ECOSTRESS METRIC EVAPOTRANSPIRATION ALGORITHM

Rick Allen, University of Idaho-Kimberly

Ayse Kilic, University of Nebraska-Lincoln

Members of the Landsat Science Team 2007-2017

EcoSTRESS Science Support

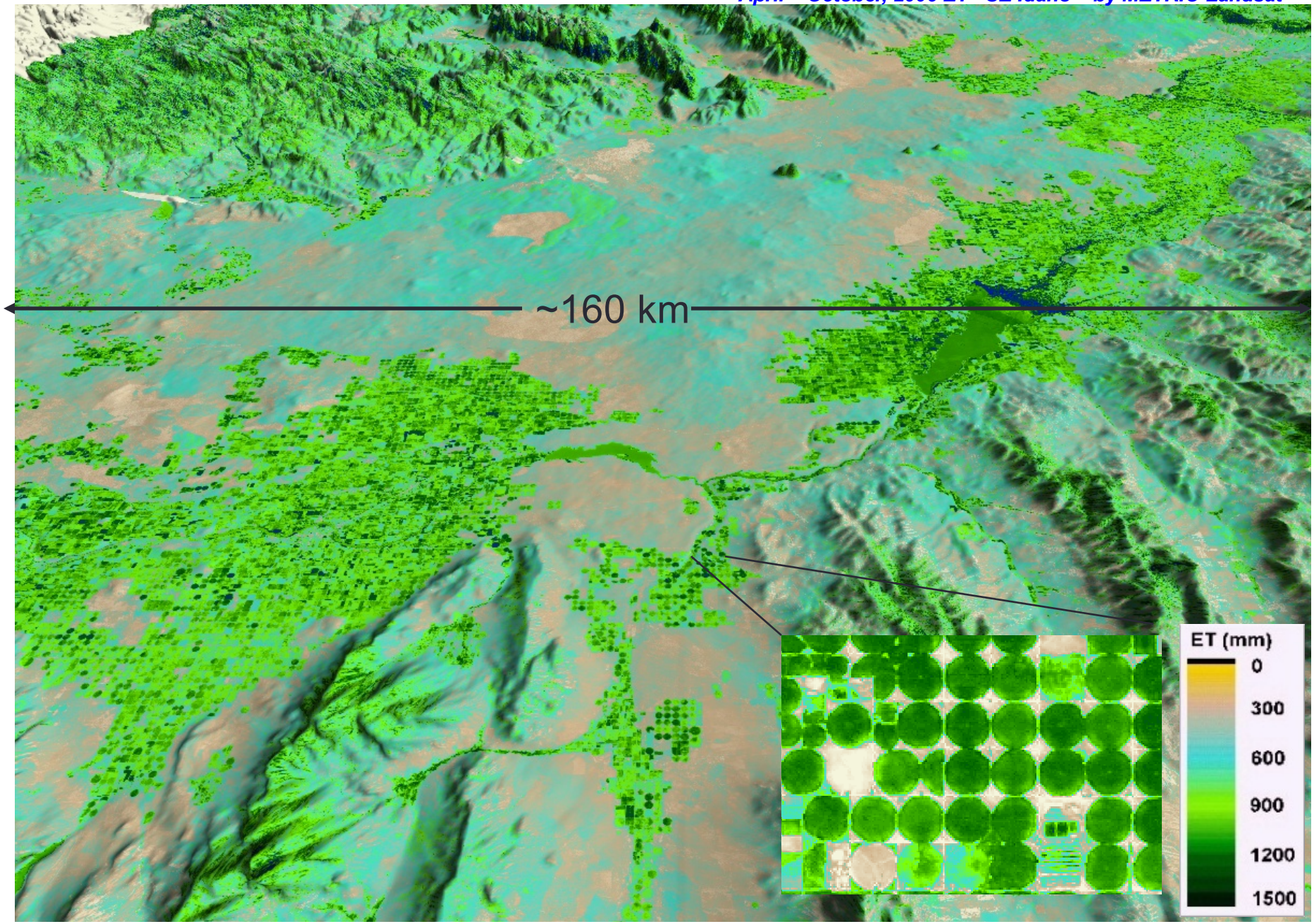
Support:

Ricardo Trezza, Univ. Idaho
Clarence Robison, Univ. Idaho
Philip Blankenau, Univ. Nebraska-Lincoln
Samuel Ortega, Univ. Nebraska-Lincoln

2017 EcoSTRESS Workshop, Davis, CA

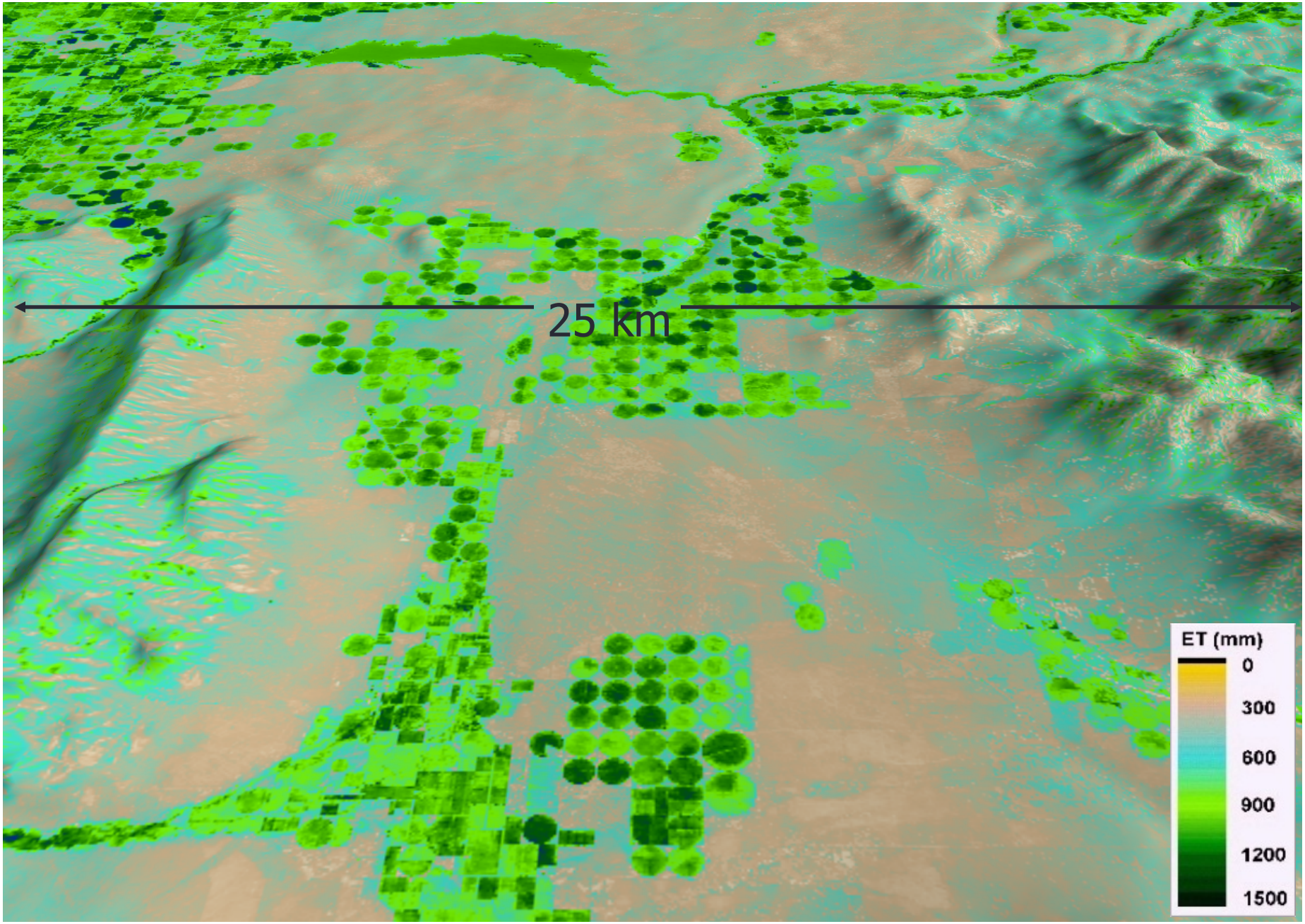
ET is needed at the field scale and for historical and present

