EEFLUX
GOOGLE EARTH ENGINE EVAPOTRANSPIRATION FLUX TOOL AT LANDSAT RESOLUTION

EEFlux Development Team

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Tyler Erickson, Google, Inc. – Earth Engine Advocate

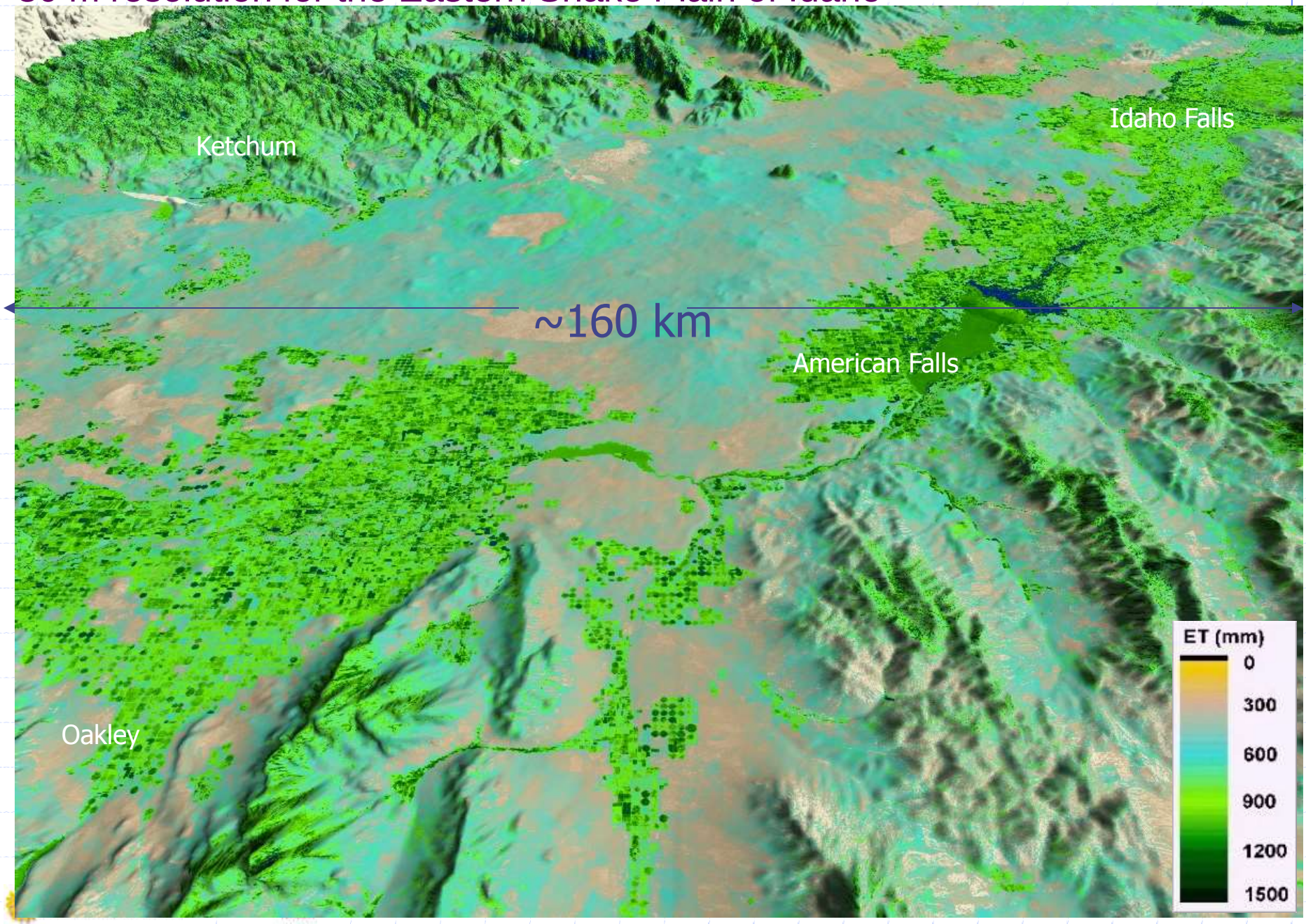
Rebecca Moore, Google, Inc. – Manager, Earth Engine / *Visionary*

Why an Evapotranspiration Tool on Google Earth Engine?

- Provide a web-based ET mapping tool with free public access
- Earth Engine (EE) has enormous computing and storage power
- EE has essentially free access
- EE holds the entire Landsat archive and NLDAS/CFSV2 gridded weather
- EE has strong developer support
- ET information is needed across the Global spectrum
- Strong Google support and encouragement to developers, ready access to spatial information, and encouragement to impact natural resources management

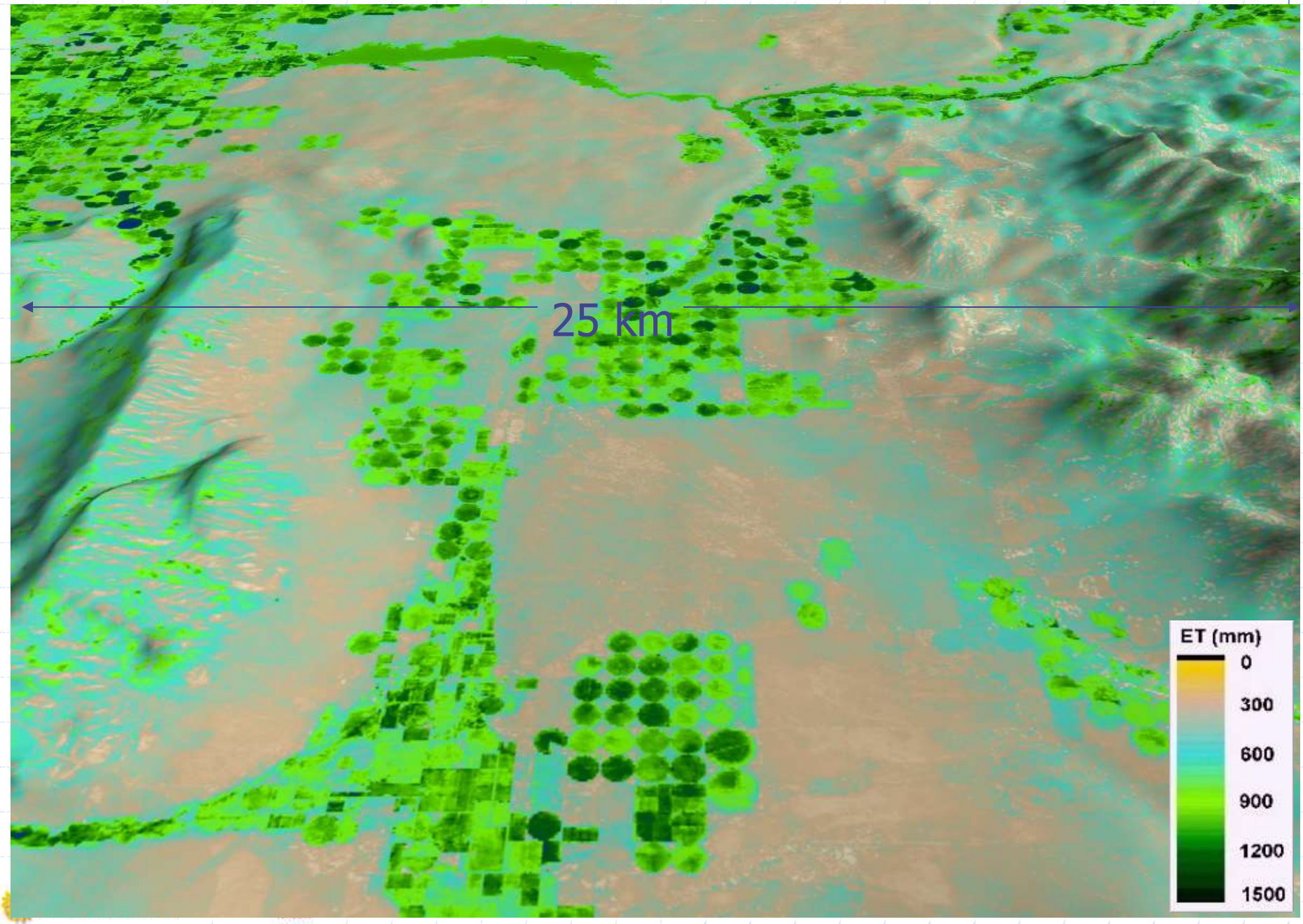
Does ET vary in Space? (Yes) -- Monthly and Seasonal ET at 30 m resolution for the Eastern Snake Plain of Idaho

