

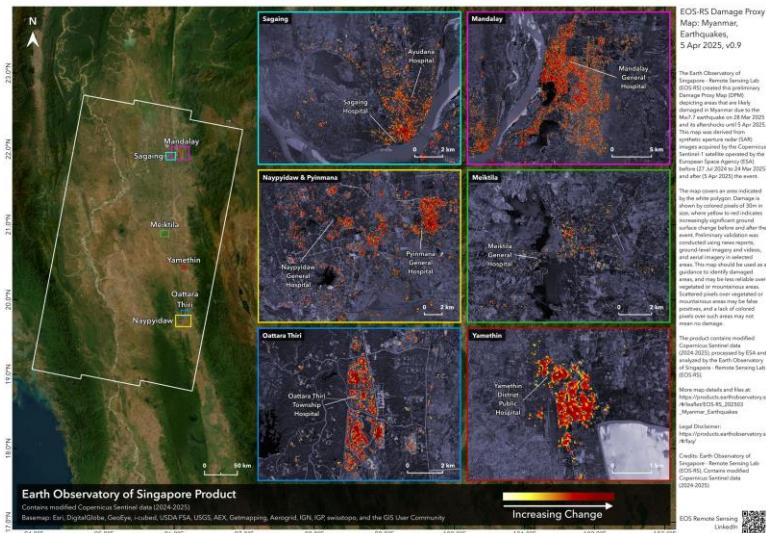
# Remote sensing applications for damage assessment

