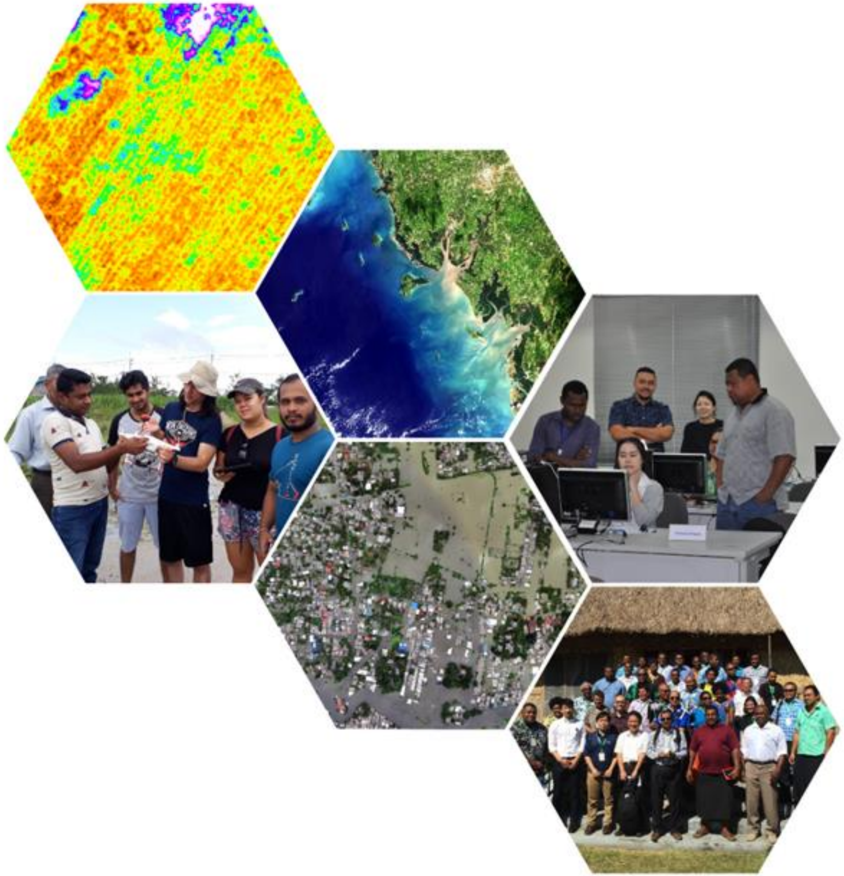


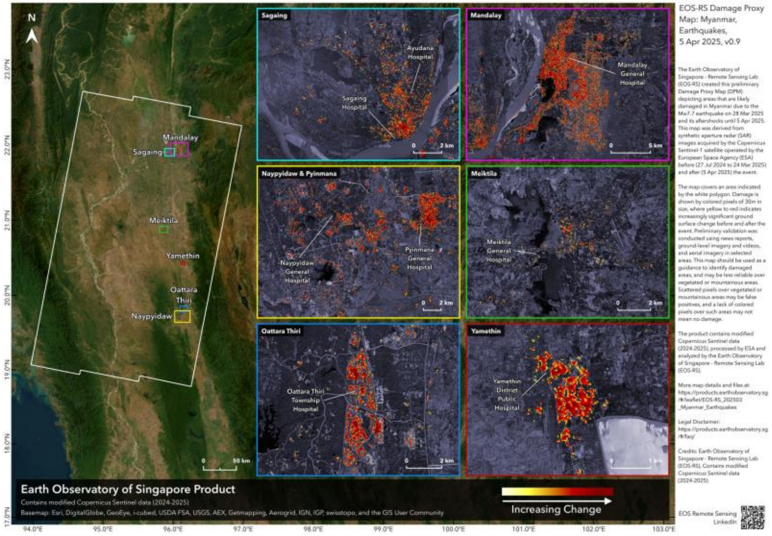
Remote sensing applications for damage assessment

