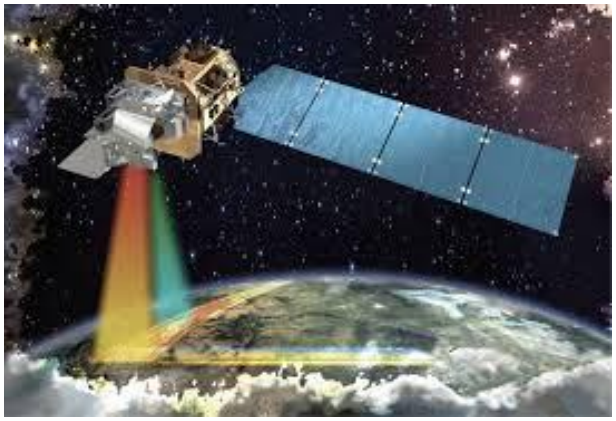
Google Earth Engine Evapotranspiration Flux --- EEFlux



Rick Allen, University of Idaho

Ayse Kilic, University of Nebraska-Lincoln

Justin Huntington, Desert Research Institute

Members of the Landsat Science Team

Landsat Science Team Meeting – EROS, July 8, 2015

EEFlux-Development Team

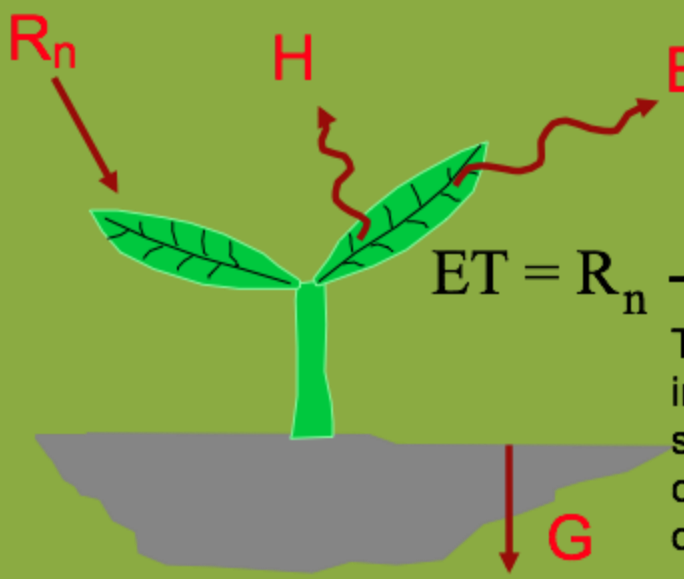
An Evapotranspiration Modeling Tool on Google Earth Engine

Baburao Kamble – University of Nebraska – Developer
Charles Morton – Desert Research Institute – Developer
Ayse Kilic – University of Nebraska -- Professor, *Member Landsat Science Team*
Justin Huntington – Desert Research Institute – Professor, *Member Landsat Science Team*
Rick Allen -- University of Idaho – Professor, *Member Landsat Science Team*
Clarence Robison – Univ. Idaho – GIS technician
Ian Ratcliffe – University of Nebraska – Remote Sensing Analyst
Ricardo Trezza – University of Idaho – Professor
David Thau, Google, Inc. – Earth Engine Advocate
Tyler Erickson, Google, Inc. – Earth Engine Advocate
Noel Gorelick, Google, Inc. – Earth Engine Advocate
Rebecca Moore, Google, Inc. – Manager, Earth Engine / *Visionary*

EEFlux = Implementation of METRIC ET mapping algorithms into EarthEngine for processing Landsat and MODIS imagery

ET is calculated as a "residual" of the energy balance

EEFlux uses thermal imagery from Landsat and MODIS



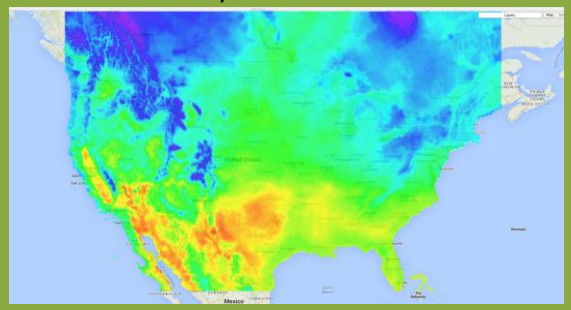
Basic Truth: Evaporation consumes Energy

$$ET = R_n - G - H$$

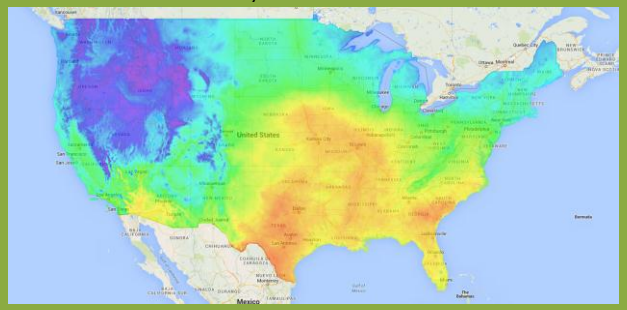
The energy balance includes all major sources (R_n) and consumers (ET, G, H) of energy

Data Resources Used by EEFlux

NLDAS-Jan 1, 1979 - Current



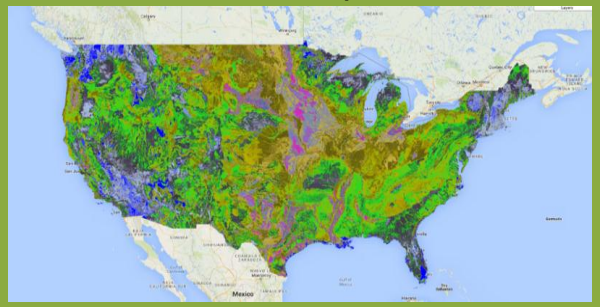
GRIDMET-Jan 1, 1979 - Current



NLCD Landuse

DEM

Soil Data Layers



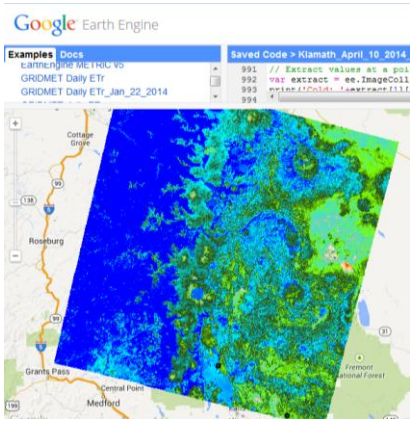
- Landsat 5/7/8 and MODIS
- Weather Data
  - Hourly Weather Data (NLDAS)--CONUS
  - Daily Weather Data (GRIDMET)--CONUS
  - Climate Forecast System Version 2, 6-hourly Products (CSFV2)--nonCONUS
- Landuse and Digital Elevation Maps
- Soil Data Layers (STATSGO--CONUS and FAO)