Geoinformatics Center - AIT

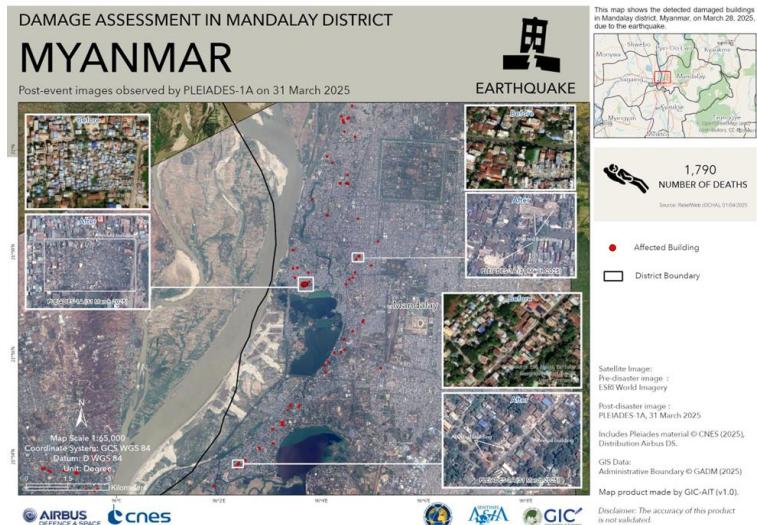
# Overview

## 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

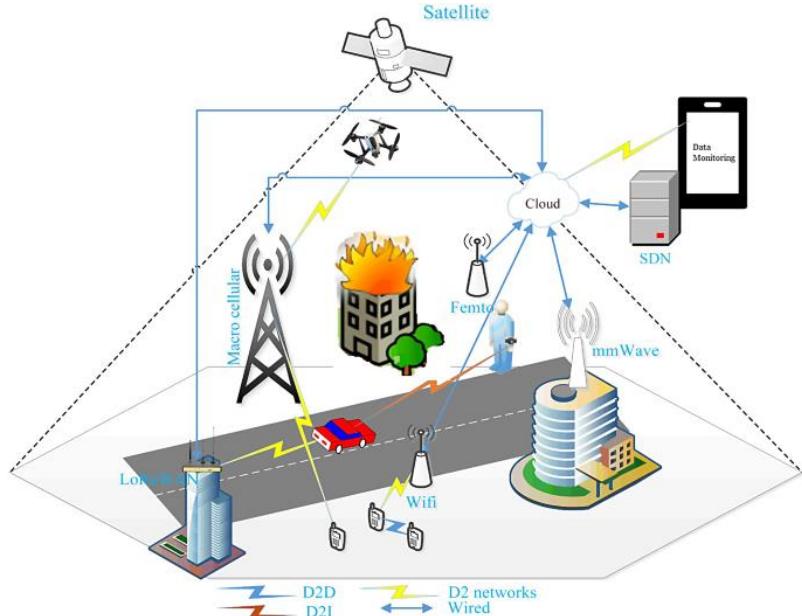
# Overview

## 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)

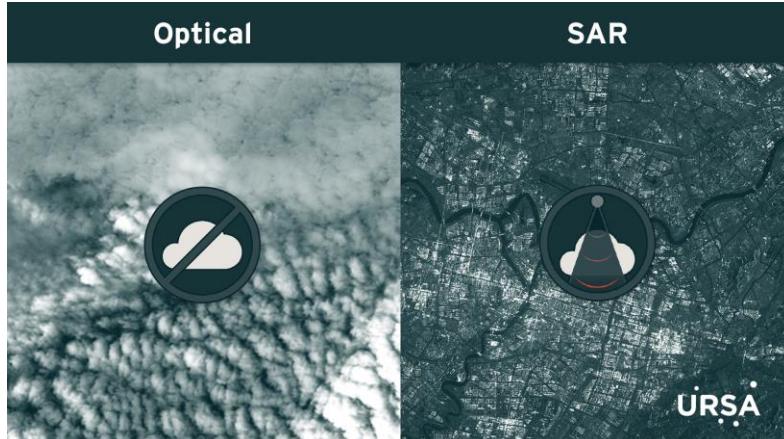
- Active sensor using microwave radar
- Works day/night and through clouds
- Detects surface movement, structure, roughness



# 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

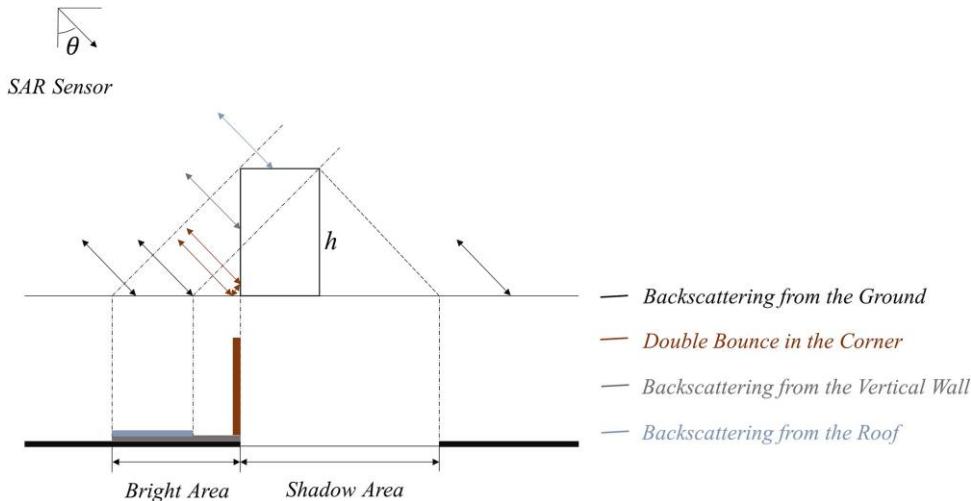
- Synthetic Aperture Radar (SAR) captures backscattered signals from different surfaces.
- Urban features like buildings produce distinct scattering patterns.

## 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  $\sim 1$ : No change (e.g., undamaged buildings)

Coherence  $\sim 0$ : Major change (e.g., collapsed structures, debris)

# Damage Assessment Techniques Using SAR Data

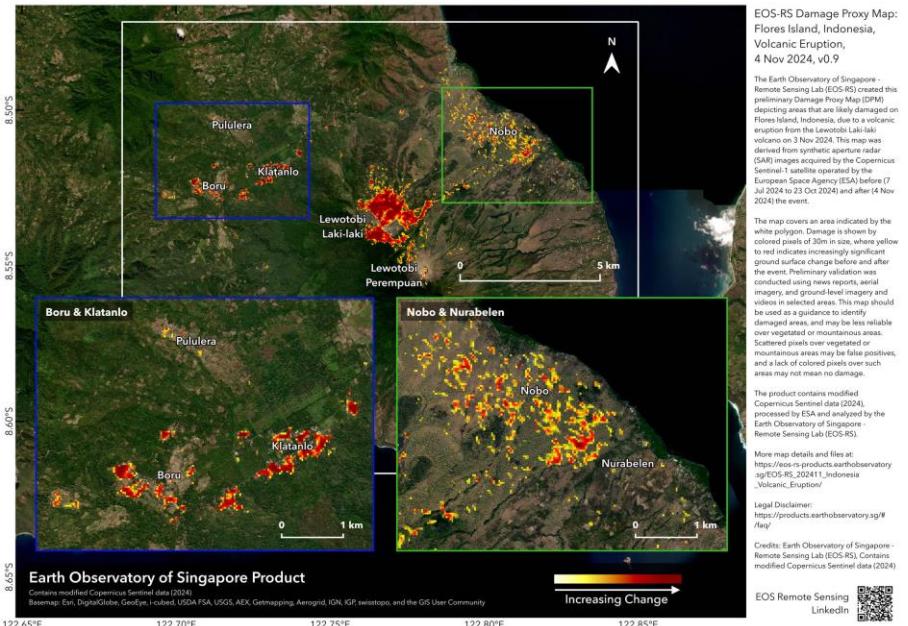
## Coherence Change Detection (Three-Image Method)

