Final Project Report

Flood Mapping in Peace-Athabasca Delta using SARscape

By

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ABSTRACT

The Peace-Athabasca Delta (PAD), located in northeastern Alberta, Canada, is one of the world's most ecologically significant wetland ecosystems, recognized as both a Ramsar Wetland of International Importance and a UNESCO World Heritage Site. In May 2020, the PAD experienced severe flooding due to a combination of snowmelt and heavy rainfall. This project investigates the flood extent using radar remote sensing techniques, specifically Sentinel-1 Synthetic Aperture Radar (SAR) data, processed through the SARscape module in ENVI. The study utilized three Single Look Complex (SLC) images representing pre-flood, during-flood, and post-flood conditions, dated April 23, May 5, and May 17, 2020, respectively. Key processing steps included multilooking, coregistration, radiometric calibration, and geocoding and flood classification and refinement which enabled accurate flood delineation despite atmospheric interference like cloud cover. The findings demonstrate the strength of SAR-based approaches in rapid flood assessment.

Keywords: PAD, Flood Inundation, Wetland hydrology

1. Introduction

One of the world's most famous inland freshwater deltas in terms of ecology is the Peace-Athabasca Delta (PAD), which is situated in northern Alberta at the confluence of the Peace, Athabasca, and Birch rivers. The PAD, a UNESCO World Heritage Site and Ramsar Wetland of International Importance, provides vital habitats for aquatic life, migrating birds, and Indigenous peoples for their traditional uses. However, the delta is experiencing increasing environmental stress, especially when it comes to hydrological changes that alter its typical flood cycle (Timoney, 2021)

More recent work by Beltaos emphasized how both climatic variability and human-induced regulation influence ice-jam formation and flood extent (Beltaos, 2024) . Changes in ice dynamics have reduced the natural renewal of wetland basins. In parallel, studies by Wang have identified large-scale avulsion processes, including shifts in the Athabasca River's course, which are reconfiguring flow patterns and altering local flood behavior. These findings point to a rapidly evolving hydrological landscape that demands advanced monitoring tools capable of capturing both gradual and sudden changes (Bo Wang, Laurence C. Smith, Colin Gleason3, 2023)

Conventional flood monitoring in the PAD has relied on in situ observations, historical records, and optical satellite imagery. While useful, these methods are often hampered by accessibility issues and limitations posed by cloud cover and weather conditions during flood events. Synthetic Aperture Radar (SAR), with its ability to penetrate clouds and acquire data in both day and night conditions, has emerged as a powerful tool in flood monitoring (Schumann*, 2010).

Raw SAR data, however, is not usable without significant preprocessing. Programs like SARscape, a module of the ENVI software package, are designed specifically to deal with these complex workflows. SARscape offers step-by-step automatic flood detection including multilooking, coregistration, radiometric calibration, geocoding, and

classification. It can be used on multi-temporal SAR data to generate high-resolution flood maps that support real-time environmental management and long-term ecological monitoring (Townsend, 2002).
In spite of such advancements in technology, Sentinel-1 and SARscape application in the PAD's flood monitoring is not ideally exploited. Either historical data has been used, or manual classification methods have been applied in most of the studies. Increasingly, there is a need to incorporate automatic SAR-based flood mapping methods in routine monitoring of dynamic wetland ecosystems such as the PAD. This strategy is especially relevant with the growing frequency of extreme hydrological events, like the May 2020 flood, which inundated vast parts of the delta after intense rainfall and snowmelt.

The objective of this study are:

- To map flood-affected areas in the Peace-Athabasca Delta after the May 6, 2020 event using Sentinel-1 SAR data.
- To distinguish between newly flooded areas, non-flooded areas, and existing water bodies using satellite-based backscatter analysis.

2. Study area and Data

2.1. Study area

The Peace-Athabasca Delta (PAD) is a dynamic freshwater wetland system located in northeastern Alberta, Canada, within Wood Buffalo National Park. It is primarily formed by the confluence of the Peace and Athabasca Rivers, with additional flow from the Birch and Embarras Rivers. This expansive delta covers over 6,000 square kilometers and includes a complex mosaic of lakes, channels, and floodplains that support diverse ecological communities and sustain traditional Indigenous land use practices (Peters, 2023).