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

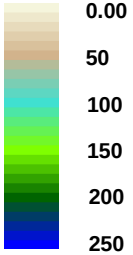
- Soils -- Used to produce a daily time series of evaporation from bare soil.
  - Statsgo soils data is available for CONUS for top 0.15 m of soil
  - FAO soils data base used for rest of globe



Klamath, 2014

ET between Landsat dates is scaled using Reference ET App of Google EE

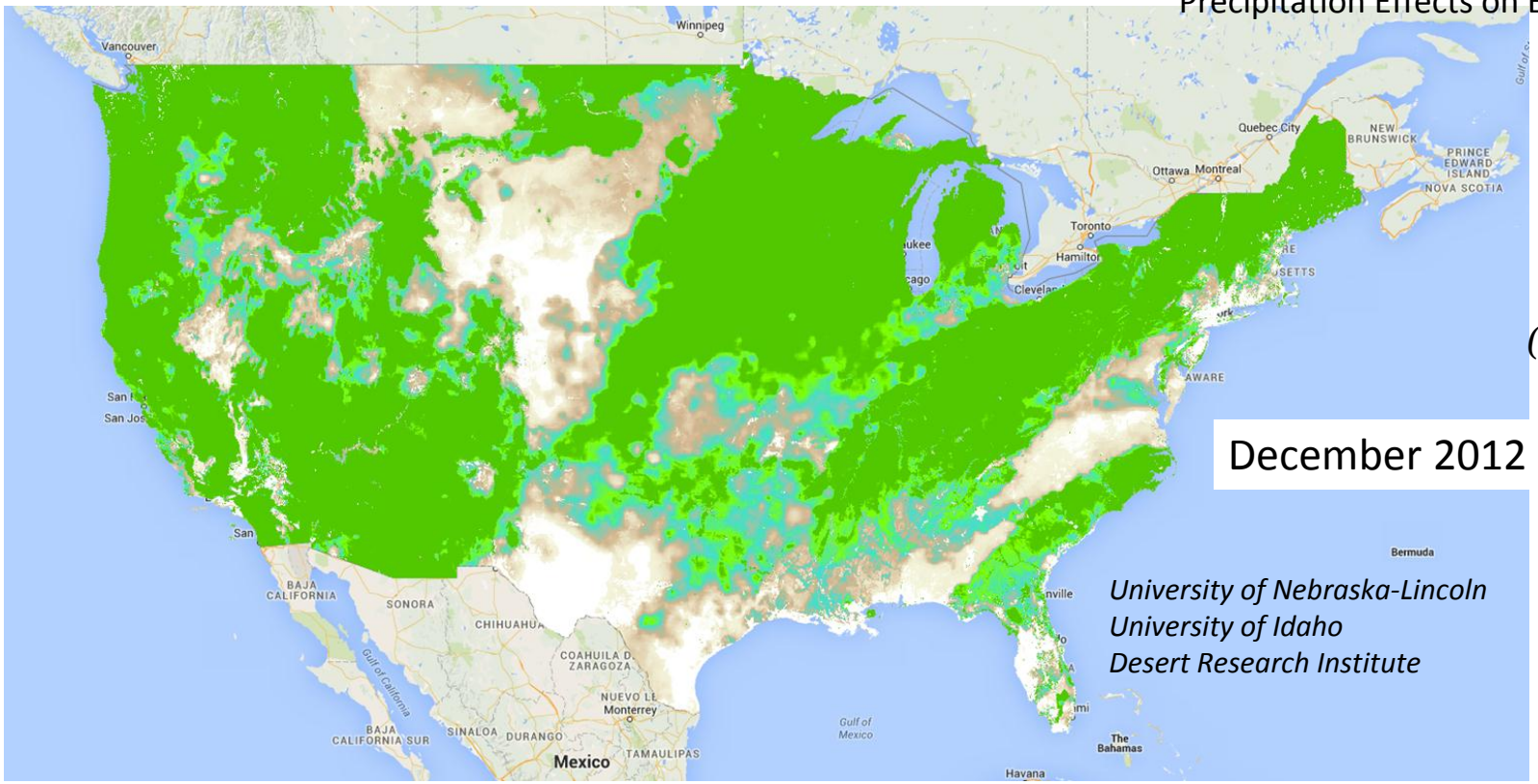
Reference ET (mm/mo)

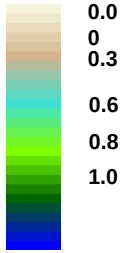


Reference ET is calculated using the ASCE Standardized Penman-Monteith Equation for the Tall Reference (Alfalfa)
--computed from the daily GridMET data set of Abatzoglou (2012)

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 background Precipitation Effects on ET Evap. Coef. (K_e)