- 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

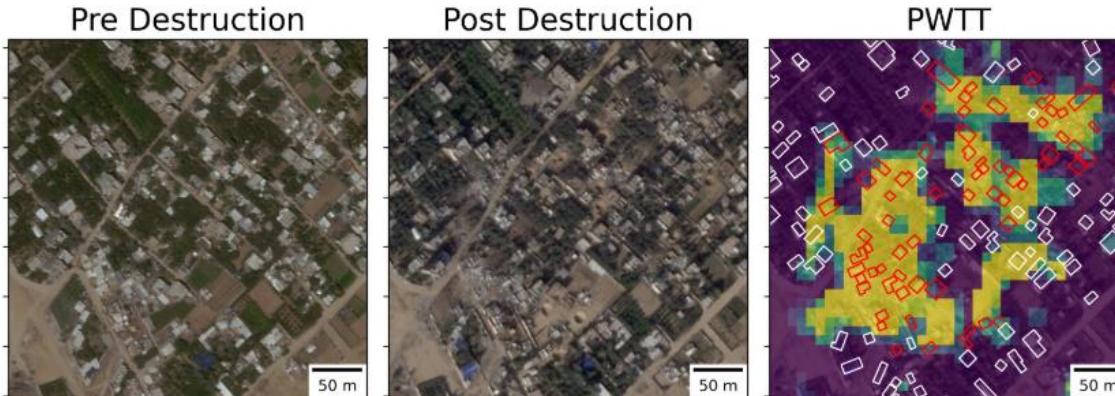
## Pixel-wise t-test

- 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

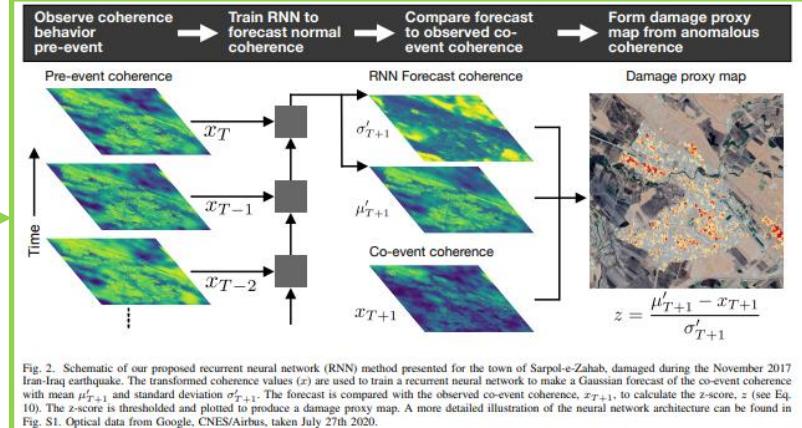
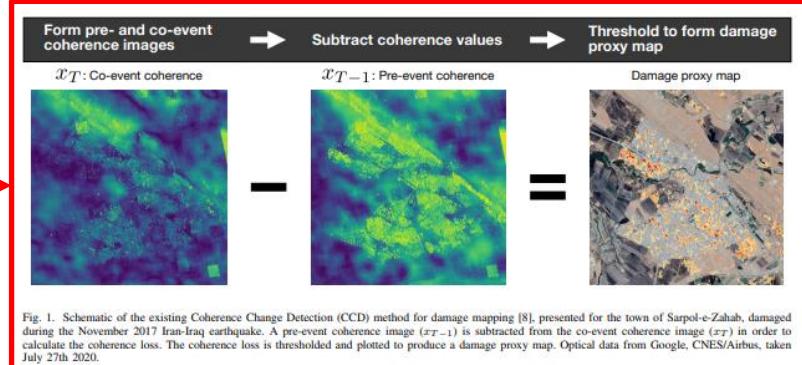
- Detect earthquake damage using time-series satellite radar (SAR).
- Use RNN (Recurrent Neural Network) to learn normal ground behavior.
- Compare predicted and actual SAR coherence after earthquake.
- Anomaly indicates possible damage.

