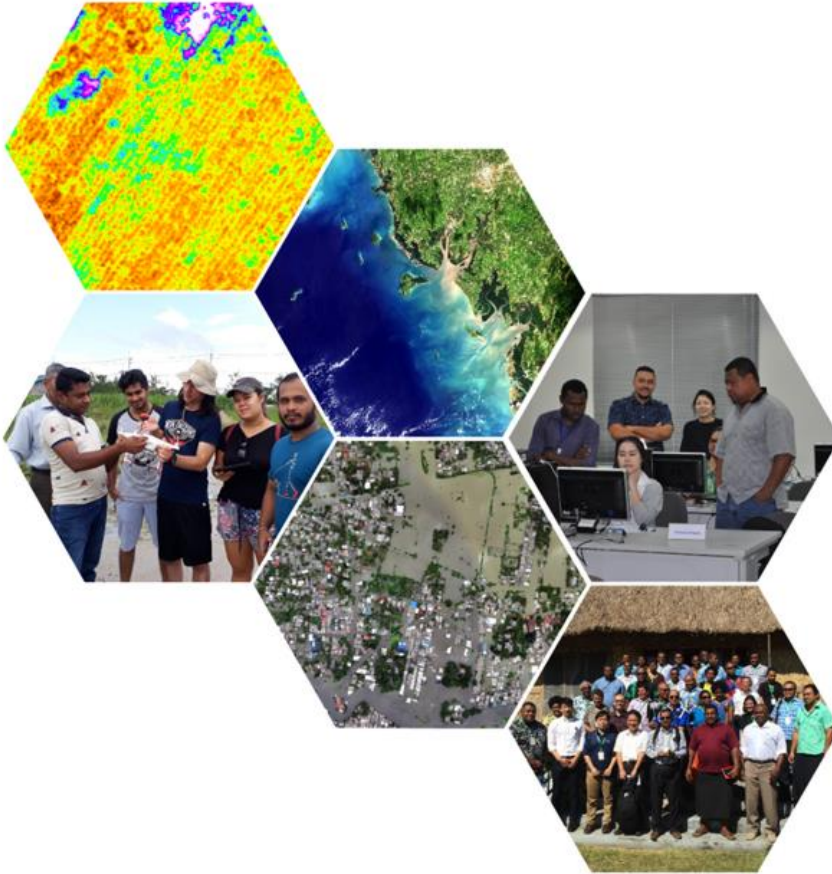


Remote sensing applications for damage assessment

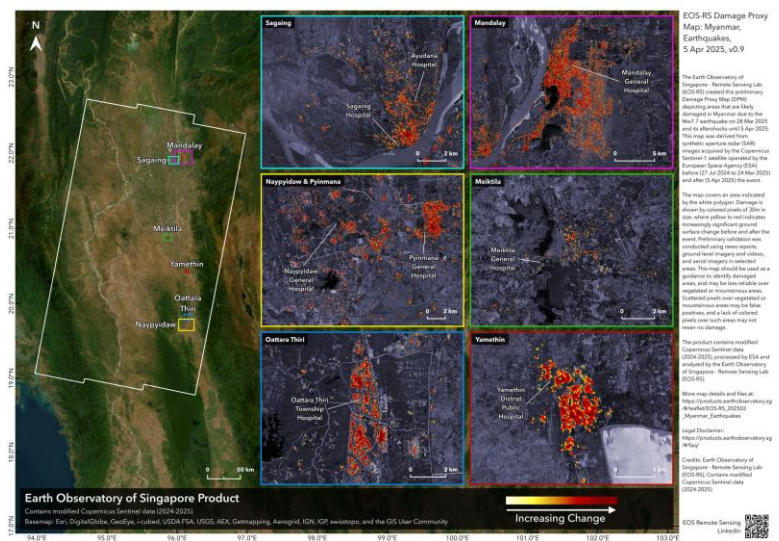


Geoinformatics Center - AIT

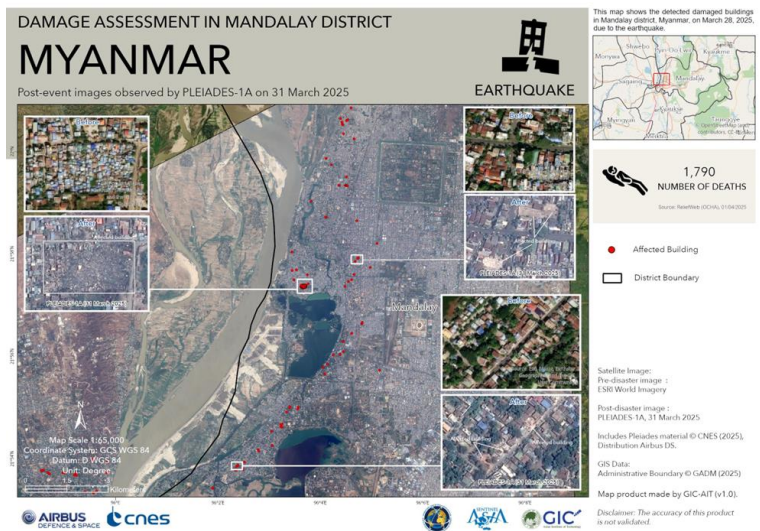
Overview

What is Damage Assessment?

- Damage assessment evaluates the impact of natural or anthropogenic disasters on infrastructure, population, and environment.
- To measure the severity and extent of damage for emergency response, recovery planning, insurance claims, and policy development



Earthquake in Myanmar (SAR)



Earthquake in Myanmar (Optical)

Overview

Types of Damage Assessment

Rapid Assessment

- Conducted within hours to days; provides preliminary estimates.

Detailed Assessment

- In-depth mapping and classification; used for long-term recovery and reconstruction

Comparison of Damage Assessment Types

Aspect	Rapid Assessment	Detailed Assessment
Timeframe	Hours to a few days	Days to weeks
Purpose	Immediate response	Recovery planning
Accuracy	Approximate	Precise
Output	Preliminary maps	Comprehensive analysis

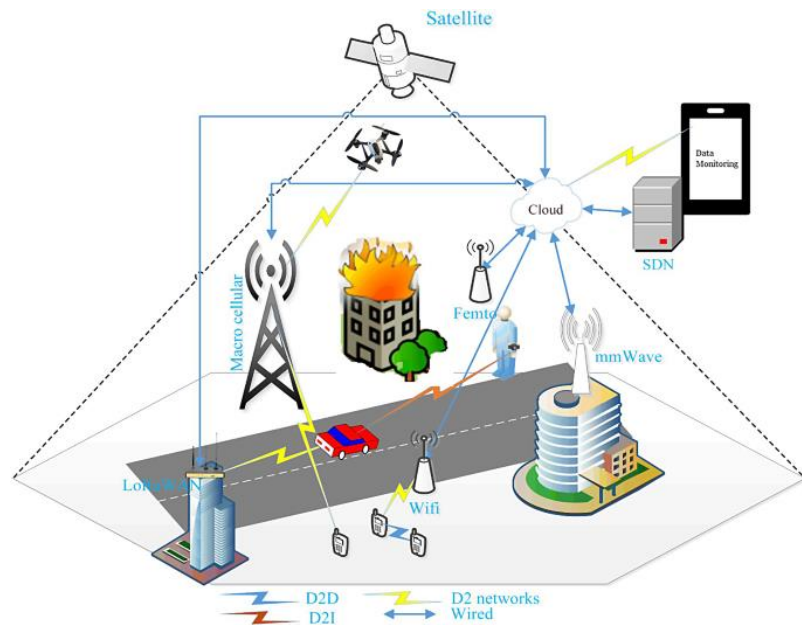
Overview

Why Use Remote Sensing?

