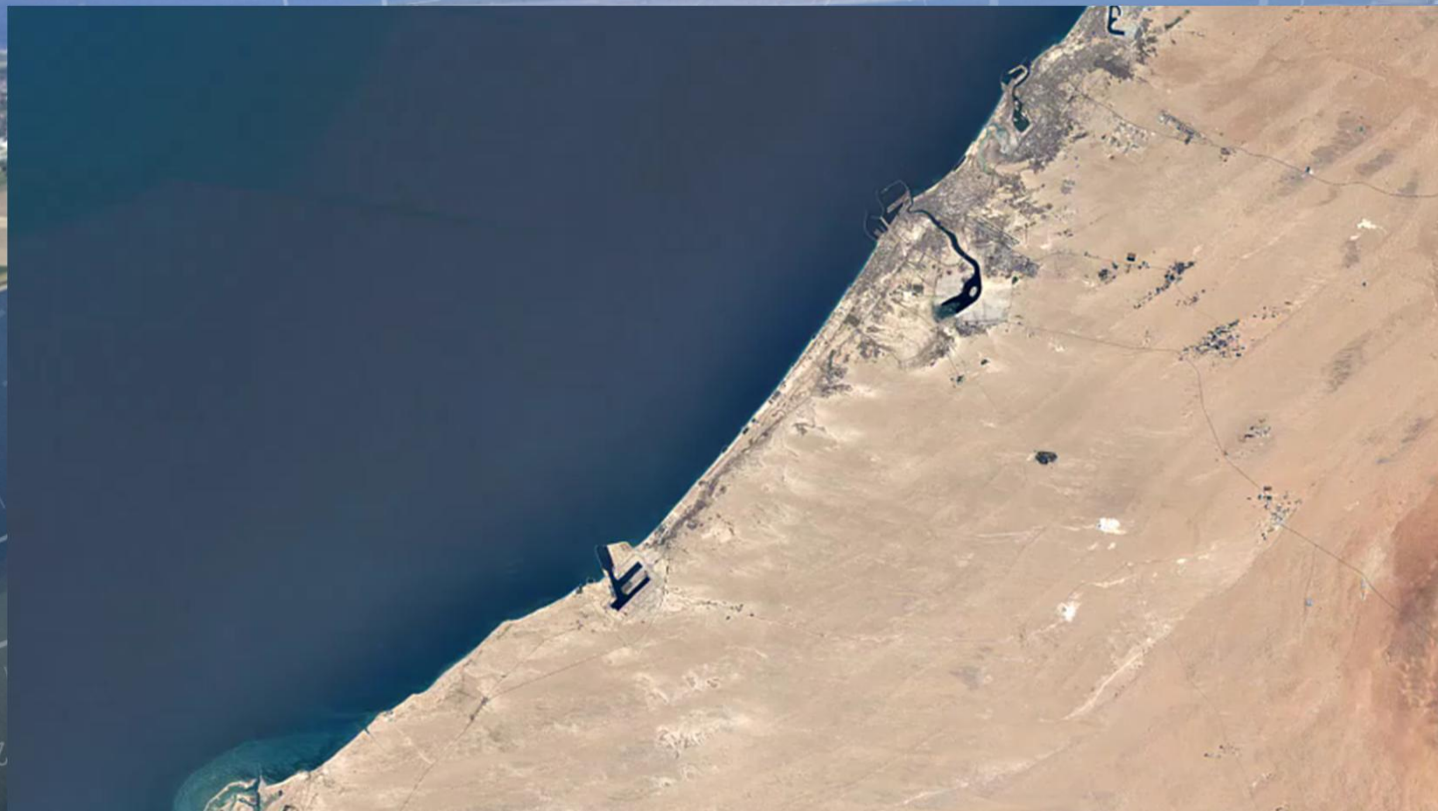


Google Earth Engine Workshop

Gennadii Donchyts

Deltares

Resolutions

Temporal: months to seconds
Spatial: 1km to 1m
Spectral: 3-15 bands
Radiometric: 8 → 16bit

Coverage

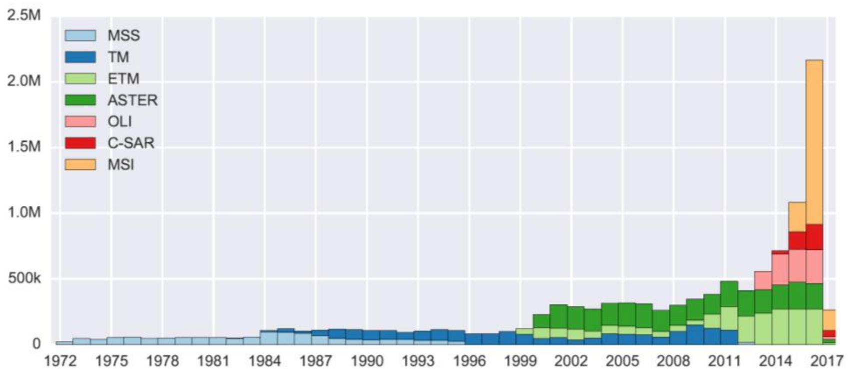
Local → Global

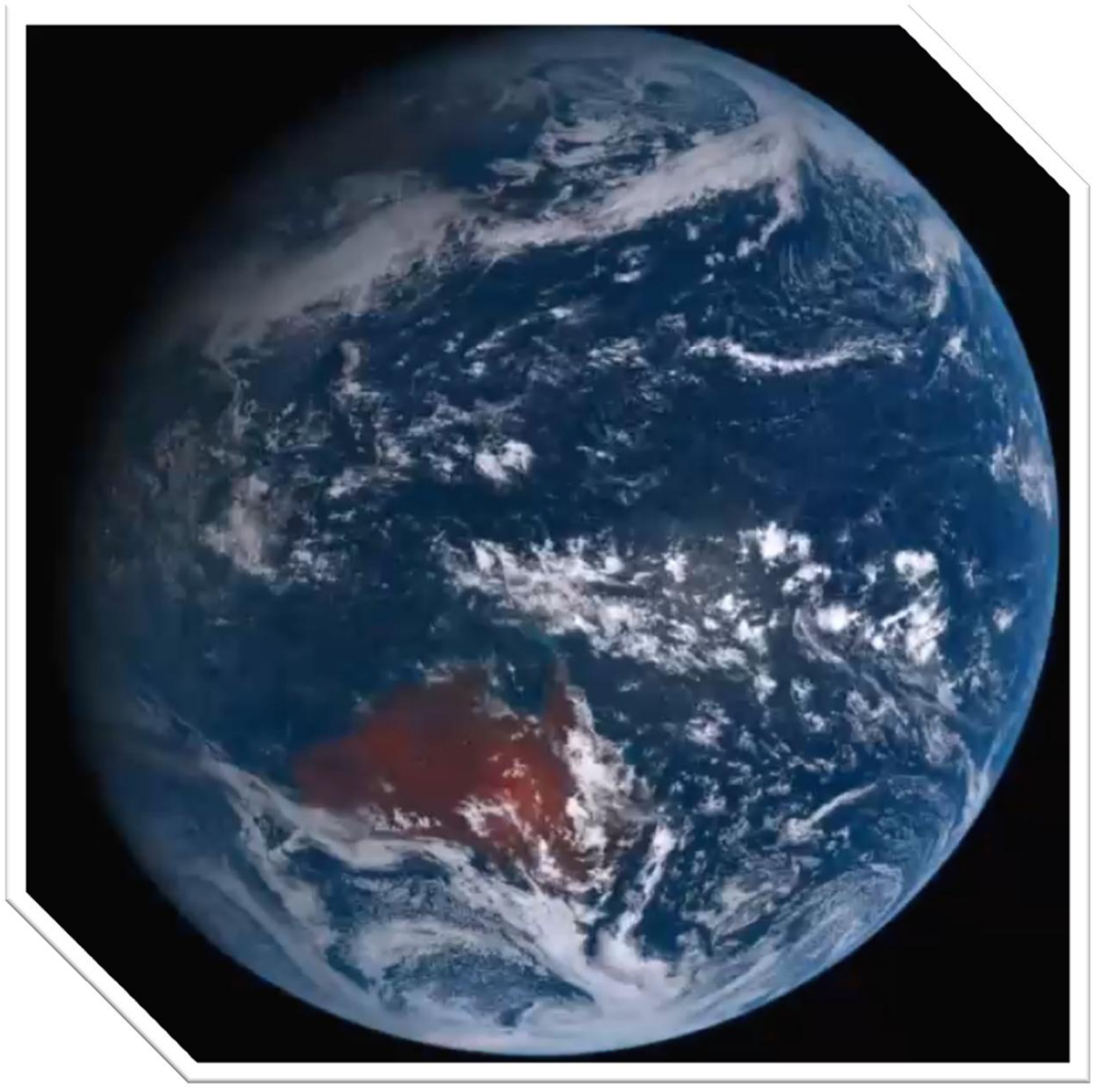
Volumes

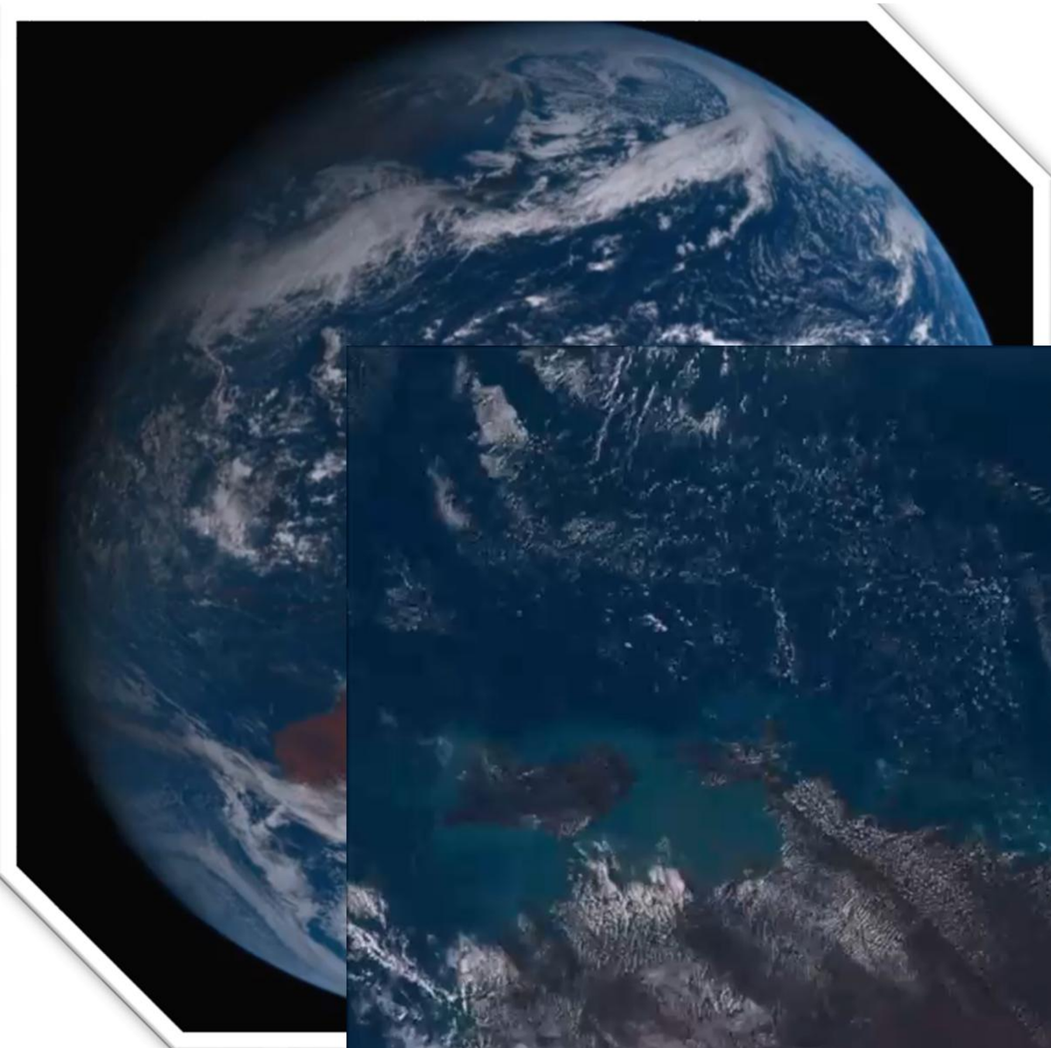
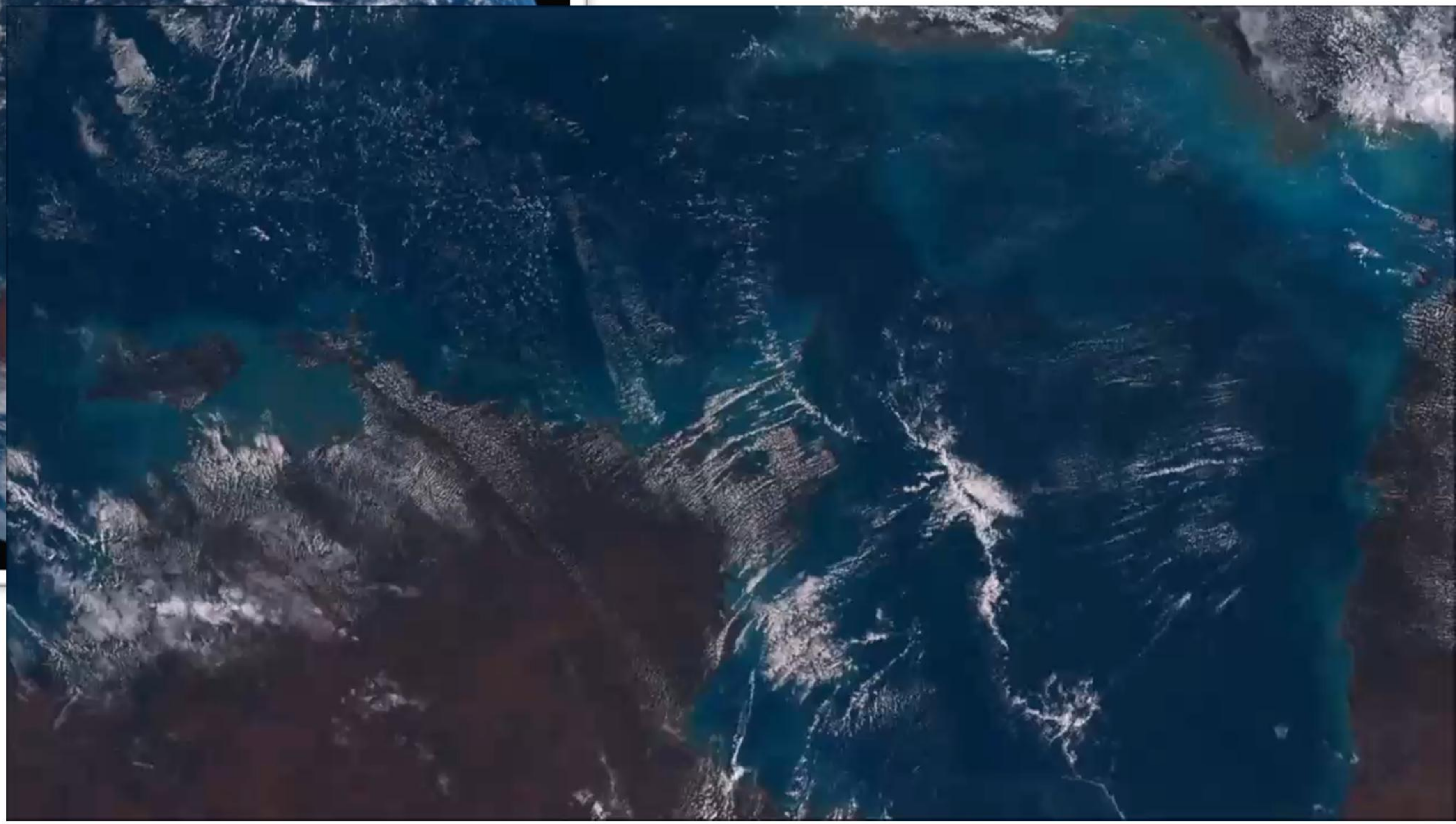
100 MB → 10 000 000 000 MB

