RESERVOIR ASSESSMENT TOOL (RAT)

RATATHON
Ultimate Guide to RAT 3.0

By Sanchit Minocha
with contributions from Pritam Das,
SASWE Group, University of Washington
Analogy: Rivers and Arteries
Analogy: Dams and Heart
Big Picture: How RAT Works?

Outflow = Inflow – Evaporation – Storage Change
Reservoir Assessment Tool 1.0

- Reservoir operations monitoring using **publicly available satellite data** and **hydrological modeling**

  Biswas et al. (2021)

- **Monthly Estimates:**
  - **Inflow** ($I$): Modeled using VIC
  - **Surface Area** ($A$): Landsat 7, 8
  - **Storage Change** ($\Delta S$): $A$ and Area-Elevation Curve (AEC)
  - **Outflow** ($O$): $I$ and $\Delta S$
Reservoir Assessment Tool 2.0

- More Sensors
  - Optical – Landsat-8, Sentinel-2
  - SAR – Sentinel-1
  - Altimetry – JASON-3

- Weekly Observations
  - 3-7 Days surface area
  - 10 Days altimetry

- Better Performance using parallel processing

BUT ....

- Limited to Mekong Region
- Not open source
- Not easy to use
- Memory Inefficient

Das et al. (2022)
Reservoir Assessment Tool 3.0

- More Sensors
  - Optical – Landsat-8 and 9, Sentinel-2
  - SAR – Sentinel-1
  - Altimetry – JASON-3
- Sub-weekly Observations
  - 2-4 Days surface area
  - 10 Days altimetry
- Globally applicable
- Efficient
- User-Friendly
- User-Focused Web Application
Technological Evolution of RAT 3.0

**RAT 1.0**
- Frequency - Monthly
- Landsat 8

**RAT 2.0**
- Frequency - Weekly
- Landsat 8, Sentinel 1, Sentinel 2, Jason 3

**RAT 3.0**
- Frequency - 2-4 days
- Landsat 8, Landsat 9, Sentinel 1, Sentinel 2, Jason 3

Performance Enhancement

Architectural Enhancement
Advancements in RAT 3.0

- Minimal input requirement
- Globally applicable
- Scalable
- Automated pipeline
- Customizable
- Easy to operationalize
- Directory structuring
- Efficient
- Parallel computations
- Hot start with no spin-up
- Automatic clean up
- Data adaptability
- Robust
- Modular architecture
- Error exception handling
RAT 3.0 : Requirements

1. A Linux-based system with Python installed and preferably VS Code or any code editor that you like.
   a) You can download VS Code [here](https://wwwlectron.github.io).
   b) Make sure you have downloaded the following utilities in Linux OS:
      • gfortran
      • make
      • miniconda or conda

2. Login credentials for Aviso ([for reservoir height data](https://www.aviso.altimetry.fr/en/data/data-access/registration-form.html))

3. Login credentials for Imerg ([for pulling precipitation data for hydrologic model](https://registration.pps.eosdis.nasa.gov/registration/))

4. Login credentials for Earth Engine using service account ([for reservoir storage change calculation](https://developers.google.com/earth-engine/cloud/earthengine_cloud_project_setup))

*Note*: Next section details on how to get login credentials for requirements 2, 3 and 4. Follow the instructions and keep the credentials (or password file) handy while installing and initializing RAT 3.0.
IMERG Account Setup

https://registration.pps.eosdis.nasa.gov/registration/

Step 1  PPS Registration

Click on "Register" to get access to PPS Products.

Fill out the form and click on "Save". You will get a confirmation e-mail and use it to complete the process.

MAKE SURE TO CHECK NRT PRODUCTS

If you don’t receive this e-mail in one hour, please check in your spam folder or contact Support.

Once you are registered, you can edit your information by entering in you contained in the automated email to complete the process.

Please note that by registering to get access to GPM data through PPS, you do not receive system status emails then please do not register for it.

We do not accept email addresses that require us to take a manual action

You can add/remove NRT access using the "Verify Email"

Please note that your Email will be converted to lower case. Once registered, your account will only allow access to production data on archive for NRT access. You can add/remove NRT access using the "Verify Email"

NEVER reply to an email that is sent to you. If you have questions, please contact Support.

OR

Enter registered email:

Verify Email or Update Info  Remove from access to PPS

Step 2

Please note that your Email will be converted to lower case. Once registration is completed use.

We do not accept email addresses that require us to take a manual action (Boxe, etc.). Please

Email

Confirm Email:

First Name

Last Name

Checking the following box will enable access to the jsimpson@pps.eosdis.nasa.gov FTPS portal.

Please select this option only if you intend to access these products immediately!