- Offers consistent, objective, and scalable methods to monitor disaster impacts over time and space.

Key Benefits

- ✓ Rapid overview of large areas
- ✓ Access to remote or dangerous zones
- ✓ Multitemporal analysis
- ✓ Data available soon after events
- ✓ Historical archives for baseline comparison



Overview

Types of Remote Sensing Data

Optical

- Captures reflected sunlight in visible, NIR, SWIR bands
- Applications: visual damage, vegetation stress, flood extent.



SAR (Synthetic Aperture Radar)

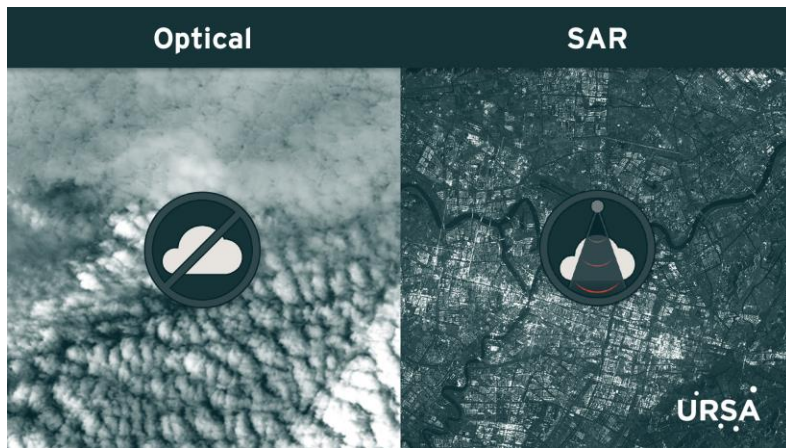
- Active sensor using microwave radar
- Works day/night and through clouds
- Detects surface movement, structure, roughness



Overview

Optical vs SAR - Comparison

Feature	Optical	SAR
Sensor Type	Passive	Active
Weather Dependence	Cloud-sensitive	All-weather
Spatial Resolution	Often high	High to moderate
Spectral Detail	RGB, NIR, SWIR	Intensity, coherence
Applications	Visual change, vegetation	Surface motion, water, structure



Workflow for Damage Mapping

1.Data Collection

- Pre- and post-disaster imagery from satellites or UAVs
- Select appropriate sensors based on event type

2.Preprocessing

- Optical: Radiometric & atmospheric correction, cloud masking
- SAR: Speckle filtering, co-registration, geocoding

3.Change Detection

- Optical: Image differencing, NDVI change, object-based change
- SAR: Coherence change, amplitude ratio

4.Classification

- Manual interpretation or supervised ML algorithms
- Use of ancillary data (DEM, land cover) for context

5.Accuracy Assessment

- Confusion matrix, ground truth validation, Kappa coefficient

SAR Backscattering from Buildings

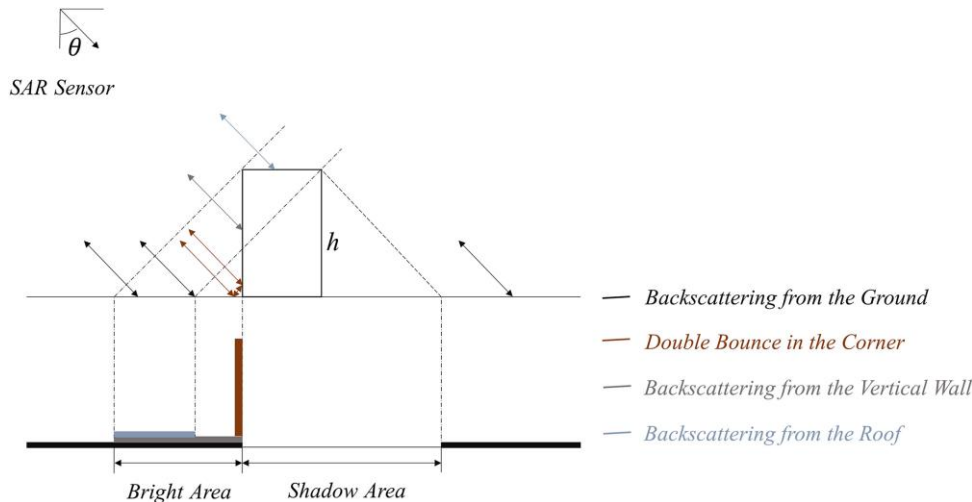
- Synthetic Aperture Radar (SAR) captures backscattered signals from different surfaces.
- Urban features like buildings produce distinct scattering patterns.

Scattering Types:

- Ground scattering (black): low intensity
- Double bounce (brown): strong return from wall-ground corner → bright in SAR
- Wall scattering (gray): moderate intensity
- Roof scattering (blue): weak, angle-dependent

Shadow Area:

- Behind tall objects → no return → dark in SAR



Damage Assessment Techniques Using SAR Data

Coherence (Two-Image Method)

- A basic technique to detect surface changes by measuring similarity between two SAR images taken before and after the earthquake.
- SAR coherence is a measure of phase correlation between two complex SAR images.
- Sensitive to changes in structure, surface roughness, or moisture.
- Value Interpretation

Coherence ~ 1 : No change (e.g., undamaged buildings)

Coherence ~ 0 : Major change (e.g., collapsed structures, debris)

Damage Assessment Techniques Using SAR Data

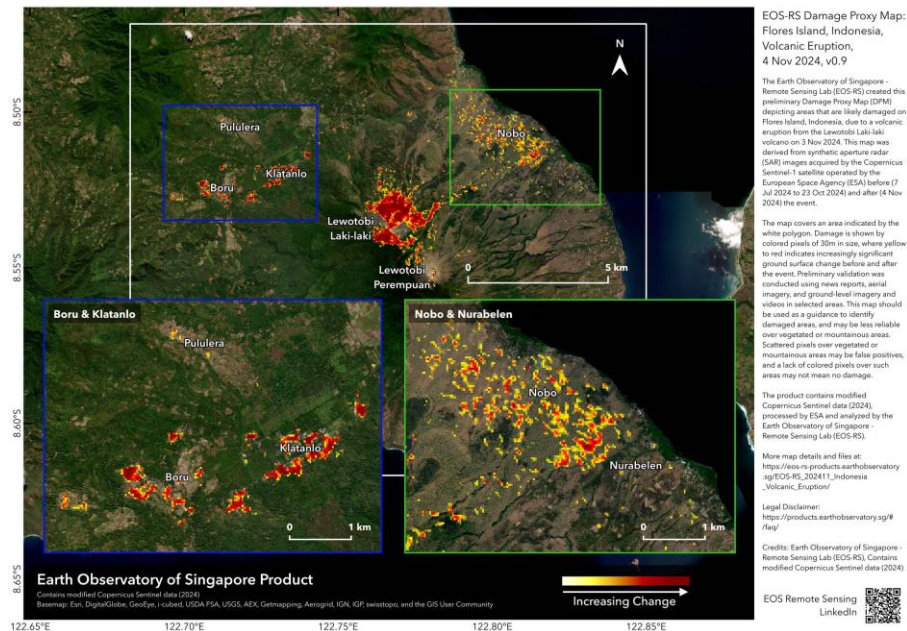
Coherence Change Detection (Three-Image Method)