Geoinformatics Center - AIT

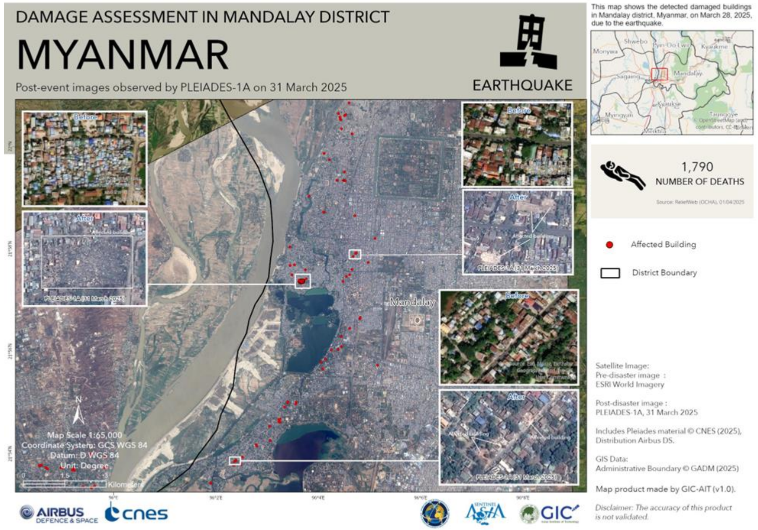
Overview

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

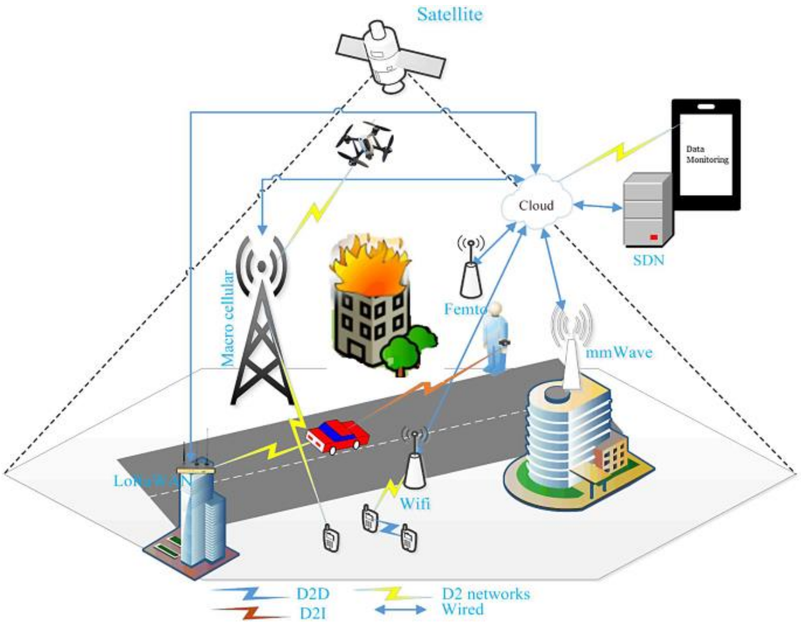
Overview

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.

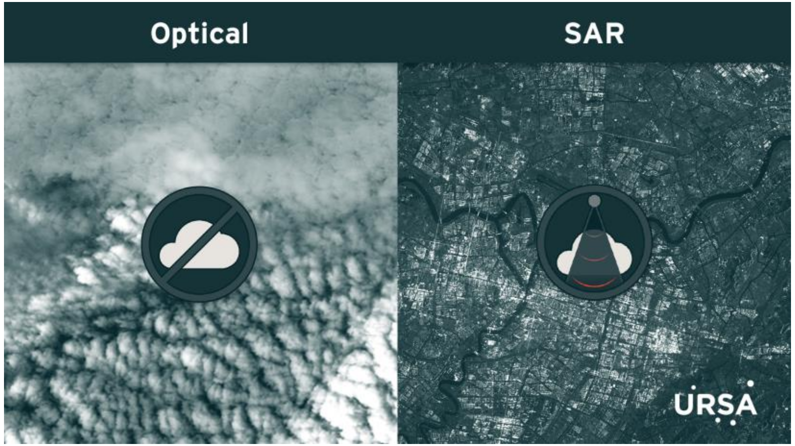
SAR (Synthetic Aperture Radar)

- 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

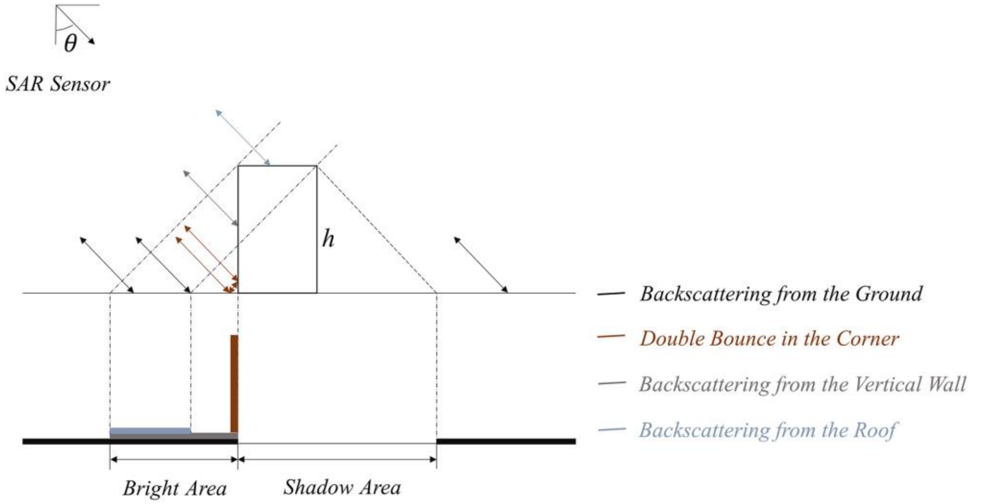
- Synthetic Aperture Radar (SAR) captures backscattered signals from different surfaces.
- Urban features like buildings produce distinct scattering patterns.

