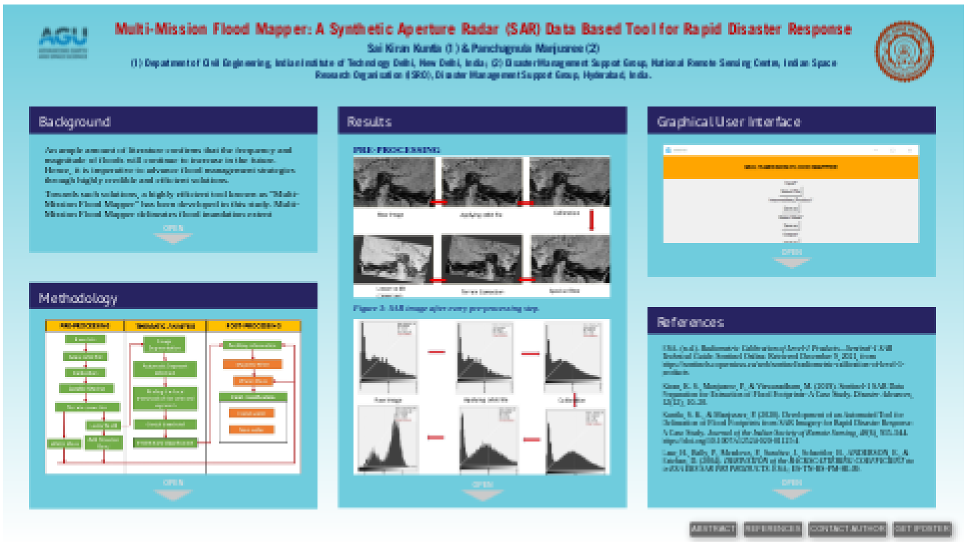
Multi-Mission Flood Mapper: A Synthetic Aperture Radar (SAR) Data Based Tool for Rapid Disaster Response



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PRESENTED AT:

BACKGROUND

An ample amount of literature confirms that the frequency and magnitude of floods will continue to increase in the future. Hence, it is imperative to advance flood management strategies through highly credible and efficient solutions.

Towards such solutions, a highly efficient tool known as "Multi-Mission Flood Mapper (MMFM)" has been developed in this study. MMFM delineates flood inundation extent without any human intervention from SAR images captured by a large number of microwave SAR satellite missions, including ALOS PALSAR CEOS, ALOS 2 CEOS, COSMO-SkyMed, ENVISAT ASAR, ERS 1/2 CEOS, ERS 1/2 SAR(.E1, .E2), ICEYE, JERS CEOS, KOMPSAT-5, PAZ, RADARSAT-1 & -2, RCM, SAOCOM, SeaSat, Sentinel-1, TerraSAR-X, and TanDEM-X.

In the literature, though many algorithms exist on SAR-based flood map generation in near real-time, most support only one or very few sources of SAR data. The primary reason hindering the development of algorithms compatible with more than one satellite mission is that different satellite missions demand varying data and formulae during various pre-processing steps. Hence, finding a better alternative for coping with the pre-processing task in our tool, rapid generation capability, high accuracy, and a user-friendly interface makes it unique and a better choice for dealing with multiple SAR missions.