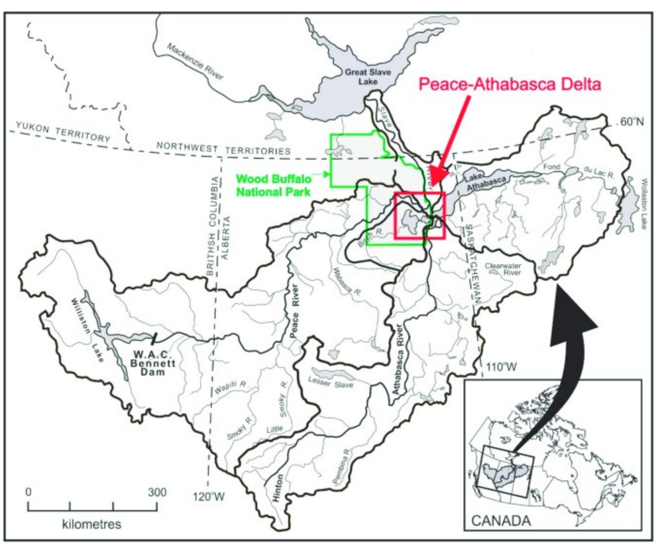


Fig 1. Study area map (Peters, 2023)

2.2. Data and Data Sources

Well, the data that has been used in this research has been shown in Table 1

Type	Source	Year
Sentinel-1 SAR SLC Imagery	ASF Vertex-Alaska Satellite Facility (https://search.asf.alaska.edu)	2020 (April 23, May 5, May 17)
Digital Elevation Model (DEM)	USGS Open Topography (https://opentopography.org)	SRTM 30m, 2024

Table 1. The source and type of data used in the study

2.2.1. Spatial and Spectral Details of Data

- **Bands Used:** Sentinel-1 SAR SLC data with VV polarization (C-band), acquired on April 23, May 5, and May 17, 2020
- **Spatial Resolution:** 10 meters (SAR imagery, azimuth and range), 30 meters (DEM)

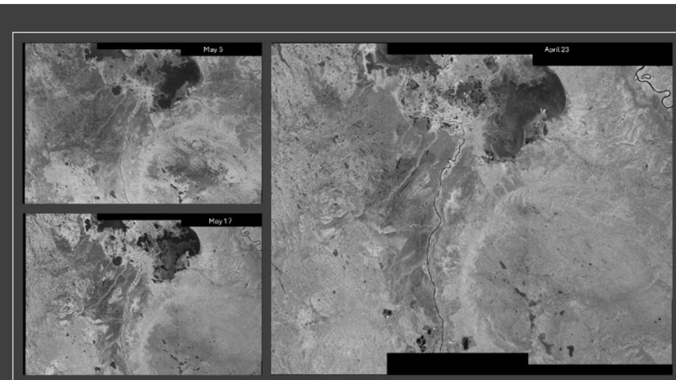


Fig 2. Sentinel 1-SLC for pre and post flood event

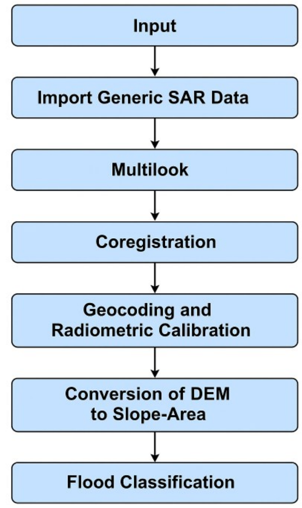
Fig 2 shows three Sentinel-1 Single Look Complex (SLC) images were used to monitor and assess flood dynamics. The pre-event images, acquired on April 23 and May 5, 2020, capture the conditions before the major flood event that occurred on May 6, 2020. The post-event image, dated May 17, 2020, reflects the aftermath and extent of flooding. These datasets, with VV polarization and ~10 m resolution, were processed using the SARscape workflow to perform flood mapping of PAD

3. Methods

This chapter explains the methods used to analyze the flood extent using Sentinel-1 SAR imagery. To understand the impact of the flood, we used SAR data captured before and after the event. By comparing these multi-temporal images, we were able to detect changes and map the areas affected by flooding. The process involved several key steps, including preprocessing of the SAR data, which is described in detail in the workflow below.