### 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)

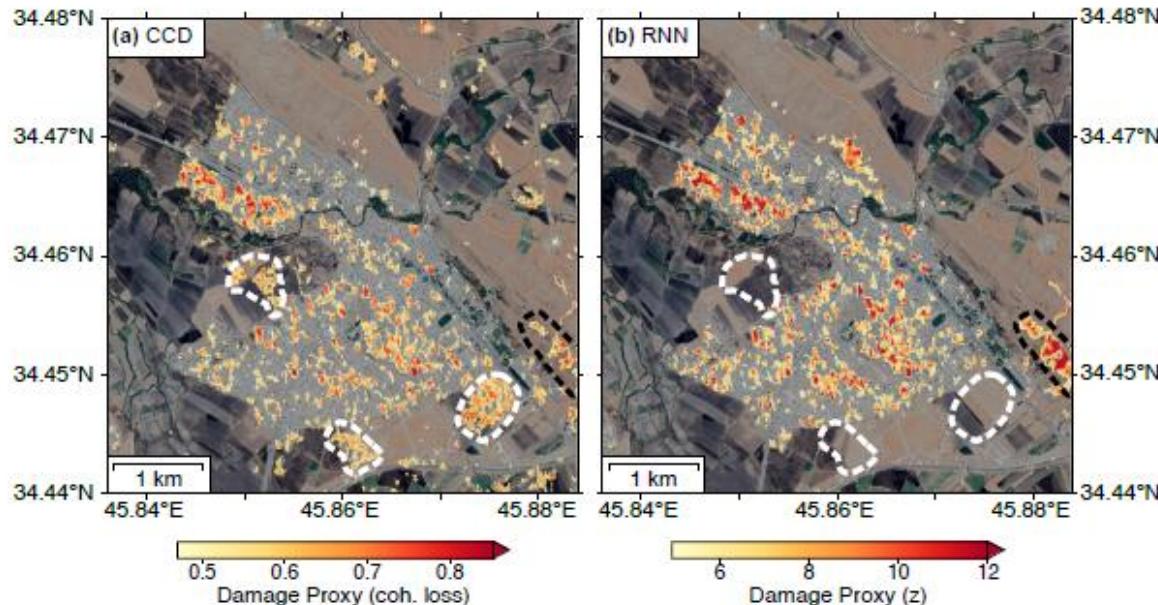


# Damage Assessment Techniques Using SAR Data

## 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.



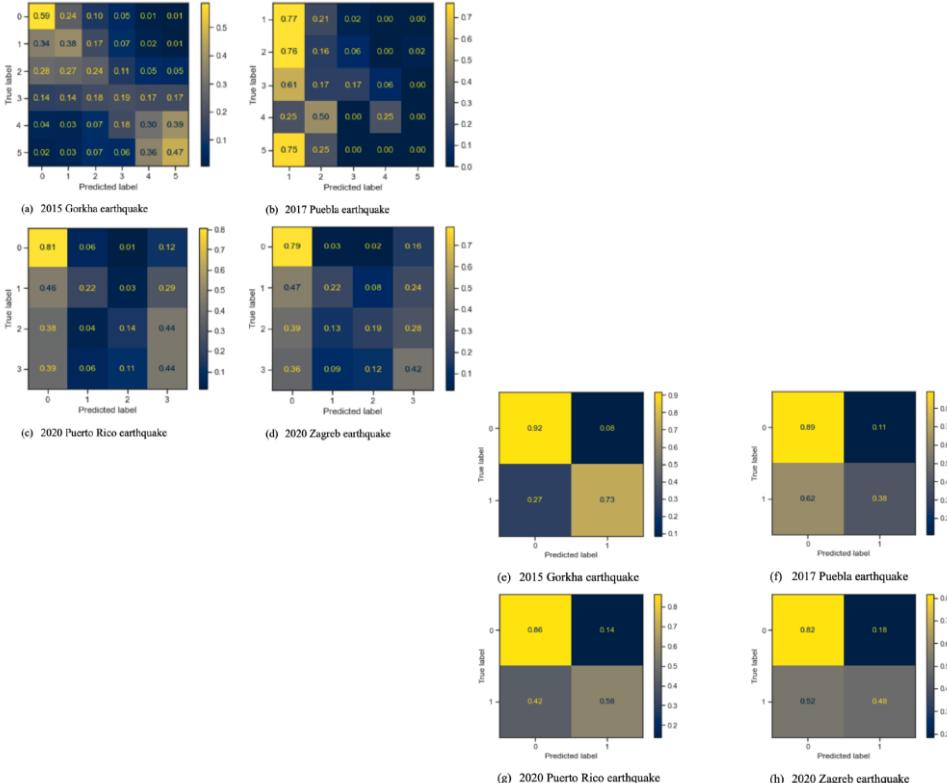
# Damage Assessment Techniques Using SAR Data