METHODOLOGY

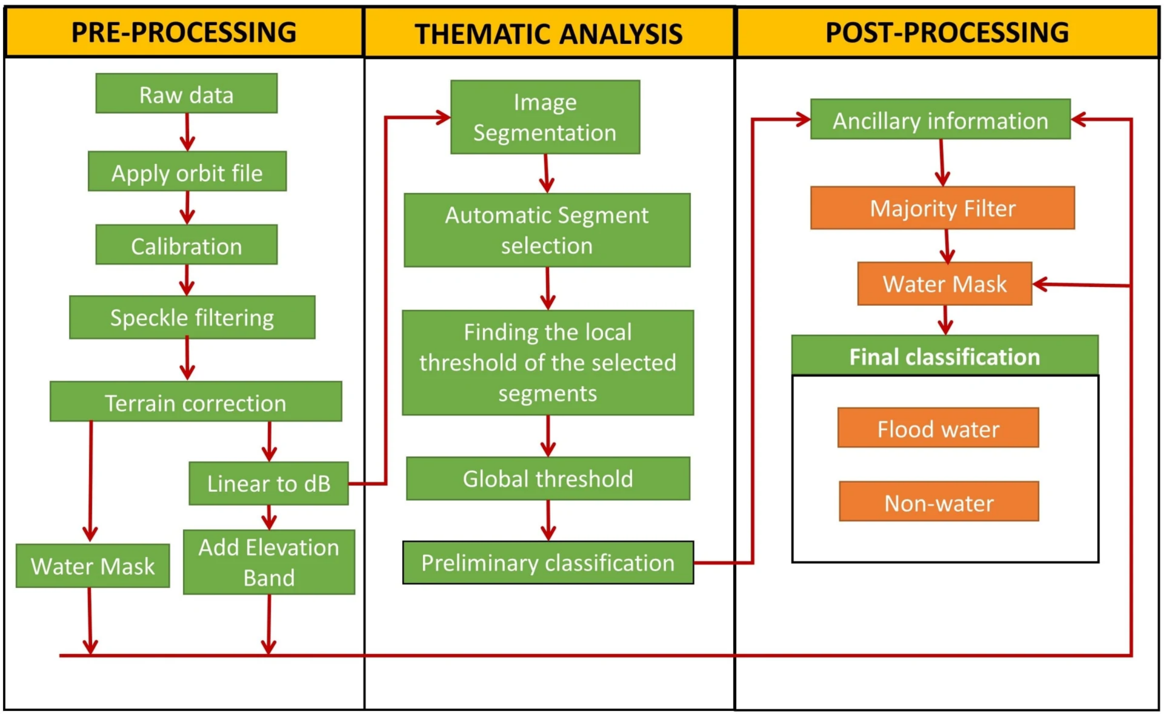

Figure 1: The workflow of the Multi-mission Flood Mapper backend processing.

The tool is programmed in python language. Its backend workflow consists of three components: pre-processing of SAR data, thematic analysis, and post-processing.

PRE-PROCESSING

The pre-processing is carried out by invoking ESA's SNAP operators using Graph Processing Tool (GPT) from the python script, one of the three approaches for automating SNAP software-based processing (Kiran et al., 2019). An XML-encoded graph file containing the list of pre-processing steps along with their parameters was used to feed the GPT for seamless performance. More details about GPT and Graph Processing Framework (GPF) can be found at Veci (2020). As MMFM deploys SNAP software operators for pre-processing, it adjusts a few parameters itself based on the SAR mission of the acquired data. For instance, SNAP uses varying (necessary) formulae for radiometric calibration of different satellite missions as they demand (SNAP Desktop Help file, 2021) – ex. Sentinel-1 (ESA, n.d.), ERS (Laur et al., 2004), Radarsat-2(*RADARSAT -Data Products Specifications*, 2000). Besides, "Apply orbit file" works only if the input image is a product of Sentinel-1 or ASAR or ERS. Else, the tool skips this step and moves directly to the "Calibration". More details about all the pre-processing steps answering why they are necessary and what they do, are available in Kuntla & Manjusree (2020). The derived elevation band and water mask (Figure 5) during pre-processing will be used in post-processing.