April – October, 2006 ET



ET features at 30 m resolution

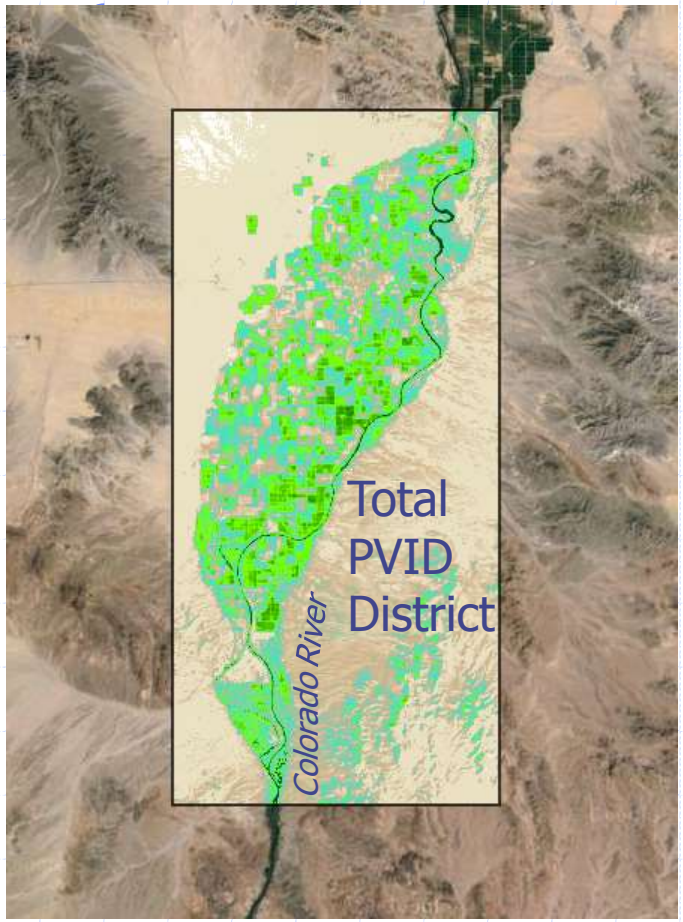
April – October, 2006 ET from METRIC-Landsat



General EB Components in EEFlux – from METRIC (Mapping ET at high Resolution using Inverse Calibration)

- Net Radiation (R_n)
  - Reflected shortwave from satellite
  - Incoming shortwave from theory
  - Emitted longwave from satellite
  - Incoming longwave from emitted and atmospheric transmissivity
- Sensible Heat Flux (H)
  - Near surface vertical air temperature gradient (dT) keyed from surface temperature (T_s) – calibrated to each image date ($dT = a + b\ T_s$)
  - Aerodynamic resistance from
    - Wind speed at blending height (from gridded or local weather)
    - Aerodynamic roughness from vegetation indices and land use type
    - Buoyancy effects from iterative solutions
- Soil Heat Flux (G)
  - Function of H for nearly bare soil and function of R_n for vegetation
- $\lambda E = R_n - G - H$

Google Earth Engine App --- EEFlux

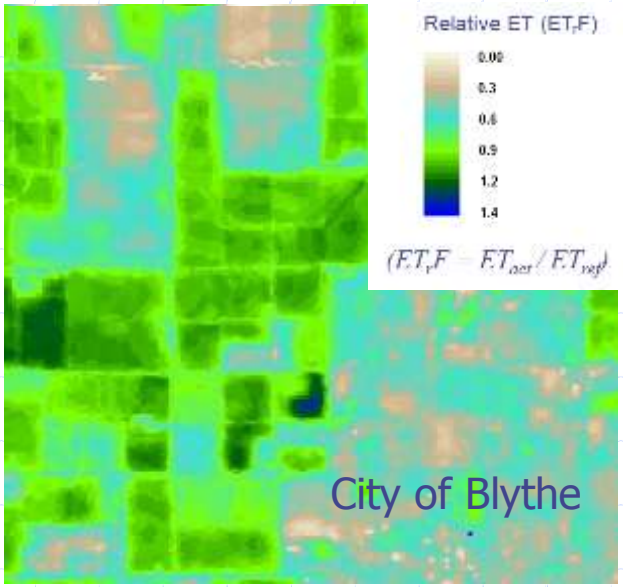


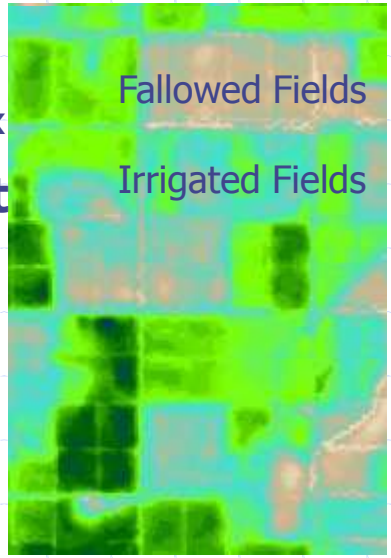
Earth Engine Evapotranspiration Flux

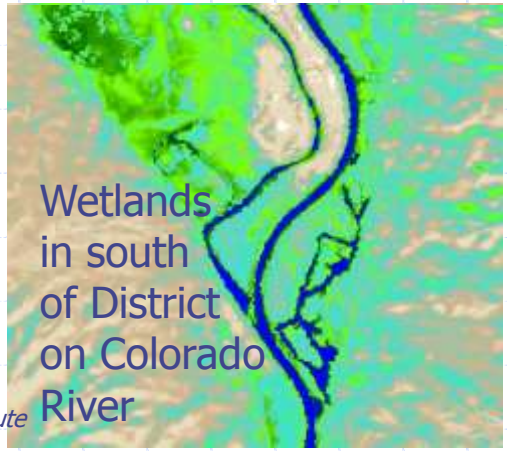
Palo Verde Irrigation District

Blythe, California – Jan. – Dec. 2008

-- Landsat 5 imagery Dec.







