REMOTE SENSING FOR ENVIRONMENTAL EDUCATION USING GOOGLE EARTH ENGINE

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ABSTRACT: Global environmental problems are becoming increasingly diverse and serious. To realize a sustainable society under these circumstances, it is essential to fundamentally review our current socioeconomic activities and lifestyles. Therefore, it is important for every citizen to understand the current state of the global environment and to take action toward to improve the situation. For this purpose, environmental education and training for each citizen, including students, is crucial. Satellite remote sensing technology is one of the most powerful tools for understanding the current state of the global environment. In this paper, we report on a method of using satellite imagery in Google Earth Engine (GEE) to understand the marine environment from a regional to a global scale as part of environmental education for students. The GEE is a cloud computing platform designed to store and process a vast amount of satellite imagery for analysis with free of charge. The GEE API is provided in JavaScript and Python, making it easy for students to use. On the other hand, we have developed a method to estimate sea surface temperature and chlorophyll-a concentration from Landsat-8 OLI and TIRS data in the Hiroshima Bay and Uwa Sea, Japan. Thus, we coded the equations for estimating sea surface temperature and chlorophyll-a concentration by GEE so that we could generate and display data for any season at any location for environmental education. The marine environmental information using satellite imagery and GEE is useful for students to learn about changes in the local and global marine environment and to think about the impact of these changes on marine life and fisheries.

1. INTRODUCTION

Global environmental problems are becoming increasingly diverse and serious, ranging from air pollution caused by increased automobile traffic and water pollution caused by domestic wastewater to global environmental problems such as global warming and the decline of tropical forests. Under these circumstances, to realize a sustainable society as represented by the sustainable development goals (SDGs), it is essential to fundamentally review our current socioeconomic activities and lifestyles, as well as the social systems that support them. Therefore, it is important for every citizen to understand the current state of the global environment and to take action toward to improve the situation. For this purpose, environmental education and training for each citizen is crucial. Satellite remote sensing technology is one of the most powerful tools for understanding the current state of the global environment.

On the other hand, there are many challenges in using satellite remote sensing for education. For example, satellite data access, long-term data acquisition and storage, software cost, and software-focused analysis skills. Google Earth Engine (GEE) is a cloud computing platform designed to store and process a vast amount of satellite imagery for analysis with free of charge. GEE has easy access to satellite imageries and stores large datasets, such as Landsat, Sentinel, and MODIS. Users need to learn computer programming, but will be able to access the large datasets in the same procedure.

In this report, the generation of marine environmental information, sea surface temperature (SST), and chlorophyll-a (Chl.a) concentration, using GEE was examined for university students.

2. MATERIALS

To use GEE, users need a Google account and require a simple sing up on the GEE website at first time (Google, 2021a). Free of charge for educational and research use. GEE provides a web-based integrated development environment (Code Editor) as a tool for satellite data analysis.

Landsat-8 observatory is designed for a 705 km, Sun-synchronous orbit, with a 16-day repeat cycle (USGS, 2019). The satellite has the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) instruments. The OLI sensor collects image data for 9 spectral bands in 185 km swath with a 30 m spatial resolution except the band 8 (Pan band). The TIRS sensor collects image data for two thermal infrared bands in 185 km swath with a 100 m spatial resolution. In GEE, Landsat-8 data has stored a variety of datasets. We use raw and TOA (top-of-atmosphere) reflectance data. The raw data uses the “USGS Landsat 8 Collection 1 Tier 1 and Real-Time data Raw Scenes” dataset for estimating SST. The raw data contains digital number (DN), scaled to the sensor's radiance. The TOA reflectance data uses the “USGS Landsat 8 Collection 1 Tier 1 and Real-Time data TOA Reflectance” dataset for estimating Chl.a concentration. The data are calibrated TOA reflectance using calibration coefficients in the metadata (Google, 2021b).

