Flood Extent Extraction NoteBook User Manual

Gaussian Mixture Model (GMM) method

Introduction

This manual describes the deployment and usage of the Flood Extent Extraction (FEE) notebooks developed for the Department Of Customer Services (DCS). This manual contains guides on how to download and execute said Notebooks within the Amazon Web Services AWS Sagemaker Environment. This manual will also cover the expected input data type and outputs that are configured.

Assumptions

Because of the nature of the FEE system the following assumptions have been made about the user as well as the ability to access private storage systems (bitbucket, AWS S3) used to host the data and executable Notebooks. While many steps are covered some details may be missing such as logging into AWS / Bitbucket, navigating AWS / Bitbucket. etc

- User has access to an AWS account
- User has access to an AWS S3 bucket containing flood imagery for analysis
- User understands how to start / stop Sagemaker Notebooks
- User understands how to open Sagemaker JupyterLab Notebook
- User has access to Bitbucket repository hosting required notebooks
- User understands cloning of Bitbucket repositories
- User is computer literate and has some programming experience (ideally python)

Overview

This manual will cover the following components in higher detail.

Image / Data inputs

Flood data to be processed is expected to be JPEG2000 format images with Near Infra-Red Red Green (NRG) colour channels in the respective Channel 0 = Near Infra-Red, Channel 1 = Red, and Channel 2 = Green. Images need to have geodetic information embedded in the images metadata, specifically pixel size, projection datum, image location in relation to datum. Often these images are exported from GIS systems that already contain the required geodetic information in the image metadata.

Environment

The FEE has been developed and tested with the AWS Sagemaker environment. The Sagemaker environment is primarily a preconfigured Conda and python environment. AWS The execution Environment stack is as follows:

- AWS Sagemaker

- AWS Instance (Linux based host)
- Python / Conda Environment
- Executable Notebook

FEE Notebook execution steps

The complete start to stop process for operating the FEE can be described in the following steps:

1. Starting a correctly specified Sagemaker Notebook
2. Cloning the FEE Bitbucket repository
3. Configuring the Notebook
4. Executing the Notebook
5. Examine the output
6. Shut down the Notebook instance

Standard and high probability data

During the data extraction process the GMM will produce the probability of a pixel belonging to any of the clusters contained in the GMM model. This allows us to produce 2 data sets;

standard probability flood extent: Contains the default GMM pixel. Ie the pixel's highest probability is a known flood cluster.

high probability flood extent: Contains the default GMM pixel clustering output and pixels that have a high probability of belonging to a flood cluster. Ie the pixel's highest probability is a known flood cluster, and the pixel also has a high probability of belonging to a flood cluster.

The high probability flood cluster is aggressive compared to the alternative and may be able to include areas missed in the standard probability but may also result in false positive identification of the flood area.

Both of the datasets are contained in the Shapefile output from the Notebook and can be filtered by tag in GIS software.

Perquisites

- Access to the Bitbucket repository containing the required Notebook:
https://bitbucket.org/csu-spatialservices/flood-extent-extraction.git
- Authorised access to AWS and AWS Sagemaker
- Compatible JPEG2000 Images hosted on AWS S3 and access to said images from same AWS Sagemaker instance

Sagemaker Notebook

Notebook instance type

A Sagemaker Notebook will need to be started within the AWS environment. The Notebook Instance type best suited to the GMM process is a memory optimised instance. This is not because of GMM specifically but opening JP2 images uses a lot of memory.