April – October, 2006 ET –SE Idaho – by METRIC-Landsat



ET features at 30 m resolution

April – October, 2006 ET from METRIC-Landsat



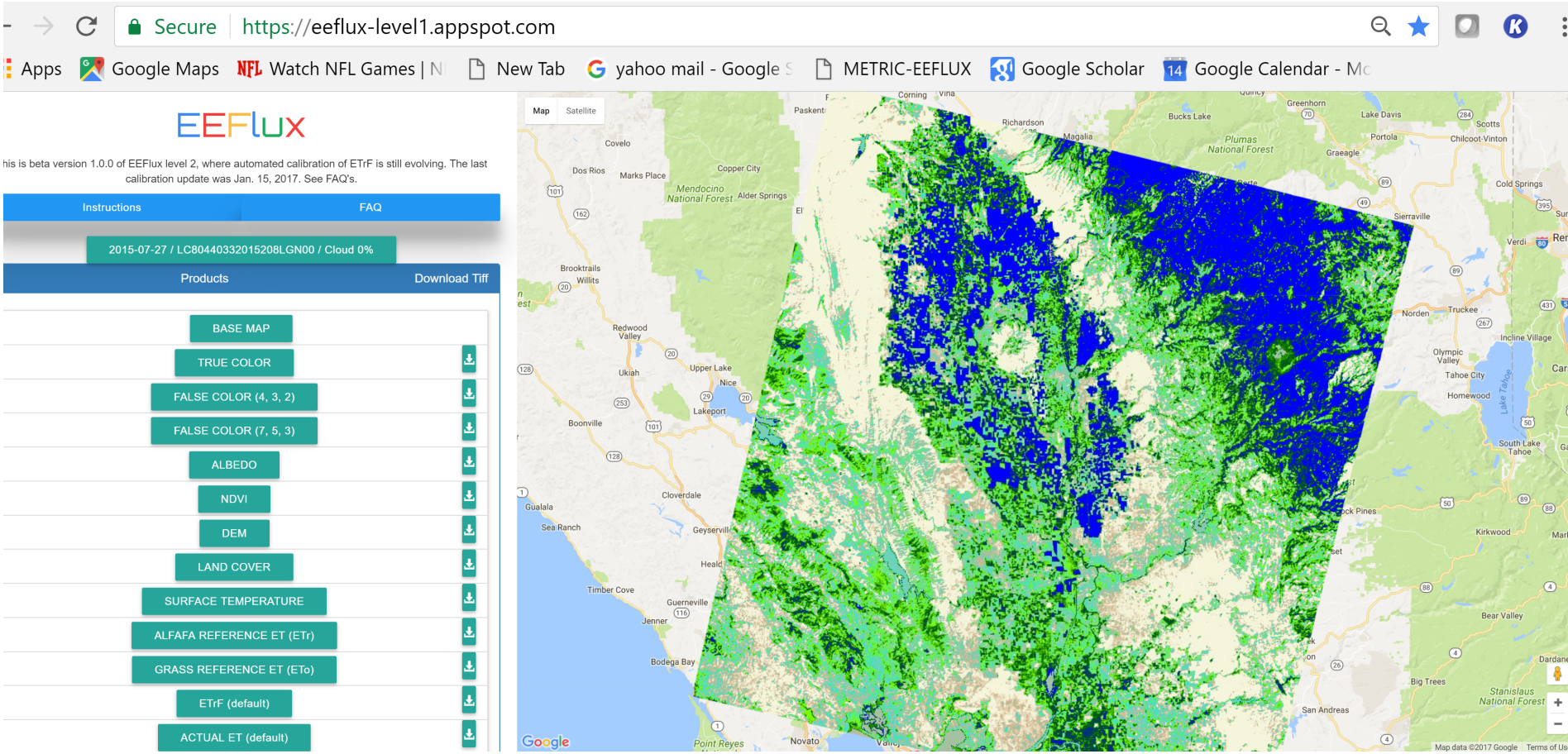
Close up Orbit -- 420 km

International Space Station

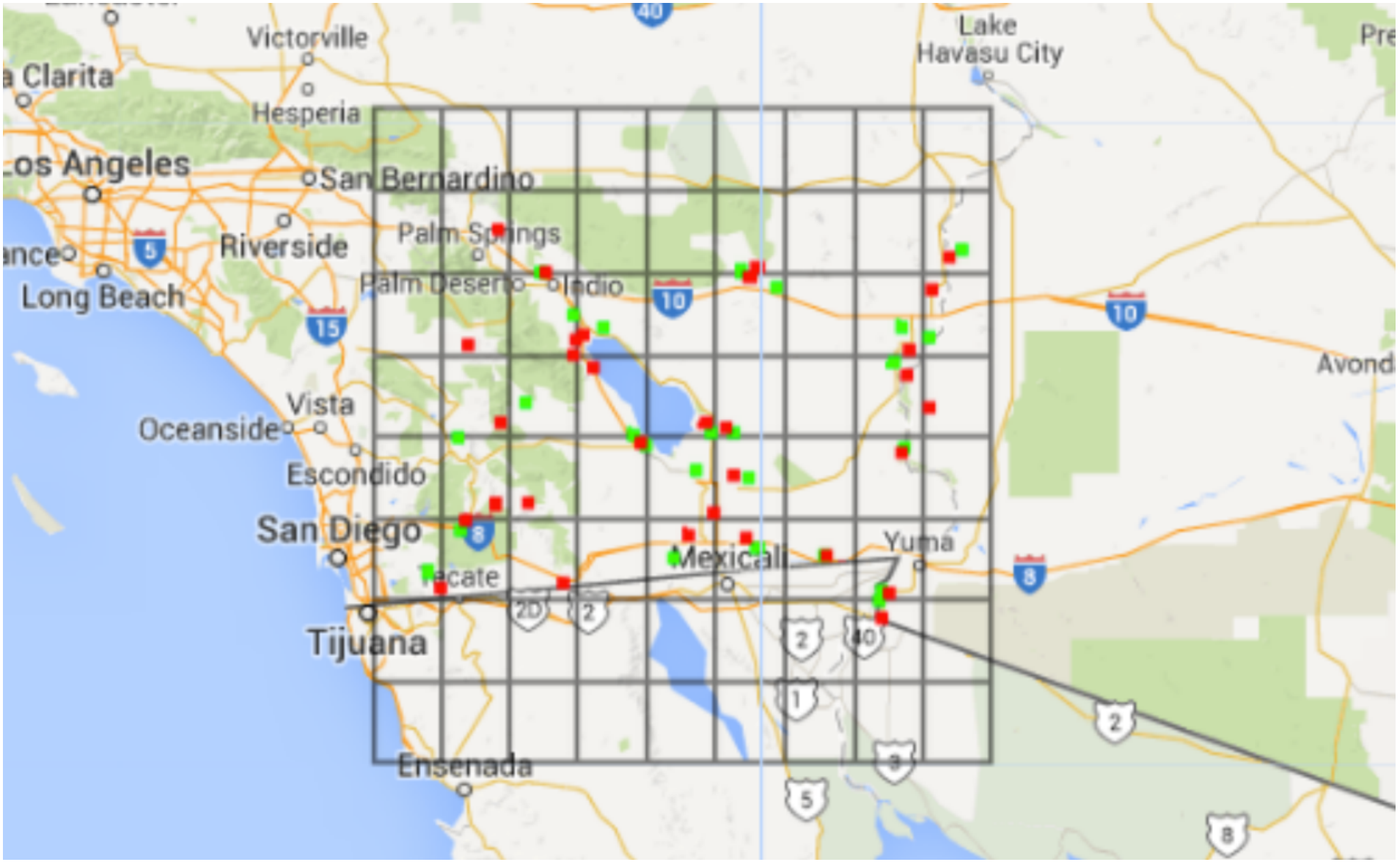
METRIC/EEFLUX-ECOSTRESS

Porting Algorithms

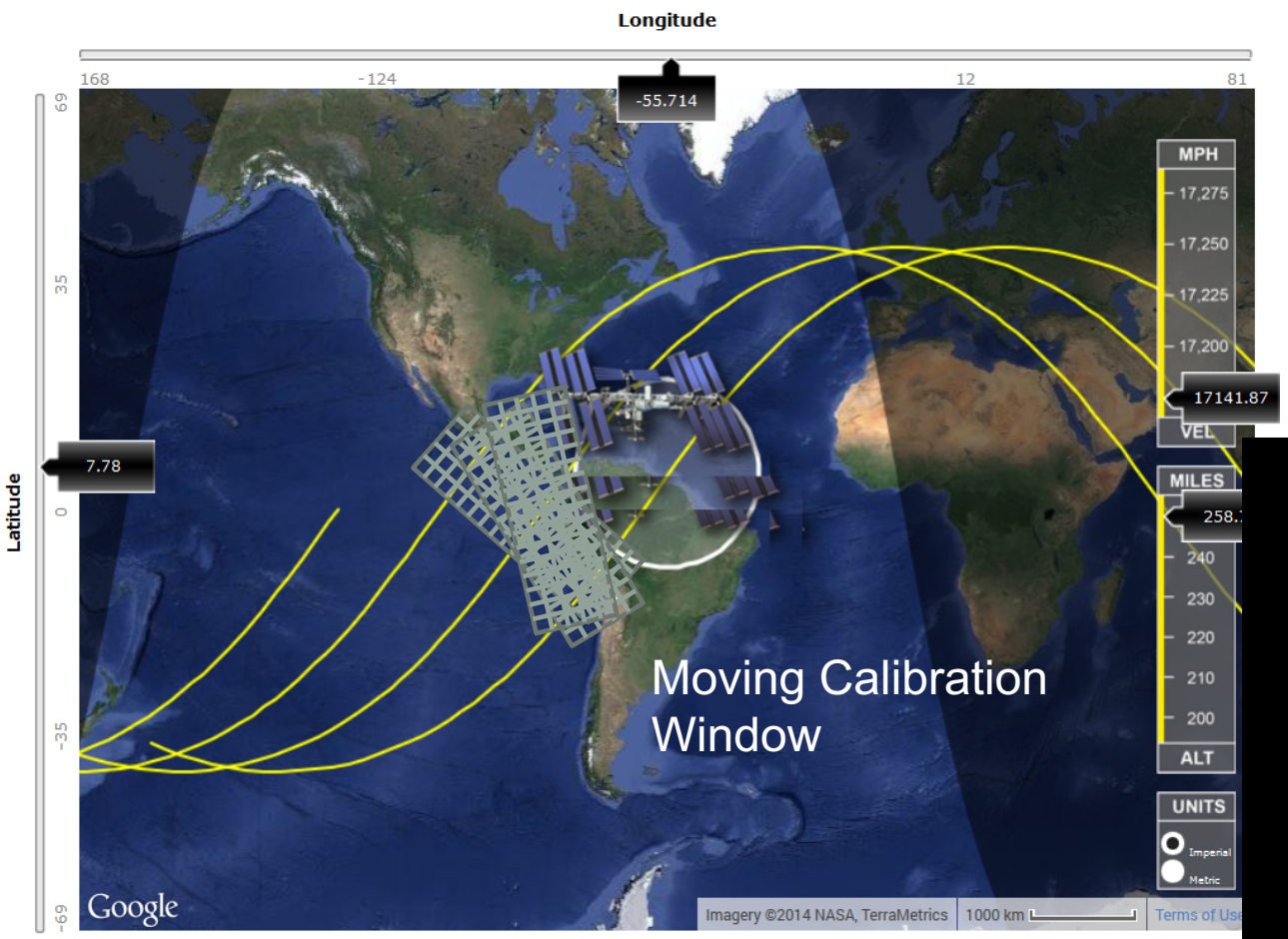
EEFlux – Landsat-based (30 m) ET mapping on Google Earth Engine



Gridded Calibration of Energy Balance in EEFlux – Using Near-Endpoints in Thermal

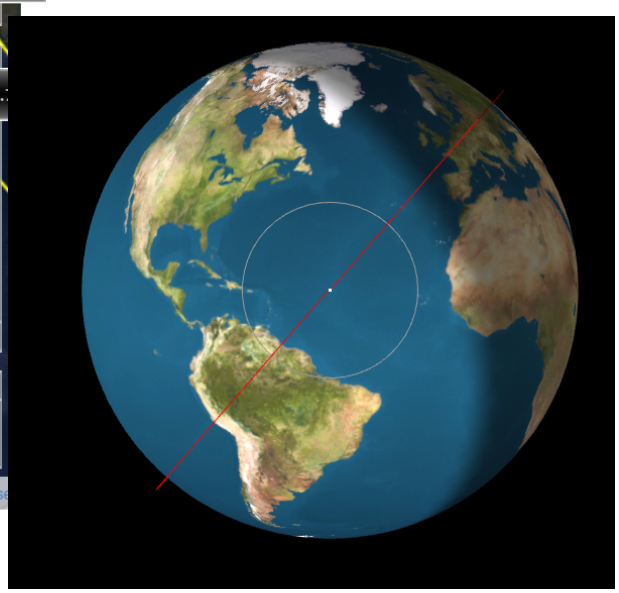


I.S.S. TRACKER



Orbital speed
17000 mph
7660 meters/second

Altitude: 420 km



Sun angle continually changing.
Land / precipitation conditions continually changing.
Rotate Calibration Window to Equalize <u>Sun Angle</u> and <u>Time of Warming.</u>

CALIBRATION OF METRIC/EEFLUX:

$bias_{Rn-G} \rightarrow bias_{H-cal} \rightarrow bias_{dT} \rightarrow bias_{H-pixel} \rightarrow LE$

unbiased

The Sensible Heat (H) Function with end-member LST calibration *calibrates around Biases in many of the Energy balance components:*

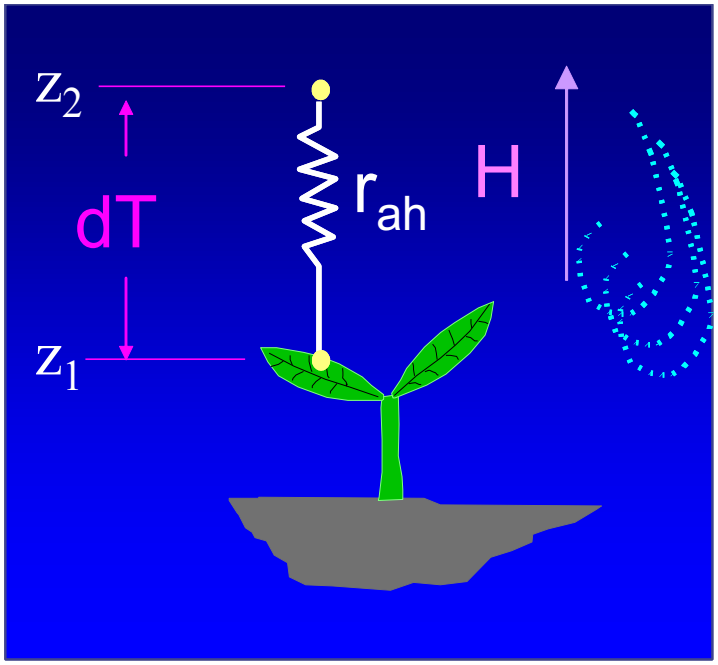
(Biases exist in: net radiation, soil heat flux, aerodynamic stability, aerodynamic roughness, absolute surface temperature, atmospheric correction)

any biases

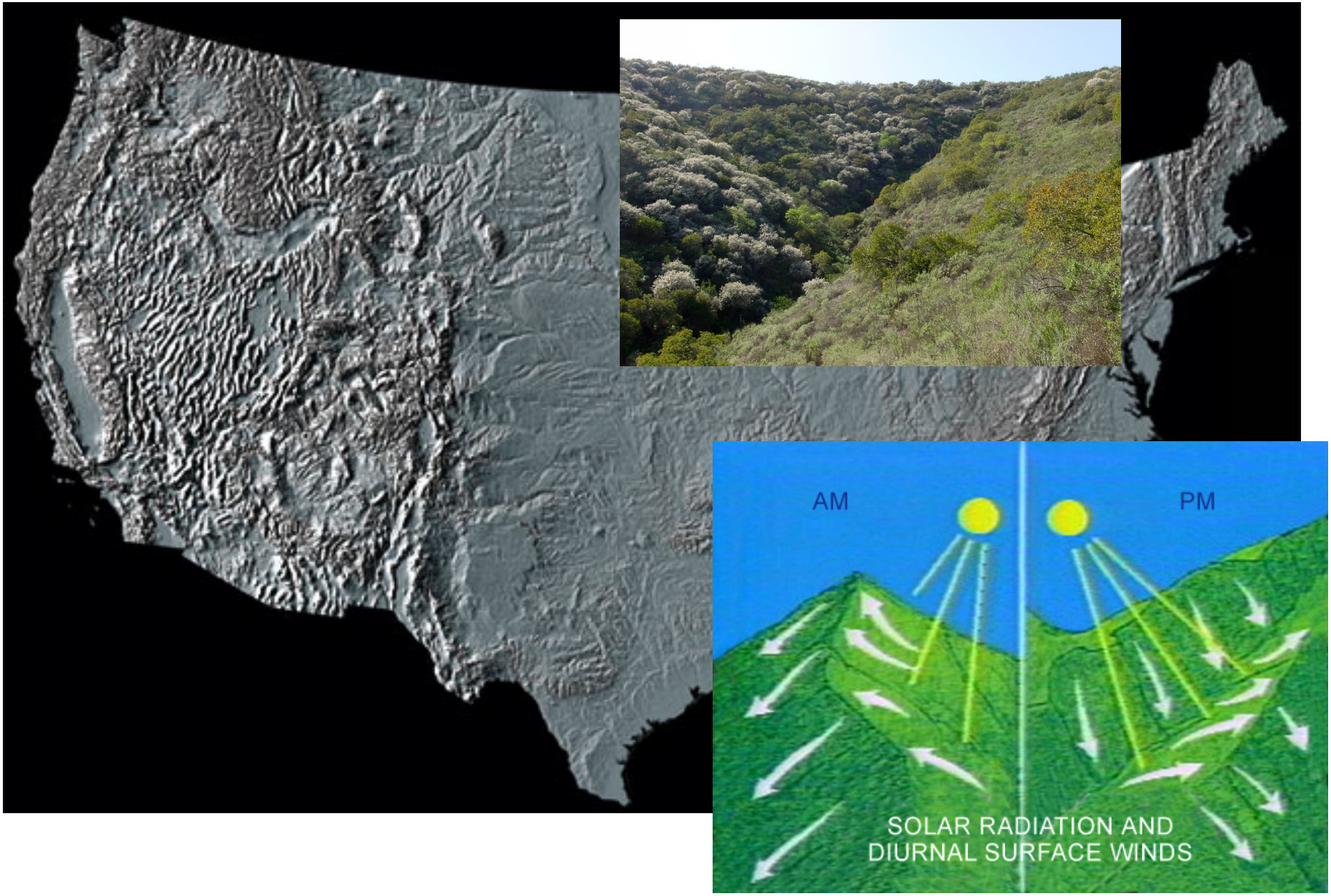
$$H = R_n - G - LE$$ *(for calibration)*

$$LE = R_n - G - H$$ *(during application)*

Biases cancel out



Topography of the United States and World is Complex – impacting solar radiation balance



METRIC includes radiation algorithms for slopes and terrain roughness algorithms

Data Sources

Albedo and Vegetation Indices

- From Landsat, Sentinel II Images Closest/Bracketed in time

Wind Speed, Humidity, Reference ET

- From CFSV2 or GLDAS2 Gridded Weather Data

Science Questions

- How does the ET_rF (ET as a fraction of Reference ET) vary <u>space-wise</u> during the day for:
  - Irrigated Crops
  - Rainfed Crops
  - Riparian Systems
  - Rangeland
  - Forest
- How does variation in ET_rF impact time-integrated ET estimation (which often assumes constant ET_rF)?

