Google Earth Engine

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Contents

1 Preface

Google Earth Engine sucks! Below (Fig. 1) we have a simple example to show GEE is very specific. Accessing to elements/entries of its object is not intuitive. Figuring out every single step is a challenge.

Figure 1: GEE sucks.

Here is the code used for generation of Fig. 1.

Algorithm 1.1: GEE Sucks.

```
1. print(''Print #1:  3+10'', 3+10);
2. var x=3;
3. var y=10;
4. print(''Print #2:  x+y'', x+y);

5. var big_delta_x = 3;
6. print(''Print #3:  big_delta_x'', big_delta_x);

7. var x_big = ee.List.sequence(-125.0, -111.3, big_delta_x)
   ;

8. print (''Print #4:  x_big'', x_big);
9. print(''Print #5:  x_big.get(1)'', x_big.get(1));
10. print(''Print #6'',
ee.Number(big_delta_x).add (ee.Number(x_big.get(1))));

11. var aaa = x_big.get(1) + big_delta_x;
12. // print(''Print #7:  aaa'', aaa);
13. print(''Print #8:  ee.Number(aaa)'', ee.Number(aaa));
```

2 JavaScript or Python Interface

I think Python should be avoided in this particular case for the following reasons:

1. The interface is too slow,
2. The interface needs authentication every single time,
3. Google does not maintain the Python. Therefore, the functions are first written/updated for the JavaScript (JS) by Google, and the Python equivalents/updates will not be provided in a timely manner (who knows when?).
4. The tutorials for JS is already hard to find, it is much worse for Python. Again, since Google is responsible for JavaScript, it releases the tutorials for it, but not Python.

   P.S. tutorials for JS might be abundant, but finding your exact needs might be hard. Even when you find something you may not be sure if that is the best possible solution.

3 Landsat Products and Differences

There are different products that fall under different labels; tier 1 vs tier 2, collection 1 vs collection 2, level 1 and level 2. Some of these have the same description on Google developer pages. For example, USGS Landsat 8 Surface Reflectance Tier 1 [1] and USGS Landsat 8 Surface Reflectance Tier 2 have the same description and identical bands. In this particular example we want to use Tier 1. But we need a deeper understanding of differences(?)

Base on the information below and references therein, Collection 2 is an improvement over Collection 1 (is there any time period for which Collection 2 does not exist but 1 does?). Moreover, Collection 1 has only level-1 data, however, Collection 2 has level-1 data as well as level-2.

Collection 1 Landsat Collection 1 was established in 2016 to improve archive management. It is being ***superseded*** by Collection 2 as processing continues. Learn more about Collection 1 from the USGS.

Collection 2 Landsat Collection 2 marks the second major reprocessing effort on the Landsat archive by the USGS that results in several data product improvements that harness recent advancements in data processing, algorithm development, and data access and distribution capabilities. Learn more about Collection 2 from the USGS.

[1] This page says "Caution: This dataset has been superseded by LANDSAT/LC08/C02/T1_L2." So, it seems USGS Landsat 8 Level 2, Collection 2, Tier 1 should be superior to Tier 1 SR, but in my plots it was not!

4 Access a Feature/Entry of a FeatureCollection

Suppose your `featurecollection` is called `SF`. In order to access its entries you have to convert it to a `list` and then use `get(.)`:

```
print (''SF.get(0)'', SF.toList(4).get(0));
```

where `4` is the size of `SF` known in advance, and `0` is index of first entry of `SF`. In general you can use:

```
print (''SF.get(0)'', SF.toList(SF.size()).get(index));
```

Please note if you use `SF.get(0)` you will get an error.

5 Add a Property to a Feature

Suppose you have uploaded a shapefile `SF` into your assets. The shapefiles usually have a component/slice called `data` (which is of type datatable) that can be accessed via `SF@data` in R. This component stores metadata corresponding to each polygon.

Say each polygon is an agricultural field that has some attributes associated with it such as irrigation type, area of the field, etc. After some computations on GEE you may want to attach these metadata to the output to use later. These metadata is referred to by `properties` on GEE. If you want to manually add a property to a feature you should use:

```
a_feature = a_feature.set('my_property', 1);
```

If you want to copy `properties` (metadata) of `feature_b` into `feature_a` you can do:

```
feature_a = feature_a.copyProperties(feature_b, ['ID', 'Irrigation_type']);
```

where `['ID', 'Irrigation_type']` is a subset of `properties` of `feature_b` to be copied into `feature_a`. I guess if that argument is dropped, then all `properties` will be copied.