Note that, as of 15 July 2020, only FTPS and HTTPS can be used to access NRT data. Standard

FTPS Access in addition to

Standard Research

Products

Please enter a valid organization below. PPS will perform random checks of organizations and

Organization

Address

Governmental

Non-Governmental Organization

International Organization

University / College

Other Education

Research Institute

Commercial Weather

Insurance

Other Commercial

Private Individual

Organization Type

Area of Interest

Check the box below saying that you agree to allow PPS to send you emails relating to system

Allow Emails

Save
AVISO Account Set up


Step 1: Fill out the form.

Step 2: Select ‘GDR/IGDR (Geophysical Data Records)’
In the Product Selection section.

Step 3: Accept the terms and conditions.

Step 4: Submit the form.
## Google Earth Engine (GEE) Set up

<table>
<thead>
<tr>
<th>User Account</th>
<th>VS</th>
<th>Service Account</th>
</tr>
</thead>
<tbody>
<tr>
<td>➢ User accounts are normal google account being used by us in day-to-day tasks.</td>
<td>➢ A service account is a special type of Google account intended to represent a non-human user that needs to authenticate and be authorized to access data in Google APIs.</td>
<td></td>
</tr>
<tr>
<td>➢ <a href="mailto:saswegee@gmail.com">saswegee@gmail.com</a> is a user account.</td>
<td>➢ <a href="mailto:sanchit-rat@globalrat.iam.gserviceaccount.com">sanchit-rat@globalrat.iam.gserviceaccount.com</a> is a service account.</td>
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Google Earth Engine (GEE) Set up

When to use Service Account?

- Running workloads on virtual machines (VMs).
- Running workloads on on-premises workstations or data centers that call Google APIs.
- Running workloads which are not tied to the lifecycle of a human user.
Google Earth Engine (GEE) Set up

Task 1 - Create a google cloud project

https://developers.google.com/earth-engine/cloud/earthengine_cloud_project_setup

Step 1

Create a Cloud project

Note: You can create a Cloud Project through the Code Editor as described in the Code Editor Quickstart. If you create a project using the Code Editor, the Earth Engine API is automatically enabled and an Earth Engine assets folder associated with the project is automatically created.

If you haven’t already, create a Google Cloud Project. You can do so from the projects page of the Cloud Console or click the following button:

Create a Cloud project

You can manage your Google Cloud projects from the Google Cloud Console.

Tip: Project name can be something like ‘RAT-SE-Asia’ or ‘RAT Mekong’.

Step 2

Enter a Project name and Click on ’CREATE’.

Note: Do not close the project window which will open up.
Google Earth Engine (GEE) Set up

Task 2 - Enable Earth Engine API

https://developers.google.com/earth-engine/cloud/earthengine_cloud_project_setup

Step 1   Click on ‘Enable the Earth Engine API’

Enable the Earth Engine API

To enable the Earth Engine API for your project, click the following button to go to the Earth Engine API page:

Enable the Earth Engine API

On the Earth Engine API page, ensure that you have selected your project, and click Enable

You can manage your APIs for a Cloud project from the APIs & Services page of the Google Cloud Console.

Step 2   Make sure the right project is selected and Click on ‘ENABLE’

Google Earth Engine API

Geospatial insights for a more sustainable world.
Google Earth Engine (GEE) Set up

Task 3 - Create a service account

Note: In the project window which was opened up while following instructions in the second last page.

Step 1
Make sure the right project is selected and Click on ‘IAM & Admin’ > ‘Service Accounts’

Step 2
Click on ‘CREATE SERVICE ACCOUNT’

Step 3
Click on ‘CREATE AND CONTINUE’

Tip: (1) Service account name can be something like ‘rat-Mekong-YOUR_NAME’ (‘rat-mekong-sanchit’).
(2) Description can be who will be using this service account and for what.
Google Earth Engine (GEE) Set up

Task 3 - Create a service account

Step 4
Choose ‘Earth Engine’ > ‘Earth Engine Resource Admin’ and click on ‘CONTINUE’. After that click on ‘Done’.

Step 5
Click on ‘Actions’ > ‘Manage Keys’ for the service account you created.

Step 6
Click on ‘Add KEY’ > ‘Create new key’ and select json.
Task 4- Register the service account to use Earth Engine

https://developers.google.com/earth-engine/guides/service_account#register-the-service-account-to-use-earth-engine

Step 1: Click on ‘this page’ and select your email address.

Register the service account to use Earth Engine

If you use a Cloud project to access Earth Engine, all service accounts in that project with the correct permissions have access to the EE API, and there’s no need to register them separately.

If you don’t use a registered Cloud project to access Earth Engine, you can use this page to register your service account for use with the Earth Engine API. Once you’ve successfully registered your service account, follow the instructions that appear on the confirmation screen to enable access to the Earth Engine API.

Step 2: Fill out the form and accept the terms.

Step 3: Click on submit.