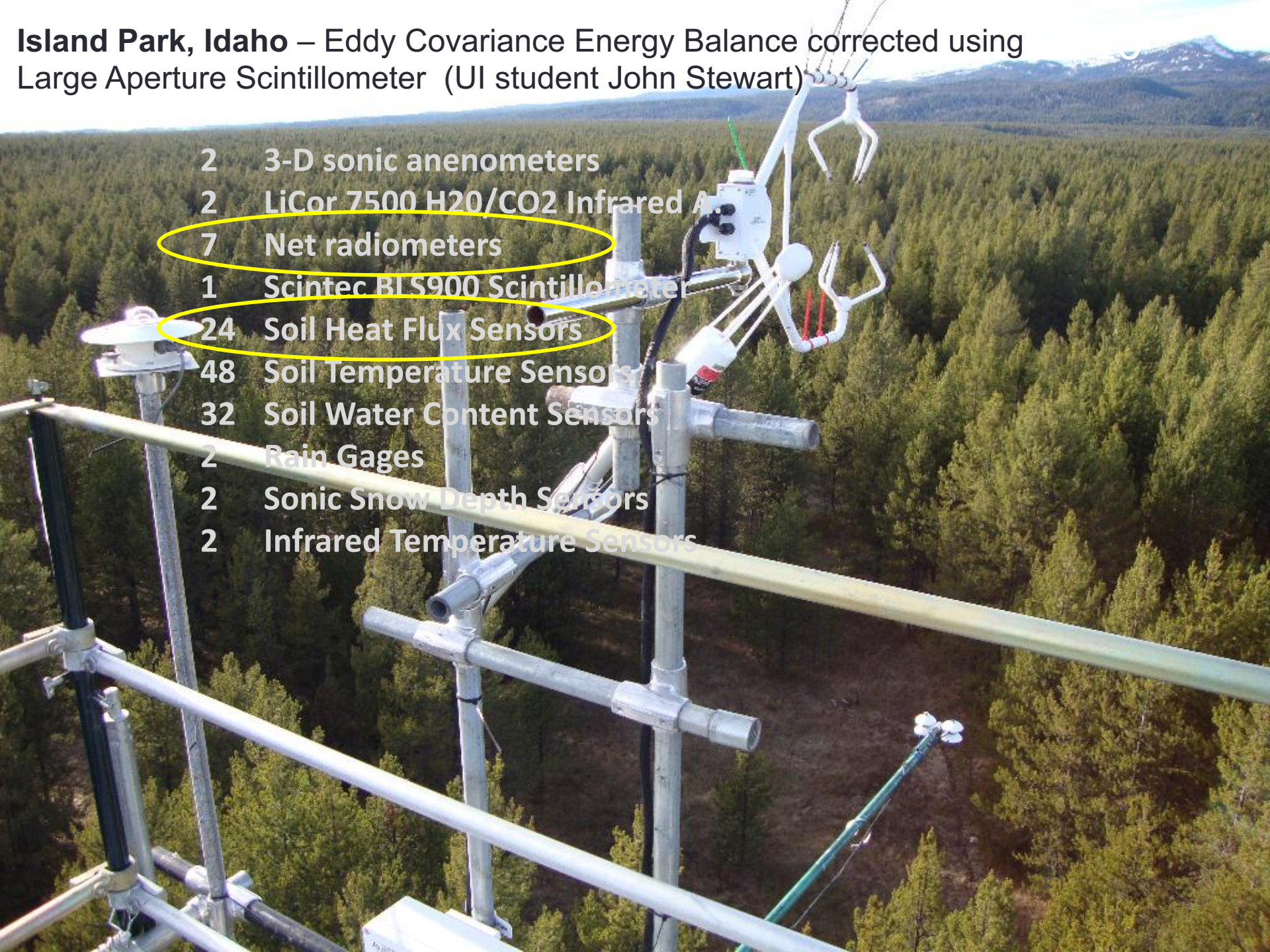
Student/Post-Graduate Collaboration

- Assist Technical Staff and Faculty in
  - development of strategies and coding and testing of algorithms for applying a moving window-based calibration scheme to develop endmember based calibration points for the surface energy balance employed in the METRIC ET process.
  - Automated calibration of EEFlux surface energy balance.
  - algorithm testing using an archive of METRIC-based ET imagery from Landsat-based processing since 2000.
- Two NSF-supported energy and CO_2 flux systems in Idaho for testing the moving window-based calibration for sagebrush and lodgepole pine.
- Applications to other targeted sites by ECOSTRESS teams
- Collaborative ingestion by Idaho, Nebraska and California state Departments of Water Resources to explore ingestion of ET data into their water operations.

Ground Data - Island Park, Idaho Lodgepole Pine

- Installed 2010 – Univ. Idaho

Island Park, Idaho – Eddy Covariance Energy Balance corrected using Large Aperture Scintillometer (UI student John Stewart)



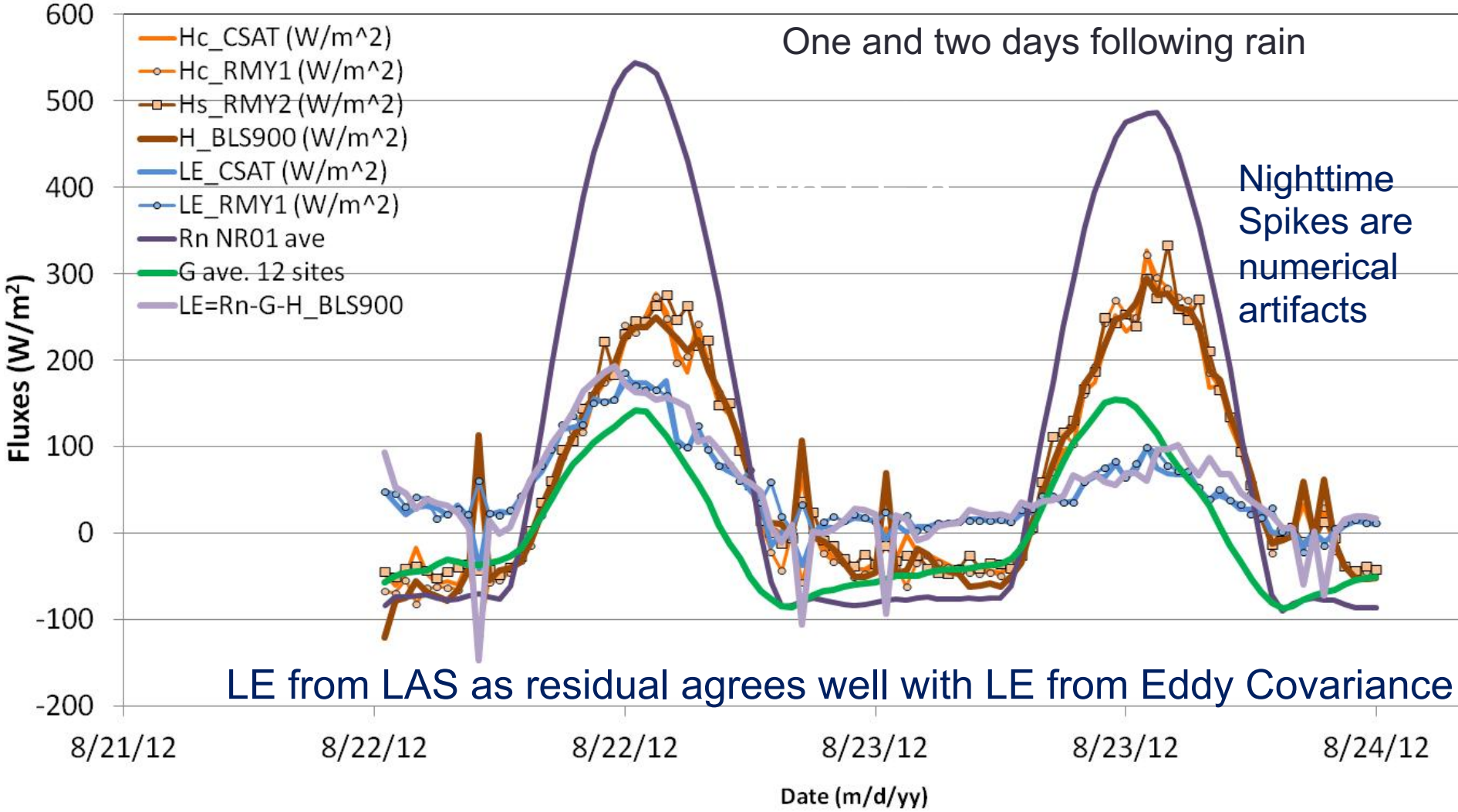
Hollister Sage Brush site
– Installed Feb. 2010

Best combination of 16 Soil Heat Flux sites optimized by UI student Jeremy Greth

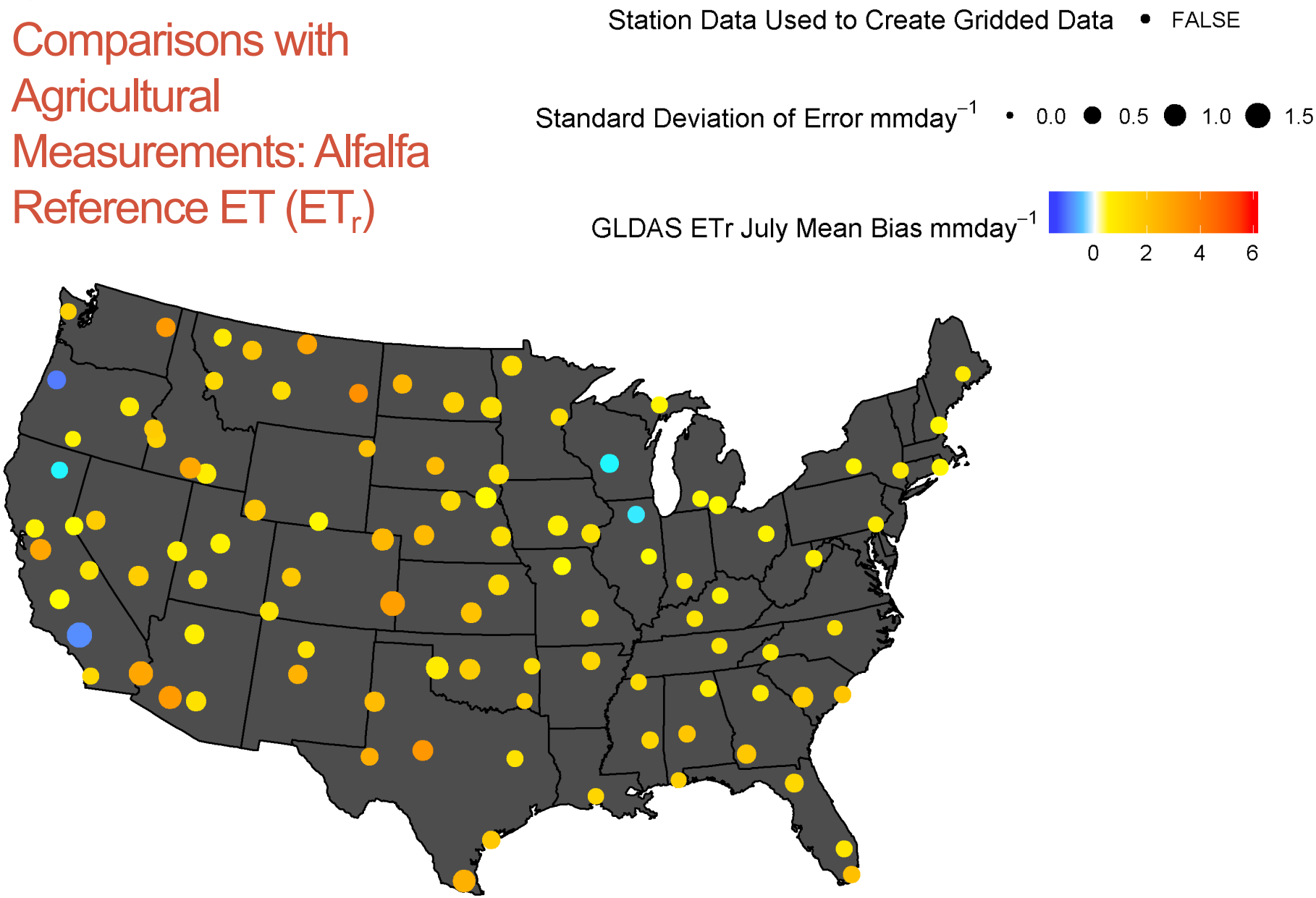
"Sensor Redundancy"

