# Precision in Peril: SAR Strategies for Disaster and Emergency Operations

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data courtesy: APAC Geospatial | data courtesy: sarmap


## ABSTRACT


The increasing frequency and intensity of climate-induced natural disasters demands the adoption of advanced geospatial technologies to support emergency response and operational planning. Synthetic Aperture Radar (SAR) satellite-based remote sensing, and here especially the Copernicus Sentinel-1 mission of the European Space Agency (ESA), is standing out as an indispensable asset due to its unique technical advantages and broad application potential.

SAR acquires data under almost any conditions – unlike passive optical satellite sensors that require daylight and clear skies to function. Active all-weather satellite imaging makes SAR ideal for capturing disaster information at nighttime, during disasters that cause large amounts of smoke like fires or volcanoes, in cloudy equatorial regions and in polar darkness.

Interpreting SAR data, however, requires advanced analytic tools and considerable expertise, underscoring the need for continued investment in training and technology development. On this poster, we explore the pivotal role of SAR in crisis and emergency operations, drawing on real-world examples of NV5, partners and customers, to demonstrate its transformative impact.


## NV5 PROJECTS

NV5 leverages SAR technologies alongside high-resolution airborne optical and LiDAR data acquisitions combined with advanced Desktop and cloud-based geospatial analytics based on its own ENVI Ecosystem software suite. Examples:

- In March 2025, NV5 has been awarded $9 million in contracts to support wildfire mitigation and resiliency efforts for major utility clients across the United States. In the U.S., NV5 is one of the largest geospatial service providers for utilities vegetation encroachment mapping.
- NV5 is a prime contractor to the 3D Elevation Program via the USGS Geospatial Products and Services Contracts. As part of this contract, NV5 acquired high-resolution airborne lidar data of the devastating Southern California wildfires in January 2025, and offered free licenses of ENVI and SARscape software to organization involved in disaster response efforts.

## SAR vs. OPTICAL / BENEFITS

**Comparison between SAR and Optical Remote Sensing**

- Optical Sensors: Optical remote sensing systems (e.g. Sentinel-2) measure primarily sunlight which is reflected from the Earth's surface to create an image. As a passive system, clear skies and daylight is required, making them prone to data gaps caused by clouds, smoke, fog, or darkness.
- Synthetic Aperture Radar (SAR): SAR (e.g. Sentinel-1) is an active system that emits its own microwave energy and measures the amount of backscattered energy at the sensor to produce an image. This allows SAR to operate day and night, regardless of weather conditions, providing consistent data acquisition even through clouds and smoke.

**Benefits of SAR for Disaster Management**

- Continuous Monitoring: SAR provides critical situational awareness in all weather and lighting conditions, making it a crucial source of data in emergency situations.
- Enhanced Situational Awareness: SAR provides insights that optical sensors cannot provide, such as coherence change detection, or mapping subtle ground movements.

## CASE STUDIES

**Wildfire Mapping – Southern California (January 2025)**
Data: Worldview-3 SWIR, Sentinel-1 SAR
Tools: ENVI 6.1, SARscape 6.1, ENVI Connect 2.1
Processing: Change detection, multitemporal SAR analysis
Use: Rapid wildfire damage assessment despite persistent wind, smoke and night conditions, to facilitate collaboration and support of immediate disaster response

**Cyclone Alfred Flooding – Australia (March 2025)**
Data: Sentinel-1 SAR, Sentinel-2 optical
Tools: ENVI 6.1, SARscape 6.1, ENVI Connect 2.1
Processing: Multi-temporal flood classification
Use: Activate disaster response plan and acquire data upfront to be prepared for disaster response, then near real-time flood mapping during the storm despite wind, rain and clouds, to aid disaster management

**Valencia Flooding – Spain (October 2024)**
Data: Sentinel-1 SAR, Sentinel-2 optical
Tools: ENVI 6.1, SARscape 6.1, ENVI Connect 2.1
Processing: Multi-temporal flood classification
Use: Immediate flood extent mapping despite rain and clouds for emergency relief

**Cumbre Vieja Volcanic Eruption – La Palma (Sept. 2021)**
Data: Sentinel-1 SAR (Interferom. pair, ascending/descending)
Tools: SARscape 6.1
Processing: Differential Interferometry (DInSAR) Surface Displacement Mapping
Use: Volcanic activity monitoring and evacuation planning

## CONCLUSION

Continuous data acquisition is critical in emergency situations, where every moment counts to ensure uninterrupted situational awareness. SAR's active, all-weather imaging bridges the gap between data and action. Freely available Sentinel-1 data, along with commercial SAR imagery for higher resolution, provides critical, near real time resources for disaster monitoring and response.