Step 4: Again click on the link mentioned above and follow step 1.
Google Earth Engine (GEE) Set up

Task 4- Register the service account to use Earth Engine

https://developers.google.com/earth-engine/guides/service_account#register-the-service-account-to-use-earth-engine

Step 4: Again click on the link mentioned above and repeat step 1 by clicking on ‘this page’.

Register the service account to use Earth Engine

Tip: Service account’s email address will look something like “foo-name@project-name.iam.gserviceaccount.com”

Step 5: Enter the created service account’s email address.

Step 6: Click on ‘REGISTER SERVICE ACCOUNT’.
RAT 3.0 Installation

1. Create an empty project directory and move into it. Ex - ‘rat_project’
   
   ```
   mkdir rat_project
   cd ./rat_project
   ```

2. Create a conda environment directory inside project directory. Ex - ‘.rat_env’
   
   ```
   mkdir ./rat_env
   ```

3. Create a conda environment using directory created above
   
   ```
   conda create --prefix ./rat_env
   ```

4. Activate this environment using conda
   
   ```
   conda activate ./rat_env
   ```

5. Install RAT 3.0 using conda
   
   ```
   conda install rat -c conda-forge
   ```
RAT 3.0 Initialization

Initialize RAT using ‘rat init’ command.

```
rat init -d . -g -gp <PATH_TO_DOWNLOAD/OF_DOWNLOADED_GLOBAL_DATA> -s <PATH_TO_SECRETS_FILE> -dr google
```

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>-d or --dir</td>
<td>Put project directory path</td>
<td>OPTIONAL</td>
</tr>
<tr>
<td>-g or --global_data</td>
<td>Whether to download global data</td>
<td>OPTIONAL</td>
</tr>
<tr>
<td>-gp or --global_data_dir</td>
<td>Path of global database (to download or if existing)</td>
<td>OPTIONAL</td>
</tr>
<tr>
<td>-s or --secrets</td>
<td>Put secrets file path (if you have)</td>
<td>OPTIONAL</td>
</tr>
<tr>
<td>-dr or --drive</td>
<td>Which drive to download data from (google/dropbox)</td>
<td>OPTIONAL</td>
</tr>
</tbody>
</table>

Note: A ‘rat_config.yaml’ file is prepared using ‘rat_config_template’ in PROJECT_DIRECTORY >> ‘Params’ which is created after initializing RAT.
Create a ‘secrets.ini’ file using a text editor with the following content:

```
#Enter user credentials (email, password) for aviso
[aviso]
username=
pwd=

#Enter user credentials (email, password) for imerg
[imerg]
username=
pwd=

#Enter service account (account_email, path to private json key) for google earth engine
[ee]
service_account=
key_file=
```

Note: A ‘secrets_template.ini’ file is provided in PROJECT_DIRECTORY >> ‘Params’ which is created after initializing RAT. Fill in the credentials, rename the file to ‘secrets.ini’ and save it to PROJECT_DIRECTORY >> ‘secrets’ or any safe place.
RAT 3.0 Testing

Test RAT using ‘rat test’ command.

```
rat test -d . -b NUECES -s ./secrets/secrets.ini -dr google
```

- **-d or --dir**  
  Put project directory path  
  **REQUIRED**

- **-b or --basin**  
  Which basin to test RAT on? (NUECES/GUNNISON)  
  **REQUIRED**

- **-s or --secrets**  
  Put secrets file path (if you have)  
  **REQUIRED**

- **-dr or --drive**  
  Which drive to download data from (google/dropbox)  
  **OPTIONAL**

- **!! Checkboxes:**
  - Download Test data
  - Create test_config.yml file
  - Run RAT for Test data
  - Verifies if RAT has produced outputs as expected.

**Note:** A ‘test_config.yaml’ file is prepared using ‘rat_config_template’ in PROJECT_DIRECTORY >> ‘Params’ which is created after initializing RAT.
RAT 3.0 Configuring

Autofill RAT configuration file using ‘rat configure’ command.

```
rat configure -d . -p ./params/rat_config.yaml -gp <GLOBAL_DATA_DIRECTORY_PATH> -nc <NO_CORES> -s ./secrets/secrets.ini
```

- **-d or --dir**  
  Put project directory path  
  **REQUIRED**

- **-p or --param**  
  Path of the rat configuration file to update  
  **REQUIRED**

- **-gp or --global_data_dir**  
  Path of downloaded global database  
  **OPTIONAL**

- **-nc or --n_cores**  
  Enter number of cores for RAT to use  
  **OPTIONAL**

- **-s or --secrets**  
  Put secrets file path (if you have)  
  **OPTIONAL**

- **Checkmarks:**  
  - Update provided parameter file.  
  - Does not prepare a new file.