THEMATIC ANALYSIS

The thematic analysis component includes classifying water from SAR images using multi-segmentation and Otsu's thresholding techniques. To be precise, the linear to decibels converted image, the end product of pre-processing, will be divided into segments each of size 100 x 100 pixels. Further, each parent segment will be divided into 4 sub-segments of size 50 x 50 pixels, as shown in Figure 2. The size of segments and sub-segments was fixed after testing on a significant number of images covering different landscapes. Subsequently, mean intensity values are calculated in each sub-segment. Later, using the respective mean values of four sub-segments, the standard deviation of its parent segment is calculated. Now, two conditions are checked to select 5 segments out of all for finding the global mean:

1. The standard deviation of the segment must be high (more than 95% quantile). This criterion helps find the segments with a greater probability of distribution of more than one class within it, and the no of pixels of each class is of good ratio.
2. The mean intensity value of the segment must be lesser than the mean intensity value of the whole image. This criterion ensures that the selected segments have a good number of water pixels.

If the number of segments satisfying the conditions mentioned above is less than 5, then the size of segments and sub-segments is reduced to half. Moreover, the quantile for tile selection is reduced to 90% to ensure that the segments are also selected in data with a relatively low extent of water surfaces or with smaller dispersed water bodies. Finally, the top 5 segments in terms of standard deviation are selected for further analysis. Later, the Otsu thresholding technique is used to automatically find the optimum thresholds, which separates the water and surrounding surface over the selected five segments. The arithmetic mean of thus derived five local thresholds results in a global threshold value. Consequently, the global threshold will be applied to the whole image to get a preliminary classified water layer, as shown in Figure 6.

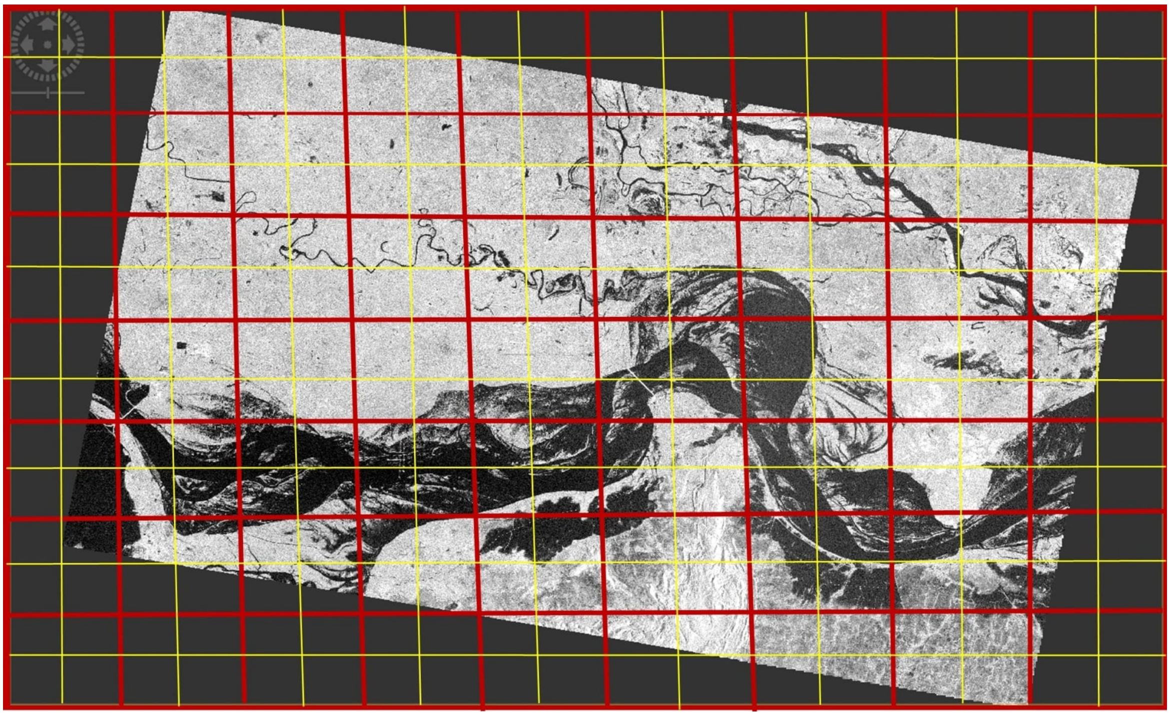

Figure 2: Schematic image of multi-segmentation. The red color boxes correspond to segments of size 100 x 100 pixels; the yellow color boxes correspond to sub-segments of size 50 x 50 pixels.

