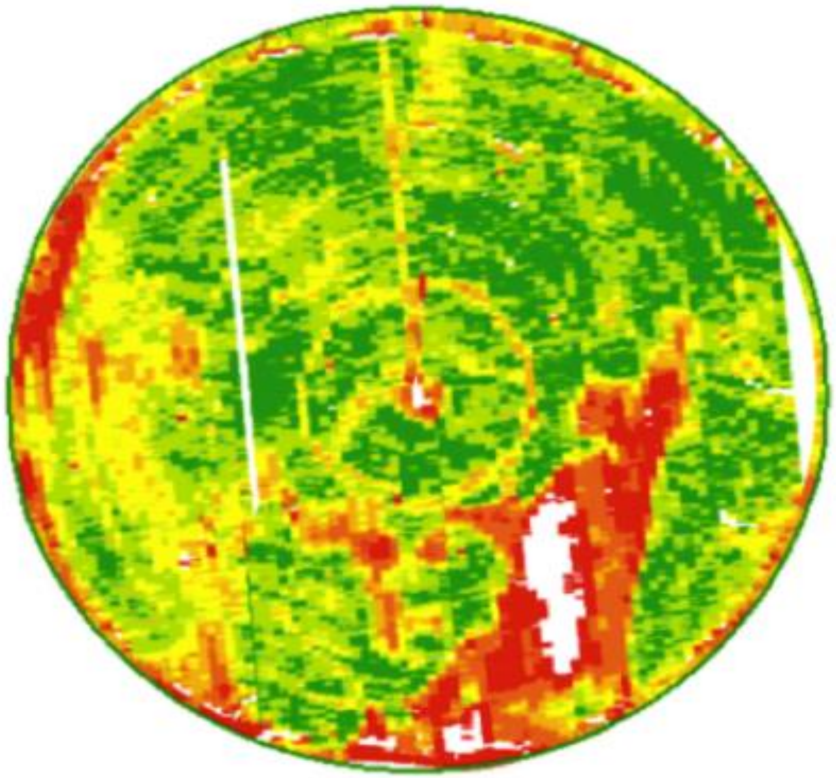
- Point measurements
- Maintenance
- Data collection



dielectric or capacitance

sap flow thermocouple

Sensor Based Scheduling
Selecting sensor placement



- Selecting the location for sensor placement impacts scheduling decisions.
- Sensors placed in an area with low soil water capacity may result in over watering.
- Sensors placed in an area with a high soil water capacity may result in under watering.

Irrigation scheduling in the age of computers and satellites

CalETa DATA ACQUISITION FROM LANDSAT TO DESKTOP

STATEWIDE IMAGE ANALYSIS FRAMEWORK

Image Processing

- Automated Imagery Download (Landsat & MODIS)
- Automated Cloud Screen
- Conversion to Surface Reflectance
- Derive Physical & Biophysical Variables

Climate / Weather

- Conditions at Satellite Overpass
- Spatial CIMIS: Daily Reference ET
  - Solar Radiation
  - Air Temperature
  - Relative Humidity
  - Wind Speed
  - Reference ET

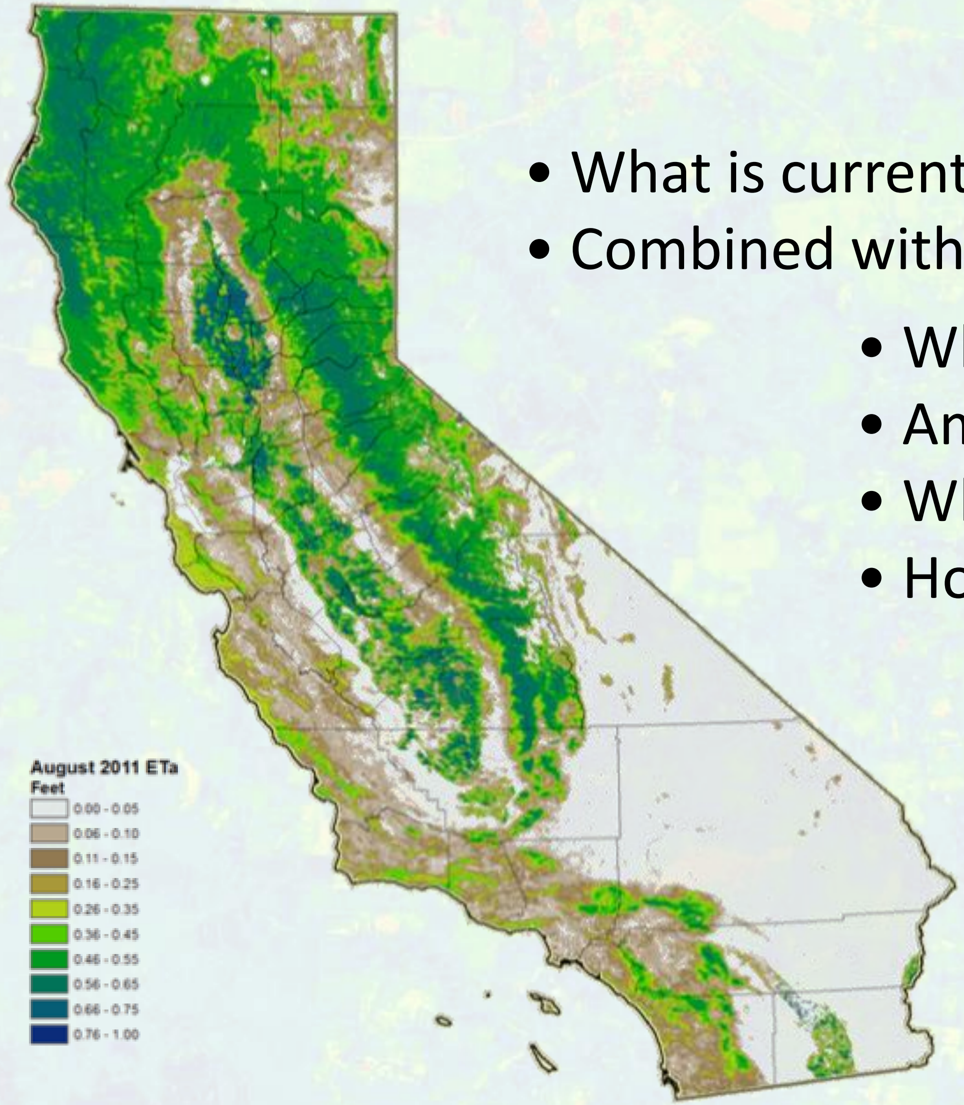
Surface Energy Balance Equation

↓

CalETa

Daily ETa (Statewide, 30 meter resolution)

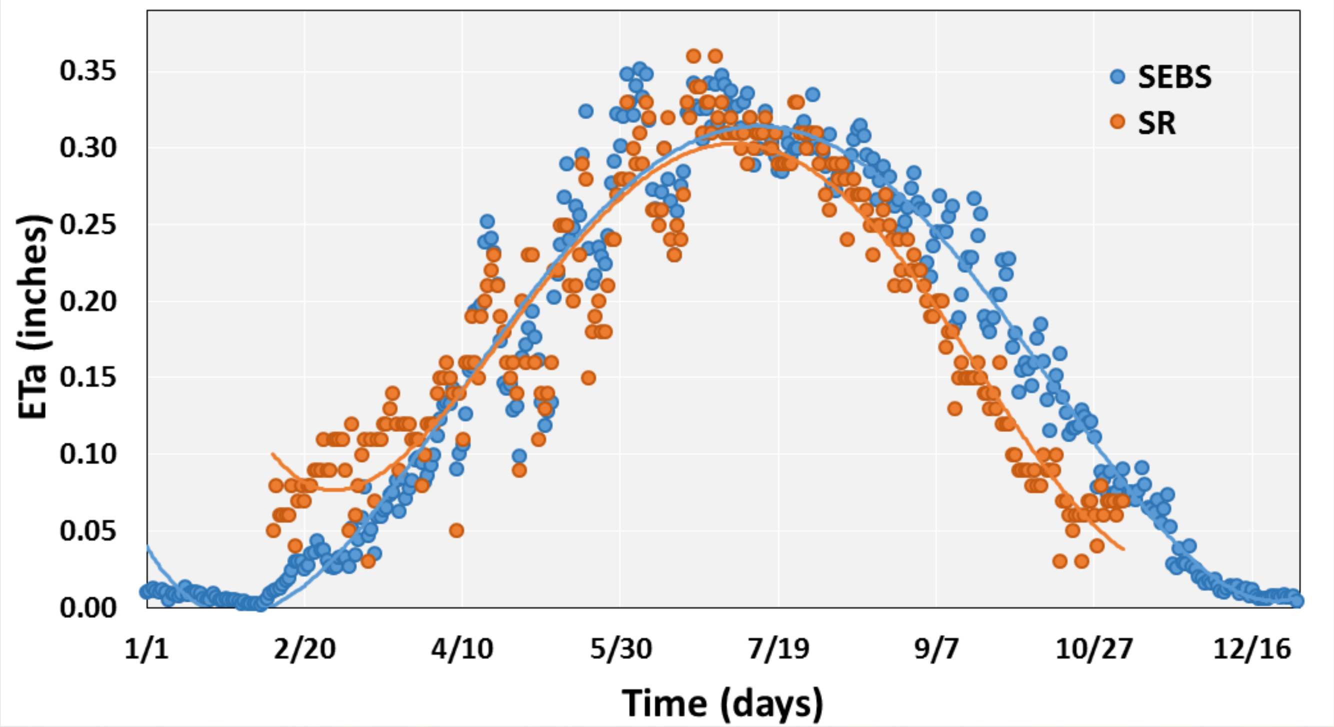
Connecting ETa with Irrigation Scheduling