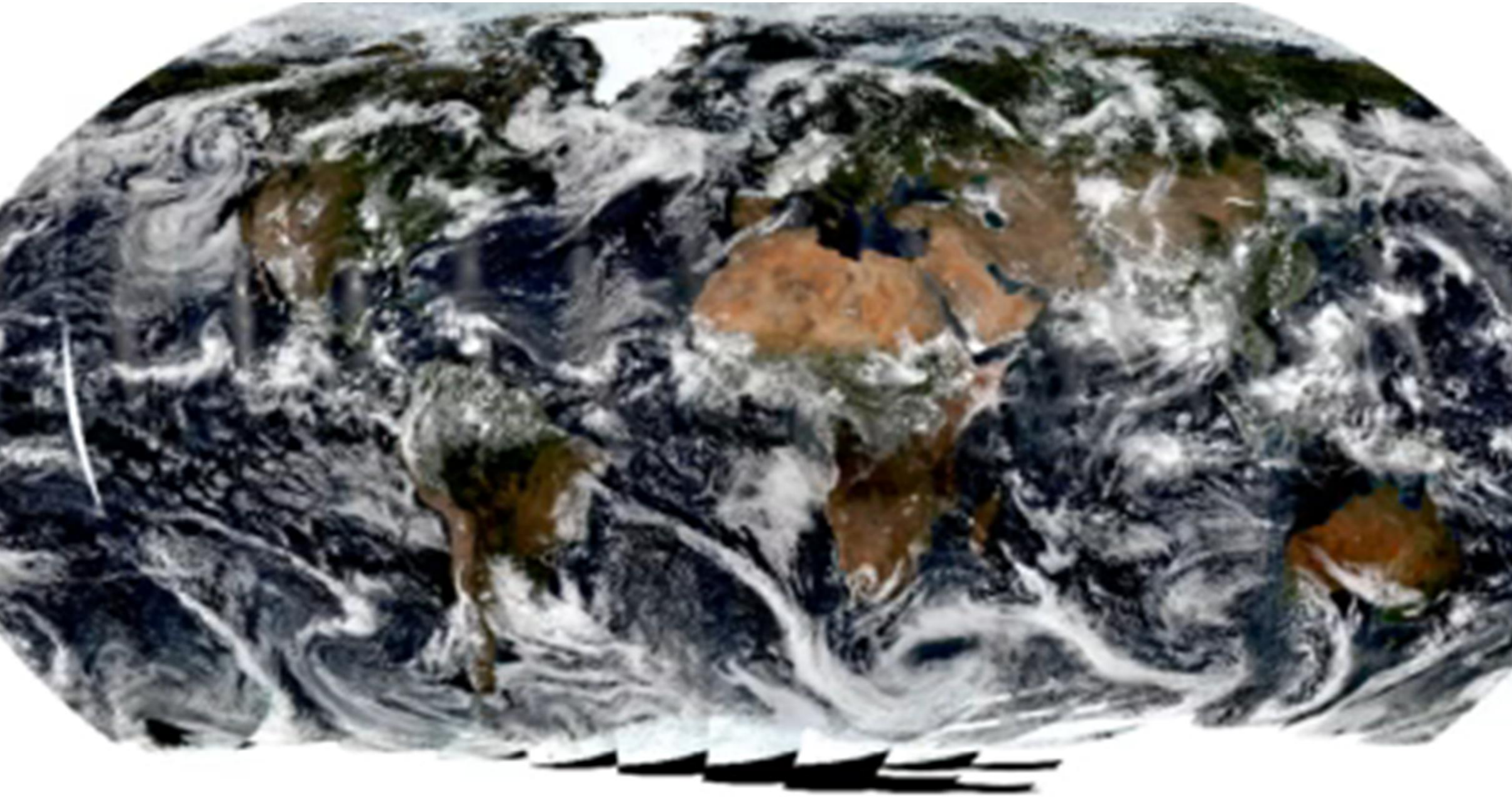
Availability

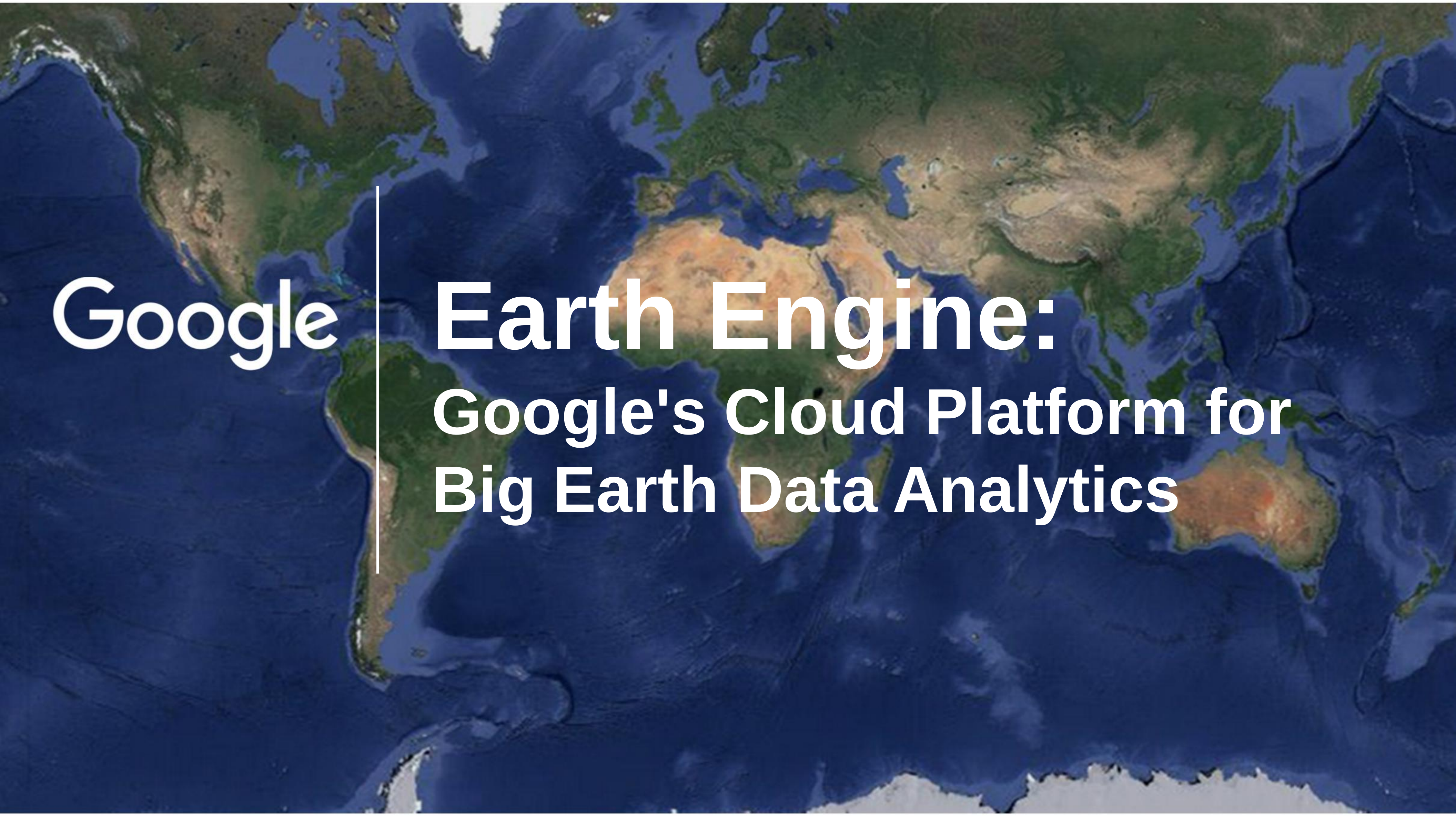
~2PB satellite images, <30m







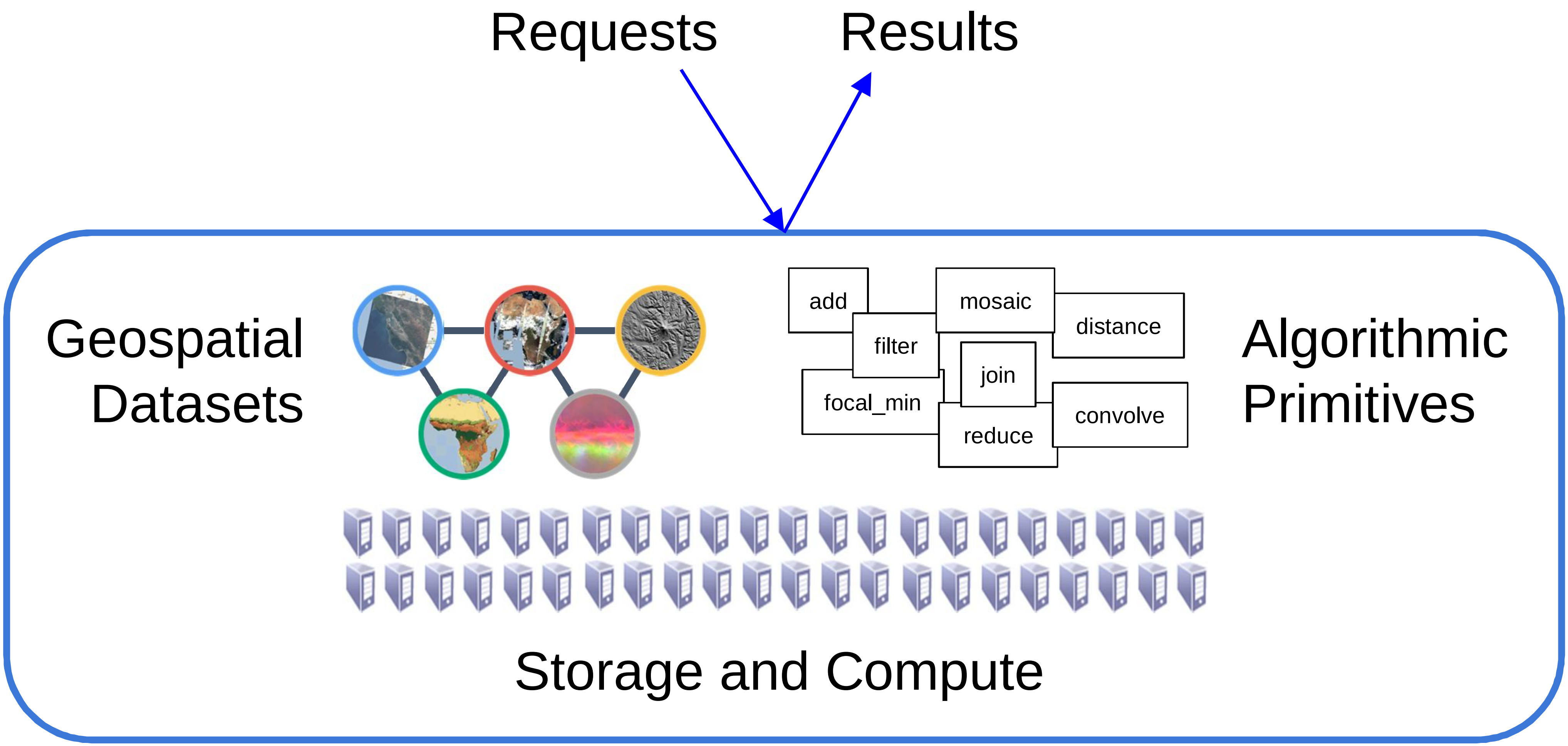

Google
Earth Engine:
Google's Cloud Platform for
Big Earth Data Analytics

Google Earth

3-D Globe Visualization

Earth Engine

Geospatial Analysis


Requests
Results
Geospatial Datasets
add
mosaic
distance
filter
join
focal_min
convolve
reduce
Algorithmic Primitives
Storage and Compute

The Earth Engine Public Data Catalog

Landsat 4, 5, 7, 8
Raw, TOA, SR, ...

MODIS
Daily, NBAR, LST, ...

Terrain
SRTM, GTOPO, NED, ...

Land Cover
GlobCover, NLCD, ...

Atmospheric
NOAA NCEP, OMI, ...

... and many more, updating daily!