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

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

-- GridMET is traceable to NLDAS and PRISM data sets

EEFlux Applications

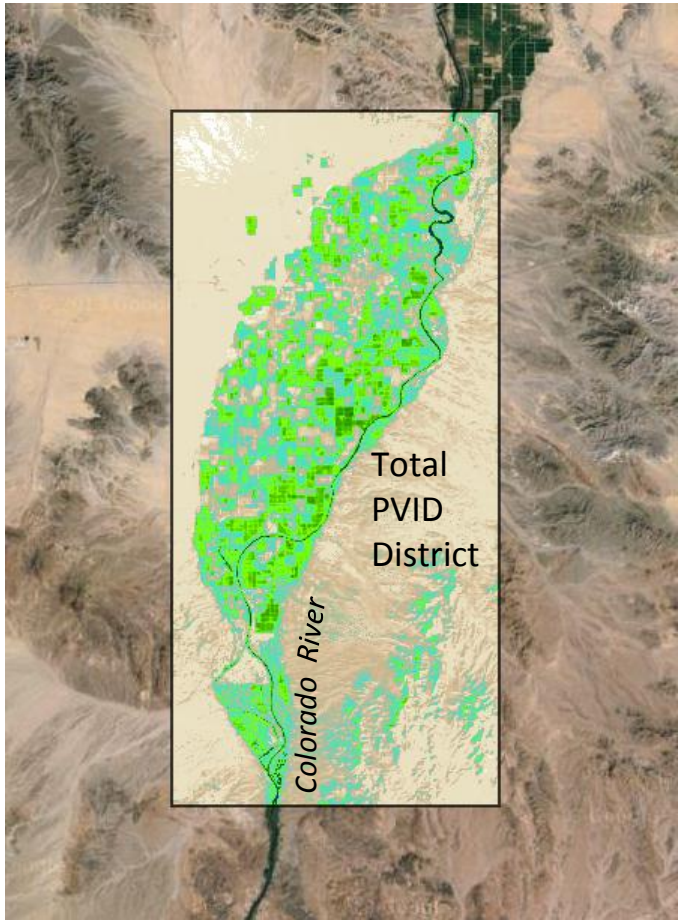
Imperial Valley and Palo Verde, CA

Jordan

Chile

We are testing EEFlux over the globe in a number of Countries and Conditions

Google Earth Engine Flux --- EEFlux



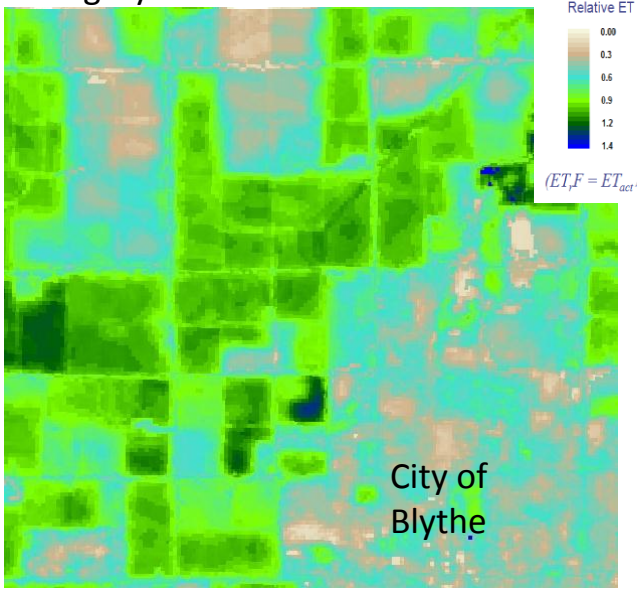
Earth Engine Evapotranspiration Flux

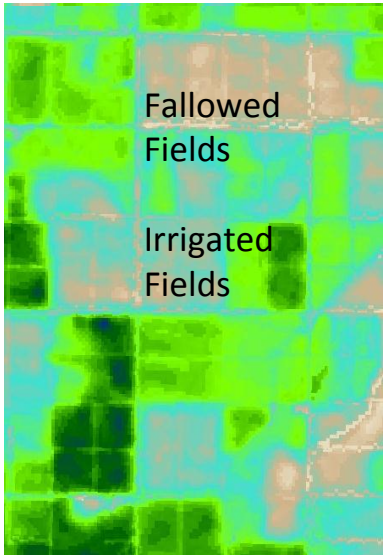
Palo Verde Irrigation District

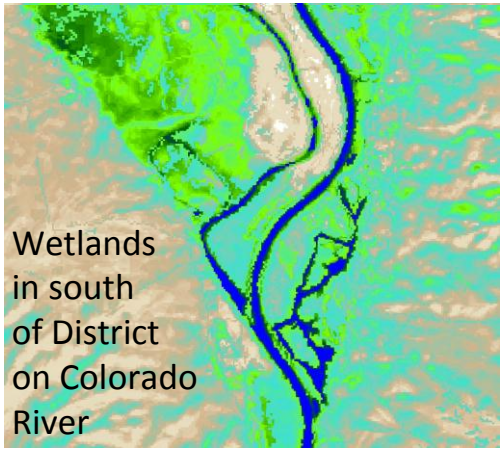
Blythe, California – Jan. – Dec. 2008

-- Landsat 5 imagery

Dec.







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

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

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

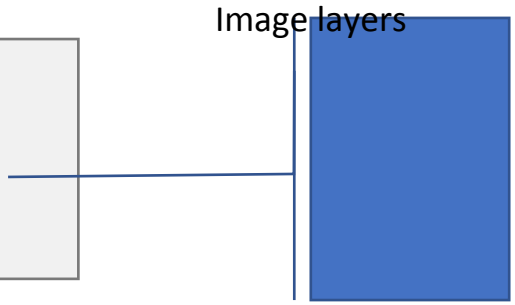
ee.Algorithm.EEFlux

- 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:

sample ee call

ee.Algorithm.EEFlux.HourlyETr

- ee.Algorithms.EEFlux.HourlyETr(Tair, SPH, Rs, WindSpeed, Elevation, Zw, doy, hour, ReferenceSurface)
  - Reference evapotranspiration (ETr) is the rate at which readily available soil water is vaporized from specified vegetated surfaces (Grass or Alfalfa).
  - This algorithm is based on the 'Standardized Reference Evapotranspiration Equation' recommended by American Society of Civil Engineers (ASCE-ET).
  - Outputs a single band containing the computed hourly reference ET.
- Arguments:
- Input layers:
  - Tair: Air Temperature (C)
  - SPH: Specific Humidity (kg/kg)
  - Rs: Solar Radiation (W/m2)
  - WindSpeed: Wind speed (m/s)
  - Elevation : Elevation (meters)
  - DoY: Julian Date / Day of Year (Integer (0-365/366))
  - Hour: Hour in GMT (Integer 00-23)
  - Zw : Anemometer Height (meter)
  - Reference surface (0/1):
    - Grass (0) or Alfalfa (1)

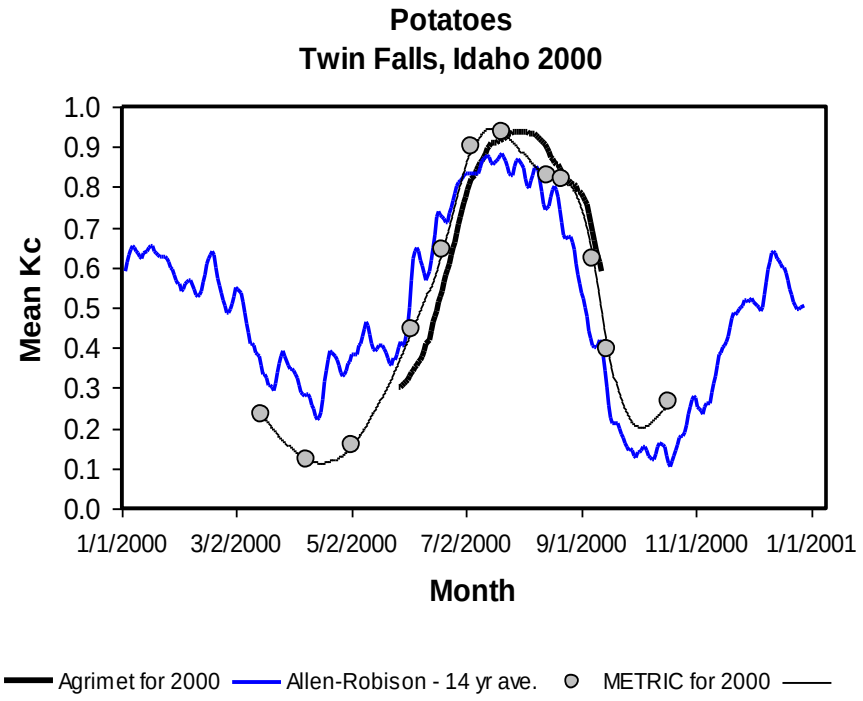


- **Returns:** Image of ETr/ETo (mm)
- Reference: Allen, R. G. et al. The ASCE Standardized Reference Evapotranspiration Equation. Reston, VA: American Society of Civil Engineers, 2005.