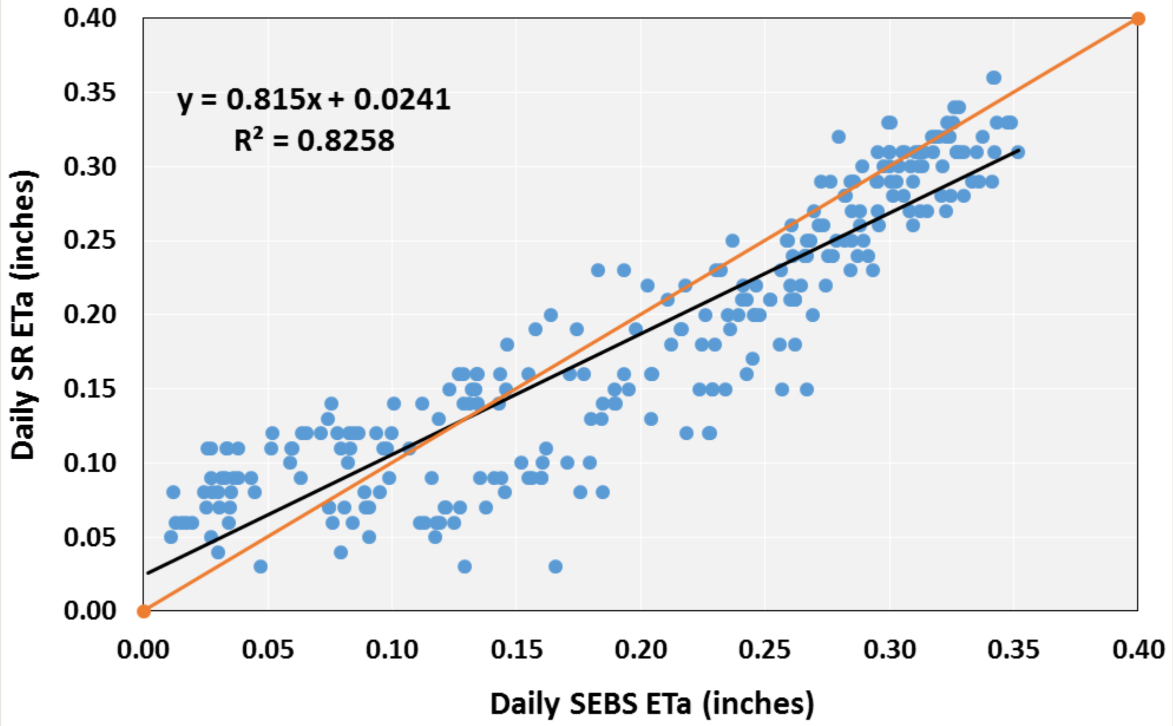


- What is current and historic ETa for specific crop types?
- Combined with surface water, how much groundwater is being used?
  - What is the uniformity of water use?
  - Am I meeting my crop’s water needs?
  - Where to locate field-sensors?
  - How to make point-measurements actionable?

CalETa

DATA VALIDATION TO ENSURE ACCURACY





Trend and relationship of CalETa and a ground-based surface energy monitoring station (Tule surface renewal) for a fully irrigated pistachio orchard.

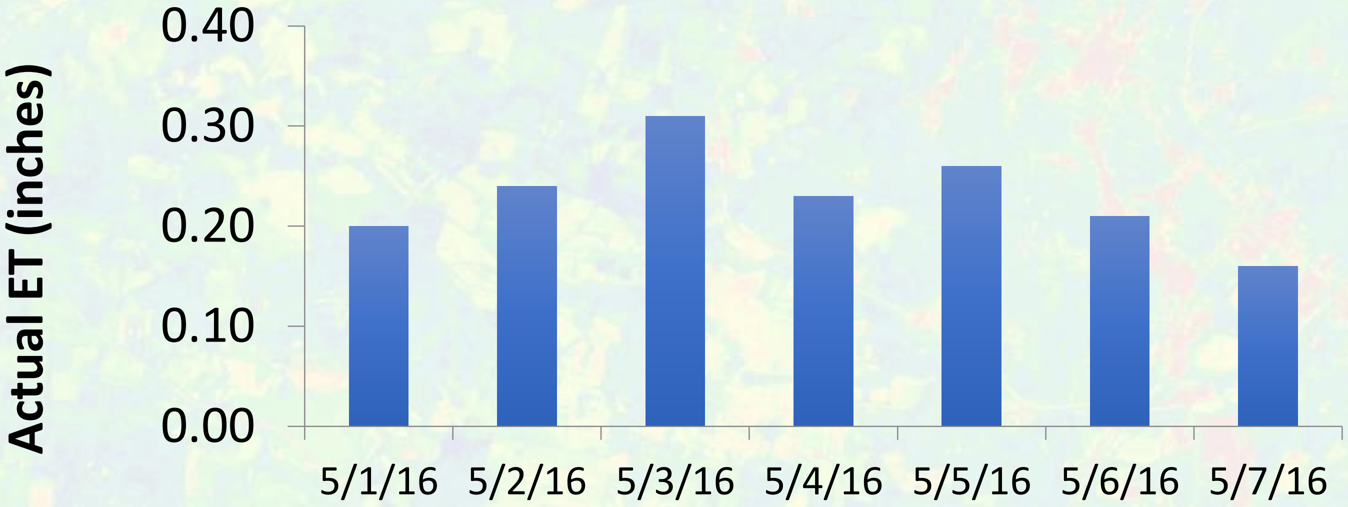
DATA VISUALIZATION TRANSLATING DATA TO INFORMATION

- Color image shows ETa by pixel.
- Color is used to represent the depth of ET.
- Blue (cool) color is high ET.
- Brown (warm) color is low ET.
- A uniform color = uniform ET.

- Image is 169 pixels or 34 acres.
- 169 ET measurements points for analyzing ET.
- Each pixel is the average for all trees within the boundary of the pixel.
- Assuming a planting density of 125 trees/acre each pixel is the average ET of 25 trees.

CalETa

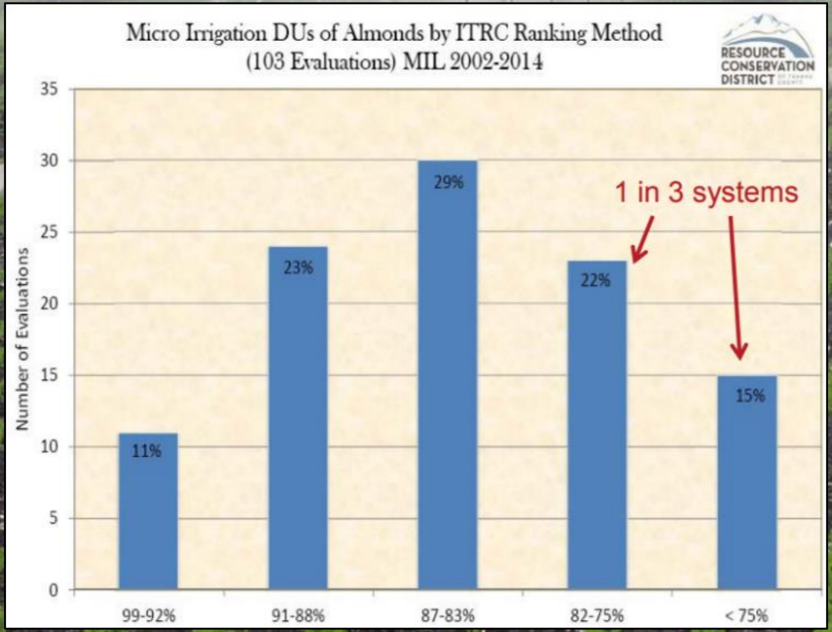
DATA USE CALCULATING ORCHARD WATER USE



Weekly demand for May 1-7, 2016 was 1.61 inches or 4.5 acre-feet for the 34 acre orchard.