Univ. Nebraska-Lincoln, Univ. Idaho, Desert Research Institute

Computations are based on a complete surface energy balance ***(METRIC)***

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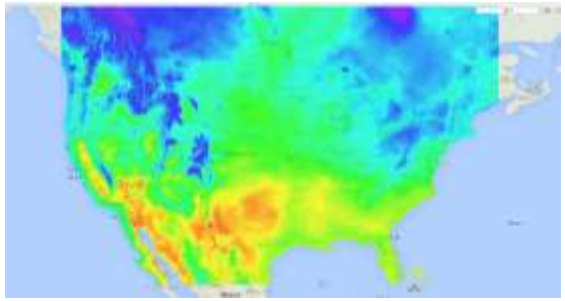
Data Resources Used by EEFlux

NLDAS-Jan 1, 1979 - Current

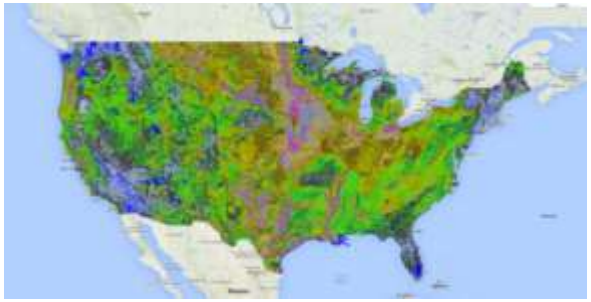


GRIDMET-Jan 1, 1979 - Current

NLCD Landuse

DEM

Soil Data Layers



- Landsat 5/7/8 and MODIS
- Weather Data
  - Hourly Weather Data (NLDAS)--CONUS
  - Daily Weather Data (GRIDMET)--CONUS
  - Climate Forecast System Version 2, 6-hourly Products (CFSV2)--nonCONUS
- Landuse and Digital Elevation Maps
- Soil Data Layers (STATSGO--CONUS and FAO)

Reference ET on the Google Earth Engine EEFlux App.

Reference ET calculated using the ASCE Standardized Penman-Monteith Equation for the Tall Reference (Alfalfa) --computed from the GridMET data set of Abatzoglou (2012)

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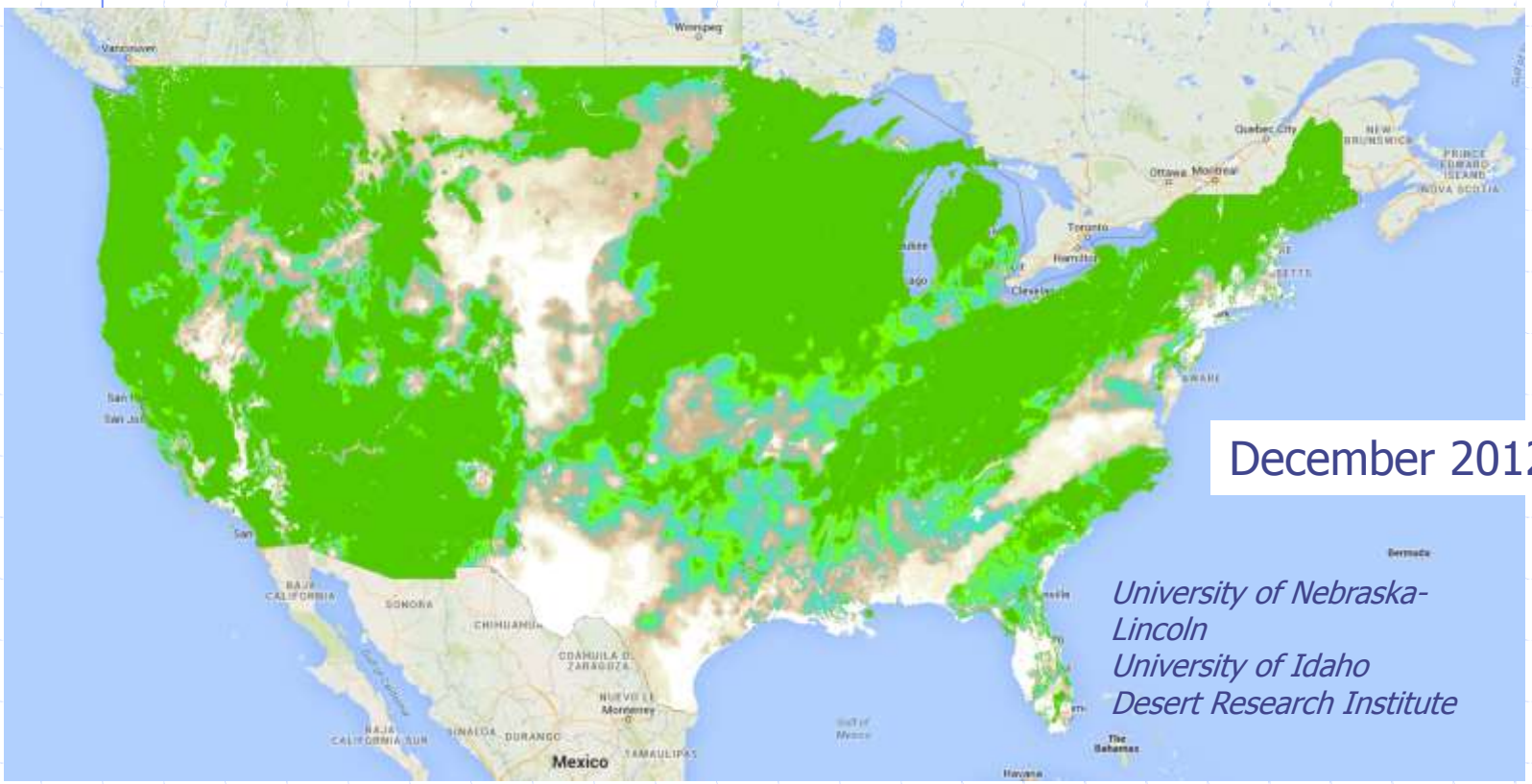
The Soil Surface Evaporation Component of the Google Earth Engine EEFlux App.

