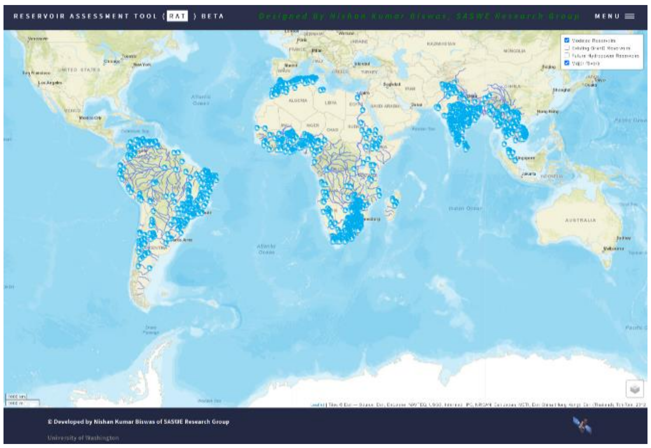

USER MANUAL

Global Reservoir Assessment Tool (RAT) version 1.01

ABOUT RAT

Global Reservoir Assessment Tool (RAT) is developed for near-real-time monitoring of 1598 dams over South America, Africa and South-East Asia region. It can be used to study existing reservoirs in ungauged basins for hydrologic impact and to predict operating pattern for short and long term decision making and policy analysis.

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This user manual accompanies the following two resources:

Reservoir Assessment Tool (Front-end) http://depts.washington.edu/saswe/rat_beta/

Software at GitHub: https://github.com/nbiswasuw/rat-reservoir_assessment_tool

Contents

1. Overview of the framework

1.1. Introduction

Reservoir Assessment Tool (RAT) is an integrated software framework that consists of an interactive state-of-the-art web-based visualization system to facilitate the visualization of reservoir monitoring parameters in a near-real-time scale. The tool has been designed to monitor 1598 reservoirs over South America, Africa, and South-East Asia region. The tool facilitates the visualization of reservoir states (such as, storage change, inflow, and outflow), which is useful in understanding downstream impact.

1.2. Main idea

The basic idea of the RAT framework is a satellite data-based mass balance method to calculate monitoring parameters. Initially, an area-elevation relationship based on the reservoir bathymetry was built using SRTM elevation data. The two consecutive satellite imagery is analyzed to calculate the reservoir surface area. Based on the area-elevation curve (AEC) and reservoir surface area, the corresponding reservoir water levels are computed. Finally, storage change is calculated from reservoir surface area and elevation data. Reservoir inflow is computed from a hydrological model named Variable Infiltration Capacity (VIC). Finally, inflow, evaporation, and storage change are used in a mass balance method mentioned in equation (1) to calculate the reservoir outflow. The technical detail of each component of the idea has been discussed in the publication of the tool.

$$O = I - E - \Delta S \qquad (1)$$

Where O = outflow, I = inflow, E = Evaporative loss, and ΔS is the storage change.

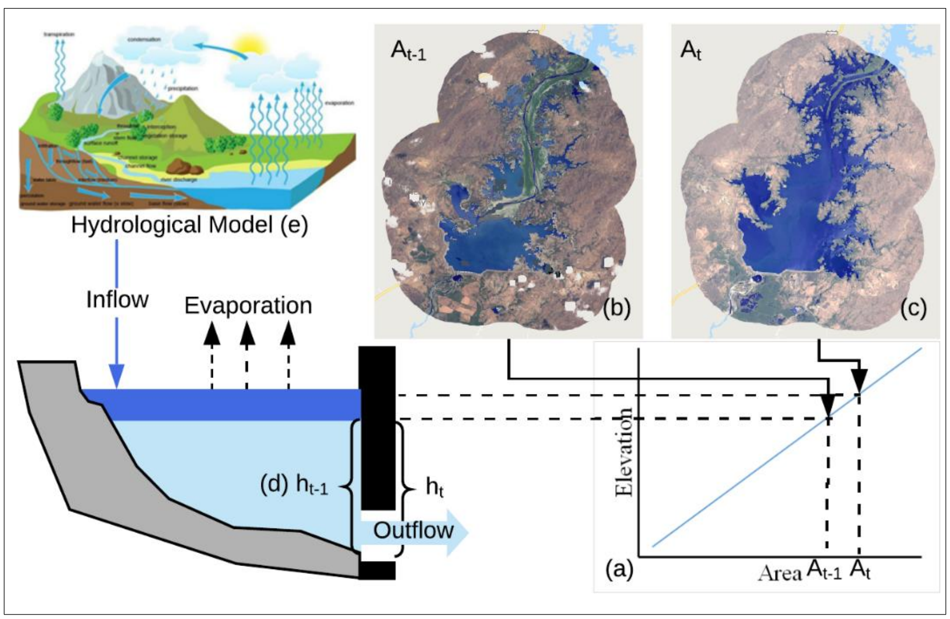


Figure 1: Concept of satellite data-based mass balance for reservoir monitoring. Satellite datasets used are for following reservoir states: a) The Area-Elevation relationship Curve (AEC) derived from SRTM, b) and c) are from visible/NIR satellite imagery, d) is derived from AEC, and e) from satellite-based meteorological observations.

2. The Framework

The framework consists of two main components, 1) frontend where the user can click and see different updated reservoir monitoring parameters and 2) backend where all the analysis and calculations are performed in an automated way. Both the frontend and backend components are discussed briefly in the following sections.

2.1. Frontend component

2.1.1. Main window

The main window of the frontend is shown in figure 2 (beta version of the tool hosted at http://depts.washington.edu/saswe/rat_beta). This frontend was developed from a freely-available template at https://html5up.net/forty and necessary changes made in HTML, CSS, and JavaScript code as per the requirements. Currently, 1598 Dams from the GranD Database version 1.3 (http://globaldamwatch.org/grand/) over South America, Africa, and South-East Asia are modeled operationally for monitoring reservoir dynamics and added to the RAT frontend interface. A major river network is added for user convenience to the GUI, which was downloaded from https://www.naturalearthdata.com. Leaflet API (https://leafletjs.com/) was used to visualize geoJSON formatted dam locations and river networks over the basemap layer. GeoJSON is an open standard format designed for representing simple geographical features, along with their non-spatial attributes.