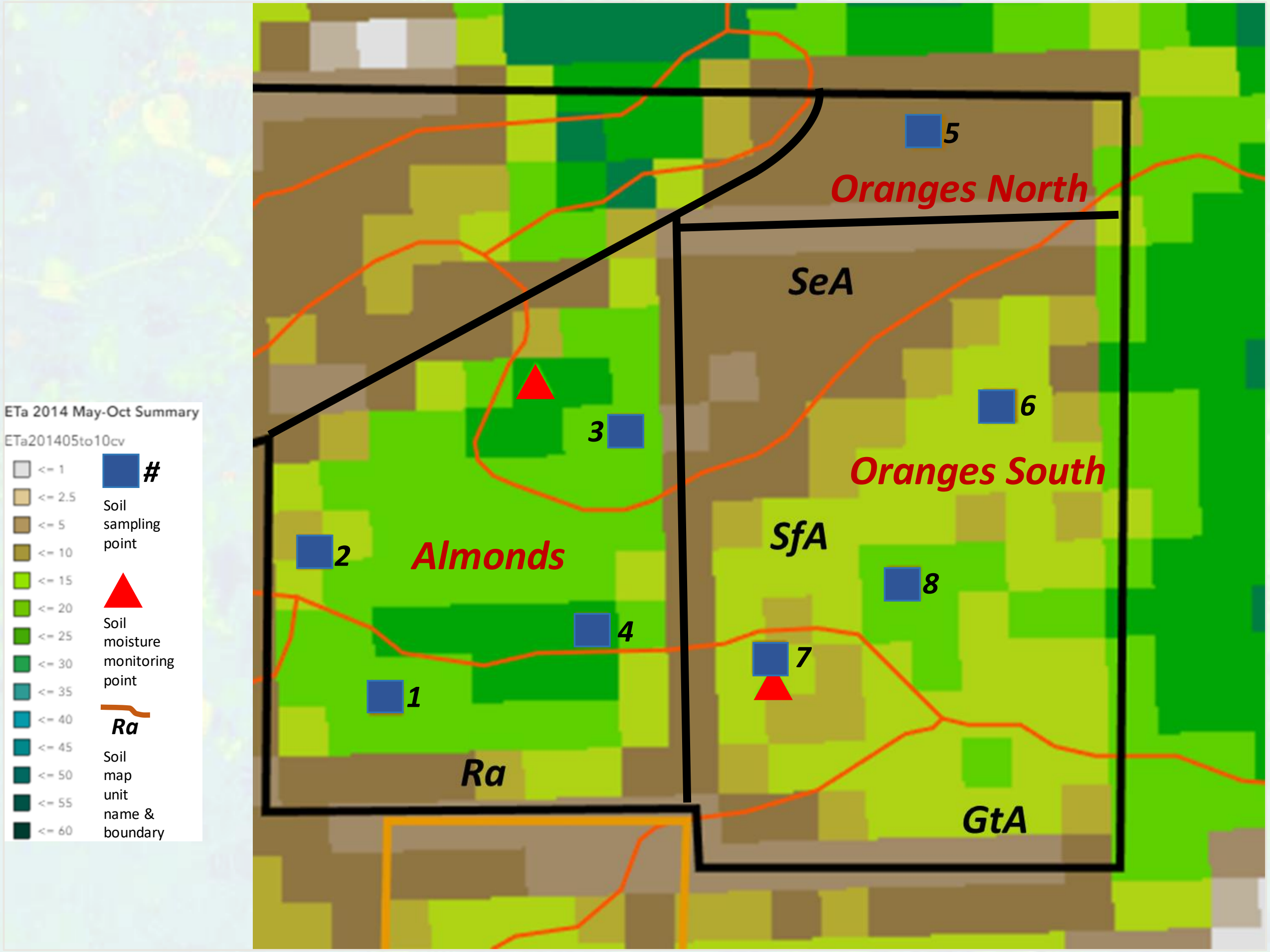
Irrigation system performance: Distribution uniformity (D.U.)

% D.U. = (inches applied to driest quarter of field / field average inches applied)*100



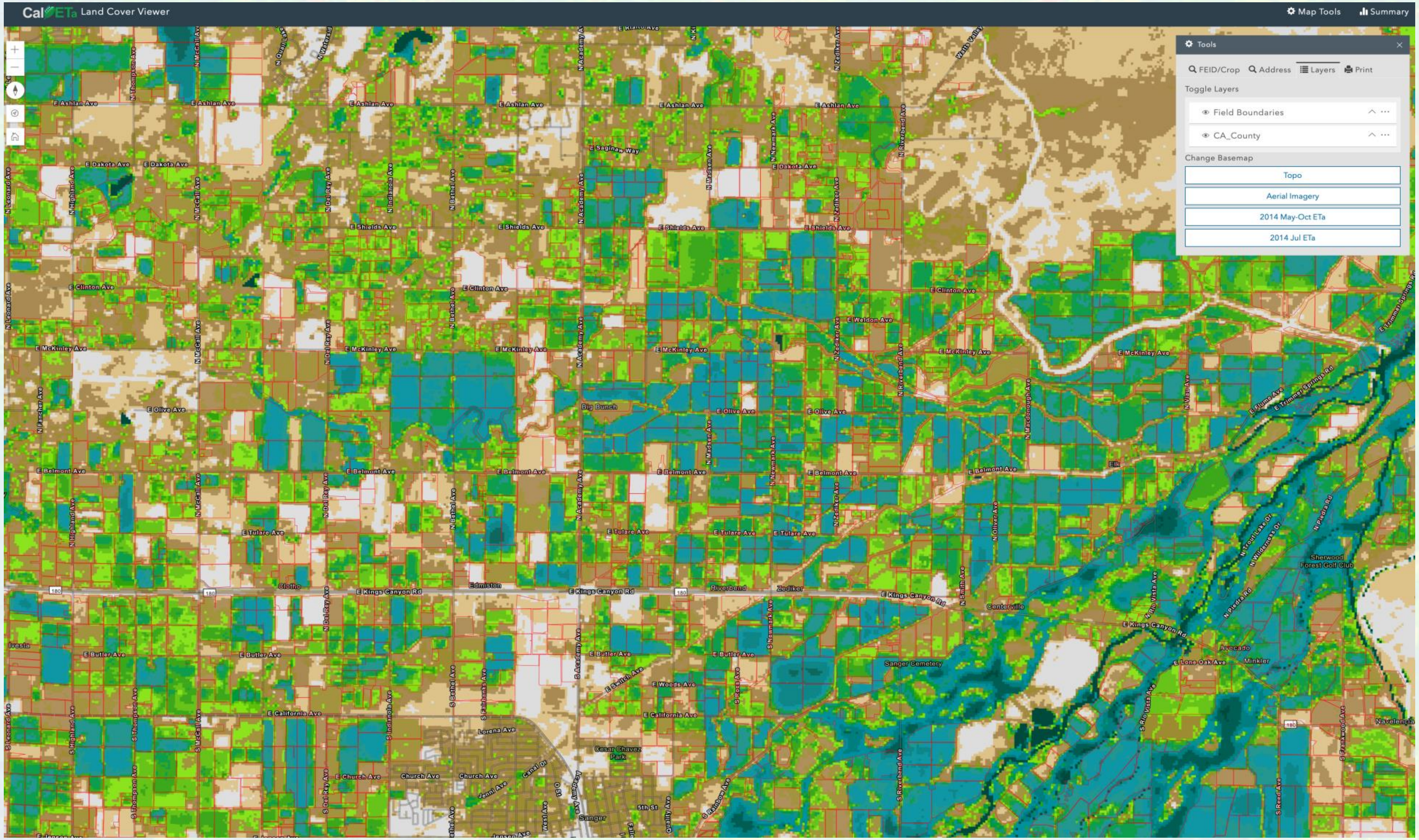
Source: Allan Fulton, UCCE

VISUALIZING ETa UNIFORMITY IN ORCHARDS



- Soil series delineated to help understand ET variability.
- Grower can use ET variability to investigate problem areas and to target solutions.
- Uniformity is a map – it does not tell you why there is an issue.