3.1. General workflow of the study

The flood mapping process followed a step-by-step workflow using Sentinel-1 SAR data. First, the SAR images were imported and preprocessed by applying multilooking to reduce noise. Next, coregistration was done to align the pre- and post-flood images. The data was then calibrated and geocoded using a DEM to ensure accurate location and reflectivity values. From the DEM, slope and contributing area were derived to better understand terrain influence on flooding. Finally, flooded areas were classified by analyzing changes in backscatter and topographic features. The methodology follows the flood mapping workflow recommended by the United Nations Platform for Space-based Information for Disaster Management and Emergency Response



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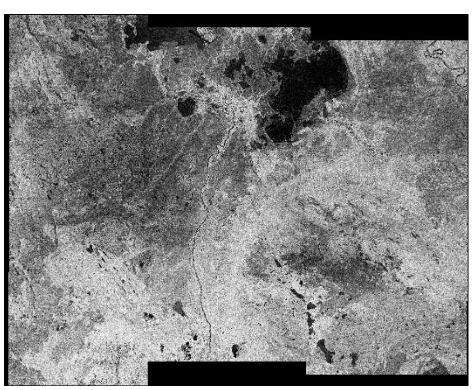
4. Results and Discussion

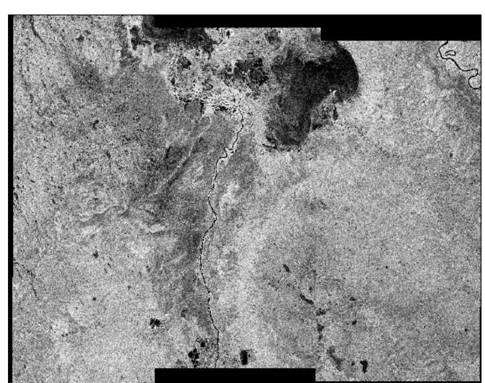
This chapter will show the overall findings of the workflow.

4.1. Multilooking

Multilooking was performed with factors of 4 in range and 1 in azimuth to reduce speckle and improve image interpretability. This resulted in a power image (_pwr) with enhanced radiometric quality and approximately square pixels, suitable for geocoding and further analysis.



April 23



May 5

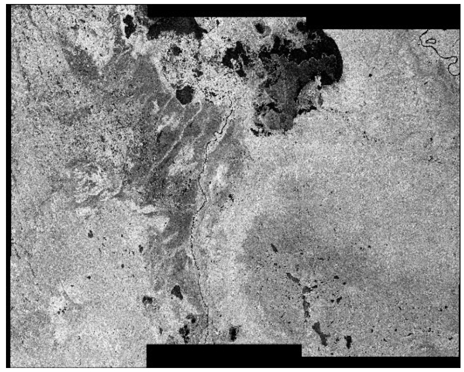


Fig 4. Multilooked images. The first two images are pre-event while the third one is post-event.

4.2. Coregistration

Coregistration was carried out to align the multi-temporal SAR images and ensure a precise pixel-to-pixel match across the dataset. This step is crucial for detecting changes between pre- and post-event imagery. In this process, multiple SAR images acquired with the same orbit and acquisition mode were superimposed in slant range geometry. Proper alignment guarantees that each pixel in the stack corresponds to the same ground location, which is essential for accurate change detection and flood mapping.

Figure 5 shows the coregistered SAR image, represented as an RGB composite of the pre- and post-flood acquisitions. Each color band (red, green, and blue) corresponds to a different date, allowing for a visual check of alignment accuracy. The presence of sharp features and consistent boundaries across the image confirms that the coregistration was successfully performed, while variations in color highlight changes over time.