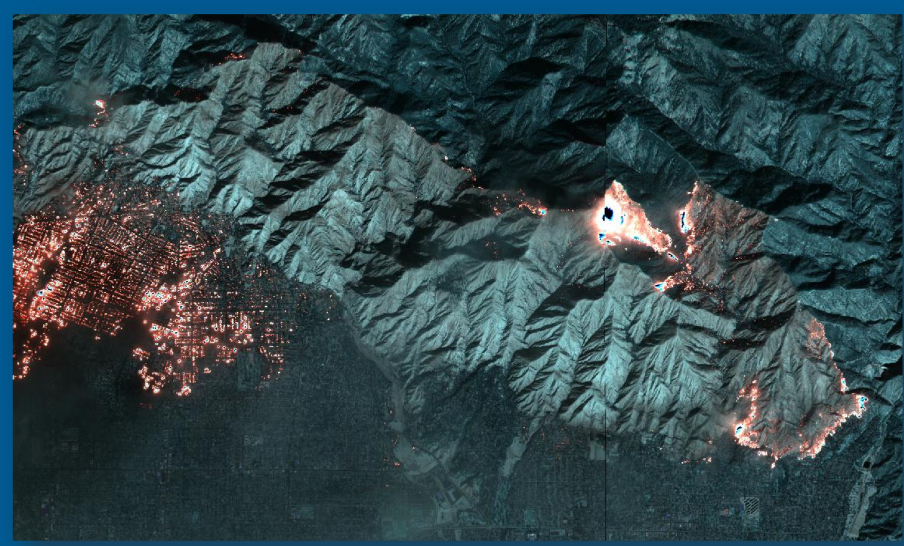


Figure 1: Southern California Wildfire / Eaton (January 2025): WorldView-3 SWIR
*WorldView-3 SWIR image of the Eaton wildfire, showing active burning fire zones through dense smoke. SWIR not only penetrates smoke and haze, but also reveals high-temperature areas such as active fires and burn scars, enabling fire detection when aerial surveys are limited by smoke, darkness, or wind.*