POST-PROCESSING

The post-processing component includes the removal of stray pixels and applying a water mask to delineate the final flood layer. Firstly, the elevation band obtained from the pre-processing stage will be used to remove over classified water pockets from the preliminary classified water layer where floods can never occur (Figure 7). It is implemented by giving a specific limitation to the relative height from the nearest drainage course, like the concept of height above the nearest drainage (HAND). After that, Majority filter will be applied to refine the image by removing stray pixels, as shown in Figure 7. Finally, the permanent water body (obtained from pre-processing) will be masked out of the refined water layer so that the final output corresponds to floods only, as shown in Figure 8.

RESULTS

PRE-PROCESSING

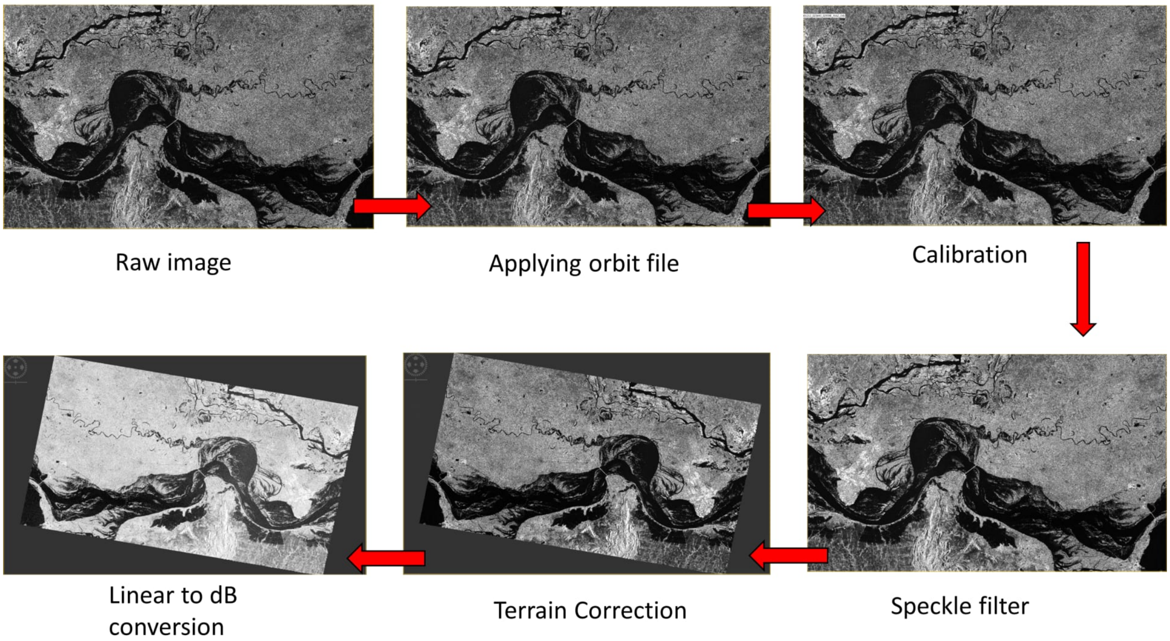

Figure 3: SAR image after every pre-processing step.

