Introduction to Google Earth Engine

Zhiqiang Yang

USFS, Rocky Mountain Research Station

2021 Operational Lidar Inventory Meeting, April 7, 2021

What is Earth Engine

A computation Platform

Tools for analyzing and visualizing geospatial data at scale

A Data Catalog

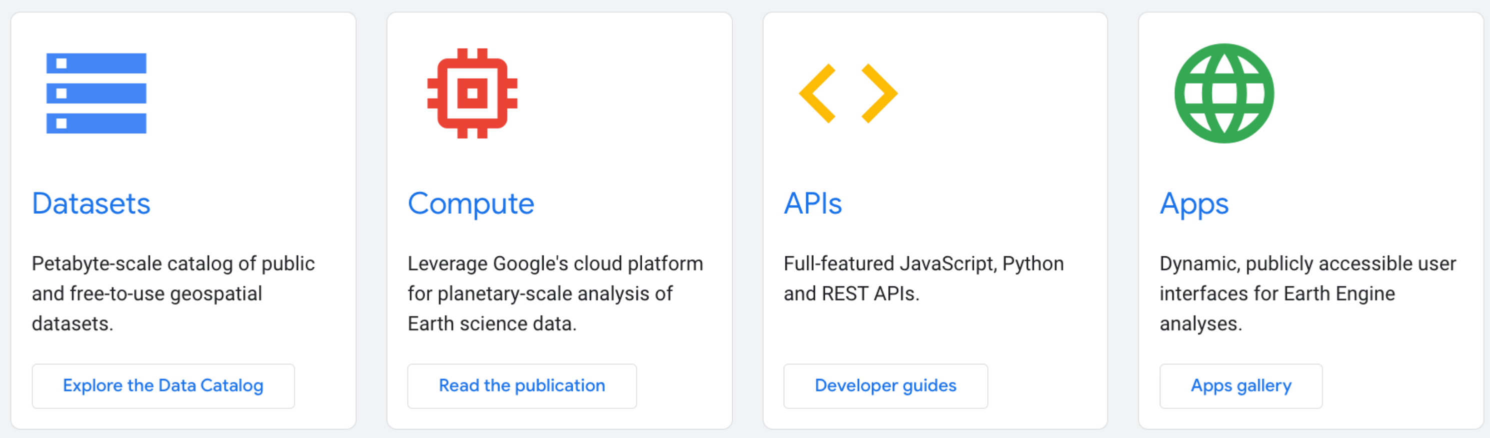
50PB archive of satellite imagery and other geospatial datasets

What makes GEE powerful

Co-located

- Big Data
- Massive Computation
- Scientific Algorithms

src: wikipedia



Datasets

Petabyte-scale catalog of public and free-to-use geospatial datasets.

Explore the Data Catalog

Compute

Leverage Google's cloud platform for planetary-scale analysis of Earth science data.

Read the publication

APIs

Full-featured JavaScript, Python and REST APIs.

Developer guides

Apps

Dynamic, publicly accessible user interfaces for Earth Engine analyses.

Apps gallery

Gorelick et al. https://doi.org/10.1016/j.rse.2017.06.031

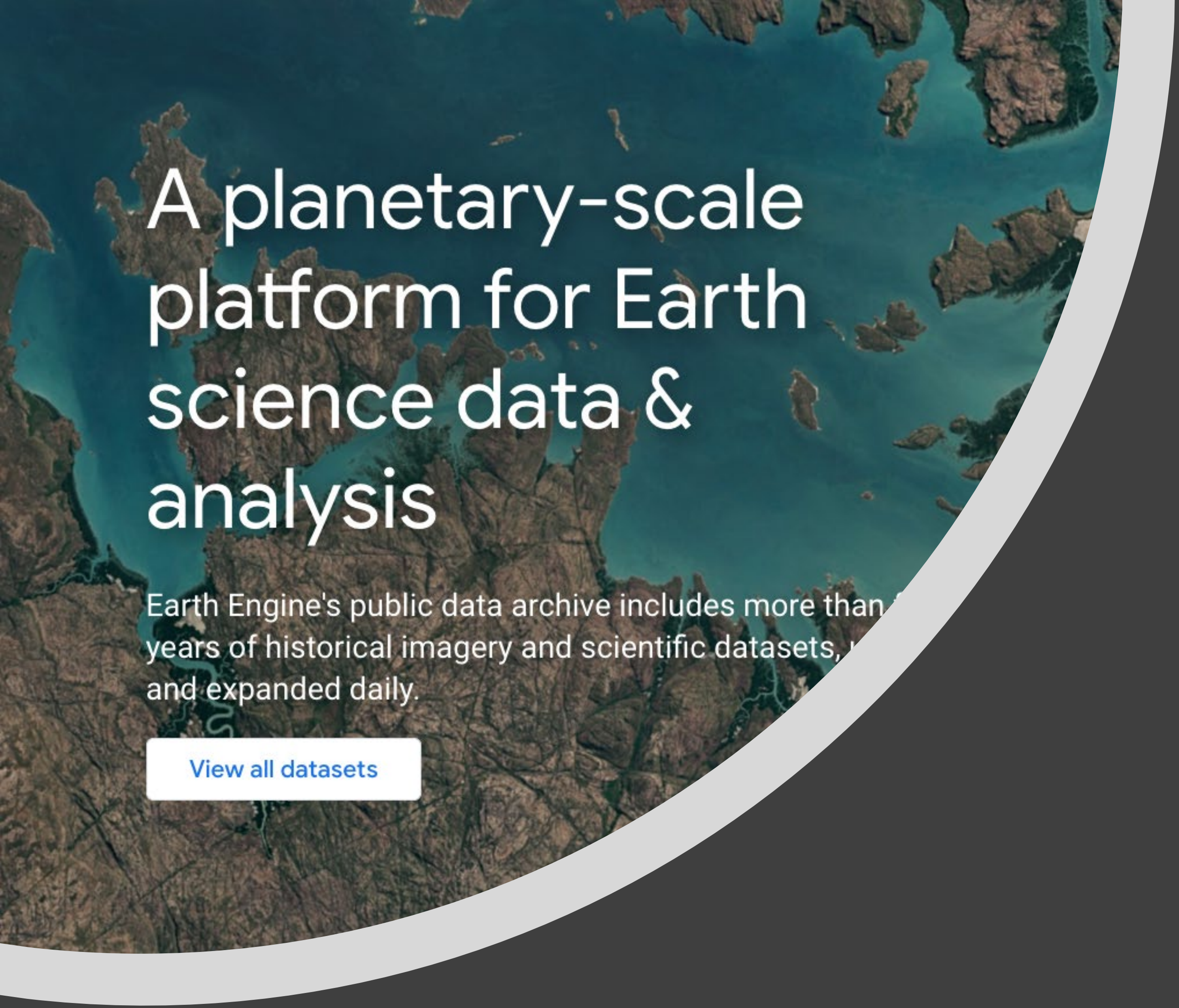
Image Credit: Noel Gorelick

Data Catalog

Massive Data Catalog

- **35** petabytes total
- **~1** petabyte/month
- **>700** datasets
- **~100** datasets / year

- Landsat from 1972
- Sentinel 1, 2, 3, 5P
- Many more: topography, weather, population, etc

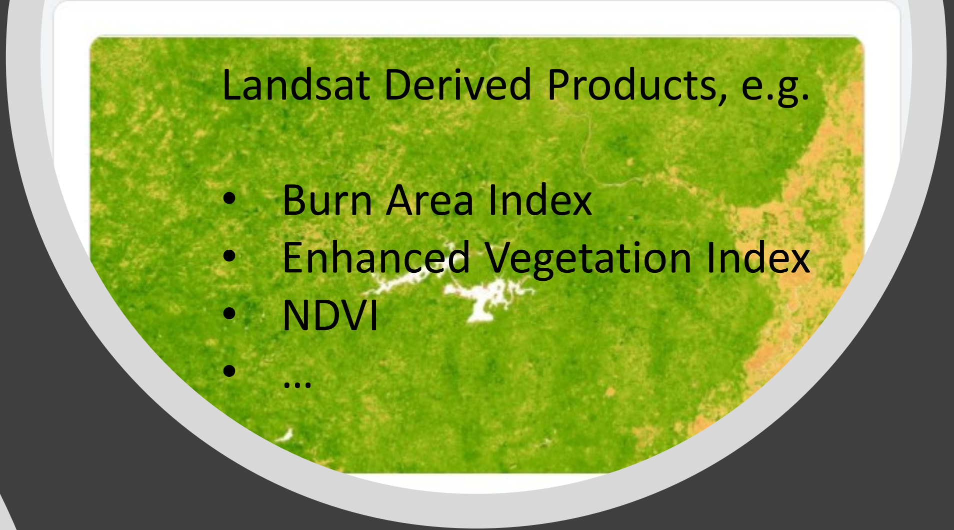


A planetary-scale platform for Earth science data & analysis

Earth Engine's public data archive includes more than years of historical imagery and scientific datasets, and expanded daily.