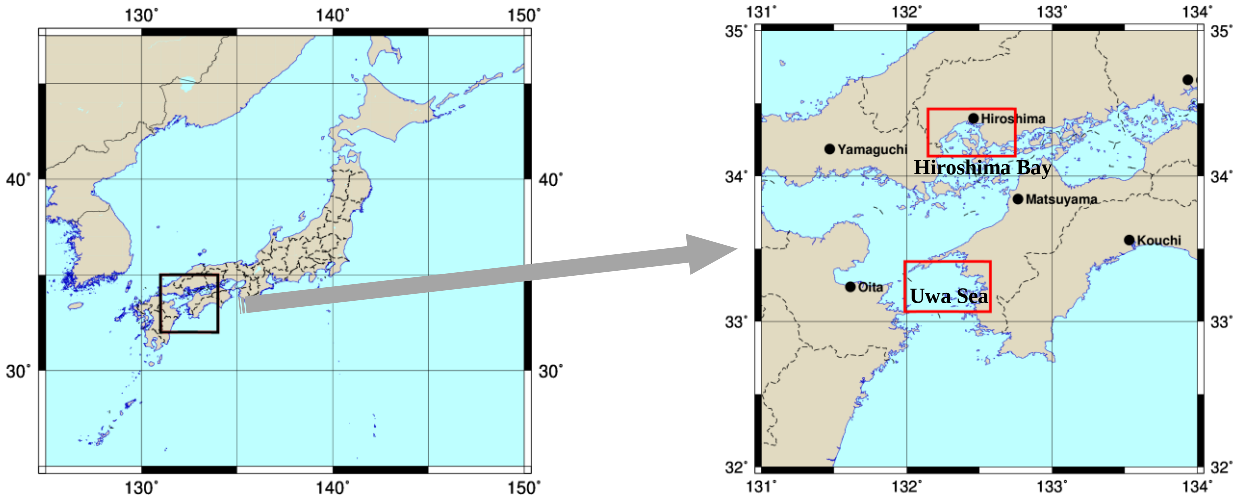


Figure 1. A map of test site in Japan. The red rectangle in the right image represents the test sites.

The test sites are the Hiroshima Bay and Uwa Sea, Japan as shown in Figure 1. Oyster farming and boat seine fishing are thriving in Hiroshima Bay. Cultivation of pearls, yellowtail, and sea bream is thriving in the Uwa Sea.

3. METHOD

3.1 Estimation for SST

Estimation of SST was based on brightness temperature (Oguro, 2018). Landsat-8/TIRS raw data was used for estimating SST. Brightness temperature was calculated based on the Landsat 8 handbook (USGS, 2019). First, the DN (Q_{cal}) data was converted to spectral radiance (L_λ) using Eq. (1)

$$L_\lambda = M_L \times Q_{cal} + A_L \ \ (W/m^2 \cdot sr \cdot \mu m)\,, \tag{1}$$

where M_L is radiance multiplicative scaling factor for the band L, A_L is radiance additive scaling factor for the band L. Then, spectral radiance (L_λ) was converted to SST using Eq. (2)

$$SST = \frac{K_2}{ln\left(\varepsilon \times \frac{K_1}{L_\lambda} + 1\right)} \ \ (K), \tag{2}$$

where K_1 and K_2 are calibration constants. ε is the emissivity. Here, the sea surface emissivity is assumed to 0.98. SST is estimated by Landat-8 band 10 in this report. Then, the temperature in Kelvin converted to degrees Celsius.

3.2 Estimation for Chl.a concentration

Estimation of Chl.a concentration was based on the linear combination index (LCI) (Frouin, 2006). Oguro et al. (2020) used LCI to estimate Chl.a concentration in Uwa Sea from Landsat-8/OLI data. The LCI is estimated by Eq. (3)