## 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.

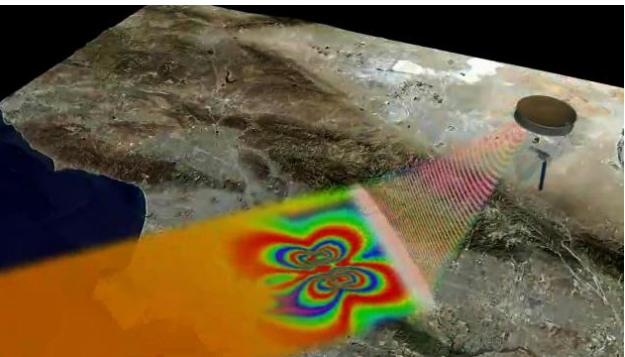
## ➤ Optical RS Usage

- Detects rubble, collapsed structures, road cracks



## ➤ SAR

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



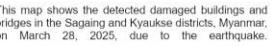
# Case Study – Earthquake in Myanmar (Optical)



## DAMAGE ASSESSMENT IN SAGAING AND KYAUKSE DISTRICTS

# MYANMAR

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



- 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)

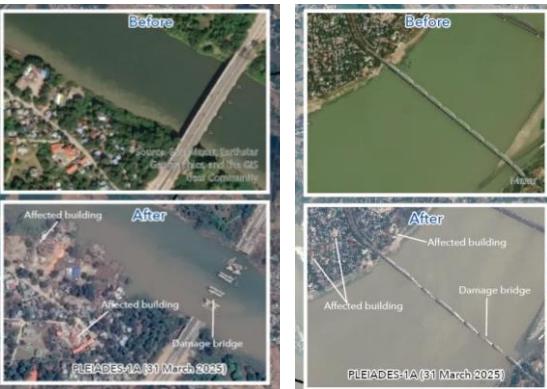
*Disclaimer: The accuracy of this product is not validated.*

## Sentinel Asia activation:

## Earthquake in Mandalay, Myanmar

- 28 March 2025

Pleiades-1A



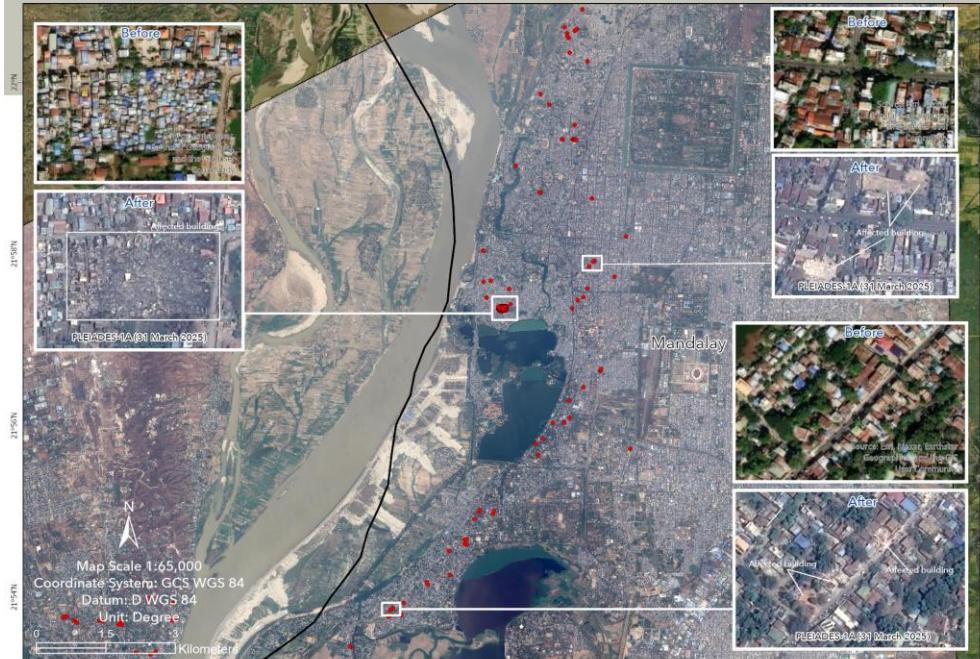
# Case Study – Earthquake in Myanmar (Optical)



