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Devastating natural hazard observation with the combination of optical and microwave remote sensing datasets, Valencia 2025 flood

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Abstract

Floods represent some of the most catastrophic natural hazards, impacting infrastructure, ecosystems, and human lives significantly. The flood event in Valencia in 2025 serves as a critical case for investigating flood dynamics and developing disaster preparedness strategies. In response, remote sensing datasets, including Sentinel-1 SAR and PlanetScope MSI, provide invaluable insights by capturing changes in land cover and fluctuations in water extent both before and after flood occurrences. This study employs a multi-sensor approach to analyze the 2025 Valencia flood, integrating optical and microwave datasets to produce comprehensive and precise observations of the flood's impact, spatial patterns, and potential causal factors. Furthermore, assessments based on the Normalized Difference Water Index (NDWI) further illustrate the limitations associated with optical methods in flood mapping, thereby reinforcing the indispensable role of SAR in crisis management.

The findings highlight the critical importance of flexible urban planning, including creating flood protection zones to prevent loss of life and reduce structural damage in cities vulnerable to flooding. A comparison with previous flood incidents indicates rising extreme weather, reinforcing the need for proactive government measures. This study confirms the essential role of remote sensing in contemporary disaster management, providing essential, large-scale, real-time data for informed policymaking, effective emergency response, and building long-term resilience. By incorporating advanced satellite technologies, this research establishes a new standard for flood evaluation and early warning systems, with far-reaching effects on climate adaptation and strategies for risk reduction.

1. Introduction

The integration of optical and microwave remote sensing for flood monitoring has been satisfactorily confirmed. Sentinel-1, with its synthetic aperture radar (SAR) capabilities, enables data acquisition irrespective of weather conditions, effectively detecting water bodies and flooded areas through backscatter intensity variations (Gebremichael et al., 2020). PlanetScope MSI optical data provide high-resolution, multispectral imagery that has been useful for finding signs of plant stress, changes in land cover, and the extent of floods when the weather is clear (Chanda and Hossain, 2024). Recent studies have emphasized combining optical and SAR data for enhanced flood mapping accuracy and flood stage monitoring, with examples such as the Kerala (India) flood analysis demonstrating improved temporal and spatial mapping (Vishnu et al., 2020; Pramanick et al., 2022). The integration of these datasets allows for a fuller temporal and spectral perspective, capturing both immediate impacts and longer-term post-disaster changes.

Beyond traditional flood detection methods, advanced image processing techniques such as threshold-based classification, object-based image analysis (OBIA), and machine learning algorithms are increasingly used to improve flood extent mapping (Ouled Sghaier et al., 2018). SAR backscatter changes before and after flood events serve as reliable indicators of inundation, particularly in urban and vegetated regions where water penetration differs significantly from open water surfaces. Optical sensors complement these observations by providing spectral indices such as the Normalized Difference Water Index (NDWI), enhancing the ability to distinguish floodwaters from non-water features (McFeeters, 1996; Makineci and Arıkan, 2024). Combining SAR and optical datasets enhances flood detection reliability and facilitates detailed assessments of affected regions.

This study leverages the strengths of Sentinel-1 SAR data to identify flood-inundated areas and track water movement patterns, while PlanetScope MSI contribute additional spectral and spatial details on post-flood landscape transformations (Makineci, 2022). By integrating these data sources, we aim to construct a detailed flood chronology, assess damage extent, and evaluate potential drivers such as topographic factors and precipitation anomalies. This multi-sensor approach not only enhances flood monitoring accuracy but also contributes to early warning systems and risk mitigation strategies for future extreme weather events.

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2. Methods

This research operates Sentinel-1 and PlanetScope MSI datasets to analyze Valencia's pre- and post-flood conditions, concentrating on areas impacted by flooding and their potential causes. The Sentinel-1 SAR data acts as a strong basis for mapping water coverage before and after the event, leveraging its ability to operate independently of weather conditions. The process for detecting floods using SAR data starts with preprocessing tasks like radiometric calibration, speckle filtering, and terrain correction. This is followed by thresholding and change detection analyses to identify flooded regions.

The study uses a threshold-based classification approach that distinguishes water from non-water surfaces using SAR backscatter intensity to enhance flood detection accuracy. Typically, water surfaces exhibit low backscatter values due to their smooth texture, whereas urban and vegetated areas present higher backscatter values. The change detection process compares pre- and post-flood SAR images, identifying newly inundated regions by analyzing variations in backscatter intensity.