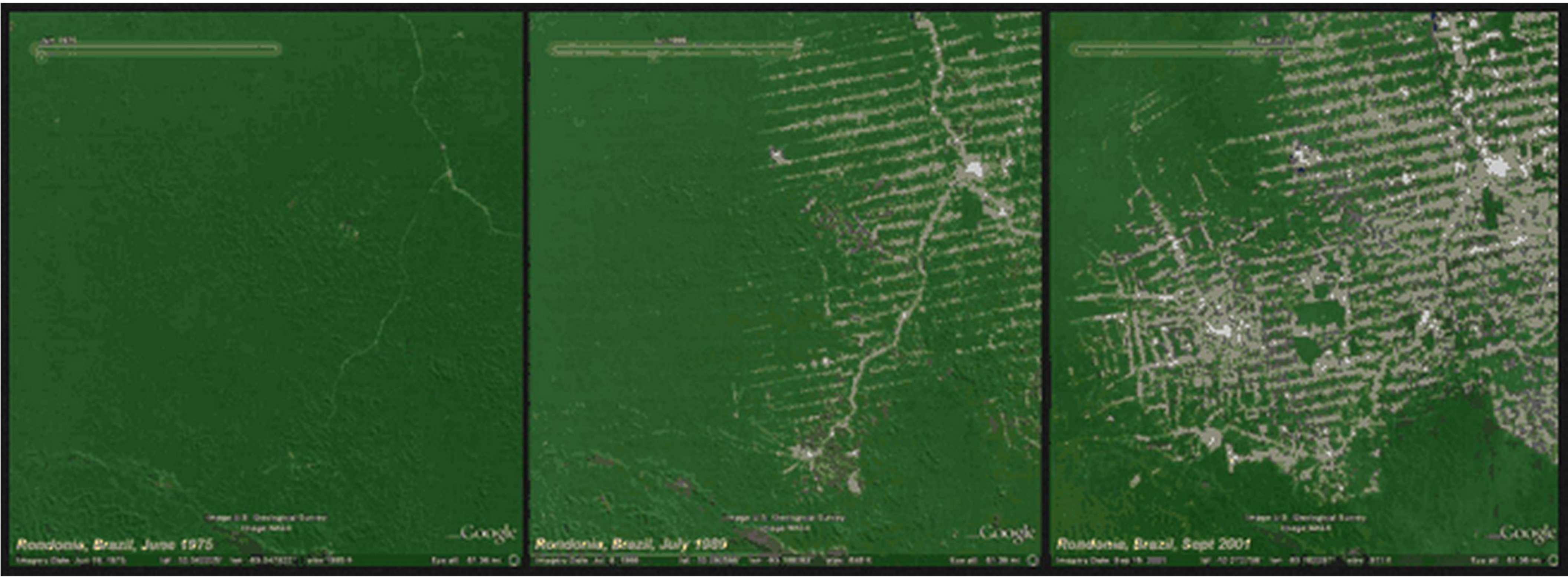
> 200 public datasets

> 5 million images

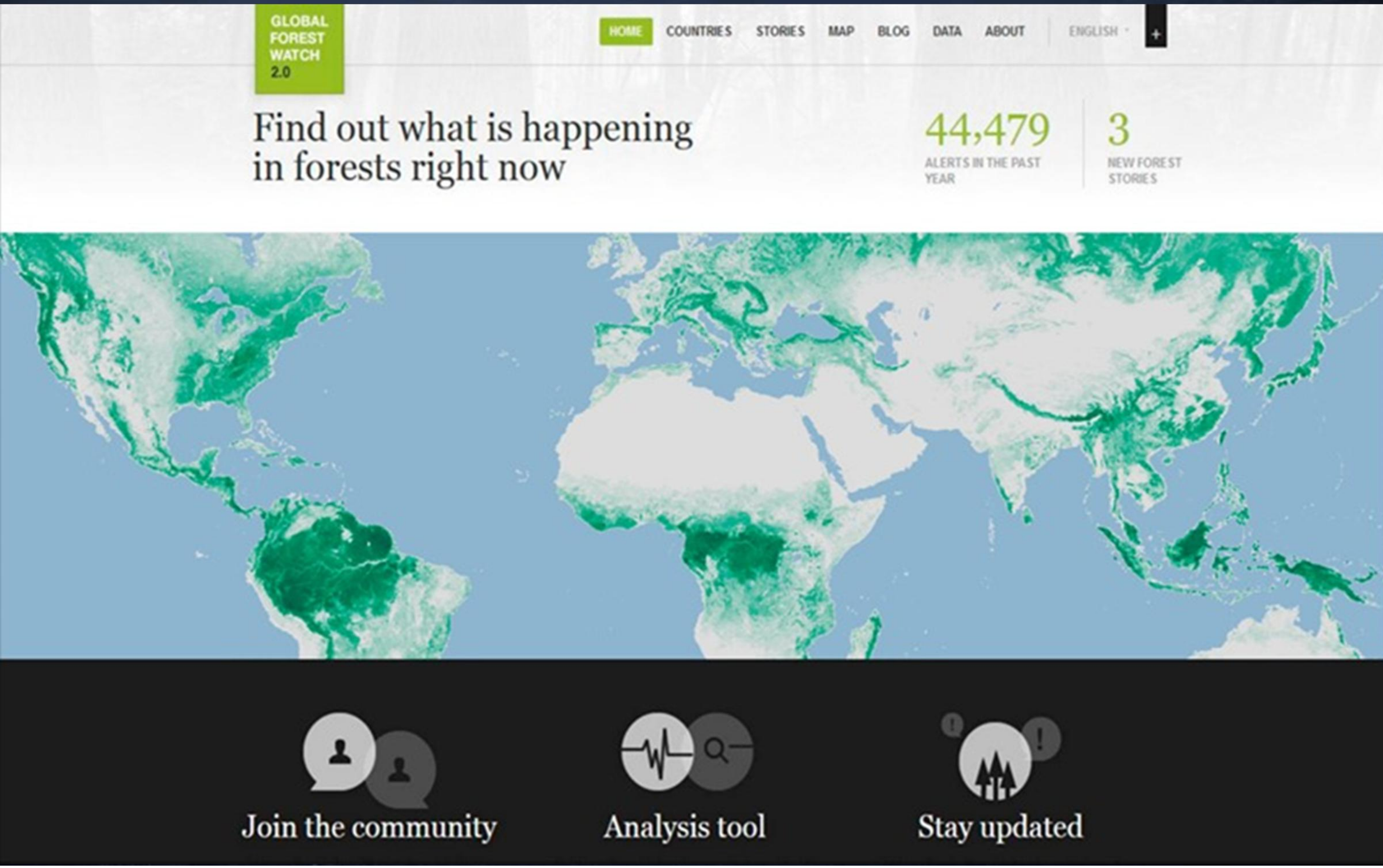
> 4000 new images every day

> 5 petabytes of data

Earth Engine: Origins



Global Forest Watch



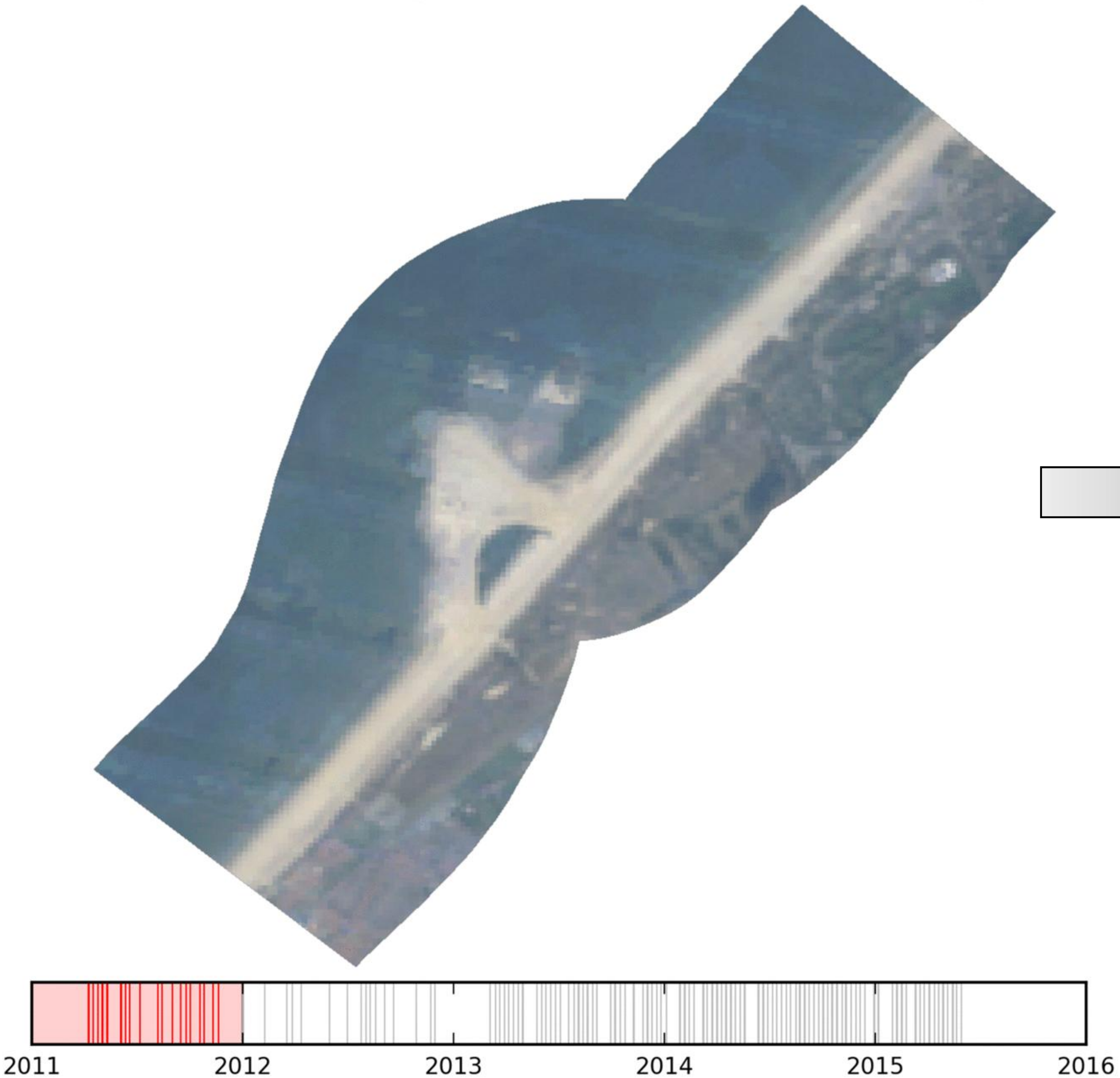
JavaScript & Python API

```
// Make a median composite from two years of Landsat 7.

// Load the image collection.
var collection = ee.ImageCollection('LANDSAT/LE7_L1T');

// Filter it down to 2011 and 2012.
var filtered = collection.filterDate('2011-01-01', '2012-12-31');

// For each pixel, for each band, calculate the median and make an image
// of the result. The median tends to remove clouds, shadows, data gaps.
var medianImage = filtered.median();

// Add the image to a map.
Map.addLayer(medianImage, {bands:['B3', 'B2', 'B1'], min:35, max:170});
```

Code Editor link:
https://code.earthengine.google.com/d7e0877fe7ad644bd6b50e6843150469

Coastline Extraction – Zandmotor

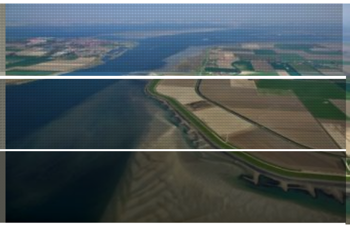
Zandmotor [2011/01/01 to 2012/01/01]



Deltares

Contact: josh.friedman@deltares.nl

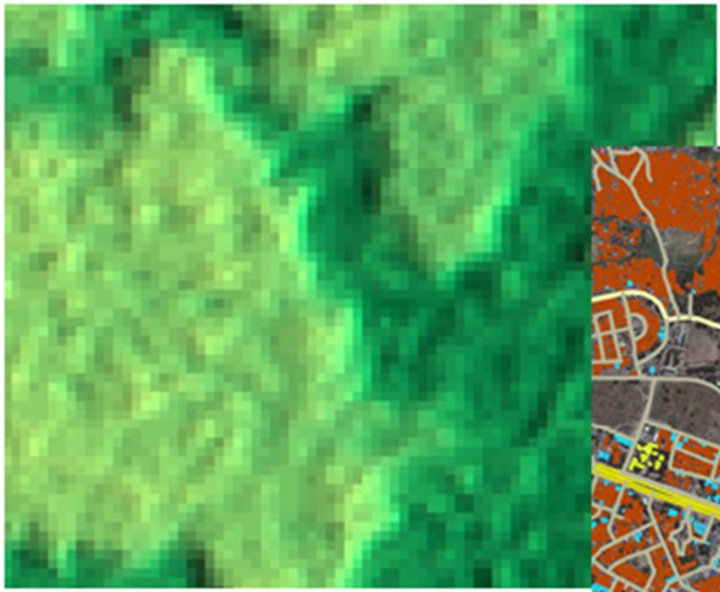
Participatory DEM generation

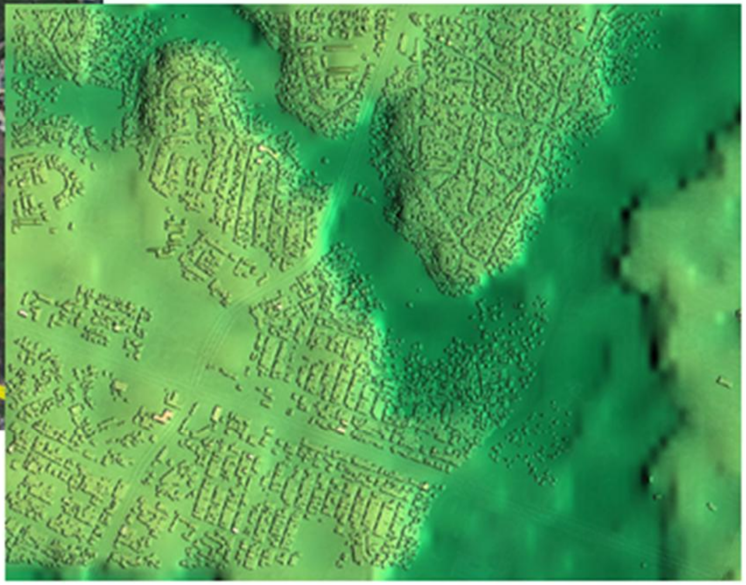


SRTM 30m

OSM data

SRTM + OSM fusion
=
HighRes Digital Surface Model





Deltares Enabling Delta Life

THE WORLD BANK

VU UNIVERSITY AMSTERDAM

Nelen & Schuurmans

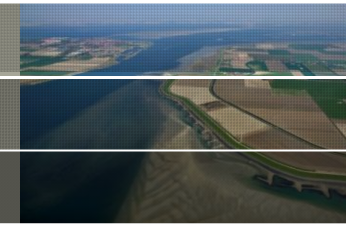
The Netherlands Red Cross

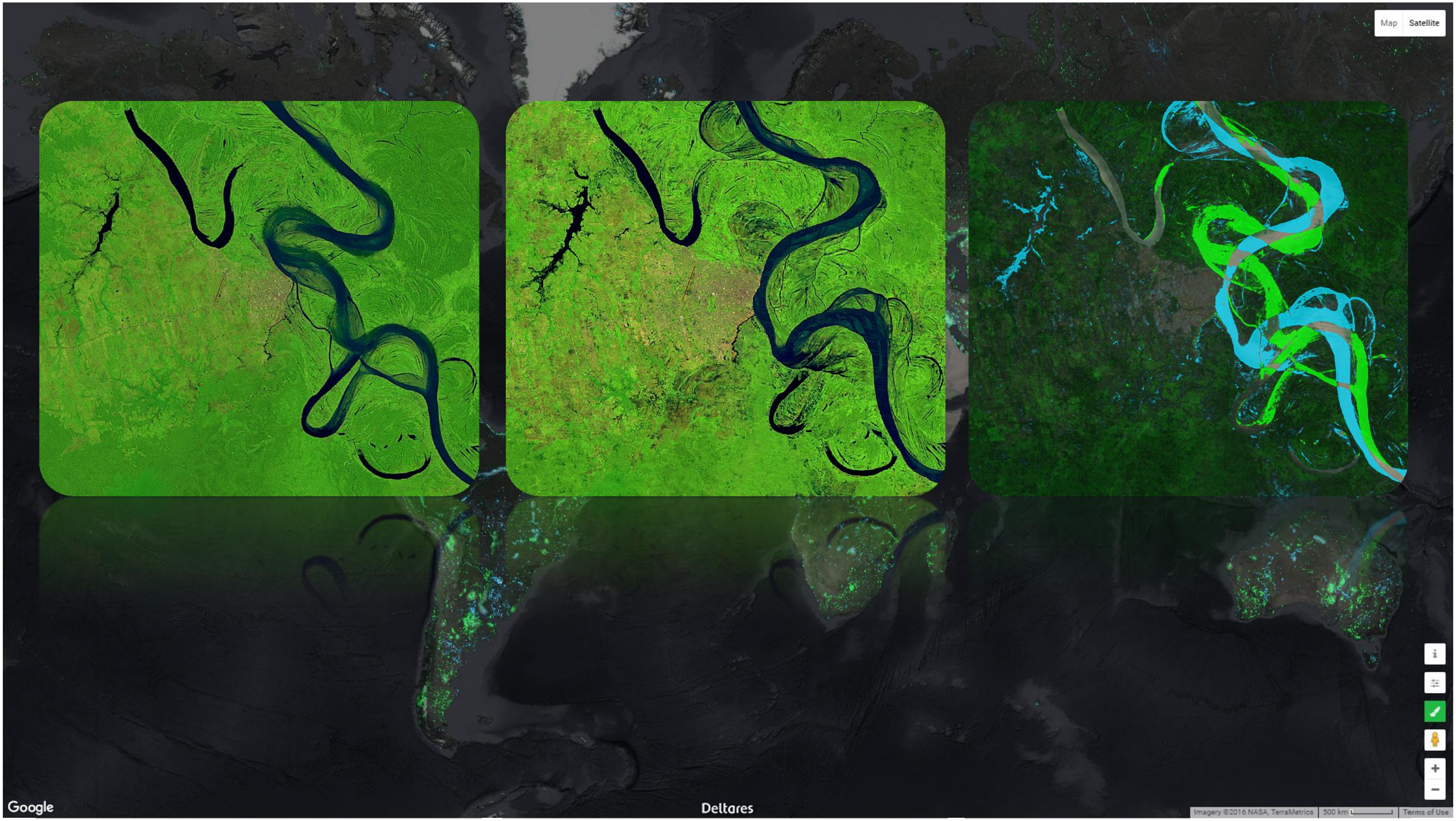
RED CROSS RED CRESCENT CLIMATE CENTRE

Deltares

Contact: hessel.winsemius@deltares.nl

Aqua Monitor

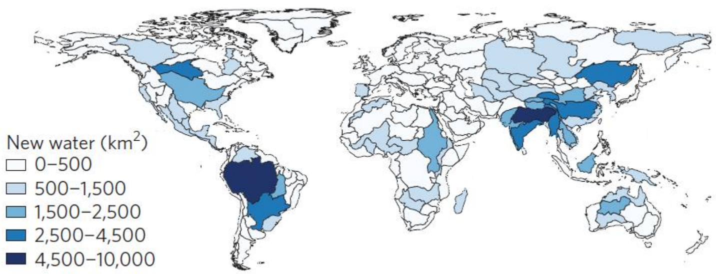




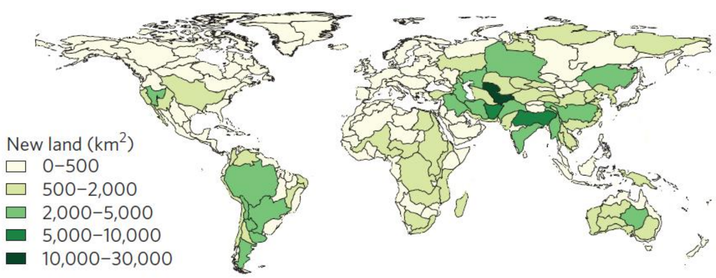
http://aqua-monitor.appspot.com

Deltares

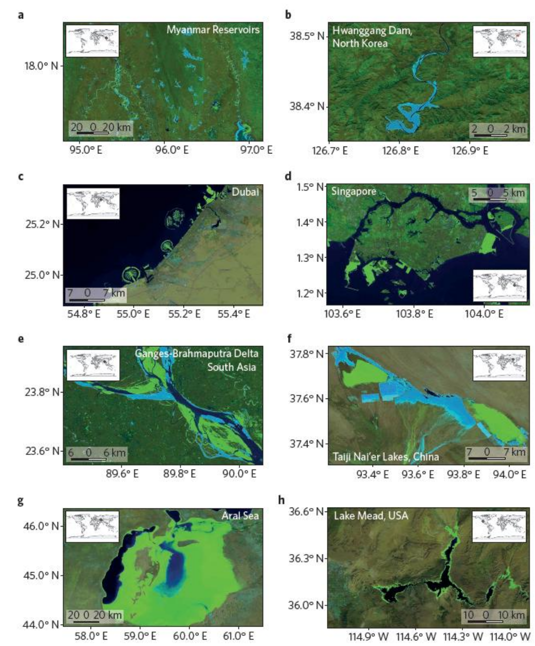
Aqua Monitor



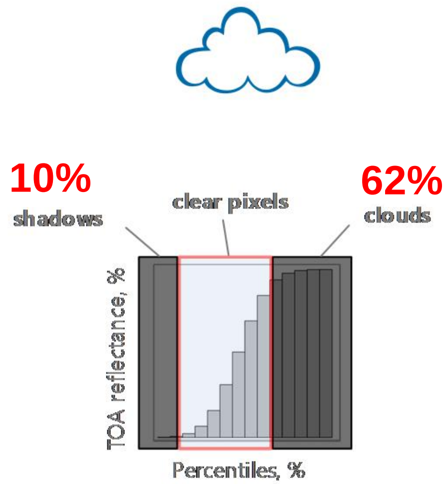
Name	Area (km^2)
Tibetan Plateau	7,661
Amazon River	7,058
Ganges-Brahmaputra Rivers	5,495
Rio de la Plata	4,410
River Nelson	4,101
India	3,677
River Amur	3,494
Yangtze River	3,238
Tigris and Euphrates Rivers	2,636
Thanlyin; Sittang; Ayeyarwady	2,592
Indus River	2,312
Mississippi River	2,231
Mekong River	2,074



Name	Area (km^2)
Aral Sea	27,841
Meghna River	9,580
Hamun Lake	6,044
Tigris and Euphrates Rivers	4,897
Amazon River	4,888
Lake Eyre	4,672
Rio de la Plata	4,020
India	3,851
Lake Urmia, Caspian Sea	3,759
Great Salt Lake; Malheur Lake	3,752
Ural River	3,455
Amur River	3,344
Ob River	3,068