We Need a 30 – m SELFIE of Planet Earth DAILY

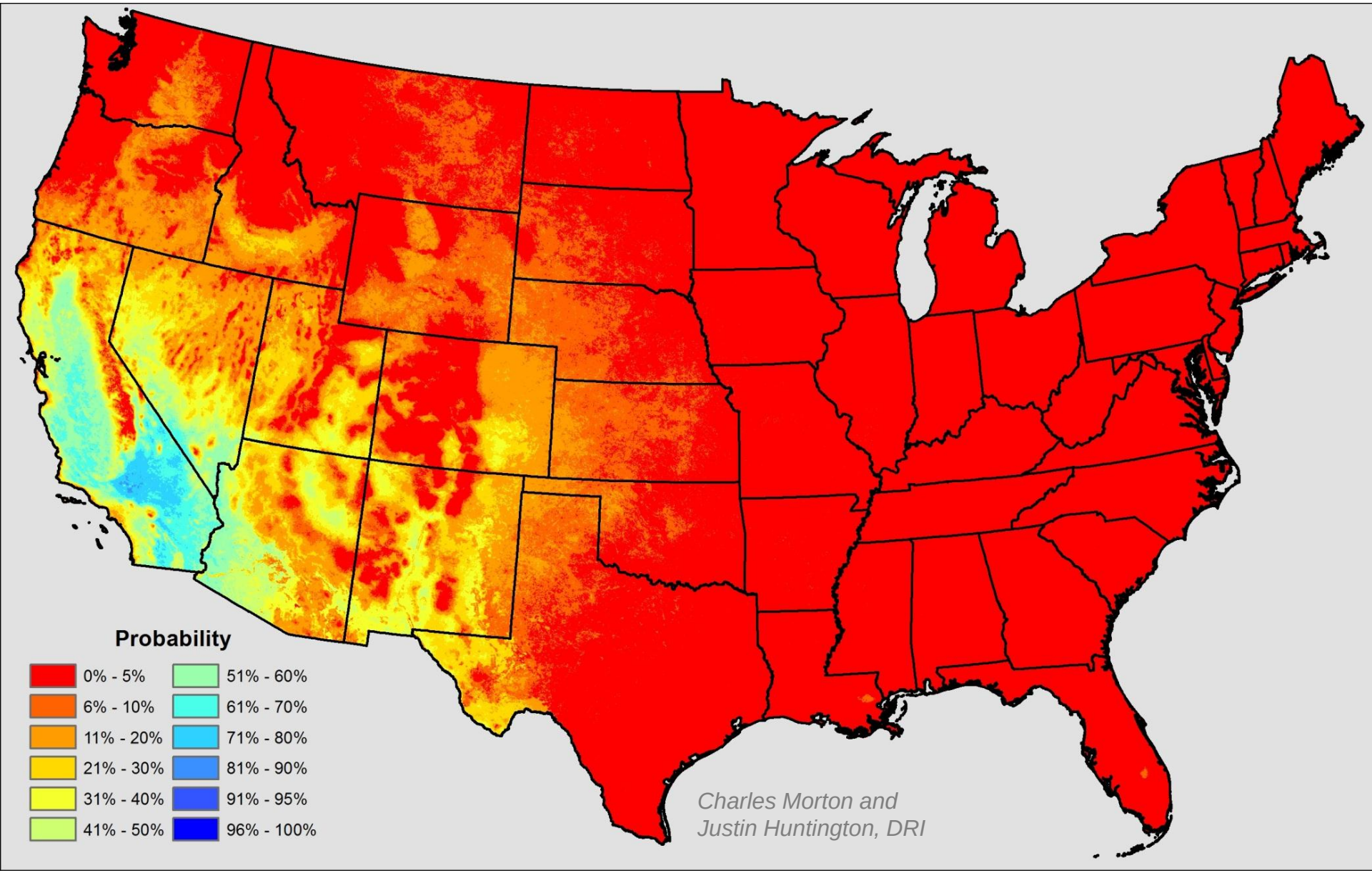
The impact of Number of Satellites (Revisit time) on estimating Water Consumption

- *For estimating ET over extended time periods, we would 'like' information for any one 'point' each 32 days (at a minimum) to follow evolution of vegetation and water availability*
- *For parcel scale ET mapping, this requires multiple Landsat-type satellites*



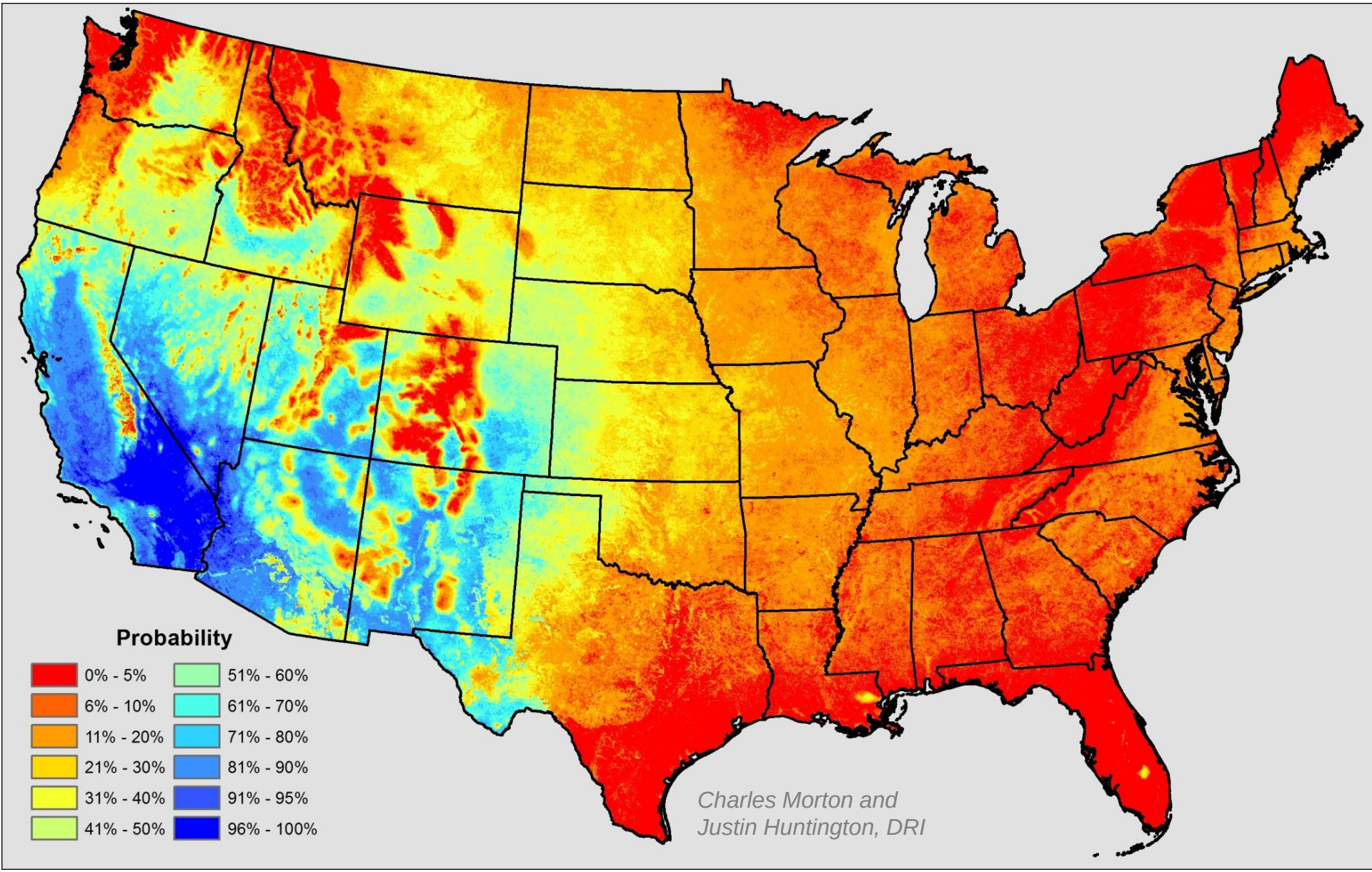
1 (180 km path) Landsat Satellite (each 16 days)