6 Find Centroid of Polygons

Suppose you have a shapefile that you have uploaded to GEE as an *asset*. Here we will see how to find the centroids of the polygons in the shapefile. Let the name of shapefile be `Our_ShapeFile`. The function to compute centroids of the polygons in `Our_ShapeFile` is given by Alg. 2. Line 4 of the Alg. 2 is keeping the columns of data slice in `Our_ShapeFile`; `Our_ShapeFile`@data.

Algorithm 6.1: Find Centroids of Polygons in a Shapefile.

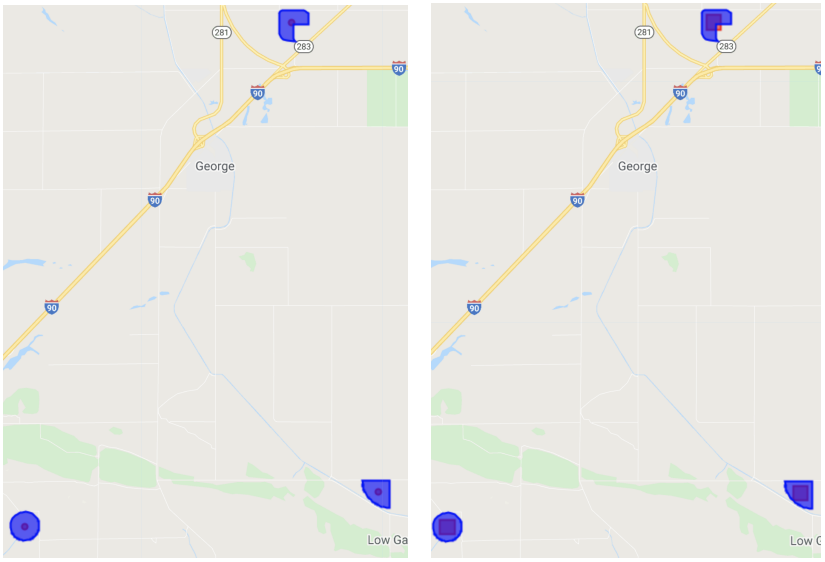
```
1. function getCentroid(feature) {
    2. // Keep this list of properties.;
    3. var keepProperties = ['ID', 'county'];

    4. // Get the centroid of the feature's geometry.;
    5. var centroid = feature.geometry().centroid(); ;

    6. // Return a new Feature, copying properties from the
          old Feature.;
    7. return ee.Feature(centroid).copyProperties (feature,
                                                   keepProperties);
8. }

9. var SF = ee.FeatureCollection(Our_ShapeFile);
10. var centroids_from_GEE = SF.map(getCentroid);
```

Warning: Imagine your polygon looks like a doughnut. Then the centroid would be in the center of the disk in the center of the doughnut which is not part of the doughnut/polygon/region of interest. So, if you want to look at an area around the centroid, then that area (or parts of it, depending on how large the area is) would not belong to the polygon (See Fig. 2b; it is not a doughnut, but it delivers the message!) By adding one line (line 5.5 in Alg. 3) to the function `getCentroid(.)` we can get a buffer (a rectangular or a circle area) around the centroids.



(a) Bad Centroid (b) Bad Buffer

Figure 2: Centroids and buffers around the centroids of polygons in a shapefile.

Algorithm 6.2: Make a Buffer Around Centroids of Polygons.

```
1. function get_rectangle_arround_centroid(feature){
    2. // Keep this list of properties.;
    3. var keepProperties = ['ID', 'county'];

    4. // Get the centroid of the feature's geometry.;
    5. var centroid = feature.geometry().centroid(); ;
    5.5 centroid = ee.Feature(centroid.buffer(200).bounds());
    6. // Return a new Feature, copying properties from the
    old Feature.;
    7. return ee.Feature(centroid).copyProperties(feature,
                                                 keepProperties);
8. }
9. var SF = ee.FeatureCollection(Our_ShapeFile);
10. var centroids_from_GEE =
                          SF.map (get_rectangle_arround_centroid);
```

7 Cloud Filtering

Handling clouds for Sentinel and Landsat are different. Let us start by **Sentinel**.

First, the followings are equivalent:

- **var** `filtered = my_IC.filterMetadata( 'CLOUDY_PIXEL_PERCENTAGE', 'less_than', 70);`
- **var** `filtered = my_IC.filter('CLOUDY_PIXEL_PERCENTAGE < 70')`
- **var** `filtered = my_IC.filter(ee.Filter.lte('CLOUDY_PIXEL_PERCENTAGE', 70))`

They all filter out *images* with cloud cover less than or equal to 70%. Those images will NOT be in our `filtered` collection. Said differently, our `filtered` collection may include images that are covered by cloud up to 70%.