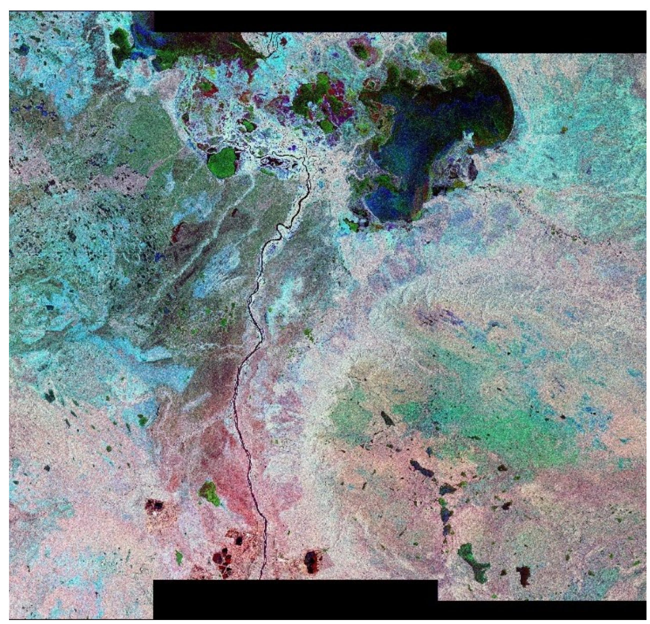


Fig 5. Coregistered image

4.3. Geocoding and Radiometric Calibration

Geocoding and radiometric calibration were applied to correct geometric distortions and ensure consistent backscatter values across images. SAR data, initially in slant range geometry, were calibrated to sigma nought (σ^0) values to enable accurate comparison across dates. Geocoding adjusted for terrain-induced distortions using a DEM, aligning the imagery to ground coordinates. This step was essential for ensuring compatibility between scenes for flood classification, as it required consistent acquisition geometry, polarization

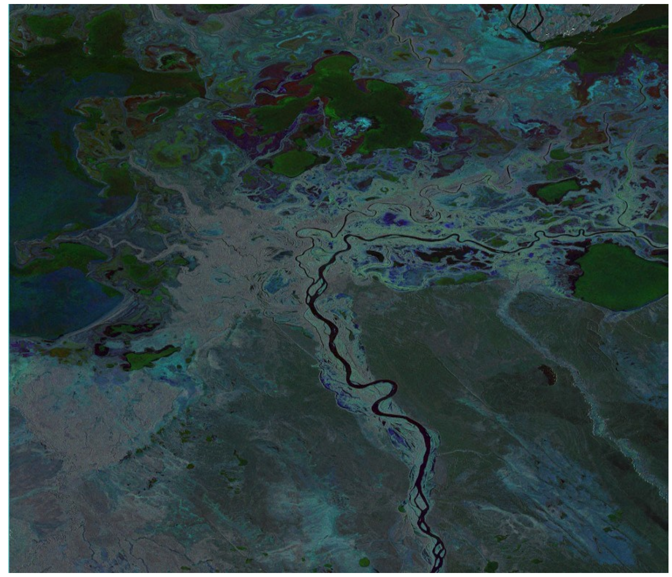


Fig 6. Geocoded and radiometric corrected image

Figure 6 displays the geocoded and radiometrically calibrated SAR image. The data has been corrected for geometric distortions and projected into ground range coordinates, making it suitable for analysis.

4.4. Flood classification and refinement

Flood classification was carried out using the SARscape Flooding Classification tool, which compares pre- and post-event SAR images to detect changes in backscatter caused by floodwater. The tool requires coregistered and geocoded inputs and benefits from auxiliary data like a DEM and slope file to refine the accuracy.
Key parameters included during this procedure are as follows:

- Water Threshold which identify pixel with low back scatter indicating water
- DEM and Slope Threshold which remove the steep slopes like flooded areas\
- Ratio Threshold compares the pre and post event back scatter to indicate flood
- High Scattering Point filter reduces false positives caused by any bright objects