Note: It is not advised to use configure command with ‘rat_config_template.yml’. Make a copy of it and then use the copy to configure.
Directory Structure after RAT Initialization

- **data**: All files processed and created by running RAT will be in this directory.
- **models**: Metsim, VIC and routing models are saved here.
- **params**: Metsim, VIC, routing parameter files and RAT configuration files are updated here. Template files for secrets.ini, basins_metadata.csv and rat_config are also provided.
- **global_data**: All default global data provided along with RAT 3.0 is stored here. Once RAT has been run successfully for a basin ‘global_data’ can be deleted except ‘global_basin_data’.
Steps in RAT 3.0

- 2 mandatory and 14 optional steps in RAT 3.0
- Though optional, they should all be run logically (example: Metsim should run before VIC)
- Optionality gives advantage to skip a step if it’s run already for the same dates for that basin
- If any mandatory step fails, RAT will stop running for that basin
- If any optional step results in an error, RAT will still try to execute next step given by user
## Steps in RAT 3.0

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Configuration Parameters

Update parameters in ‘rat_config’ file in ‘Project Directory > params’ as follows:

GLOBAL:

steps: [1,2,3,4,5,6,7,8,9,10,11,12,13,14]
# List of step numbers that needs to be executed by RAT. Default is all steps from 1 to 14.

project_dir: # Main directory path for all RAT models, parameters and global data. RAT Output Data can have a separate directory

data_dir: # Data Directory path for RAT output and intermediary files. It can be inside project directory.

basin_shpfile: # Basin Shapefile in json/shapefile format which can have multiple basins with unique id.

basin_shpfile_column_dict: #example- {'id': 'MRBID'} # Dictionary of column names in basin_shpfile defined above (must have a unique id column)
Configuration Parameters

Update parameters in ‘rat_config’ file in ‘Project Directory > params’ as follows:

BASIN:

region_name: # Name of the region – used to cluster data for multiple basins within one region

basin_name: # Basin name – used for saving data related to that basin

basin_id: # Basin id to map the basin in ‘GLOBAL:basin_shpfile’ # must match with the ‘id’ column specified through dictionary of column names in ‘GLOBAL’
Configuration Parameters

Update parameters in ‘rat_config’ file in ‘Project Directory > params as follows:

**BASIN:**

- **spin_up:** False # True if vic spin-up is required, otherwise False # True is recommended if it’s the first RAT run for a particular basin
- **start:** #example– 2022-08-01 #yyyymm-dd #Start date for RAT excluding any spin-up-time
- **end:** #example– 2022-08-31 #yyyymm-dd #End date for RAT
- **vic_init_state_date:** #example– 2022-08-18 #yyyymm-dd #Date of which initial state of VIC for the particular basin exists #Ignored if first_run is True #It can be left blank if no initial state file exists even when first_run is False
Function: Reading Configuration

- **Basin Name**, Region and ID
- **start**, end, spin_up, vic_init_state_date
- Mostly ‘BASIN’ section parameters
- **Basin Shapefile** in ‘GLOBAL’ section
- **project_dir** and **data_dir** in ‘GLOBAL’ section
- `['CLEAN_UP'][(clean_previous_outputs')]`
- **clean_previous_outputs** in ‘CLEAN_UP’ section

- ✓ Reading these parameters
- ✓ Declaring them globally
- ✓ Starts internal-detailed logging
- ✓ Cleans Previous Outputs (if desired)
- ✓ No Output
Steps in RAT 3.0 – Step (0)

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Function: Directory Structure

- Reading paths in the configuration
- Defining paths globally
- Creating directories if do not exist

- ✔ Reading some parameters
- ✔ Declaring them globally
- ✔ No Output
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Function: Downloading

- Precipitation is downloaded as IMERG late product.
  - In Ascii format

- Temperature products are from NOAA Global Daily Temperature.
  - In netcdf format

- Wind data is from NCEP/NCAR.
  - In netcdf format

✅ Downloading raw data from servers.
✅ Output in raw.
Function: Preprocessing

- Data Downloaded from providers
- Scaled
- Aligned
- Clipped
- Stored for further use

- Pre-process downloaded data
  ✓ Output in pre_processing
## Steps in RAT 3.0 – Step (2)

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METSIM

- Python Package – Meteorological Simulator and forcing disaggregator
- Simulates weather data
- Input is Meteorological data: (i) Current data (`metsim_input.nc`) (ii) 3 months historic data (`state.nc`)
- Requires 2 parameter files: `domain.nc` and `params.yaml`
- It’s output is required by VIC (`6h_VIC_<start>-<end>.nc`)
Configuration Parameters

Update parameters in ‘rat_config’ file in ‘Project Directory > params’ as follows:

**METSIM:**

- **metsim_env:** # Path of Metsim python environment
- **metsim_param_file:** # Default Metsim configuration parameter file
- **metsim_domain_file:** # Path of Metsim domain parameter file #Required if elevation file is not provided else will be automatically created
- **historical_precipitation:** # Path of dataset which has historical precipitation (>=3 years) for climatology based correction of satellite precipitation. Optional.
Configuration Parameters