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

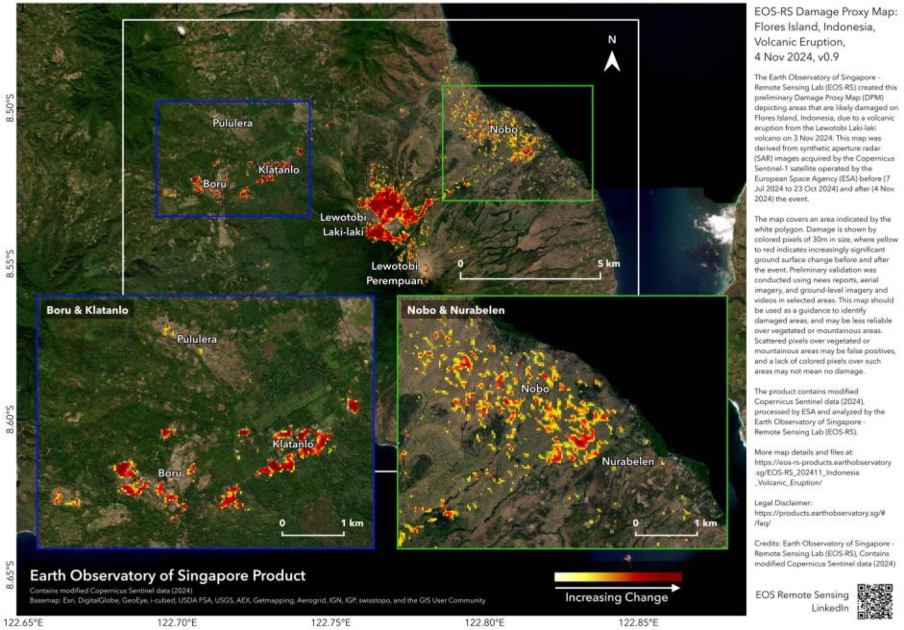
Damage Assessment Techniques Using SAR Data

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

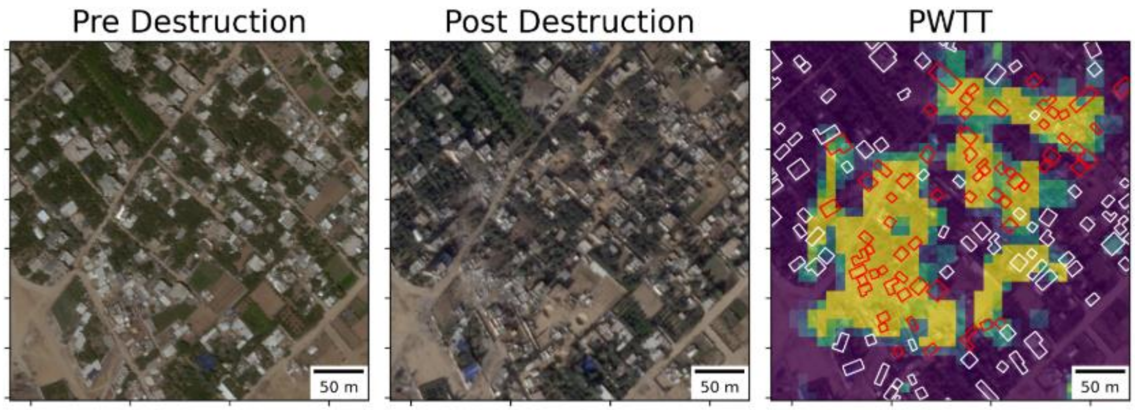
Pixel-wise t-test

- 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)

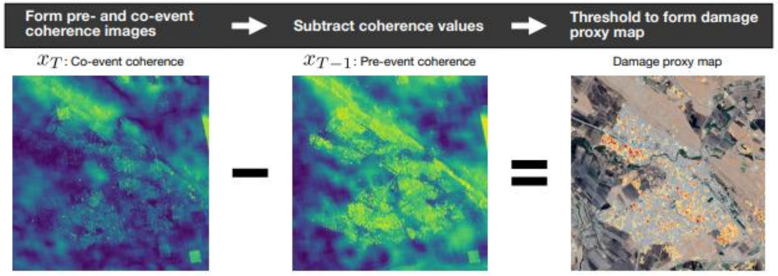


Fig. 1. Schematic of the existing Coherence Change Detection (CCD) method for damage mapping [8], presented for the town of Sarpol-e-Zahab, damaged during the November 2017 Iran-Iraq earthquake. A pre-event coherence image (x_{T-1}) is subtracted from the co-event coherence image (x_T) in order to calculate 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.