3	3-D sonic anenometers
1	LiCor 7500 H20/CO2 Infrared A.
3	Net radiometers
1	Scintec BLS900 Scintillometer
16	Soil Heat Flux Sensors
32	Soil Temperature Sensors
20	Soil Water Content Sensors
7	Soil Water Potential Sensors
2	Rain Gages
2	Infrared Temperature Sensors

EB Components - Hollister Sage Brush Flux Site



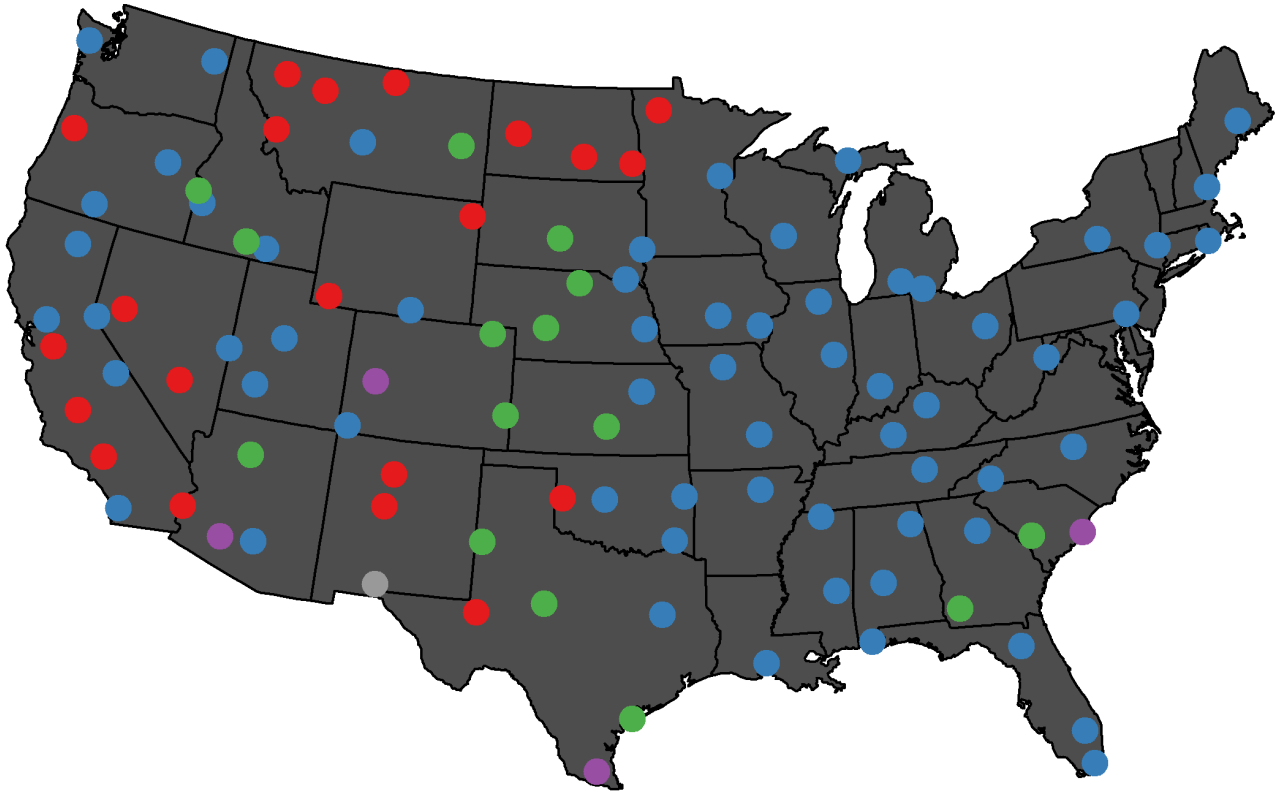
Gridded Weather Comparisons with Agricultural Measurements: Alfalfa Reference ET (ET_r)



Philip Blankenau, MS Student, UNL – Dr. Ayse Kilic, Advisor

Best Gridded Data sets for Least Bias in Reference ET (ET_r)

Best Analysis Data Set for ETr in Summer by KGE



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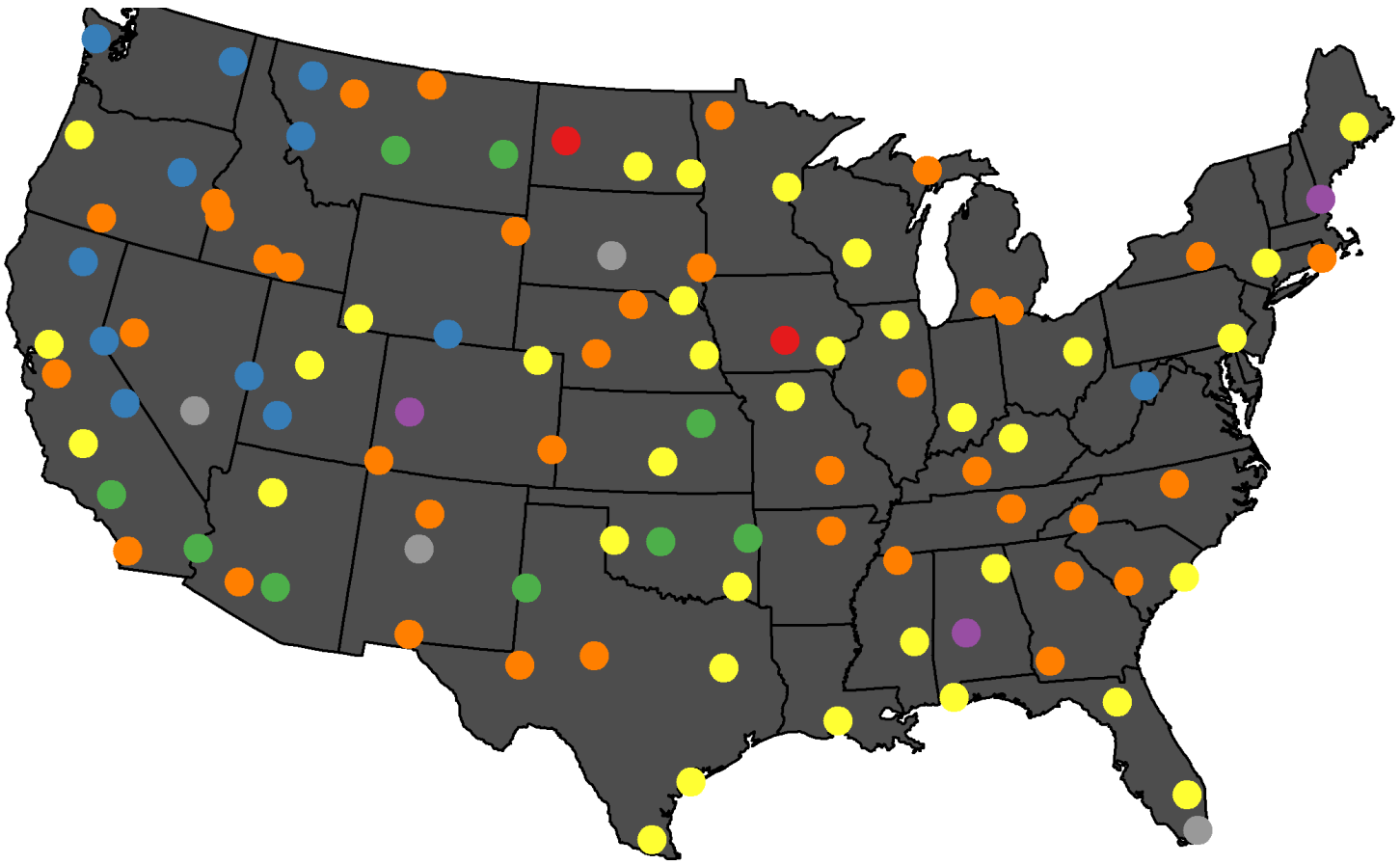
Best Gridded Data sets for Least Bias in Reference ET (ET_r)

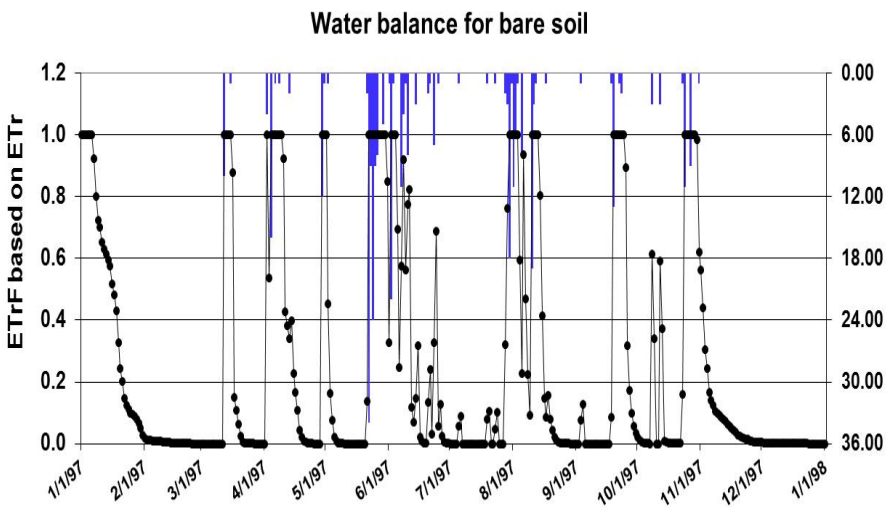
Best Analysis Data Set for ETr in Summer 2015 by KGE