## DAMAGE ASSESSMENT IN MANDALAY DISTRICT

# MYANMAR

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



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



## EARTHQUAKE



- 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

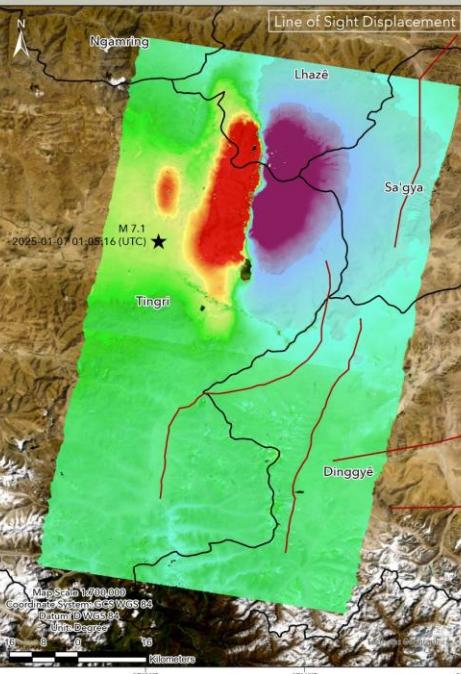
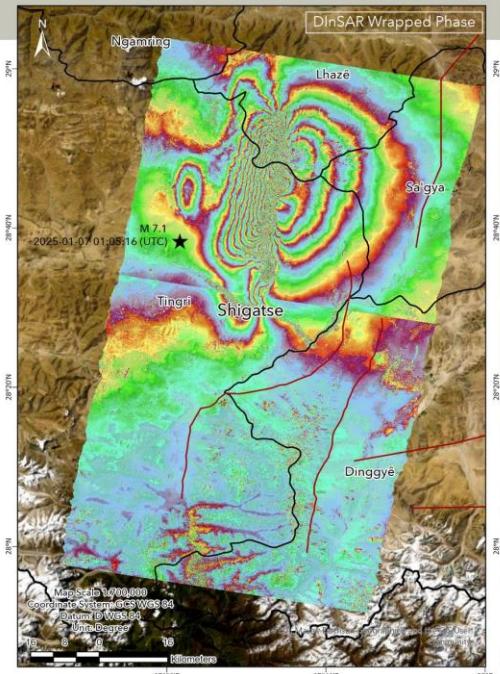


# Case Study – Earthquake in China (SAR)



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



★ Epicenter  
County boundary  
Active fault  
LOS Direction  
Satellite look direction  
DInSAR wrapped phase (red)  
Value : High : 3.14  
Low : -3.14  
Line of Sight Displacement (cm)  
Value : High : 135.13  
Low : -77.94

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.



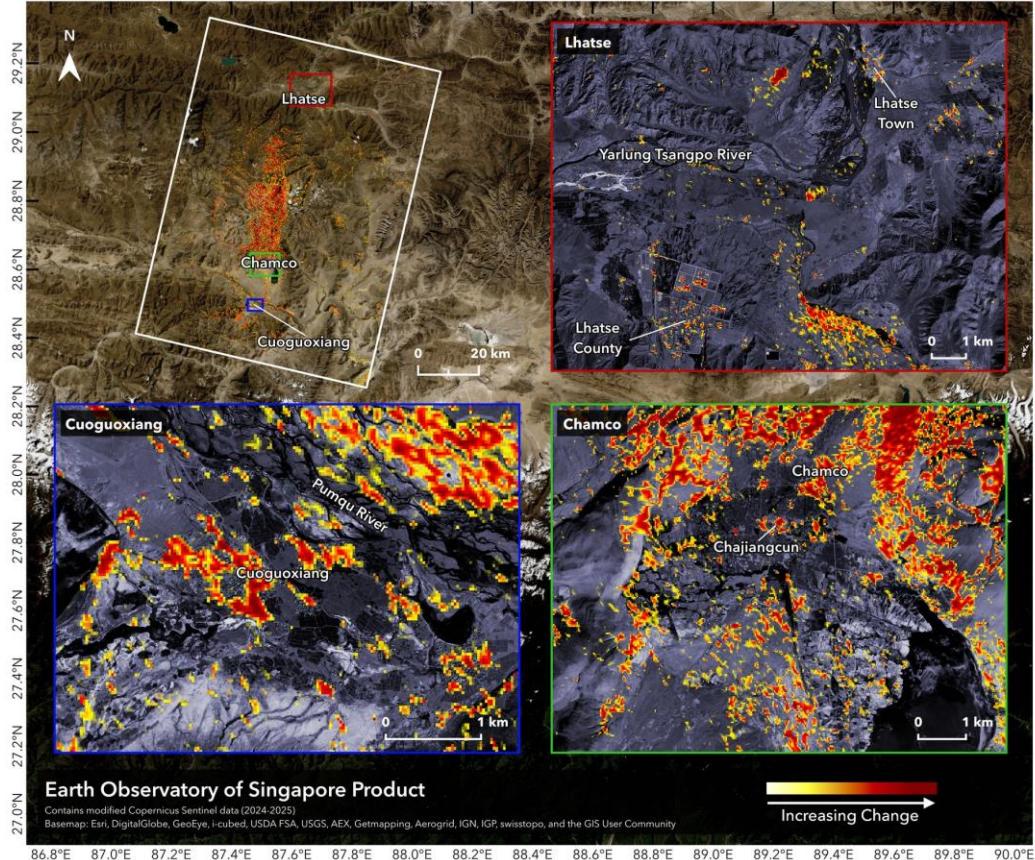
(<https://sentinel-asia.org/EO/2025/article20250107CN.html>)