--- **Evaporation from Bare Soil** --- used to calibrate the EEFlux Evapotranspiration Surface Energy Balance to account for Precipitation Effects on ET



($K_e = E_{act} / ET_{ref}$)

--computed from the GridMET weather data set of Abatzoglou (2012)

-- GridMET is traceable to NLDAS and PRISM data sets

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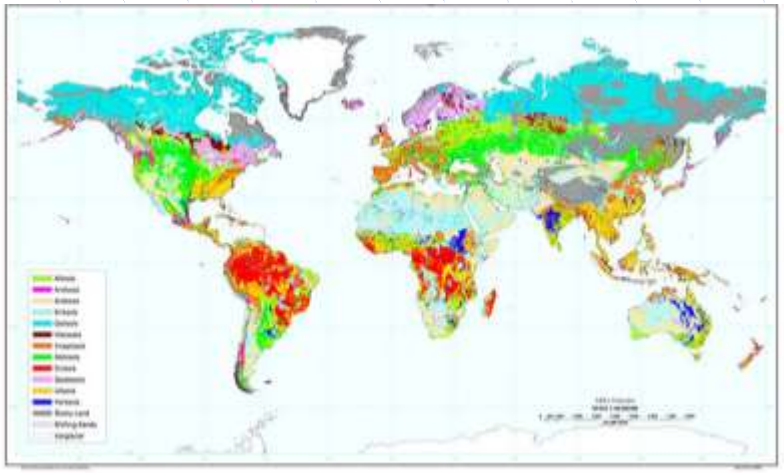
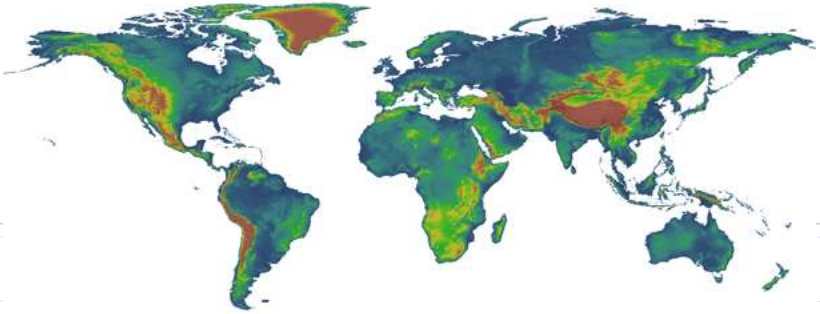
EEFlux -- Data sets for Global Applications outside the USA