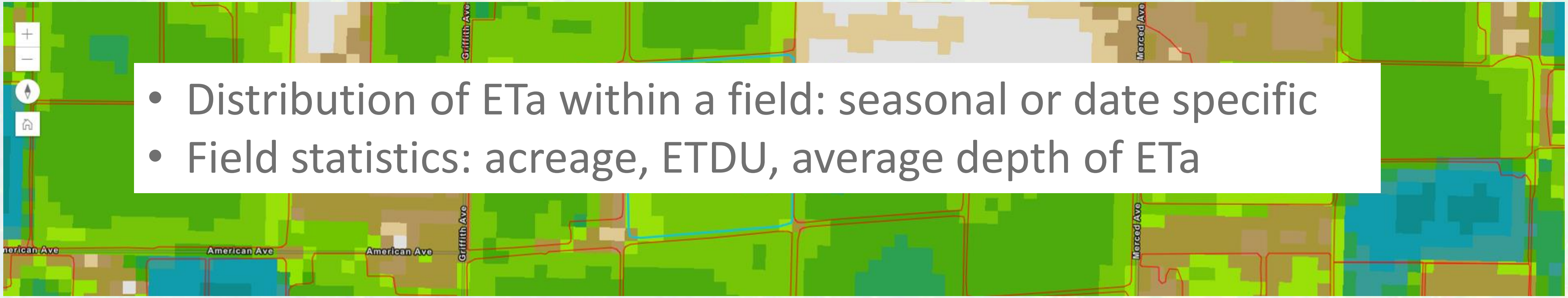
VISUALIZING ETa UNIFORMITY IN ORCHARDS

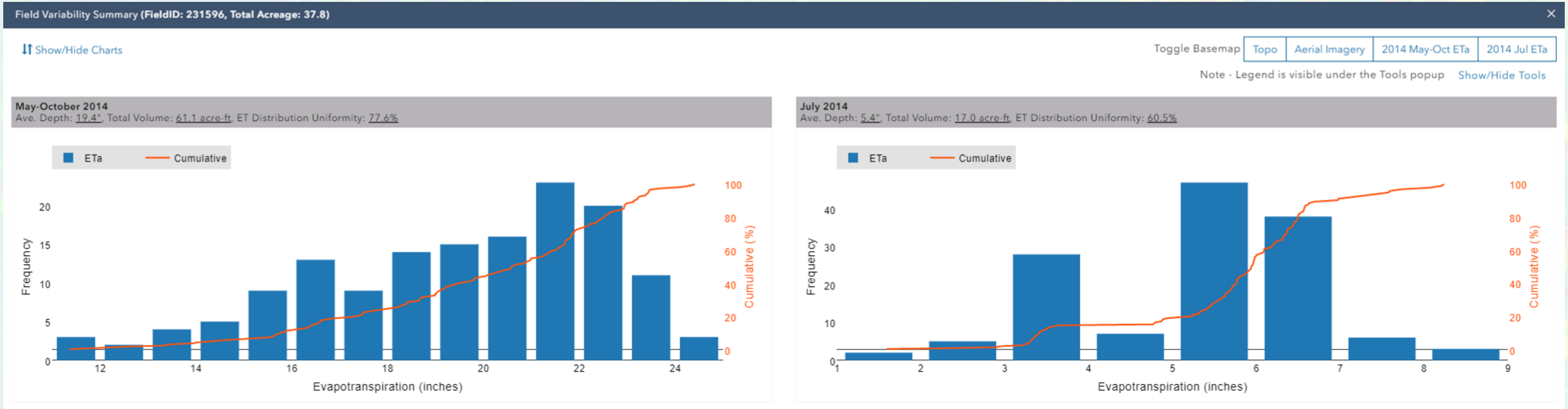


- Custom web interface panel to select geographic or other feature

VISUALIZING ETa UNIFORMITY IN ORCHARDS

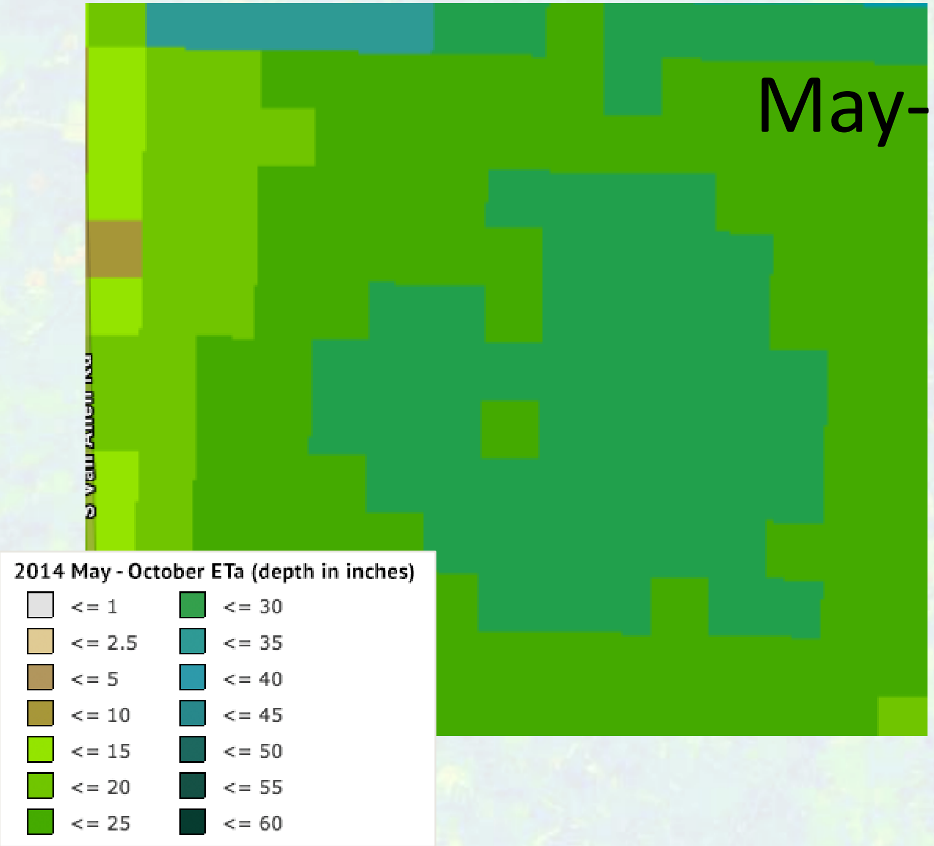
- Distribution of ETa within a field: seasonal or date specific
- Field statistics: acreage, ETDU, average depth of ETa





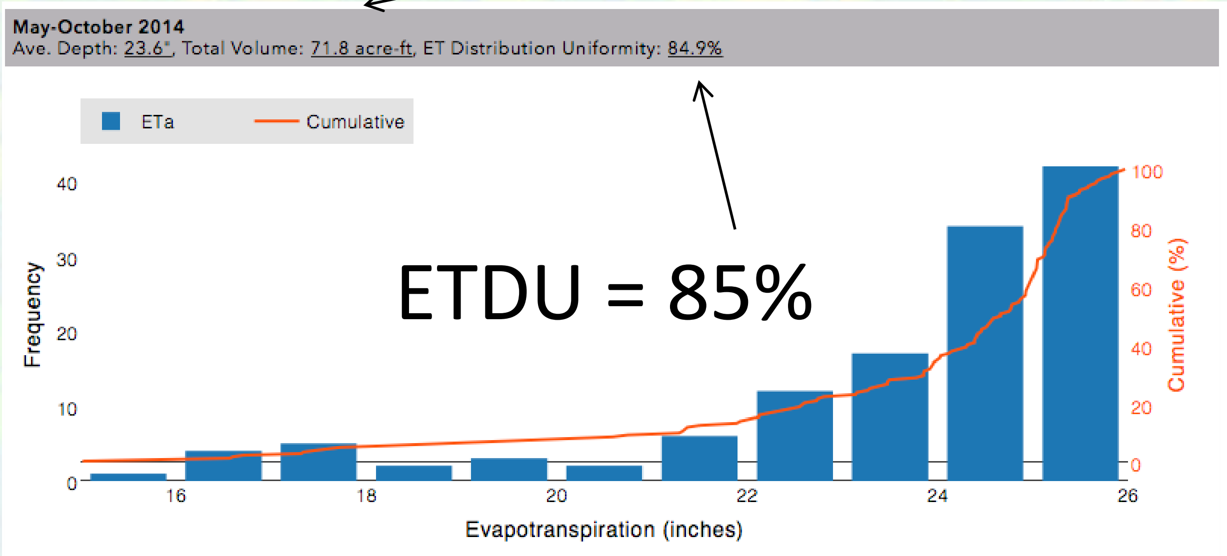
DATA USE TAKING IN ACCOUNT ET UNIFORMITY: WEBVIEWER

Using the distribution of ET in a field a measurement of irrigation uniformity is calculated using driest/average ET.