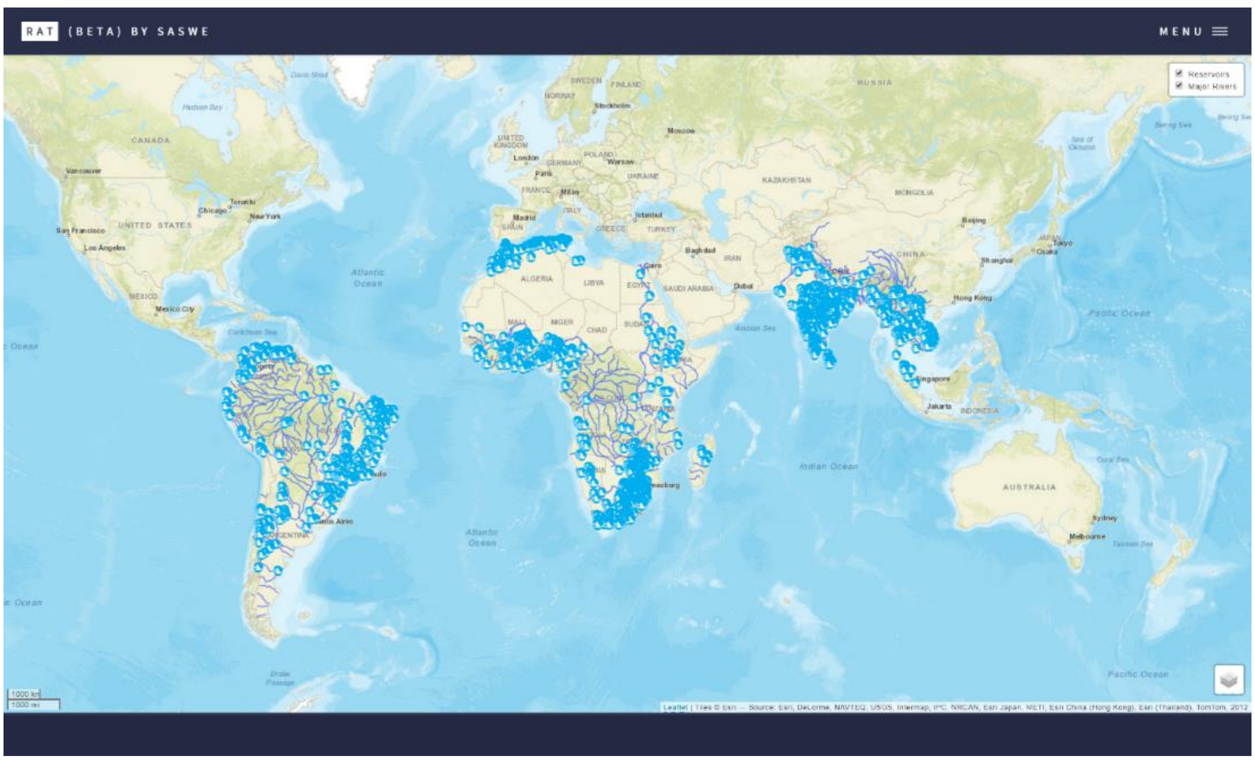


Figure 2: Frontend web interface of the RAT tool operational framework with the blue reservoir icons showing reservoir locations and the polylines are the river network downloaded from https://www.naturalearthdata.com. The upper right corner of the window allows users to toggle between selections of layers, and available base-maps could be switched from the lower right corner.

2.1.2. Basemap layers

Seven different basemap layers are provided in the frontend to visualize administrative boundaries, water extents, and imagery information, which can be toggled from the lower right corner of the main window. The provided basemap layers are ESRI world imagery, ESRI world street map, ESRI NatGeo World Map, Thunderforest landscape map, Google Satellite Map, and global surface water occurrence map. The icon for changing basemap layers and options are shown in figure 3. Change in the main window due to the use of 4 different types of basemap layers are shown in figure 4.

Figure 3: left) Icon for switching basemap layers, right) Available basemap layers

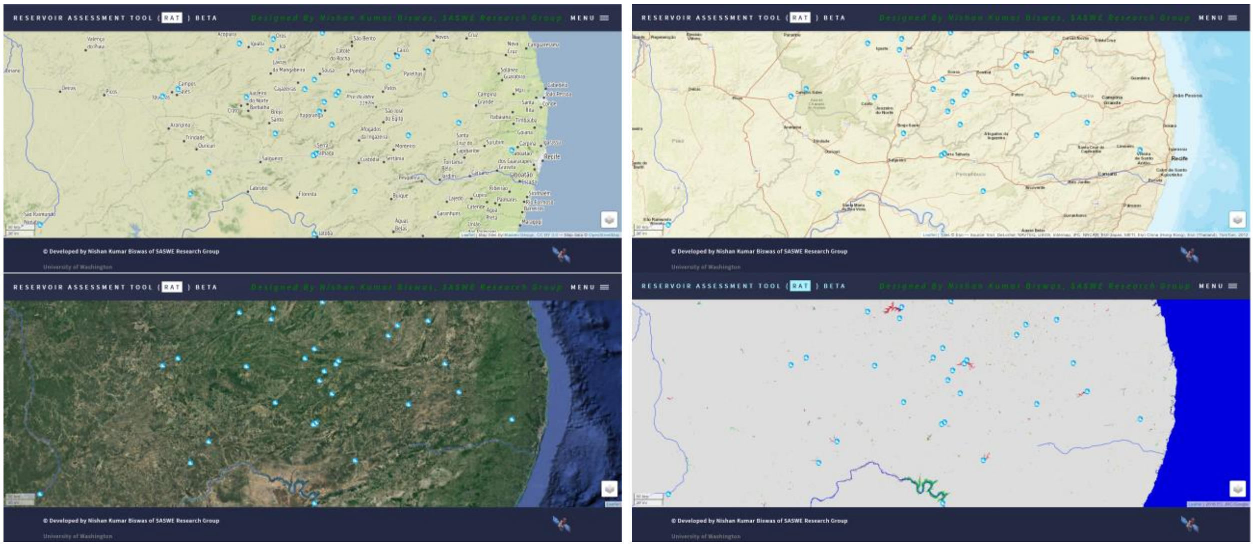


Figure 4: Different types of basemap layers shown for the same region of Brazil, upper left) terrain map, upper right) Street map, lower left) Google satellite map, lower right) Global surface water occurance map

2.1.3. Overlaying data layers

In the upper right corner of the main window, the layers available in the RAT frontend were added. The four available layers are, 1) Modeled reservoirs (the reservoirs those are included and analyzed in the tool), 2) Existing GranD Reservoirs (the reservoirs which are available in the GranD Database v1.3), 3) Future Hydropower reservoirs from https://doi.org/10.1007/s00027-014-0377-0, and 4) Major rivers network downloaded from https://www.naturalearthdata.com. The available layers and their appearance are shown in figure 5.