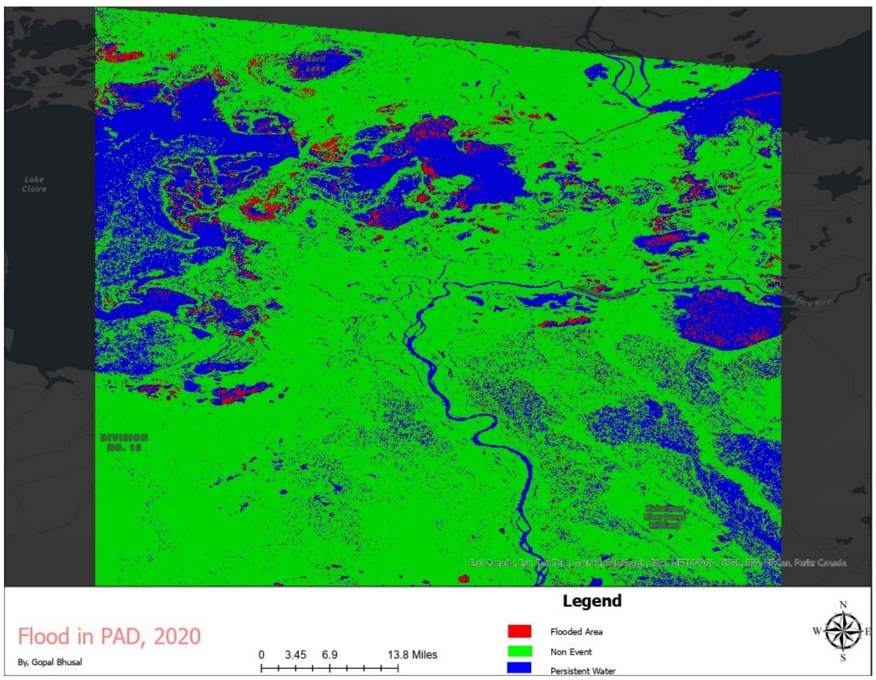


Fig 7. Classified flood mapped image

Figure 7 represents the final classified image generated from the SAR-based flood analysis. In this map:

- Red areas represent flooded zones detected post-event,
- Blue indicates persistent water bodies, and
- Green or non-event areas likely correspond to vegetation, forest, or dry land unaffected by the flood.

This classification clearly highlights the extent and spatial distribution of the flood-affected areas, providing valuable insight into the landscape changes caused by the event.

Discussion

The outcomes of flood classification clearly demonstrate the spread and magnitude of flooding in the Peace-Athabasca Delta following the May 6, 2020 event. Through the assessment of Sentinel-1 SAR imagery acquired before and after the event, the areas that were newly inundated were effectively mapped. The classification map indicates that floodwaters penetrated deeply into vegetated and low-lying regions, especially in the center and western regions of the delta.

SAR data utilization was effective in monitoring surface water alteration regardless of cloud cover or illumination, which typically impacts optical data. C-band VV polarization was sensitive to surface roughness and change in moisture, thus allowing flooded and non-flooded areas to be separated.

Multilooking and coregistration stabilized image comparison, and geocoding and radiometric calibration preserved spatial and spectral integrity. The inclusion of slope and elevation information from the DEM enhanced classification, particularly distinguishing between higher ground and floodplains.

May be some effects in the study area of strong reflectors may have caused some false classification as well. Except for these limitations, the general approach worked well for operational flood mapping in wetland ecosystems like the Peace-Athabasca Delta.

Conclusion

This research illustrates the capability of Sentinel-1 SAR data for mapping and monitoring flood events in dynamic wetland ecosystems. The technique was able to detect and classify the newly flooded surfaces after the May 6, 2020 flood event.

Using a standard processing chain consisting of multilooking, coregistration, calibration, and flood classification analysis, the study generated clear visual and quantitative information about the effect of the flood. Incorporating topographic information increased precision as well.

These findings highlight the potential of satellite-based SAR monitoring as a rapid, reliable, and scalable approach to flood analysis, particularly in remote and environmentally sensitive areas. A potential future avenue would include the integration of optical data or time-series SAR analysis to further improve the detection of flood development over time.

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