BROSS User Manual- Google Earth Engine

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1. Introduction

BROSS ("Bangladesh Remote Sensing of Suspended Sediments") is a tool developed for the Bangladesh Water Development Board (BWDB) by the University of Washington SASWE Research Group. BROSS provides spatially and temporally distributed suspended sediment concentration (SSC) predictions for the Brahmaputra-Jamuna, Ganges-Padma, and Padma rivers of Bangladesh (Figure 1). BROSS uses satellite remote sensing imagery in the visible (red, green, blue) and near-infrared (NIR) spectra as inputs to models calibrated to Bangladesh rivers. It is intended that BROSS will help BWDB with river sediment monitoring and management.

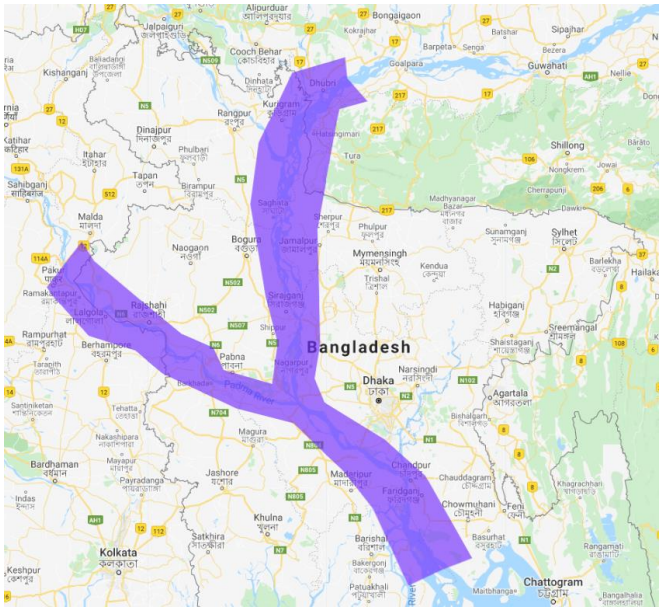

Figure 1: BROSS (Google Earth Engine tool) domain

This manual provides user instructions for operating BROSS on Google Earth Engine (GEE) (https://cbev.users.earthengine.app/view/bross-gee/). This is a living document stored at https://github.com/cbev/bross/blob/master/manual_user_GEE.docx. Detailed technical background on the remote sensing and modeling techniques is found in the technical manual. We recommend that users who will be using SSC data from BROSS review the manual to understand the limitations and uncertainties of the data. The technical manual is a living document stored at https://github.com/cbev/bross/blob/master/manual_technical.docx.

The BROSS GEE system operates using Landsat (5, 7, 8), Sentinel-2, and MODIS satellite data. This system provides two data output options: (1) SSC estimated from satellite data using a regression model; and (2) satellite reflectance data in the visible (red, green, and blue) and near-infrared (NIR) wavelengths. Each of these outputs are provided in two forms: (1) a time series of SSC estimates or reflectance data averaged within a user-specified region of interest (ROI), over a user-specified date range; and (2) mapped over the BROSS domain (Figure 1) for each date of the time series. Figure 2 shows and example of these two forms of outputs for the SSC option. The SSC and satellite reflectance time series can be downloaded as .csv or image files.