GLOBAL SOIL



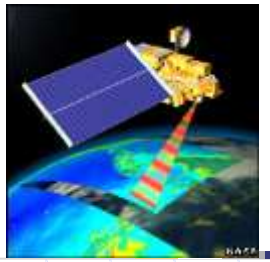
LANDUSE-ESA

DIGITAL ELEVATION DATABASE-SRTM



LANDSAT 5/7/8

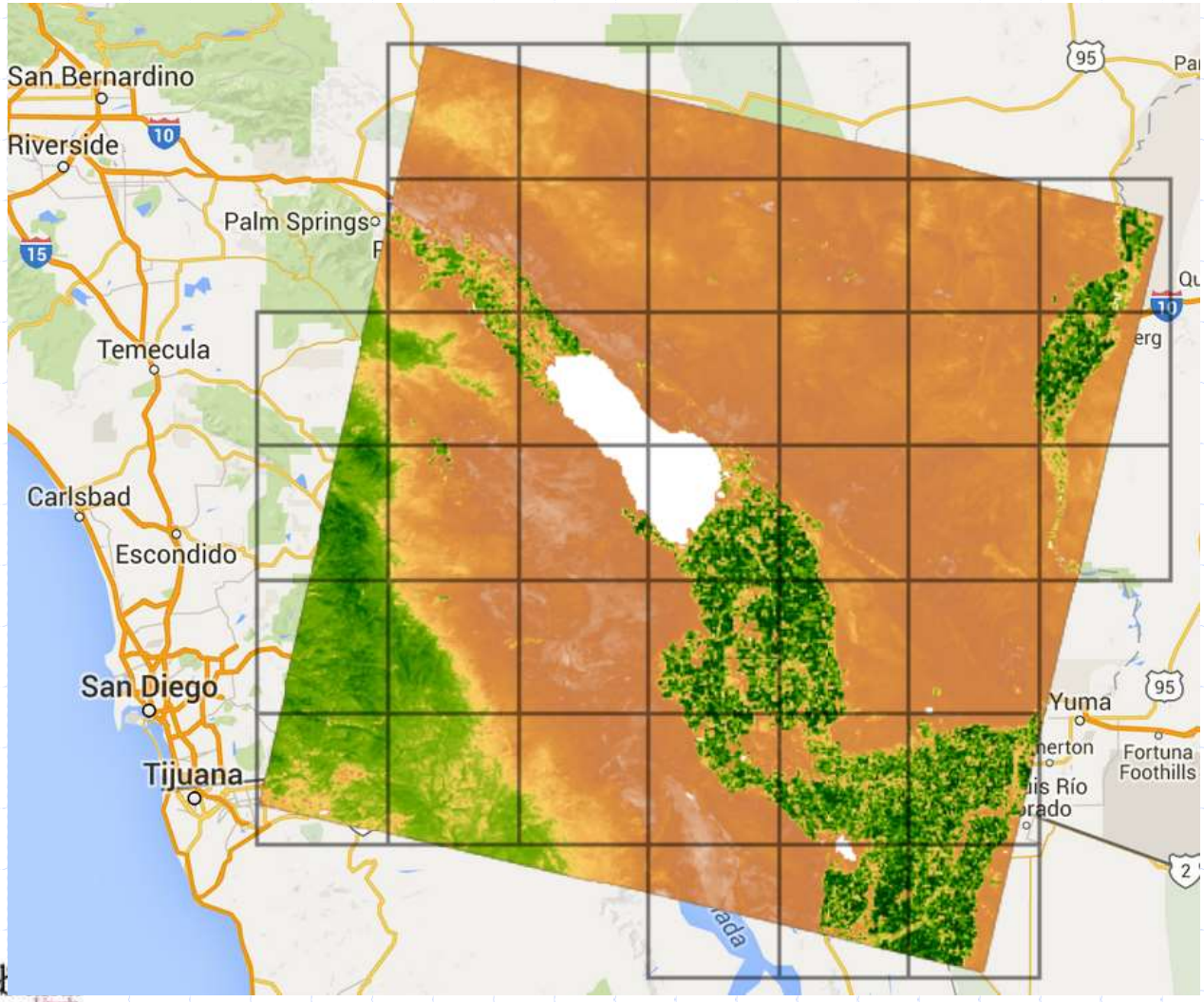
MODIS



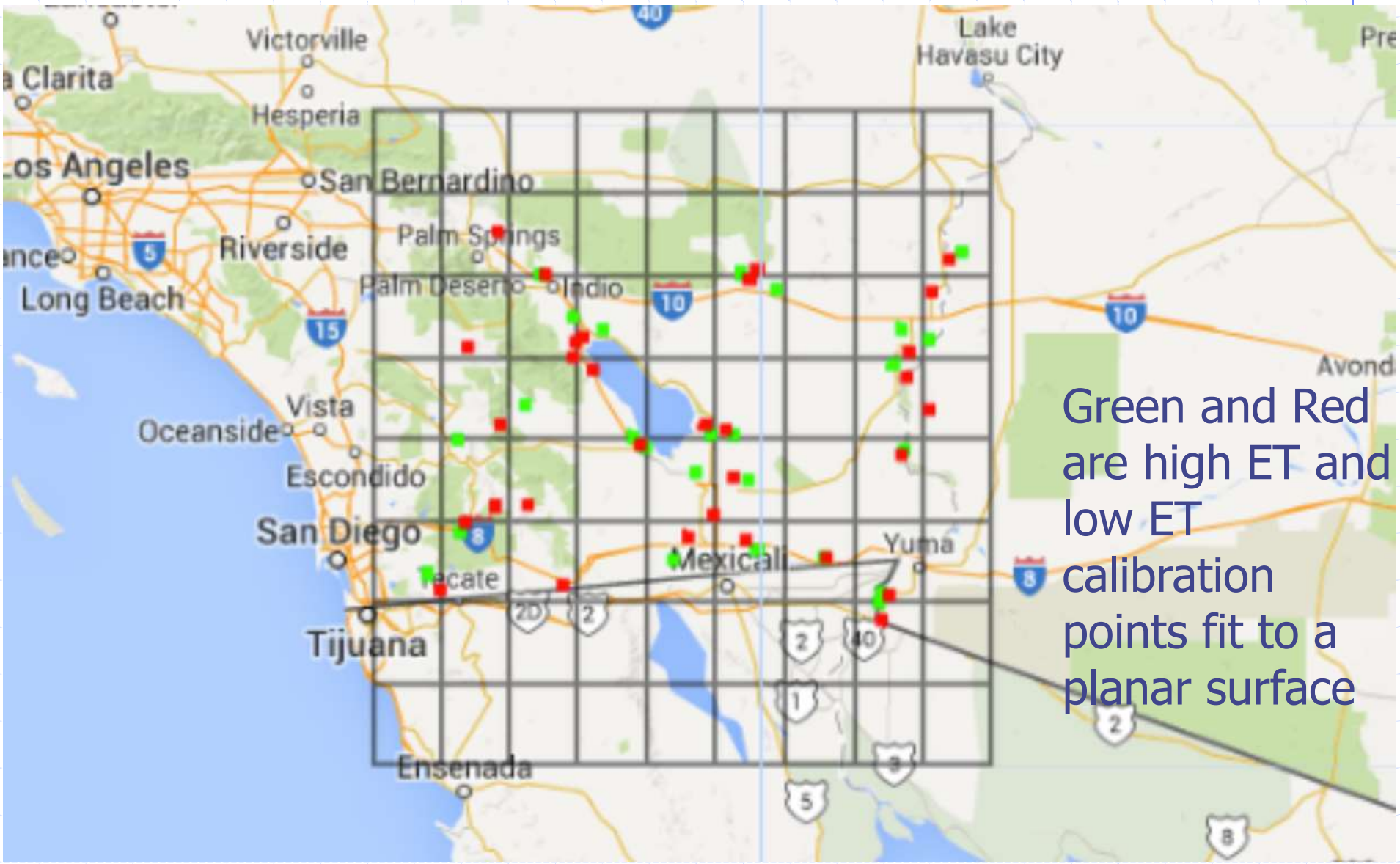
These data products are loaded and are functional on Earth Engine

University of Nebraska Lincoln University of Idaho DRI Google

EEFlux Automated Calibration on a Grid – more robust for complex terrain and near large water bodies – fit to a planar surface



Calibration of Energy Balance on a Grid



Development Steps in Progress

http://eeflux-level1.appspot.com/

Refinement of a Web-based User Console

- to save project information
- free access to level 1 EEFlux API's by outside users
- tuning dials for level 1 EEFlux to adjust calibration
- more beta testing on level 2 to permit advanced tuning

Seamless National and Global applications

Cloud detection and mitigation for clouds *(Fmask)*

Time integration to produce monthly and annual ET volumes *(in progress by Desert Research Institute)*

Ingestion of METRIC "mountain" algorithms for aerodynamics and solar radiation estimation in complex terrain

Bias correction to gridded weather data sets for aridity

Other Energy Balance Enhancements in METRIC/EEFlux

- Soil heat flux of thawing soils (frozen during prior night)
- Soil heat flux under organic mulches including straw
- Soil heat flux optimization using EB inversion
- Excess aerodynamic resistances in sparse brush and grapes
- Nadir-based albedo adjustment for deep canopies
- **Aerodynamic-based estimation of evaporation from water**
- Radiation and Aeodynamic Algorithms from METRIC Level 3 for Complex Terrain (Mountains)

EEFlux API's

- ee.Algorithms.EEFlux(Landsat)
  - ee.Algorithm.EEFlux.HourlyETr
  - ee.Algorithm.EEFlux.DailyETr
  - ee.Algorithm.EEFlux.SoilWaterBalance
  - ee.Algorithm.EEFlux.LandsatPreprocessing
  - ee.Algorithm.EEFlux.surfaceReflectance
  - ee.Algorithm.EEFlux.surfaceAlbedo
  - ee.Algorithm.EEFlux.surfaceTemperature
  - ee.Algorithm.EEFlux.AutoHC
  - ee.Algorithm.EEFlux.NetRadiation
  - ee.Algorithm.EEFlux.dT
  - ee.Algorithm.EEFlux.SensibleHeatFlux
  - ee.Algorithm.EEFlux.SoilHeatFlux
  - ee.Algorithm.EEFlux.EnergyBalance

API = Application Programming Interface

Each API will be callable by any user's Earth Engine Script

Soon to be available in earth engine playground

sample ee call

ee.Algorithm.EEFlux

- ee.Algorithms.EEFlux.HourlyETr(Tair, SPH, Rs, WindSpeed, Elevation, Zw, doy, hour, ReferenceSurface)
  - EEFlux (Earth Engine Evapotranspiration Flux), is patterned after the operational stand-alone model METRIC (mapping evapotranspiration at high resolution with internal calibration). EEFlux is a full surface energy balance model, producing estimates of net radiation (Rn), sensible heat flux to the air (H), and conductive heat flux to the ground (G). ET is estimated from these surface energy balance components as a residual: ET = Rn – H – G.
- Arguments:
- Input layers:
  - **input (Image):** The Landsat image to process.
- Returns:
  - ETrF: Fraction of Evapotranspiration (ET/ETrF)
  - ET: Evapotranspiration (mm/day)

- Reference:

Demo of EEFlux

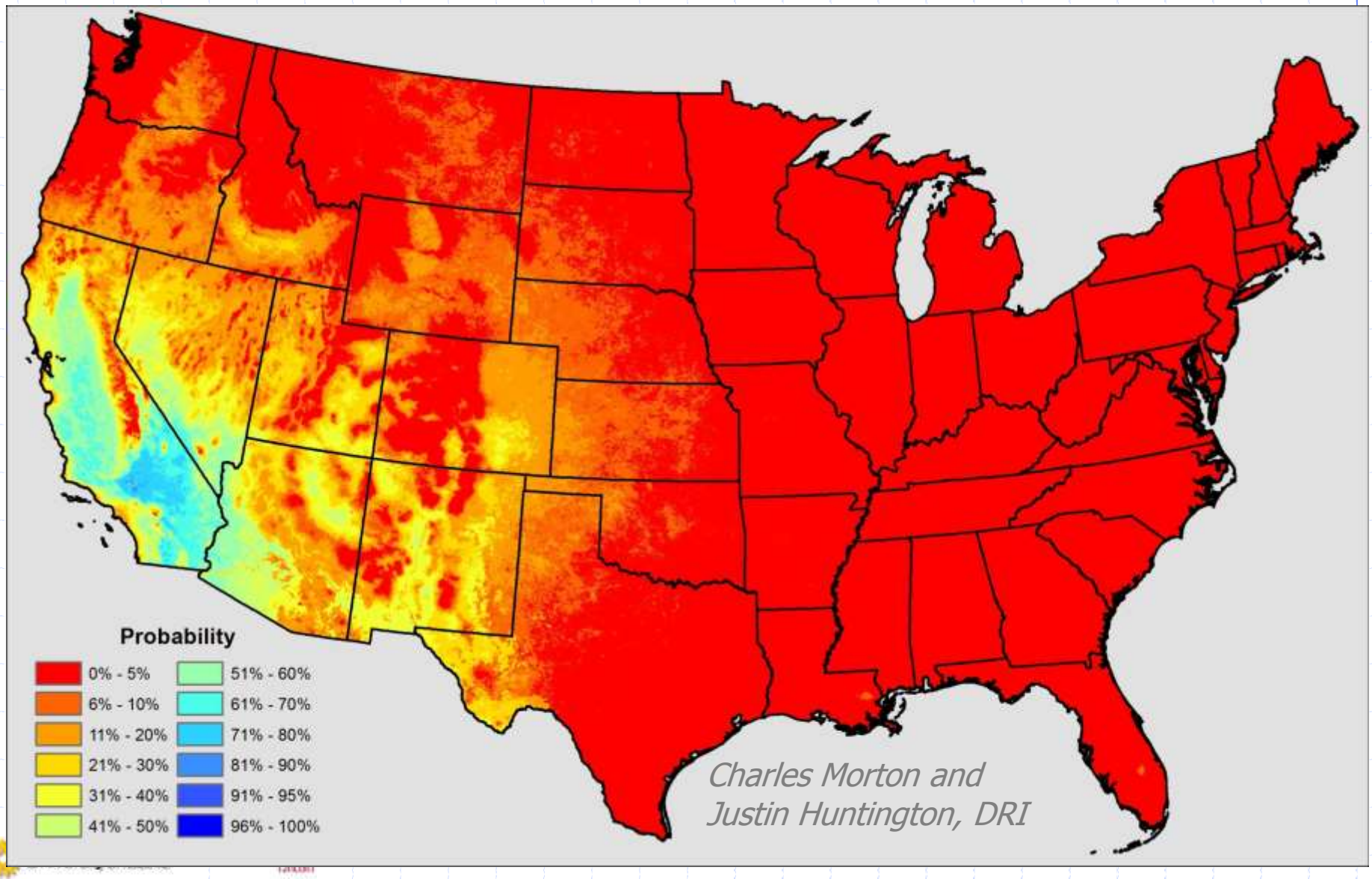
http://eeflux-level1.appspot.com/

Public Service Announcement:

Need for Shorter Revisit Time for Landsat-type Satellites (with Thermal Imaging) to Mitigate for Clouds

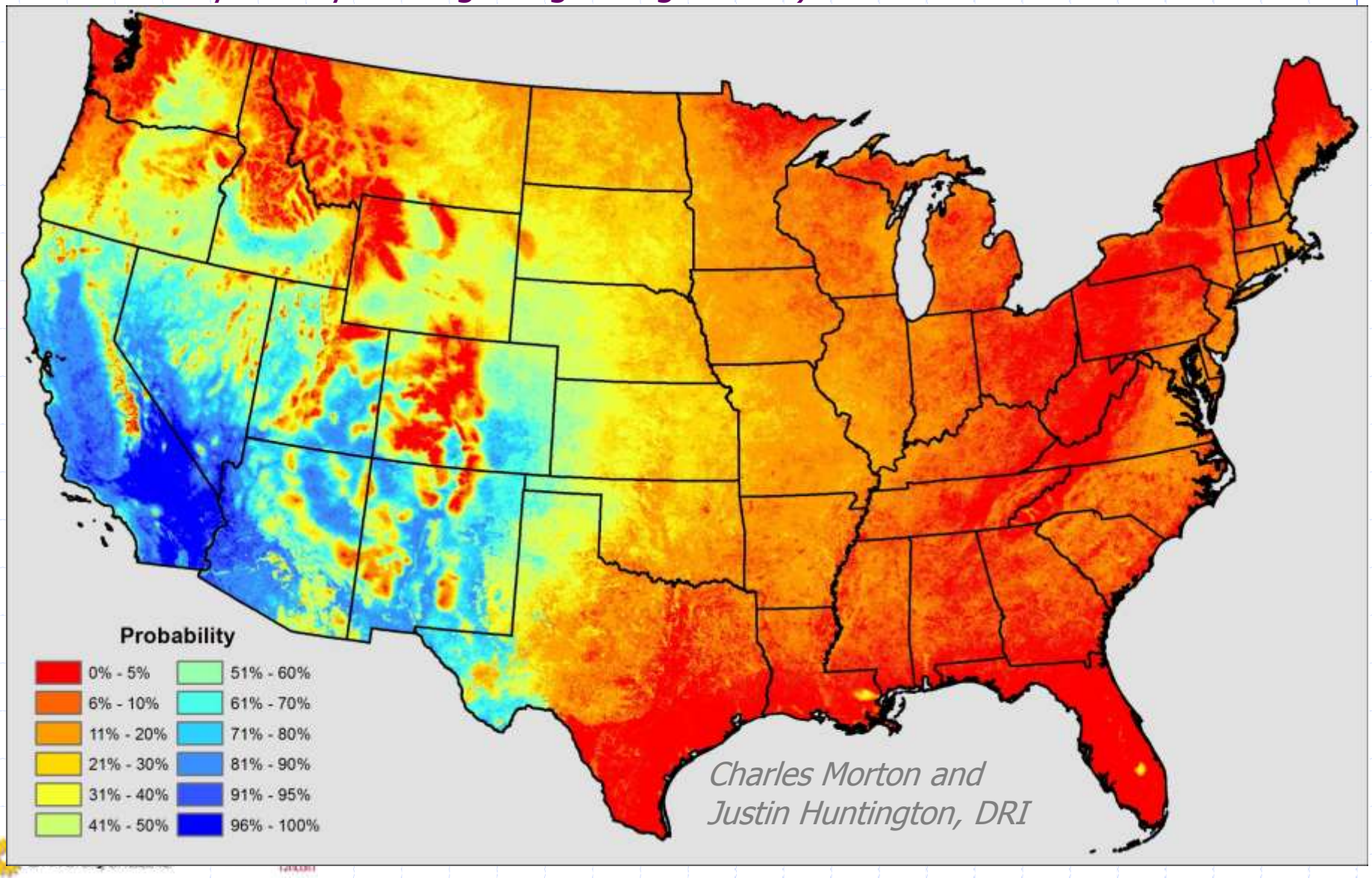
1 Satellite (image each 16 days)

Probability of producing a good estimate of Water Consumption over any given year (having a Cloud-free Image at least every 32 days during the growing season)