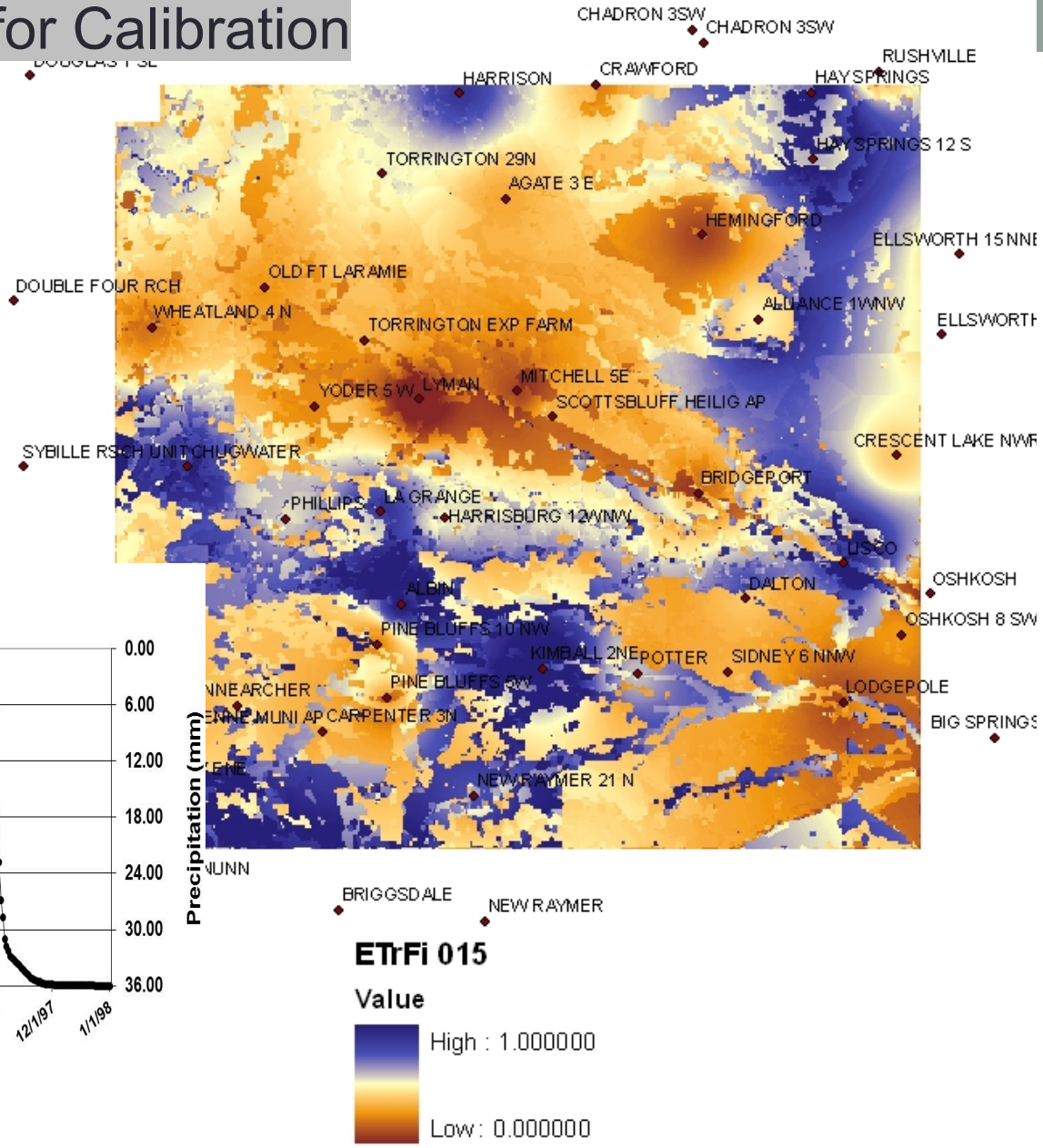


Background Evaporation for Calibration

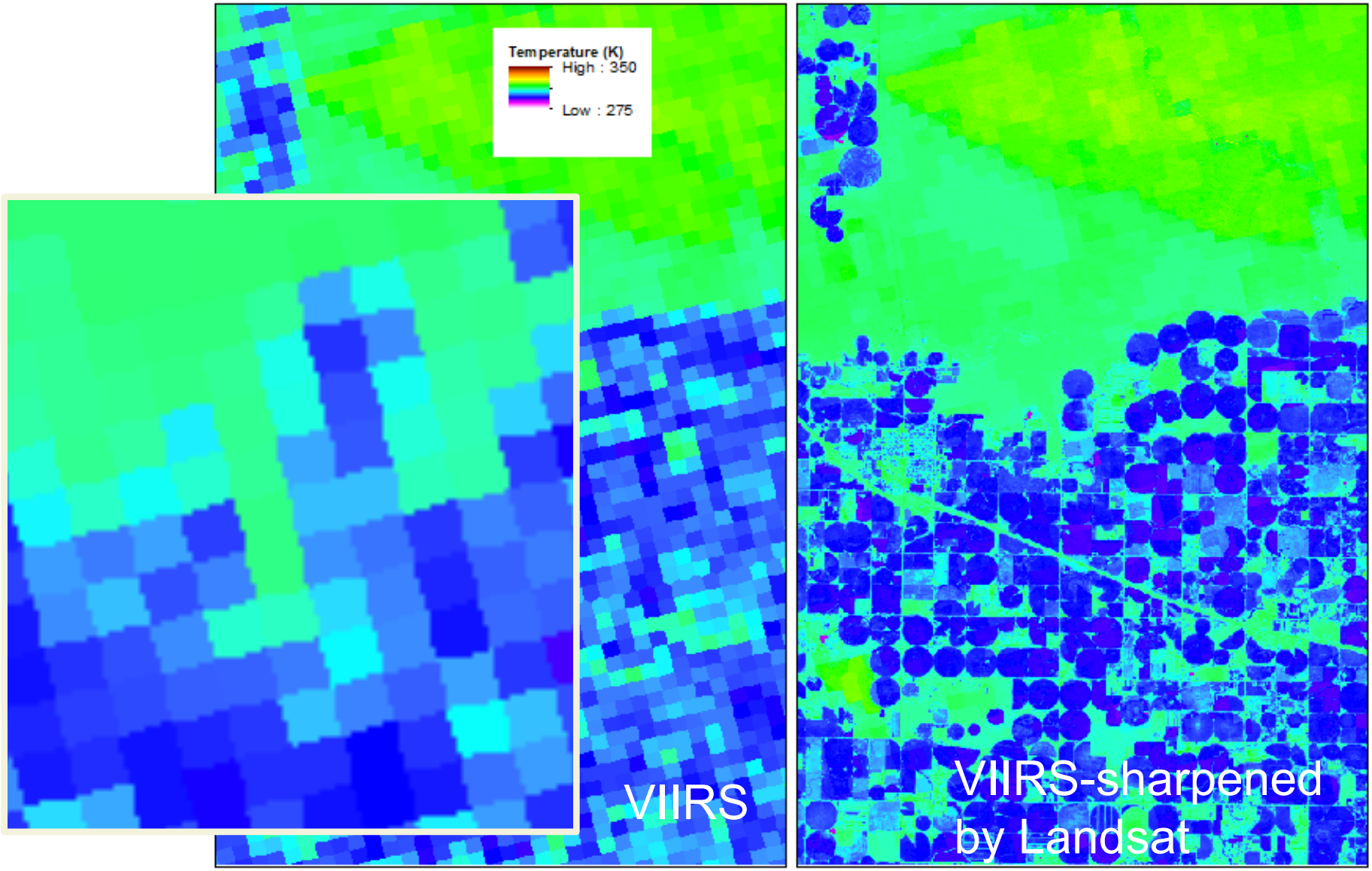
Daily water balance using gridded weather and precipitation

EcoEEFlux will use bare soil evaporation from CFSV2 or GLDAS





Importance of “pre” Resampling and Projection of Large Pixels → Smaller Pixels



Residential Water Use

Google Earth Engine App for Residential Water Use and Preservation --- --- GEARUP

Beta versions are available

http://appgearup.appspot.com

Development Team:
Doruk Ozturk, UNL
Samuel Ortega-Salazar, UNL / Univ. Talca, Chile
Dr. Ayse Kilic, UNL
Dr. Richard Allen, Univ. Idaho
Dr. Tyler Erickson, Google, Inc.

A Tool For Smarter Lawn Irrigation

- **Help homeowners manage water applications for their lawn**
- Designed for the whole Continental United States (CONUS)
- Beta version: **http://appgearup.appspot.com/**
- Link to You tube video that shows calibration of NAIP with LANDSAT: https://www.youtube.com/watch?v=9aV8vduSTu0

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Current Interest in GEARUP

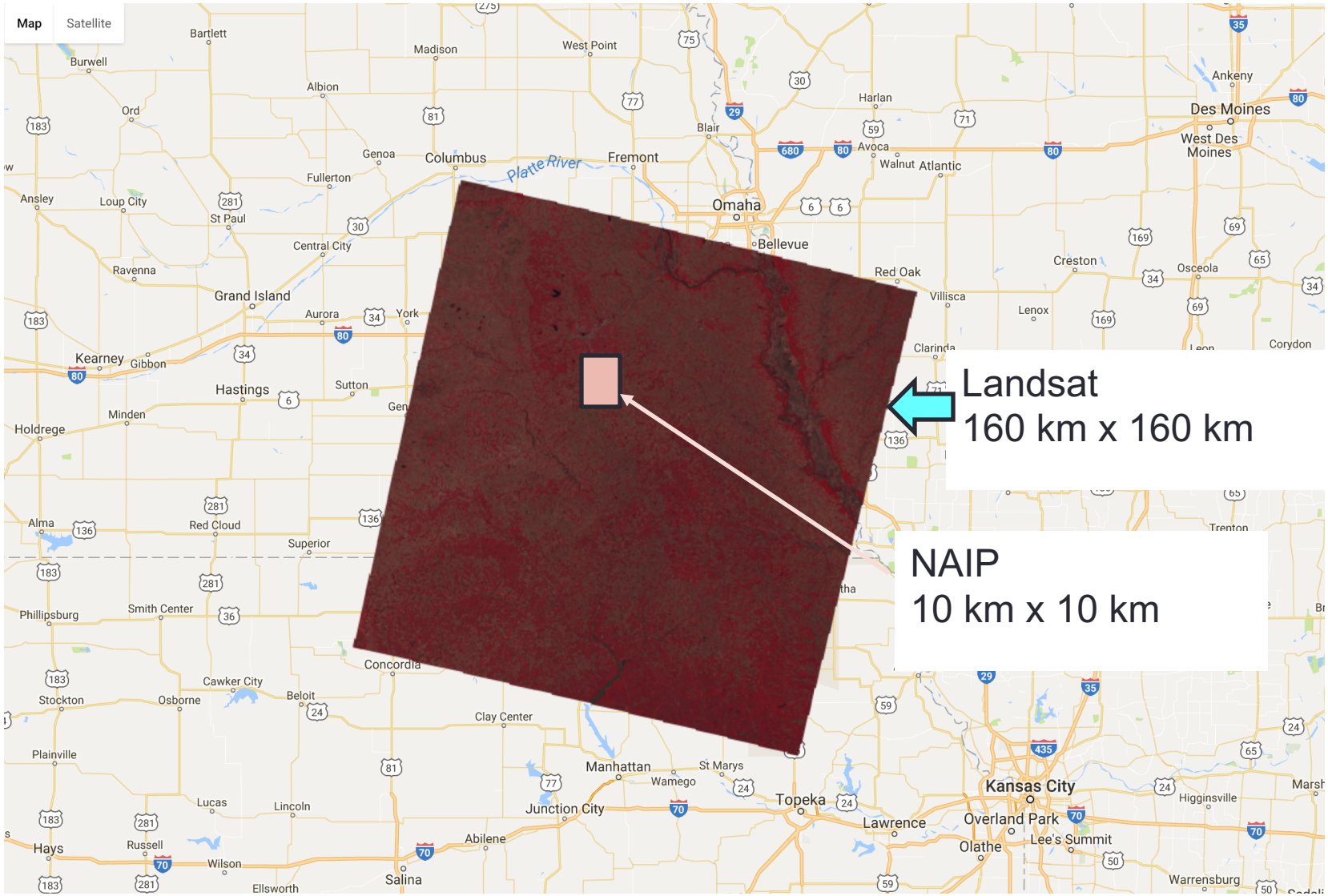
- **Metropolitan Water District of Southern California**
  - Help Home-Owners schedule lawn watering (targets: 80+ year olds)
  - Conversion of Residential Turf to Artificial Turf
  - Transfer of Agricultural Water to Cities
  - Linking EEFlux to GEARUP for NAIP 1m Scale ET

- **Potential Use in Agriculture**
  - Conversion of Landsat 30 m to 1 m (with limitations)
  - Use ETref and Precipitation forecasting for scheduling irrigation

Basic Problem

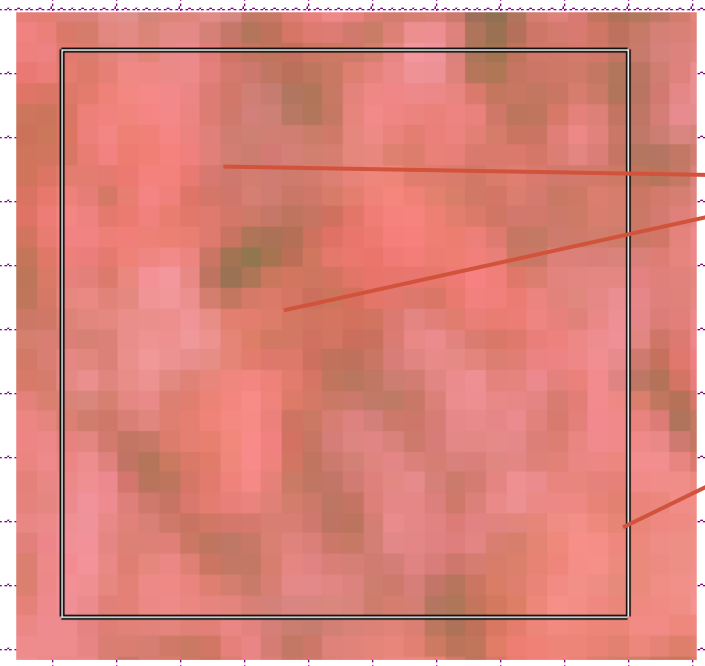
- NAIP (National Agriculture Imaging Program) images have 1.0 meter spatial resolution and are necessary to “see” residential areas (this is good)
- NAIP imagery is ingested onto Google Earth Engine (this is good)
- However, NAIP does not report “reflectance” (ρ) (this is bad)
- NAIP imagery is collected only once per year or 3 years (this is bad)
- NAIP only reports uncalibrated, raw “digital numbers” (DN) that range from 0 to 255 (2^8 (8 bit values)) (this is bad)
- Therefore, to calculate NDVI, we must first calibrate NAIP DN’s to “reflectance.”
- We do this using Landsat reflectance
- Landsat has 30 meter spatial resolution and reflectance
  - (too large for residential work, but OK to calibrate NAIP)