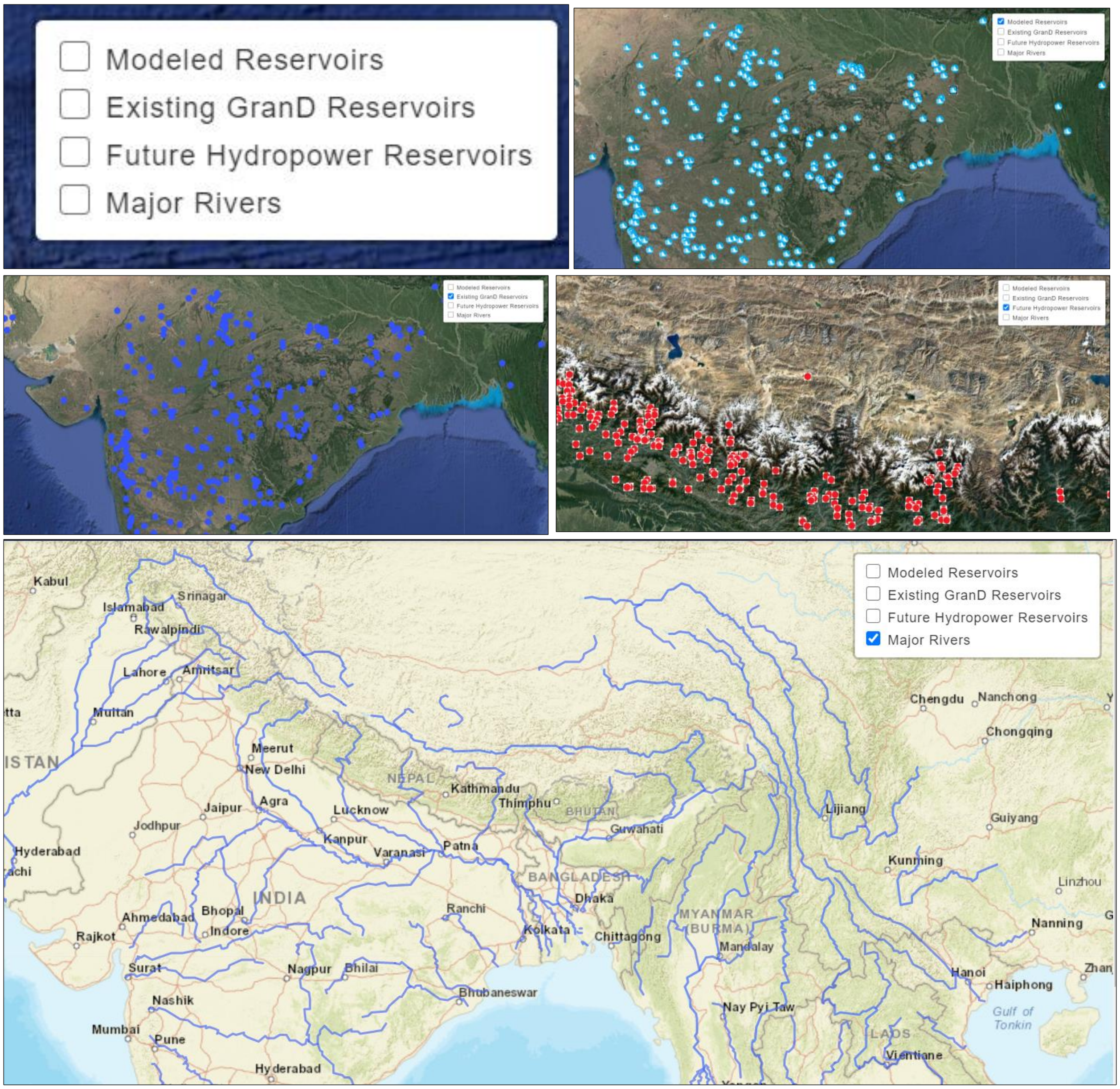
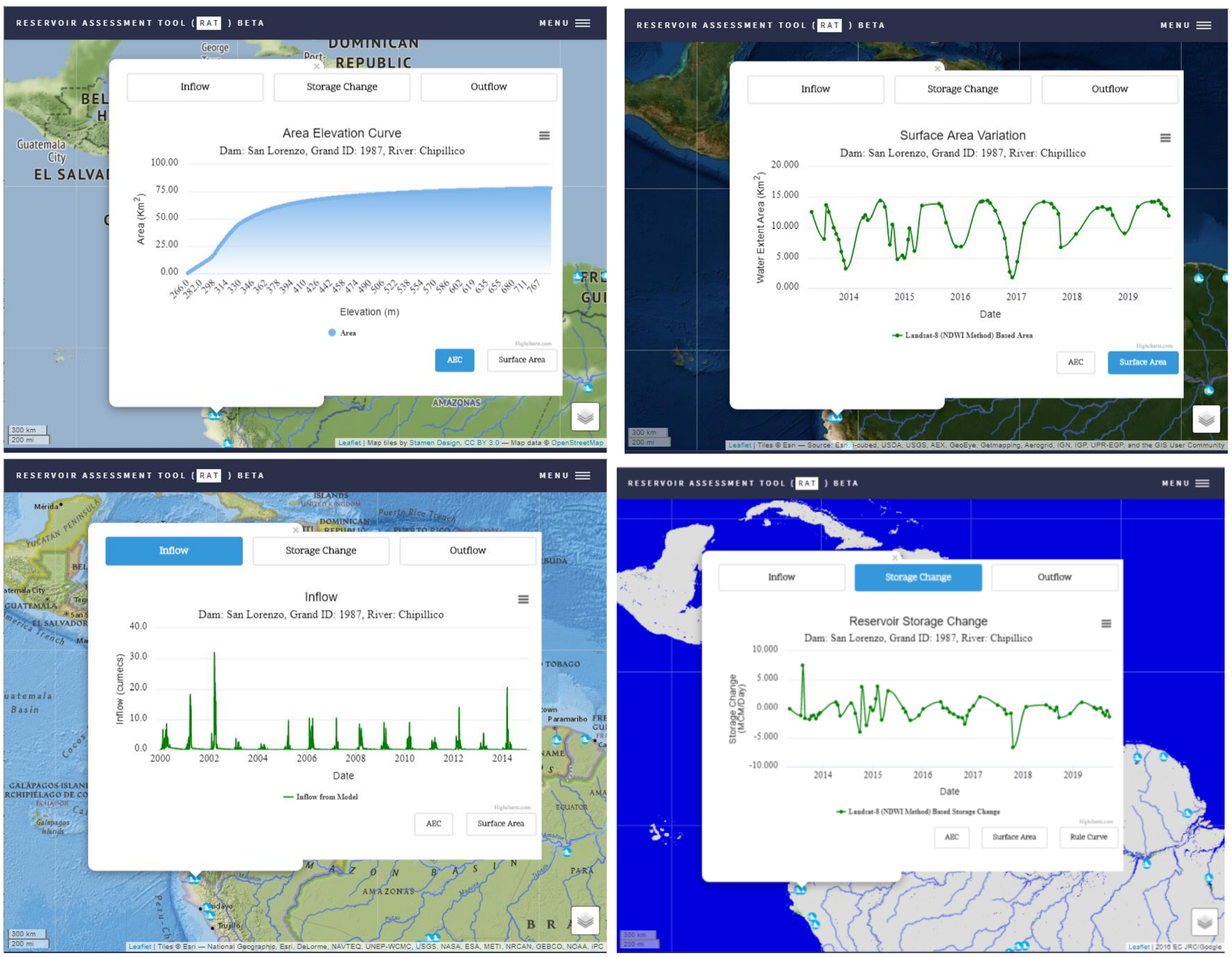


Figure 5: Overlaying data layers of the front end. Upper left panel: Overlaying layers available in the RAT frontend; Upper right panel: Modeled reservoirs; Middle left panel: Existing dams; Middle right panel: Future hydropower dams; lower panel: Major rivers.