This is a pre-filtering step. Later, we can toss out the cloudy *pixels* from every single image.

Algorithm 7.1: Filter Cloudy Pixels for Sentinel.

```
1. function maskS2clouds(image) {

2.   // Each Sentinel-2 image has a bitmask band with cloud
       mask information QA60.;
3.   var qa = image.select('QA60');

4.   // Bits 10 and 11 are clouds and cirrus, respectively.;
5.   var cloudBitMask = 1 << 10 ;
6.   var cirrusBitMask = 1 << 11 ;

7.   // Both flags should be set to zero, indicating clear
       conditions.;
8.   var mask = qa.bitwiseAnd(cloudBitMask) .eq(0).and(
                qa.bitwiseAnd(cirrusBitMask) .eq(0));

9.   // Return the masked and scaled data, without
       the QA bands.
10.  return image.updateMask(mask)
                 .divide(10000)
                 .select(''B.*'')
       .copyProperties( image, [''system:time_start'']);
11. }
```

Note 1: Please note the last line in Alg. 4 is copying the system start time into the image which has nothing to do with clouds. It may be handy later.

Note 2: Please note the three (equivalent) pre-filtering of images mentioned above do not exist for Landsat!

Landsat(s) is a different satellite, and therefore, the cloud filtering must be handled differently; the band names that includes cloud information are different between Sentinel and Landsat or even among different Landsats.

Landsat-8 *Surface Reflectance* cloud mask [1]:

Algorithm 7.2: Filter Cloudy Pixels for Landsat-8 **Tier 1 and 2** *Surface Reflectance*.

```
1. function maskL8sr(image) {
2.   // Bits 3 and 5 are cloud shadow and cloud,
       respectively.;
3.   var cloudShadowBitMask = (1 << 3);
4.   var cloudsBitMask = (1 << 5);

5.   // Get the pixel QA band.;
6.   var qa = image.select('pixel_qa');

7.   // Both flags should be set to zero, indicating clear
       conditions.;
8.   var mask = qa.bitwiseAnd(cloudShadowBitMask).eq(0)
                 .and(qa.bitwiseAnd(cloudsBitMask).eq(0));

9.   return image.updateMask(mask);
10. }
```

Note: This is written for Landsat-8 (Surface Reflectance Tier 1 and 2).

The code for masking the cloudy pixels in Landsat-4, 5, and 7 *Surface Reflectance* is given by [2] that is given below by Alg. 6:

Algorithm 7.3: Filter Cloudy Pixels for Landsat-4, 5, and 7 **Tier 1 and 2** *Surface Reflectance*.

```
function cloudMaskL457(image) {
  var qa = image.select('pixel_qa');
  // If the cloud bit (5) is set and the cloud confidence (7)
       is high or the cloud shadow bit is set (3),
       then it's a bad pixel.
  var cloud = qa.bitwiseAnd(1 << 5)
                  .and(qa.bitwiseAnd(1 << 7))
                  .or(qa.bitwiseAnd(1 << 3));
  // Remove edge pixels that don't occur in all bands
  var mask2 = image.mask().reduce(ee.Reducer.min());
  return image.updateMask(cloud.not()).updateMask(mask2);
}
```

I have copied the cloud masking functions from GEE development/data-product pages into a script that can be found here [3]. More on masking clouds of Sentinel-2 and shadows are provided here by GEE developers [4].

8 Timelines

Figure 3 shows the timeline of Landsat satellites [5] and Table 1 shows the exact dates.

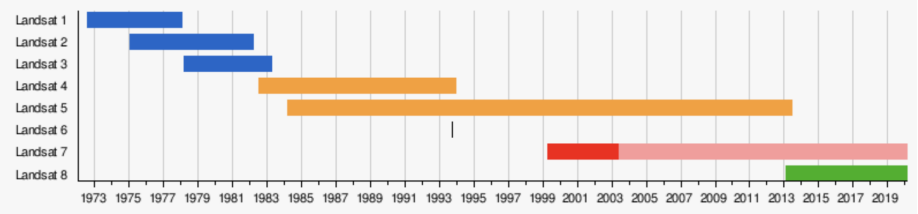


Figure 3: Landsat Timeline.

9 Band Names and Indices

Band names are different in each instrument (see Table 2). Hence the indices must be defined differently using proper band names. Below we see some of indices.