The suggested Sagemaker Notebook instances are as follows:

ml.r5.24xlarge (memory optimised)
Tested on whole flood regions of up to 179590px * 72510px (13 Giga Pixel)

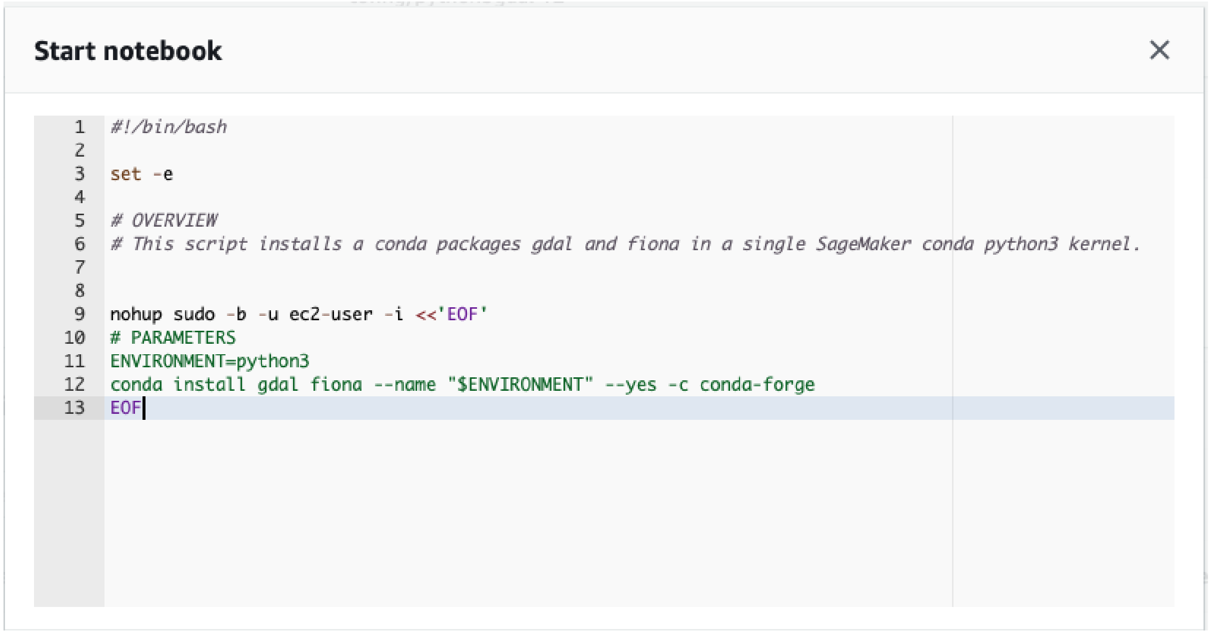
ml.r5.4xlarge (memory optimised)
Tested on tiled flood region sets of up to 144 images of 10000px * 10000px

Lifecycle Configuration / Conda setup

A Lifecycle Configuration has been created that will automatically set up the Conda Environment by installing GDAL and Fiona packages in the python3 Conda environment.

Lifecycle Configuration name: python3GDAL-v2

Python3GDAL-v2 will only be available on the same DCS AWS account that CSU students have been using for development. The Lifecycle Configuration executes the following script on every Start of the notebook / instance:

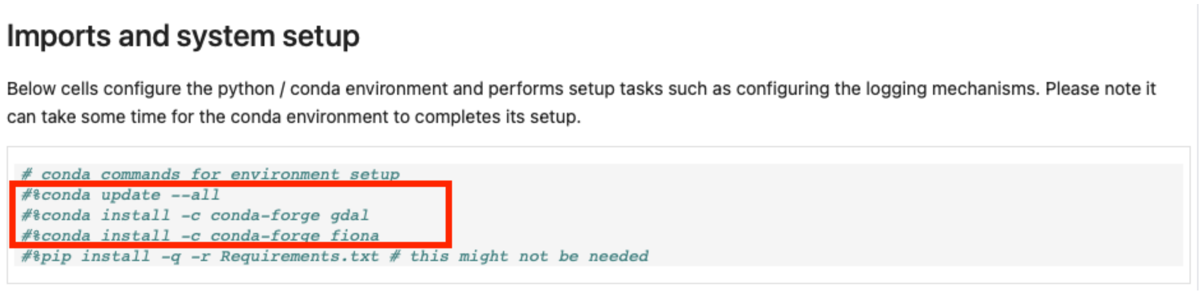

Start notebook

```
#!/bin/bash

set -e

# OVERVIEW
# This script installs a conda packages gdal and fiona in a single SageMaker conda python3 kernel.


nohup sudo -b -u ec2-user -i <<'EOF'
# PARAMETERS
ENVIRONMENT=python3
conda install gdal fiona --name "$ENVIRONMENT" --yes -c conda-forge
EOF
```