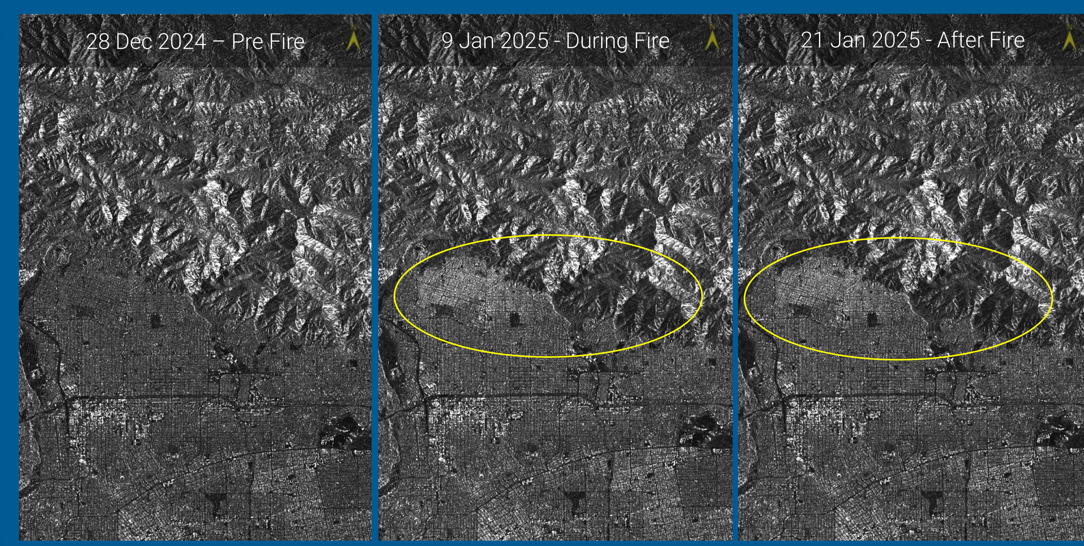
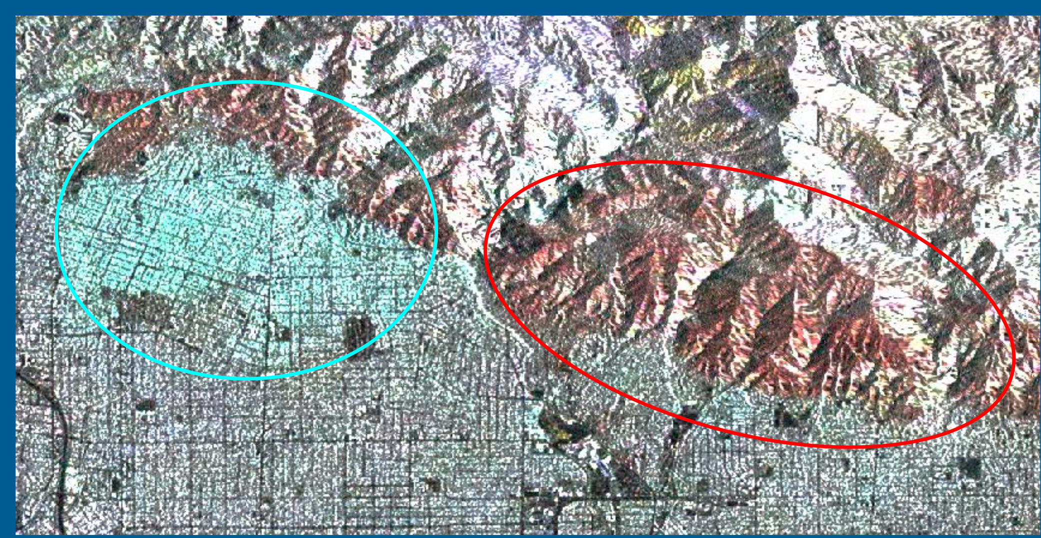



Figure 2: Southern California Wildfires / Eaton (January 2025): SAR Sentinel-1 Time Series (VH)
*Difference in backscatter mainly because of change in vegetation cover: Following the fire, urban areas appear much brighter and clearly delineate from surroundings, because of now ruined and uncovered building structures as result of disappeared vegetation. Controversially, in the mountain areas, vegetation burnt down as well, but is now exposing bare ground.*