Probability of a Cloud-free Pixel at least every 32 days



2 Landsat Satellites (image each 8 days)

Probability of a Cloud-free Pixel at least every 32 days



3 Landsat Satellites (image each ~5 days)

Probability of a Cloud-free Pixel at least every 32 days

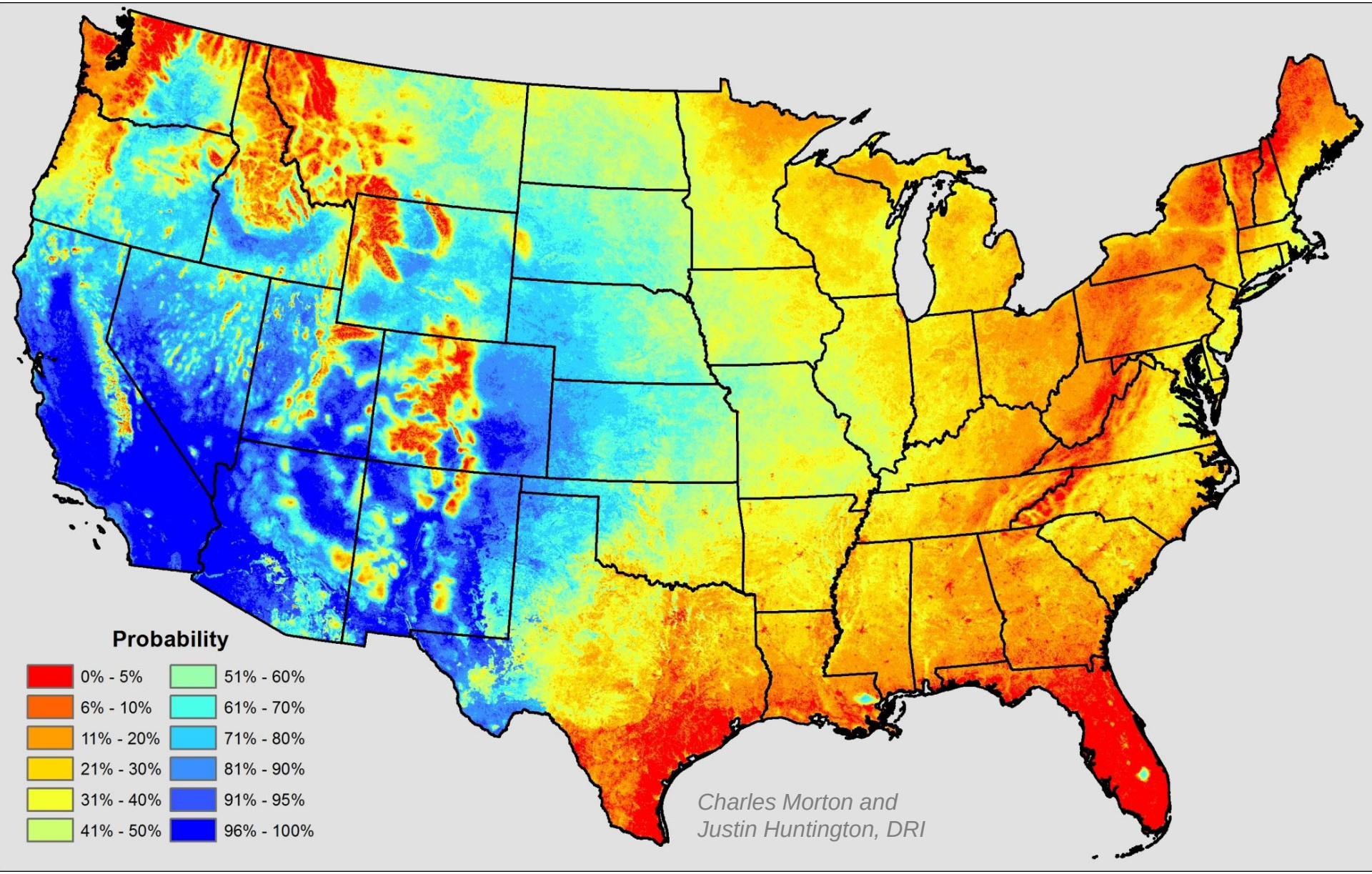


Image each 4 days -- Four 180 km Landsat Satellites or Two 360 km Landsat Satellites