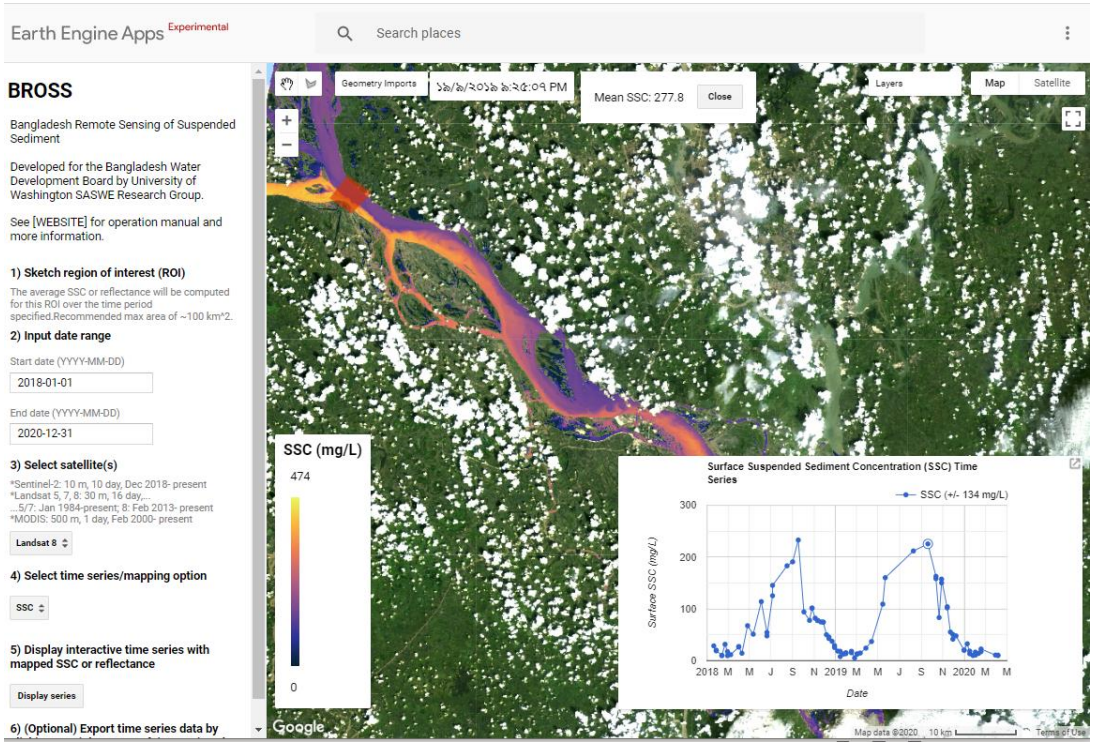

Figure 2: Example output of BROSS in GEE*- A map of SSC along the Padma river and a time series of the SSC averaged for region of interest (red box, upper left of satellite image)*

Accompanying the GEE tool is a computational notebook that uses the satellite reflectance data downloaded from GEE to generate a time series of SSC predicted from an artificial neural network (ANN) model (see more information in step v of Section 2). Table 1 summarizes the difference between the regression and ANN model performance, and further details are provided in the technical manual.

Table 1: Statistical Tests for Model Performance of SSC Predictions (ANN vs Regression).

*Stronger results for each satellite group and indicator is in **bold.***

Root mean square error (RMSE)	ANN	Regression
Landsat 8 + Sentinel 2	139 mg/L	**134 mg/L**
Landsat 5 + Landsat 7	**123 mg/L**	165 mg/L
MODIS	228 mg/L	**202 mg/L**

Coefficient of detemrination (r^2)	ANN	Regression
Landsat 8 + Sentinel 2	**0.74**	0.71
Landsat 5 + Landsat 7	**0.35**	0.22
MODIS	0.31	**0.40**

Anomalies	ANN	Regression
Landsat 8 + Sentinel 2	**-102 mg/L**	-130 mg/L
Landsat 5 + Landsat 7	**-236 mg/L**	-386 mg/L
MODIS	**-70.2 mg/L**	-278 mg/L

Anomaly correlation coefficient (ACC)	ANN	Regression
Landsat 8 + Sentinel 2	**0.86**	0.83
Landsat 5 + Landsat 7	**0.93**	0.89
MODIS	0.52	**0.61**

Spearman r (r_S)	ANN	Regression
Landsat 8 + Sentinel 2	**0.88**	0.81
Landsat 5 + Landsat 7	**0.60**	0.46
MODIS	**0.64**	**0.64**

In addition to the GEE tool, there is a standard SASWE monitoring system which displays prediction of SSC from both regression and ANN models. Table 2 summarizes the differences between the GEE and SASWE tool. The SASWE tool is found at http://depts.washington.edu/saswe/bross/ and its manual is found at https://github.com/cbev/bross/blob/master/manual_user_SASWE.docx.