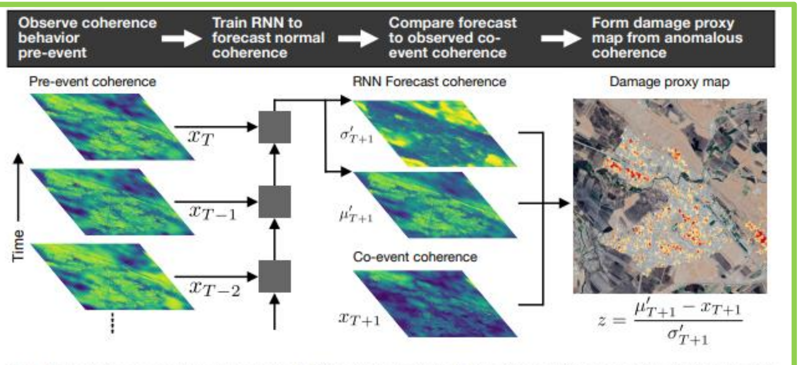


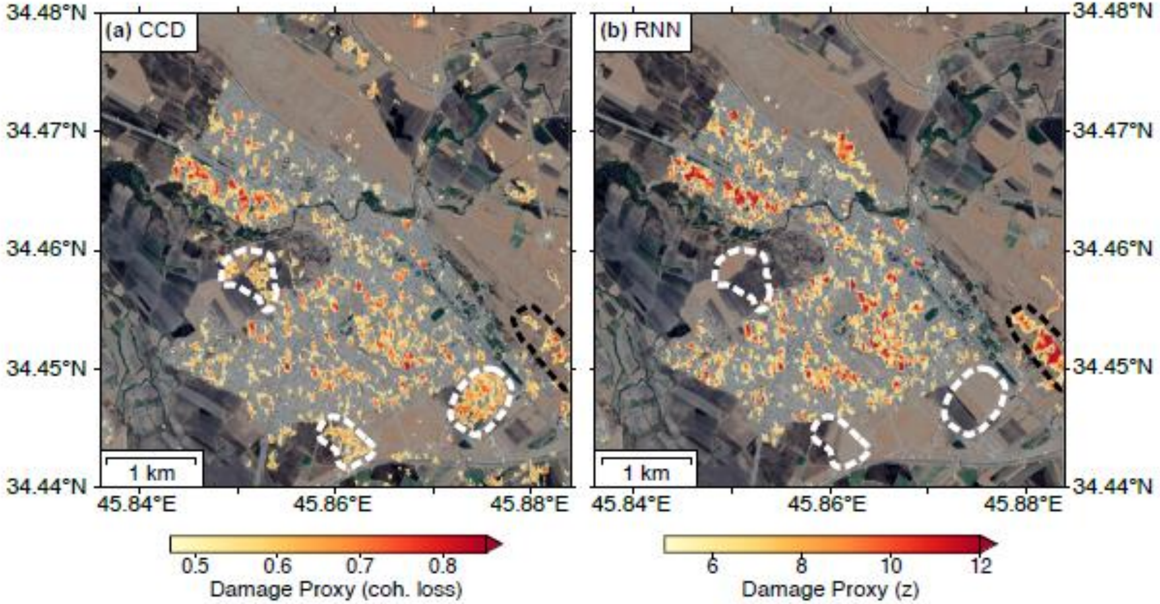
Fig. 2. Schematic of our proposed recurrent neural network (RNN) method presented for the town of Sarpol-e-Zahab, damaged during the November 2017 Iran-Iraq earthquake. The transformed coherence values (x) are used to train a recurrent neural network to make a Gaussian forecast of the co-event coherence 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.



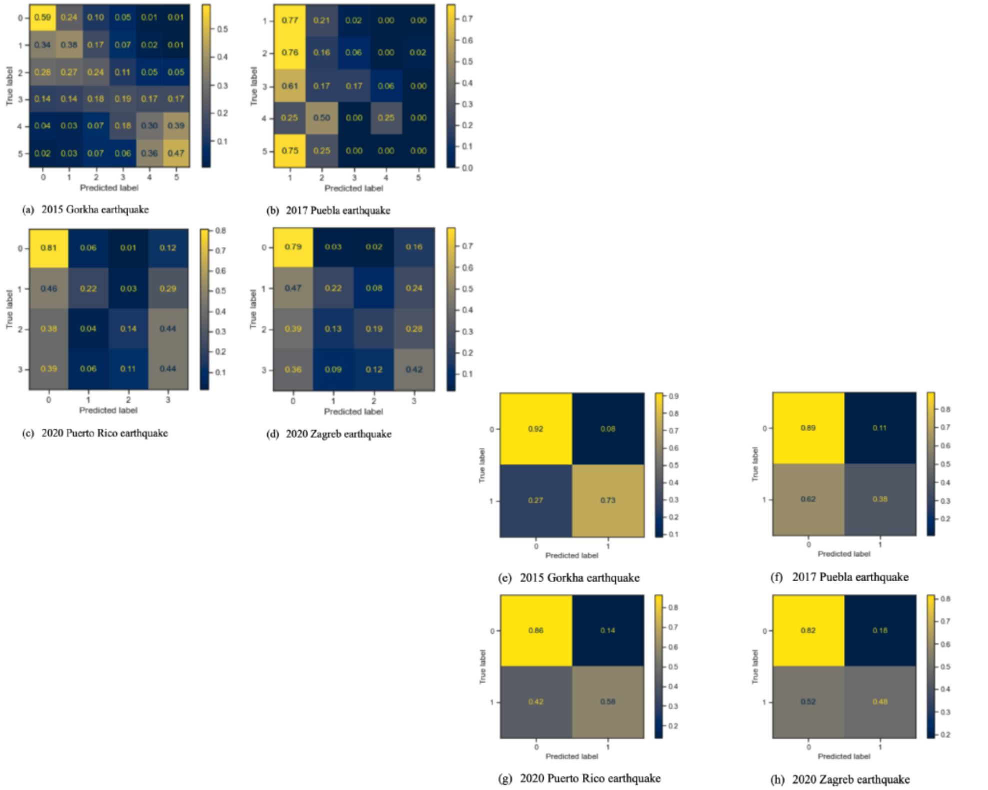
Damage Assessment Techniques Using SAR Data

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.