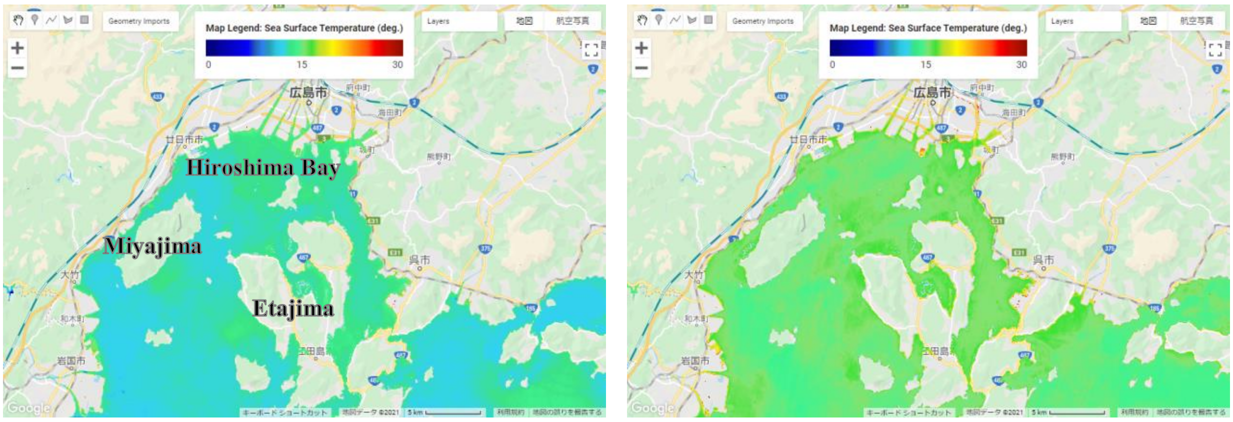
$$LCI \approx R_w(\lambda_1) - 1.9407R_w(\lambda_2) + 1.0610R_w(\lambda_3) - 0.1204R_w(\lambda_5), \tag{3}$$

where $R_w(\lambda_i)$ is the water reflectance of from the reflectance (λ_i) of band *i.* Then, Chl.a concentration (Chl.a) was estimated from the LCI by regression analysis based on the ground truth data in Uwa Sea (Oguro et al., 2020) as follows;

$$\mathrm{Chl.a} \approx 2.485\mathrm{exp}(159.743 \cdot \mathrm{LCI}). \tag{4}$$

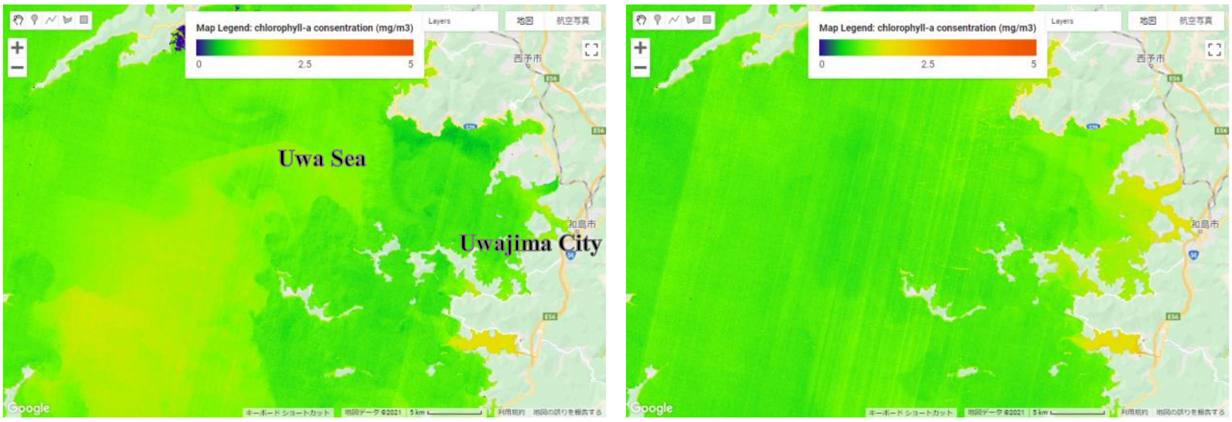
4. RESULTS

We coded the equations for estimating the SST and Chl.a concentration by GEE so that we could generate and display data for any season. Figure 2 shows the SST image on (a) April 2013 and (b) April 2020 in Hiroshima Bay. The SST



(a) April 2013 (b) April 2020

Figure 2. SST estimation image generated by GEE in Hiroshima Bay.



(a) April 2013 (b) April 2020

Figure 3. Chl.a concentration estimation image generated by GEE in Uwa Sea.

is around 13 degrees Celsius in 2013, and is around 14 degrees Celsius in 2020. In this area, oyster farming is popular using oyster beds made of bamboo. Around Miyajima and Etajima, there are many oyster farming. Adequate seawater temperature is an essential factor for growth. Users, including students, can easily compare seawater temperatures through GEE.

Figure 3 shows the Chl.a concentration image on (a) April 2013 and (b) April 2020 in the Uwa Sea. Chl.a concentration in 2013 shows a high area in offshore of the Uwa Sea. On the other hand, the Chl.a concentration of 2020 shows a high area inside the bay along the coast of Uwajima City.