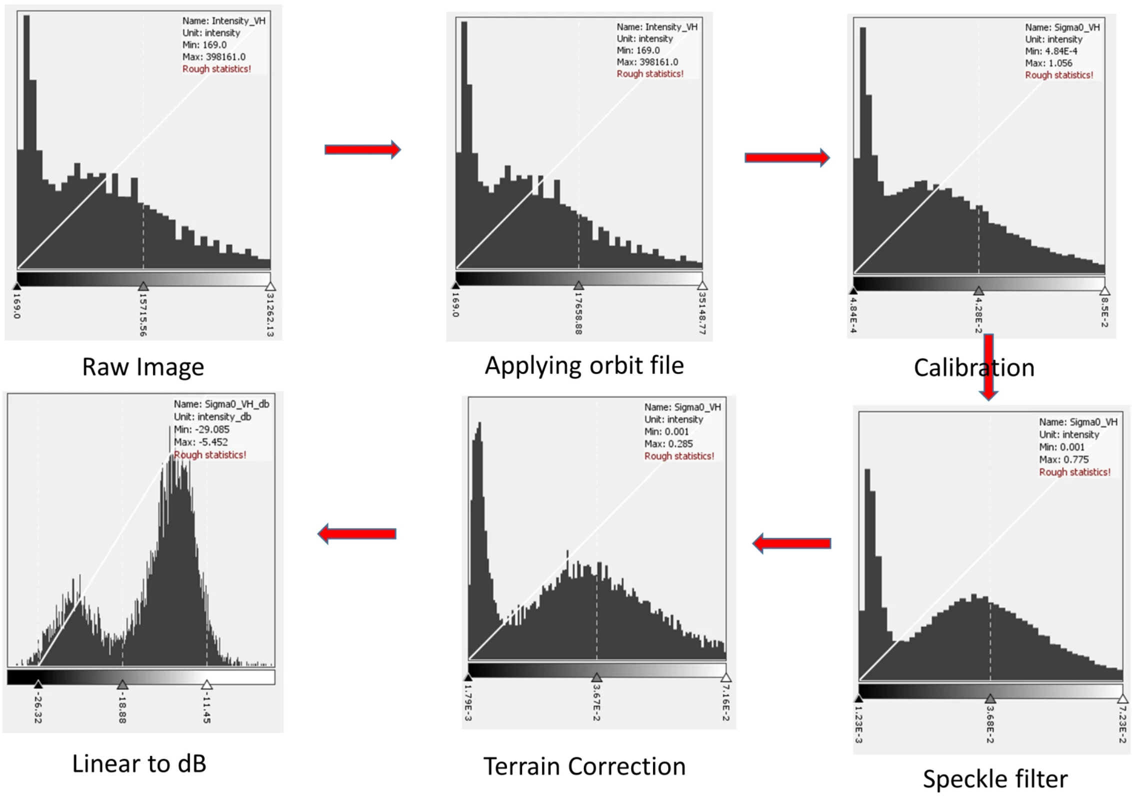

Figure 4: Histograms of the SAR image after every pre-processing step. The final bimodal histogram makes it easy to pick up a threshold separating water and its surroundings.

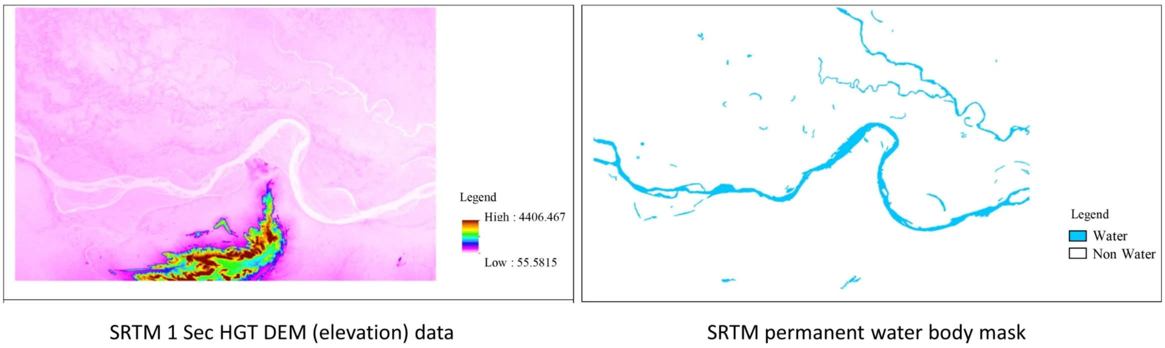

Figure 5: Elevation data and Waterbody mask obtained in pre-processing.