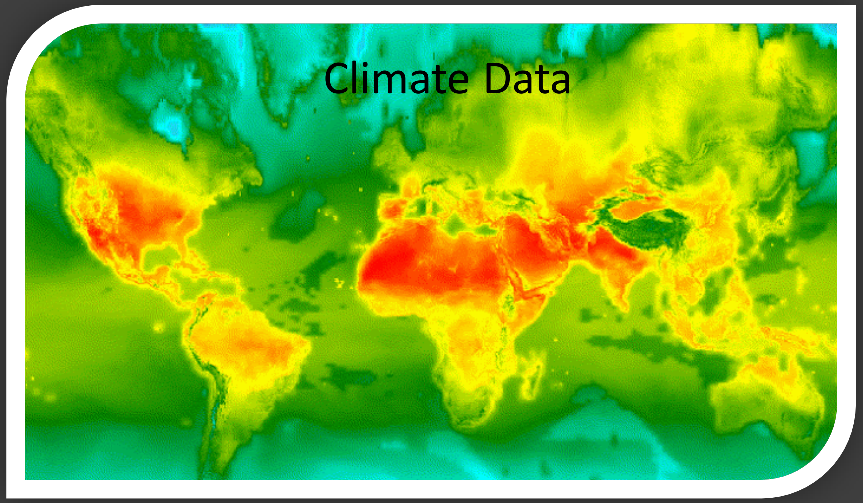
https://developers.google.com/earth-engine/datasets

A few Examples



Landsat Derived Products, e.g.

- Burn Area Index
- Enhanced Vegetation Index
- NDVI
- …

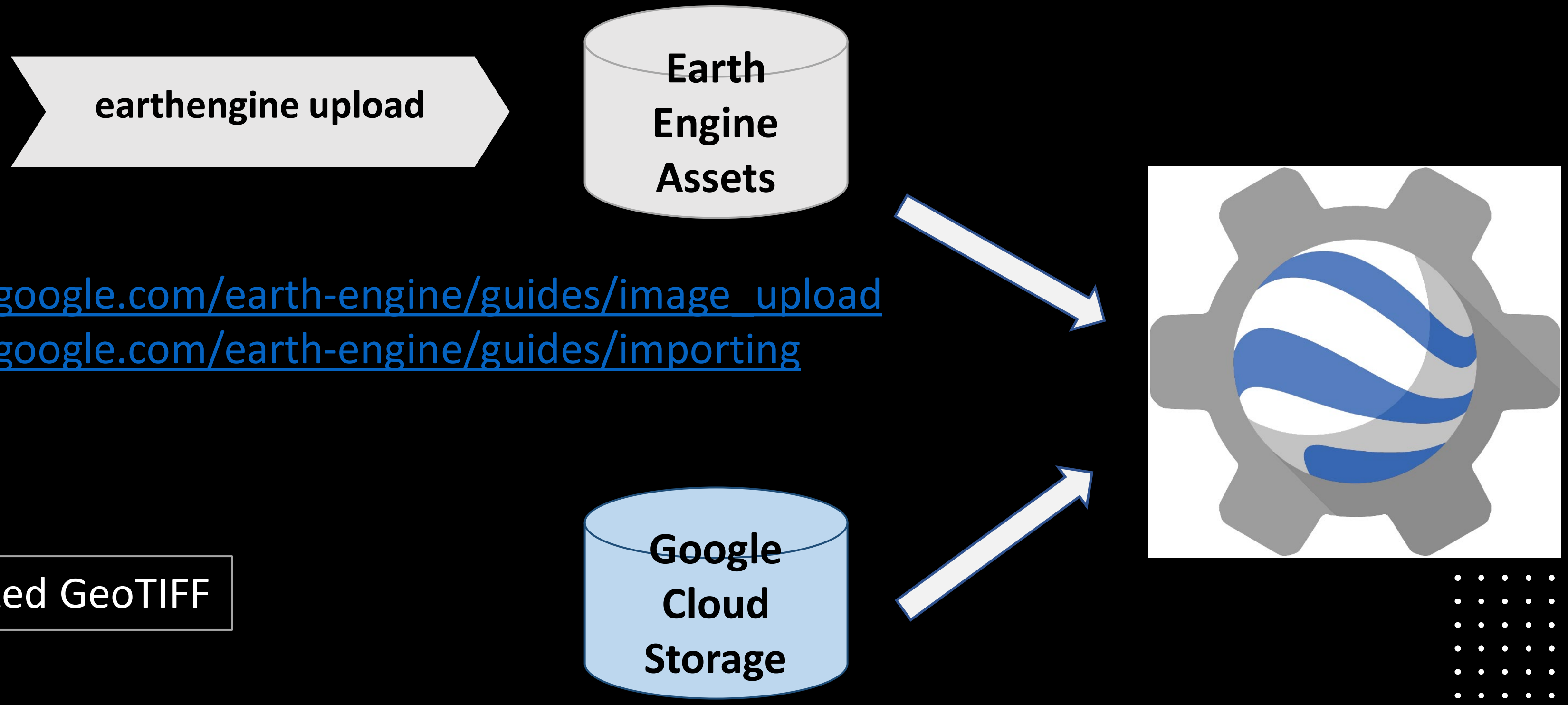


Climate Data

Bring your own data

- Shapefiles
- CSV
- TFRecord
- GeoTiff

https://developers.google.com/earth-engine/guides/image_upload
https://developers.google.com/earth-engine/guides/importing