## Sentinel Asia activation:

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

ALOS-2 PALSAR-2

# Case Study – Earthquake in China (SAR)



EOS-RS Damage Proxy Map:  
 Tibet, China, Earthquake,  
 13 Jan 2025, 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 in Tibet, China, due to a Mw7.1 earthquake on 7 Jan 2025. 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 (3 Sep 2024 to 1 Jan 2025) and after (13 Jan 2025) the event.

This 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 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 (2024-2025), 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\\_202501\\_China\\_Tibet\\_Earthquake/](https://eos-rs-products.earthobservatory.sg/EOS-RS_202501_China_Tibet_Earthquake/)

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

Credits: Earth Observatory of Singapore - Remote Sensing Lab (EOS-RS). Contains modified Copernicus Sentinel data (2024-2025)

**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



## 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



0

NUMBER OF DEATHS



70

AFFECTED HOUSEHOLDS



15

AFFECTED VEHICLES

Source: Kuensel newspaper, 12/08/2024

## Sentinel Asia activation:

### Mudflow in Bhutan (10 August 2024)

### Sentinel-2

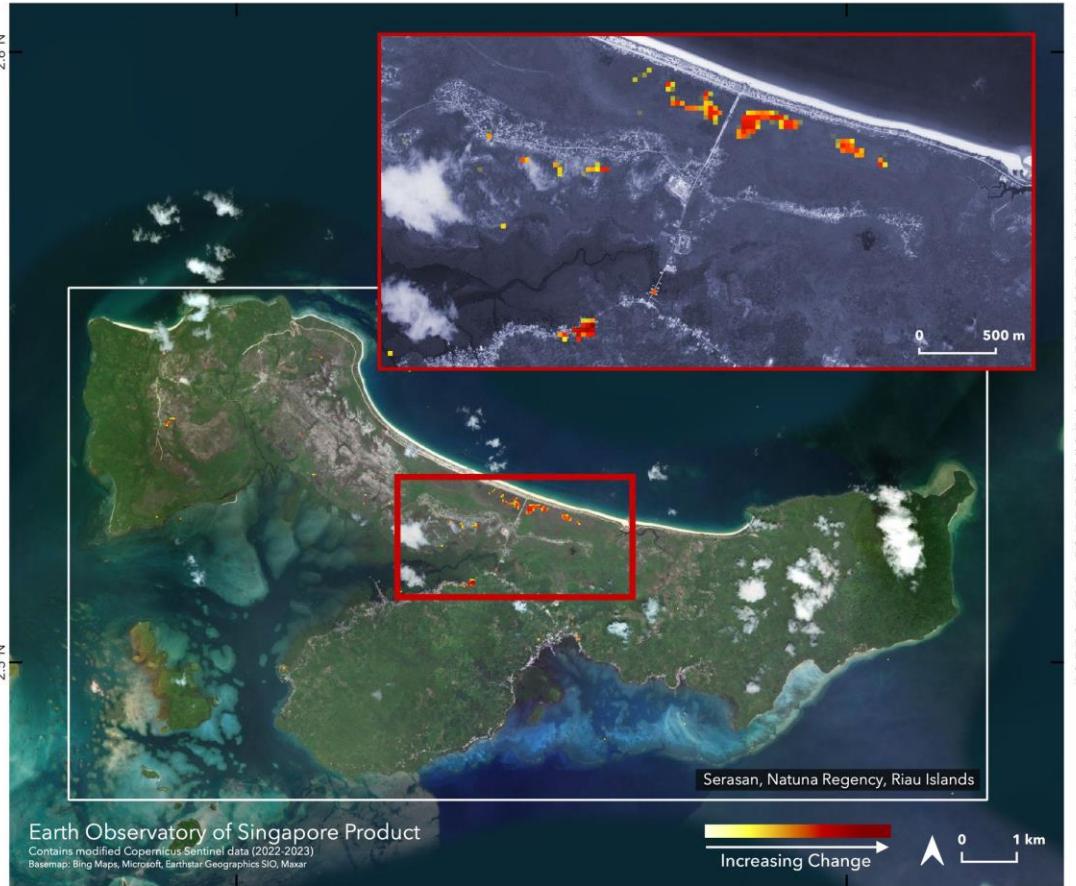


(<https://sentinel-asia.org/EO/2024/article20240810BT.html>)