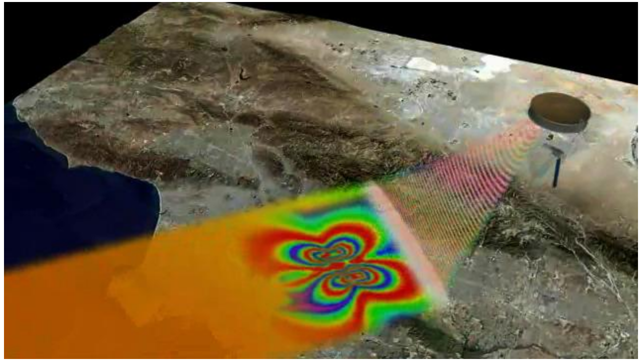


(a) 2015 Gorkha earthquake (b) 2017 Puebla earthquake (c) 2020 Puerto Rico earthquake (d) 2020 Zagreb earthquake (e) 2015 Gorkha earthquake (f) 2017 Puebla earthquake (g) 2020 Puerto Rico earthquake (h) 2020 Zagreb earthquake

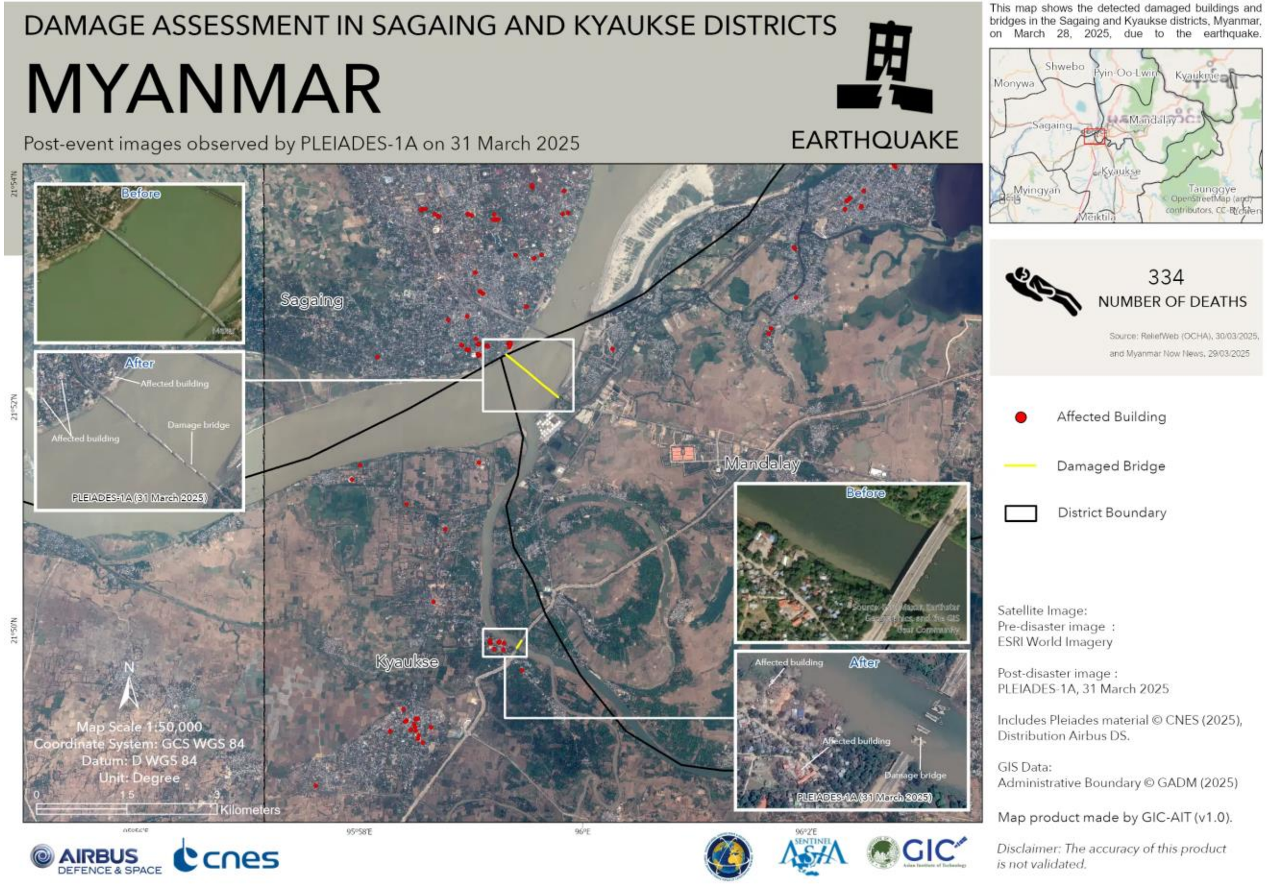
Earthquake

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)