THEMATIC ANALYSIS

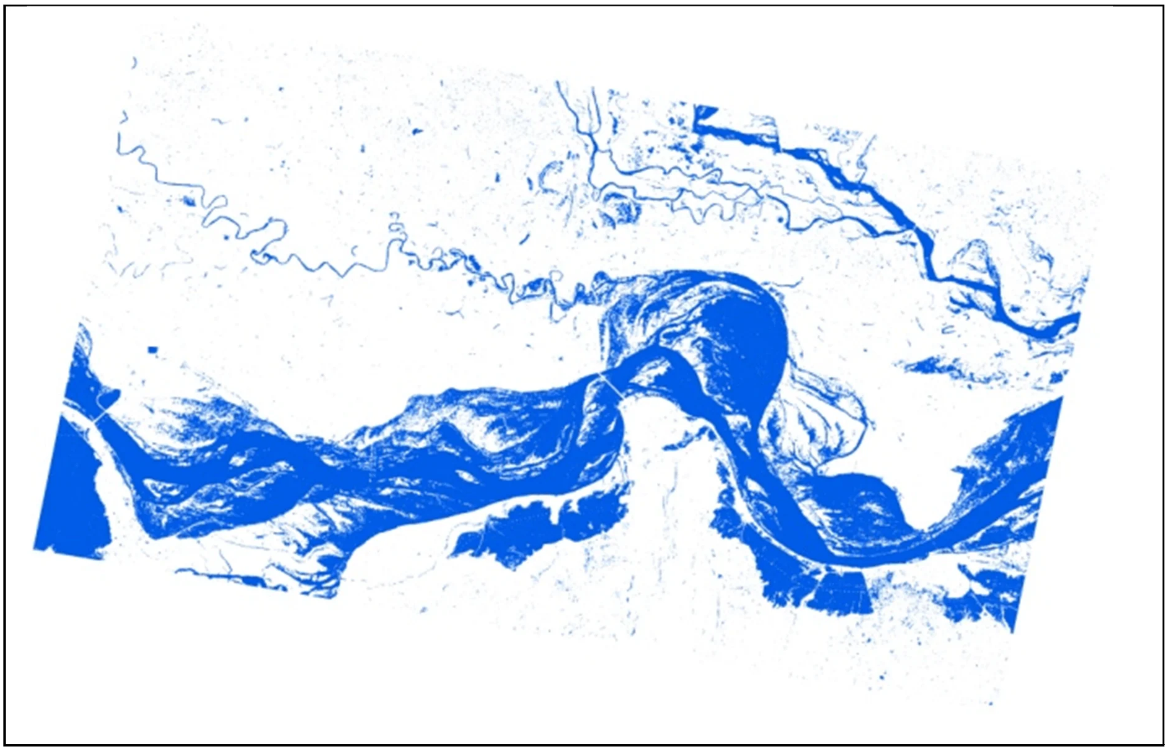

Figure 6: Preliminary classified water layer.