- Improved method that compares two coherence values to isolate disaster-specific change and reduce seasonal/vegetation-related noise.
- Reference Coherence (normal surface variation)
Compare before disaster images (T1 vs T2)
- Event Coherence (possible damage)
Compare before vs after disaster (T2 vs T3)
- Delta Coherence (more likely damage)
Compare Event Coherence vs Reference Coherence
- Value Interpretation
 - 0 = Stable area
 - > 0.3 = Possible damage
 - > 0.5 = Strong structural destruction

Damage Assessment Techniques Using SAR Data

Damage Proxy Map (DPM)

- A product that maps potential damage areas using coherence loss, optimized by filtering and masking techniques.
- Developed by NASA-JPL.
- Combines coherence change with masks:
 - Built-up area masks (from land cover or Nighttime Lights)
 - Slope masks (to avoid false positives on steep terrain)



Damage Assessment Techniques Using SAR Data

Pixel-wise t-test

- A statistical method comparing backscatter values before and after the event.
- Computes a t-statistic per pixel to test if change is statistically significant

- Value Interpretation

$|t| > 2.0$ and $p < 0.05$: Significant change

Low t-value: no confidence in change



Damage Assessment Techniques Using SAR Data

Deep Learning-based Damage Mapping with InSAR Coherence Time Series

- Detect earthquake damage using time-series satellite radar (SAR).
- Use RNN (Recurrent Neural Network) to learn normal ground behavior.
- Compare predicted and actual SAR coherence after earthquake.
- Anomaly indicates possible damage.

Traditional CCD:

- Subtract pre- and post-event coherence
- Threshold the loss → Damage Proxy Map

RNN-Based Method:

- Train RNN on pre-event coherence
- Forecast expected coherence
- Compare with actual → compute z-score
- Threshold z to detect anomalies (damage)

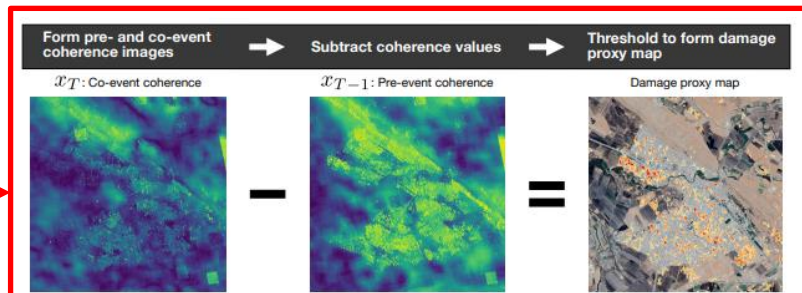


Fig. 1. Schematic of the existing Coherence Change Detection (CCD) method for damage mapping [8], presented for the town of Sarpol-e-Zahab, damaged during the November 2017 Iran-Iraq earthquake. A pre-event coherence image (x_{T-1}) is subtracted from the co-event coherence image (x_T) in order to calculate the coherence loss. The coherence loss is thresholded and plotted to produce a damage proxy map. Optical data from Google, CNES/Airbus, taken July 27th 2020.

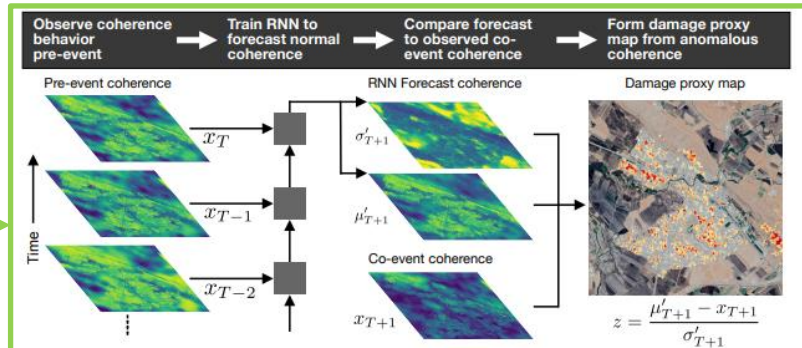


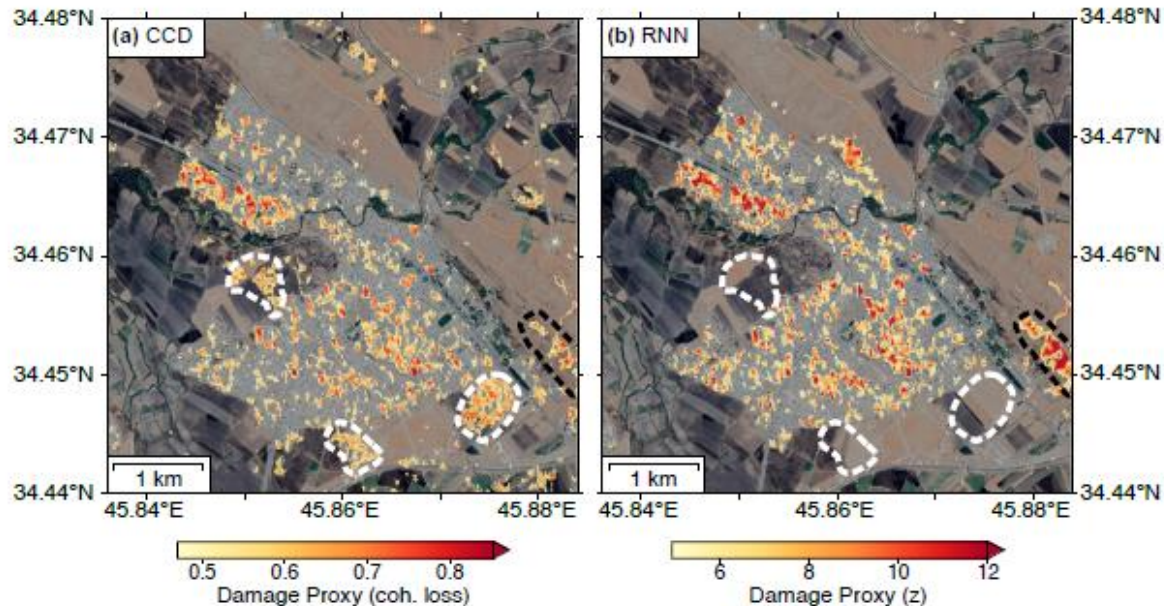
Fig. 2. Schematic of our proposed recurrent neural network (RNN) method presented for the town of Sarpol-e-Zahab, damaged during the November 2017 Iran-Iraq earthquake. The transformed coherence values (x) are used to train a recurrent neural network to make a Gaussian forecast of the co-event coherence with mean μ'_{T+1} and standard deviation σ'_{T+1} . The forecast is compared with the observed co-event coherence, x_{T+1} , to calculate the z-score, z (see Eq. 10). The z-score is thresholded and plotted to produce a damage proxy map. A more detailed illustration of the neural network architecture can be found in Fig. S1. Optical data from Google, CNES/Airbus, taken July 27th 2020.