Figure 1 - Lifecycle Configuration script (python3GDAL-v2)

Note: The Lifecycle Configuration Script will run in the background during every Start of the notebook instance and can take ~20mins to execute. During this time, you may experience errors when importing python packages.

<u>If the Lifecycle Configuration is not available</u> during creation of the Sagemaker instance the environment can be setup from within the Notebook by uncommenting and executing the following lines within the notebook. This process can take ~20mins to execute.



Imports and system setup

Below cells configure the python / conda environment and performs setup tasks such as configuring the logging mechanisms. Please note it can take some time for the conda environment to completes its setup.

```
# conda commands for environment setup
#%conda update --all
#%conda install -c conda-forge gdal
#%conda install -c conda-forge fiona
#%pip install -q -r Requirements.txt # this might not be needed
```

Figure 2 - Alternate Conda setup

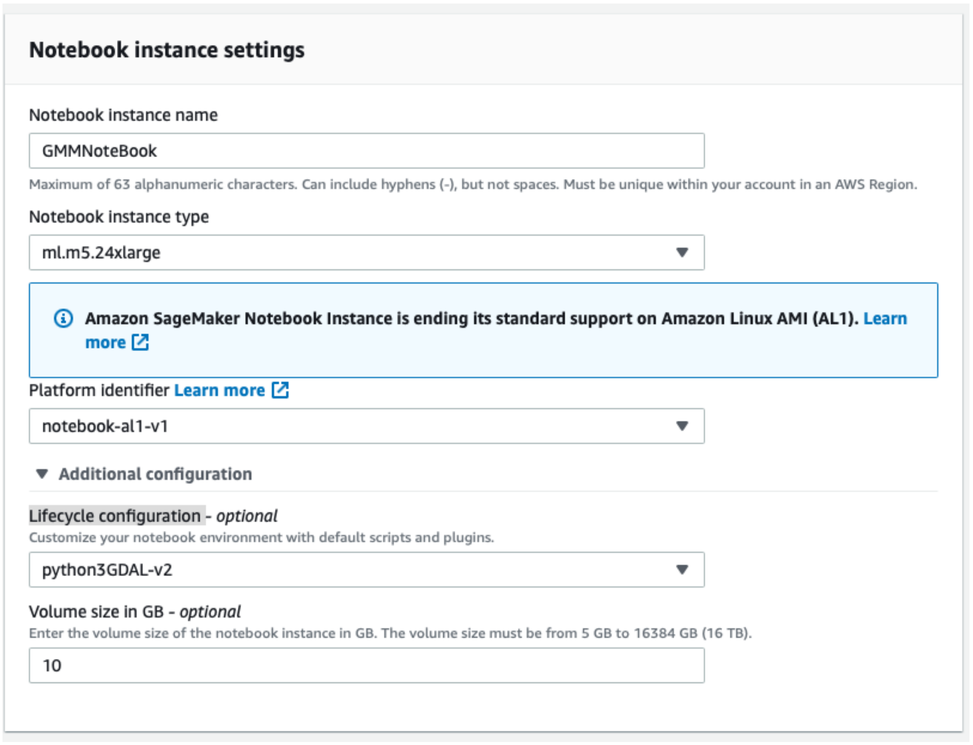
Volume size

It is recommended to configure the instance to have at least **10GB of local storage**. It is unlikely that all of this will be used however it does provide storage in case of larger datasets.

Sagemaker Notebook Example

Instance suitable for large single images.