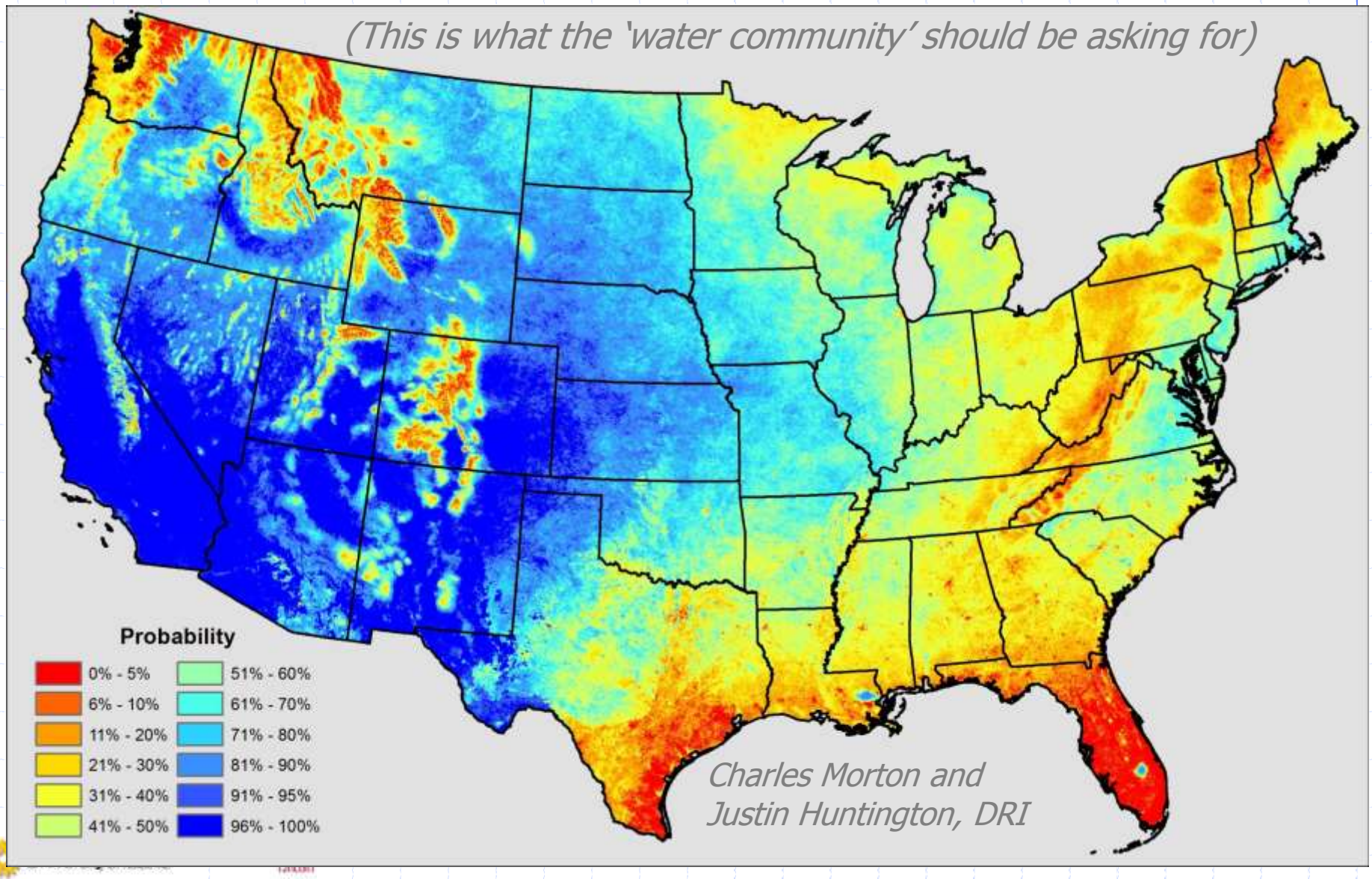
2 Satellites (image each 8 days)

Probability of producing a good estimate of Water Consumption over any given year (having a Cloud-free Image at least every 32 days during the growing season)



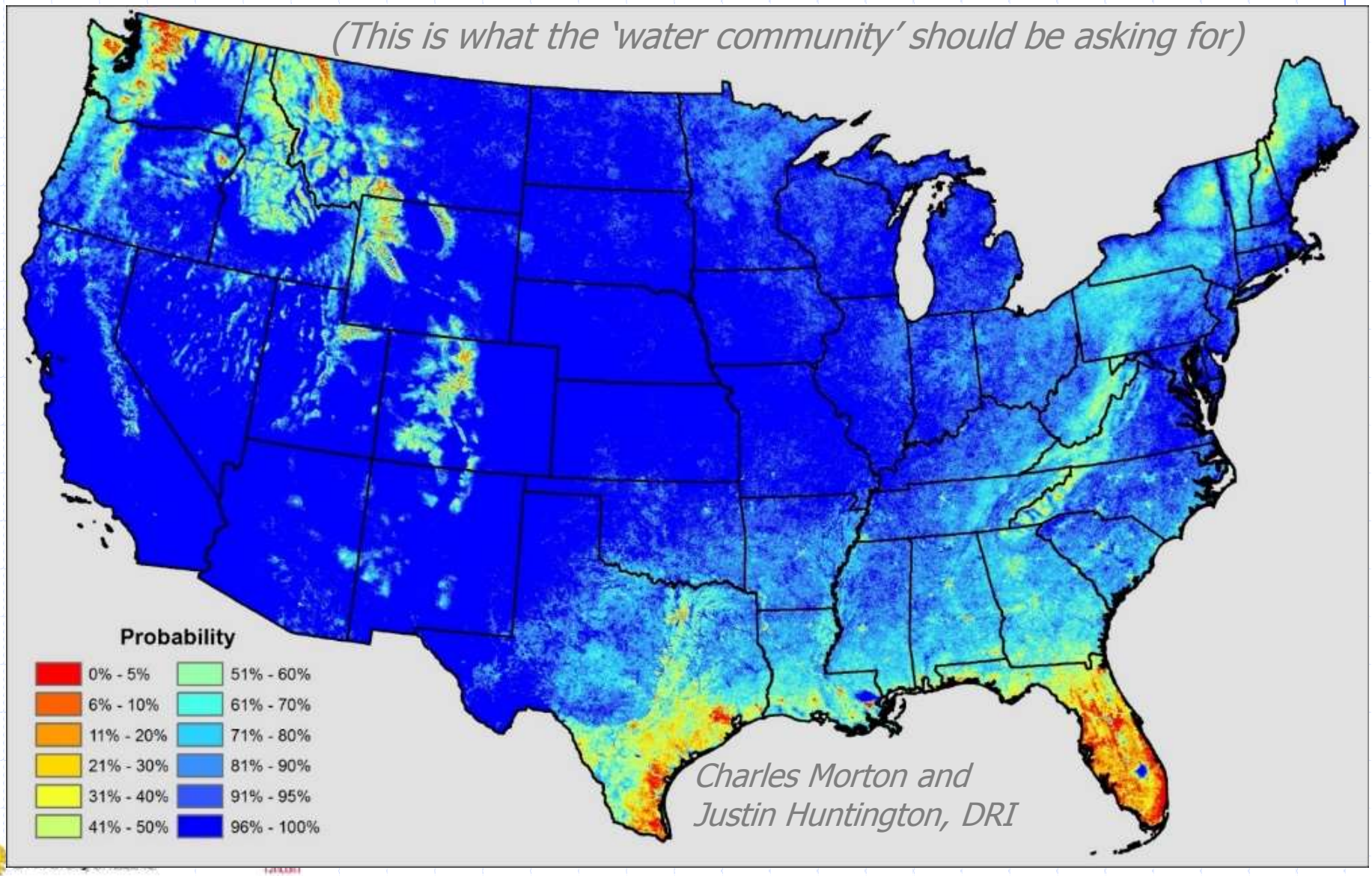
4 Satellites (image each 4 days)