Probability of a Cloud-free Pixel at least every 32 days

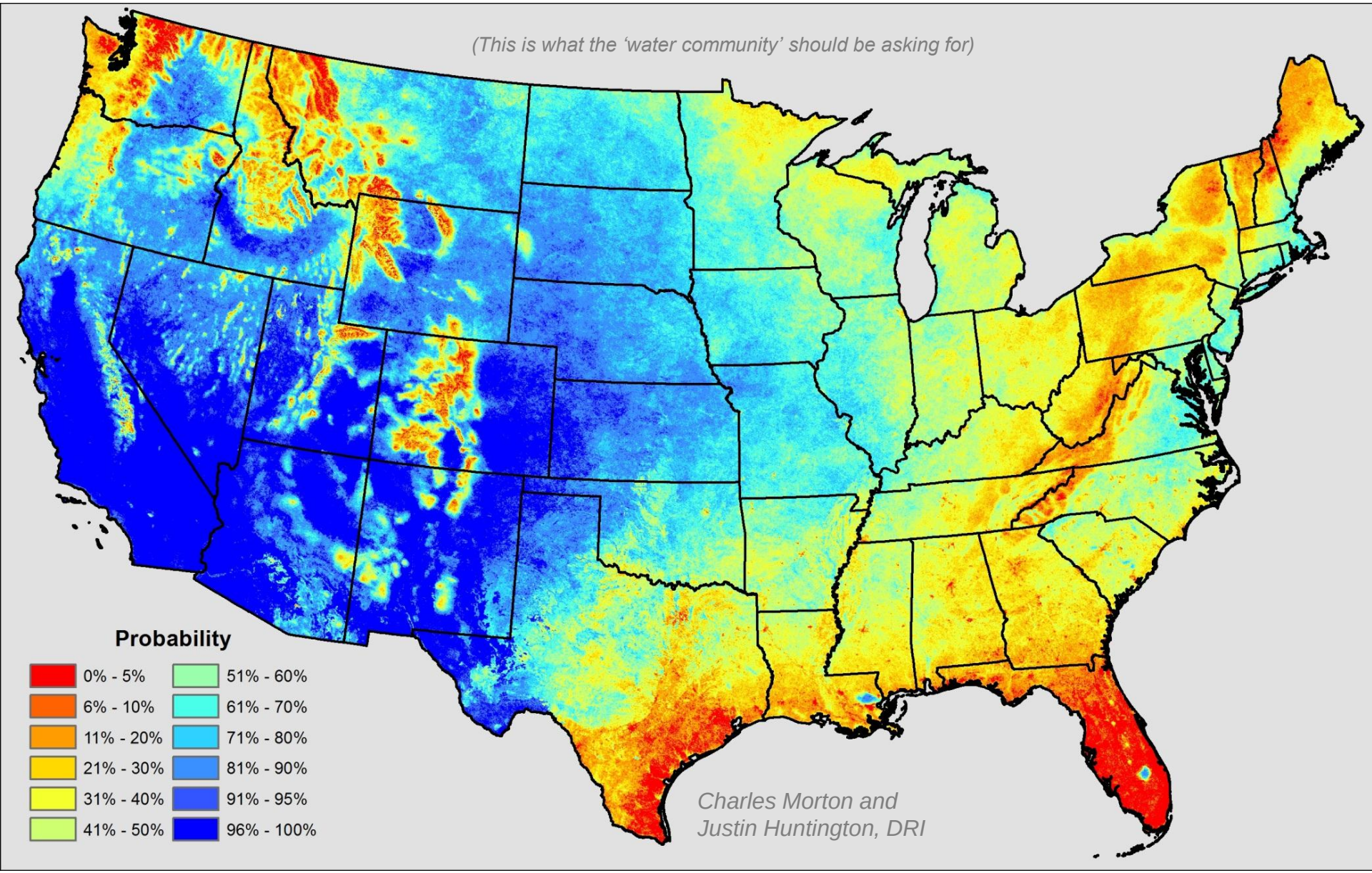
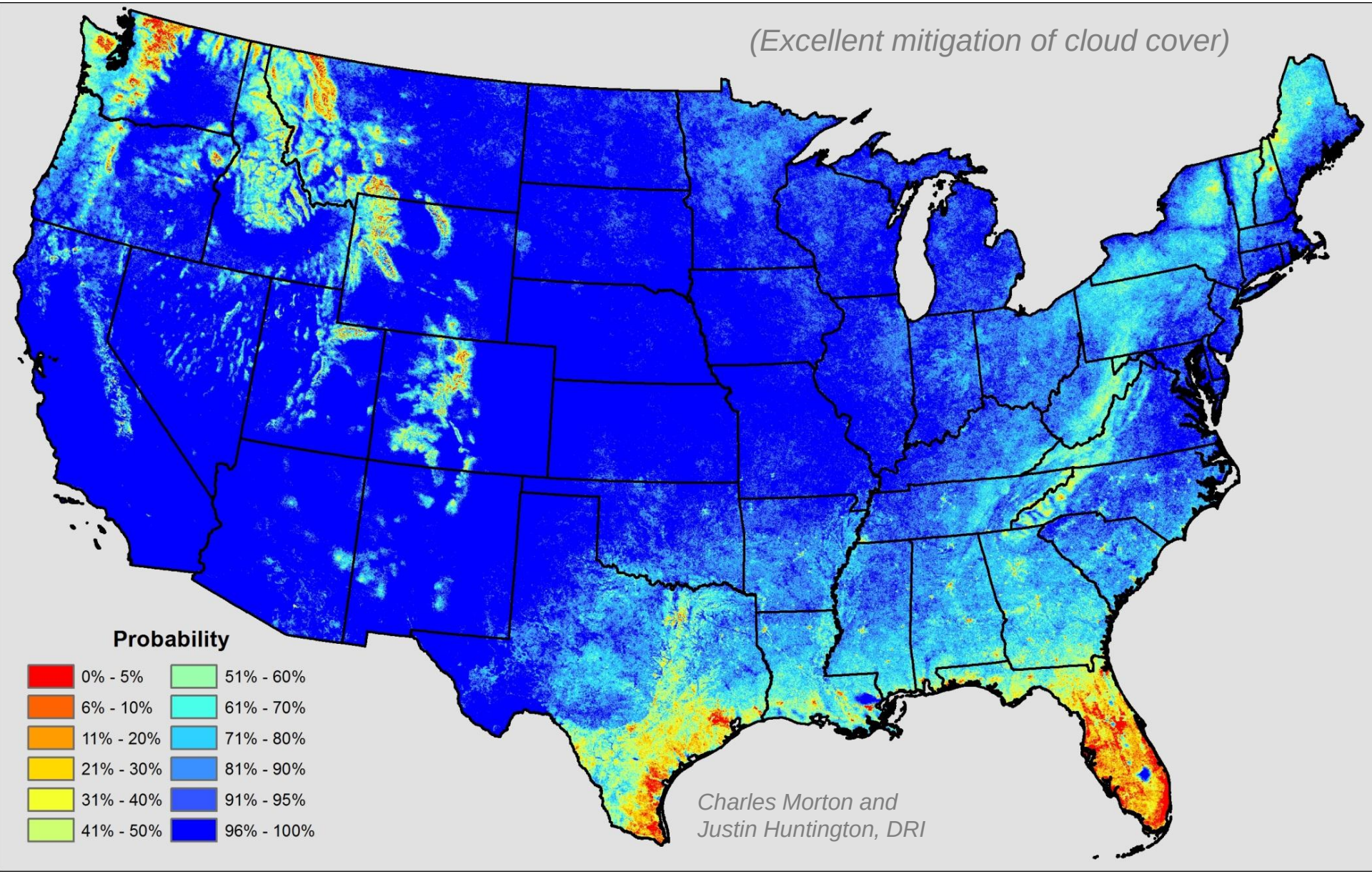