Additionally, Sentinel-2 and PlanetScope MSI datasets are used to assess land cover changes and the influence of urban infrastructure on flood extent. The NDWI is applied to optical data to enhance water body delineation and monitor flood dynamics. The NDWI equation is given by:

$$NDWI = (Green - NIR) / (Green + NIR) \quad (1)$$

where Green represents the green spectral band, and NIR corresponds to the near-infrared band. High NDWI values indicate water presence, while lower values suggest non-water surfaces. This index is particularly useful for distinguishing between flooded and non-flooded areas, especially when combined with SAR-derived flood maps.

By integrating SAR-based flood detection with NDWI-derived water masks, this study enables cross-verification of flooded zones, facilitating more accurate flood mapping and assessment of landscape recovery. Within this context, Figure 1 shows the study area.

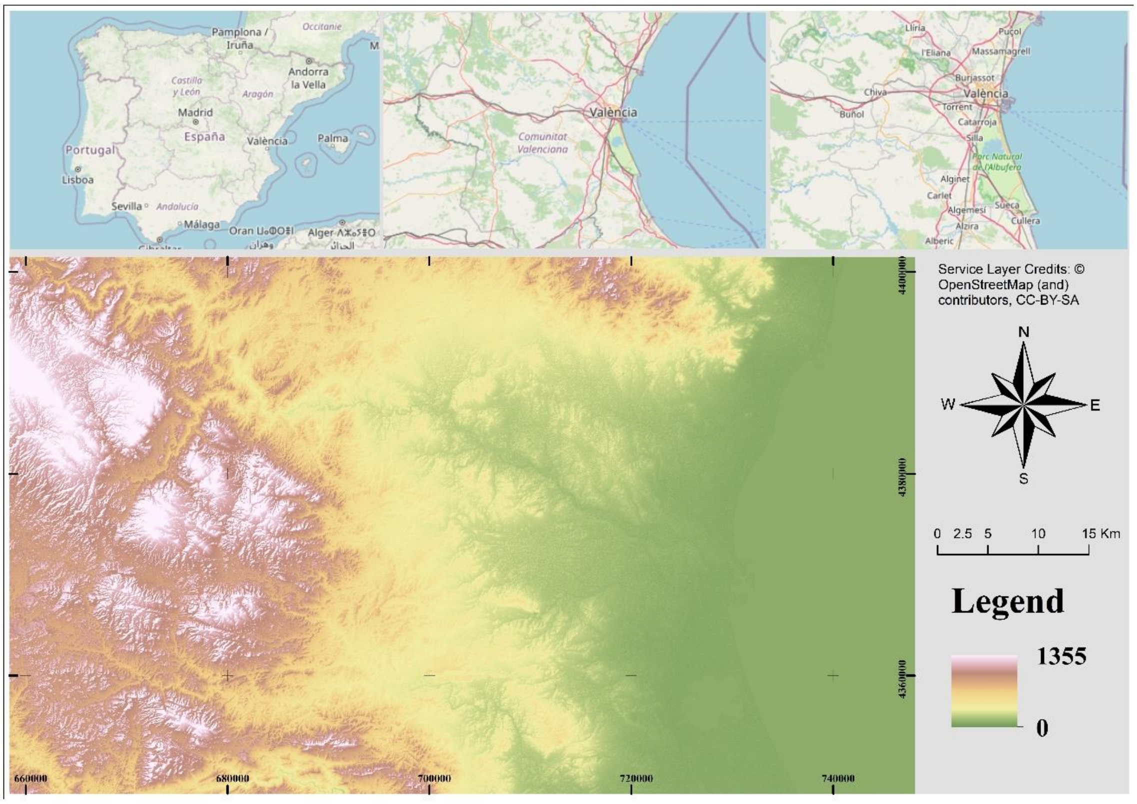

Figure 1. Valencia, Study Area.

3. Results

Research indicates notable changes in land cover in Valencia's low-lying and urban regions as a result of the flood. Analysis from Sentinel-1 SAR shows significant water accumulation in areas prone to flooding, while imagery from PlanetScope reveals vegetation loss and structural damage after the flood. Key factors contributing to the flood in Valencia include high precipitation levels and increased river flow upstream, which are driven by climate anomalies coupled with inadequate urban drainage systems.