2.1.4. Parameter visualization

After toggling the "Modeled Reservoirs" option from the upper right corner, the user can visualize all of the reservoir parameters (i.e., AEC, surface water extent, inflow, storage change, and outflow) which is added to the frontend through an iframe. When a user clicks on any of the dam icon (blue marked icons shown in the upper right corner of figure 5), an iframe pops up where all the buttons are available to visualize the AEC, surface water extent area, inflow, storage change, and outflow, and operating rule curve. In figure 6, all of the above components are shown as they are being displayed on the RAT Graphical User Interface. When the user clicks on any button, the JavaScript and JQuery checks for available data of the corresponding parameters. If the dataset is available, a plot similar to figure 6 produced on the fly using Highcharts API (https://www.highcharts.com/). If the requested data not available, a notification is shown to the user like figure 16. The user can send a request to the system following section 3 if any missing data notification appears.



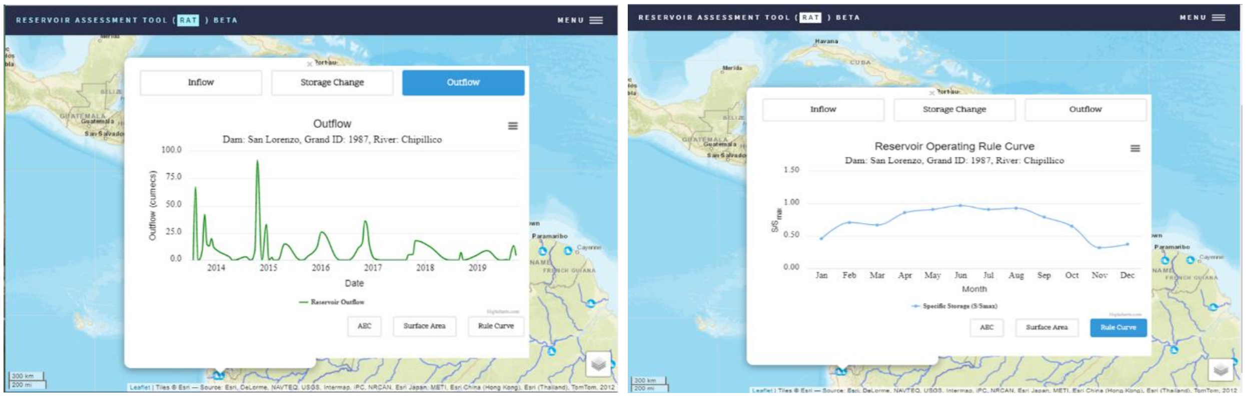


Figure 6: Call out window for various reservoir states along with different basemap option for San Lorenzo Dam over Chipillico River, Peru. Upper left panel: Area-Elevation Curve; upper right panel: Surface water extent area time-series; middle left panel: Reservoir inflow, and middle right: Storage change; lower left panel: Outflow from the reservoir, and lower right panel: Reservoir operating rule curve based on the historical observations.

2.1.5. Main menu options

From the header (shown in figure 7), the main menu of the frontend can be navigated. If the user clicks the "menu" button located on the right corner of the header, a pop-up window will appear as shown in figure 8. From the pop-up menu, "Home", "About RAT", "How to use RAT", "How to cite", "Acknowledgements", "SASWE Home", and "SASWMS" can be navigated. The screenshot of each of these pages is shown in figure 9, figure 10, figure 11, and figure 12.