May-Oct Avg Depth: 23.6 in

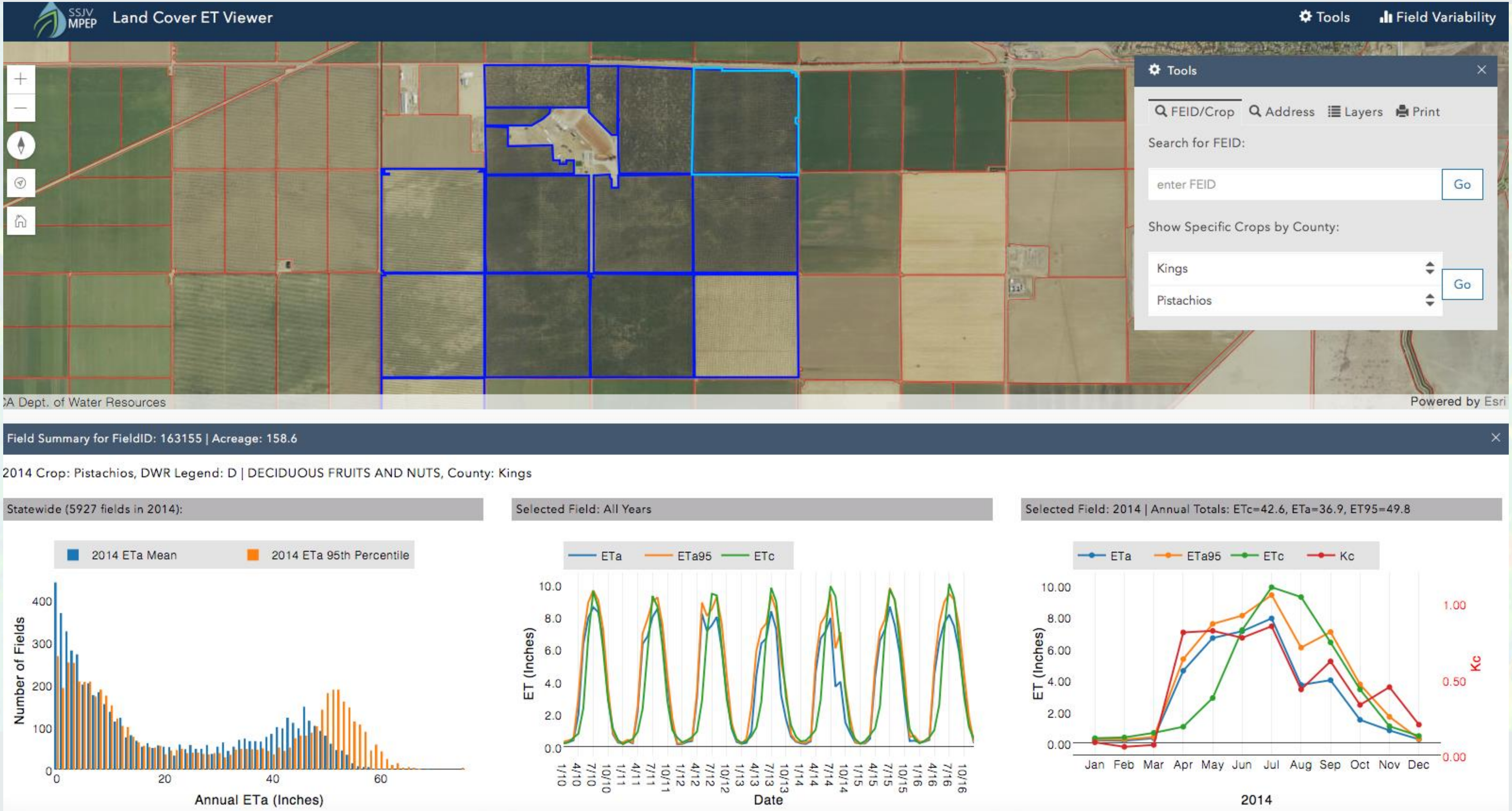
Volume: 72 AF



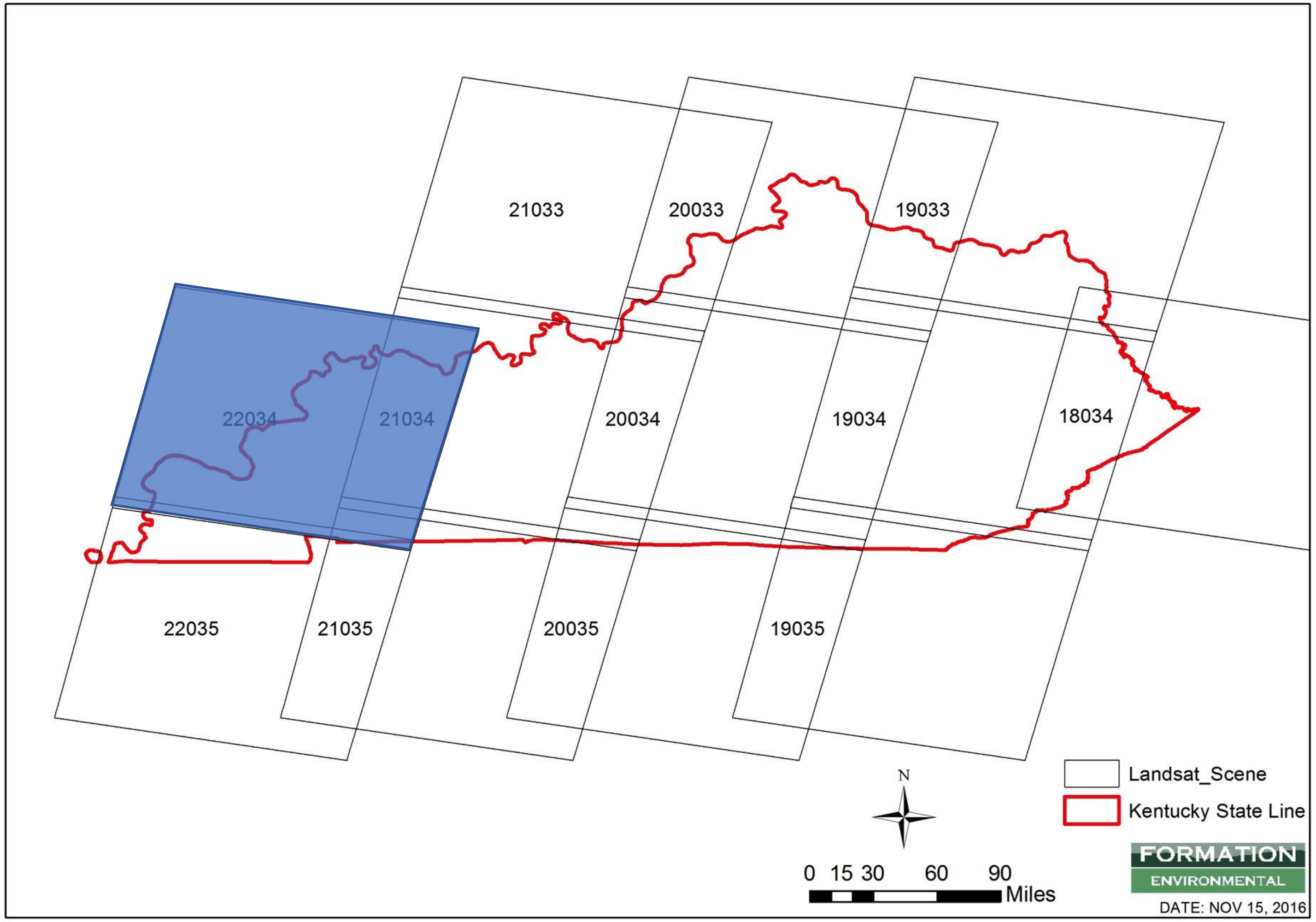
ETDU = 85%

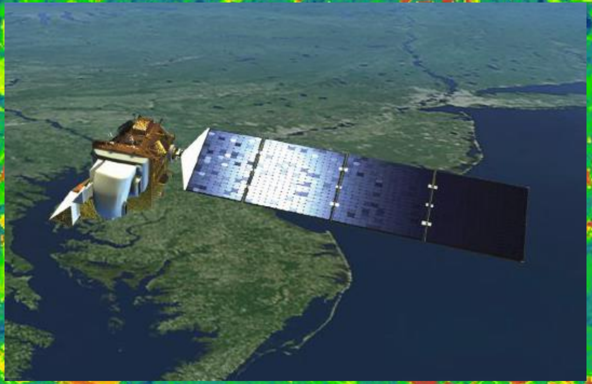
CalETa

APPLICATIONS ETa IN ORCHARDS



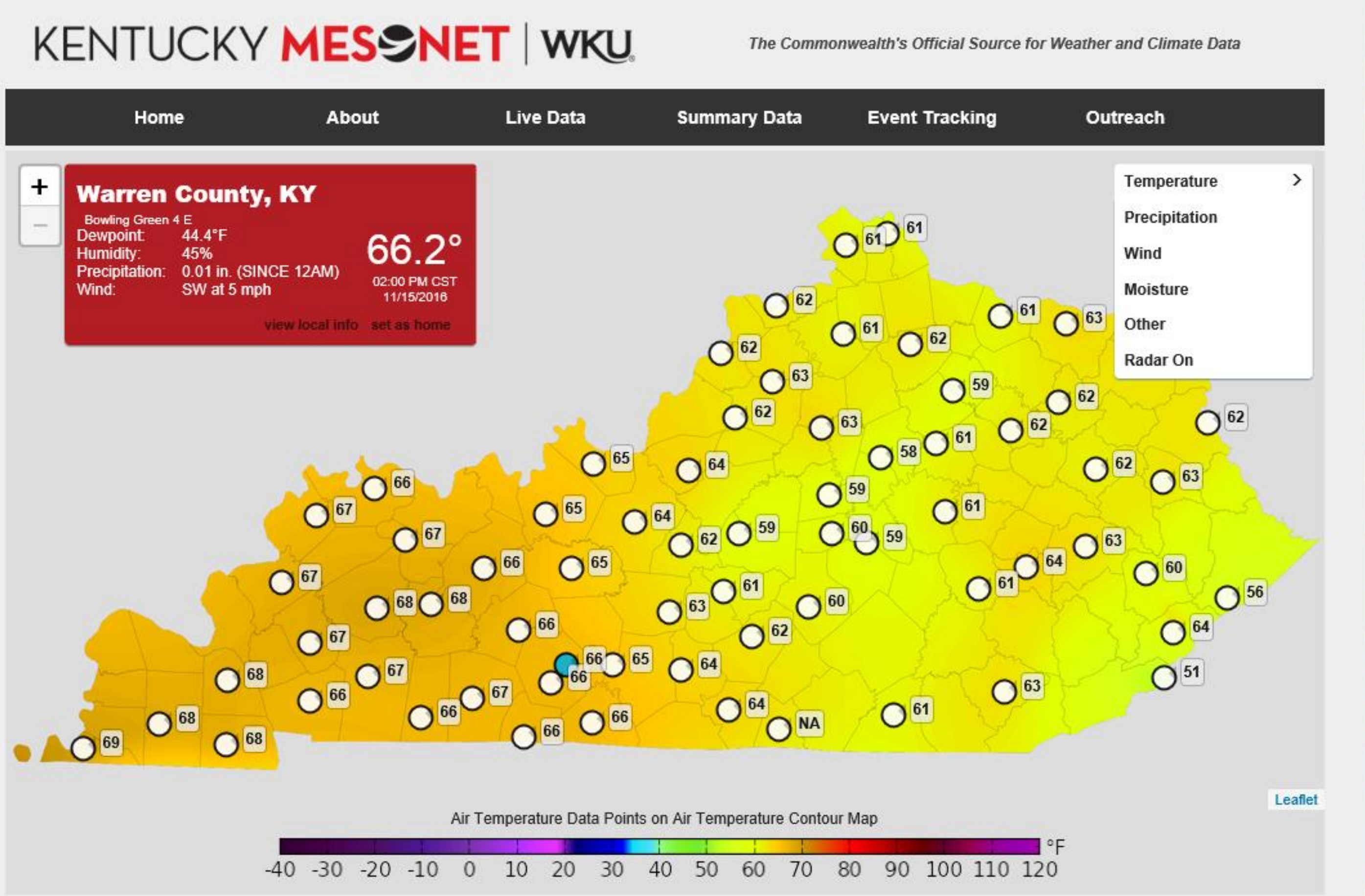
Remote Sensing of Evapotranspiration Kentucky





- Landsat (NASA via USGS) missions L7, and L8 each on an 8 day return
- Scene is ~ 106 by 114 mi (12,152 mi^2)
- Imagery is free
- Processed 11/2018-10/2019