Calibration of NAIP with Landsat

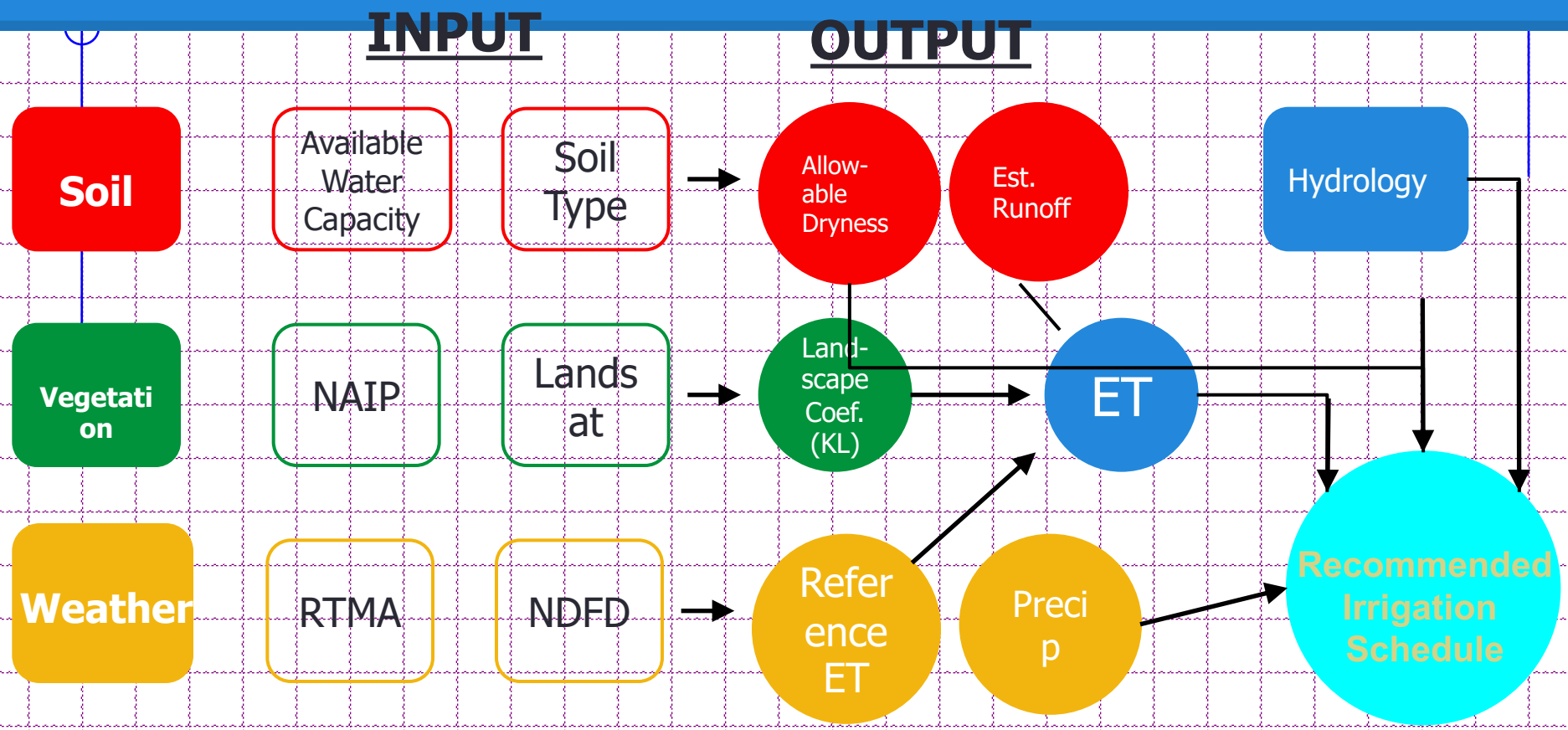


Calibration of NAIP

NAIP surface reflectance = a + b*DN



Data flow for GEARUP App



RTMA = Real-Time Mesocale Analysis Weather (last 7 days)
NDFD = National Digital Weather Forecast Database (next 7 days)

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Click on the buttons below to see your products on the map.

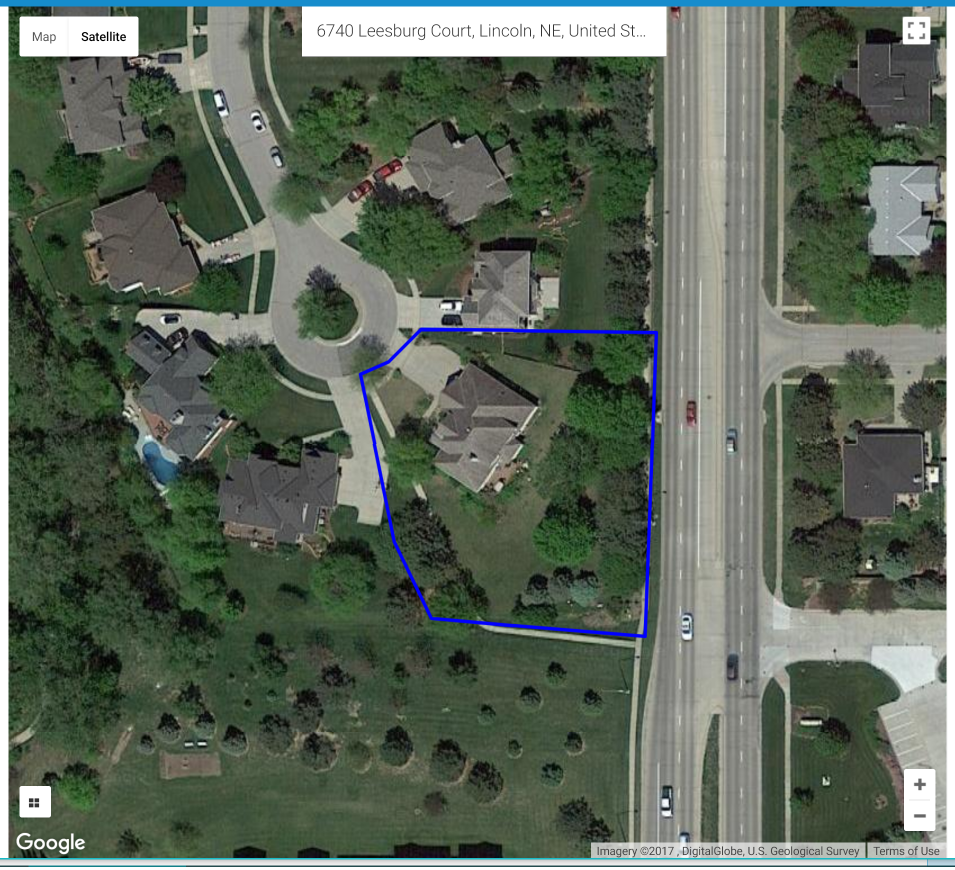
- BASE MAP
- SOURCE IMAGE(NAIP)
- SOURCE IMAGE(NAIP FALSE COLOR)
- CLASSIFICATION
- NAIP NDVI LANDSAT ADJUSTED
- NAIP NDVI TEMPORAL LANDSAT ADJUSTED
- LANDSCAPE COEFFICIENT
- TEMPERATURE
- WATER CONSUMPTION
- IRRIGATION SCHEDULE

Customize

If you do not want to provide input, go ahead and click on the "Irrigation Schedule" button to use our default values.

Please provide water meter readings:

Before Running One Cycle After Running One Cycle



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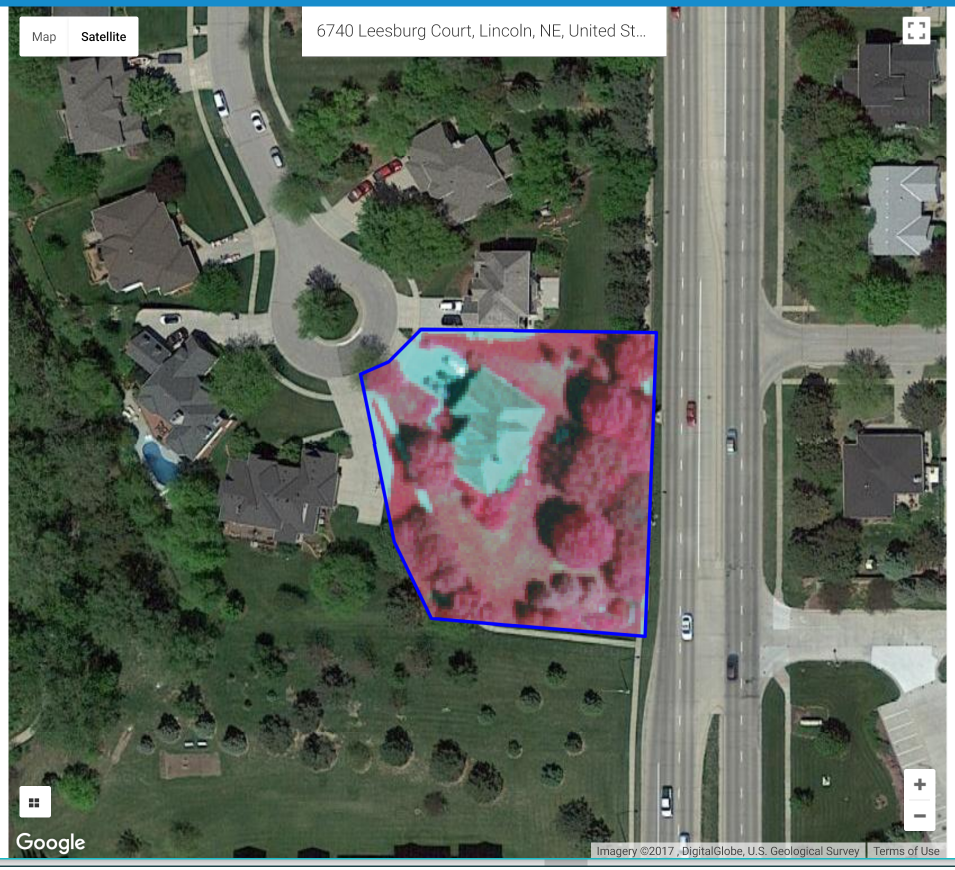

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BASE MAP

SOURCE IMAGE(NAIP)

SOURCE IMAGE(NAIP FALSE COLOR)

CLASSIFICATION

Trees | Grass | Shadows | Man Made

NAIP NDVI LANDSAT ADJUSTED

NAIP NDVI TEMPORAL LANDSAT ADJUSTED

LANDSCAPE COEFFICIENT

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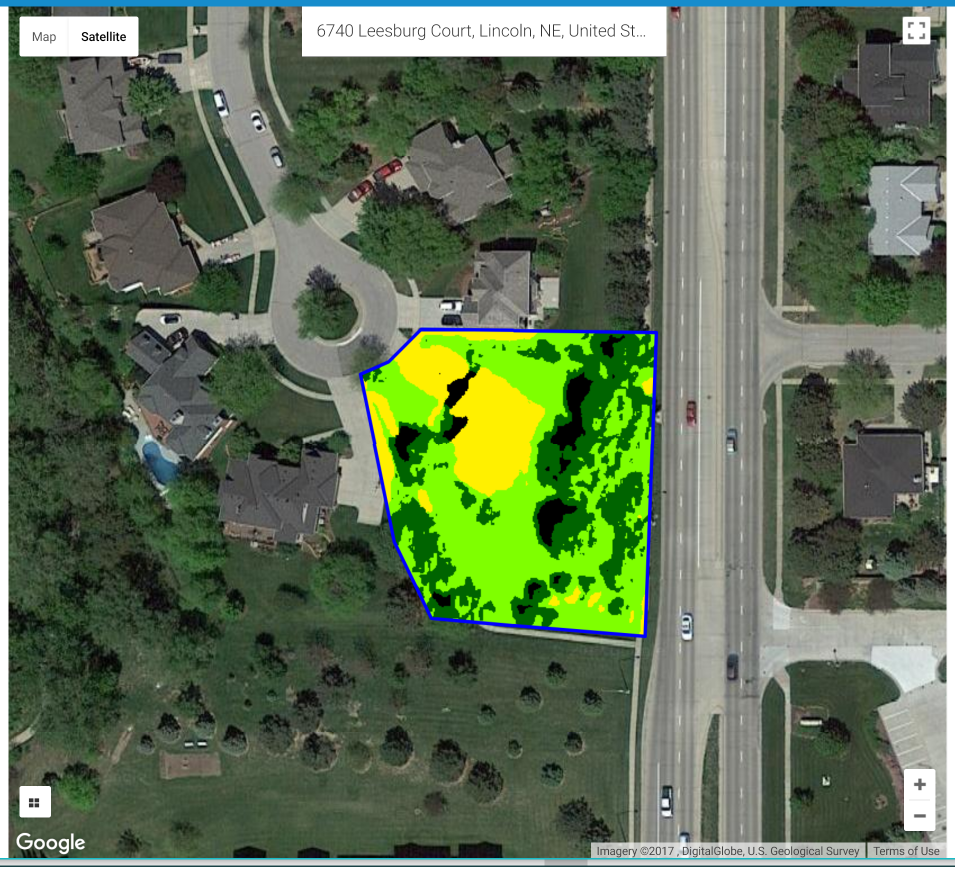

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BASE MAP

SOURCE IMAGE(NAIP)

SOURCE IMAGE(NAIP FALSE COLOR)