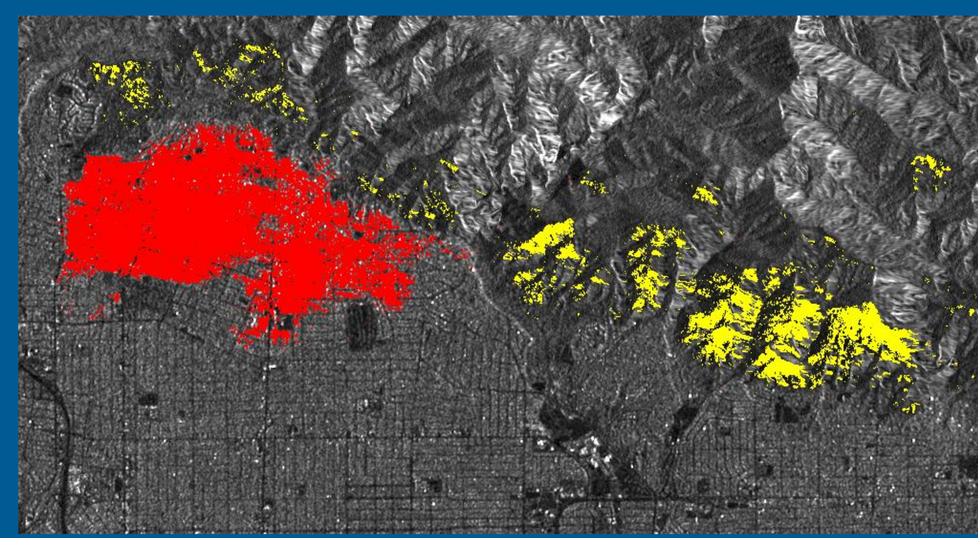


Figure 3 & 4: Southern California Wildfires / Eaton (January 2025): SAR Sentinel-1 (VH) Change Detection / Wildfire Mapping / Classification of Type of Damage
*Mapping burnt areas as result of change in backscatter is easily possible with SAR amplitude change detection images. Figure 3 shows a triple date Red (28 Dec 2024) / Green (9 Jan 2025) / Blue (21 Jan 2025) SAR Sentinel-1 VH Amplitude (descending pass) composite image processed with ENVI SARscape:*
- *Cyan (burnt: 28 Dec – 9 Jan): Increased backscatter on 9 Jan (vs. 28 Dec) in urban area, which remained unchanged on 21 Jan (Green + Blue is increasing over Red)*
- *Red (burnt: 28 Dec – 9 Jan): Decreased backscatter on 9 Jan (vs. 28 Dec) in natural areas, which remained unchanged on 21 Jan (Green + Blue is decreasing over Red)*

*Figure 4 shows a Random Forest classification result from ENVI to allow mapping fire extent and to distinguish residential fire damage (Red) from non-residential damage (Yellow).*

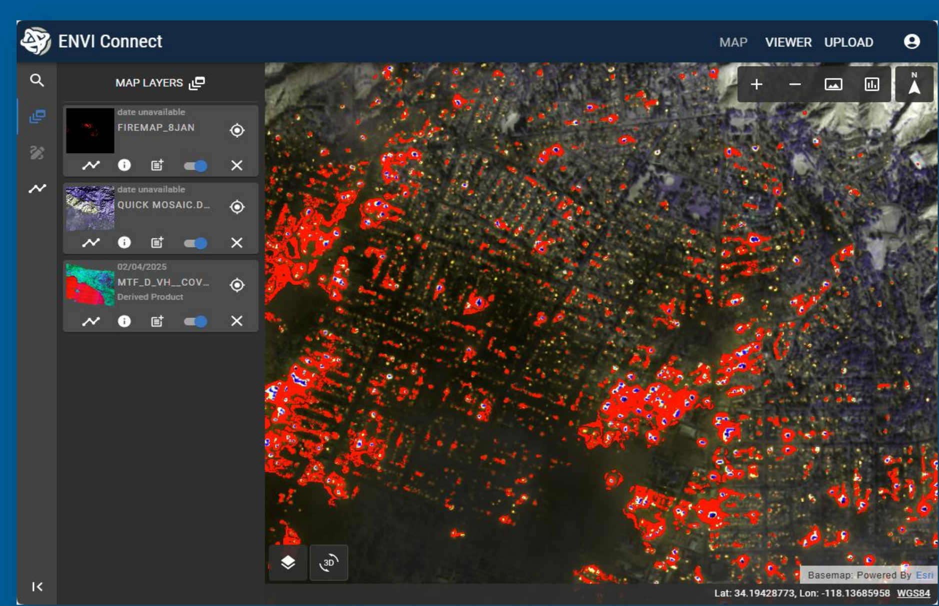



Figure 5: Southern California Wildfire / Eaton (January 2025): ENVI Ecosystem
*Rapid wildfire mapping and collaboration with stakeholders for disaster response and recovery was realized through the ENVI Ecosystem software suite of NV5:*
- ***ENVI Desktop**: Image processing, analysis, and visualization software suite*
- ***ENVI Connect**: Cloud-based geospatial collaboration and mapping platform*