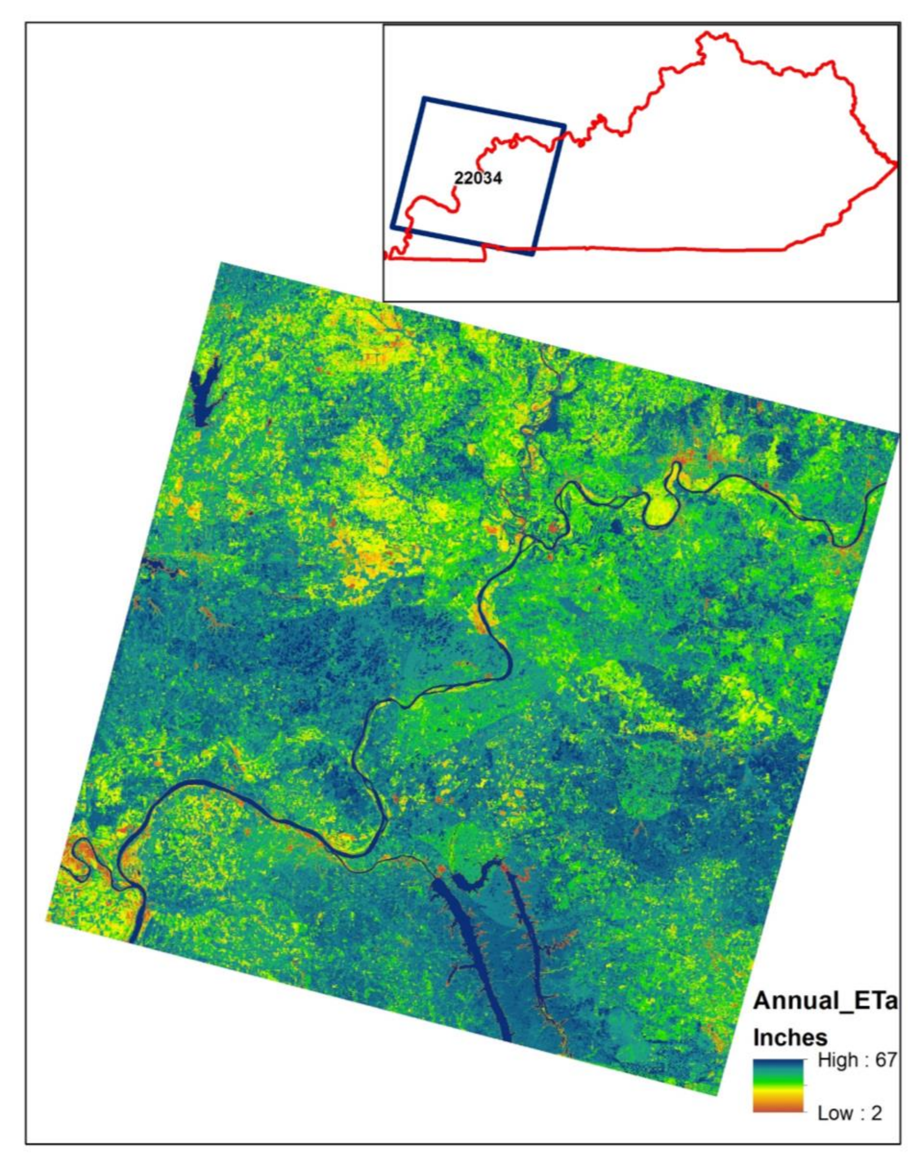
Remote Sensing of Evapotranspiration
Ground-based Weather Network



Available Data

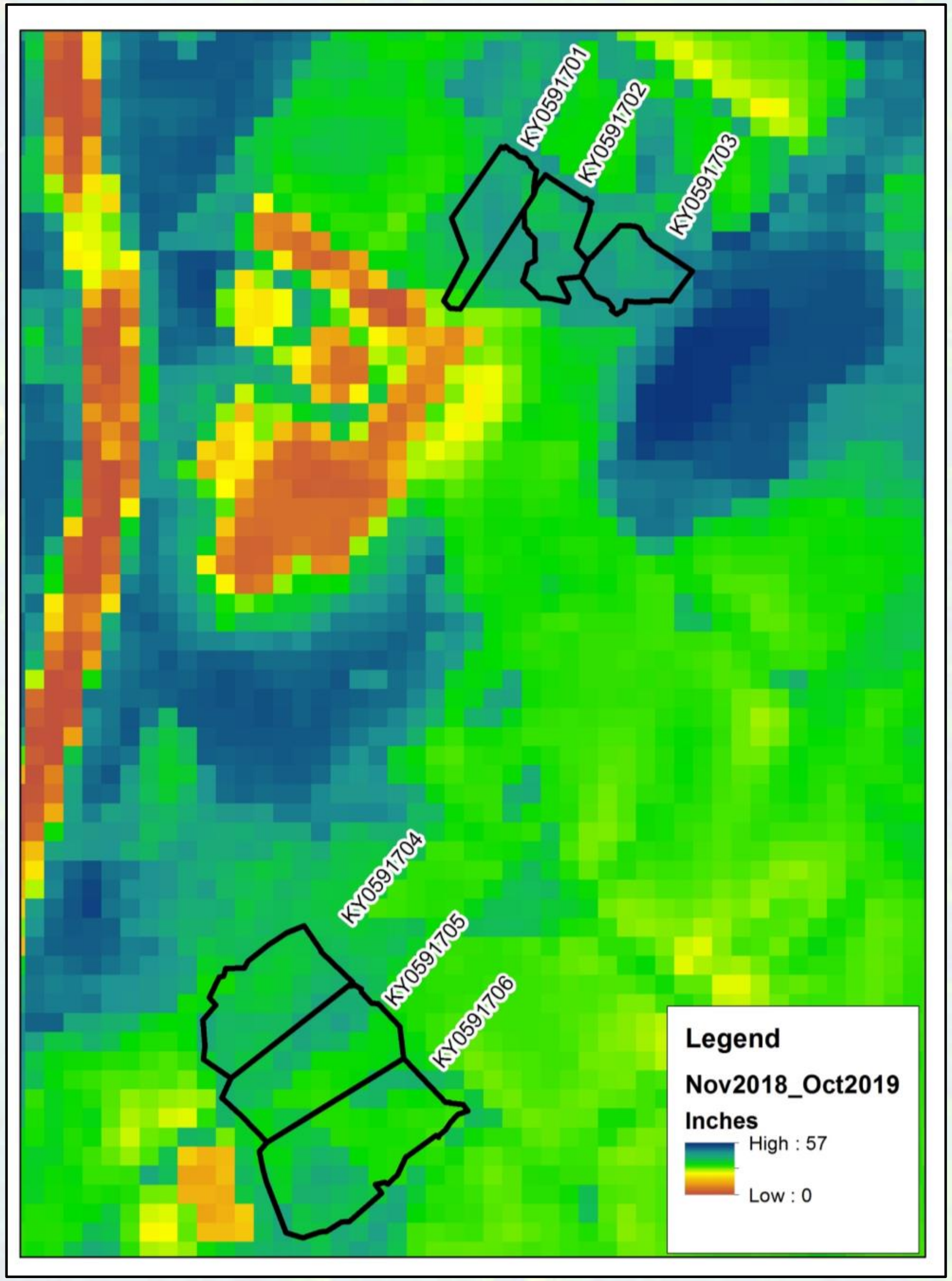
- Air Temperature
- Relative Humidity
- Solar Radiation
- Wind Speed
- Dew Point Temperature
- Precipitation
- Wind Direction

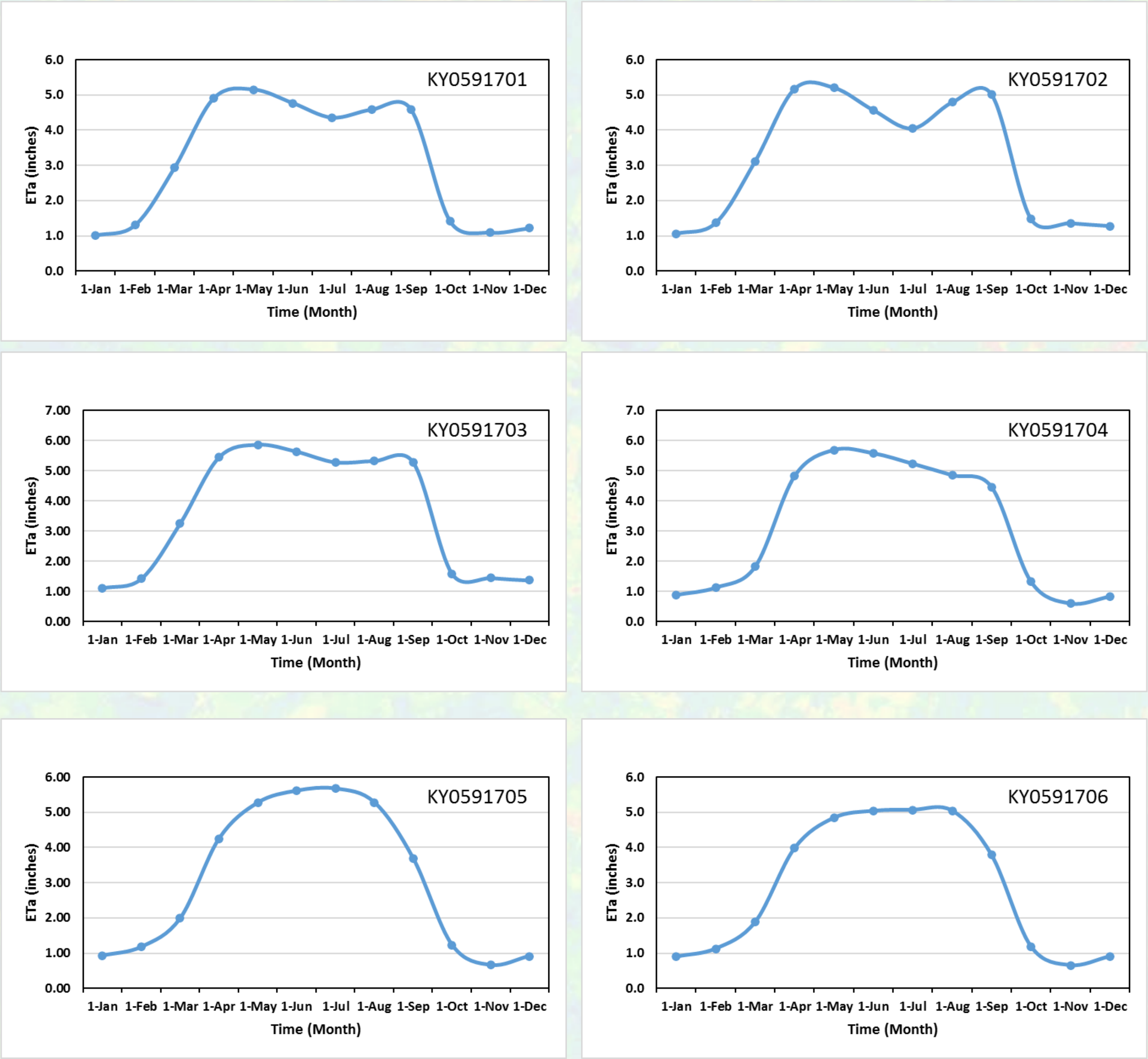
Remote Sensing of Evapotranspiration
Kentucky