earthengine upload

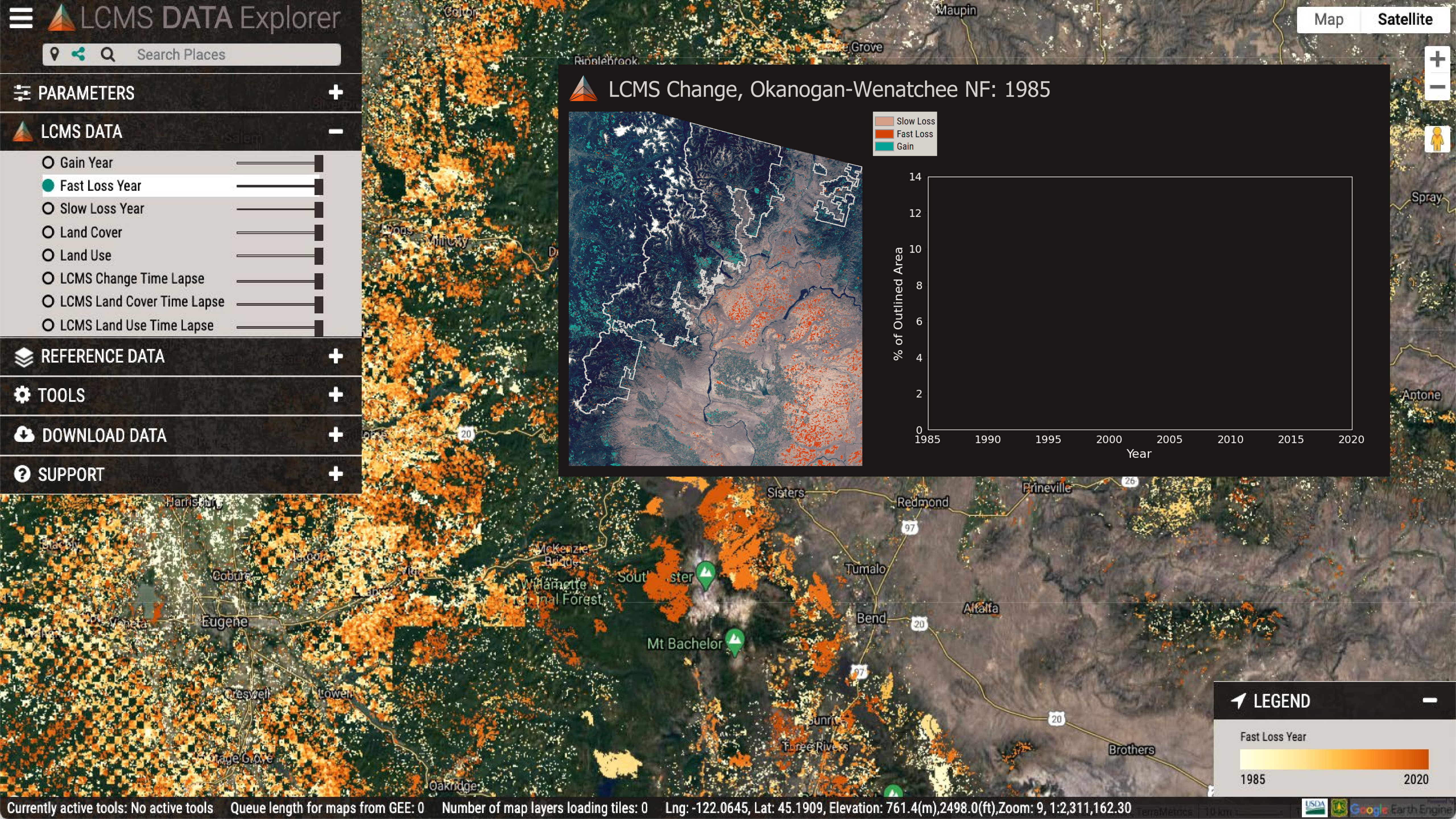
Earth Engine Assets

Google Cloud Storage

Cloud Optimized GeoTIFF

Example Applications

Image Credit: Noel Gorelick



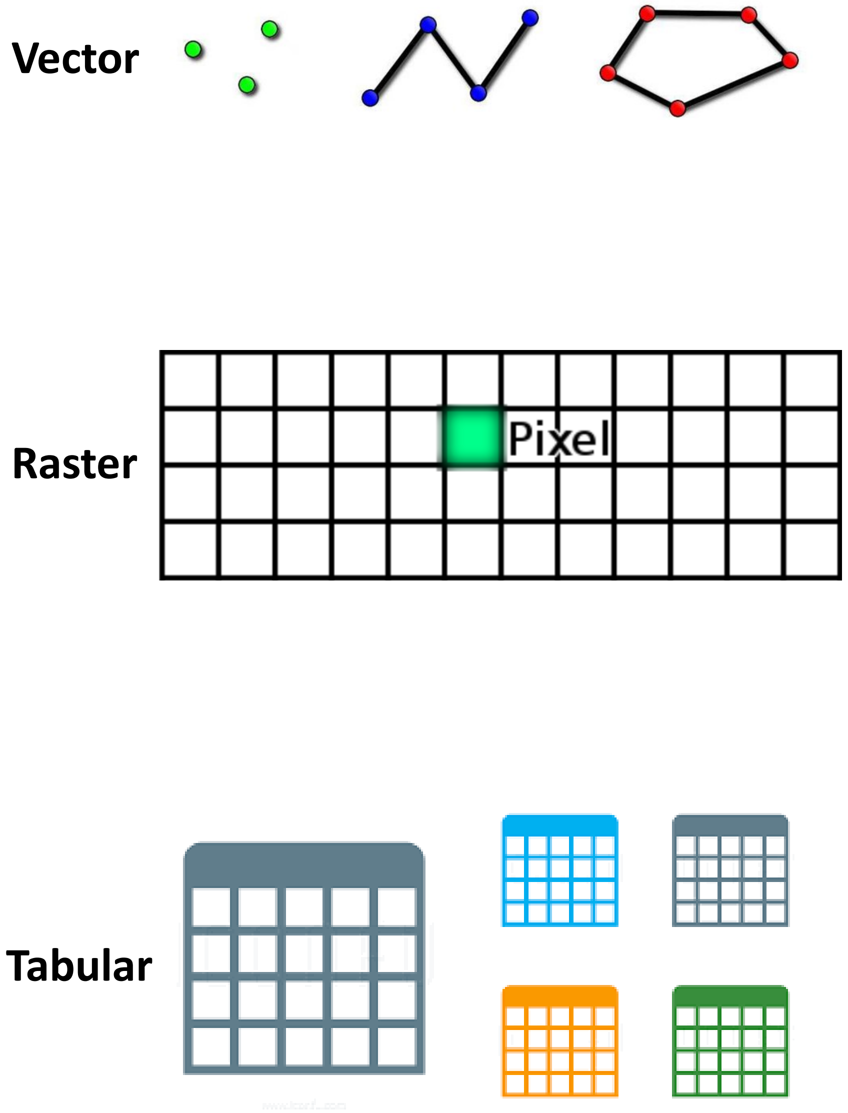
Currently active tools: No active tools   Queue length for maps from GEE: 0   Number of map layers loading tiles: 0   Lng: -122.0645, Lat: 45.1909, Elevation: 761.4(m),2498.0(ft),Zoom: 9, 1:2,311,162.30

API

Powerful API

- Analysis in Python and JavaScript
  - Same interface
  - Across platform

- **Geometry & Feature:** buffer, centroid, intersection, union, transform ...
- **FeatureCollection:** aggregate, filter, flatten, merge, sort ...



Powerful API (cont.)

Image: band math, clip, convolution, neighborhood ...

Image Collection: map, aggregate, filter, mosaic, sort ...

Filter: by bounds, within distance, date, day-of-year ...

Reducer: mean, linearRegression, percentile, histogram ....

Join: simple, inner, outer, inverted ...

Kernel: square, circle, gaussian, sobel, kirsch ...

Classifier: decision tree, GBT, randomForest ...

Cluster: kMeans, xMean, Cobweb ...

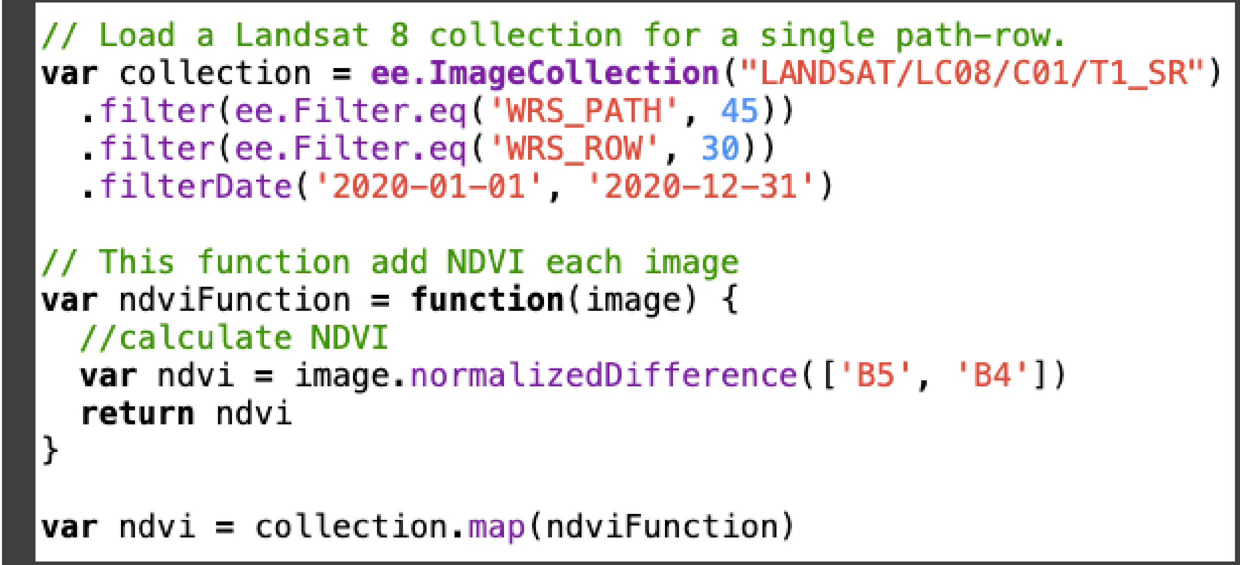
Matrix computation: determinant, decomposition ...

Processing Concept: Map

Apply an operation to every element of a collection (FeatureCollection or ImageCollection)

For example:

- Compute NDVI for all images in 2018
- Derive area of each feature in a FeatureCollection
- Create monthly max and min temperature



```
// Load a Landsat 8 collection for a single path-row.
var collection = ee.ImageCollection("LANDSAT/LC08/C01/T1_SR")
  .filter(ee.Filter.eq('WRS_PATH', 45))
  .filter(ee.Filter.eq('WRS_ROW', 30))
  .filterDate('2020-01-01', '2020-12-31')

// This function add NDVI each image
var ndviFunction = function(image) {
  //calculate NDVI
  var ndvi = image.normalizedDifference(['B5', 'B4'])
  return ndvi
}

var ndvi = collection.map(ndviFunction)
```

- https://developers.google.com/earth-engine/guides/ic_mapping
- https://developers.google.com/earth-engine/guides/feature_collection_mapping

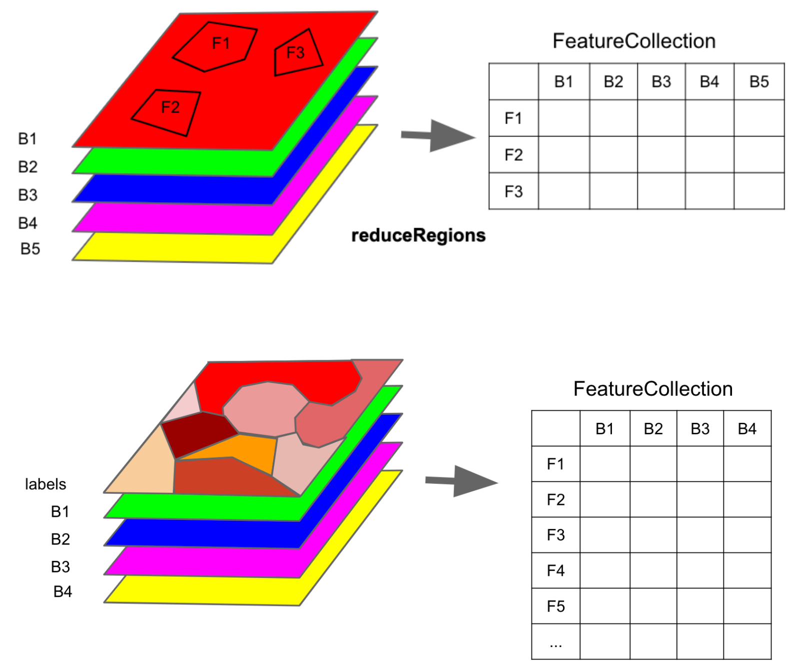
Processing Concept: Reduce

Aggregate over a collection or over a spatial context to derive summary values.