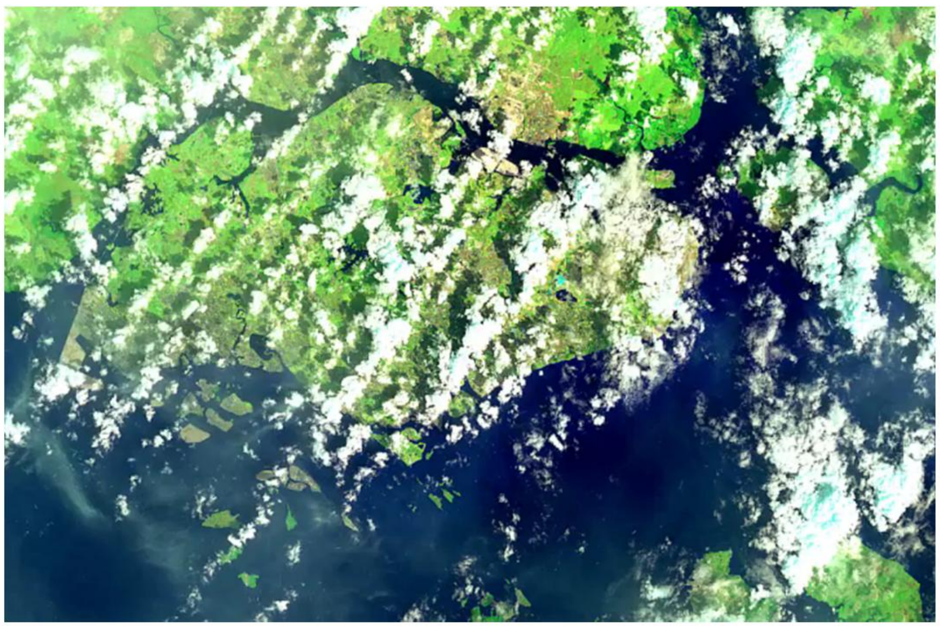
Donchyts et. al. 2016, http://nature.com/nclimate/journal/v6/n9/full/nclimate3111.html

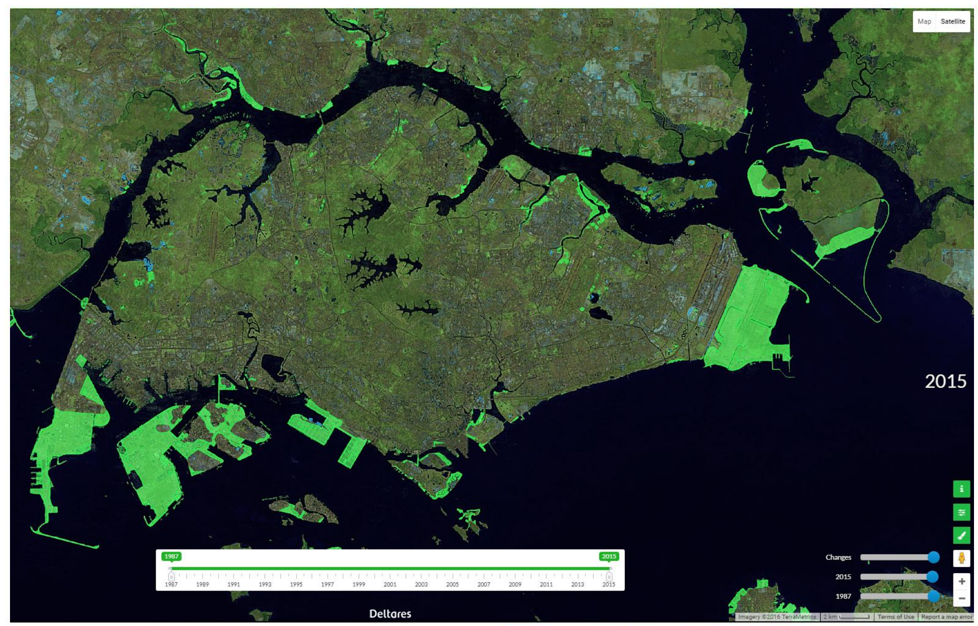


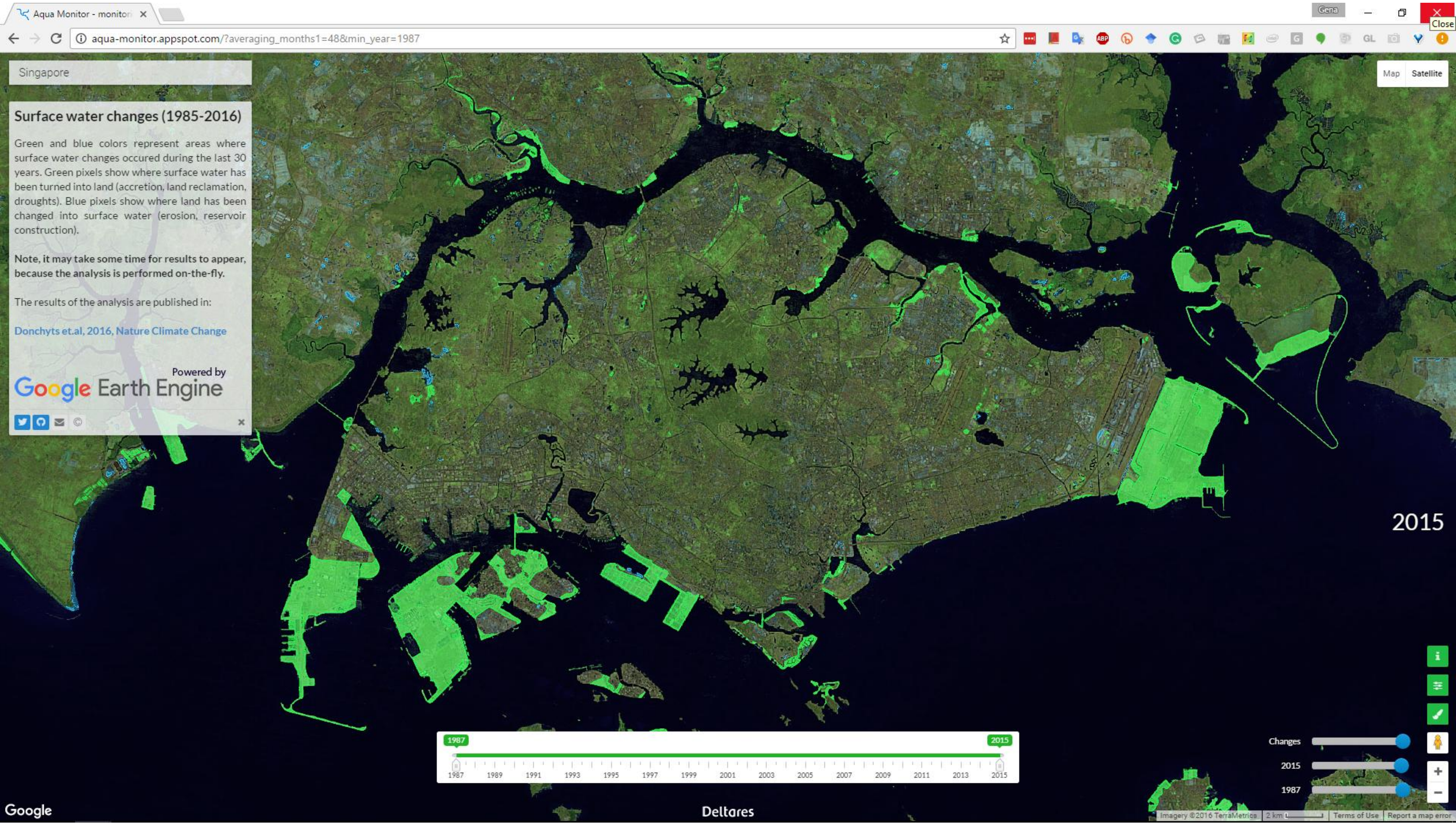
$$F(\rho) = \int_{-\infty}^{\rho^i} P(\rho)\,d\rho$$

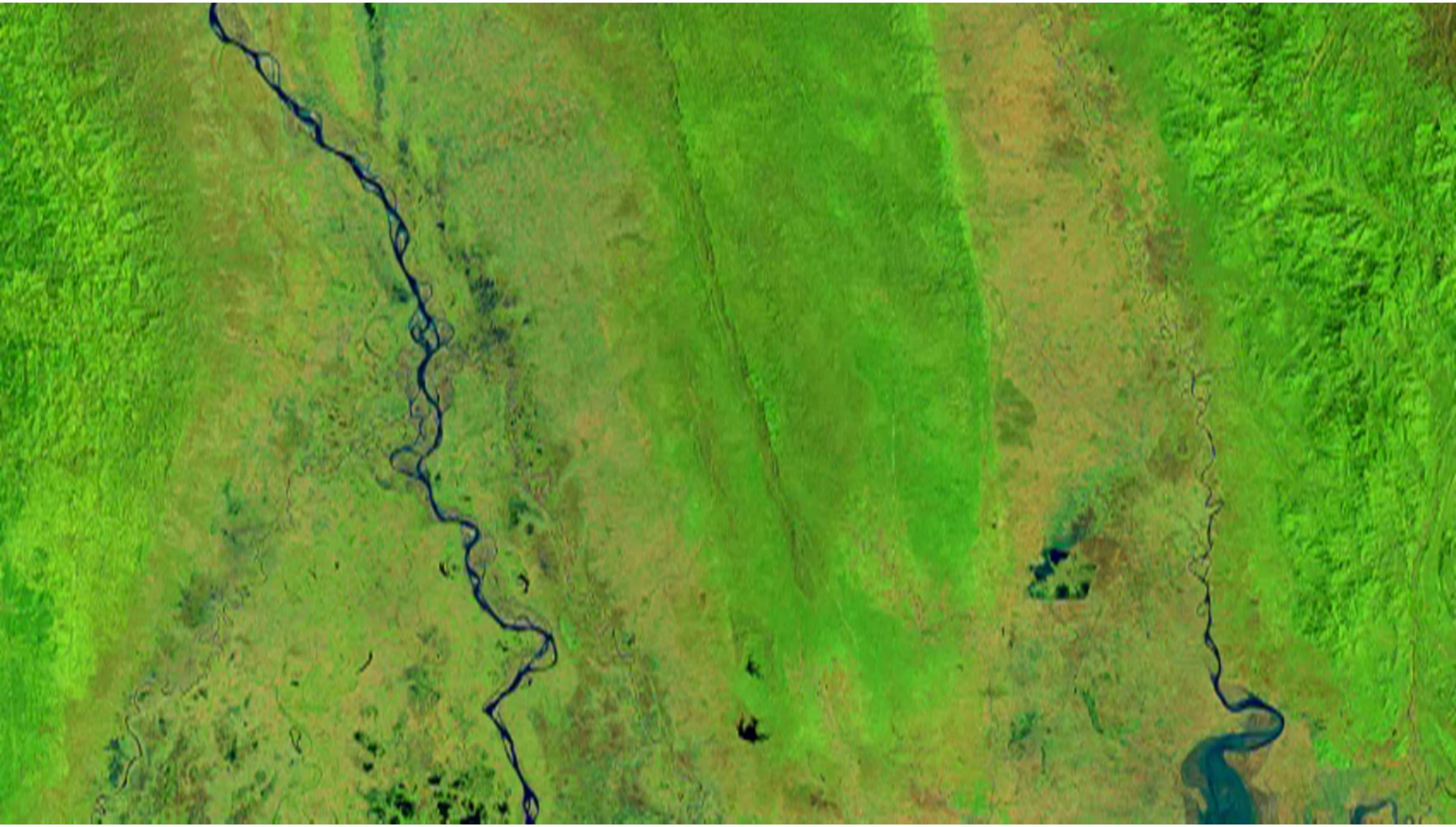
$$I = \frac{\rho^i_{green} - \rho^i_{nir}}{\rho^i_{green} + \rho^i_{nir}}$$

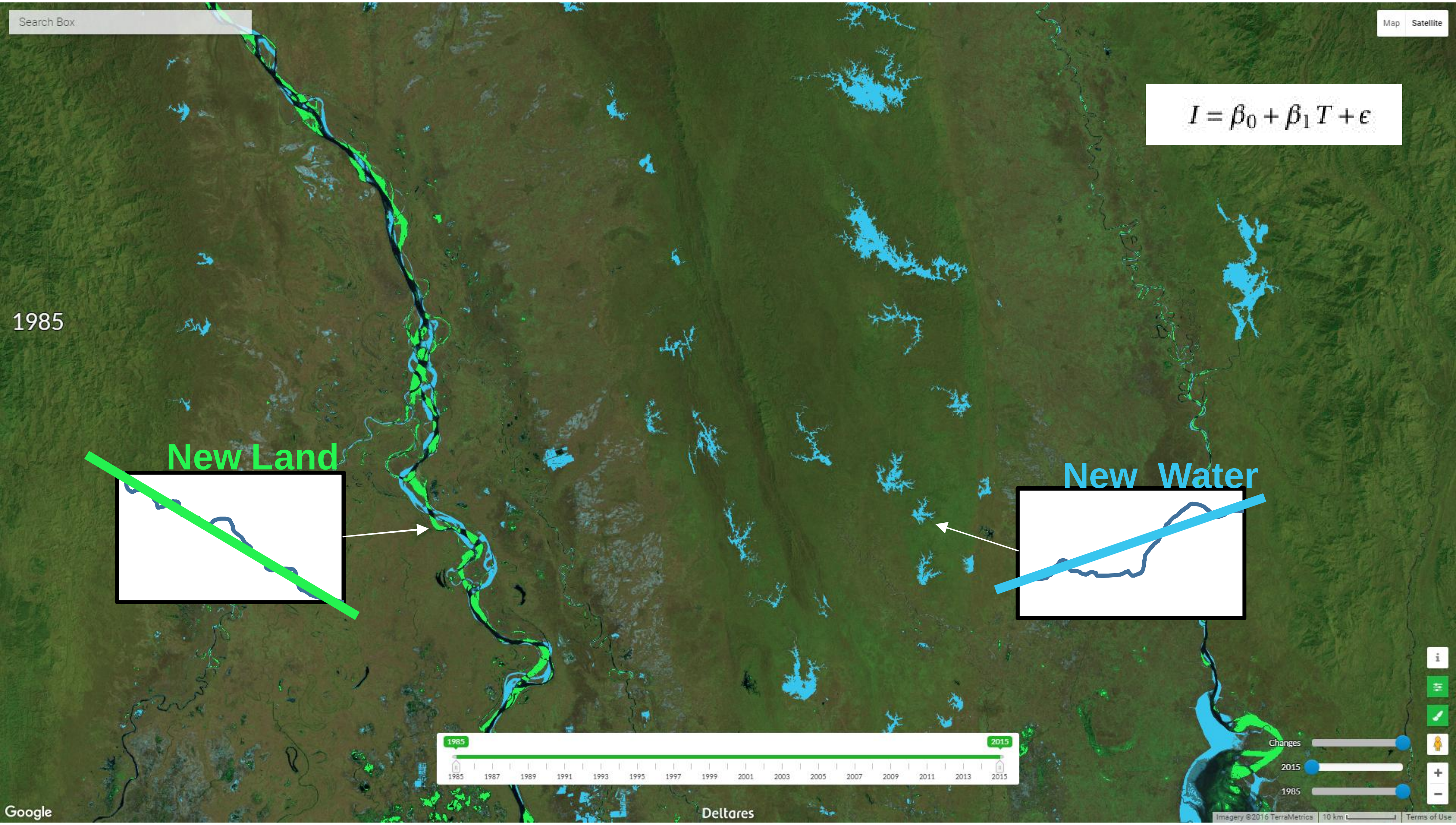
$$I = \beta_0 + \beta_1 T + \epsilon$$





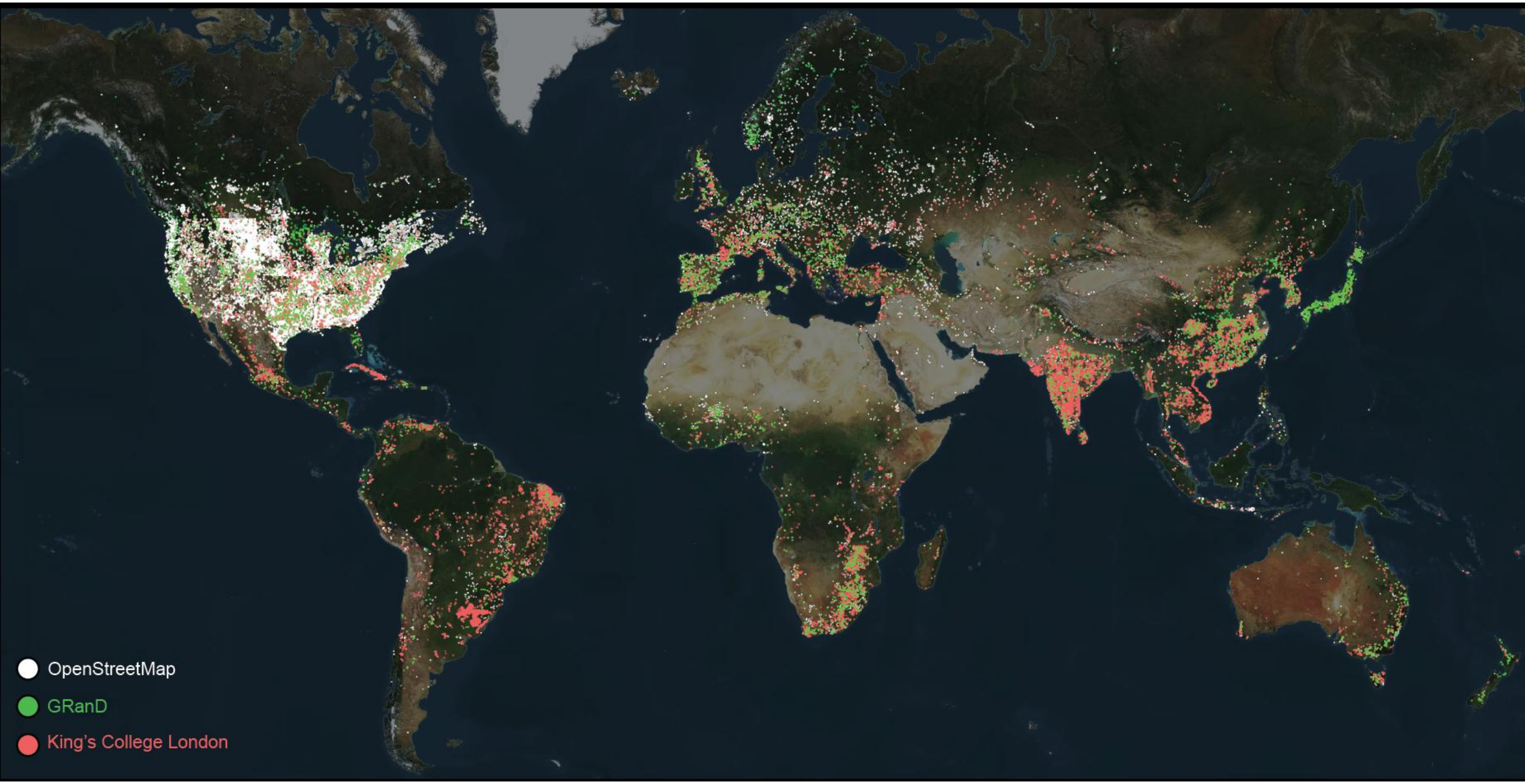

Aqua Monitor - monitor
aqua-monitor.appspot.com/?averaging_months1=48&min_year=1987
Singapore
Surface water changes (1985-2016)
Green and blue colors represent areas where surface water changes occured during the last 30 years. Green pixels show where surface water has been turned into land (accretion, land reclamation, droughts). Blue pixels show where land has been changed into surface water (erosion, reservoir construction).
Note, it may take some time for results to appear, because the analysis is performed on-the-fly.
The results of the analysis are published in:
Donchyts et.al, 2016, Nature Climate Change
Powered by
Google Earth Engine
Map
Satellite
2015
Changes
2015
1987
1987
2015
1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Google
Deltares
Imagery ©2016 TerraMetrics
2 km
Terms of Use
Report a map error