A comparison of past flood events shows a trend of heightened flood frequency, likely associated with climate change impacts on severe weather patterns. Figure 2 illustrates the findings derived from SAR datasets.

Additionally, Figure 3 displays wetland regions identified from eight distinct dates of PlanetScope data superimposed on a Digital Elevation Model (DEM). These changes over time facilitate the evaluation of the flood's effects on hydrological systems and the monitoring of water redistribution (Hall et al., 2014). Concurrently, Figure 4 showcases NDWI results obtained from RGB imagery, highlighting how cloud cover affects the detection of water bodies. It is noted that cloudy conditions in various PlanetScope images significantly impair the accuracy of NDWI, resulting in discrepancies in estimating wetland areas. In contrast, SAR-based flood mapping is unaffected by atmospheric disturbances, demonstrating the benefits of utilizing SAR data for flood monitoring in challenging weather conditions.

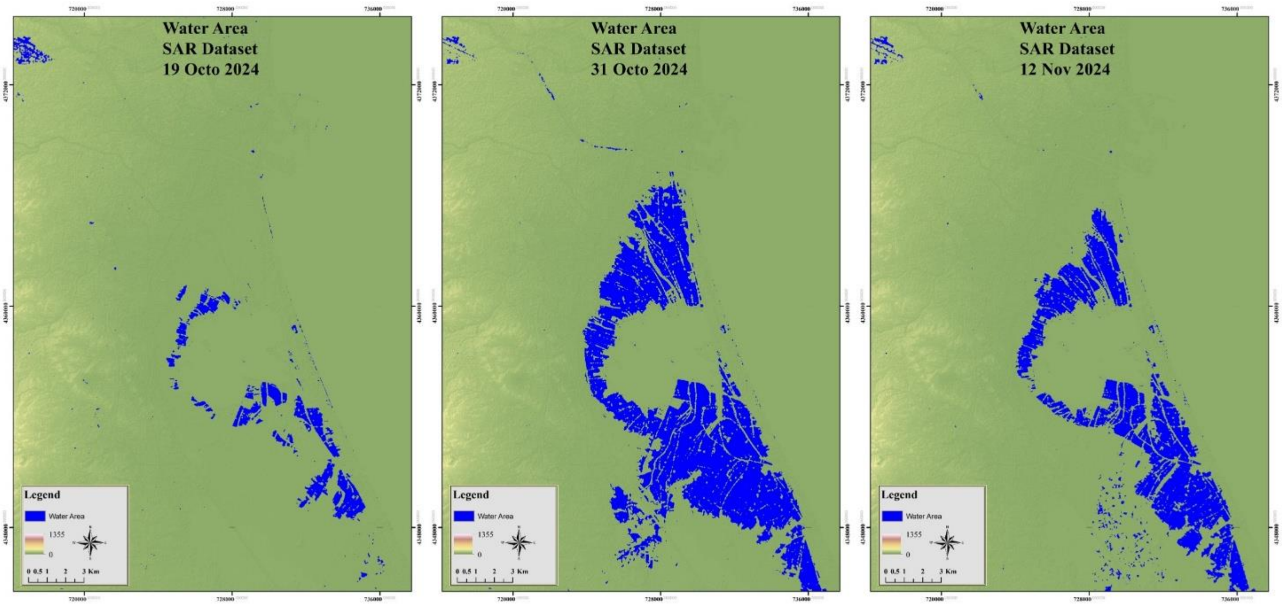

Figure 2. SAR Results

This study highlights the importance of combining SAR and optical datasets to enhance flood monitoring capabilities and disaster preparedness. The findings stress the urgent need for adaptive urban planning and infrastructure resilience in flood-prone areas, particularly as climate-related weather patterns become increasingly erratic. The Valencia 2025 flood illustrates the advantages of using integrated remote sensing approaches to assess and mitigate future natural disasters, establishing a benchmark for similar studies worldwide (Gu et al., 2024; Zhang et al., 2025).