Reduce Bands

Reduce Neighborhood

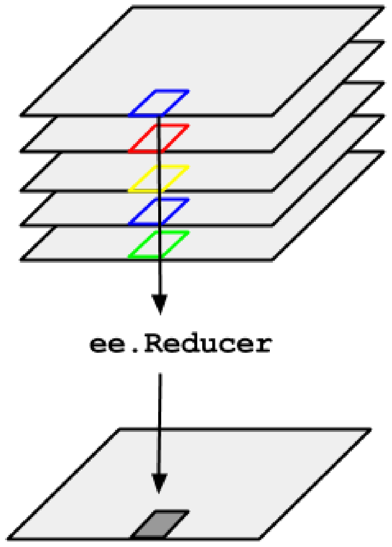
Reduce ImageCollection

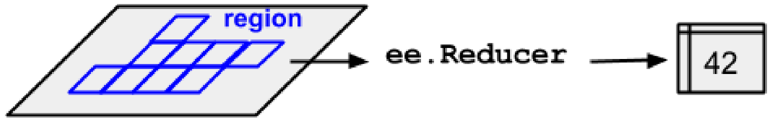


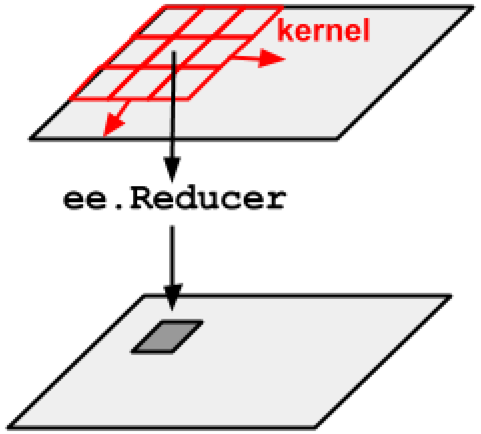
	B1	B2	B3	B4	B5
F1					
F2					
F3					

	B1	B2	B3	B4
F1				
F2				
F3				
F4				
F5				
...				

Image: Nick Clinton



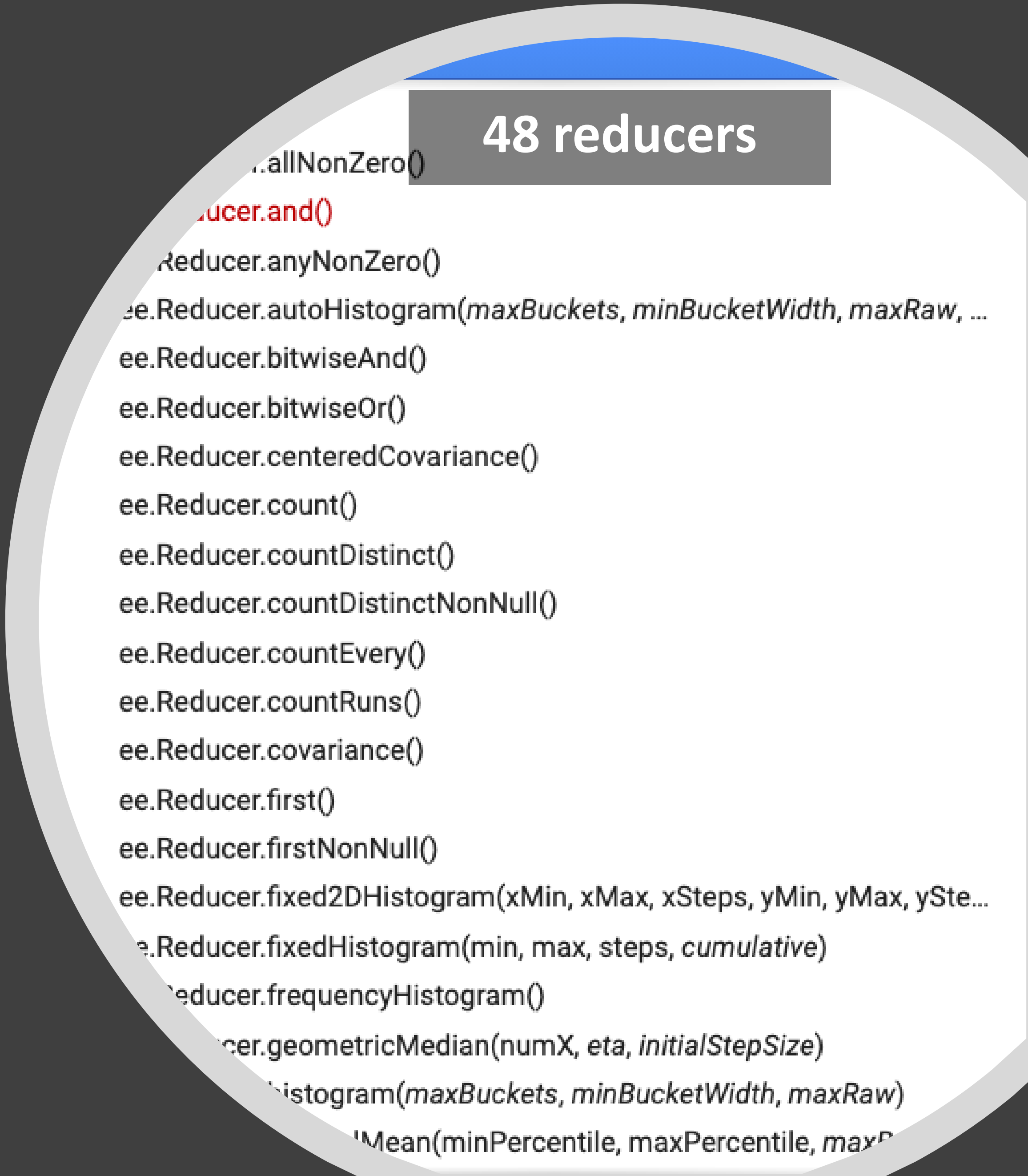




https://developers.google.com/earth-engine/guides/reducers_intro

Reducers

- ee.Array.reduce
- ee.List.reduce
- ee.FeatureCollection
    - reduceColumns
    - reduceToImage
- ee.Image
    - reduce
    - reduceConnectedComponents
    - reduceNeighborhood
    - reduceRegion
    - reduceRegions
    - reduceToVector
- ee.ImageCollection
    - reduce