Update parameters in ‘rat_config’ file in ‘Project Directory > params as follows:

GLOBAL:

**elevation_tif_file**: # Elevation raster file in tif format. It should be having elevations in meter and in WGS84 crs.

**multiprocessing**: # How many CPU cores to use

**multiple_basin_run**: False # True if running RAT for multiple basins in one go, will require basins_metadata(in csv format) to update any basin particular parameter in this configuration file. This will allow you to run RAT for multiple basins with just one configuration file.
Function: Merging Data & Metsim Input

- Basin is gridded at a resolution of 0.0625°.
- Basin grid file is created (<basin_name>_grid_mask.tif)
- All preprocessed data is combined into single file (combined.nc)
- Metsim inputs:
  - Data from start to end (metsim_input.nc)
  - Past 90 days data (state.nc)

- No extra parameter from configuration
- Basin grid file created
- Data Aggregation
- Metsim Input Data
Steps in RAT 3.0 – Step (3)

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Function: Metsim Parameter

- Requires elevation file in ‘GLOBAL’ section
  - In Tif format

- Output is metsim domain file (domain.nc)
## Steps in RAT 3.0 – Step (4)

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Function: Metsim Run

- Updates Metsim Parameter file (*params.yaml*)
- Runs Metsim using `<n_core>` parallel processing
  - `<n_core>` defined in ‘GLOBAL’ section

- Metsim Output (*6h_VIC_*<start>-<end>*.nc)
- Vic Input (*forcings_<year>*.nc)
Steps in RAT 3.0 – Step (5)

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- VIC

- Python Package – Variable Infiltration Capacity Model

- Macroscale Hydrologic Model to get gridded surface runoff

- Input is Meteorological forcings: Current data (forcings_<year>.nc)

- Requires 3 parameter files: (i) vic_domain.nc  
  (ii) vic_soil_param.nc  
  (iii) vic_params.txt

- It’s output is required by Routing (nc_fluxes.<start>.nc)
Update parameters in ‘rat_config’ file in ‘Project Directory > params’ as follows:

**VIC:**

`vic_env`: # Path of Vic python environment

`vic_param_file`: # Default vic global configuration parameter file. OPTIONAL. If passed, this file will be used to initialize, but will be over-riden by any options specified in this config file. If not passed, all necessary options must be specified in this file in 'VIC PARAMETERS'.
Update parameters in ‘rat_config’ file in ‘Project Directory > params as follows:

**VIC:**

- **vic_global_data**: # True if vic global (relative to basin) parameter information is available and should be used

  ## If global (relative to basin) vic parameter information is available and needs to be cropped for the basin [vic_global_data must be True], provide the following three parameters

- **vic_global_param_dir**: # Directory of global vic soil and domain parameters # Only required if vic_global_data=True, otherwise ignored

- **vic_basin_continent_param_filename**: # Name of the global vic soil parameter file (in netcdf format) # Only required if vic_global_data=True, otherwise ignored

- **vic_basin_continent_domain_filename**: # Name of the global vic soil parameter file (in netcdf format) # Only required if vic_global_data=True, otherwise ignored
Configuration Parameters

Update parameters in ‘rat_config’ file in ‘Project Directory > params’ as follows:

**VIC:**

## If basin vic parameter information is available and can be used as it is for basin [vic_global_data must be False], provide the following two parameters

**vic_soil_param_file:** #Vic Soil Parameter File Path (in netcdf format) # Only required if vic_global_data=False, otherwise ignored

**vic_domain_file:** #Vic Domain File Path (in netcdf format) # Only required if vic_global_data=False, otherwise ignored
Configuration Parameters

Update parameters in ‘rat_config’ file in ‘Project Directory > params as follows:

```bash
## OPTIONAL
# If vic_param_file is not provided

# VIC PARAMETERS
# STARTYEAR: '2001'
# STARTMONTH: '04'
# STARDDAY: '02'
# ENDYEAR: '2023'
# ENDMONTH: '04'
# ENDDAY: '01'
# LAT: lat
# LON: lon
# MASK: mask
# AREA: area
# FRAC: frac
# YDIM: lat
# XDIM: lon
# FORCING: Directory path for vic/forcing
# FORCE_TYPE:
# AIR_TEMP: temp
# PREC: prec
# PRESSURE: air_pressure
# SNDOWN: shortwave
# LDOWN: longwave
# VP: vapor_pressure
# WIND: wind
# OUTVAR: # Specify as list
# - OUT_PREC
# - OUT_EVAP
# - OUT_RUNOFF
# - OUT_BASEFLOW
# RESULT_DIR: Directory path for vic results
```
Function: VIC Parameters

- Requires `vic_soil_param` and `vic_domain` files
global/basin in ‘VIC’ section
  - In Netcdf format

- Outputs are vic domain file (**vic_domain.nc**) and vic soil parameter file (**vic_soil_param.nc**)
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**Function: VIC Run**

- Updates VIC Parameter file (*vic_params.yaml*).
- Runs VIC using `<n_core>` parallel processing. `<n_core>` defined in ‘GLOBAL’ section.
- Vic Input (*forcings_<year>.nc*).
- VIC Output (*nc_fluxes_<start>.nc*).
- Routing Input (*fluxes_<lat>_<lon>*).
- Creates VIC Init State for end (*state_<end>.nc*).