Damage Assessment Techniques Using SAR Data

Deep Learning-based Damage Mapping with InSAR Coherence Time Series

Benefits

- Better detection than traditional methods.
- Reduces false alarms from farming.
- No need for labeled damage data.



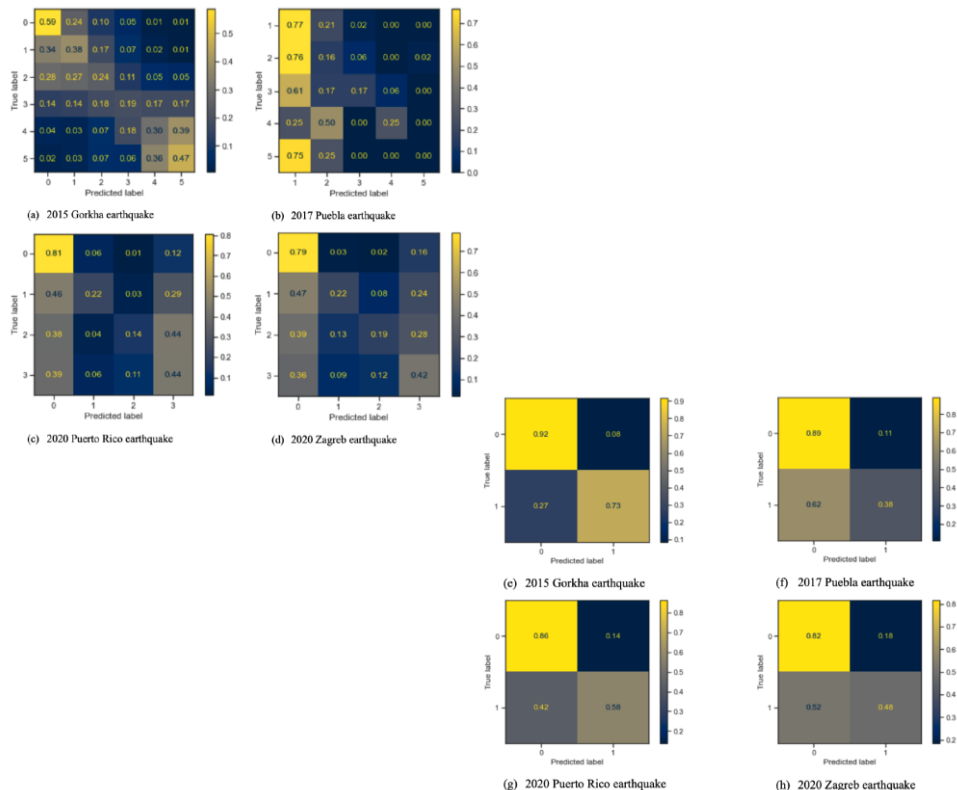
Damage Assessment Techniques Using SAR Data

Earthquake Building Damage Detection Using SAR and Machine Learning

- Classify damaged buildings after an earthquake.
- Uses SAR images, ShakeMaps, building maps, and field survey data.
- Machine learning model (Random Forest) predicts:
 - Binary (damaged / not damaged)
 - Multi-class (slight, moderate, severe)

Benefits

- Binary accuracy: 50–80%; Multi-class: 30–60%.
- Best results with combined SAR + ShakeMap + building info.





Earthquake



Earthquake Damage Assessment

➤ Hazard Characteristics

- Sudden ground shaking, surface rupture, building collapse, landslides.
- Secondary hazards: liquefaction, tsunamis.

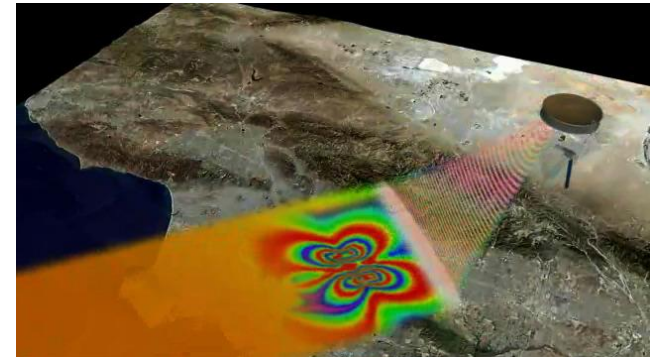
➤ Optical RS Usage

- Detects rubble, collapsed structures, road cracks



➤ SAR

- Coherence change (interferometric pairs)
- Displacement maps (InSAR, D-InSAR)



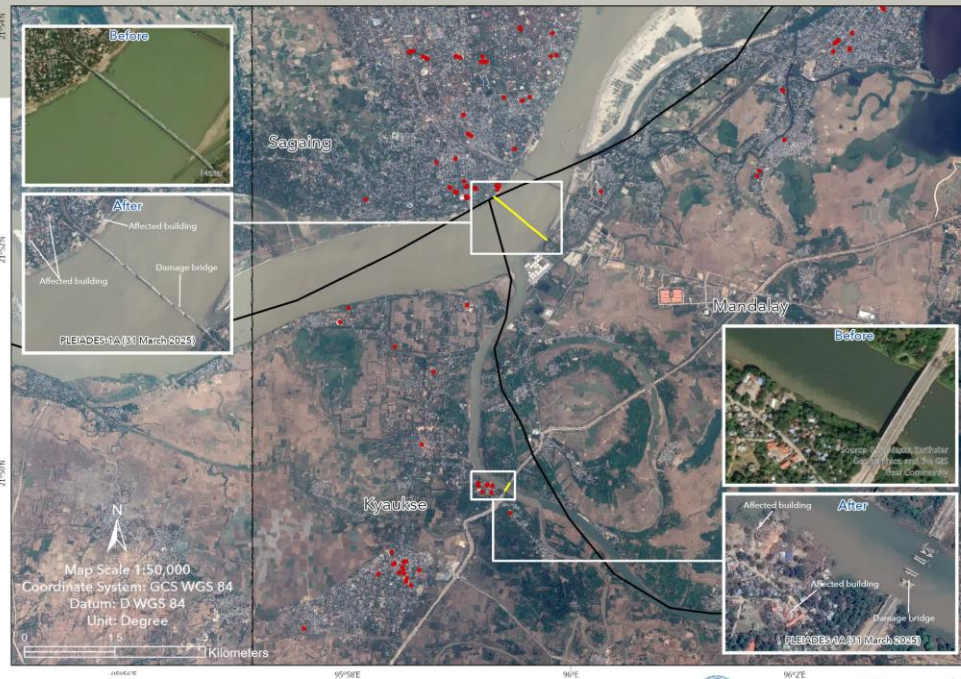
Case Study – Earthquake in Myanmar (Optical)

DAMAGE ASSESSMENT IN SAGAING AND KYAUKSE DISTRICTS

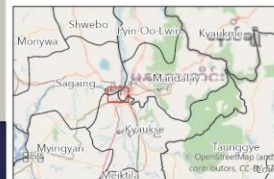
MYANMAR

Post-event images observed by PLEIADES-1A on 31 March 2025

EARTHQUAKE



This map shows the detected damaged buildings and bridges in the Sagaing and Kyaukse districts, Myanmar, on March 28, 2025, due to the earthquake.