Figure 7: Main header of the frontend of RAT website

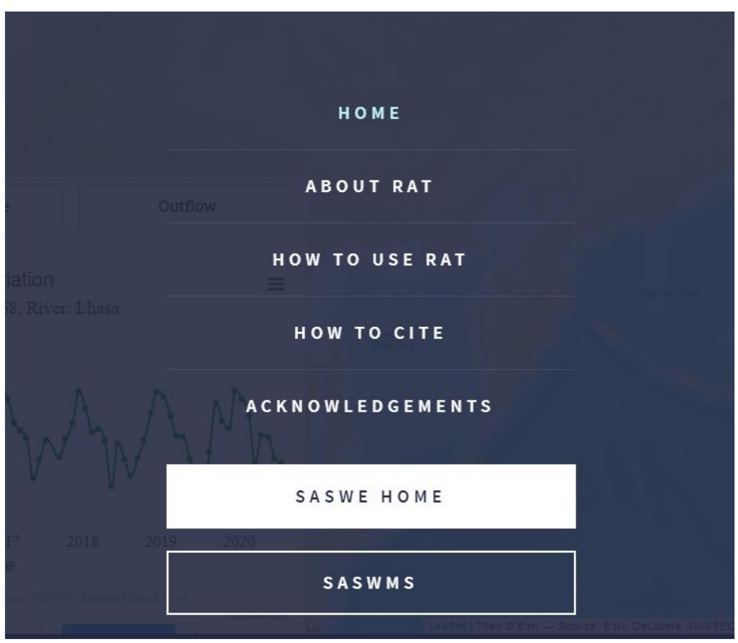


Figure 8: Menu option to navigate the information about the RAT tool

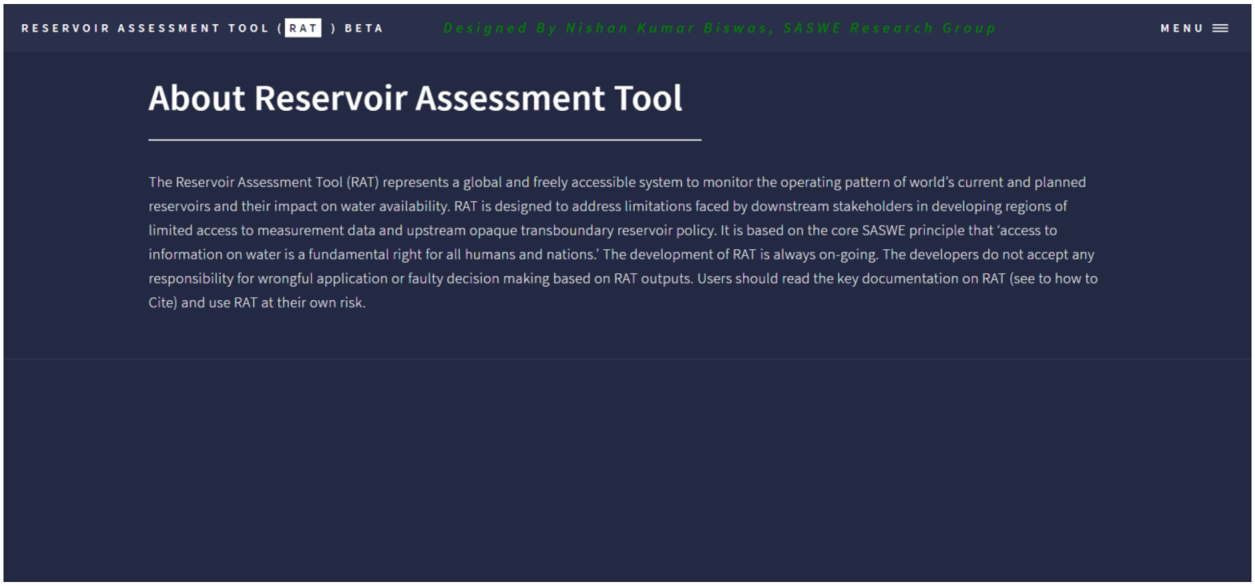


Figure 9: "About Reservoir Assessment Tool" page of RAT website

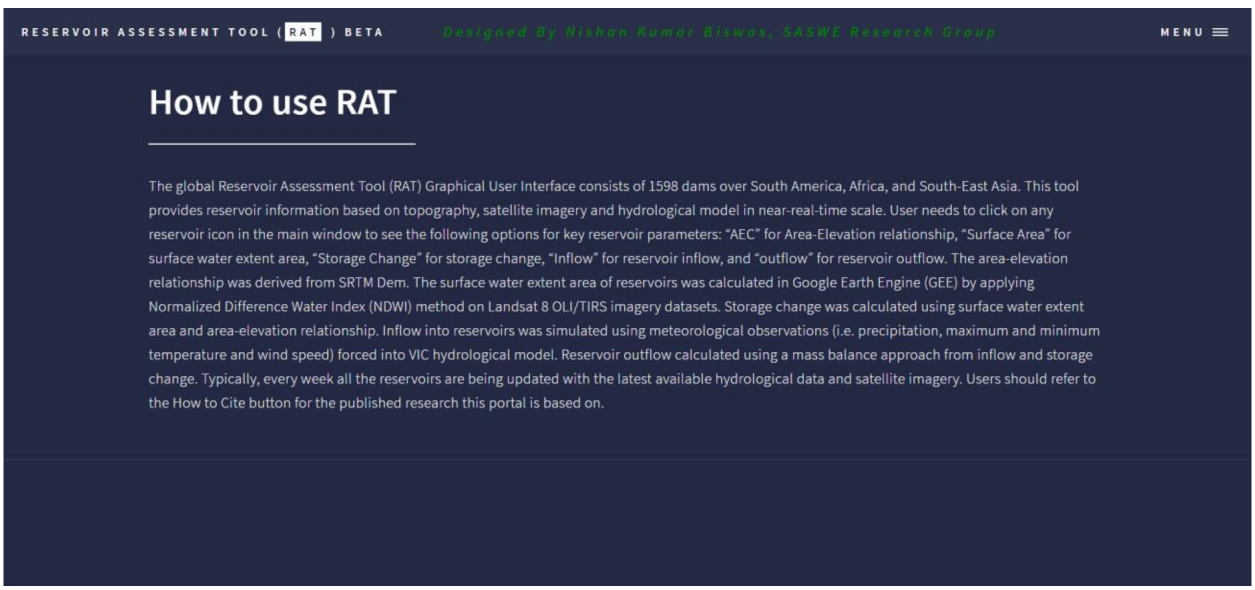


Figure 10: "How to use RAT" page of RAT website

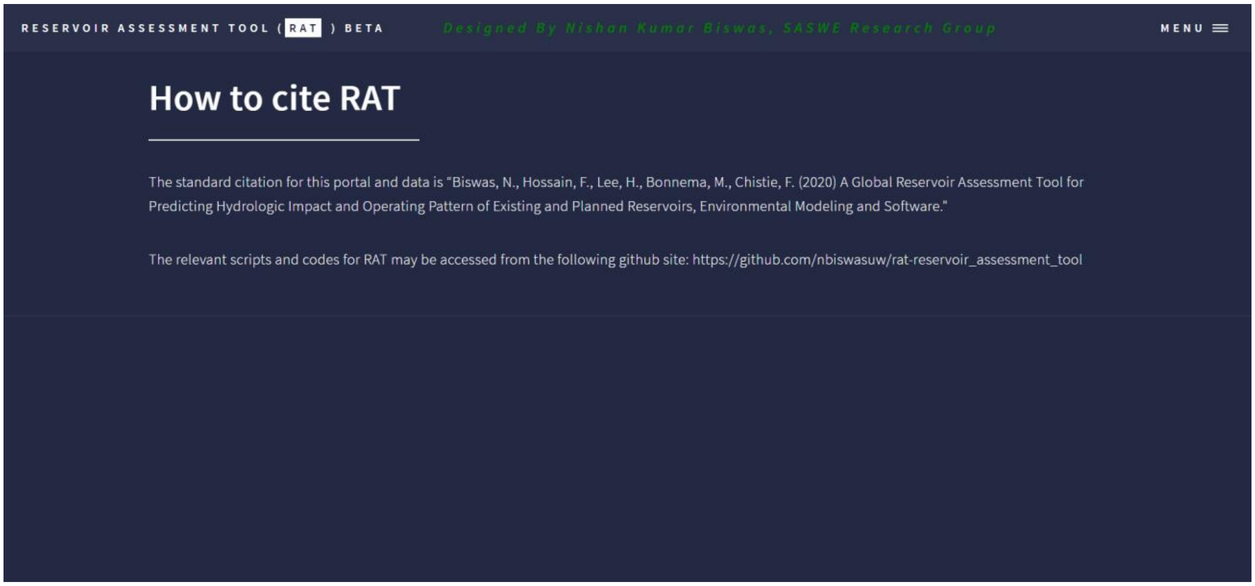


Figure 11: “How to cite RAT” page of RAT website

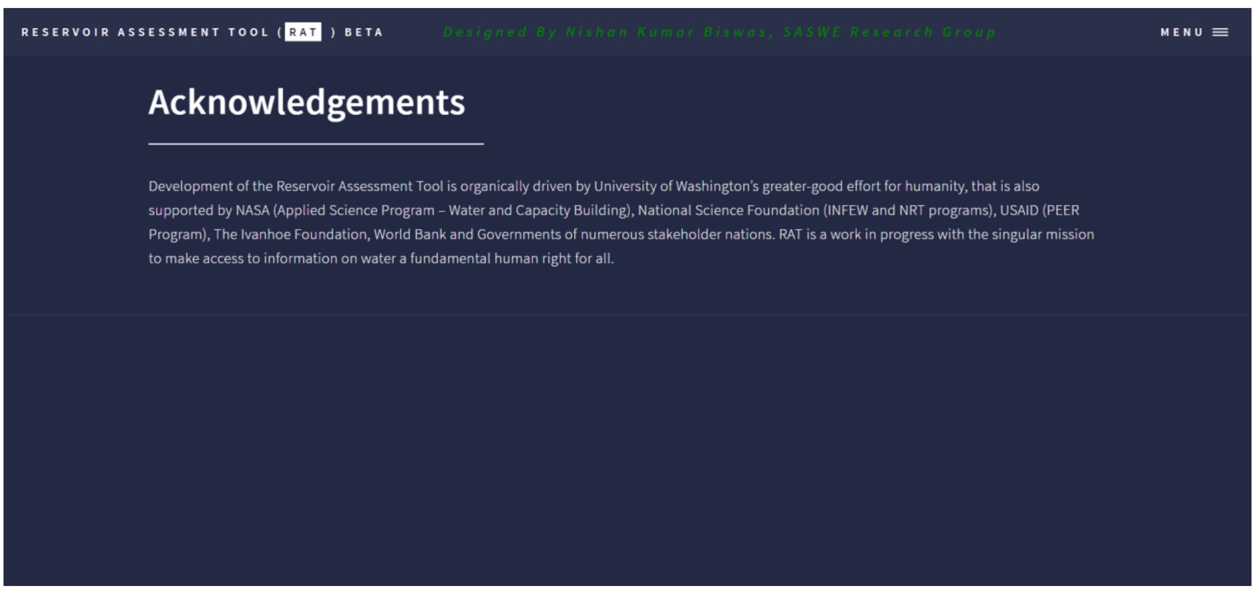


Figure 12: “Acknowledgements” page of RAT website

2.2. Backend Component

All the necessary data download, processing, including Google Earth Engine (GEE) cloud computing are included in the backend component of the framework. At a scheduled time of the week, the storage change module goes to GEE python API to process the latest available imageries to get the latest available surface area and storage change. The data download module goes to different data servers to download necessary datasets and prepares VIC Model inputs. The responsibility of the model simulation module is to simulate VIC hydrological model, and the post-processing module analyzes the reservoir inflow and storage change to get the reservoir outflow.

2.2.1. Storage change module

The storage change calculation of every reservoir is done by using this module. It is written in python programming language and uses several libraries which ingests the latest available imageries to produce reservoir surface area timeseries. The workflow of this module is given in figure 13 and discussed in the accompanying paper. First, it selects a single reservoir from the