POST-PROCESSING

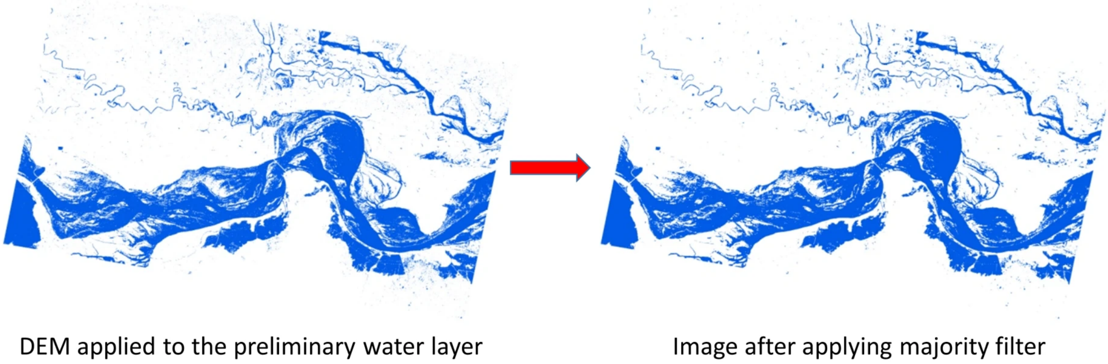

Figure 7: Refined preliminary classified water layer by applying elevation data and majority filter.

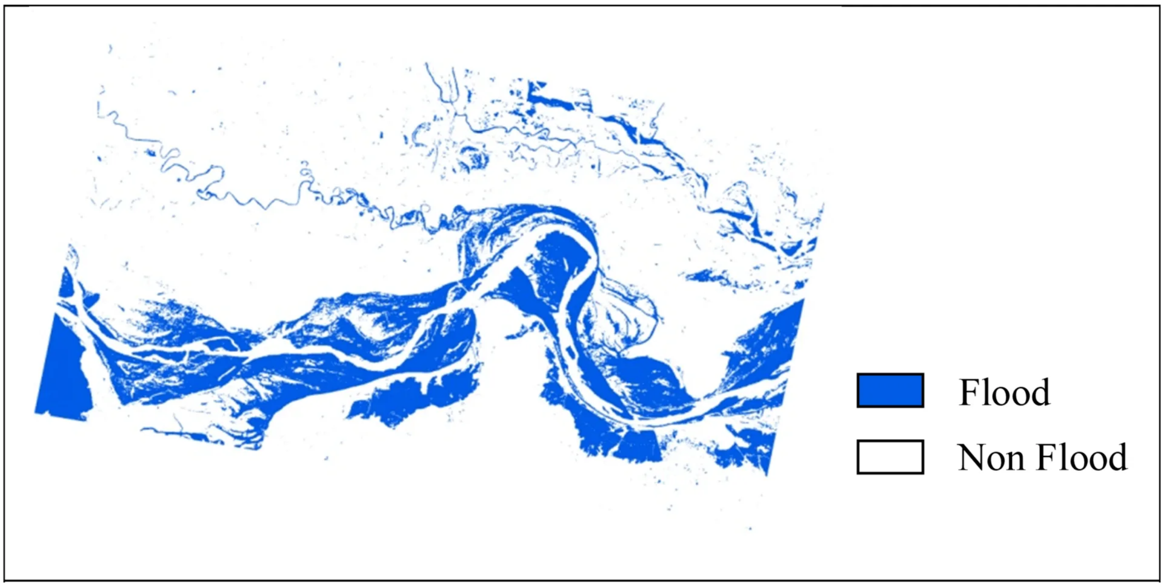

Figure 8: Final output - flood layer - of the tool.

For a detailed description of the results, please refer to Kuntla & Manjusree (2020).