334

NUMBER OF DEATHS

Source: ReliefWeb (OCHA), 30/03/2025,
and Myanmar Now News, 29/03/2025

● Affected Building

— Damaged Bridge

□ District Boundary

Satellite Image:
Pre-disaster image :
ESRI World Imagery

Post-disaster image :
PLEIADES-1A, 31 March 2025

Includes Pleiades material © CNES (2025),
Distribution Airbus DS.

GIS Data:
Administrative Boundary © GADM (2025)

Map product made by GIC-AIT (v1.0).

Disclaimer: The accuracy of this product
is not validated.

Sentinel Asia activation:

Earthquake in Mandalay, Myanmar

- 28 March 2025

Pleiades-1A



Case Study – Earthquake in Myanmar (Optical)

DAMAGE ASSESSMENT IN MANDALAY DISTRICT

MYANMAR

Post-event images observed by PLEIADES-1A on 31 March 2025

EARTHQUAKE



This map shows the detected damaged buildings in Mandalay district, Myanmar, on March 28, 2025, due to the earthquake.



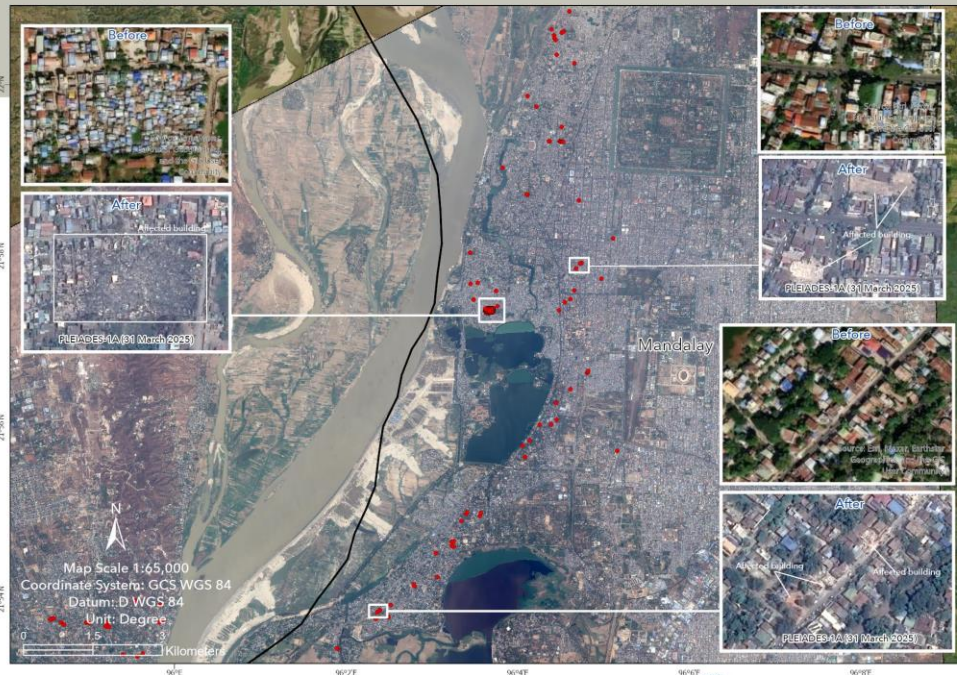
1,790

NUMBER OF DEATHS

Source: ReliefWeb (OCHA), 01/04/2025

● Affected Building

□ District Boundary



Satellite Image:
Pre-disaster image :
ESRI World Imagery

Post-disaster image :
PLEIADES-1A, 31 March 2025

Includes Pleiades material © CNES (2025),
Distribution Airbus DS.

GIS Data:
Administrative Boundary © GADM (2025)

Map product made by GIC-AIT (v1.0).

Disclaimer: The accuracy of this product
is not validated.

Sentinel Asia activation:

Earthquake in Mandalay, Myanmar

- 28 March 2025

Pleiades-1A



Case Study – Earthquake in China (SAR)

EARTHQUAKE IN TIBET AUTONOMOUS REGION

CHINA

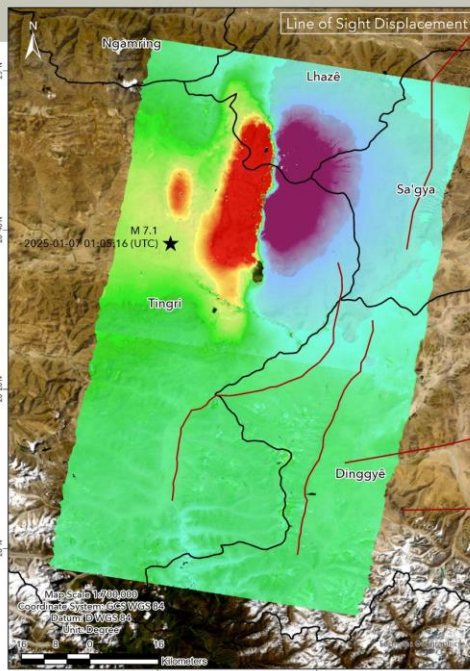
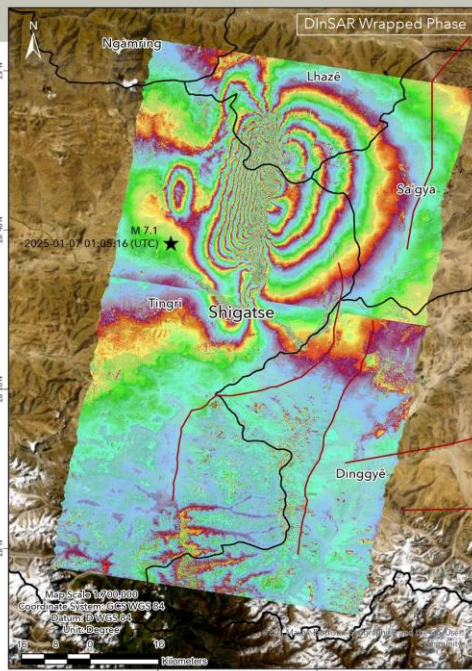
As observed by ALOS-2 images on 7 January 2025

EARTHQUAKE



These maps show the differential interferogram and the line of sight displacement generated from interferometric analysis using ALOS-2 images (Descending track), acquired before and after the earthquake occurred on 7 January 2025, in Tibet Autonomous Region, Southwest China, China.

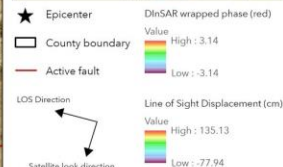
Positive values indicate deformation of the surface towards the satellite's sensor (such as uplift), while negative values indicate movement away from the sensor (such as subsidence).