reservoir database of the RAT framework. Then it creates a buffer polygon around the reservoir based on the distance provided. It selects all the available satellite imageries (of a selected sensor) and removes cloud and cloud shadow using a bit-masking algorithm. After removing the scenes with higher than threshold cloud cover, it mosaics all the scenes and applies the threshold-based method to create the water area of the reservoir. Finally, using the area-elevation relationship and the water area timeseries, it calculates the storage change for the selected reservoir. The module iterates all the reservoirs in the same way and generates the reservoir storage change timeseries for every reservoir.

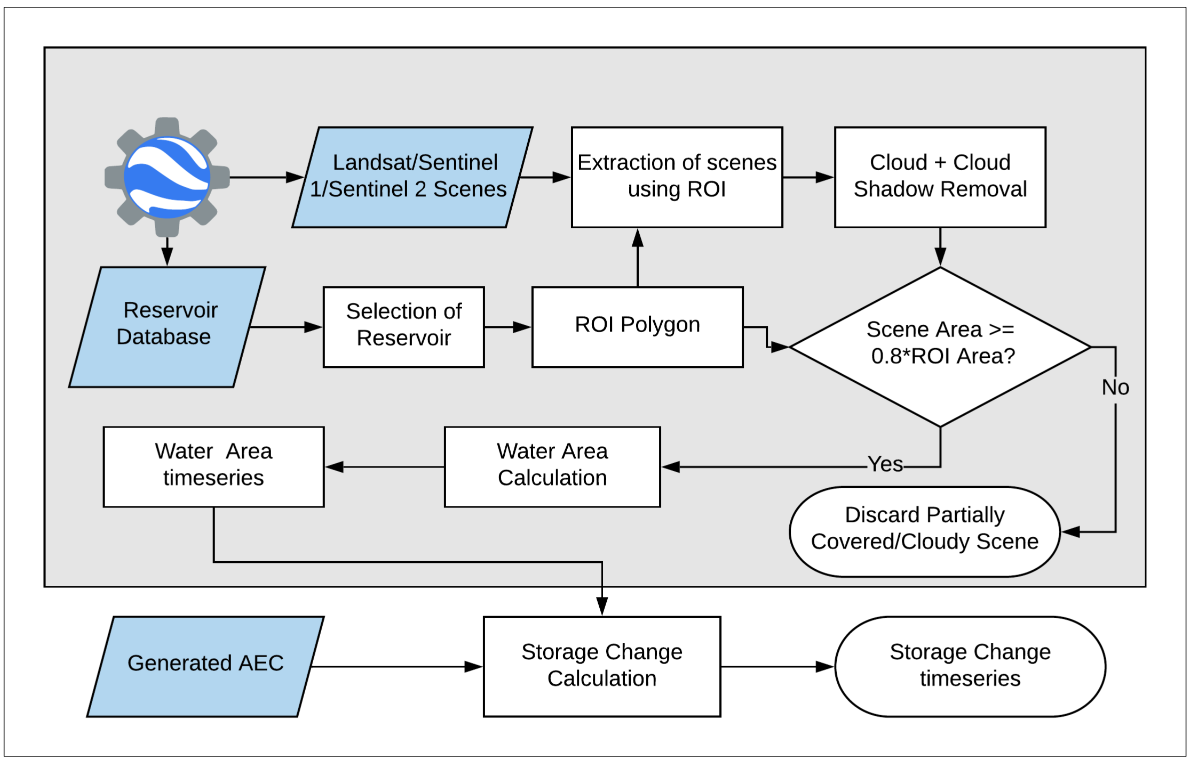


Figure 13: Surface water area time-series and storage change calculation workflow

2.2.2. Data download module

The data download module is for downloading meteorological forcing that are necessary to simulate the VIC hydrological model. It goes to the IMERG late run precipitation data portal located at https://gpm.nasa.gov/data/imerg to download the daily precipitation. It downloads maximum and minimum temperature from NOAA CPC global daily temperature data portal (https://psl.noaa.gov/data/gridded/data.cpc.globaltemp.html). It also downloads average wind speed data from NOAA NCEP/NCAR Reanalysis data from https://psl.noaa.gov/data/gridded/data.ncep.reanalysis.surface.html. Spatial resampling and subsetting of the above datasets are also done in this module. Finally, it converts all the above parameters to the VIC simulation forcing grid data, required data format to run the VIC model.