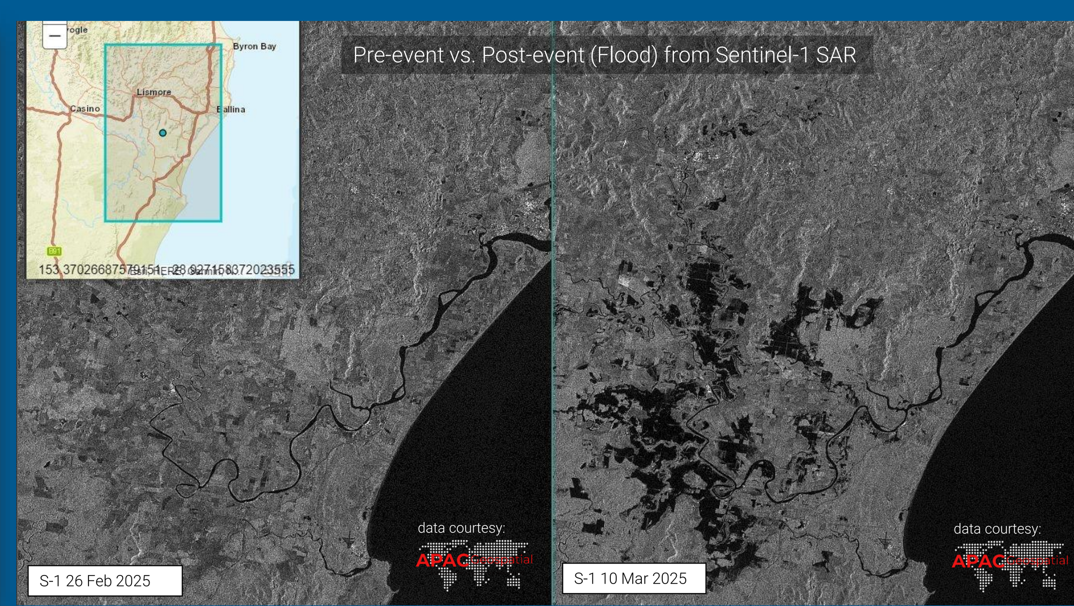



Figure 6: Tropical Cyclone Alfred – Australia (March 2025): SAR Sentinel-1 Flood Mapping (VH)
*Before a storm is coming, organizations can acquire data upfront to be prepared for disaster response. And then, as SAR has the capability to see through clouds and rain, images can be acquired even during an event, so that flooded areas can be mapped, and critical event response decisions be taken in near real-time to assist first responders and stakeholders (data courtesy: APAC Geospatial).*