126
NUMBER OF DEATHS

46,500
AFFECTED PEOPLE

Source: ReliefWeb (OCHA), 8/01/2025



Satellite Image:
Pre-disaster : ALOS-2 PALSAR-2,
15 October 2024

Post-disaster : ALOS-2 PALSAR-2,
7 January 2025

Copyright: © JAXA (2025) -
All rights reserved.

GIS Data:
Administrative Boundary © GADM (2025)

Epicenter: USGS
Active faults: Living Atlas

Map product made by GIC-AIT (v1.0).

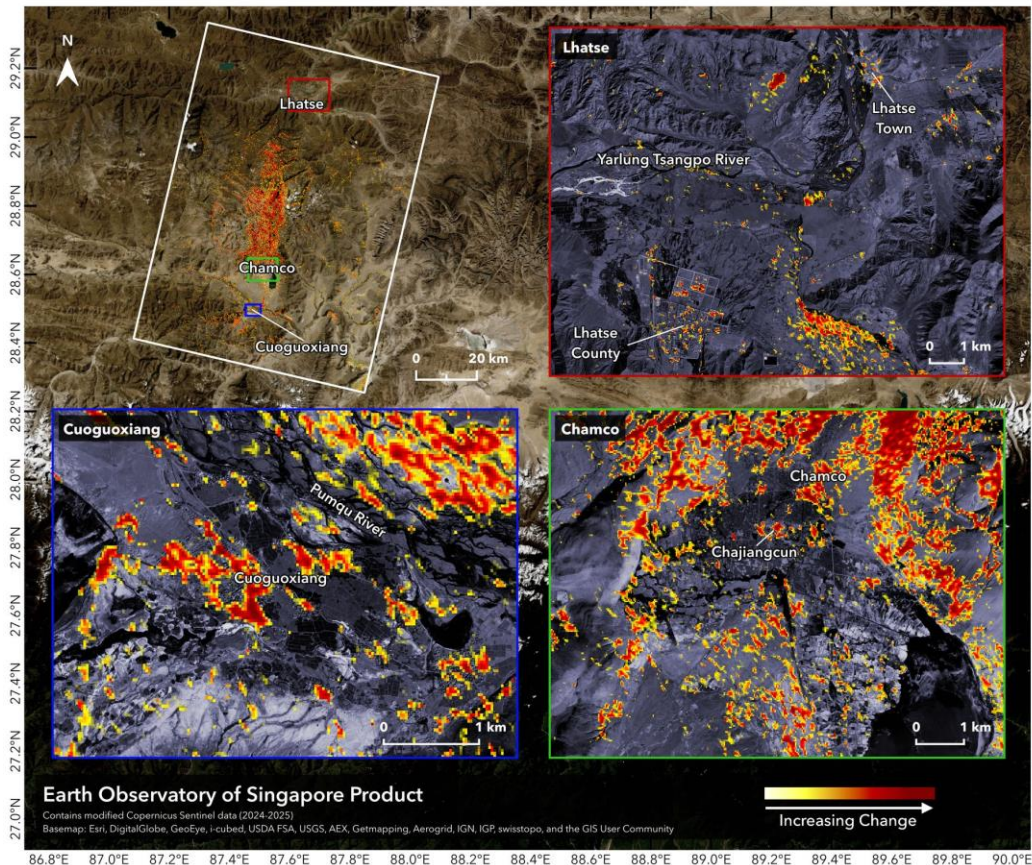
Disclaimer: The accuracy of this product
is not validated.

Sentinel Asia activation:

Earthquake in Xizang, Southwest
China (7 January, 2025)

ALOS-2 PALSAR-2

Case Study – Earthquake in China (SAR)



Sentinel Asia activation:

Earthquake in Xizang, Southwest China (7 January, 2025)

Sentinel-1



Landslide and Mudflow



Landslide and Mudflow Detection

➤ Hazard Characteristics

- **Landslides:** Sudden downslope movement of rock/soil due to rain or earthquakes.
- **Mudflows:** Fast-moving debris-laden flows caused by water saturation or volcanic activity.

➤ Optical RS Usage

- Identifies scars, vegetation removal, debris trails.

➤ SAR

- Detects pre-failure movement (InSAR), post-event surface disturbance, moisture zones.

Case Study – Mudflow in Kyrgyzstan(Optical)

MUDFLOW IN ISSYK KUL REGION

KYRGYZSTAN

As observed by PLEIADES-1A images on 21 August 2024



This map shows the powerful mudflow in Issyk Kul Region, Kyrgyzstan, on August 18, 2024, due to heavy rain caused mudflows from the mountains.

	0
NUMBER OF DEATHS	
	497
AFFECTED HOUSEHOLDS	
	1
AFFECTED SCHOOLS	

Source: Kazinform News Agency, 20/08/2024

- Affected building
- Affected road
- Mudflow
- Road

Satellite Image:
Pre-disaster image :
PLEIADES-1B, 21 April 2024
PLEIADES-1A, 21 July 2024

Post-disaster image :
PLEIADES-1A, 21 August 2024

Includes Pleiades material © CNES (2024),
Distribution Airbus DS.

GIS Data:
Road © OSM (2024)
Administrative Boundary © GADM (2024)

Map product made by GIC-AIT (v1.0).

Disclaimer: The accuracy of this product
is not validated.

Sentinel Asia activation:

Mudflows flood in Issyk-Kul district,
Kyrgyz (18 August 2024)

Pleiades-1A



Case Study – Mudflow in Bhutan (Optical)

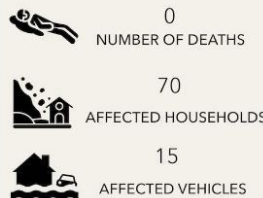
MUDFLOW IN KAWANG GEWOG, THIMPHU DISTRICT

BHUTAN

As observed by Sentinel-2 images on 11 August 2024



This map shows the mudflow in Kawang Gewog, Thimphu District, Bhutan, on August 10, 2024, due to landslides



Satellite Image:
Pre-disaster image :
Sentinel-2, 03 May 2024

Post-disaster image :
Sentinel-2, 11 August 2024

Contains modified Copernicus
Sentinel data (2024)

GIS Data:
Road © OSM (2024)
Administrative Boundary © GADM (2024)

Map product made by GIC-AIT (v1.0).