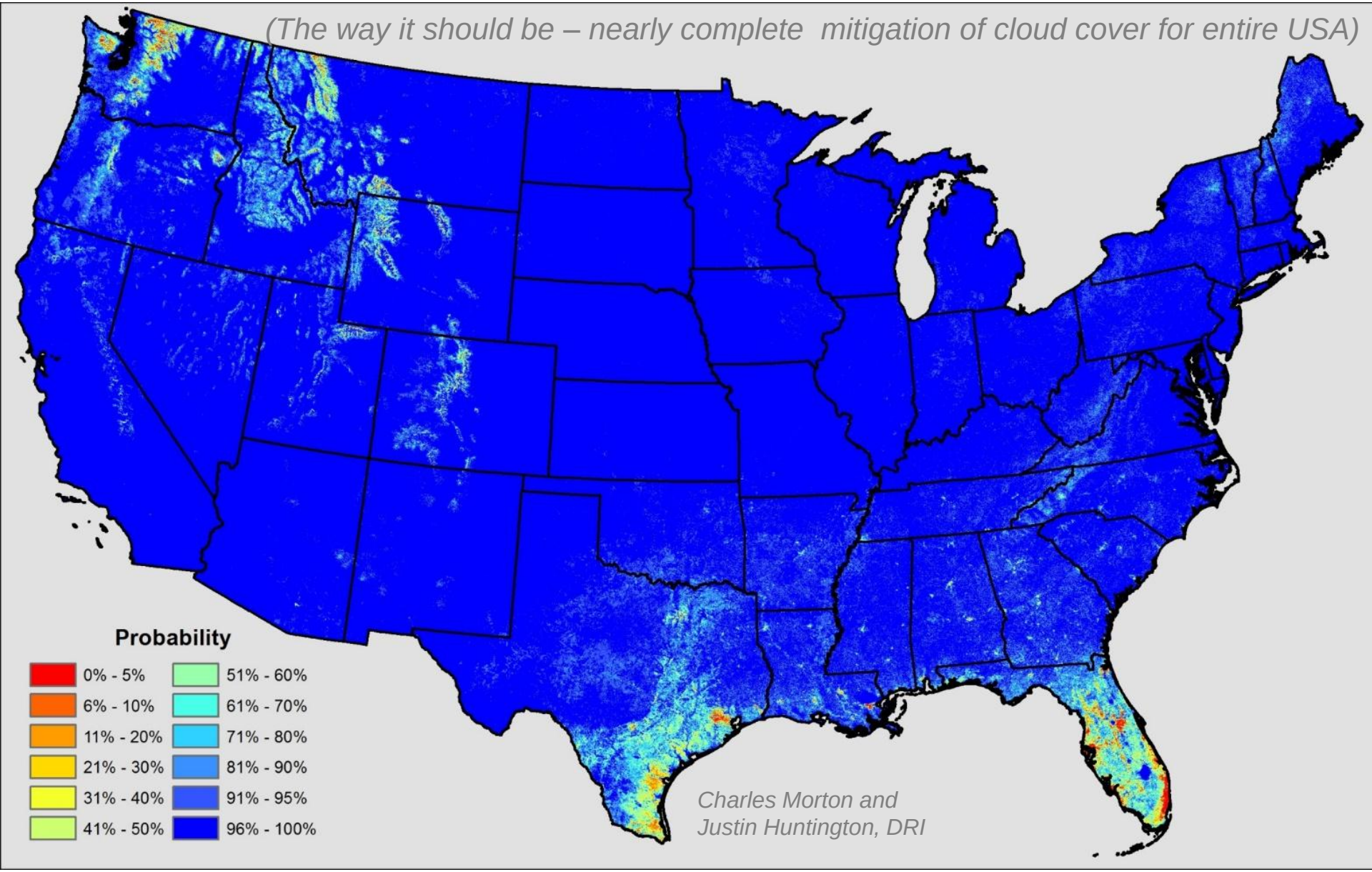
Image each 2 days – Eight 180 km Landsat Satellites or Four 360 km Landsat Satellites

Probability of a Cloud-free Pixel at least every 32 days



A daily **SELFIE** at 30 m -- 16 – 180 km Landsat Satellites or 8 – 360 km Landsat Satellites

Probability of a Cloud-free Pixel at least every 32 days

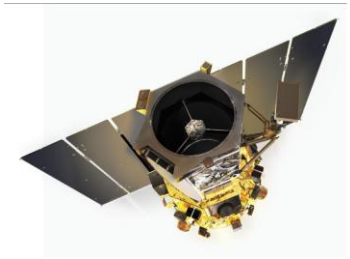


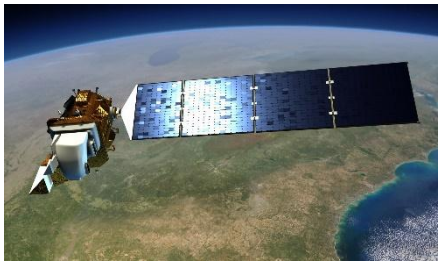
Why 30 m? (or 10 m or 20 m)

- 30 m provides enough detail for parcel – scale observations ---- The level of human impacts
  - agricultural fields
  - riparian systems
  - wetlands
- 30 m ‘blends’ very fine details such as shadows and individual vegetation into 30 m ‘blocks’ of blended impacts having intra-parcel definition
- 30 m pixel size is constrained by size, optics, accuracy and revisit time of satellite

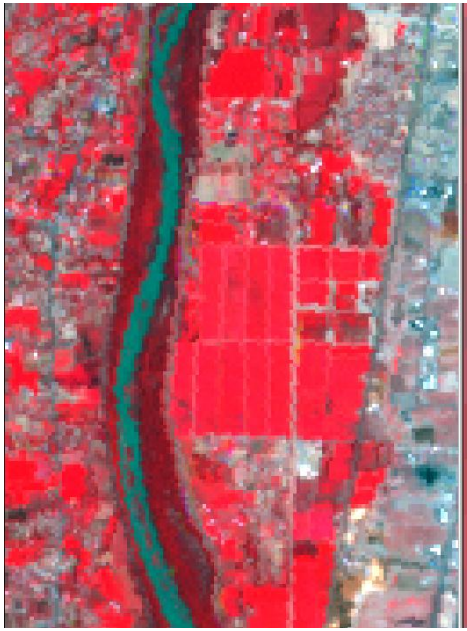
Matching Imaging with Impact Scale

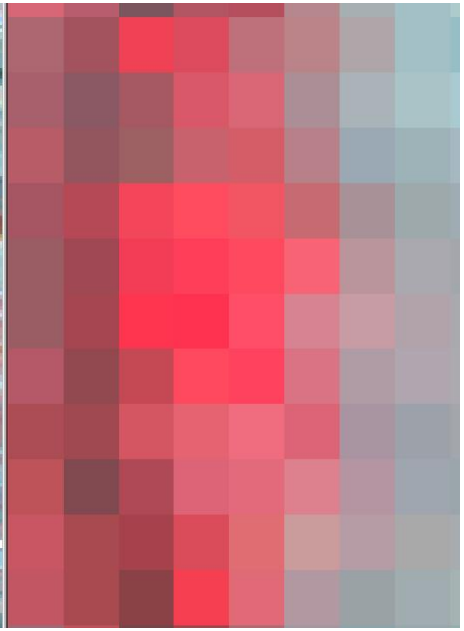
High resolution (< 10 m) imaging is highly valuable, but not necessary for high frequency mapping of evolutionary processes like vegetation growth and water consumption on 1) a parcel scale and 2) nationally or globally