Probability of producing a good estimate of Water Consumption over any given year (having a Cloud-free Image at least every 32 days during the growing season)



8 Satellites (image each 2 days)

Probability of producing a good estimate of Water Consumption over any given year (having a Cloud-free Image at least every 32 days during the growing season)



A Landsat-based "Earth-Selfie" concept

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

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

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

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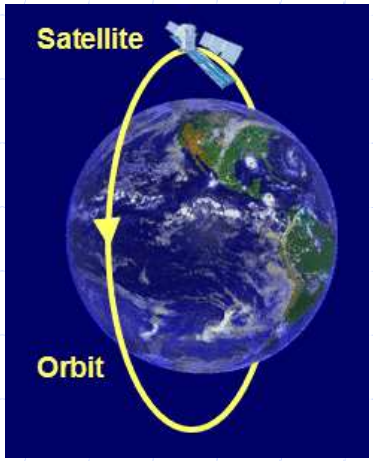
University of Nebraska Lincoln

A formula for calculating revisit time for a satellite (and the number of satellites needed for a daily "Selfie")

Earth's Circumference = 40,000,000 m

Satellite Orbit time = 98.9 minutes for L8



x

= 16 days for 1 sat.
or 16 satellites for daily

x

constrained by telescope size and signal to noise ratio req.

Effective Number of Detectors (no. pixels) = ~5,700 for L8

Pixel size = 30 m for L8

Swath Width of Satellite

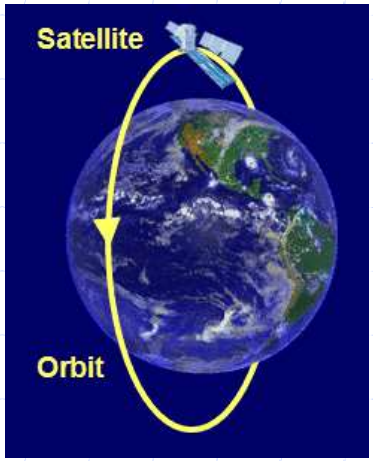
University of Idaho

Nebraska Lincoln

A formula for calculating revisit time for a satellite (and the number of satellites needed for a daily "Selfie")

Earth's Circumference = 40,000,000 m

Satellite Orbit time = 98.9 minutes for L8



x

= 48 days for 1 sat.
or 48 satellites for daily

x

constrained by telescope size and signal to noise ratio req.

Effective Number of Detectors (no. pixels) = ~5,700 for L8

Pixel size = 10 m

Swath Width of Satellite

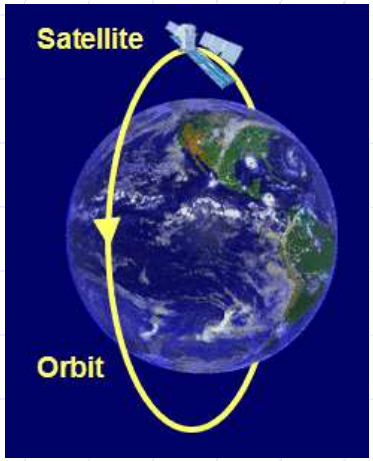
University of Idaho

Nebraska Lincoln

A formula for calculating revisit time for a satellite (and the number of satellites needed for a daily "Selfie")

Earth's Circumference = 40,000,000 m

Satellite Orbit time = 98.9 minutes for L8



x

= 480 days for 1 sat.
or 480 satellites for daily

x

constrained by telescope size and signal to noise ratio req.

Effective Number of Detectors (no. pixels) = ~5,700 for L8

Pixel size = 1 m

Swath Width of Satellite

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Thank You

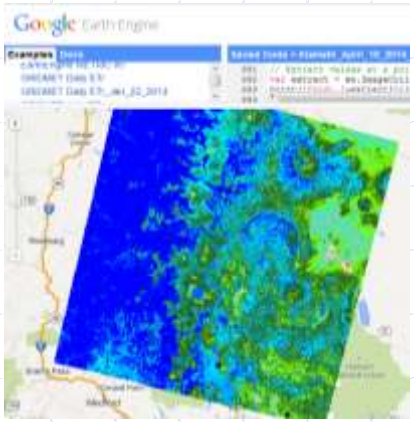
- http://eeflux-level1.appspot.com/

EEFlux (ET) on Google Earth Engine

Data:

- Gridded Weather data – used to calibrate EEFlux energy balance and to calculate Reference ET used for Time Interation of ET:
  - NLDAS – North American Land Data Assimilation System
    -- hourly weather data at 12 km available for > 30 year period for CONUS
  - GridMET - daily, bias corrected weather data at 4 km available for > 30 year period for CONUS
  - Climate Forecast System Version 2, 6-hourly Product (CSFV2)—nonCONUS
  - Real Time Mesoscale Analysis (RTMA) – downloaded daily to Earth Engine – used to fill in time gaps between NLDAS and today for processing recent Landsat imagery

- Soils -- Used to produce a daily time series of evaporation from bare soil.
  - Statsgo soils data is available for CONUS for top 0.15 m of soil
  - FAO soils data base used for rest of globe



Klamath, 2014

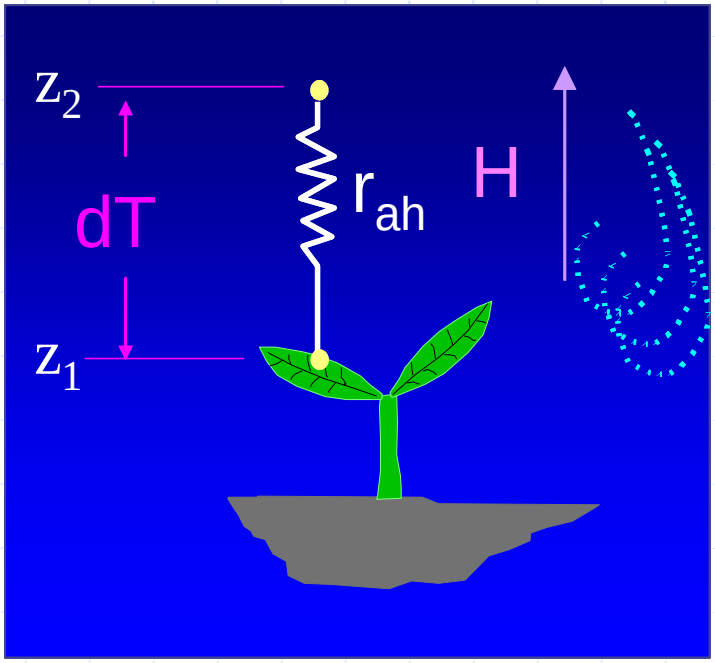
Calibration of METRIC/EEFlux:

$bias_{Rn-G} \rightarrow bias_{H-cal} \rightarrow bias_{dT} \rightarrow bias_{H-pixel} \not\rightarrow LE$

unbiased

The Sensible Heat (H) Function *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

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