Moreover, this study underscores the significance of establishing designated flood protection zones in urban areas susceptible to flooding in order to avert loss of life and minimize infrastructure damage. As key decision-makers, governments and municipalities must adopt proactive measures before disasters by implementing effective flood mitigation strategies, including enhanced drainage systems, early warning mechanisms, and sustainable land-use planning (Price and Vojinovic, 2008; Dieperink et al., 2016).

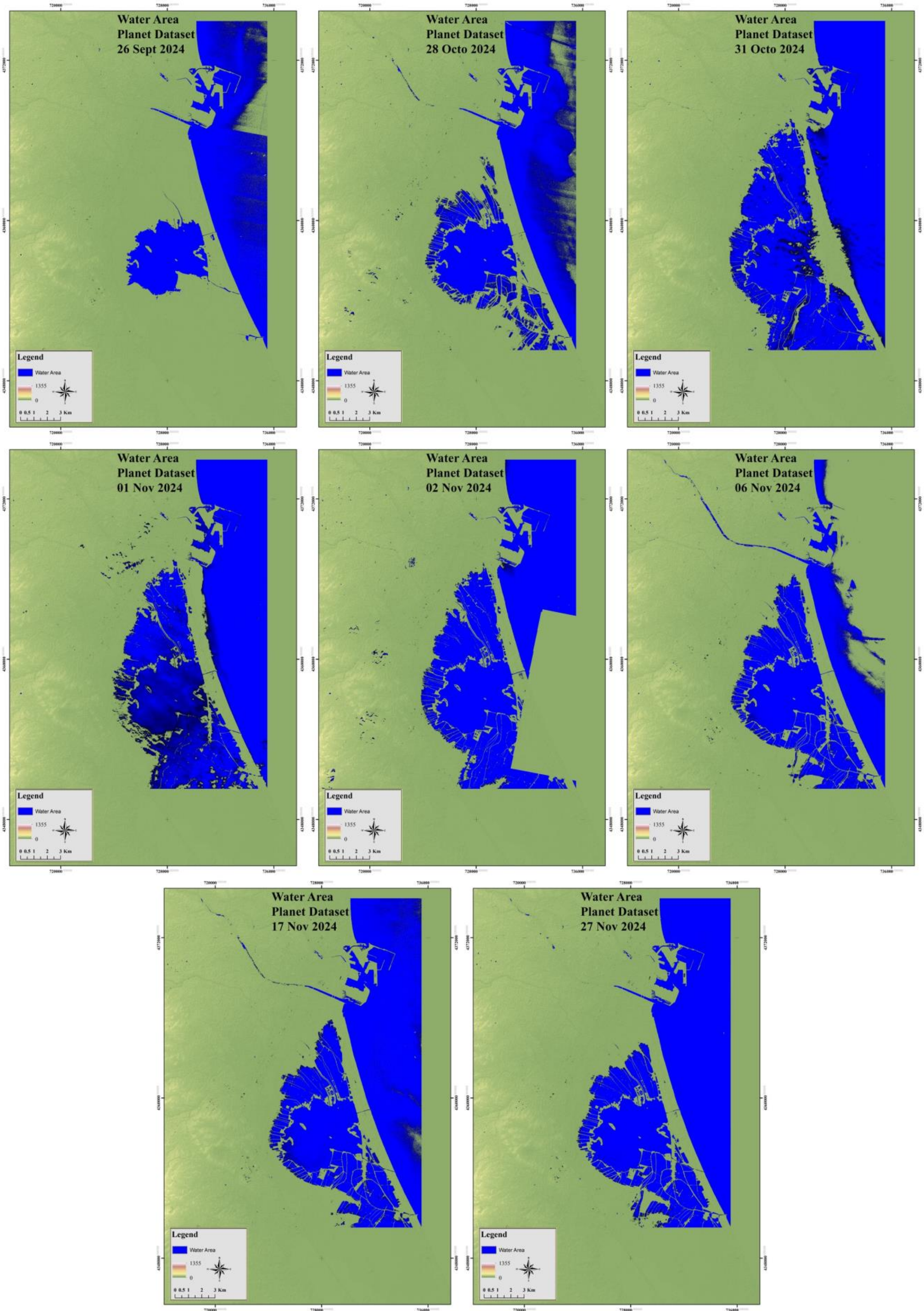

Figure 3. PlanetScope MSI Results

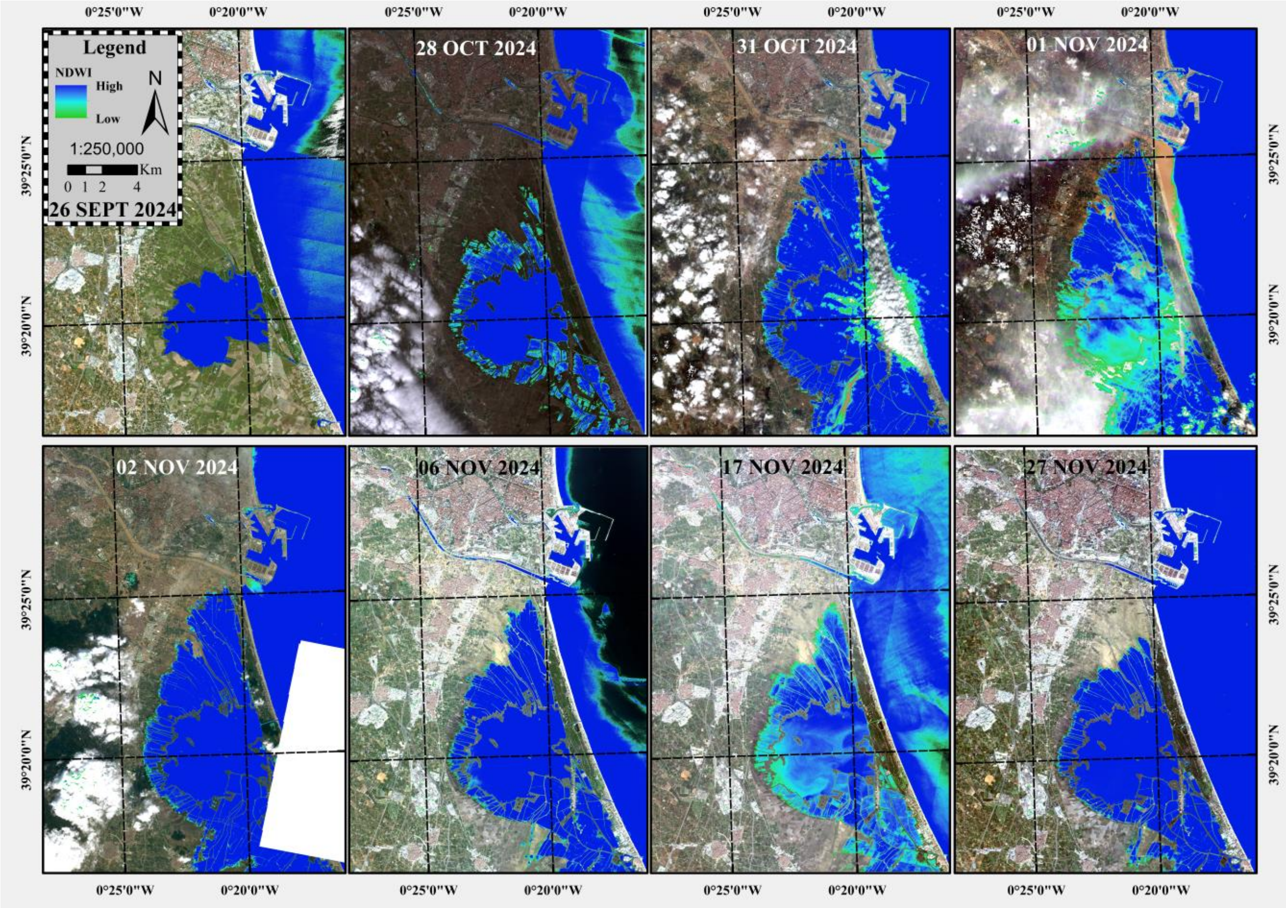

Figure 4. NDWI Results with RGB PlanetScope datasets

4. Conclusions

Remote sensing systems are critical in disaster management, providing real-time, large-scale observations that greatly enhance situational awareness. SAR's capability to penetrate cloud cover and offer continuous monitoring, coupled with the high-resolution features of optical datasets, makes remote sensing an essential tool in flood risk assessment, response, and recovery. This study confirms that incorporating remote sensing technologies into disaster management strategies is beneficial and vital for minimizing the effects of natural hazards and strengthening resilience against future extreme weather events.

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