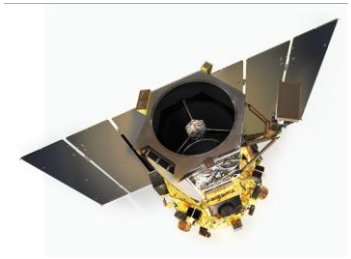


High Resolution intra-human impact scales	Landsat specific human impact scale	MODIS subregional / local scale





The Challenge for US Congress and others



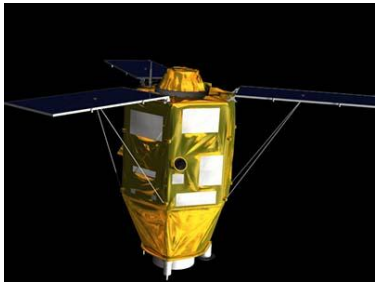
"Take me!"

"Take me!"

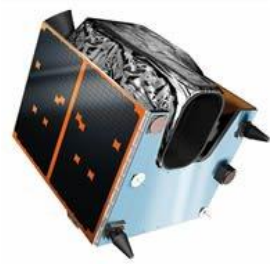
"No, Take me!"

"No, Take me!"

"Take me!"



"No, Take me!"



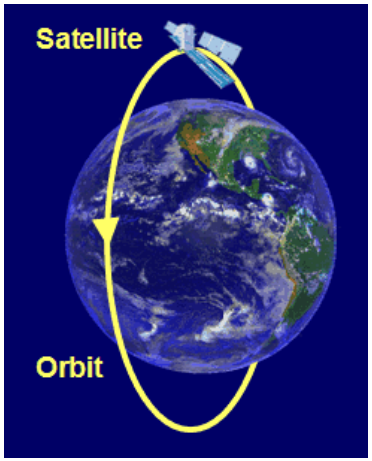
"Take me!"

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

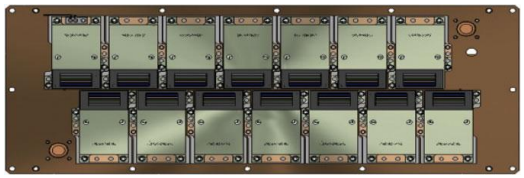
X

Satellite Orbit time = 98.9 minutes for L8



= 16 days for 1 sat.

or 16 satellites for daily



X

X 24 X 60

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

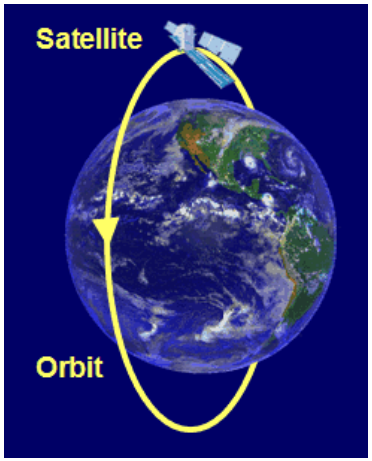
Swath Width of Satellite

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

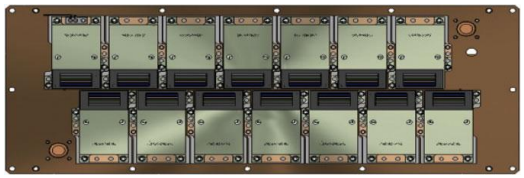
X

Satellite Orbit time = 98.9 minutes for L8



= 48 days for 1 sat.

or 48 satellites for daily



X

X 24 X 60

constrained by telescope size and signal to noise ratio req.

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

Pixel size = 10 m

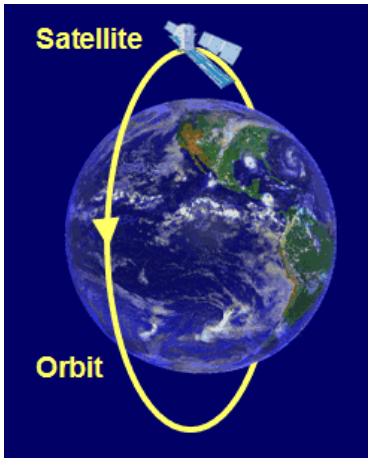
Swath Width of Satellite

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

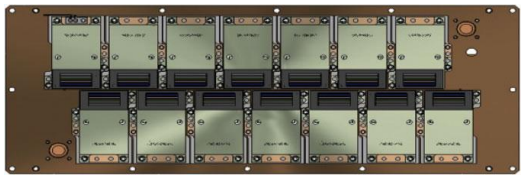
X

Satellite Orbit time = 98.9 minutes for L8



= 480 days for 1 sat.

or 480 satellites for daily



X

X 24 X 60

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

Cost - three coffee-lattes per American per year

= $15 billion over 10 years

= 16 Landsats per 10 years

A Dream for 30 meter Imaging every Day

I have a Dream today.

Where all of God's children, black and white,
Asian and African, American and Australian,
See their Earth, EVERY changing day,
in all its living and dynamic colors and transformations.

I have a Dream today,

where EVERY field of lettuce and EVERY patch of forest and EVERY patch of ice sheet and EVERY small pond of water
are seen and examined and monitored and managed EVERY day.

I have a Dream today,

A Dream for 30 meter Imaging every Day

I have a Dream today,

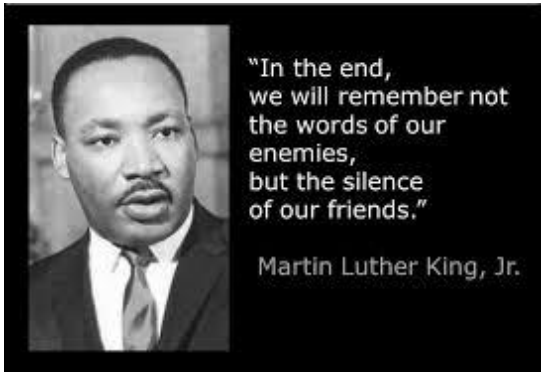
Where we do not have ONE Landsat, not TWO Landsats, but EIGHT and SIXTEEN Landsats,

Where we do not SUFFER from lack of knowledge,
where we do not SUFFER in our management of our Earth's precious resources,
where we do not SUFFER because we DO NOT have a view of ourselves.

I have a Dream today,

Where EVERY DAY, our Earth has its own Landsat SELFIE.

Yes, Let's all have this Landsat DREAM TODAY.



"No, no, we are not satisfied, and we will not be satisfied until justice rolls down like waters and righteousness like a mighty stream." M.L. King. 1963.