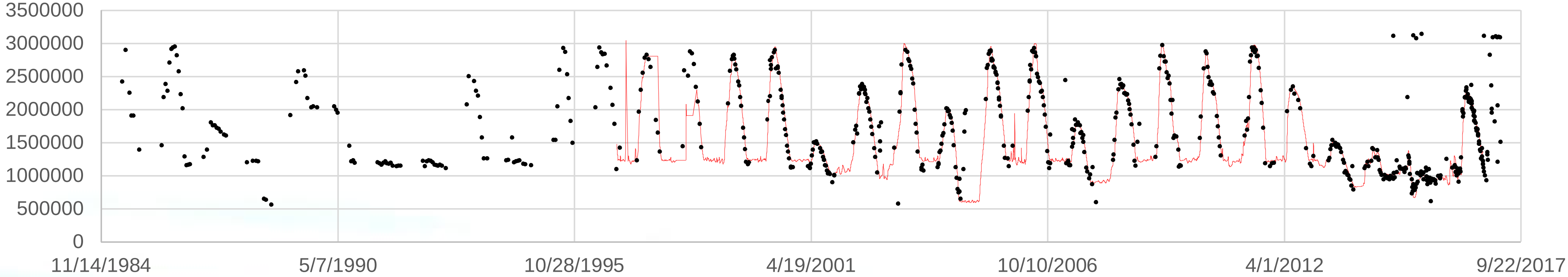
http://aqua-monitor.appspot.com

About 150 000 reservoirs mapped today (GRanD ~= 6000)

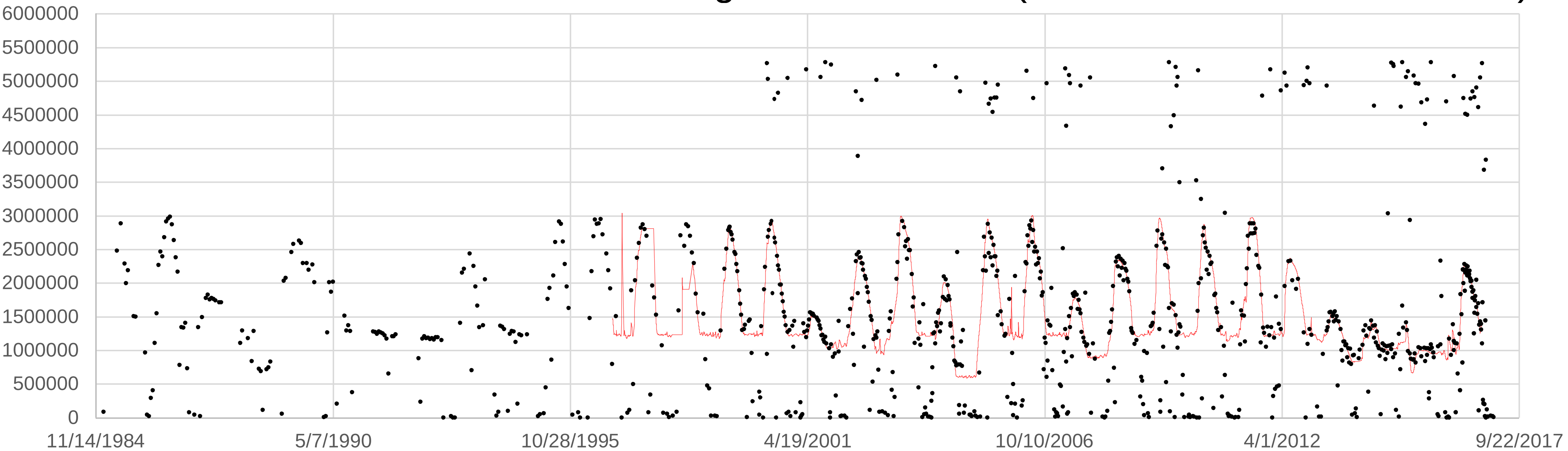


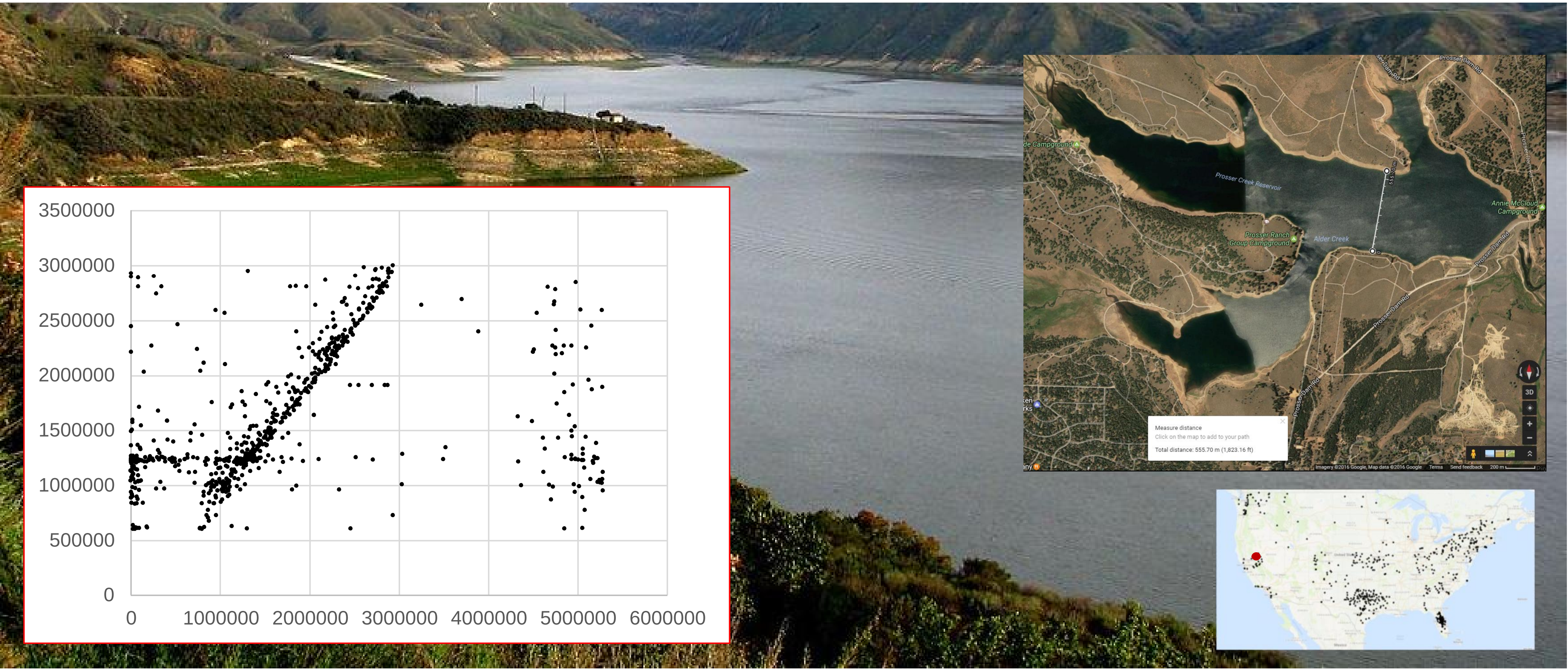
http://bit.ly/global_reservoirs_map_2016
http://bit.ly/agu16_reservoirs

Surface water area estimated from satellite and from local water level station

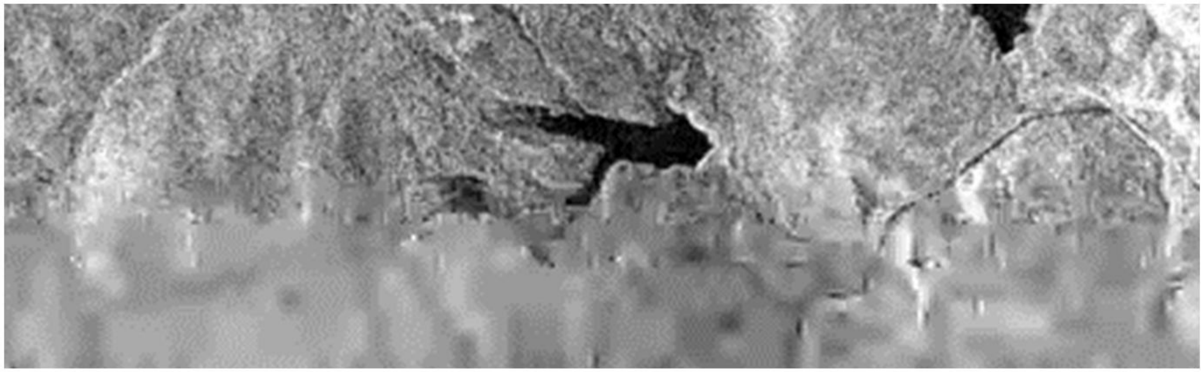


Surface water area estimates using naive methods (no cloud/snow and NDWI=0)