Table 2: Comparison of BROSS GEE and BROSS SASWE systems

Feature	Google Earth Engine app	SASWE standard app
Mapped SSC from regression	X	X
Mapped SSC from ANN		X
SSC time series from regression	X	X
SSC time series from ANN	Use separate computational notebook	X
SSC time series for user-defined region of interest	X	
SSC time series auto-generated at in situ monitoring stations		X
Satellite data availability	Landsat 5, 7, 8; Sentinel-2; MODIS	Landsat 8
Spatial resolution	Landsat: 30m, Sentinel-2: 10m, MODIS: 500m	200m
Temporal availability	Full extent of satellite data	Past 6 months
Able to export time series	X	X
Able to export map		X
Able to view values of individual pixels	X	X
Able to view and download satellite reflectance data	X	
Data storage source	Google Cloud	SASWE server
Computing source	Google Cloud	Google Cloud
Computing language	Javascript	Python

In this manual:

- Section 2 provides the mandatory and optional steps for operating the BROSS GEE system.
- Section 3 provides troubleshooting questions
- Section 4 provides frequently asked questions (FAQs)

2. Operational steps

i. **Start application.** In a web browser, navigate to the BROSS GEE website: https://cbev.users.earthengine.app/view/bwdb-ssc-prototype

ii. **Set up filters.** Note that parts a-d can be completed in any order, but *all* must be completed for BROSS to work.

   a. Sketch a region of interest (ROI) within the BROSS domain (Figures 1 and 3). The average SSC or surface reflectance will be computed for this ROI over the time period specified (in step 2)**.**

- The ROI must be a closed polygon for BROSS to work. You will know that it is closed if it turns red (see Figure 3)
- It is okay for the ROI to encompass land area as BROSS will automatically distinguish surface water pixels.
- You can move, reshape, or redo the ROI (see Section 4, Frequently Asked Questions)

Figure 3: Example region of interest (ROI)

b. Input the date range of interest. The time series of SSC will be provided for this date range.

- There are default dates already in the boxes which can be modified.
- The input format is YYYY-MM-DD (e.g., 2019-03-26 for 26 March 2019).

c. Select satellite(s) from the dropdown menu. The time series and mapped data will be generated using data from the satellite selected.

- The satellites vary in their spatial resolution, temporal resolution, date range of availability, and performance, as shown in Table 1 (Section 1) and Table 3.

Table 2: Satellite data information

Satellite	Spatial Resolution	Temporal Resolution	Date Range
Landsat 5 (TM)	30 m	16 days	1/1/1984-5/5/2012
Landsat 7 (ETM+)	30 m	16 days	4/15/1999- Present
Landsat 8 (OLI)	30 m	16 days	2/11/2013- Present
Sentinel-2	10 m	5 days	2017- Present
MODIS	500 m	1 day	2000- Present

d. Select time series/mapping option from the dropdown menu. The time series and map will be shown for either SSC or the surface reflectance (red/blue/green/NIR).

- Surface reflectance (red/blue/green/NIR) is directly from the satellite
- SSC is computed using surface reflectance and a relationship developed from empirical regression.

iii. **Click "Display interactive time series with mapped SSC or reflectance."** This will apply the filters set up in step ii and begin calculating the time series for the SSC or surface reflectance.

- The box in the bottom right hand corner will say "Generating chart…" after you click this. The box will also display an alert if and error occurs.
- It may take a few seconds or up to several minutes for the processing to finish depending on the filters applied.

iv. **Optional Steps in GEE:**

a. **Display a data map (SSC or reflectance) for a specific date** by clicking a point on the time series

- For surface reflectance data option, the red reflectance data is automatically added to the map. To add blue, green, or NIR reflectance data, hover over the "Layers" panel in the upper right hand corner. Check the box for the layer (e.g., Blue) that you would like to add to the map and uncheck "Red."

b. Get the value of a pixel (SSC or surface reflectance) by clicking on the pixel.