CLASSIFICATION

NAIP NDVI LANDSAT ADJUSTED

0 0.25 0.5 0.75 1

NAIP NDVI TEMPORAL LANDSAT ADJUSTED

LANDSCAPE COEFFICIENT

TEMPERATURE

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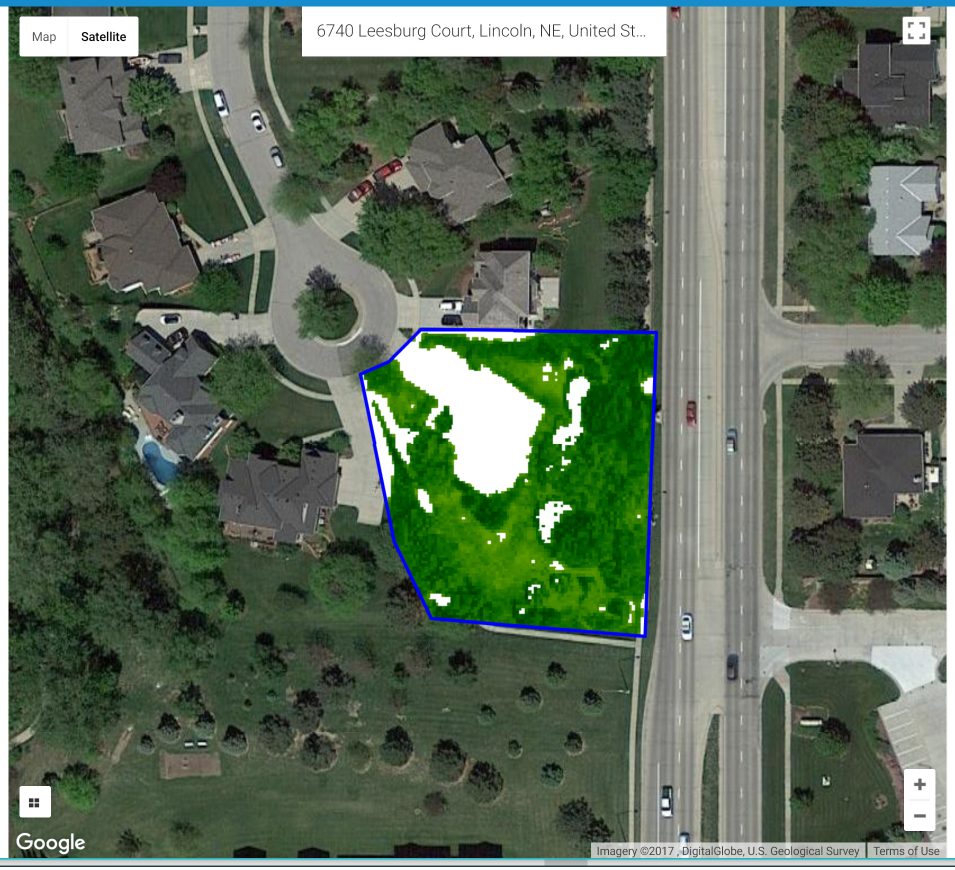

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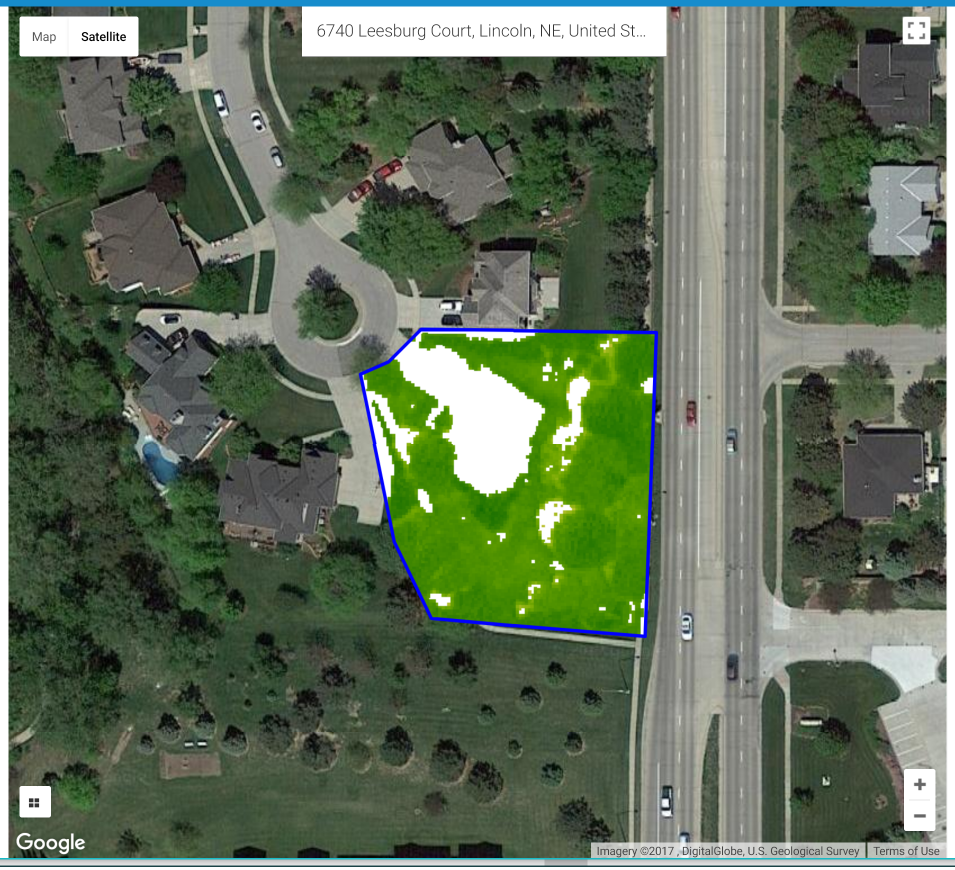

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SOURCE IMAGE(NAIP FALSE COLOR)

CLASSIFICATION

NAIP NDVI LANDSAT ADJUSTED

NAIP NDVI TEMPORAL LANDSAT ADJUSTED

LANDSCAPE COEFFICIENT

0 | 0.25 | 0.5 | 0.75 | 1 | 1.25

TEMPERATURE

WATER CONSUMPTION

IRRIGATION SCHEDULE

Customize

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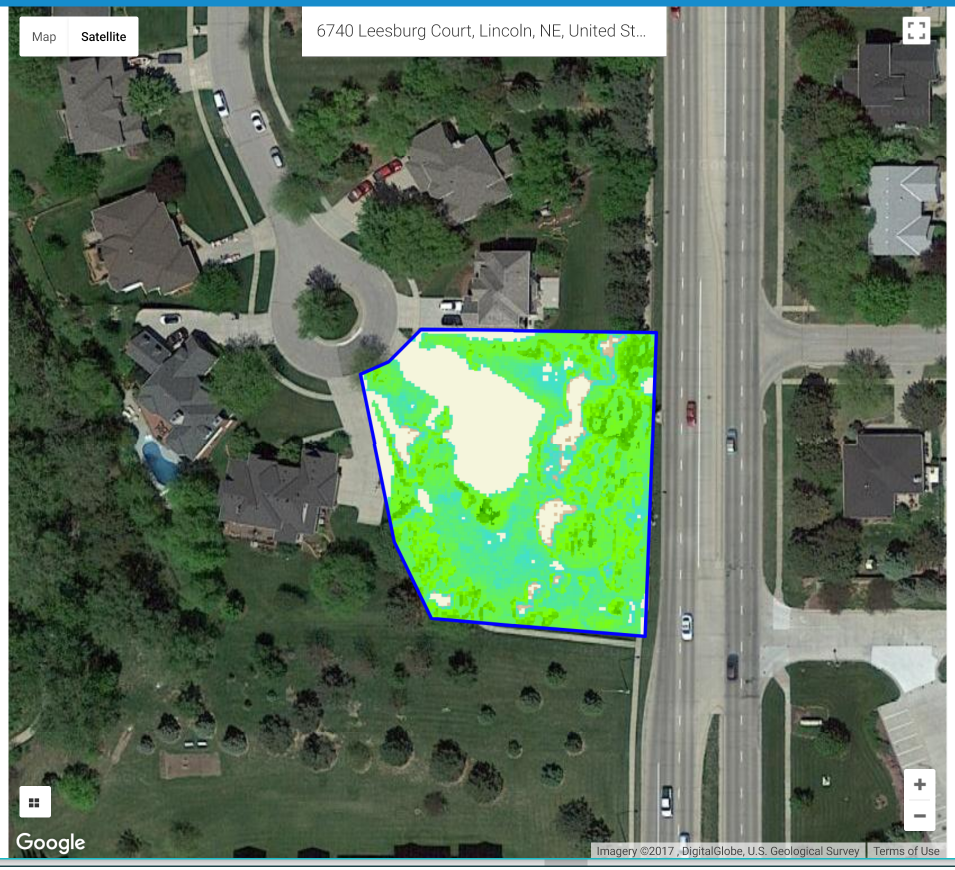

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- **Potential Use in Agriculture**
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A Field-Scale "Earth-Selfie" Every Day

- Cost: Less than 3 coffee-latte's per American per year
- Support SIXTEEN Landsats in orbit
- *DAILY* Earth-Selfie's

$800 million/Landsat
÷8 years
x 16 Landsat
÷ 300 million Americans
= $5.30 per American per year

- Consider:
  - *99% of all Americans spend at least $10 per week on superfluous things: cafe-lattes; bottled water; movies; gasoline to motor three blocks to the market-place or across town to look for designer jeans.*
  - *However, we don't want to spend the <$0.50 PER YEAR per American needed to launch and operate Landsats or similar that take field-scale 'selfies' of our Nation.*
  - *Less than $6 per American PER YEAR would place SIXTEEN Landsats into orbit, giving us DAILY Selfies of the entire Nation.*

Can you imagine what that would be like? A Landsat 'Selfie' EVERY DAY???

Thank you

Extra Slides

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EEFlux

This is beta version 1.0.0 of EEFlux level 2, where automated calibration of ETrF is still evolving. The last calibration update was Jan. 15, 2017. See FAQ's.

Instructions | FAQ

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- BASE MAP
- TRUE COLOR
- FALSE COLOR (4, 3, 2)
- FALSE COLOR (7, 5, 3)
- ALBEDO
- NDVI
- DEM
- LAND COVER
- SURFACE TEMPERATURE
- ALFAFA REFERENCE ET (ETr)
- GRASS REFERENCE ET (ETo)
- ETrF (default)
- ACTUAL ET (default)

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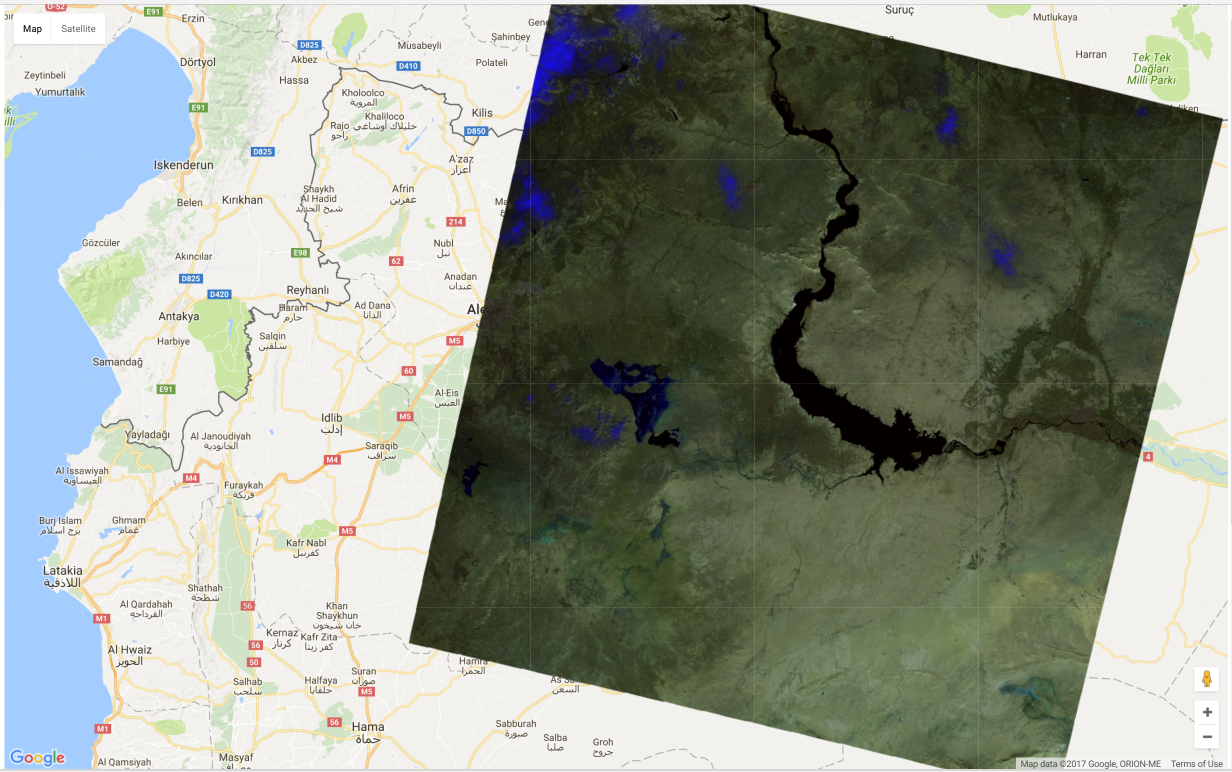
- ACTUAL ET (default)