2.2.3. Model simulation and post-processing modules

This module used to run the VIC and Route model to get the latest available reservoir inflow data. The VIC hydrological model domain of the RAT framework is shown in figure 14. Finally, the inflow and storage change timeseries are used to calculate the reservoir outflow using the post-processing module.

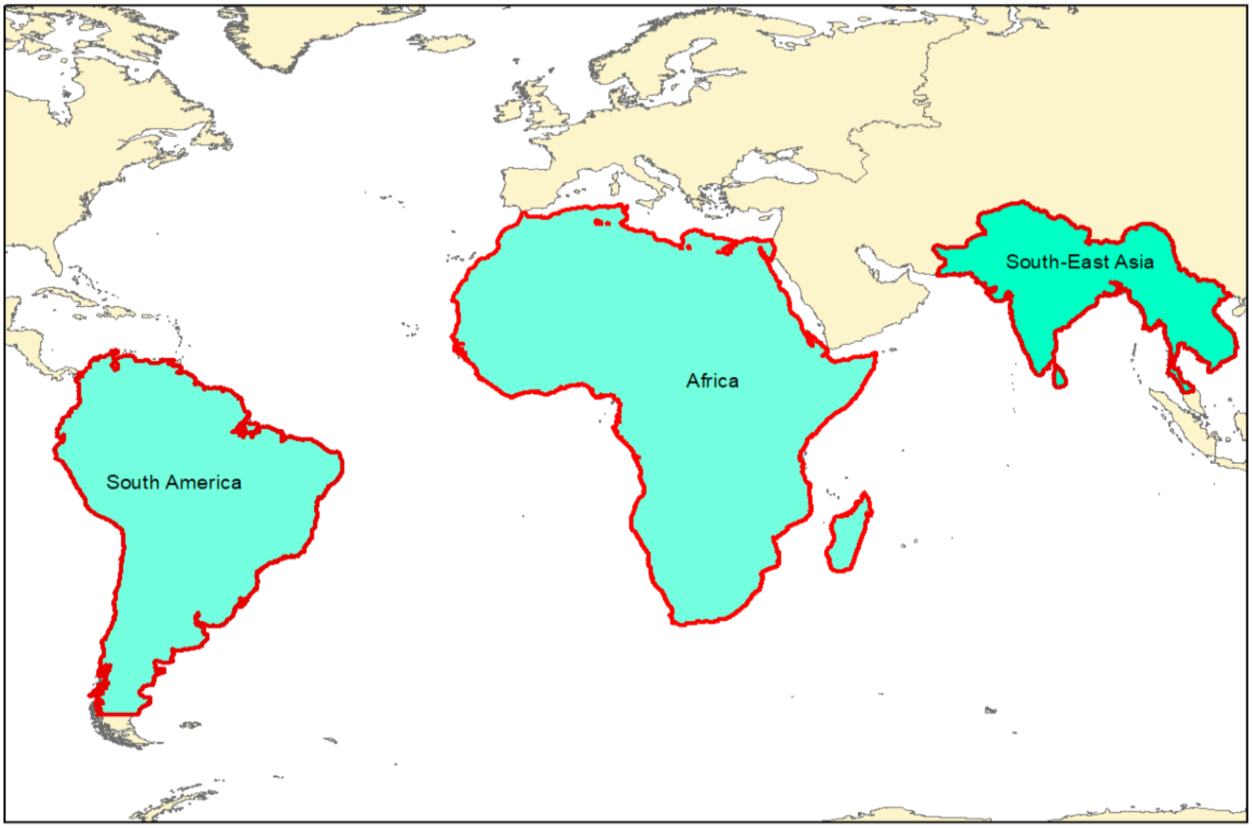


Figure 14: VIC hydrological model domain of RAT framework

2.3. Data exchange between frontend and backend

After finishing all the backend processing, inflow, storage change, outflow, surface water extent area data are pushed to the RAT frontend. These datasets are being ingested by the Highcharts API to create dynamic charts for visualization. When the user clicks on any button menu available in the iframe window, the Highcharts API looks for the corresponding data to prepare the necessary chart. The integration of the frontend and backend are shown in figure 15.

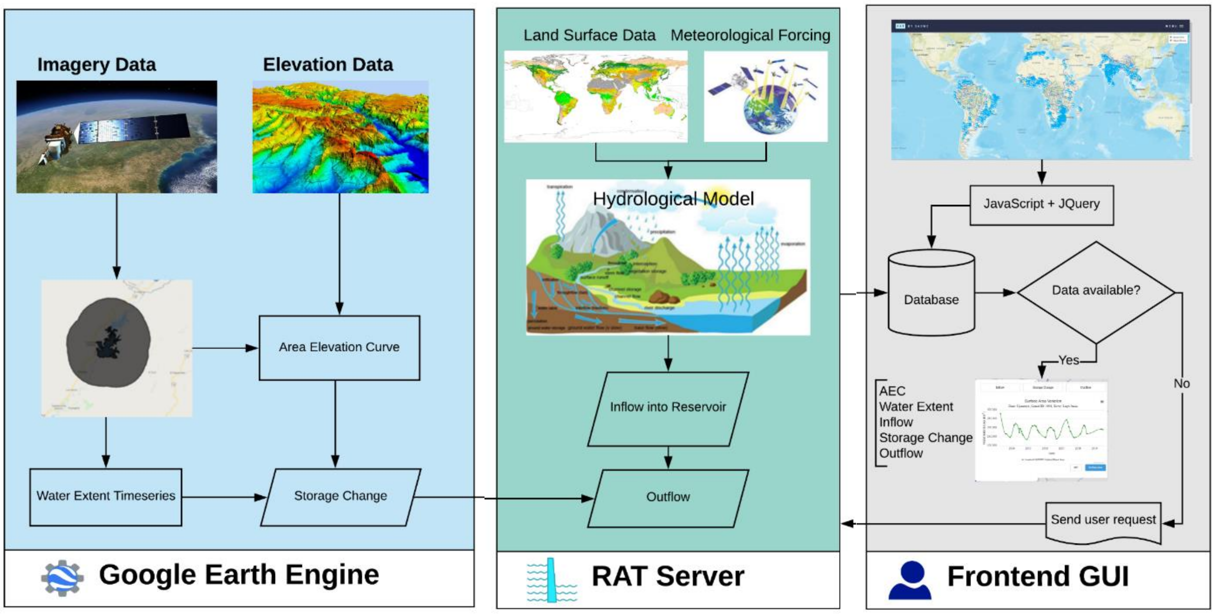


Figure 15: Incorporation of backend and frontend of the RAT framework

3. Addressing missing data and reservoirs

Users can send a request for any of the missing datasets through the frontend. The missing data notification for any of the reservoir or parameters is shown in figure 16. Users can click on the “submit a ticket” button to notify the admin to take care of the issue. The user request form is shown in figure 17. Once the requested data are being made available, the system will notify the corresponding user that the requested data is now available.