- You may need to click the "Esc" key first to get the appropriate cursor, which is a cross
- This can only be done if step iv.a. has been done first

c. Export the time series plot data and/or image by clicking on the small boxed arrow on the top right hand corner of the chart.

d. View the soil texture map

- Hover over the "Layers" panel in the upper right hand corner. Check the box for "Soil texture." The "Soil Texture" legend is shown on the left hand side of the map.
- To close the legend, click the "Close" button at the bottom.

e. Produce SSC time series for the ROI using ANN

- Follow steps i-iii to generate a time series of surface reflectance (in step ii.d., must select "surface reflectance)
- On the time series chart on the bottom right hand corner of the screen, click on the small boxed arrow on the top right hand corner of the chart.
- A new tab will open in your browser showing the time series. On that tab, click on the "Download CSV" button at the top right hand corner.
- A file called "ee-chart.csv" will download. You will need this file in the next steps, so know where the file is located.
- If desired, you can download multiple files of satellite reflectance data and combine them into a single Excel file to input into the
- Navigate to the "Google Colab" notebook by clicking on the link below Step 4 (in GEE application window) or by pasting the following into your web browser: https://colab.research.google.com/drive/1xR-YsvHcMfTR-HOhXeUWskIM3wQIqE2a?authuser=2#scrollTo=wd2Kaupw_Hid
- Follow the steps in the notebook.

3. Troubleshooting

i. **In GEE, the computation is taking too long or is timing out.** Try to decrease the size of the ROI (try ~100 km2 or smaller) and/or reduce the data range (try ~2 years)

ii. **In GEE, the box in the lower right hand size says: "Error generating chart: Array: No number in 'values', must provide a type.**" Check that an ROI is sketched and that it is filled with red on the inside. Check that remainder of the criteria are filled out. Check that the date range is valid (e.g., end date comes after the start date). Check that the date range entered is within the date range that the satellite you selected is available (date ranges are in Table 1 and listed under "3) Select satellite(s)" on the BROSS interface).

iii. **In GEE, I cannot sketch an ROI.** Go to the upper left hand corner of the screen and hover over "Geometry layer 1." It will then turn to a dropdown box with a heading of "Geometry Imports." Click on/toggle "Geometry layer 1" and ensure that it's bolded. Then, you should be able to sketch the ROI directly on the map.

iv. **In GEE, why do there appear to be "stripes" in the images?** Unfortunately, this is a known issue with Landsat data. Please see the following link for more information: https://www.usgs.gov/land-resources/nli/landsat/detector-striping?qt-science_support_page_related_con=0#qt-science_support_page_related_con

Do you have a troubleshooting question that is not shown? Please submit it at: https://forms.gle/z7WSYt4b94rZFwh78

4. Frequently Asked Questions (FAQ)

i. In GEE, how do I modify or redo the ROI after I have sketched it?

- To modify the ROI, you will need to first click on it. Then, you can move it by clicking, holding, and dragging it. You can reshape it by selecting vertices and moving them.
- To redo the ROI, click on it and hit "Delete" on your keyboard. Go to the upper left hand corner of the screen and hover over "Geometry layer 1." It will then turn to a dropdown box with a heading of "Geometry Imports." Click on/toggle "Geometry layer 1" and ensure that it's **bolded.** Then, you should be able to sketch a new ROI directly on the map.

ii. In GEE, how do I expand the range of SSC in the legend?

- The legend automatically adjusts based on the range of SSC in the ROI for a given data (it's ~2x higher than the max SSC of the ROI for each date). To change the range, move the ROI to an area with higher or lower SSC.

iii. In GEE, for the satellite reflectance data option, what it the "Satellite ID" in the legend and .csv output?

- This is a number that represents which satellite the data comes from. It is a necessary input for the ANN notebook (Step iv.e). It does not plot on the time series in GEE, however we are unable to remove it from the legend- so please ignore it.

iv. **How do I cite this tool?** See the information at the following link: http://depts.washington.edu/saswe/bross/cite.html

Do you have a question that is not shown? Please submit it at: https://forms.gle/z7WSYt4b94rZFwh78