GEE requires only a few lines of code to complete, data searching, downloading, and preprocessing of Landsat-8 imageries. Thanks to this feature, it can be easily used by university students. Students create SST and Chl.a concentration images like Figure 2-3 and write a report on the temporal changes in the target area. The advantages of this mechanism are as follows:

- No need to buy or install special software
- Easy to program
- Fast calculation and imaging
- Seasonal and temporal changes can be visualized
- Thematic maps can be compared with maps
- Provides important information for thinking about environmental issues

The above features allow users to spend more time learning and thinking about the nature of the problem. We tried to estimate SST and Chl.a concentration in five students. In their opinion, it was difficult because they were not familiar with GEE, but they were interested in the visualization of the global environment. Therefore, the next step is to develop manuals for the GEE operation and programming. The source codes used to estimate SST and Chl.a concentration are provided as Appendix 1 and 2, respectively.

5. CONCLUSION

We presented the generation of marine environmental information, SST, and Chl.a concentration, using GEE. The equations for estimating SST and Chl.a concentration were coded using GEE. Marine environmental data can be generated and displayed in any season, in any location. Thus, users including students have a opportunity to learn about changes in the local and global marine environment and to think about the impact of these changes on marine life and fisheries with free of charge. In the future, we plan to prepare manuals and use GEE as a teaching tools for environment.

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APPENDIXES

Appendix 1 -- The source code used to estimate the SST using GEE

```
// Correct the filterDate to the appropriate period.
var raw = ee.ImageCollection('LANDSAT/LC08/C01/T1_RT').filterDate('2020-04-01', '2020-04-30');

var visParams = {
  min: 0.0,
  max: 30.0,
  palette: ['040274', '040281', '0502a3', '0502b8', '0502ce', '0502e6', '0602ff', '235cb1', '307ef3', '269db1',
             '30c8e2', '32d3ef', '3be285', '3ff38f', '86e26f', '3ae237', 'b5e22e', 'd6e21f', 'fff705', 'ffd611',
             'ffb613', 'ff8b13', 'ff6e08', 'ff500d', 'ff0000', 'de0101', 'c21301', 'a71001', '911003']
};

// Load the Hansen et al. forest change dataset.
var hansenImage = ee.Image('UMD/hansen/global_forest_change_2015');

// Select the land/water mask.
var datamask = hansenImage.select('datamask');

// Create a binary mask.
var mask = datamask.eq(1).not();

// Function to estimate SST
var SST = function(image){
  return image.expression(
    '(1321.0789/log(0.98*774.8853/(0.000334*Qcal10 + 0.100000) + 1 ) -273.15)',
    {
      Qcal10: image.select('B10'),
    })
}


// Create SST image
var sst_deg = raw.map(SST);
var sst_deg_mask = sst_deg.max().updateMask(mask);
// Display SST image on the map
Map.addLayer(sst_deg_mask, visParams, 'SST');
```

Appendix 2 -- The source code used to estimate the Chl.a concentration using GEE

```
// Correct the filterDate to the appropriate period.
var toa = ee.ImageCollection('LANDSAT/LC08/C01/T1_TOA').filterDate('2020-04-01', '2020-04-30')

var visParams = {
  "opacity":1,
  "min":0.0,
  "max":5,
  "palette":["#3600a7","#00d119","#74f800","#e3e500","#f0cf00","#ffa700","#ff8800","#ff7200",
          "#fd6b00","#f35b00","#ee5200"]
}

// Load or import the Hansen et al. forest change dataset.
var hansenImage = ee.Image('UMD/hansen/global_forest_change_2015');

// Select the land/water mask.
var datamask = hansenImage.select('datamask');

// Create a binary mask.
var mask = datamask.eq(1).not();

// Function to estimate Chl.a concentration
var CHL_exp = function(image){
  return image.expression(
    '(2.485*exp(159.743*(dblue - 1.9407*blue + 1.0610*green - 0.1204*nir)))',
    {
      dblue: image.select('B1'),
      blue: image.select('B2'),
      green: image.select('B3'),
      nir: image.select('B5')
    })
}

// Create Chl.a concentration image
var chl_data = toa.map(CHL_exp).max();
var chl_data_mask = chl_data.updateMask(mask);

// Display Chl.a concentration image on the map
Map.addLayer(chl_data_mask, visParams, 'CHL')
```