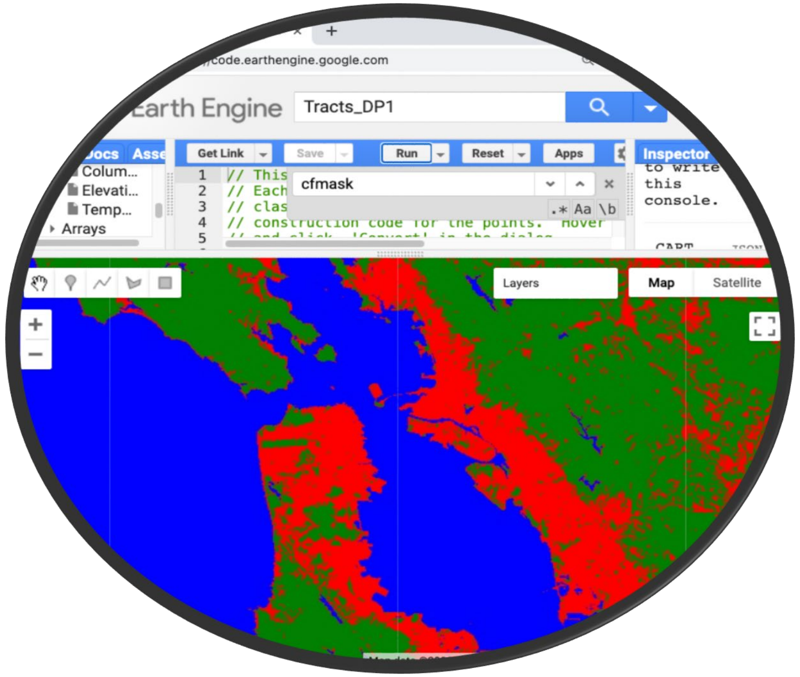
48 reducers

.allNonZero()
ucer.and()
Reducer.anyNonZero()
e.Reducer.autoHistogram(*maxBuckets*, *minBucketWidth*, *maxRaw*, ...
ee.Reducer.bitwiseAnd()
ee.Reducer.bitwiseOr()
ee.Reducer.centeredCovariance()
ee.Reducer.count()
ee.Reducer.countDistinct()
ee.Reducer.countDistinctNonNull()
ee.Reducer.countEvery()
ee.Reducer.countRuns()
ee.Reducer.covariance()
ee.Reducer.first()
ee.Reducer.firstNonNull()
ee.Reducer.fixed2DHistogram(xMin, xMax, xSteps, yMin, yMax, ySte...
.Reducer.fixedHistogram(min, max, steps, *cumulative*)
educer.frequencyHistogram()
cer.geometricMedian(numX, *eta*, *initialStepSize*)
istogram(*maxBuckets*, *minBucketWidth*, *maxRaw*)
Mean(minPercentile, maxPercentile, *max*

GEE Processing Mode

Interactive Processing

Visualize data on the fly, preview analysis results, query google data catalog



Tracts_DP1

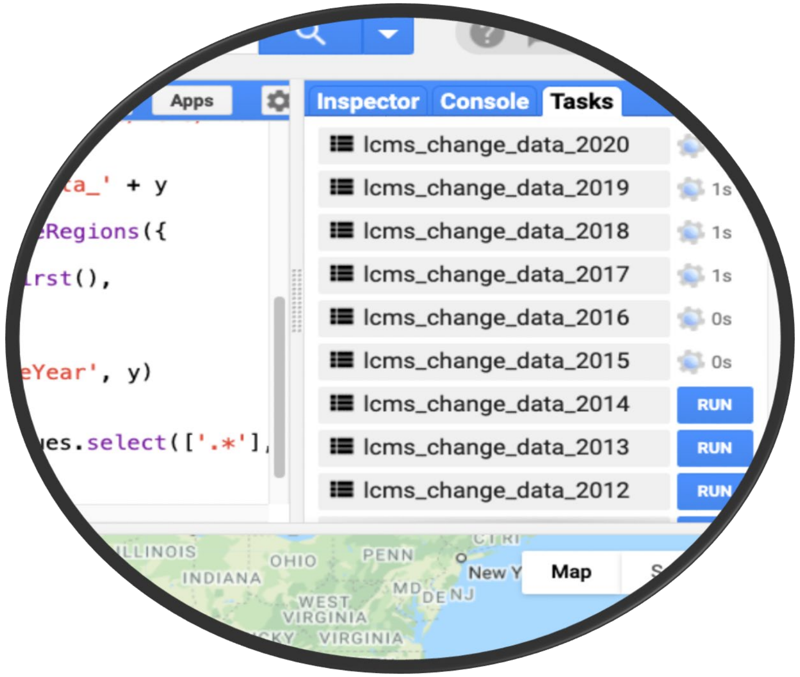
cfmask

```
// This
// Each
// clas
// construction code for the points.  Hover
```

to write this console.

Batch Processing

Large scale, complex computation; multi-batching tasks with a few button clicks



```
ta_' + y
eRegions({
irst(),
eYear', y)
es.select(['.*'],
```

```
lcms_change_data_2020
lcms_change_data_2019   1s
lcms_change_data_2018   1s
lcms_change_data_2017   1s
lcms_change_data_2016   0s
lcms_change_data_2015   0s
lcms_change_data_2014   RUN
lcms_change_data_2013   RUN
lcms_change_data_2012   RUN
```

Accessing Google Earth Engine

Earth Engine Explorer https://explorer.earthengine.google.com/#workspace

Not actively developed, use the following methods

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

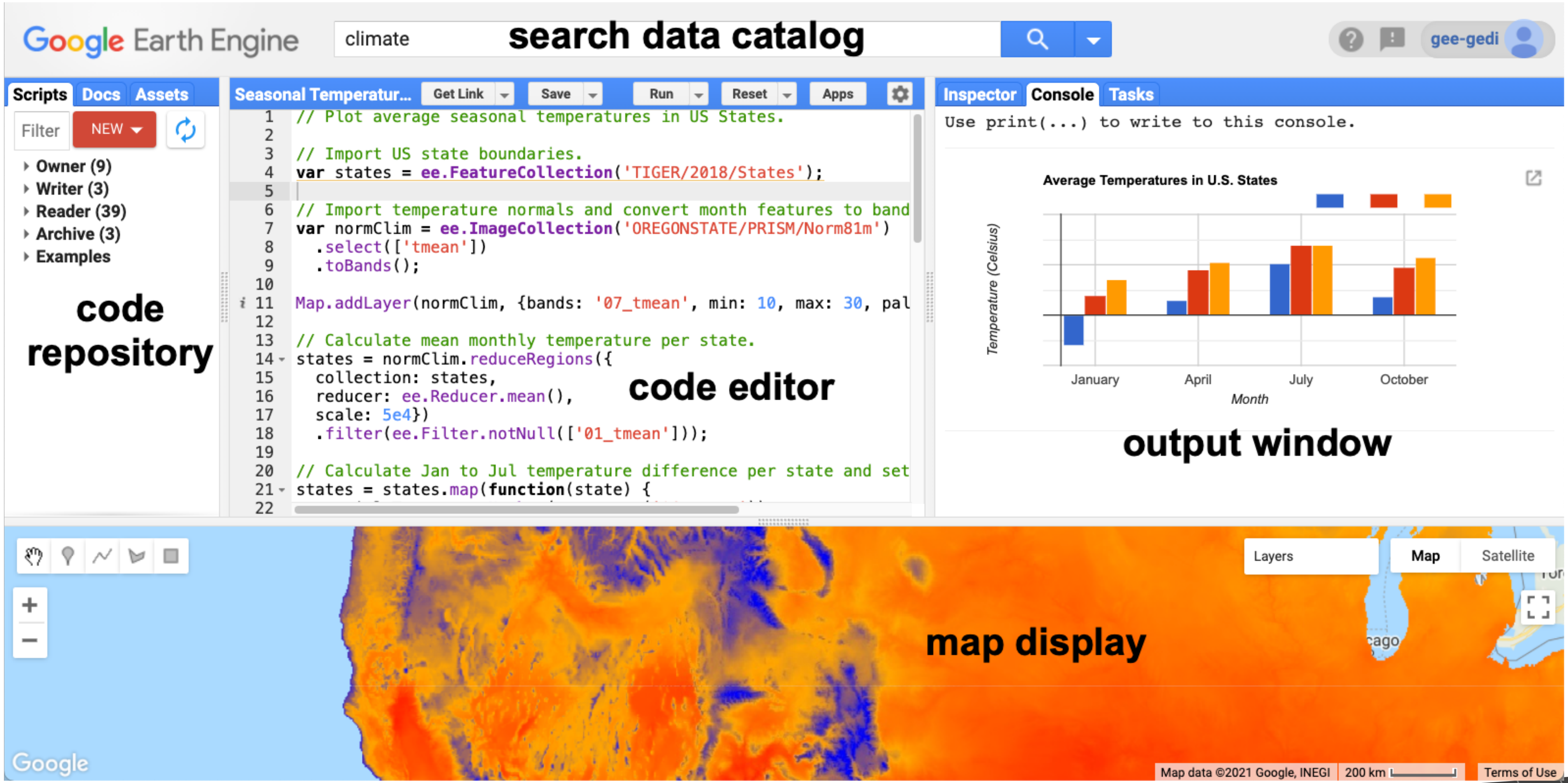
Google Colab https://colab.research.google.com/notebooks/intro.ipynb