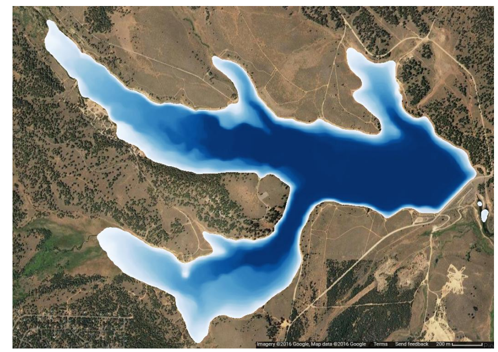
0. Input images from multiple sensors



~1200 images, <30m

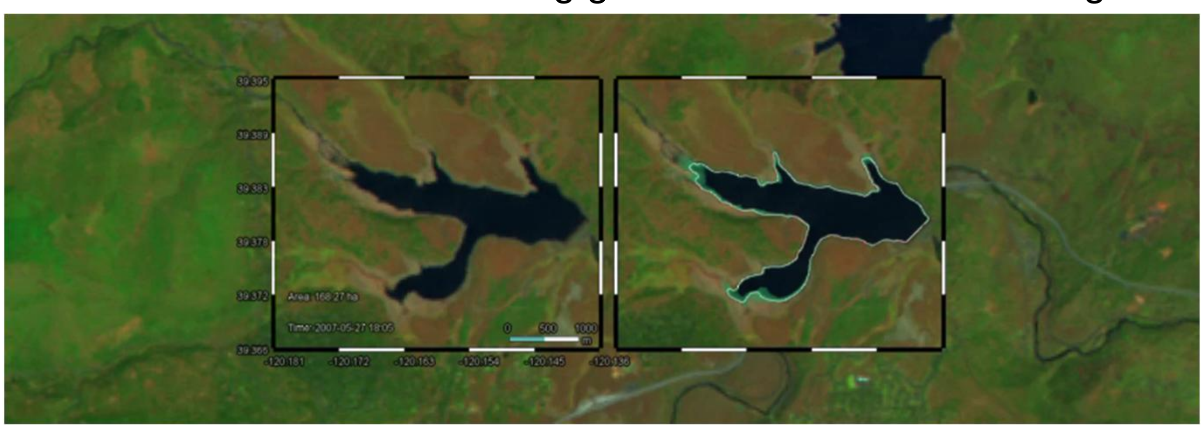
1. Detect water for cloud-free images

2. Estimate probability density (prior)

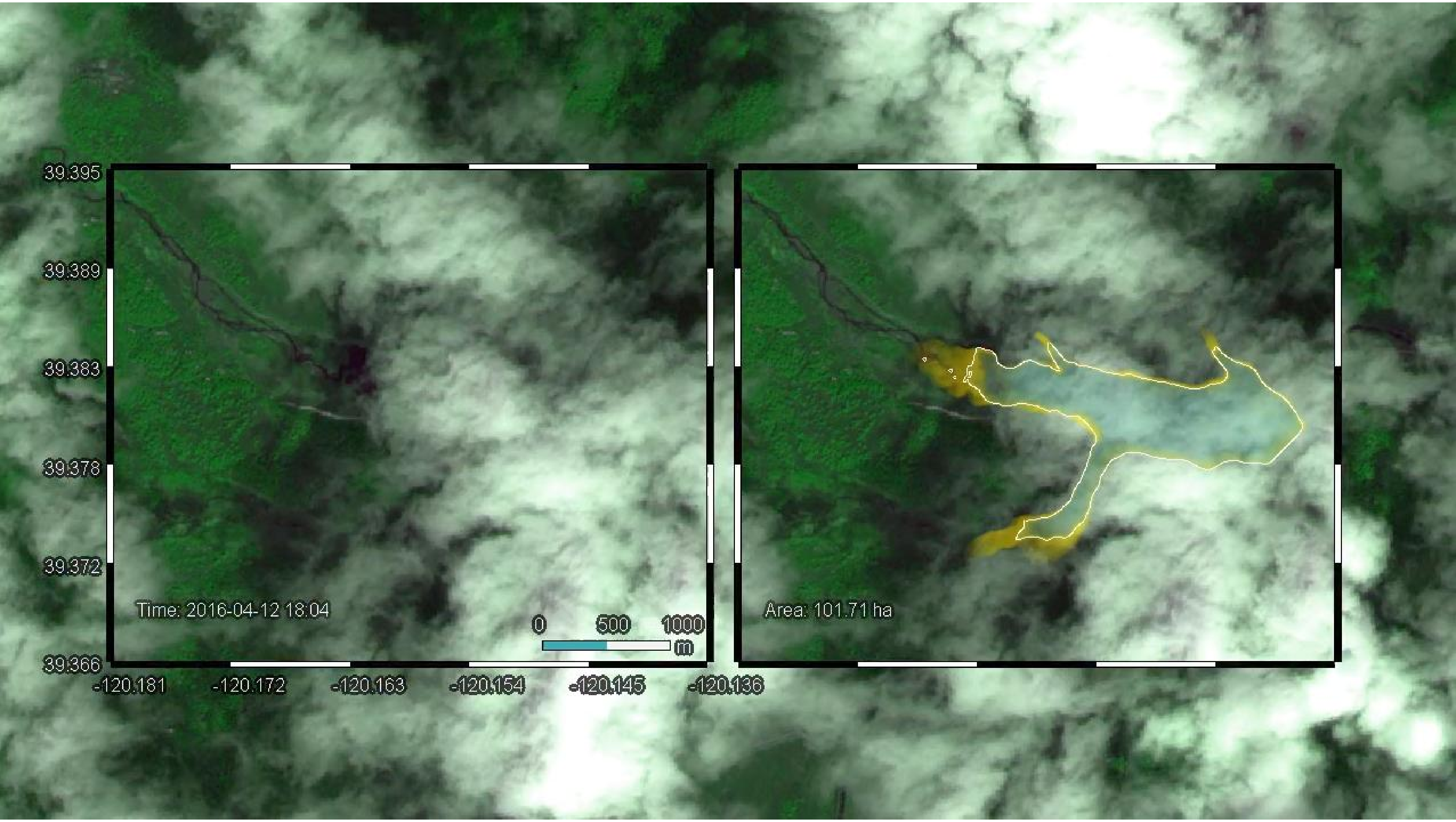


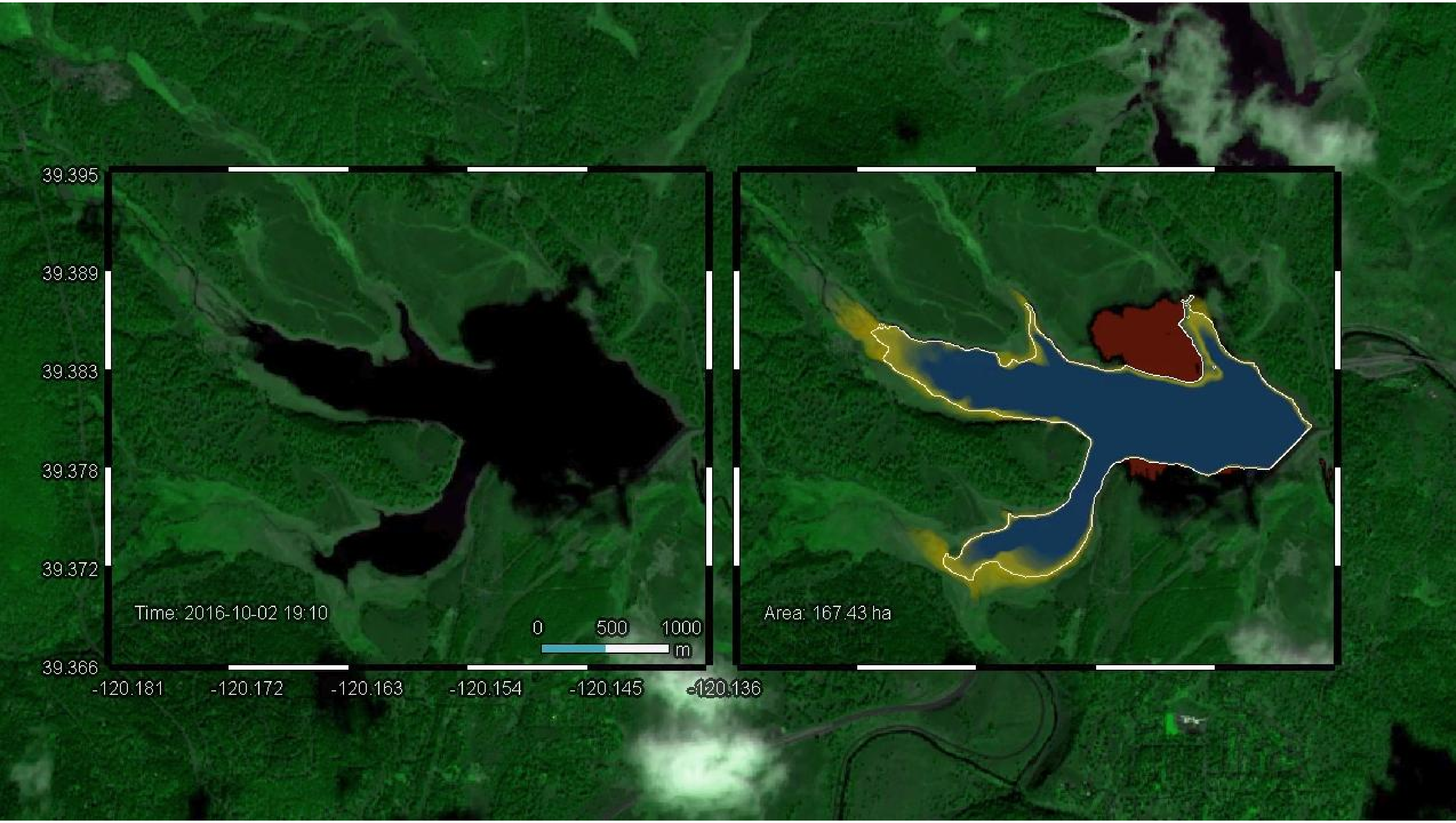
P(water | x, y, cloud=0)

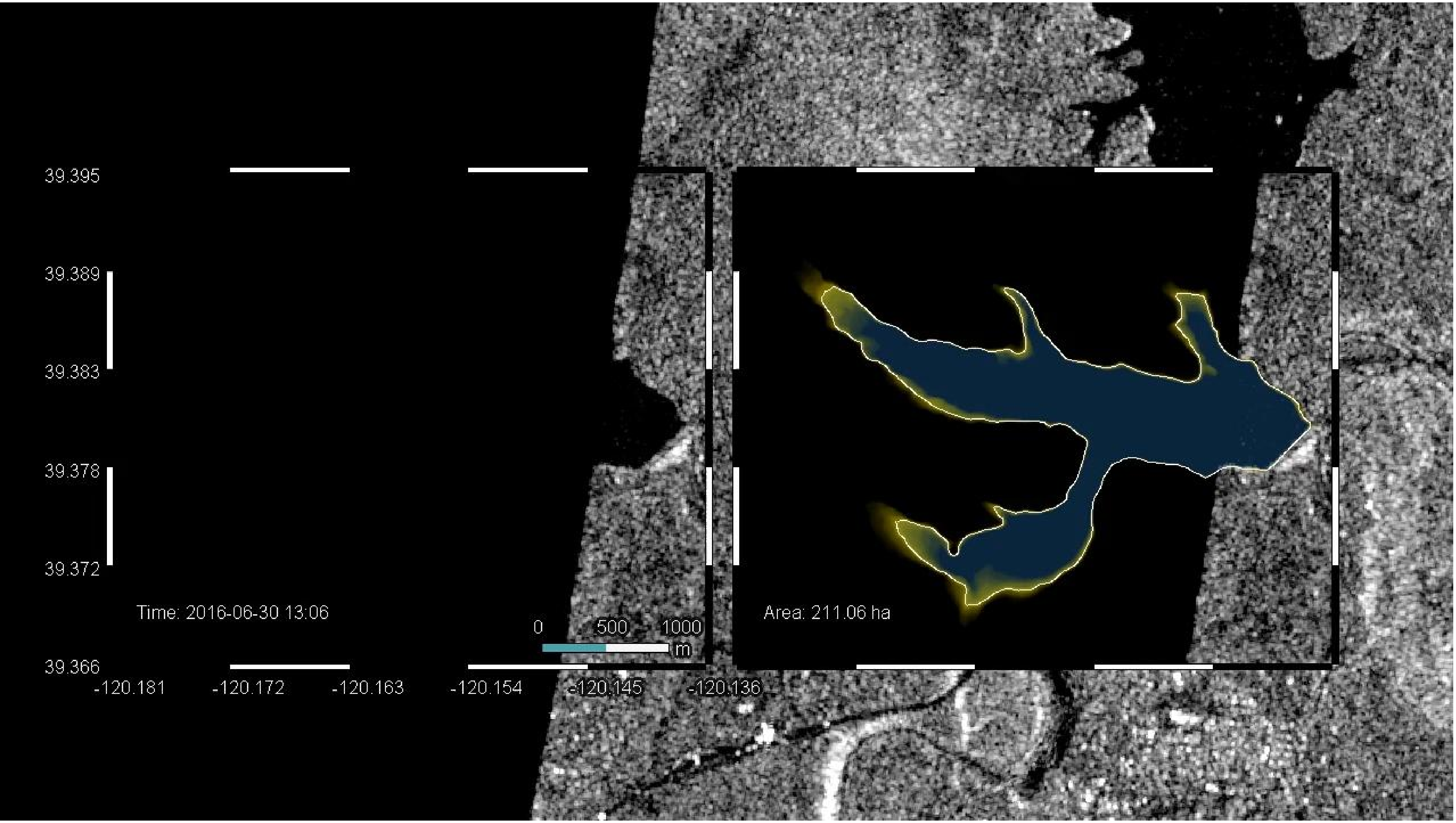
3. Estimate surface area using generative-discriminative algorithm



$$P(W|W^t) = \frac{P(W|W^t) \cdot P(W)}{P(W^t)}$$


39.395
39.389
39.383
39.378
39.372
39.366
-120.181
-120.172
-120.163
-120.154
-120.145
-120.136
Time: 2016-04-12 18:04
0
500
1000
m
Area: 101.71 ha


39.395
39.389
39.383
39.378
39.372
39.366
-120.181
-120.172
-120.163
-120.154
-120.145
-120.136
Time: 2016-10-02 19:10
0
500
1000
m
Area: 167.43 ha

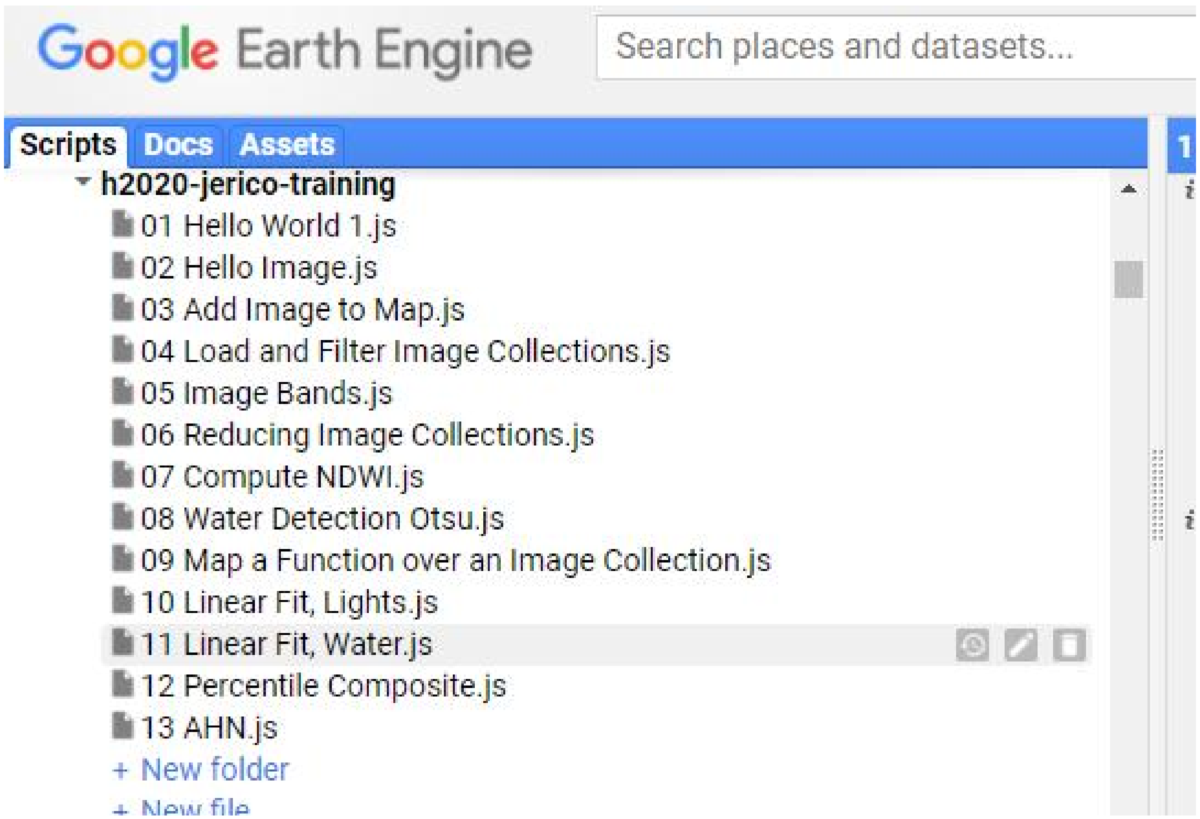

39.395
39.389
39.383
39.378
39.372
39.366
-120.181
-120.172
-120.163
-120.154
-120.145
-120.136
Time: 2016-06-30 13:06
0
500
1000
m
Area: 211.06 ha

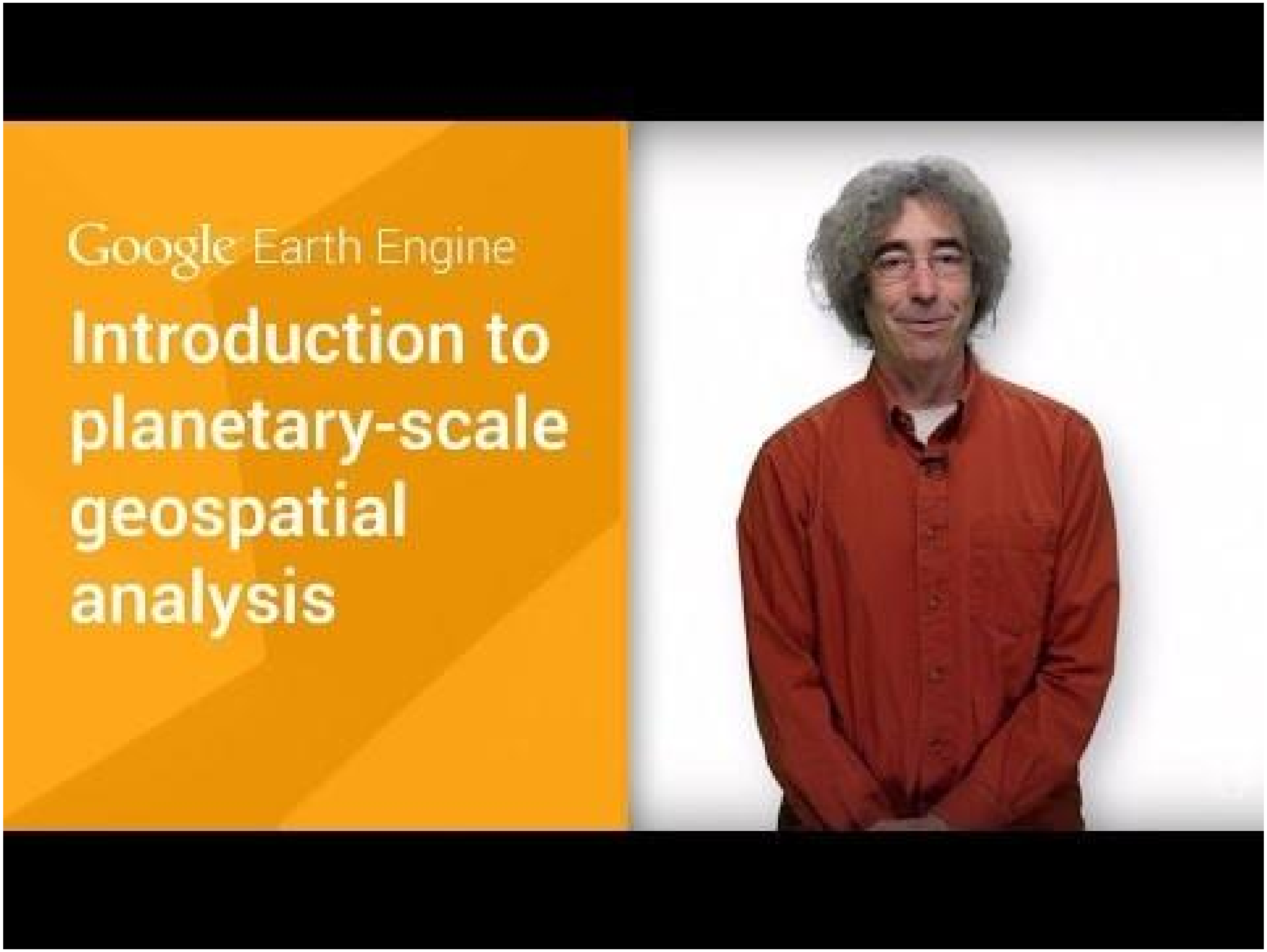
Exercices

Join Group: https://groups.google.com/forum/#!groupsettings/jerico-next-summerschool-2017

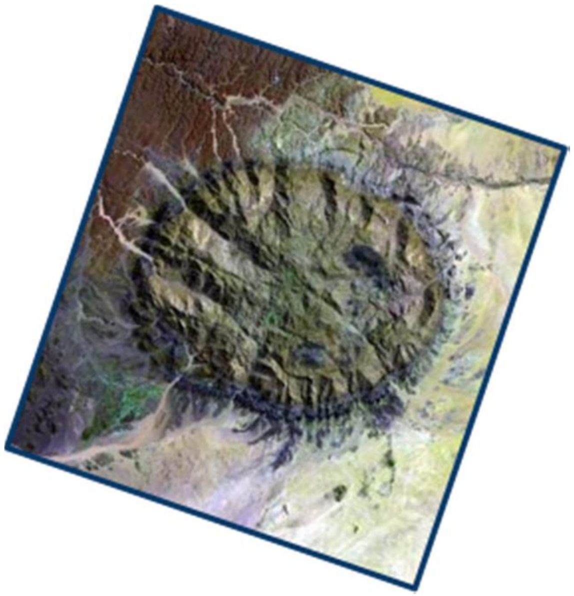
Scripts repository: https://code.earthengine.google.com/?accept_repo=h2020-jerico-training

Slides: http://bit.ly/jerico-next-gee-slides ~120Mb




Google Earth Engine
Introduction to planetary-scale geospatial analysis

Get an Image

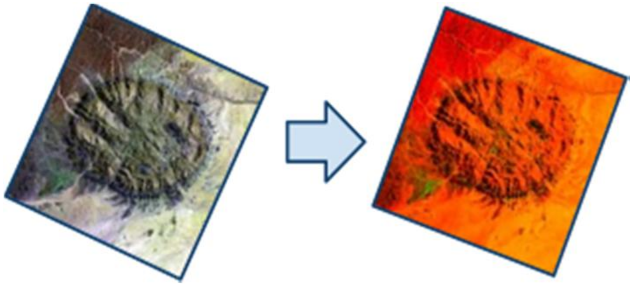


Pick your: projection, resolution, bands, bounding-box, visualization
Access as: Web map, KML, GeoTIFF

Global-scale Algorithm Processing

Get an Image

Apply an algorithm to an image



Library functions or script your own.