- Runs VIC
- VIC Output
- Prepares Routing Input
- Creates Vic Initialisation State
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Routing

- Fortran Program
- Routes surface runoff within a grid cell (in the main channel)
- Input is Surface Runoff: Current data \((\text{fluxes}_{\text{lat}}}_{\text{lon}})\)
- Requires 4 parameter files:
  1. \(\text{sta}_{\text{xy}}.\text{txt}\)
  2. \(\text{fl}.\text{asc}\)
  3. \(\text{uh}.\text{txt}\)
  4. \(\text{route}_{\text{param}}.\text{txt}\)
- It’s output is daily Inflow \((<\text{station (initial 5)}>_{\text{day}})\)
- Output converted to daily inflow in metric scale \((<\text{station (initial 5)}>_{\text{csv}})\)
Configuration Parameters

Update parameters in ‘rat_config’ file in ‘Project Directory > params’ as follows:

**ROUTING:**

*route_model:*  # Path of routing model

*route_param_file:*  # Will be used to initialize routing model. If not passed, every option must be specified in ‘ROUTING PARAMETERS’ section
Configuration Parameters

Update parameters in ‘rat_config’ file in ‘Project Directory > params as follows:

**ROUTING:**

### Flow Direction File

**If flow direction file (can be global) is available in tif format**

global_flow_dir_tif_file: # flow_direction_file in tif format (global compared to basin, so can be cropped)

replace_flow_directions: { 1: 3, 4: 5, # first replace 4 by 5 and then replace 2 by 4 2: 4, 8: 6, 16: 7, 32 64: 1, 128: 2, 255: 0 } # If no replace is required, leave it blank

**Important Note:** If using global flow direction file provided with RAT, don't change replace flow directions.
Configuration Parameters

Update parameters in ‘rat_config’ file in ‘Project Directory > params as follows:

**ROUTING:**

---

## Stations File (Each dam is a station)

## Either provide a global (relative to basin) stations_geojson_file with point geometry column and define the column names using dictionary or provide station_latlon file path in csv format

**station_global_data** : True  # True if giving global stations_file and column names, otherwise false and give station_latlon_path

**If** station_global_data **is True fill the below variables**

**stations_vector_file** : # Must have geometry(vector) column and separate lat, lon columns

**Must have unique id_column as primary key. name_column values can be left blank, but the column should exist.**

**stations_vector_file_columns_dict** : `{id_column : 'GRAND_ID',
name_column : 'DAM_NAME',
lon_column : 'LONG_DD',
lat_column : 'LAT_DD'}`
Configuration Parameters

Update parameters in ‘rat_config’ file in ‘Project Directory > params as follows:

**ROUTING:**

## Stations File (Each dam is a station)

## Or provide a stations_csvfile with columns run, name, lat, lon and name of each station must be unique with no spaces

*station_global_data : False*  # True if giving global stations_file and column names, otherwise false and give *station_latlon_path*

## If station_global_data is False fill the below variable

*station_latlon_path: # In lat lon format csv format #should have columns run, name, lat, lon*
Configuration Parameters

Update parameters in ‘rat_config’ file in ‘Project Directory > params’ as follows:

ROUTING PARAMETERS:  # (Optional; if passed, will be given the highest priority and will override the default ones calculated by scripts; Otherwise provide them in route_param.txt)

# flow_direction_file:  # Will be generated automatically from global_flow_dir_tif_file if given, otherwise uncomment and provide the path here
velocity: 1.5
diff: 800
xmask: 5000
fraction: 1
# station_file:  null # Will be generated automatically from either `stations_file`
# input_files_prefix:  null # Will be generated automatically based on vic output
input_file_precision: 2 # Default. Works fine for 0.0625° grid.
# start_date:  null # Will be automatically populated
# end_date:  null # Will be automatically populated
# output_dir:  # Will be generated automatically for each basin
uh:  # Unit hydrograph file for routing.
Function: Routing Parameters

- Prepares Basin Station File (basin_station_latlon.csv) (If desired)
  - In CSV format

- Prepares Basin grid flow direction file (fl.asc) (If desired)
  - In Ascii format