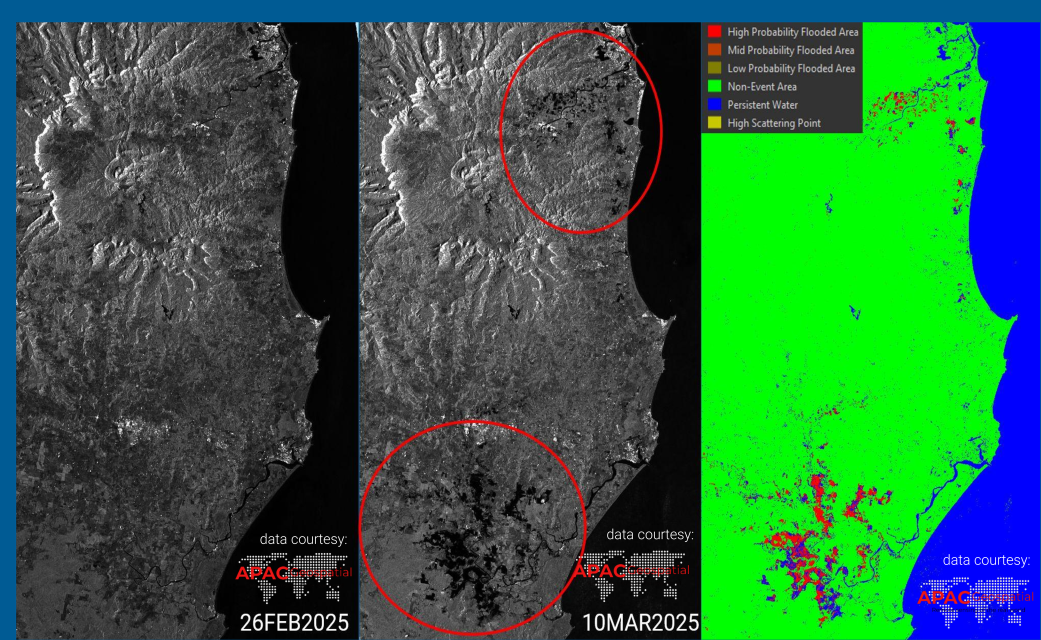



Figure 7: Tropical Cyclone Alfred – Australia (March 2025): SAR Sentinel-1 Flood Mapping
*Flood mapping in New South Wales / Australia using Sentinel-1 SAR (VH) multi-temporal imagery processed with the Flood Mapping tool of ENVI SARscape: Dark areas show flooded area due to intense rainfall caused by Alfred. Left: Pre-flood (26 Feb); middle: Post-flood (10 Mar); right: Map of flooded and permanent water areas (data courtesy: APAC Geospatial).*

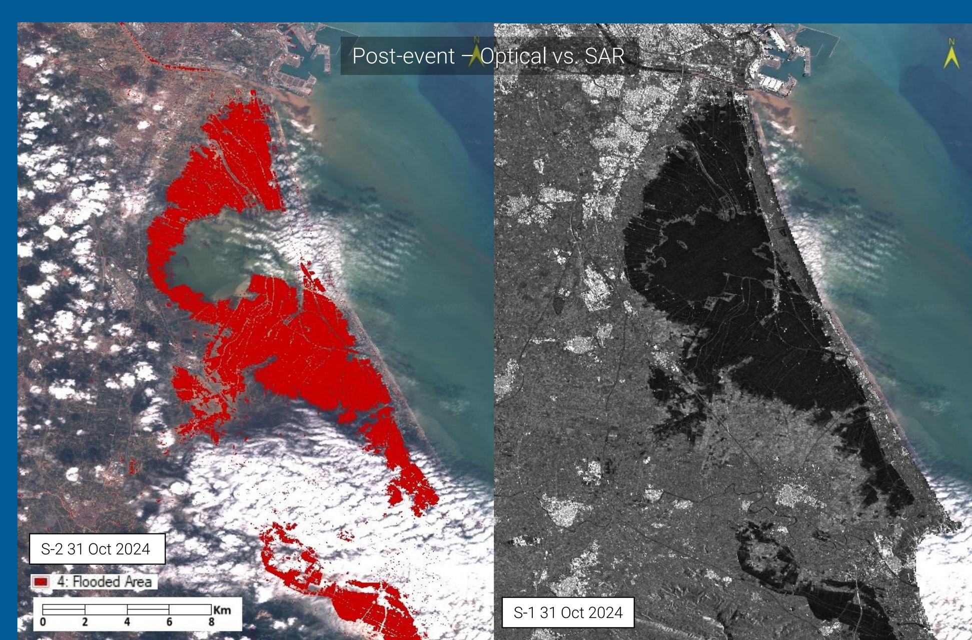
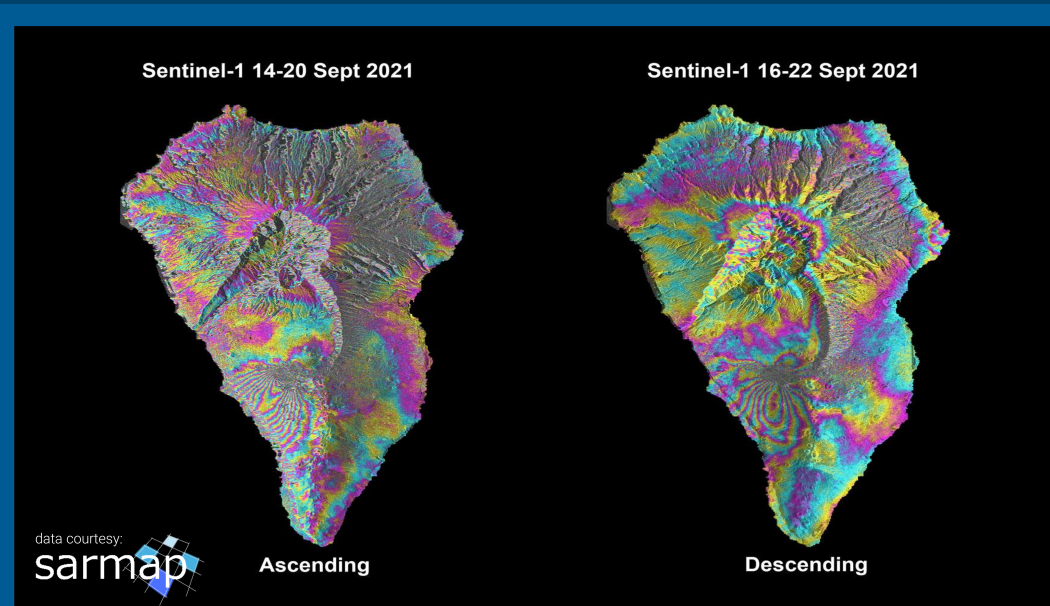