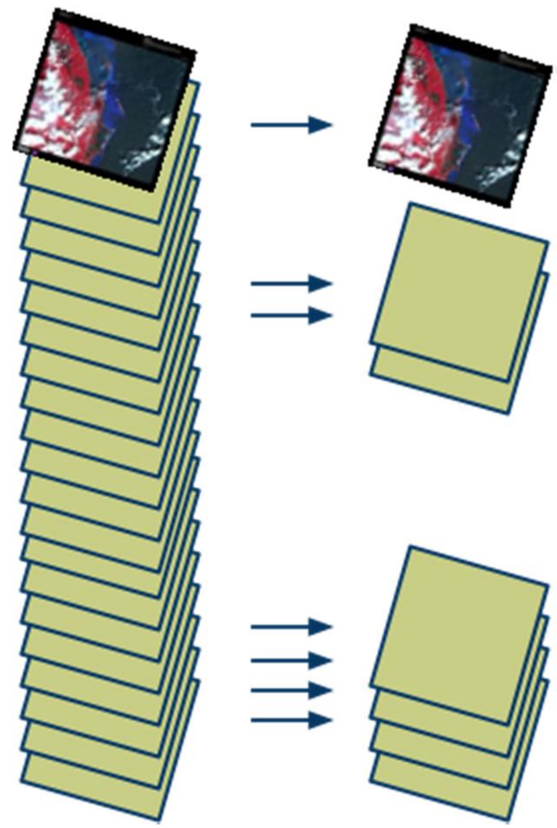
Global-scale Algorithm Processing

Google

Get an Image

Apply an algorithm to an image

Filter a collection



Time, Space & Metadata search

Global-scale Algorithm Processing

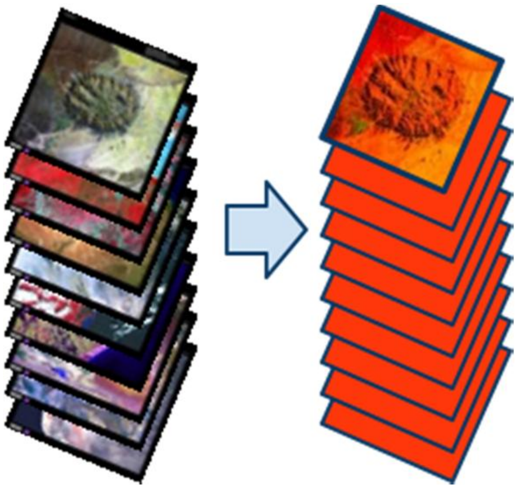
Google

Get an Image

Apply an algorithm to an image

Filter a collection

Map an algorithm over a collection



N → N

Global-scale Algorithm Processing

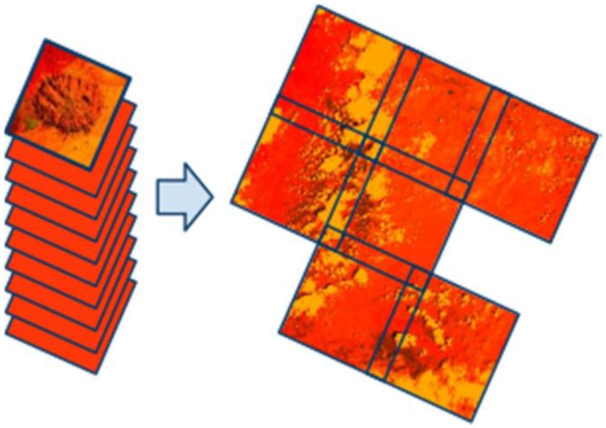
Get an Image

Apply an algorithm to an image

Filter a collection

Map an algorithm over a collection

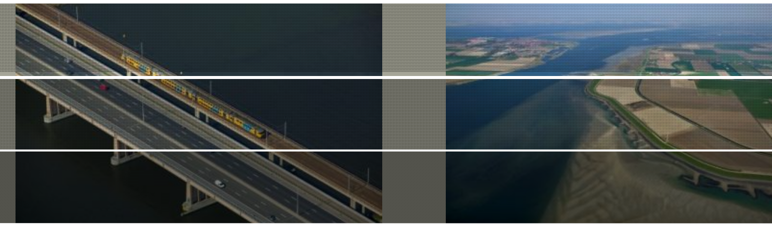
Reduce a collection



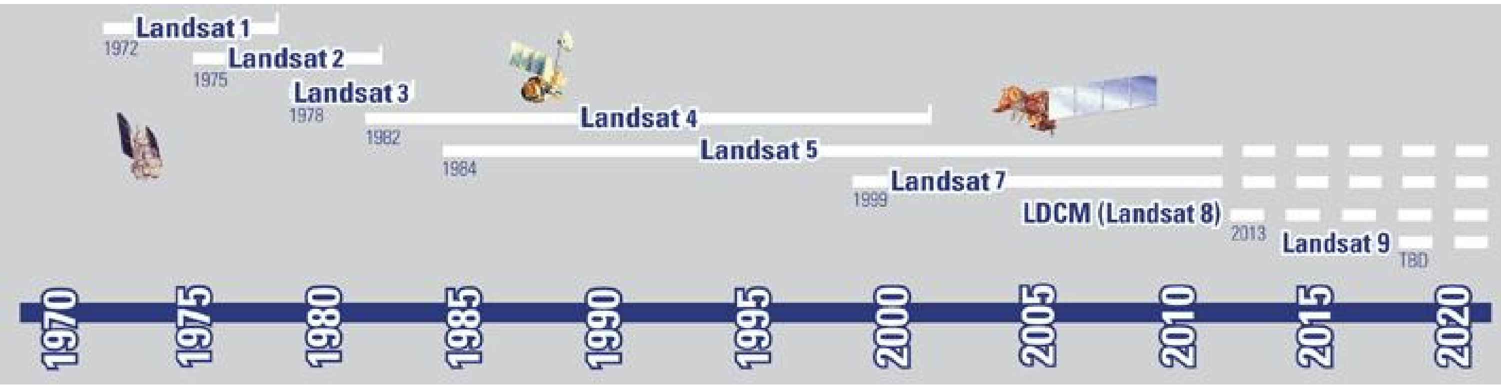
$N \rightarrow 1$ or $N \rightarrow M$

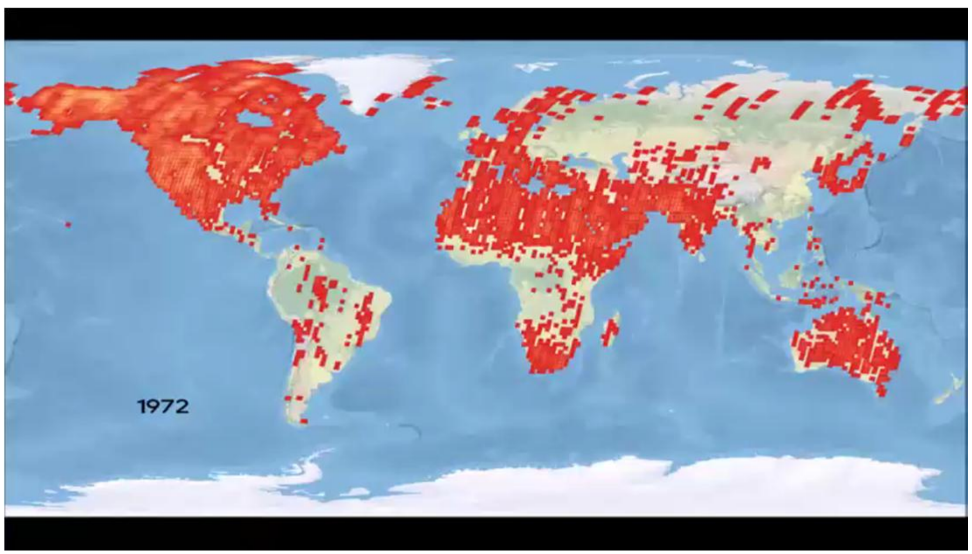
Enabling Delta Life

Optical Satellite Image Analysis

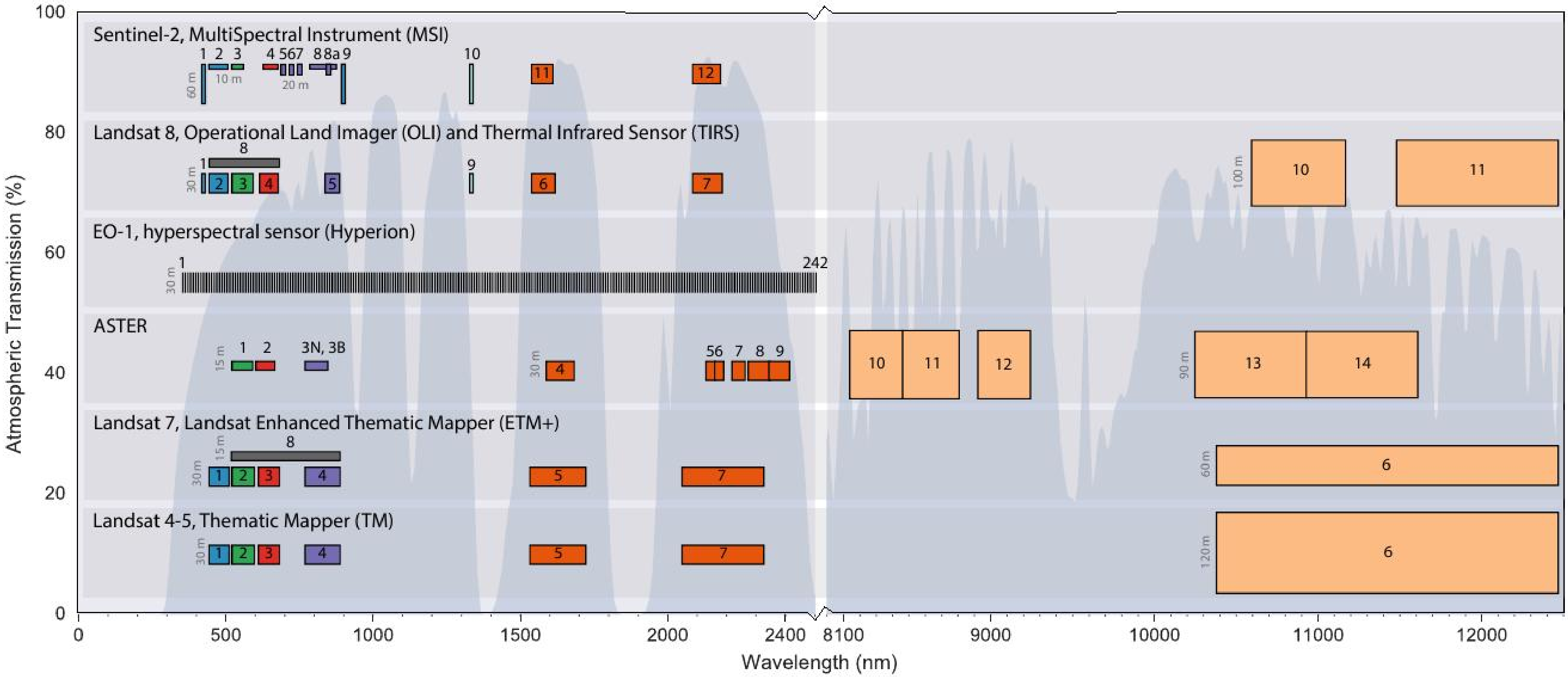


LANDSAT mission



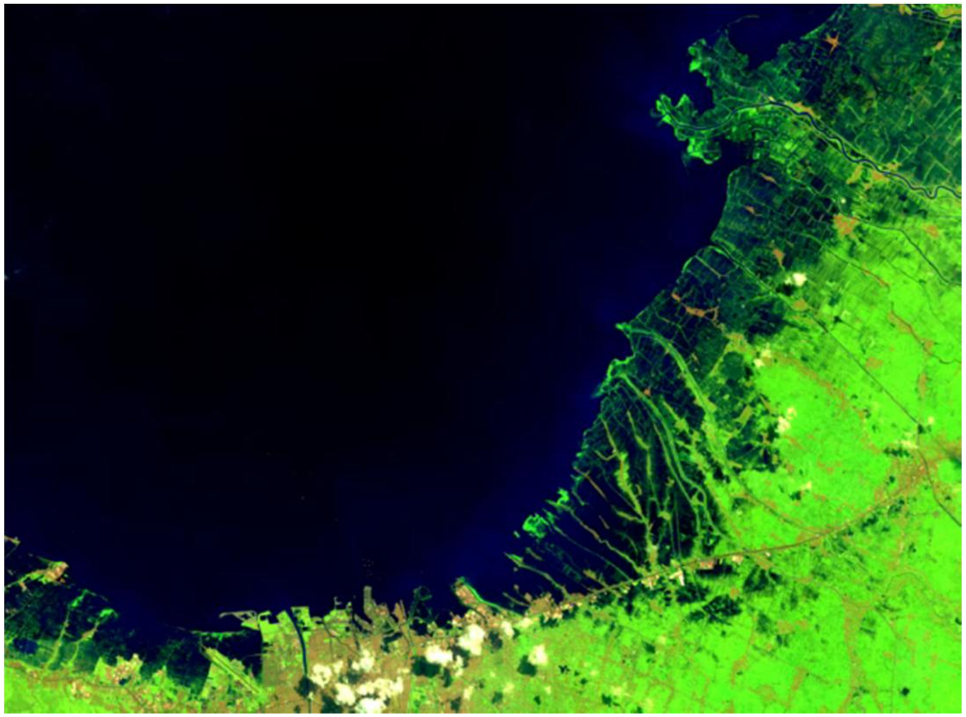


https://youtu.be/YP0et8l_bvY - true/false color composites
https://youtu.be/YP0et8l_bvY - landsat orbits



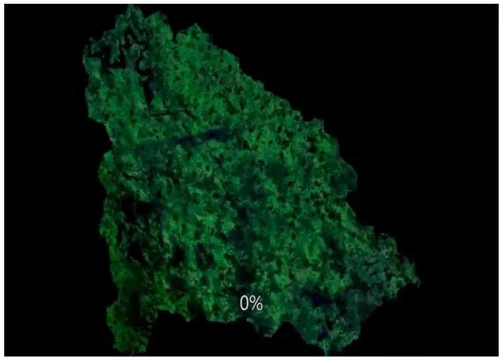
Sentinel-2, MultiSpectral Instrument (MSI)
1 2 3 4 567 8 8a 9 10 11 12
60 m
10 m
20 m
Landsat 8, Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)
1 2 3 4 5 6 7 8 9 10 11
30 m
100 m
EO-1, hyperspectral sensor (Hyperion)
1 242
30 m
ASTER
1 2 3N, 3B 4 56 7 8 9 10 11 12 13 14
15 m
30 m
90 m
Landsat 7, Landsat Enhanced Thematic Mapper (ETM+)
1 2 3 4 5 7 8 6
15 m
30 m
60 m
Landsat 4-5, Thematic Mapper (TM)
1 2 3 4 5 7 6
30 m
120 m
Atmospheric Transmission (%)
0 20 40 60 80 100
Wavelength (nm)
0 500 1000 1500 2000 2400 8100 9000 10000 11000 12000

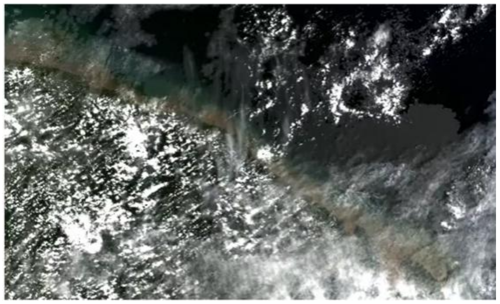
Visible and false color

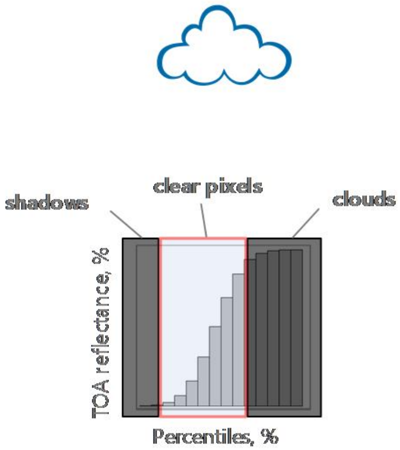


Deltares

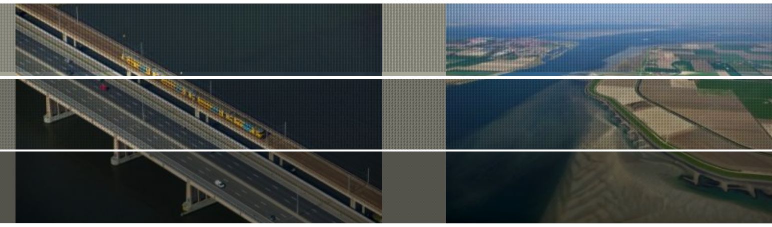
The actual images vs. percentile composites