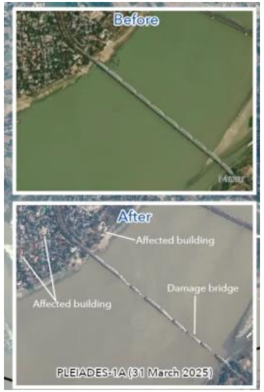
(https://disasterscharter.org/activations/earthquake-in-myanmar-activation-956-)

Sentinel Asia activation:

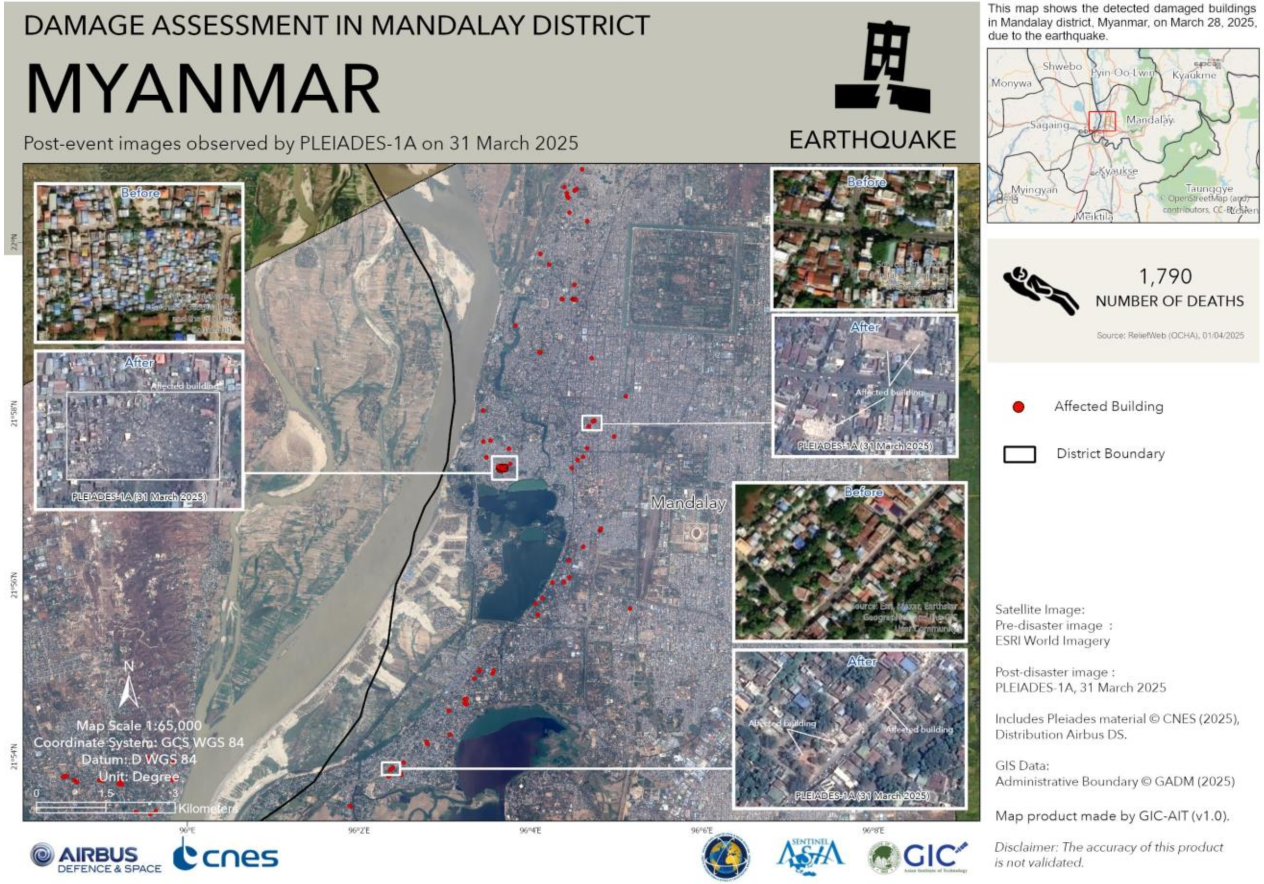
Earthquake in Mandalay, Myanmar

- 28 March 2025

Pleiades-1A



Case Study – Earthquake in Myanmar (Optical)