Not covered here

REST API https://developers.google.com/earth-engine/reference

Not covered here

Customized Applications



search data catalog

code repository

```
// Plot average seasonal temperatures in US States.

// Import US state boundaries.
var states = ee.FeatureCollection('TIGER/2018/States');

// Import temperature normals and convert month features to band
var normClim = ee.ImageCollection('OREGONSTATE/PRISM/Norm81m')
  .select(['tmean'])
  .toBands();

Map.addLayer(normClim, {bands: '07_tmean', min: 10, max: 30, pal

// Calculate mean monthly temperature per state.
states = normClim.reduceRegions({
  collection: states,
  reducer: ee.Reducer.mean(),
  scale: 5e4})
  .filter(ee.Filter.notNull(['01_tmean']));

// Calculate Jan to Jul temperature difference per state and set
states = states.map(function(state) {
```

code editor

```
Use print(...) to write to this console.
```

output window

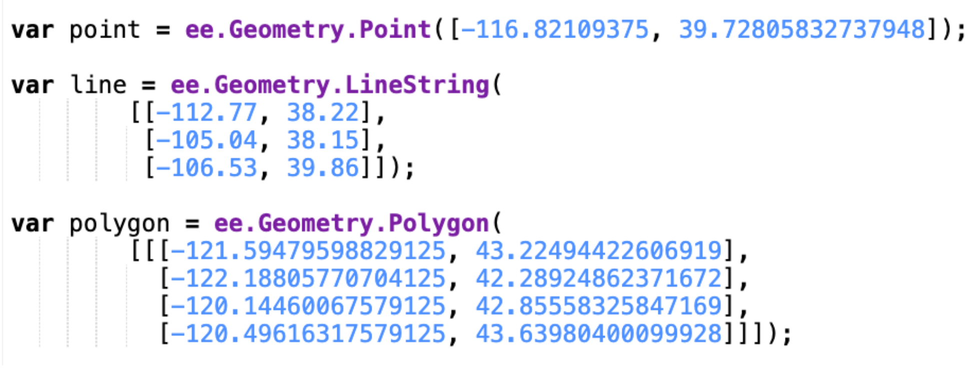
map display

Quick Tour of Code Editor

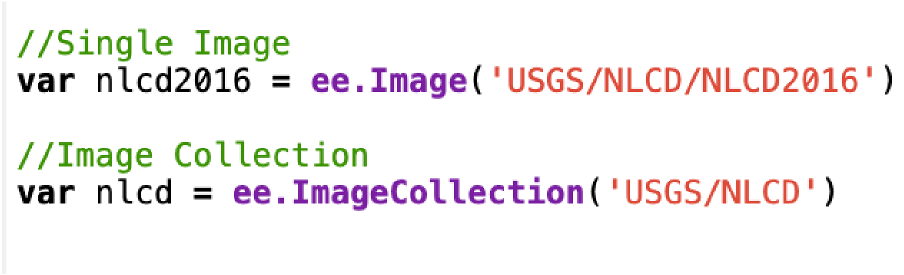
Spatial Data in GEE

- Vector Data
  - ee.Geometry or ee.Feature
  - ee.FeatureCollection (multiple features)

- Raster Data
  - ee.Image, represents a single image, usually with multiple band bands
  - ee.ImageCollection, a set of images usually with the same data structure



```
var point = ee.Geometry.Point([-116.82109375, 39.72805832737948]);

var line = ee.Geometry.LineString(
        [[-112.77, 38.22],
         [-105.04, 38.15],
         [-106.53, 39.86]]);

var polygon = ee.Geometry.Polygon(
        [[[-121.59479598829125, 43.22494422606919],
          [-122.18805770704125, 42.28924862371672],
          [-120.14460067579125, 42.85558325847169],
          [-120.49616317579125, 43.63980400099928]]]);
```



```
//Single Image
var nlcd2016 = ee.Image('USGS/NLCD/NLCD2016')

//Image Collection
var nlcd = ee.ImageCollection('USGS/NLCD')
```

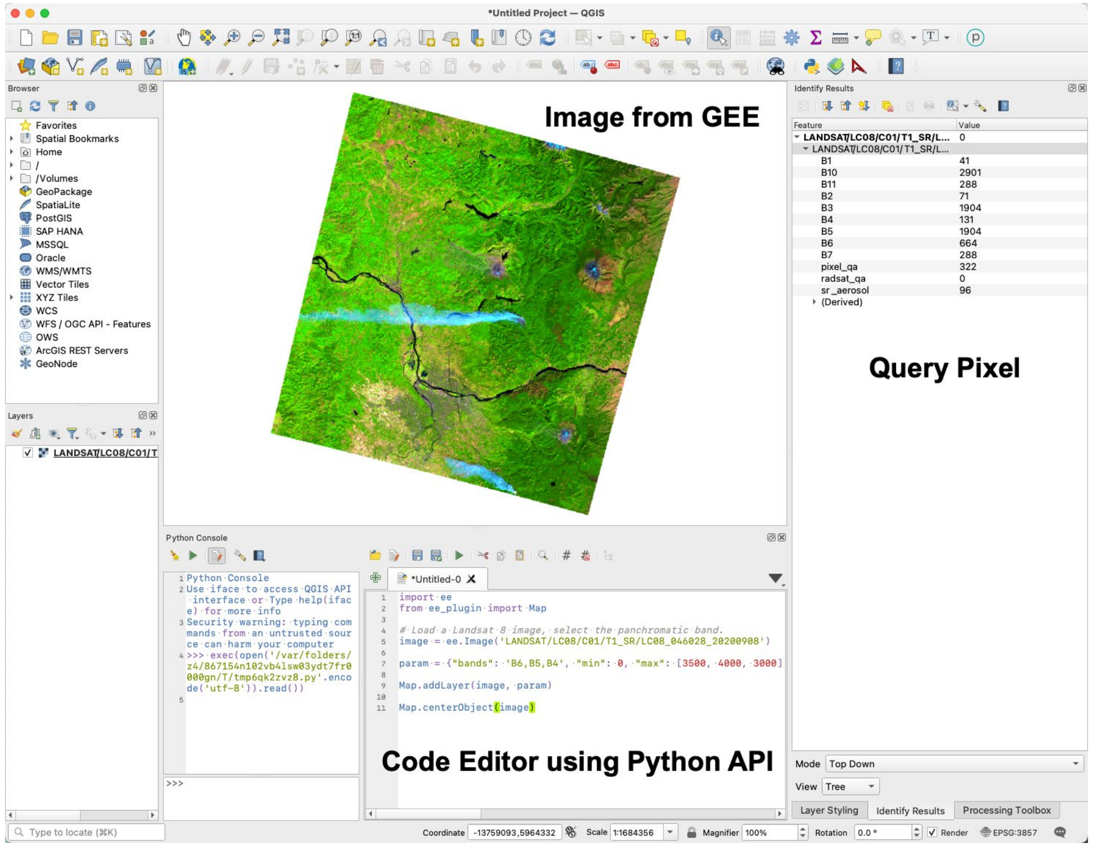


Image from GEE

Query Pixel

Code Editor using Python API

Identify Results

Feature	Value
LANDSAT/LC08/C01/T1_SR/L...	0
LANDSAT/LC08/C01/T1_SR/L...	
B1	41
B10	2901
B11	288
B2	71
B3	1904
B4	131
B5	1904
B6	664
B7	288
pixel_qa	322
radsat_qa	0
sr_aerosol	96
(Derived)	