Deltares



EarthEnv

Global, remote-sensing supported environmental layers for assessing status and trends in biodiversity, ecosystems, and climate

HOME PUBLICATIONS PARTNERS PRESS TEAM

Global 1-km Cloud Cover

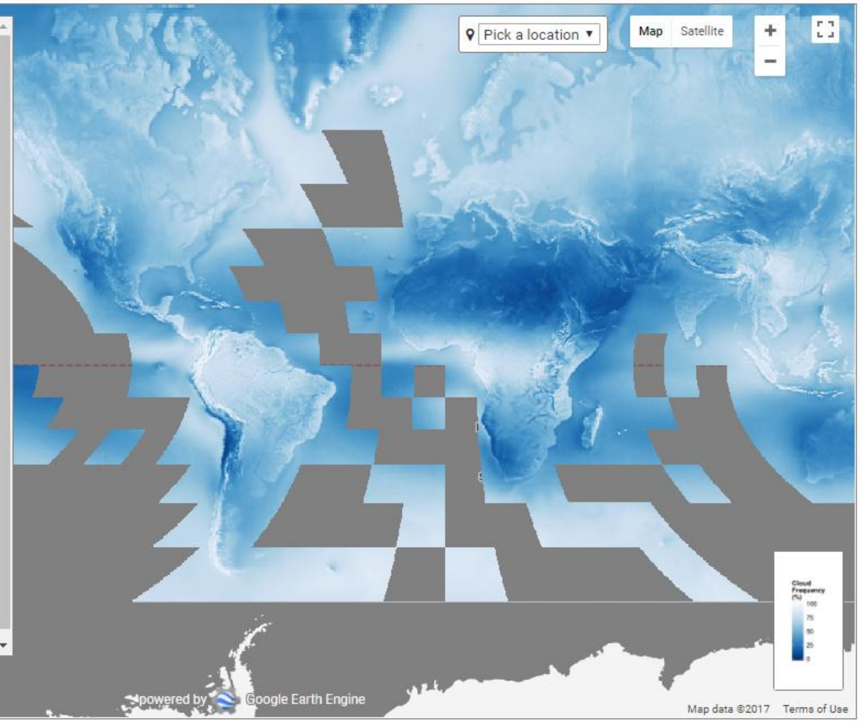
The datasets integrate 15 years of twice-daily remote sensing-derived cloud observations at 1-km resolution. For additional information about the integration approach and the evaluations of the datasets, please see the associated journal article:

Wilson AM, Jetz W (2016) Remotely Sensed High-Resolution Global Cloud Dynamics for Predicting Ecosystem and Biodiversity Distributions. PLoS Biol 14(3): e1002415. doi:10.1371/journal. pbio.1002415

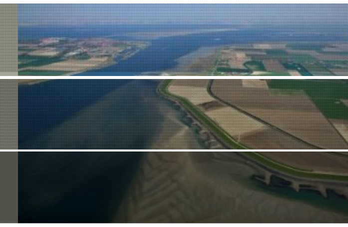
Dataset Details

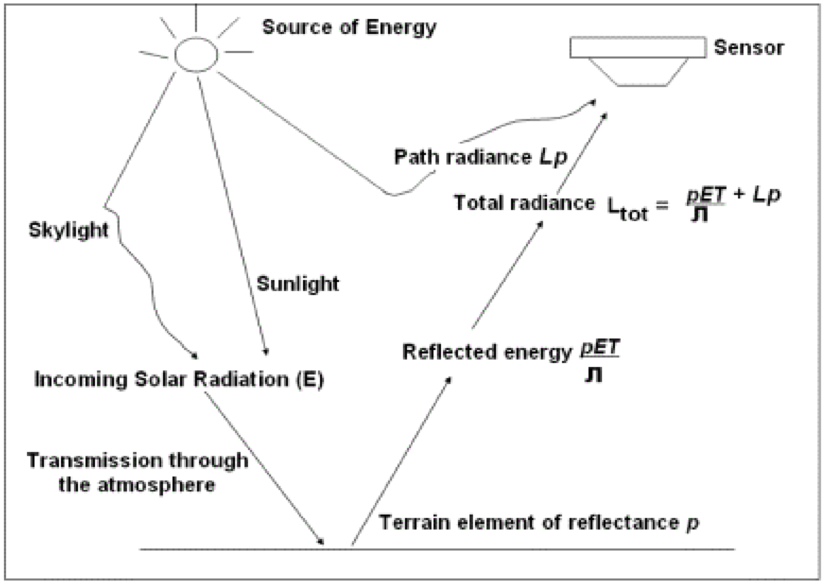
Cloud cover can influence numerous important ecological processes including reproduction, growth, survival, and behavior, yet our assessment of its importance at the appropriate spatial scales has remained remarkably limited. If captured over large extent yet at sufficiently fine spatial grain cloud cover dynamics may provide key information for delineating a variety of habitat types and predicting species distributions. Here we develop new near-global, fine-grain (≈1km) monthly cloud frequencies from 15 years of twice-daily MODIS satellite images that expose spatio-temporal cloud cover dynamics of previously undocumented global complexity. We demonstrate that cloud cover varies strongly in its geographic heterogeneity and that the direct, observation-based nature of cloud-derived metrics can improve predictions of habitats, ecosystem, and species distributions with reduced spatial autocorrelation compared to commonly used

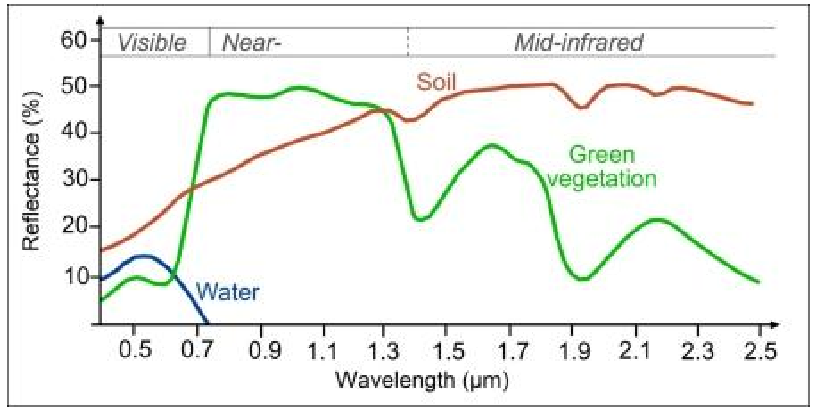
Global 1-km Cloud Cover
- Cloud Forest Prediction
- **Mean annual**
- Seasonality
- Intra-annual variation (SD)
- Inter-annual variation (SD)
- Spatial variation (SD)
- Stability Hotspots
- January
- February
- March
- April
- May
- June
- July
- August
- September
- October
- November
- December



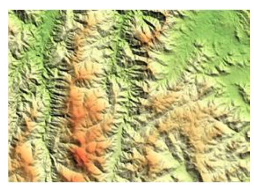
http://www.earthenv.org/cloud







$$L_\lambda = \alpha_\lambda \times Q_\lambda + \beta_\lambda$$



Cloud
Snow / ice
Topographic correction
Shadows (clouds, hills)

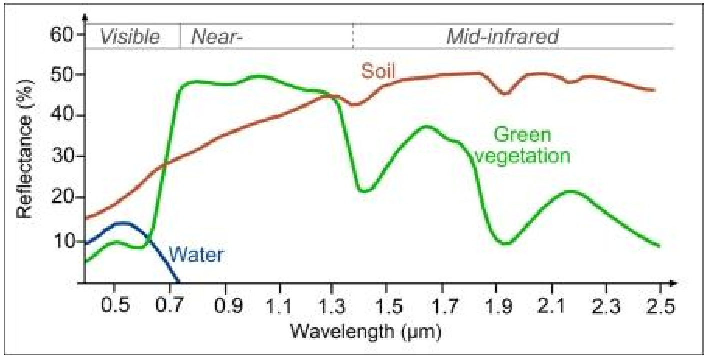
$$\rho_\lambda = \frac{\pi \times L_\lambda \times d^2}{ESUN_\lambda \times \cos\theta_s}$$

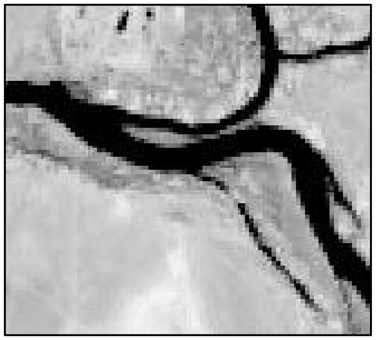
Spatial resolution
Temporal resolution
Spectral resolution
Radiometric resolution

Water detection

$$NDWI_{McFeeters} = \frac{\rho_{green} - \rho_{nir}}{\rho_{green} + \rho_{nir}}$$

$$NDWI_{Xu} = \frac{\rho_{green} - \rho_{swir1}}{\rho_{green} + \rho_{swir1}}$$



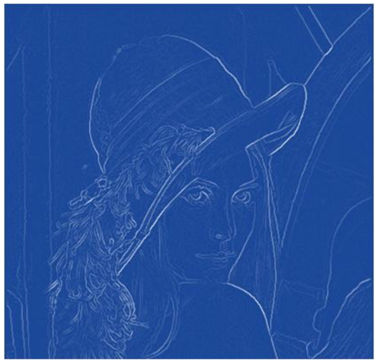


Threshold?

Water detection

Canny Edge Detection

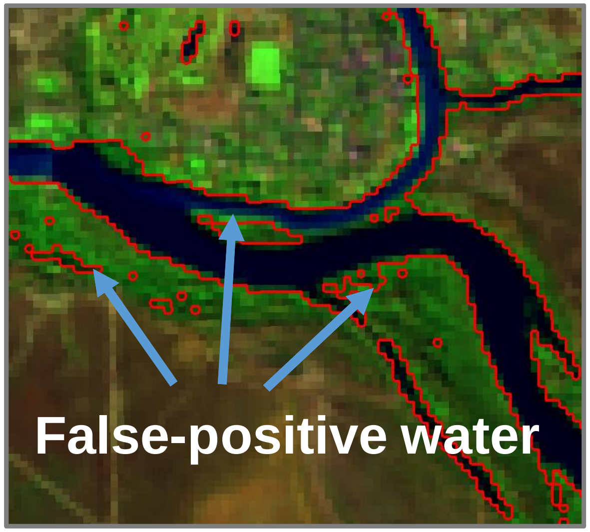
$$\mathbf{G} = \sqrt{\mathbf{G}_x{}^2 + \mathbf{G}_y{}^2}$$
$$\mathbf{\Theta} = \operatorname{atan2}(\mathbf{G}_y, \mathbf{G}_x)$$



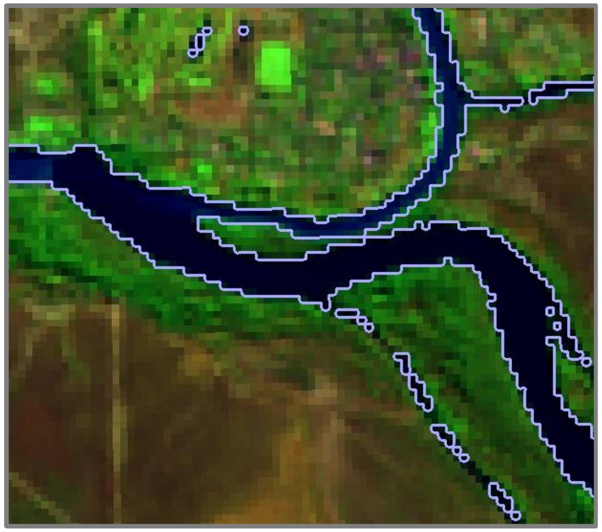
Otsu Thresholding

$$\sigma_w^2(t) = \omega_1(t)\sigma_1^2(t) + \omega_2(t)\sigma_2^2(t)$$

Water detection



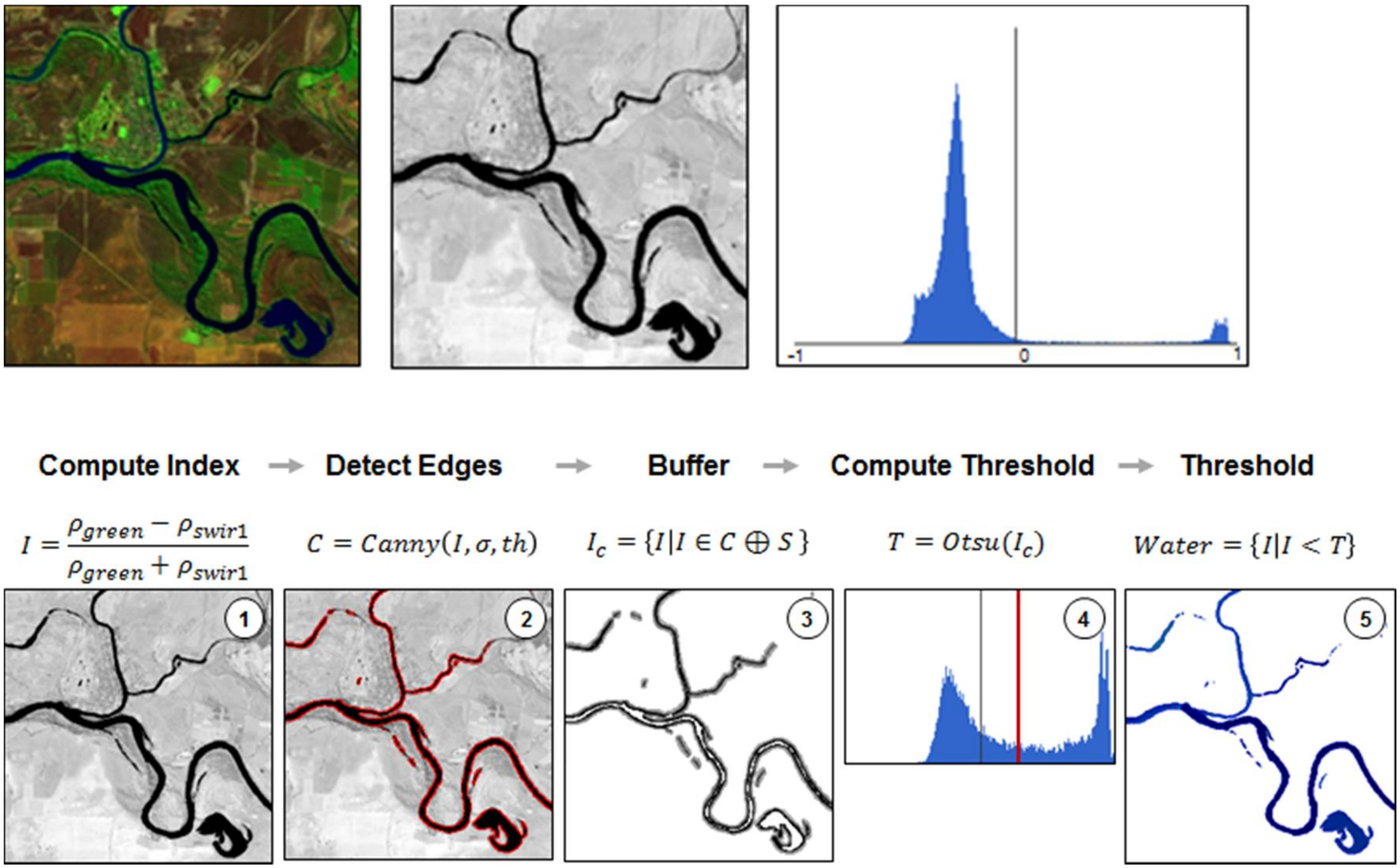
MNDWI=0



MNDWI=0.34

Water detection

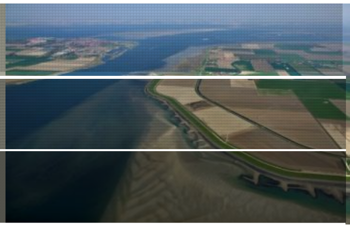
Donchyts et. al. 2016, http://www.mdpi.com/2072-4292/8/5/386



Source: https://code.earthengine.google.com/65493c1cae67bb86c038e5bef3b4ab2d
Python: https://github.com/gena/gena.github.io/blob/master/experiments/figure_water_detection.ipynb

Links

1. Homepage - official Google Earth Engine homepage
2. Code Editor (Playground) - main EE GUI (JavaScript)
3. Developers Forum - most EE discussions occur here
4. Issue Tracker - issue tracker
5. Timelapse - global timelapse video (Landsat)
6. Private Git Sources - browse you private EE git repositories
7. Documentation - Users Guide
8. Earthengine Api
9. Selected Vector Datasets
10. Earth Engine resources for higher education
11. User Summit 2016
12. gsutil tool
13. Google Cloud Storage Documentation



Selected Scripts

- Multisensor Chart
- S1 ascending / descending
- S1 speckle filters
- OSM & SRTM
- SLIC unsupervised classification
- LoG sharpening
- Regular Grid
- Elevation Profile
- PCA

$$\frac{\partial I}{\partial t} = \frac{\partial^2 (c \cdot I)}{\partial x \partial y}$$

$$c = \frac{1}{1 + (G/K)^2}$$