Notebook instance name	GMMNoteBook
Notebook instance type	ml.m5.24xlarge
Lifecycle configuration	python3GDAL
Volume size	10gb



Notebook instance settings

Notebook instance name

GMMNoteBook

Maximum of 63 alphanumeric characters. Can include hyphens (-), but not spaces. Must be unique within your account in an AWS Region.

Notebook instance type

ml.m5.24xlarge

Amazon SageMaker Notebook Instance is ending its standard support on Amazon Linux AMI (AL1). Learn more

Platform identifier Learn more

notebook-al1-v1

Additional configuration

Lifecycle configuration - *optional*

Customize your notebook environment with default scripts and plugins.

python3GDAL-v2

Volume size in GB - *optional*

Enter the volume size of the notebook instance in GB. The volume size must be from 5 GB to 16384 GB (16 TB).

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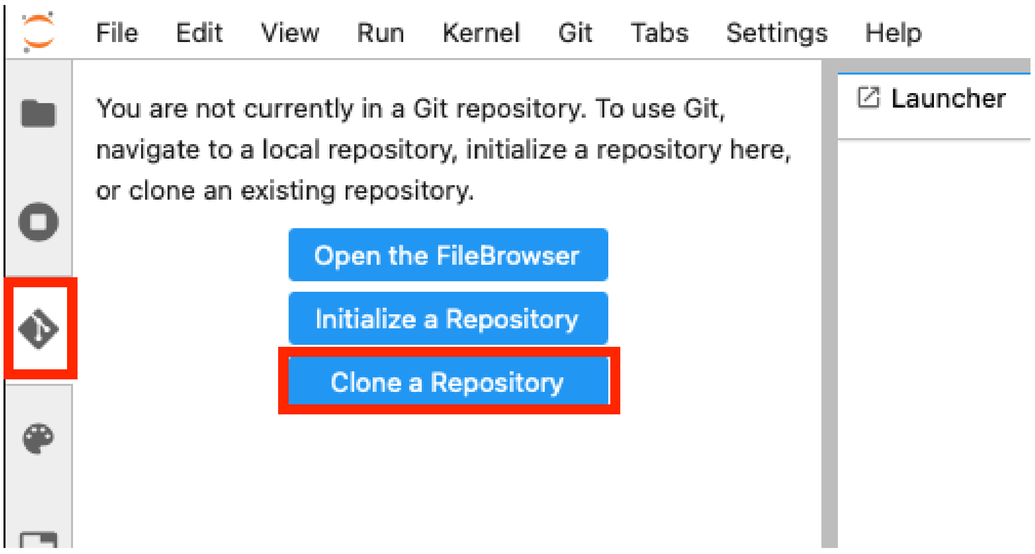
Figure 3 - Example Sagemaker instance

Clone the repository

All functional notebook code is held within the following repository within Bitbucket at the following repository URL:

https://bitbucket.org/csu-spatialservices/flood-extent-extraction.git

This repository will need to be cloned to the Sagemaker Notebook / Instance. The easiest method is to use the inbuilt Notebook Git tools access from the left menu Git icon and selecting “Clone a repository”. Once prompted enter the repository URL and fill in your Bitbucket credentials to access the repository.



You are not currently in a Git repository. To use Git, navigate to a local repository, initialize a repository here, or clone an existing repository.

Figure 4 - Accessing Git clone button

Repository Folder Structure

The repository will have the below folder structure. Most folders are empty and are intended to be default locations for runtime data (Images = Flood images, Logs = Runtime Logs of the notebook, Out = Shapefile outputs. etc). These will be the preconfigured locations used by the notebook during execution

```
flood-extent-extraction/
├── App/
│   ├── GMM Extraction Method/
├── Documentation/
├── Images/
├── Logs/
├── Models/
│   ├── GMM/
├── Out/
```

The 3 directories of most interest will be:
App – Contains executable Notebooks. For this document we will be looking at GMM Extraction Method
Documentation – Documents such as this
Models – Machine learning models and artifacts

Notebook Setup and Execution

To execute the GMM clustering technique notebook can be found at flood-extent-extraction/App/GMM Extraction Method/GMM_Flood_Extent_Extraction.ipynb Notebook. The defaults for most of the notebook should be sufficient however they should be checked to prevent errors during runtime.