✓ Routing Parameter Files are created. (if desired)
## Steps in RAT 3.0 – Step (8)

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Function: Routing Run

- Updates Routing Parameter file (*route_param.txt*)
- Runs Routing
- Rout Input (*fluxes_<lat>_<lon>*)
- Rout Output (*<station (initial 5)>_.day*)
- Inflow (*<station (initial 5)>_.csv*)
- Creates Routing Init State for end (*rout_init_state_file<end>_.nc*)

- Runs Routing
- **Routing Output**
- Generates Inflow
- **Creates routing initialization state file**

![Routing Run Diagram](image-url)
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</tr>
<tr>
<td>14</td>
<td>Conversion of output data to final format as time series</td>
</tr>
</tbody>
</table>
Configuration Parameters

Update parameters in ‘rat_config’ file in ‘Project Directory > params’ as follows:

GEE:

## All reservoir polygons in one shapefile with a column(s) mapping to station/dams and having dam area in square km
reservoir_vector_file:
## If station_global_data is True, id_column and dam_name_column values should match with the values of id_column and name_column of stations_vector_file.

## If station_global_data is False, values of dam_name_column should match with the name column in station_latlon_path or station_file in Routing or Routing Parameters.
## If station_global_data is False, id_column field is not required below, can be left blank.

reservoir_vector_file_columns_dict: {id_column: 'GRAND_ID', dam_name_column: 'DAM_NAME', area_column: 'AREA_SKM'}
GEE Surface Area

- Google Earth Engine API
- Uses TMS-OS to calculate surface area of a reservoir
- Uses Sentinel-1, Sentinel 2, Landsat 8 & 9
- Do batch wise Extraction (Example 5 days)
- It’s output is surface area timeseries (<station>.csv)
- As of now it works for after 2019 time period.
Function: Surface Area Parameters

- Filters the reservoirs which are within basin
  - Filtered using <reservoir_vector_file> provided in ‘GEE’ section
- Prepares Basin Reservoir Shape File (basin_reservoirs.shp)
  - In Shapefile format

✓ Surface Area Parameter Files are created. (if desired)
### Steps in RAT 3.0 – Step (10)

<table>
<thead>
<tr>
<th>Step Number</th>
<th>Step Name</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>
Function: GEE Run

- Connects to Earth Engine
- Calculates Surface Area using Sentinel 1,2 & landsat 8,9
- Applies TMS-OS algorithm
- Surface area time series Output (<station>.csv)

- Runs Surface Area Calculation Script
- Surface Area Time Series Output
### Steps in RAT 3.0 – Step (11)

<table>
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Altimeter Height Extraction

- Radar based technology
  - Active sensor pings the water surface

- Jason-3 data
  - 10 day frequency

- Low spatial Coverage

- Highly Accurate

- Future Missions: SWOT
Configuration Parameters

Update parameters in ‘rat_config’ file in ‘Project Directory > params’ as follows:

```
ALTIMETER:

altimeter_tracks:       ## altimeter track paths in geojson format
geoid_grid:            ## geoid egm grid data in matlab file
last_cycle_number:     226
```

Configuration Parameters

Update parameters in ‘rat_config’ file in ‘Project Directory > params’ as follows:

**ALTIMETER:**

## Unique ids of reservoirs to process for altimeter for a basin in csv format with column name ‘reservoir_uni_id’

## You can specify min and max latitudes for ROI in this file with column name ‘min_lat’ and ‘max_lat’

## If station_global_data is True, these ids should match with ‘uniq_id’ values in basion_reservoir shapefile generated automatically

## If station_global_data is False, these ids should match with dam_name_column in reservoir_vector_file

reservoirs_csv_file:

## If you want to use the above file only to specify range of latitude and not the list of reservoirs to process for altimeter

only_for_range: False
Function: Altimetry Run

- Downloads raw altimetry data
- Find reservoirs on the altimeter track path
  - Can be provided manually
- Processes data to extract height (depth) of reservoirs
- Outputs depth time series (<reservoir>.csv)

- Runs Surface Area Calculation Script
  - Surface Area Time Series Output
### Steps in RAT 3.0 – Step (12)

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Area Elevation Curve

- Relation between water level and surface area for a reservoir
- Can be obtained using satellite data
- If possible, get in-situ data
Configuration Parameters

Update parameters in ‘rat_config’ file in ‘Project Directory > params as follows:

### POST_PROCESSING:

```python
## Folder path containing aec csv files for all reservoirs with the file names should be unique_identifiers.

## If station_global_data is True, these unique_identifiers should match with 'uniq_id' values in basion_reservoir shapefile generated automatically

## If station_global_data is False, these ids should match with dam_name_column in reservoir_vector_file

## If the folder path is not present or some reservoir aec file is not present, it will be generated automatically

aec_dir:
```
Function: Area Elevation Curve Estimation