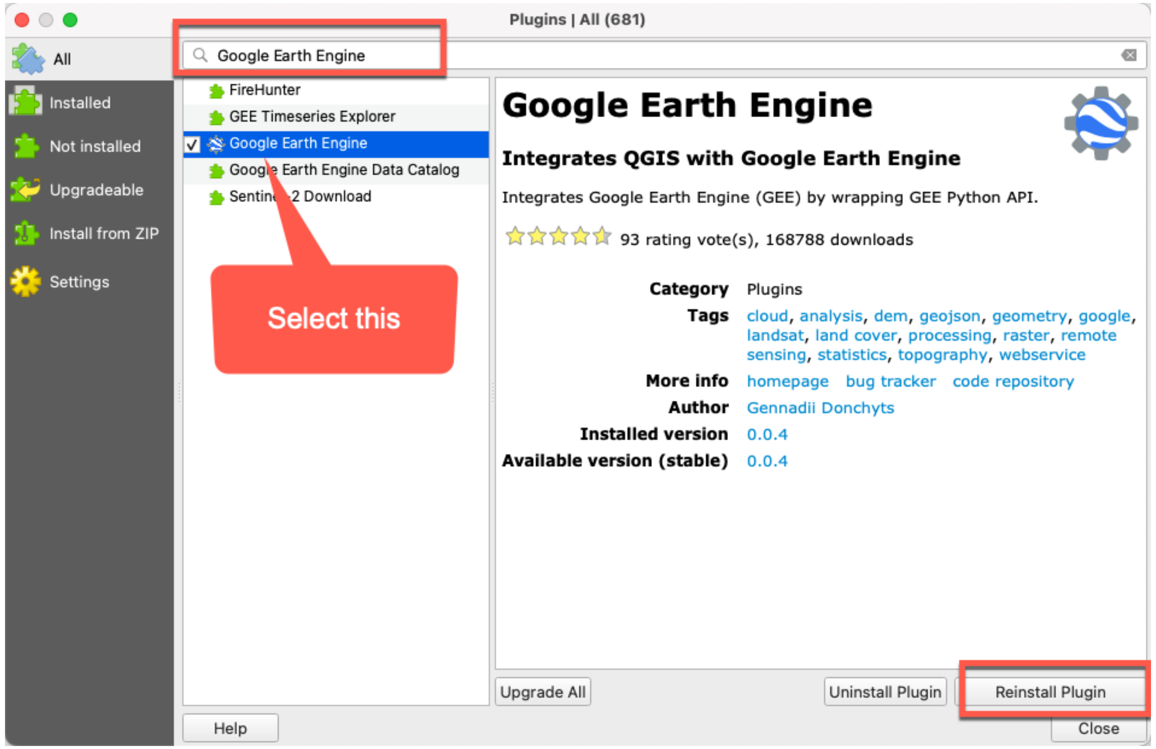
Mode: Top Down

View: Tree

```
Python Console
Use iface to access QGIS API interface or Type help(iface) for more info
Security warning: typing commands from an untrusted source can harm your computer
>>> exec(open('/var/folders/z4/867154n102vb4lsw03ydt7fr0000gn/T/tmp6qk2zvz8.py'.encode('utf-8')).read())
```

```
import ee
from ee_plugin import Map

# Load a Landsat 8 image, select the panchromatic band.
image = ee.Image('LANDSAT/LC08/C01/T1_SR/LC08_046028_20200908')

param = {"bands": 'B6,B5,B4', "min": 0, "max": [3500, 4000, 3000]

Map.addLayer(image, param)

Map.centerObject(image)
```

Coordinate: -13759093,5964332 Scale: 1:1684356 Magnifier: 100% Rotation: 0.0 ° ☑ Render EPSG:3857



Google Earth Engine

- FireHunter
- GEE Timeseries Explorer
- ☑ Google Earth Engine
- Google Earth Engine Data Catalog
- Sentinel-2 Download

Select this

Google Earth Engine

Integrates QGIS with Google Earth Engine

Integrates Google Earth Engine (GEE) by wrapping GEE Python API.

★★★★★ 93 rating vote(s), 168788 downloads

Category Plugins

Tags cloud, analysis, dem, geojson, geometry, google, landsat, land cover, processing, raster, remote sensing, statistics, topography, webservice

More info homepage bug tracker code repository

Author Gennadii Donchyts

Installed version 0.0.4

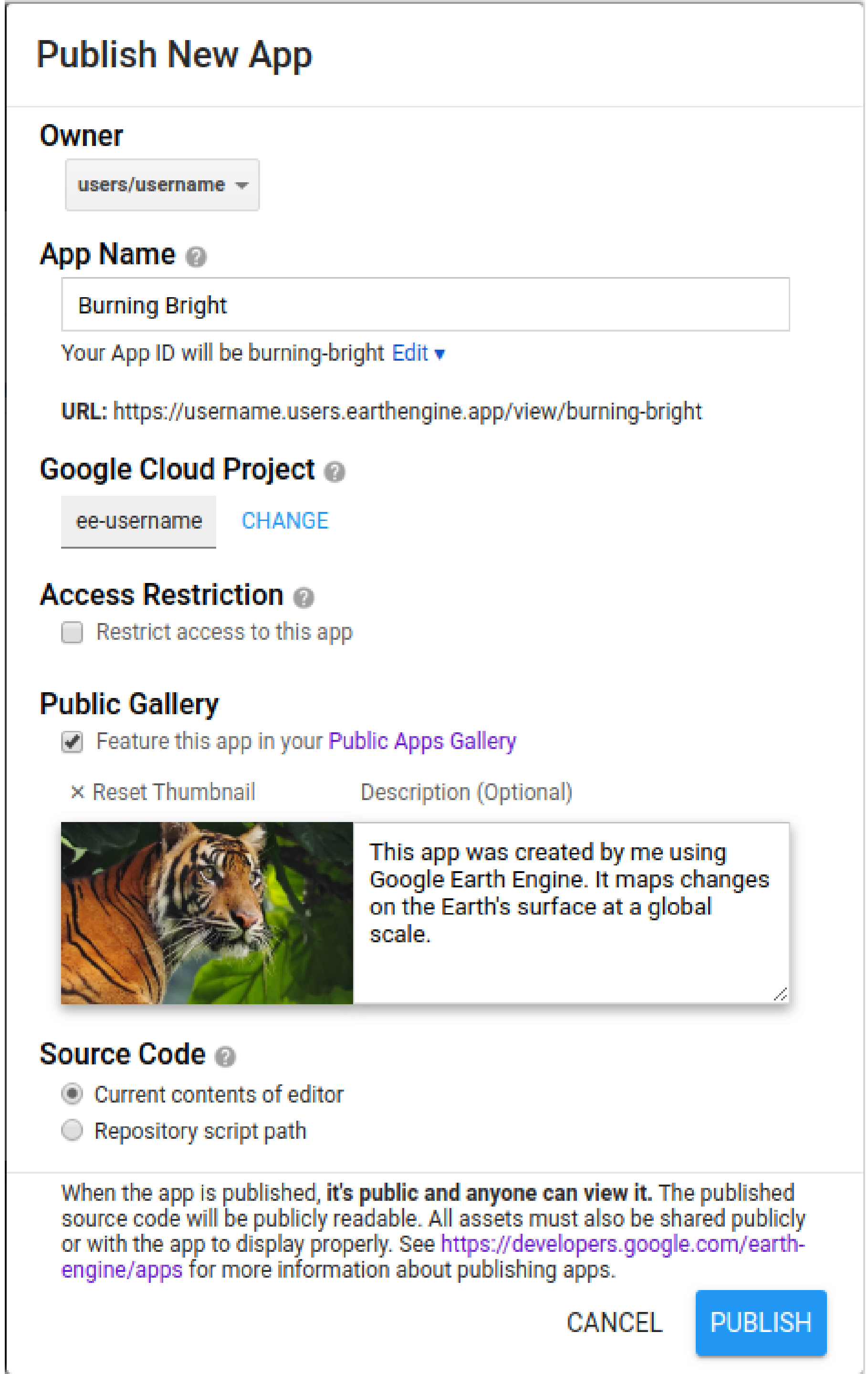
Available version (stable) 0.0.4

QGIS with Plugin

APP

Earth Engine App

- Coder interface from Code Editor
- Publish directly from Code Editor
- Share work as web application



Publish New App

Owner

users/username ▾

App Name

Burning Bright

Your App ID will be burning-bright Edit ▾

URL: https://username.users.earthengine.app/view/burning-bright

Google Cloud Project

ee-username CHANGE

Access Restriction

☐ Restrict access to this app

Public Gallery

☑ Feature this app in your Public Apps Gallery

× Reset Thumbnail

Description (Optional)