Table 1: Landsat timeline table.

Satellite	Launched	Terminated
Landsat 5	1 March 1984	5 June 2013
Landsat 6	5 October 1993	5 October 1993
Landsat 7	15 April 1999	Still active
Landsat 8	11 February 2013	Still active
Landsat 9	16 September 2021 (planned)	-

Table 2: Some Band Names in Satellites.

Satellite	NIR	Red	Blue
Sentinel	B8	B4	B2
Landsat-8	B5	B4	B2
Landsat-7	B4	B3	B1

$$
\begin{aligned}
\text{EVI} &= G \times \frac{NIR - R}{NIR + C1 \times R - C2 \times B + L} \\
\text{EVI}_S &= 2.5 \times \frac{B8 - B4}{B8 + 6 \times B4 - 7.5 \times B2 + 1} \\
\text{EVI}_8 &= 2.5 \times \frac{B5 - B4}{B5 + 6 \times B4 - 7.5 \times B2 + 1} \\
\text{EVI}_7 &= 2.5 \times \frac{B4 - B3}{B4 + 6 \times B3 - 7.5 \times B1 + 1}
\end{aligned} \tag{1}
$$

where NIR is near infrared, R is Red, B is blue, EVI_8 is the Enhanced Vegetation Index (EVI) in Landsat-8 [6], and EVI_S is the EVI in Sentinel; The NIR band in Landsat-8 is $B5$ [7] and for Sentinel is $B8$.

"EVI is similar to Normalized Difference Vegetation Index (NDVI) and can be used to quantify vegetation greenness. However, EVI corrects for some atmospheric conditions and canopy background noise and is more sensitive in areas with dense vegetation. It incorporates an "L" value to adjust for canopy background, "C" values as coefficients for atmospheric resistance, and values from the blue band (B). These enhancements allow for index calculation as a ratio between the R and NIR values, while reducing the background noise, atmospheric noise, and saturation in most cases" [6].

Below are the NDVIs for Landsat-4 to Landsat-7 [8], Landsat-8 [8], and

Sentinel:

$$\begin{aligned} \text{NDVI} &= \frac{NIR - R}{NIR + R} \\ \text{NDVI}_S &= \frac{B5 - B4}{B5 + B4} \\ \text{NDVI}_8 &= \frac{B8 - B4}{B8 + B4} \\ \text{NDVI}_{4-7} &= \frac{B4 - B3}{B4 + B3} \end{aligned} \tag{2}$$

Landsat-7 has 8-day NDVI composite already provided by GEE [9]. This product is based on TOA data which is not perfect! However, it seems running some smoothing methods on it can make it useful.

References

[1] Landsat-8 cloud mask. https://developers.google.com/earth-engine/datasets/catalog/LANDSAT_LC08_C01_T2_SR#bands. [Online; accessed August 30, 2021].

[2] Cloud cleaning in Landsat4-7. https://developers.google.com/earth-engine/datasets/catalog/LANDSAT_LE07_C01_T2_SR. [Online; accessed August 30, 2021].

[3] Cloud masking functions on gee - a part of this mini-tutorial. https://code.earthengine.google.com/?scriptPath=users%2Fhnoorazar%2FGEE_Mini_Tutorial%3ACloudMaskings. [Online; accessed August 30, 2021].

[4] Cloud and shadow masking in sentinel. https://developers.google.com/earth-engine/tutorials/community/sentinel-2-s2cloudless. [Online; accessed August 30, 2021].

[5] Landsat timelines from Wikipedia. https://en.wikipedia.org/wiki/Landsat_program. [Online; accessed August 30, 2021].

[6] Landsat-8 EVI. https://www.usgs.gov/core-science-systems/nli/landsat/landsat-enhanced-vegetation-index?qt-science_support_page_related_con=0#qt-science_support_page_related_con. [Online; accessed August 30, 2021].

[7] Landsat-8 band names. https://www.usgs.gov/faqs/what-are-band-designations-landsat-satellites?qt-news_science_products=0#qt-news_science_products. [Online; accessed August 30, 2021].

[8] Landsat-4 NDVI. https://www.usgs.gov/core-science-systems/nli/landsat/landsat-normalized-difference-vegetation-index?qt-science_support_page_related_con=0#qt-science_support_page_related_con. [Online; accessed August 30, 2021].

[9] Landsat-7 8-day NDVI composite. https://developers.google.com/earth-engine/datasets/catalog/LANDSAT_LE07_C01_T1_8DAY_NDVI. [Online; accessed August 30, 2021].