- GEE script to extract area elevation curve
  - Uses DEM defined in ‘GLOBAL’ section
    - SRTM 30 m global resolution
- Bathymetry gets extrapolated
- Outputs area elevation curve file for each reservoir (<reservoir>.csv)
<table>
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Function: Post Processing

- **Storage Change (ΔS) Calculation (Trapezoidal Method)**
  - Requires: (i) Area Elevation Curve (<reservoir>.csv)
  - (ii) Surface Area Time Series (<reservoir>.csv)
  - Output: Storage Change (<reservoir>.csv)

- **Evaporation Calculation (Penman’s Equation)**
  - Requires: (i) VIC Output – grided surface (<reservoir>.csv)
  - (ii) Surface Area Time Series (<reservoir>.csv)
  - Output: Evaporation (<reservoir>.csv)

- **Outflow Calculation (Mass Balance Approach)**
  - Requires: (i) Inflow (<reservoir>.csv)
  - (ii) Storage Change (<reservoir>.csv)
  - (iii) Evaporation (<reservoir>.csv)
  - Output: Evaporation (<reservoir>.csv)
## Steps in RAT 3.0 – Step (14)

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</table>
Function: Final Outputs & Cleaning

- Generating Final outputs
  - Website frontend compatible

- Cleans intermediate files that will not be useful next time
  - Saves memory
  - Keeps RAT outputs to append next time

Active Directory cleanup
Configuration Parameters

Update parameters in ‘rat_config’ file in ‘Project Directory > params as follows:

CLEAN_UP:

clean_preprocessing: False # Deletes pre-processing data except global raw data

clean_metsim: False # Deletes metsim outputs

clean_vic: False # Deletes vic inputs and outputs as well as previous vic_init_states

clean_routing: False # Deletes routing inputs and outputs

clean_gee: False # Deletes unnecessary small chunk files downloaded using gee; not deleting the combined file, To delete the combined file use clean_previous_outputs

clean_altimetry: False # Deletes raw altimetry data which takes a lot of time to download; does not delete the extracted altimetry data, to delete extracted altimetry data use clean_previous_outputs

clean_previous_outputs: False # Deletes previous rat_outputs, routing inflow, gee extracted area and altimetry extracted heights
Multiple Basin Run

Update parameters in ‘rat_config’ file in ‘Project Directory > params as follows:

GLOBAL:

basins_metadata: # A csv file which is multi-indexed and have same indexing as rat_config.yml # Only required if multiple_basin_run is true, otherwise ignored

basins_to_process: #example- ['basin1','basin2'] # List of basin names to process if multiple_basin_run is true, otherwise ignored (must match with index 'BASIN: basin_name:' defined in basins_metadata csv file)
Multiple Basin Run

This is a sample for basins_metadata file

<table>
<thead>
<tr>
<th>BASIN</th>
<th>BASIN</th>
<th>BASIN</th>
<th>VIC</th>
<th>VIC</th>
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<tr>
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</table>
Summarized workflow of RAT 3.0

- Step 1: Preprocessed:
  A) Precipitation
  B) Min temp.
  C) Max. temp.
  D) Wind speed
- Step 2: E) Combined meteorological data
  F) Metsim State
  G) Metsim Input
- Step 3: H) Metsim Domain
- Step 4: I) Metsim output
  J) VIC Forcing input
- Step 5: K) VIC Soil Param.
  L) VIC Domain Param.

Outputs:
- F and G
- J

Data Sources:
- GRDC River Basins
- GEE SRTM Elevation
- SRTM Elevation
- EGM 2008 Geoid Model
- GRanD Reservoirs
- Unit Hydrograph
- VIC Global Parameters
- DRT Flow Direction File
- GRanD Dams

Steps:
- Step 7
- Step 8
- Step 9
- Step 10
- Step 11
- Step 12

- V) Reservoir AEC
- U) Reservoir Elevation Time Series
- T) Reservoir Surface Area Time Series
- S) Basin Reservoir shapefile
- R) Station Daily Streamflow
- O) Basin flow direction
  P) Basin station csv
  Q) Basin station geojson
- M) VIC Output
  N) Routing grid cell Runoff input

Output:
- N
- M

Polished Time Series of all outputs for analysis

- Step 13
- Step 14
- W) Storage Change
  X) Evaporation
  Y) Inflow
  Z) Outflow
Run RAT 3.0

Test RAT using ‘rat test’ command.

```
rat run -p ./rat_project/params/rat_config.yml -o 3
```

- **Put rat configuration file path**
  - REQUIRED

- **Number of days for operational latency**
  - OPTIONAL

- **Runs RAT either once or operationally**

```python
from rat.run_rat import run_rat
run_rat(config_fn='./rat_project/params/rat_config.yml', operational_latency=None)
```
Thank You

"Let RAT help you TRACK"

www.satellitedams.net