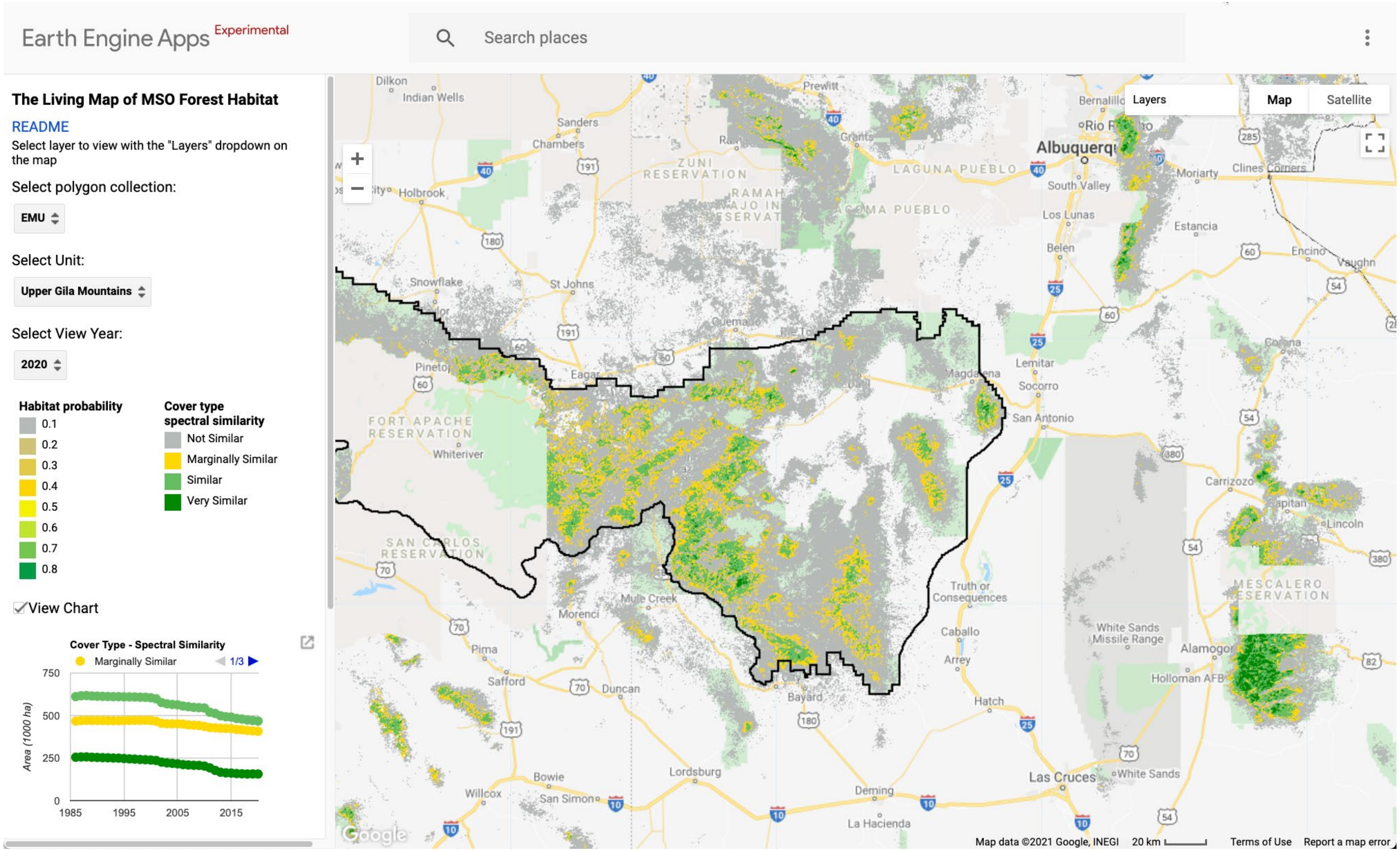
This app was created by me using Google Earth Engine. It maps changes on the Earth's surface at a global scale.

Source Code

● Current contents of editor

○ Repository script path

When the app is published, **it's public and anyone can view it.** The published source code will be publicly readable. All assets must also be shared publicly or with the app to display properly. See https://developers.google.com/earth-engine/apps for more information about publishing apps.



Earth Engine Apps Experimental

Search places

The Living Map of MSO Forest Habitat

README

Select layer to view with the "Layers" dropdown on the map

Select polygon collection: EMU

Select Unit: Upper Gila Mountains

Select View Year: 2020

Habitat probability

- ⬜ 0.1
- 🟫 0.2
- 🟨 0.3
- 🟨 0.4
- 🟨 0.5
- 🟩 0.6
- 🟩 0.7
- 🟩 0.8

Cover type spectral similarity

- ⬜ Not Similar
- 🟨 Marginally Similar
- 🟩 Similar
- 🟩 Very Similar

☑ View Chart

Cover Type - Spectral Similarity

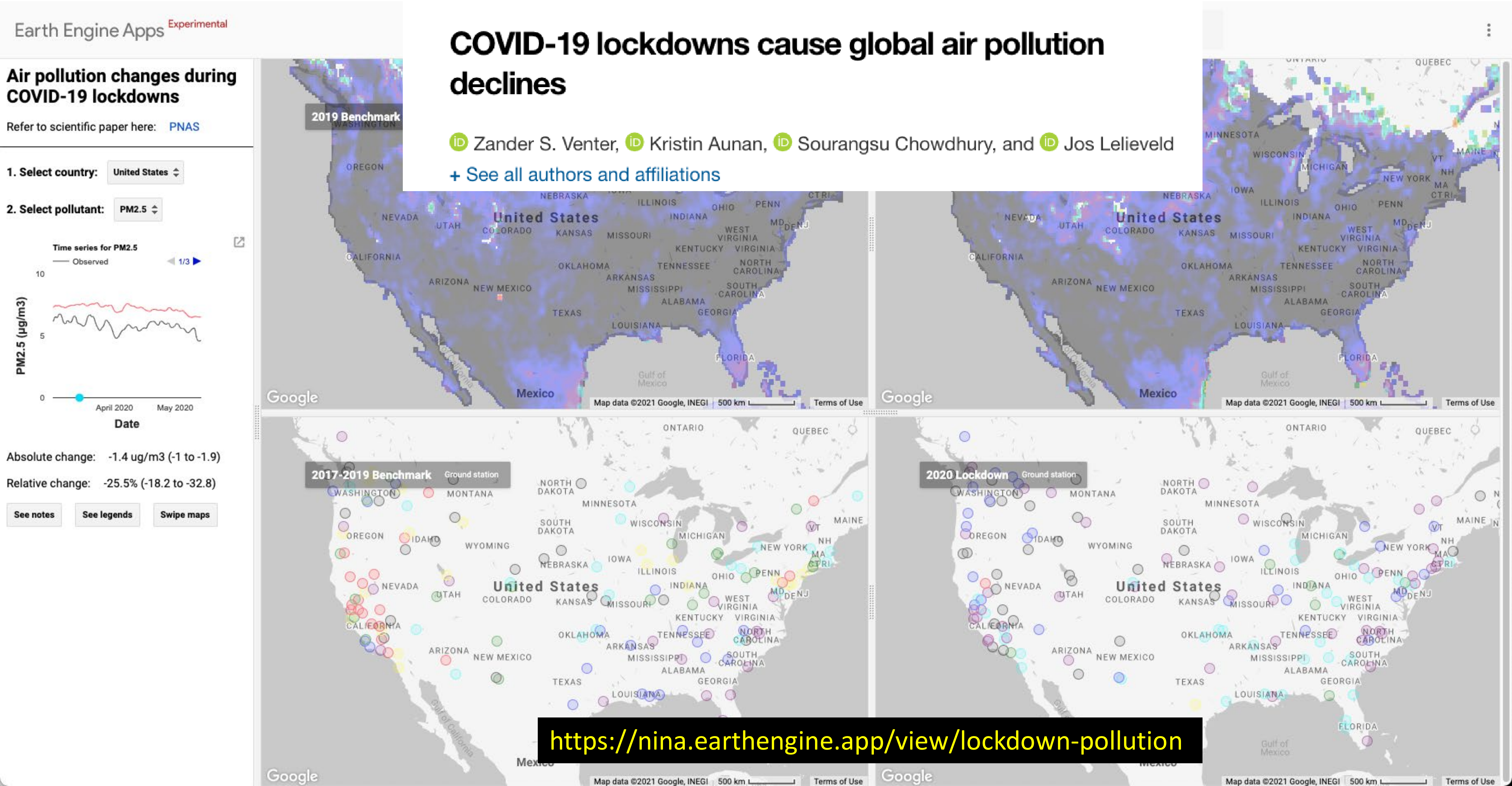
https://usfs-larse.earthengine.app/view/mso-app

RESEARCH ARTICLE

COVID-19 lockdowns cause global air pollution declines

Zander S. Venter, Kristin Aunan, Sourangsu Chowdhury, and Jos Lelieveld

+ See all authors and affiliations



Earth Engine Apps Experimental

Air pollution changes during COVID-19 lockdowns

Refer to scientific paper here: PNAS

1. Select country: United States

2. Select pollutant: PM2.5

Absolute change: -1.4 ug/m3 (-1 to -1.9)

Relative change: -25.5% (-18.2 to -32.8)

https://nina.earthengine.app/view/lockdown-pollution

Sign-up

https://signup.earthengine.google.com

Super useful demonstration code repos

Nick Clinton has put together these very useful learning script

- Basics: JavaScript, data access, visualization, mapping, reducing, compositing
  - https://code.earthengine.google.com/?accept_repo=users/nclinton/EE101
- Multi-spectral and multi-temporal classification, parameter tuning
  - https://code.earthengine.google.com/?accept_repo=users/nclinton/EE102
- Classification, phenology modeling, terrain visualization, spectral unmixing
  - https://code.earthengine.google.com/?accept_repo=users/nclinton/EE201
- Earth Engine best practices, client-server interaction, gotchas
  - https://code.earthengine.google.com/?accept_repo=users/nclinton/EE202
- UI stuff for beginners
  - https://code.earthengine.google.com/?accept_repo=users/nclinton/ui-api-101
- NDVI inspector
- https://code.earthengine.google.com/8bae27d7011e93b84db2013155f3bb23

Other Resources

- API Guide: https://developers.google.com/earth-engine/guides
- Community Guide: https://developers.google.com/earth-engine/tutorials
- GEE Blogs: https://medium.com/google-earth/tagged/earth-engine
- https://gee-community.github.io/qgis-earthengine-plugin
- GEE Map: https://geemap.org