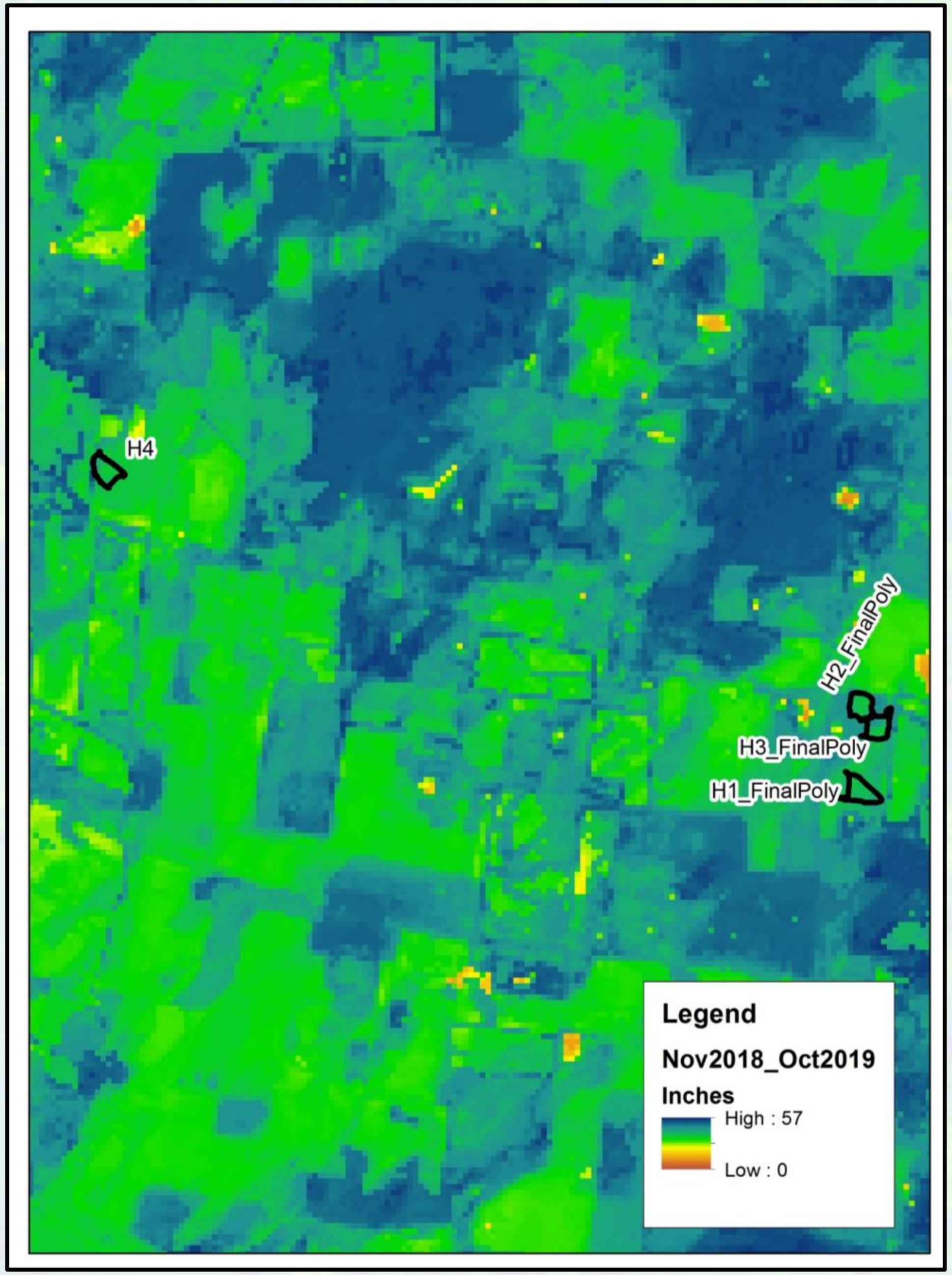
- 21 Landsat 7 scenes
- 19 Landsat 8 scenes
- Hourly data from Mesonet stations