Figure 8: Valencia Flood – Spain (October 2024): SAR Sentinel-1 Flood Mapping (VH)
*Due to extensive cloud coverage during the Valencia Flooding in October 2024, it was difficult to obtain situational awareness through optical imagery. SAR delivers critical near real-time imagery during extreme weather events by penetrating clouds and excels in precisely mapping flooded and permanent water areas with high precision.*



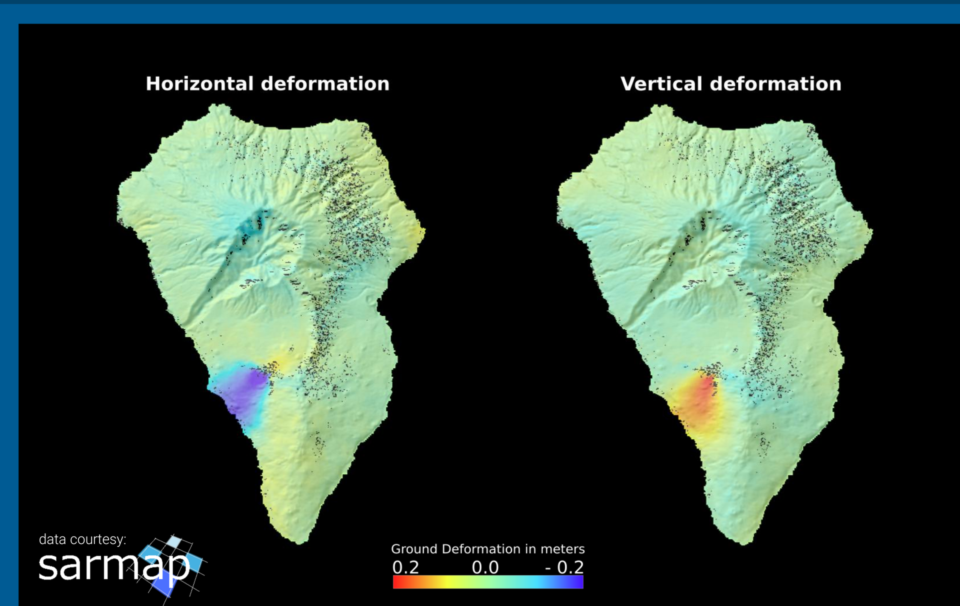




Figure 9 & 10: Cumbre Vieja Volcanic Eruption – La Palma (September 2021): SAR Sentinel-1 Differential Interferometry (DInSAR) Surface Displacement Mapping
*The September 2021 eruption of the Cumbre Vieja volcano on La Palma, Canary Islands, caused earthquakes and significant ground deformations, which have been mapped through Differential interferometry using Sentinel-1 (ascending and descending passes) with ENVI SARscape software. Figure 9 shows derived line of sight ascending (left) and descending (right) interferograms. Derived displacement maps through displacement decomposition (Figure 10) show movement in the west direction for horizontal displacement (left) and uprising for vertical displacement (right) on the southern part of the island in the Las Manchas area (data courtesy: sarmap S.A.).*