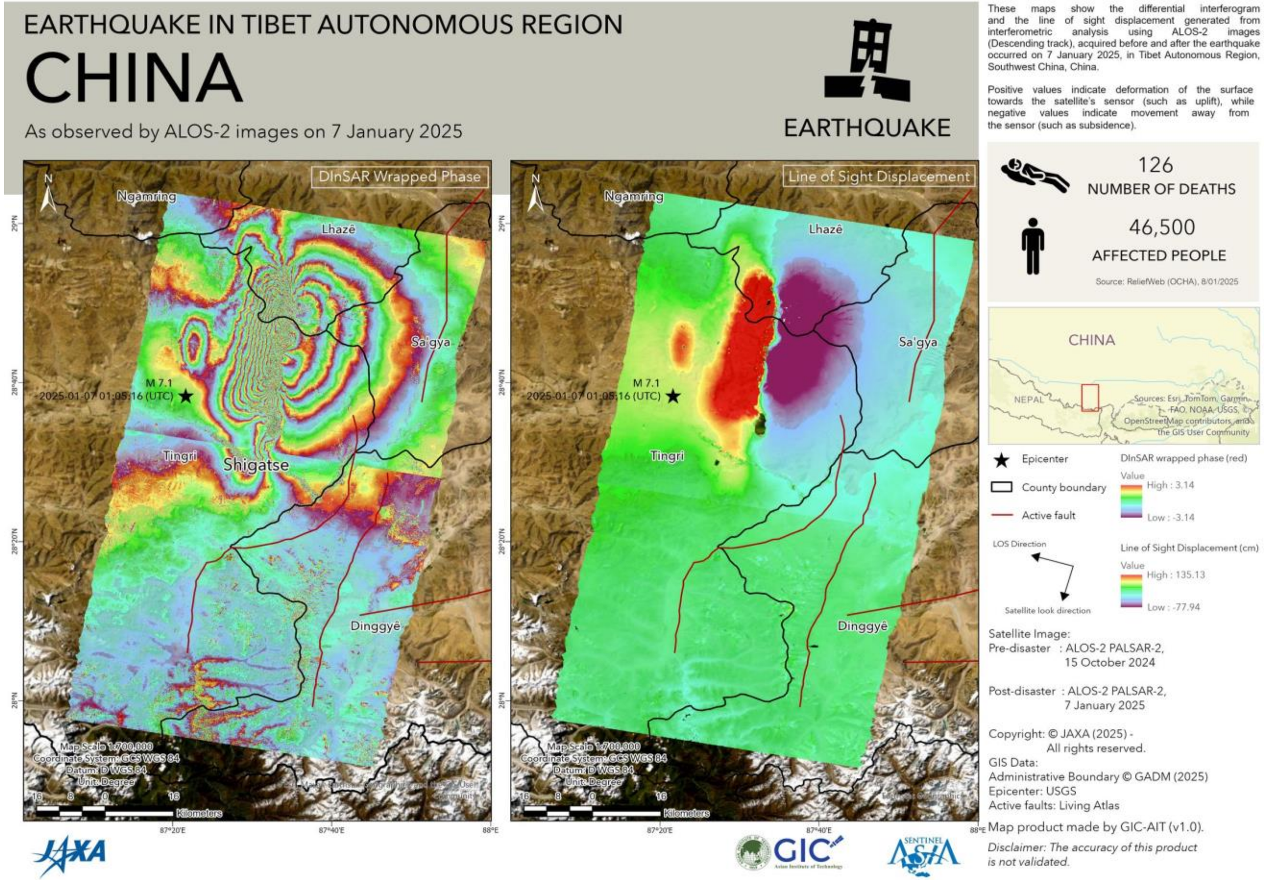
(https://disasterscharter.org/activations/earthquake-in-myanmar-activation-956-)

Sentinel Asia activation:

Earthquake in Mandalay, Myanmar
- 28 March 2025

Pleiades-1A

Case Study – Earthquake in China (SAR)



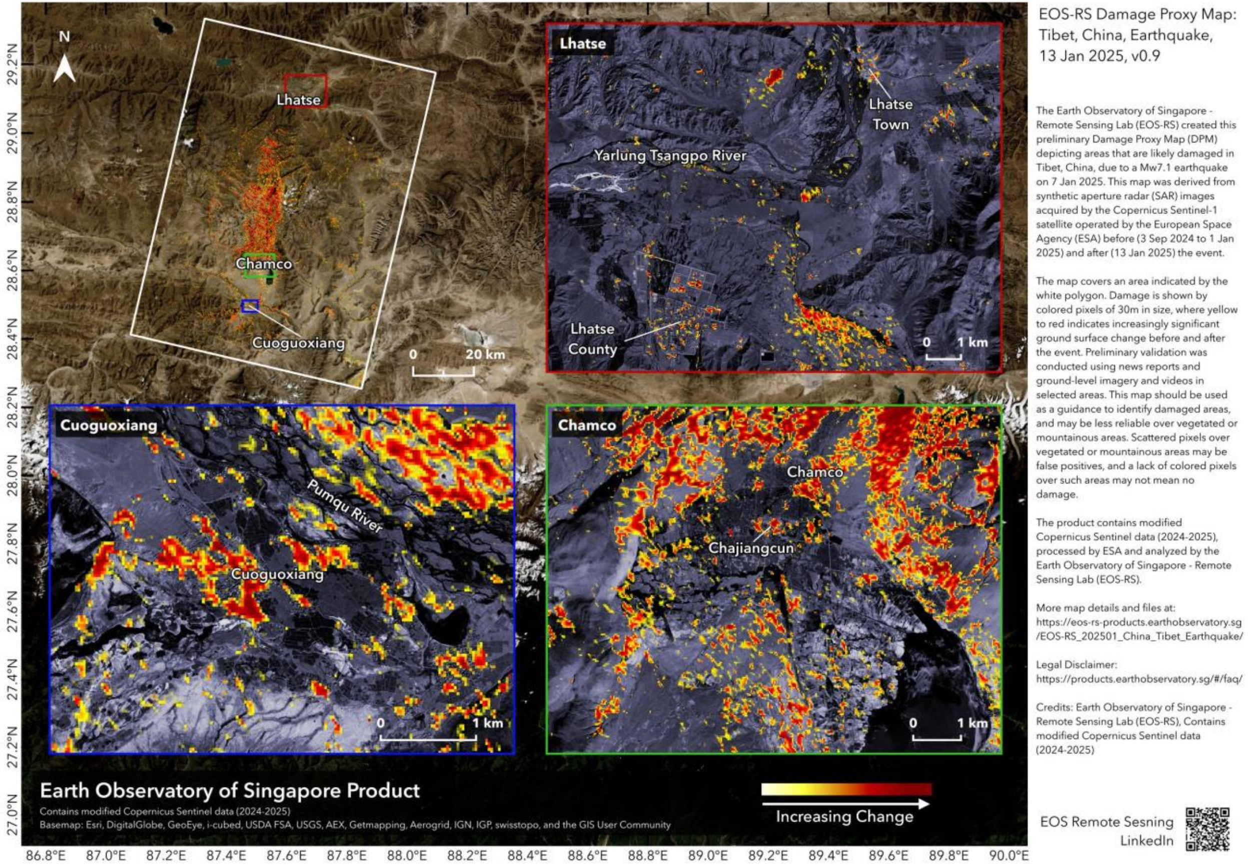
(https://sentinel-asia.org/EO/2025/article20250107CN.html)