GRAPHICAL USER INTERFACE

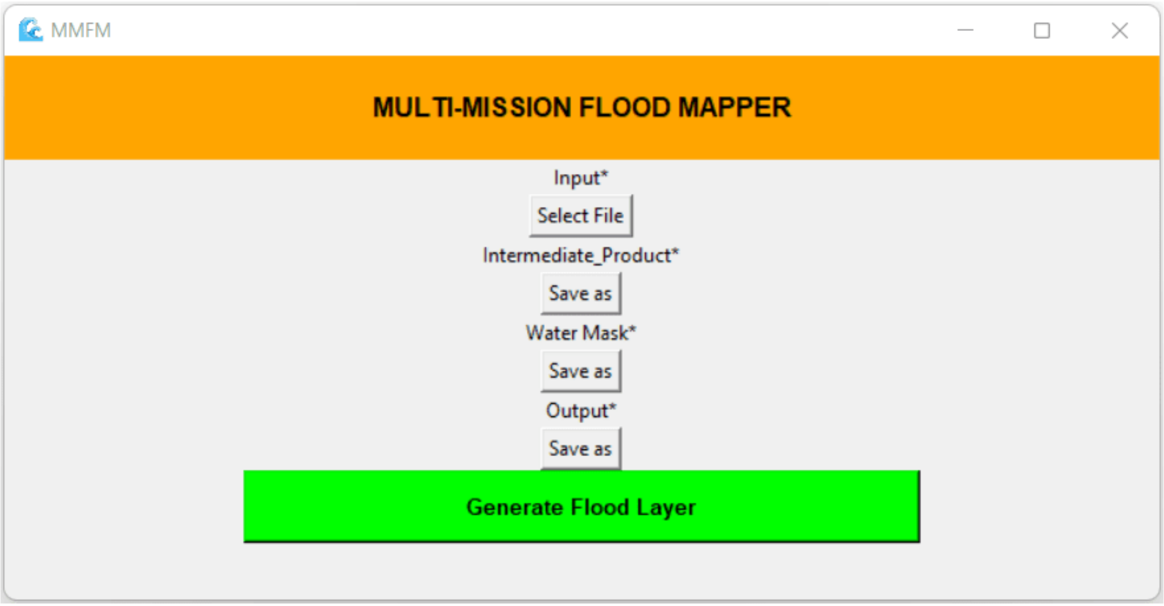

Figure 9: Graphical User Interface (GUI) of Multi-Mission Flood Mapper.

The tool is facilitated with a user-friendly Graphical User Interface (GUI), making it easy for any user, even without much technical knowledge, to comfortably use it for rapid flood inundation layer generation whenever required.

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ABSTRACT

Floods are convincingly the most frequent and widespread natural hazard across the world. With an ample amount of literature forecasting increase in its frequency and magnitude further in the future, highly credible and efficient algorithms and tools are crucial for real-time flood monitoring. In this study, a highly efficient tool, Multi-Mission Flood Mapper, has been developed to delineate flood inundation extent without any human intervention from SAR images captured by multiple microwave SAR satellite missions, including ALOS PALSAR CEOS, ALOS 2 CEOS, COSMO-SkyMed, ENVISAT ASAR, ERS 1/2 CEOS, ERS 1/2 SAR(.E1, .E2), ICEYE, JERS CEOS, KOMPSAT-5, PAZ, RADARSAT-1 & -2, RCM, SAOCOM, SeaSat, Sentinel-1, TerraSAR-X, and TanDEM-X. The efficacy of the developed tool is assessed by performing a test on a significant number of flood events in India having diverse flooding patterns and landforms. To manifest the performance of the tool, the step-by-step processing at the backend of the tool is discussed in detail in this study by taking a flood event along the Ganga River in India as a case study. The algorithm of the tool includes various processing steps: pre-processing that incorporate applying orbit file, calibrate to sigma naught, speckle filtering, terrain correction and linear to decibel conversion; thematic analysis that involves multi-segmentation and Otsu's thresholding techniques; post-processing that consists of the elimination of hill shadows, applying majority filter, and masking out permanent water bodies. Thus derived flood inundation layer is observed to be highly accurate compared to the master image. The total time taken by the tool for processing is about 4 minutes for the given image. The developed tool would be beneficial for rapid flood inundation map generation on a timely basis for flood monitoring and relief management during a disaster. In addition, the flood inundation layers can also be used for calibration/validation of hydrological/hydraulic models, geospatial planning, and generating flood hazard maps. Also, the Multi-Mission Flood Mapper tool is facilitated with a user-friendly Graphical User Interface (GUI), making it look simple and easy to use.