# Case Study – Landslide in Indonesia (SAR)

2.6°N



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 on a side. The color transition from white 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 (ARI) 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 file at: [http://eos-rs-products.earthobservatory.sg/EOS-RS\\_202303\\_Indonesia\\_Landslides/](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 (ARI), NASA, JPL/Caltech. Contains modified Copernicus Sentinel data (2022-2023)

**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)

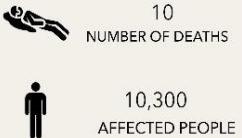


# VOLCANO ERUPTION AT THE MOUNT LEWOTOBI LAKI-LAKI **INDONESIA**

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.



Source: AHA Centre, 30/7/2024



- 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:

*Disclaimer: The accuracy of this product is not validated.*

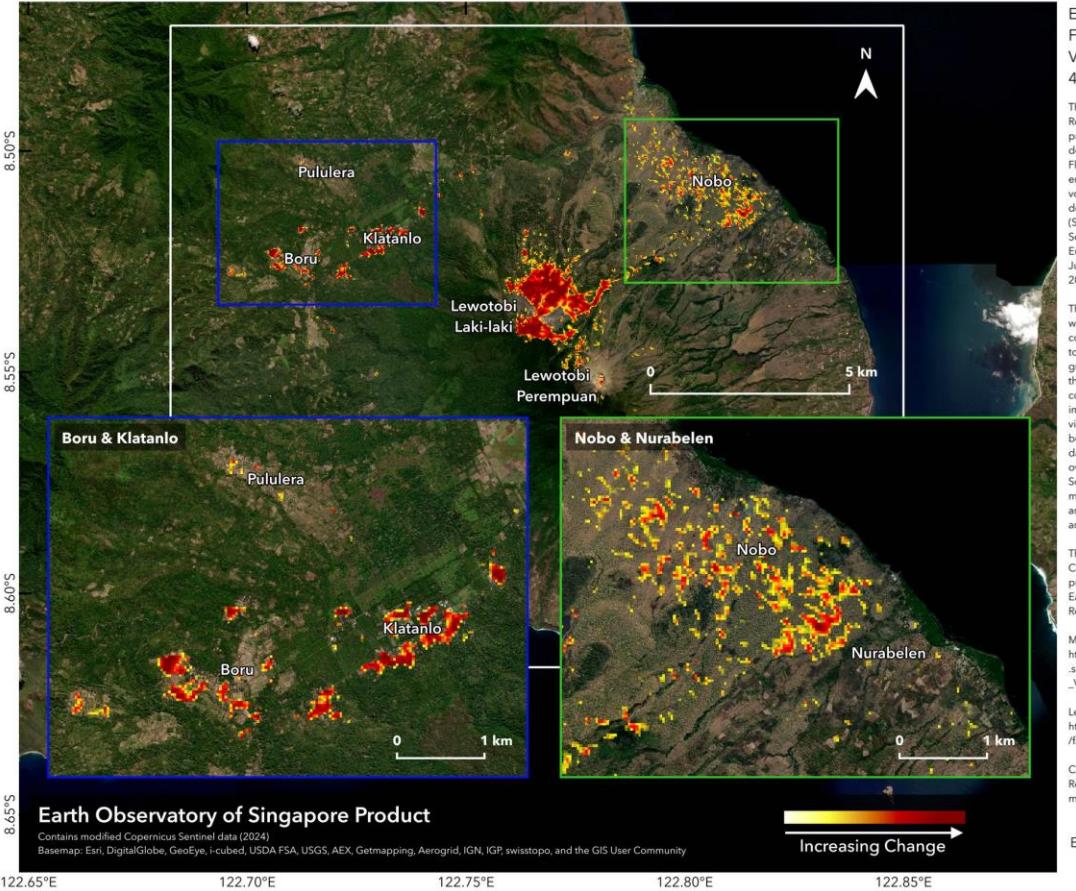
## Sentinel Asia activation:

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

## Sentinel-2



# Case Study – Volcano Eruption in Indonesia (SAR)



## Sentinel Asia activation:

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

Sentinel-1

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.

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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

# 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>

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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