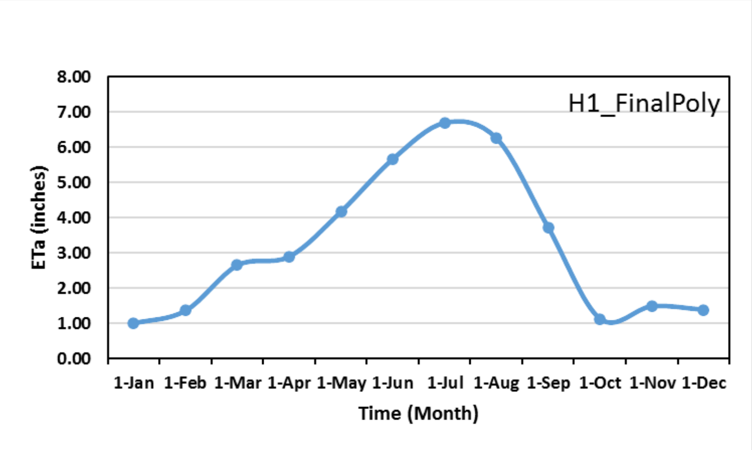
ET Signature of different fields

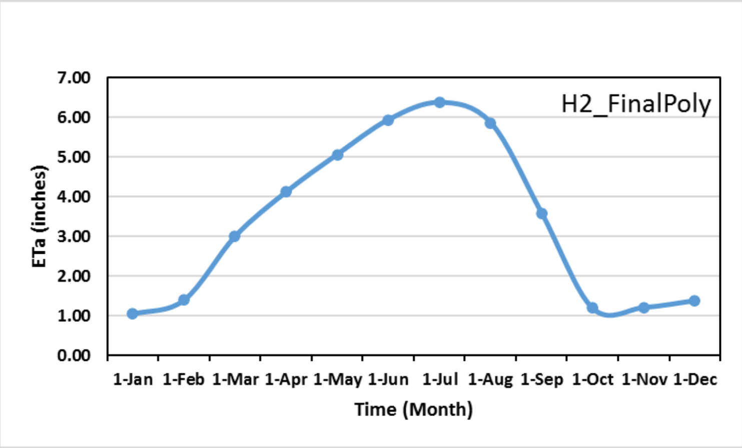


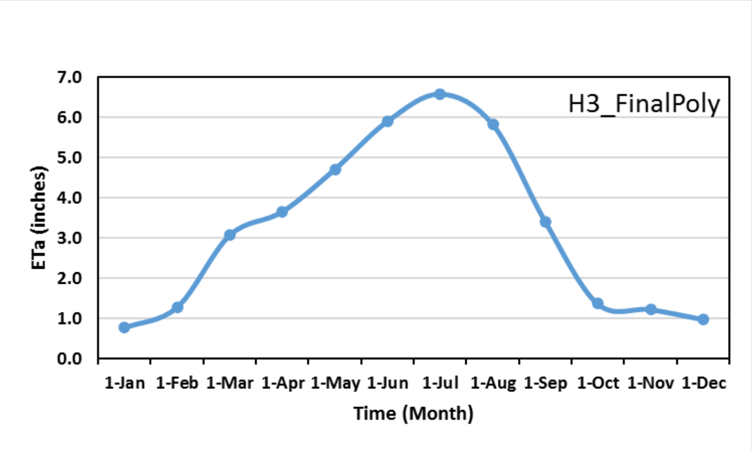


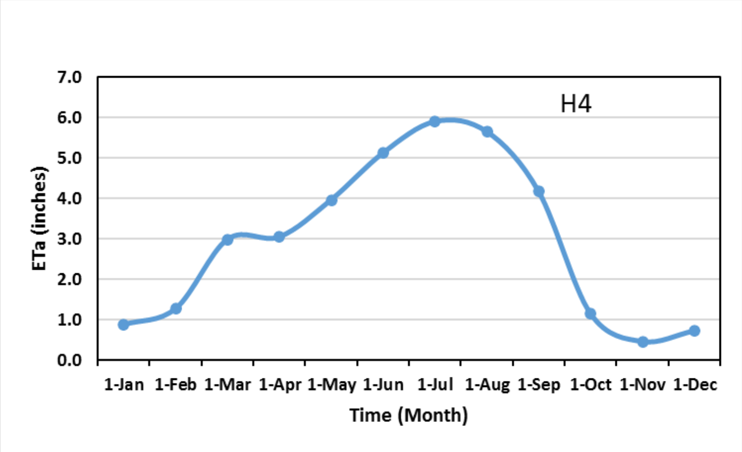
ET Signature of different fields

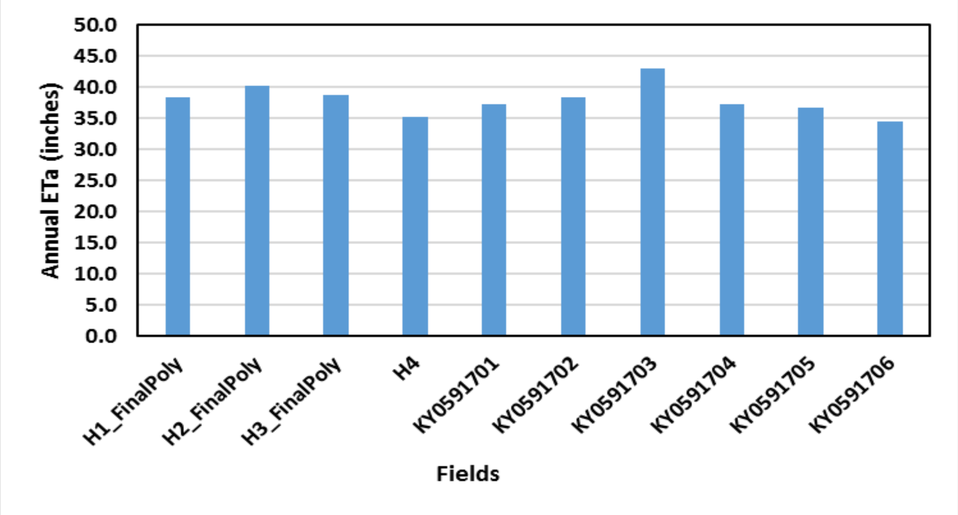




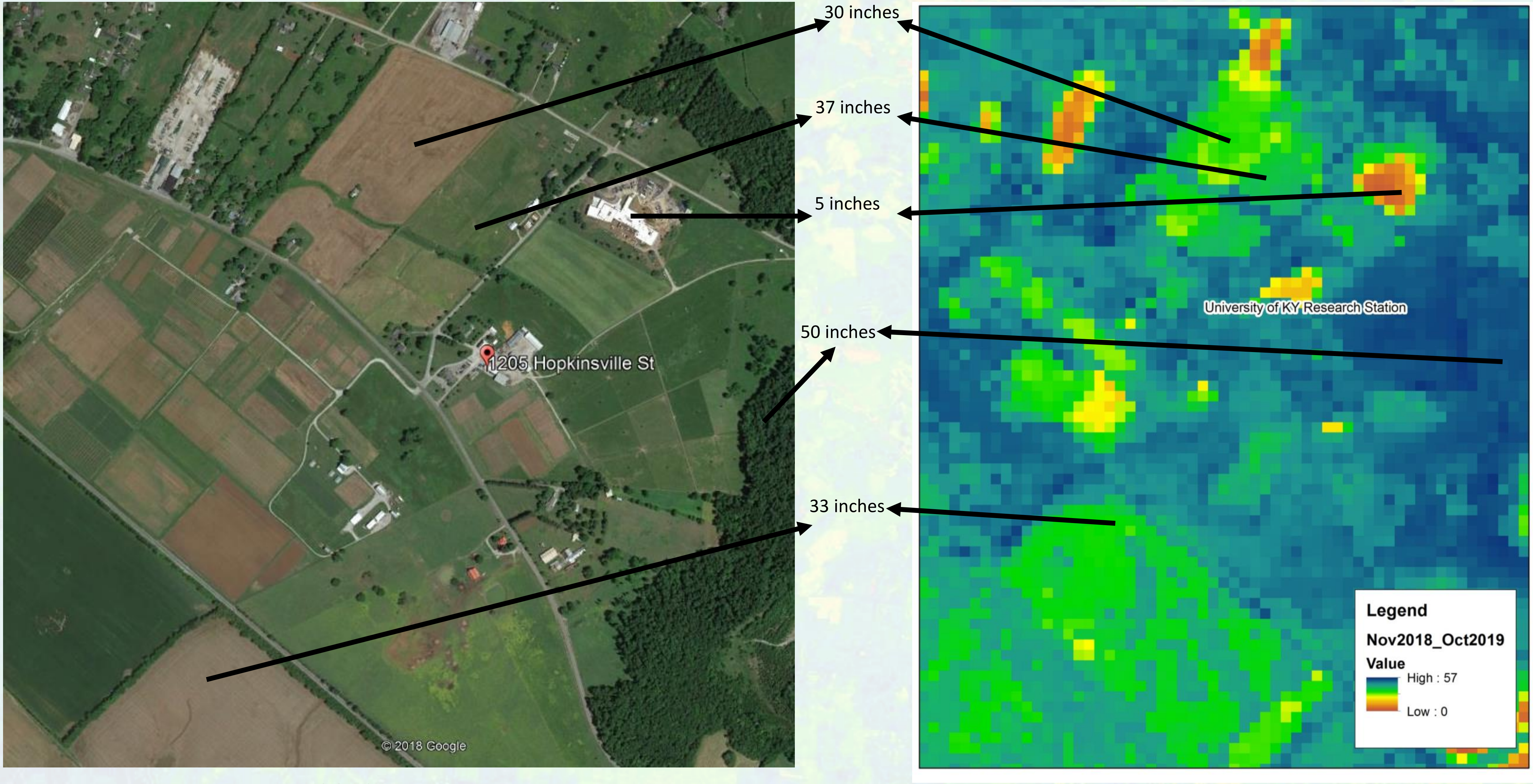








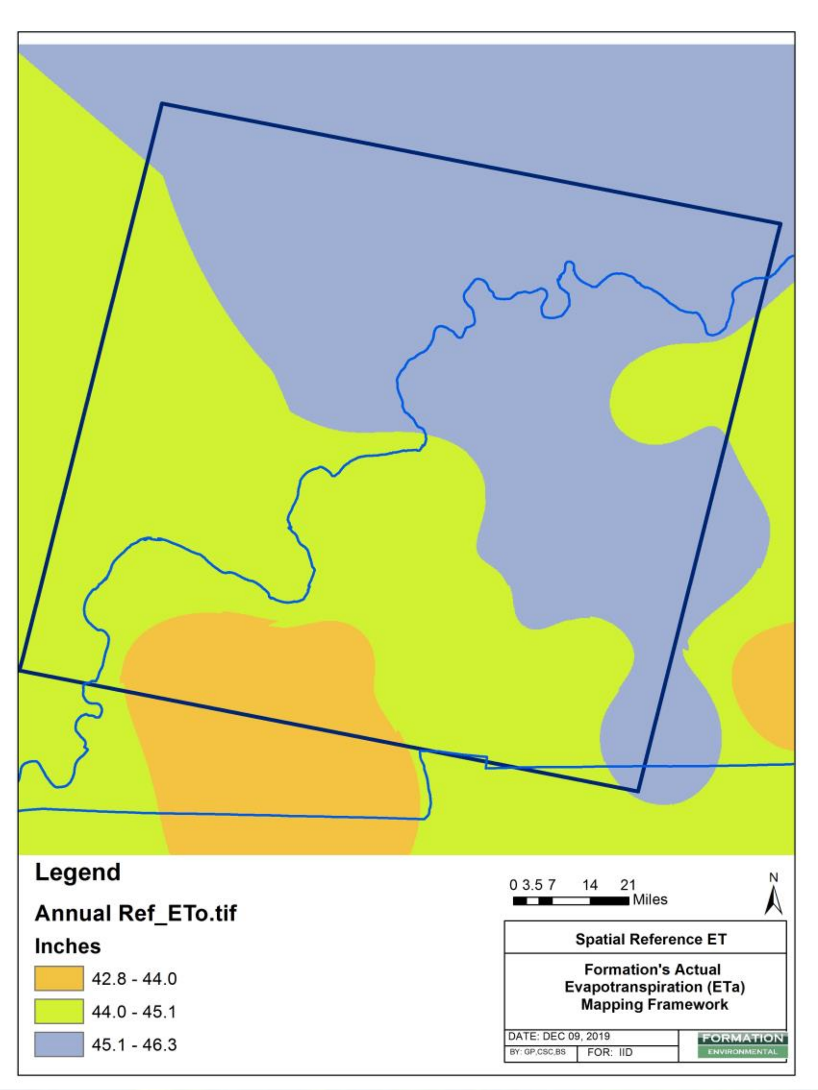
University of KY Research Station



2019 Imagery

2019 ETa Map

Kentucky ETo Map



- Annual Map
- Based on WKU Mesonet Data and ETa processing framework

Using Remote Sensing to Support Irrigation Scheduling

What does remote sensing provide?

- Historical crop water requirements and daily crop coefficients (Kc).
- Uniformity of ET.
- Understanding the spatial application of in-field sensor data.

What does remote sensing not provide?

- Forecast of ET in the future.

Questions, Discussion and

Thank you!