Jupyter Kernel

Select **conda-python3** as the kernel for the Jupyter Notebook. This is especially important if the Lifecycle Configuration is configured as Python3GDAL-v2 as the Environment packages for Conda are only installed to this Kernel.

Notebook settings

All user settings are contained in 1 cell "Notebook settings". Below is an explanation of each setting. A brief explanation of each explanation is also contained in the Notebook.

The only setting that is likely to be changed is ***nrg_image_s3_source*** as it specifies the source S3 bucket of flood images.

Input Image settings

- **<u>nrg_image_s3_source</u>** - String: Amazon S3 source directory containing flood images destined for processing
  eg. s3://ss-csu-dataset/raw/Brewarrina_Flood_2021_04_15cm_NRG/
- ***nrg_image_storage_directory*** - String: Storage directory where flood images will be stored for processing.
- ***image_scale*** - Float: Reduce image size. This is used to boost performance. This should be set to values approximate to the scale of images used to train the GMM model. Typically, this value can be set to 0.1. There is minor improvement between 0.1 to 0.3 and no difference between 0.3 to 0.5. A value of 1 has been known to cause mis classification of the flood imagery.

GMM settings

- ***gmm_storage_directory*** - String: Directory containing the pre trained GMM model. At the time of writing this gmm_1_3_4_5_v2_master_image_nrg_0.1.gmm is the best known model.
- ***gmm_flood_clusters*** - Tuple: Clusters that contain flood pixels. This will only be changed when the GMM model is changed.

Contouring / polygon settings

- ***minimum_contour_size*** - Int: Minimum pixel area for a contour / polygon to be considered valid

Logging settings

- ***log_file_prefix*** - String: Prefix that will be attached to all log files.

- ***log_storage_directory*** - String: Location to store log files
- ***write_inspection_images*** - Boolean: Create and write inspection images to disk for debugging or verification reasons. Enabling does have significant impact on overall RAM usage.
- ***inspection_images_directory*** - String: Location to store inspection images

Output settings

- ***output_directory*** - String: Location to store shape files, inspection, and zip file.

Execution

Once ***nrg_image_s3_source*** has been set to the source S3 bucket for the flood images the Notebook can be executed (Run -> Run All Cells).

Zip file output

After execution has successfully completed the ***output_directory*** will be zipped and saved to the parent directory of ***output_directory***. Eg "../***output_directory***"

Runtime outputs

Logging

During runtime the notebook will update the user via output below the executing cell. This output is limited and provides an overview of the Notebook state. A more detailed log is generated and output to the folder defined in ***log_storage_directory***, this is set to the *Logs* folder by default. An additional EXTRA logfile is also generated, this EXTRA log file contains logs of the Notebook and all imported modules. This can be used to very in depth troubleshooting of the notebook.

Inspection Images

If ***write_inspection_images*** is enabled (set True), the Notebook will output inspection images into the ***output_directory***. These images are useful for understanding and identifying potential issues in the Notebook. The inspection image consists of 5 images displaying the standard and high probability data extractions.