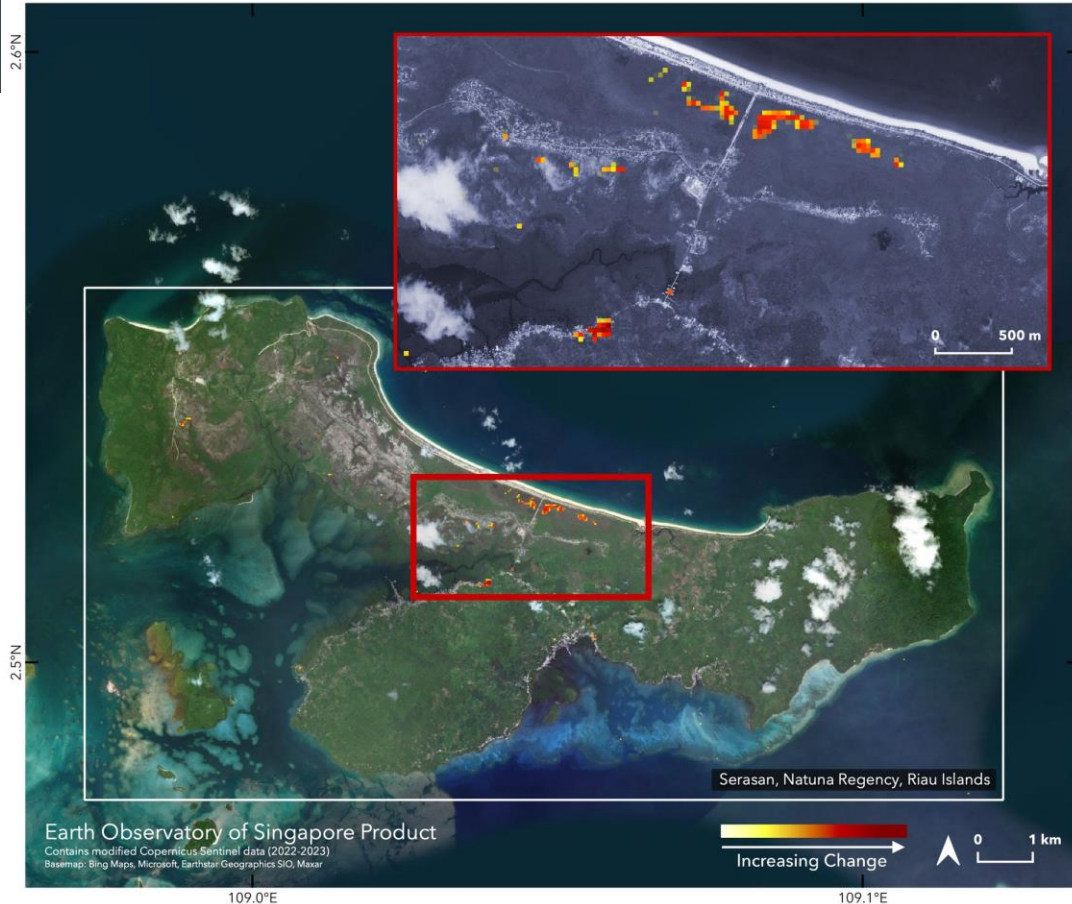
Sentinel Asia activation:

Mudflow in Bhutan (10 August 2024)

Sentinel-2



Case Study – Landslide in Indonesia (SAR)



EOS-RS Damage Proxy
Map: Indonesia,
Landslides, 7 Mar 2023,
v0.8

The Earth Observatory of Singapore - Remote Sensing Lab (EOS-RS) created this preliminary Damage Proxy Map (DPM) depicting areas that are likely damaged in Natuna Regency, Riau Islands in Indonesia due to landslides. This map was derived from synthetic aperture radar (SAR) images acquired by the Copernicus Sentinel-1 satellite operated by the European Space Agency (ESA) before (7 Nov 2022 to 23 Feb 2023) and after (7 Mar 2023) the event.

The image covers an area indicated by the large white polygon. Each pixel measures about 30 meters across. The colour variation from yellow to red indicates increasingly more significant surface change. This map has not been validated. This map could be used as a guidance to identify damaged areas, and may be less reliable over vegetated areas. Scattered pixels over vegetated areas may be false positives, and a lack of colored pixels over vegetated areas may not mean no damage.

The product contains modified Copernicus Sentinel data (2022-2023), processed by ESA and analyzed by the Earth Observatory of Singapore - Remote Sensing Lab (EOS-RS), using the Advanced Rapid Imaging and Analysis (ARIA) system originally developed at NASA's Jet Propulsion Laboratory, California Institute of Technology, and modified at EOS-RS. Data processing used an AWS Open Dataset of Copernicus Sentinel-1 data for the Asia region (<https://registry.opendata.aws/sentinel1-slc-seasia-pds>).

More map details and files at: http://eos-rs-products.earthobservatory.sg/EOS-RS_202303_Indonesia_Landslides/

Credits: Earth Observatory of Singapore - Remote Sensing Lab (EOS-RS), Advanced Rapid Imaging and Analysis (ARIA), NASA-JPL/Caltech, Contains modified Copernicus Sentinel data (2022-2023)

EOS-RS Twitter:
@eos_rs



Sentinel Asia activation:

**Landslide in Indonesia
(06 March 2023)**

Sentinel-1



Volcanic Eruption



Volcanic Eruption Monitoring

➤ Hazard Characteristics

- Emission of lava, ash, gas, and pyroclastic flows
- Can cause long-term surface change and air travel disruption
- Often includes precursors like ground uplift or thermal activity

➤ Optical RS Usage

- Pre- and post-event images help map ash spread, burnt areas, and damage zones.
- Thermal Bands detect hotspots (lava, vents)

➤ SAR

- Deformation mapping from ascending/descending pairs (e.g., Sentinel-1, ALOS-2).

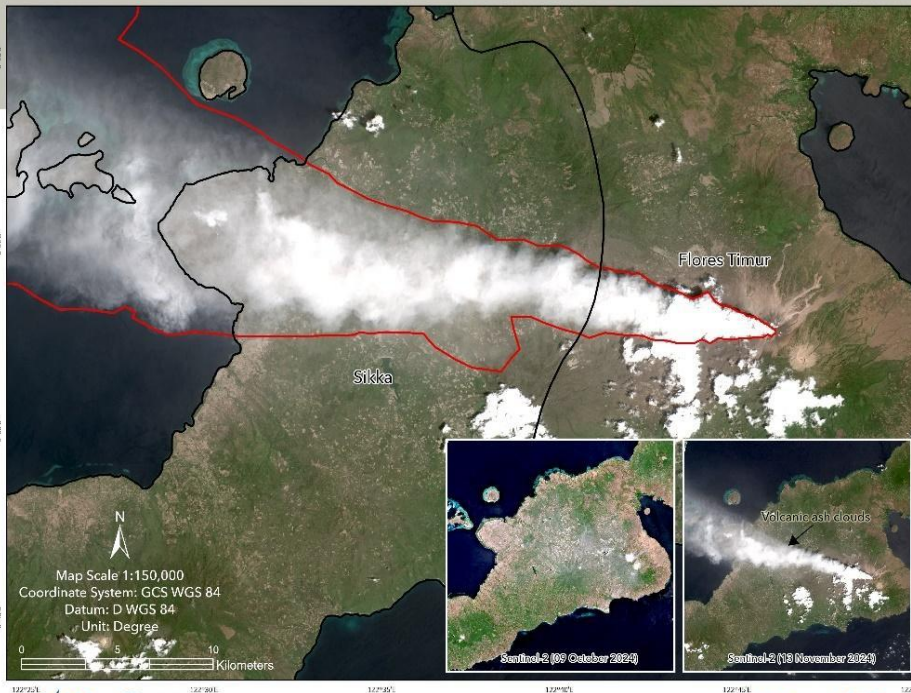
Case Study – Volcano Eruption in Indonesia (Optical)



VOLCANO ERUPTION AT THE MOUNT LEWOTOBI LAKI-LAKI

INDONESIA

As observed by Sentinel-2 images on 13 November 2024



This map shows the volcano eruption at Mount Lewotobi Laki-laki in the Flores Timur and Sikka regencies, Indonesia, on November 3, 2024.