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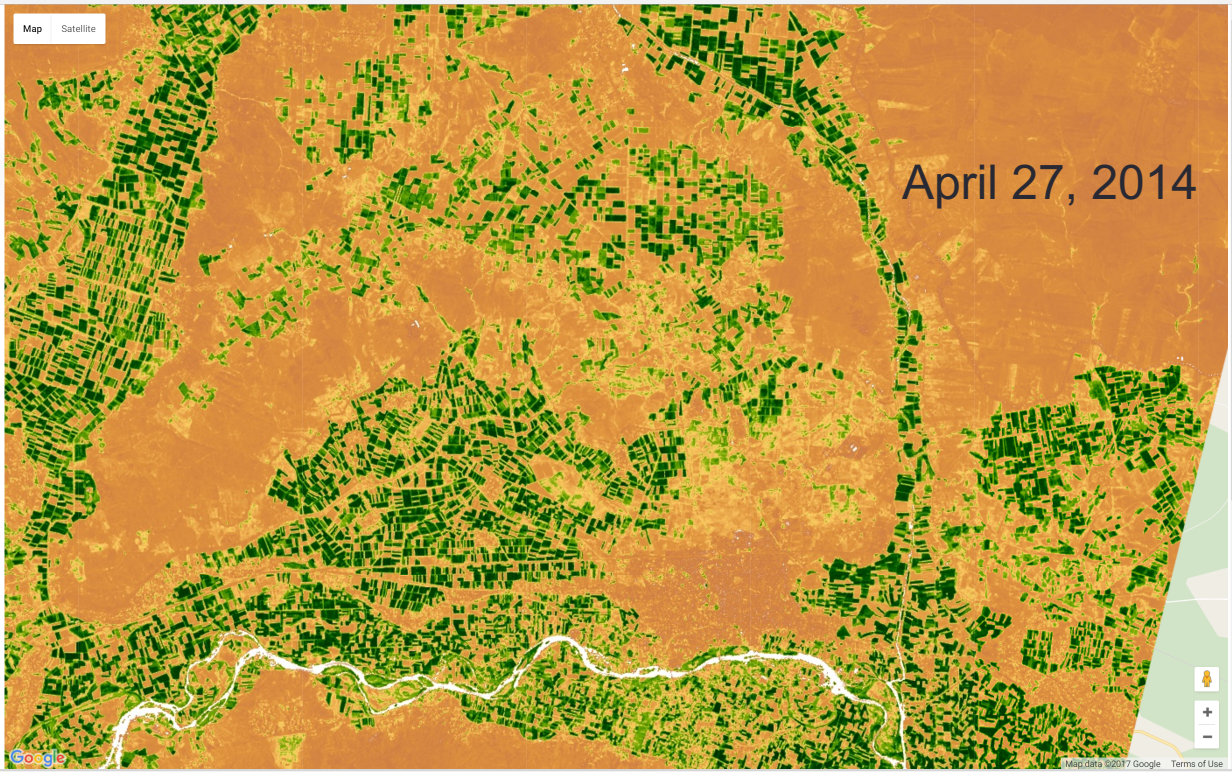
Products | Download Tiff

- BASE MAP
- TRUE COLOR
- FALSE COLOR (4, 3, 2)
- FALSE COLOR (7, 5, 3)
- ALBEDO
- NDVI

NDVI

0 0.2 0.4 0.6 0.8 1

- DEM
- LAND COVER
- SURFACE TEMPERATURE
- ALFAFA REFERENCE ET (ETr)
- GRASS REFERENCE ET (ETo)
- ETrF (default)



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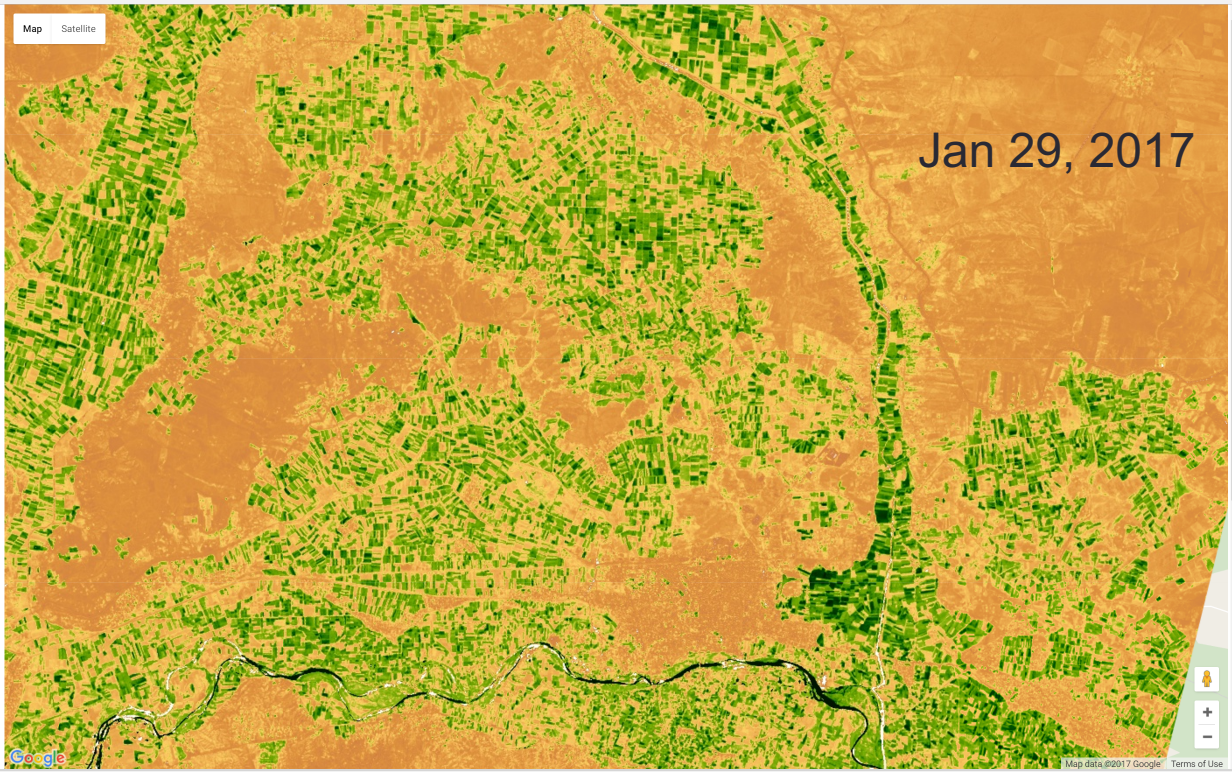
Products | Download Tiff

- BASE MAP
- TRUE COLOR
- FALSE COLOR (4, 3, 2)
- FALSE COLOR (7, 5, 3)
- ALBEDO
- NDVI

NDVI

0 0.2 0.4 0.6 0.8 1

- DEM
- LAND COVER
- SURFACE TEMPERATURE
- ALFAFA REFERENCE ET (ETr)
- GRASS REFERENCE ET (ETo)
- ETrF (default)



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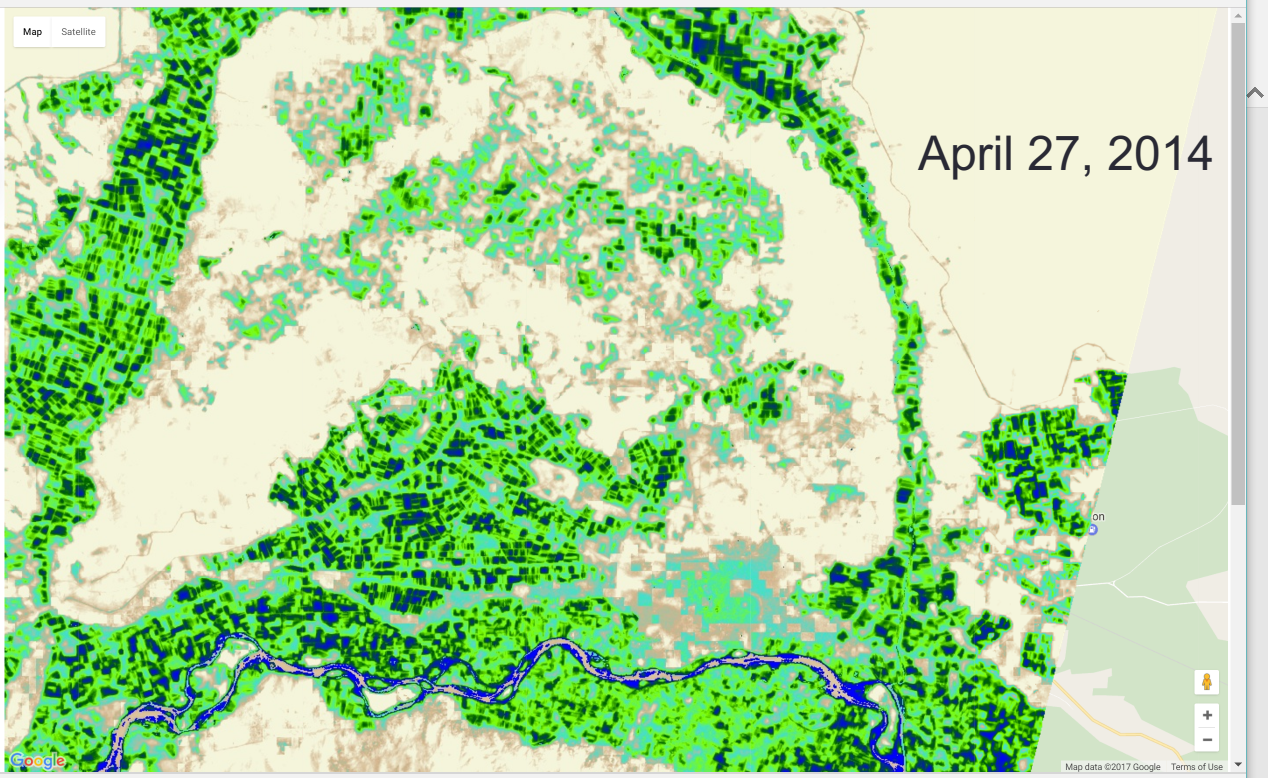
- BASE MAP
- TRUE COLOR
- FALSE COLOR (4, 3, 2)
- FALSE COLOR (7, 5, 3)
- ALBEDO
- NDVI
- DEM
- LAND COVER
- SURFACE TEMPERATURE
- ALFAFA REFERENCE ET (ETr)
- GRASS REFERENCE ET (ETo)
- ETrF (default)

ETrF



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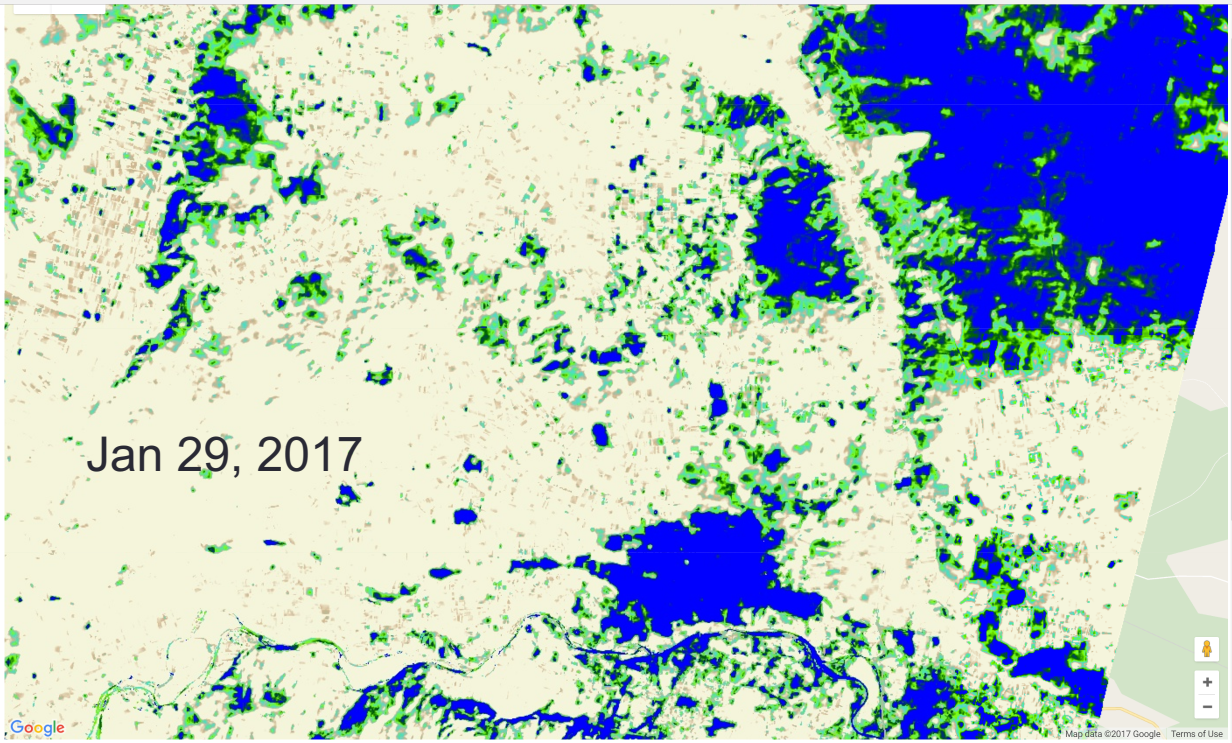
- BASE MAP
- TRUE COLOR
- FALSE COLOR (4, 3, 2)
- FALSE COLOR (7, 5, 3)
- ALBEDO
- NDVI
- DEM
- LAND COVER
- SURFACE TEMPERATURE
- ALFAFA REFERENCE ET (ETr)
- GRASS REFERENCE ET (ETo)
- ETrF (default)

ETrF

0 | 0.25 | 0.5 | 0.75 | 1 | 1.25



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