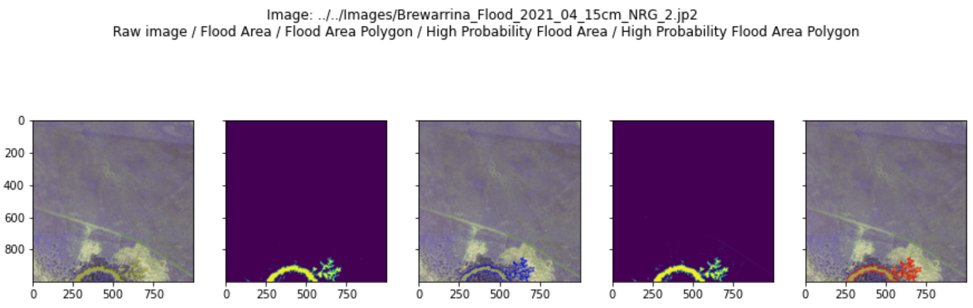


Image: ../../Images/Brewarrina_Flood_2021_04_15cm_NRG_2.jp2
Raw image / Flood Area / Flood Area Polygon / High Probability Flood Area / High Probability Flood Area Polygon
0
200
400
600
800
0 250 500 750

Shapefiles

Each flood image will result in a Shapefile output. The Shapefile output is a multipolygon that contains 2 data tags:

standard probability flood extent: Contains the default GMM pixel. I.e. the pixels highest probability is a known flood cluster.

high probability flood extent: Contains the default GMM pixel clustering output and pixels that have a high probability of belonging to a flood cluster. I.e. the pixels highest probability is a known flood cluster, and the pixel also has a high probability of belonging to a flood cluster.

The high probability flood cluster is aggressive compared to the alternative and may be able to include areas missed in the standard probability but may also result in false positive identification of the flood area.

GIS software such as QGIS allows the Shapefile to be filtered. By default, all polygons are shown however QGIS allows the user the filter the polygon by tag. Using this filter feature the user can switch between standard and high probability data.

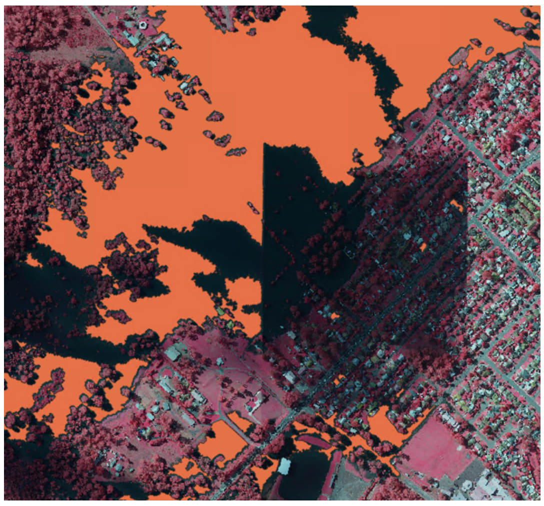


Figure 5 - Standard Probability

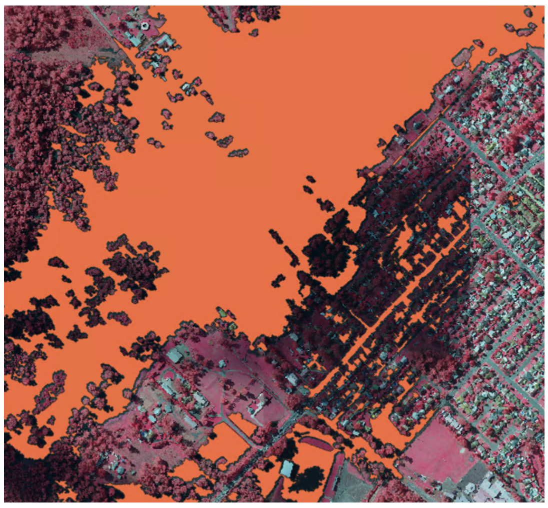


Figure 6 - High Probability

Clean up

At the end of the Notebook execution the system will automatically delete flood images and zip and save the ***output_directory.*** This is to ensure multiple runs of the notebook does not cause overfilling the local disk space and to ensure no old images are accidently processed when attempting to process new images.

The zipped outputs will be saved to the parent directory of ***output_directory.***

Note: Remember to Stop the Notebook after Execution to prevent a large AWS bill