10

NUMBER OF DEATHS



10,300

AFFECTED PEOPLE

Source: ANHA Centre, 2011-2024



Volcanic ash clouds

Regency Boundary

Satellite Image:
Pre-disaster image :
Sentinel-2, 09 October 2024

Post-disaster image :
Sentinel-2, 13 November 2024

Contains modified Copernicus
Sentinel data (2024)

GIS Data:
Administrative Boundary © GADM (2024)

Map product made by GIC-AIT (v1.0).

Disclaimer: The accuracy of this product
is not validated.

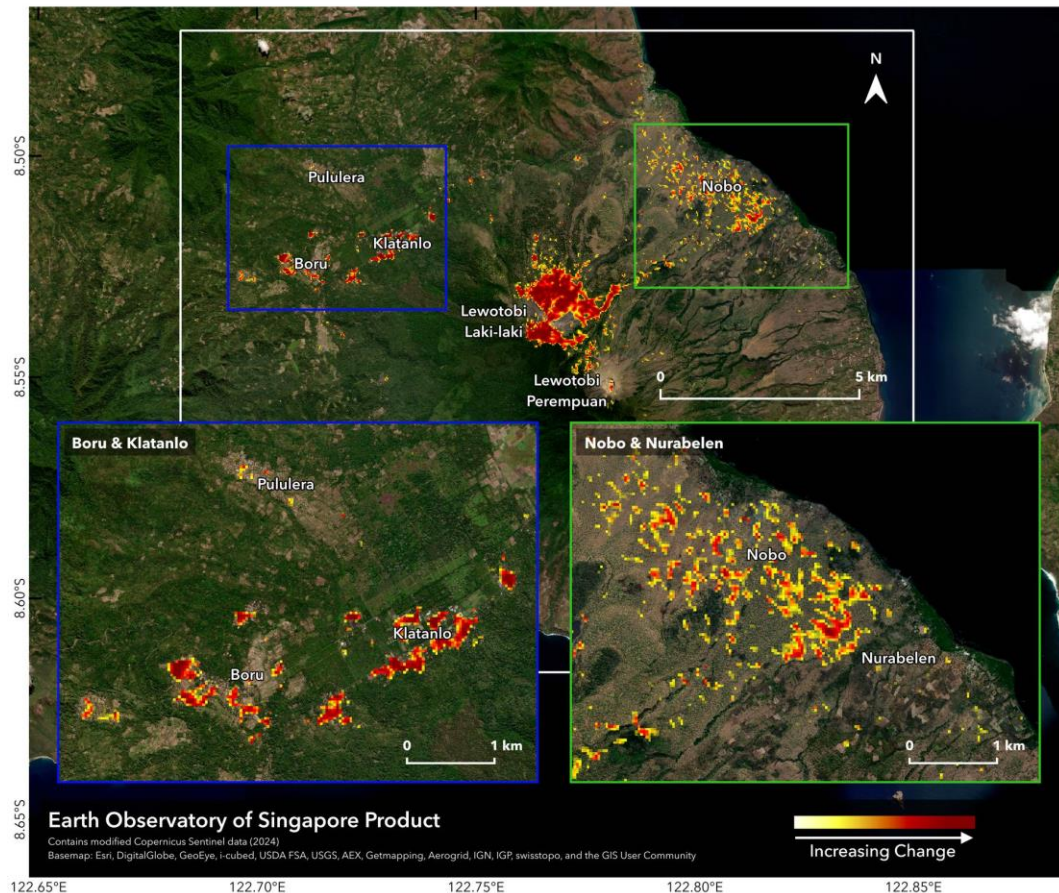
Sentinel Asia activation:

Lewotobi Laki-laki Volcano
Eruption in Indonesia
(03 November 2024)

Sentinel-2



Case Study – Volcano Eruption in Indonesia (SAR)



EOS-RS Damage Proxy Map:
Flores Island, Indonesia,
Volcanic Eruption,
4 Nov 2024, v0.9

The Earth Observatory of Singapore - Remote Sensing Lab (EOS-RS) created this preliminary Damage Proxy Map (DPM) depicting areas that are likely damaged on Flores Island, Indonesia, due to a volcanic eruption from the Lewotobi Laki-laki volcano on 3 Nov 2024. This map was derived from synthetic aperture radar (SAR) images acquired by the Copernicus Sentinel-1 satellite operated by the European Space Agency (ESA) before (7 Jul 2024 to 23 Oct 2024) and after (4 Nov 2024) the event.

The map covers an area indicated by the white polygon. Damage is shown by colored pixels of 30m in size, where yellow to red indicates increasingly significant ground surface change before and after the event. Preliminary validation was conducted using news reports, aerial imagery, and ground-level imagery and videos in selected areas. This map should be used as a guidance to identify damaged areas, and may be less reliable over vegetated or mountainous areas. Scattered pixels over vegetated or mountainous areas may be false positives, and a lack of colored pixels over such areas may not mean no damage.

The product contains modified Copernicus Sentinel data (2024), processed by ESA and analyzed by the Earth Observatory of Singapore - Remote Sensing Lab (EOS-RS).

More map details and files at:
https://eos-rs-products.earthobservatory.sg/EOS-RS_202411_Indonesia_Volcanic_Eruption/

Legal Disclaimer:
<https://products.earthobservatory.sg/#/faq/>

Credits: Earth Observatory of Singapore - Remote Sensing Lab (EOS-RS). Contains modified Copernicus Sentinel data (2024)

EOS Remote Sensing
LinkedIn



Sentinel Asia activation:

**Lewotobi Laki-laki Volcano
Eruption in Indonesia
(03 November 2024)**

Sentinel-1

Reference

Stephenson, O. L., Köhne, T., Zhan, E., Cahill, B. E., Yun, S.-H., Ross, Z. E., & Simons, M. (2022). Deep Learning-based Damage Mapping with InSAR Coherence Time Series. IEEE Transactions on Geoscience and Remote Sensing, 60, 1–16.

<https://doi.org/10.1109/TGRS.2022.3146302>

Rao, A., Jung, J., Silva, V., Molinario, G., & Yun, S. H. (2023). Earthquake building damage detection based on synthetic-aperture-radar imagery and machine learning. Natural Hazards and Earth System Sciences, 23, 789–807. <https://doi.org/10.5194/nhess-23-789-2023>

Ge, P., Gokon, H., & Meguro, K. (2020). A review on synthetic aperture radar-based building damage assessment in disasters. Remote Sensing of Environment, 240, 111693.

<https://doi.org/10.1016/j.rse.2020.111693>

Ballinger, O. (2024). Open Access Battle Damage Detection via Pixel-Wise T-Test on Sentinel-1 Imagery. arXiv preprint arXiv:2405.06323.

THANK YOU

Geoinformatics Center, Asian Institute of Technology