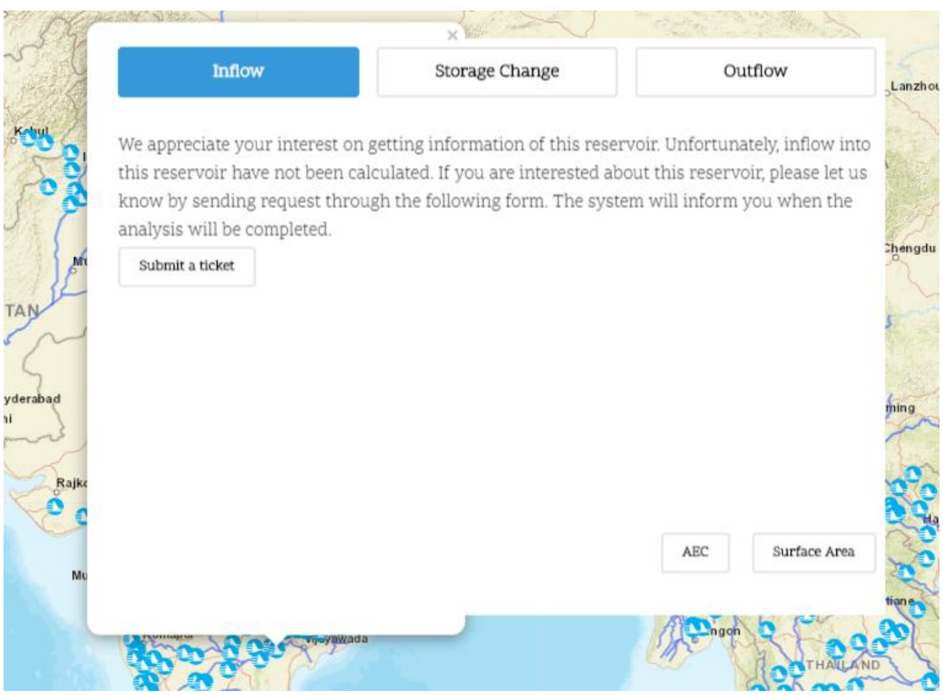
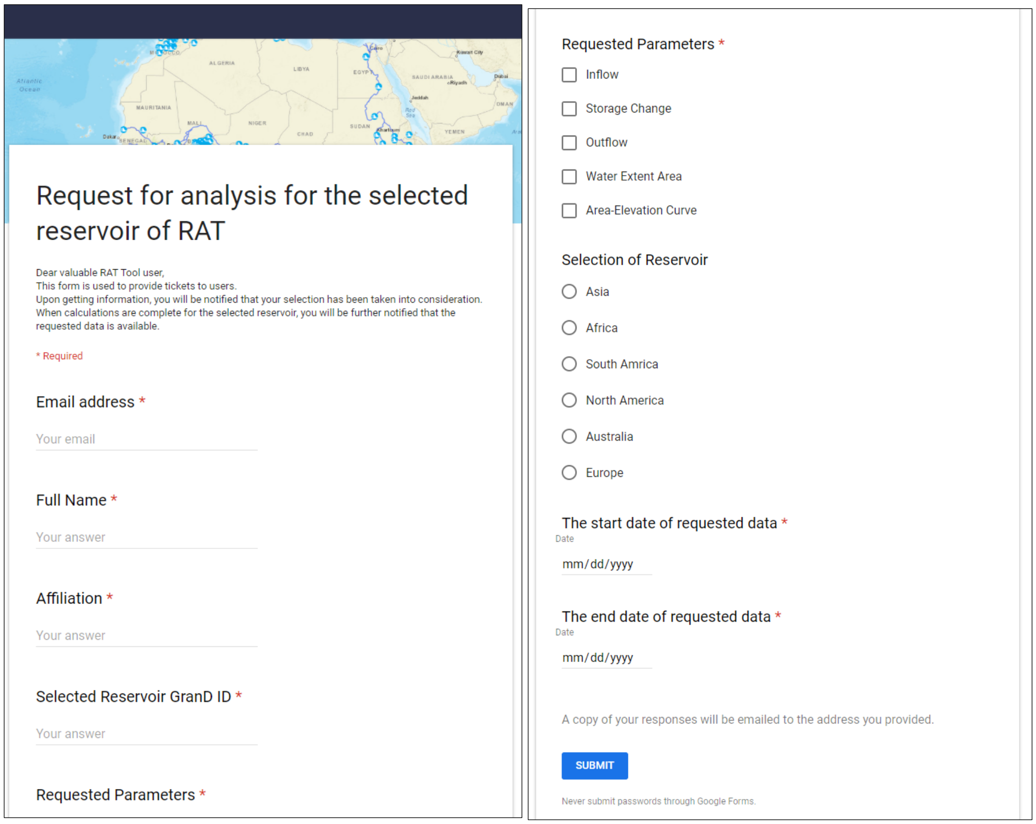


Figure 16: Missing data notification and ticket submit option



Request for analysis for the selected reservoir of RAT

Dear valuable RAT Tool user,
This form is used to provide tickets to users.
Upon getting information, you will be notified that your selection has been taken into consideration.
When calculations are complete for the selected reservoir, you will be further notified that the requested data is available.

* Required

Email address *

Your email

Full Name *

Your answer

Affiliation *

Your answer

Selected Reservoir GranD ID *

Your answer

Requested Parameters *

Requested Parameters *

- Inflow
- Storage Change
- Outflow
- Water Extent Area
- Area-Elevation Curve

Selection of Reservoir

- Asia
- Africa
- South Amrica
- North America
- Australia
- Europe

The start date of requested data *

Date

mm/dd/yyyy

The end date of requested data *

Date

mm/dd/yyyy

A copy of your responses will be emailed to the address you provided.

SUBMIT

Never submit passwords through Google Forms.

Figure 17: Designed request submission form (left and right, original form can also be accessed from https://forms.gle/MUebn4bheie1b91J7)