Sentinel Asia activation:

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

ALOS-2 PALSAR-2

Case Study – Earthquake in China (SAR)



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

Sentinel Asia activation:

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

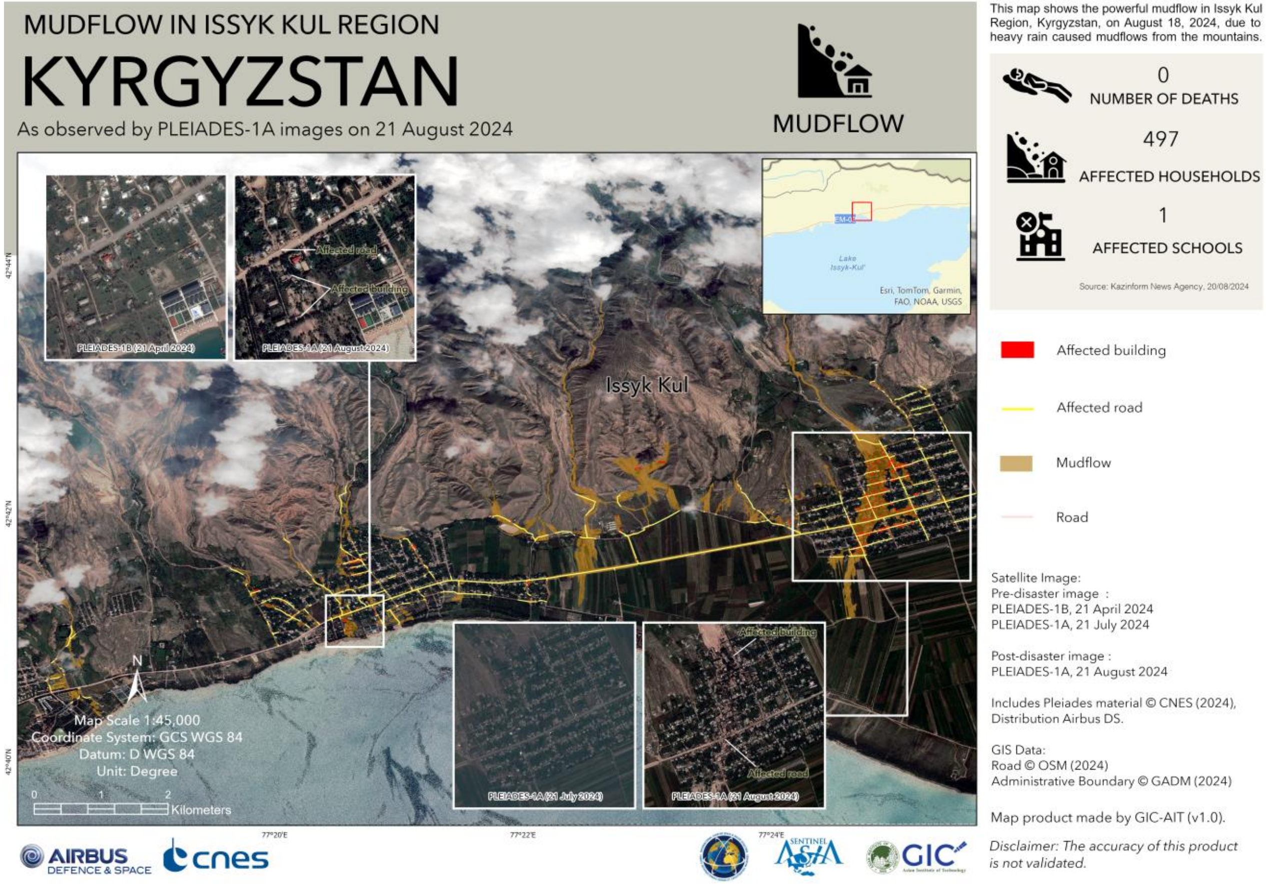
Sentinel-1

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)



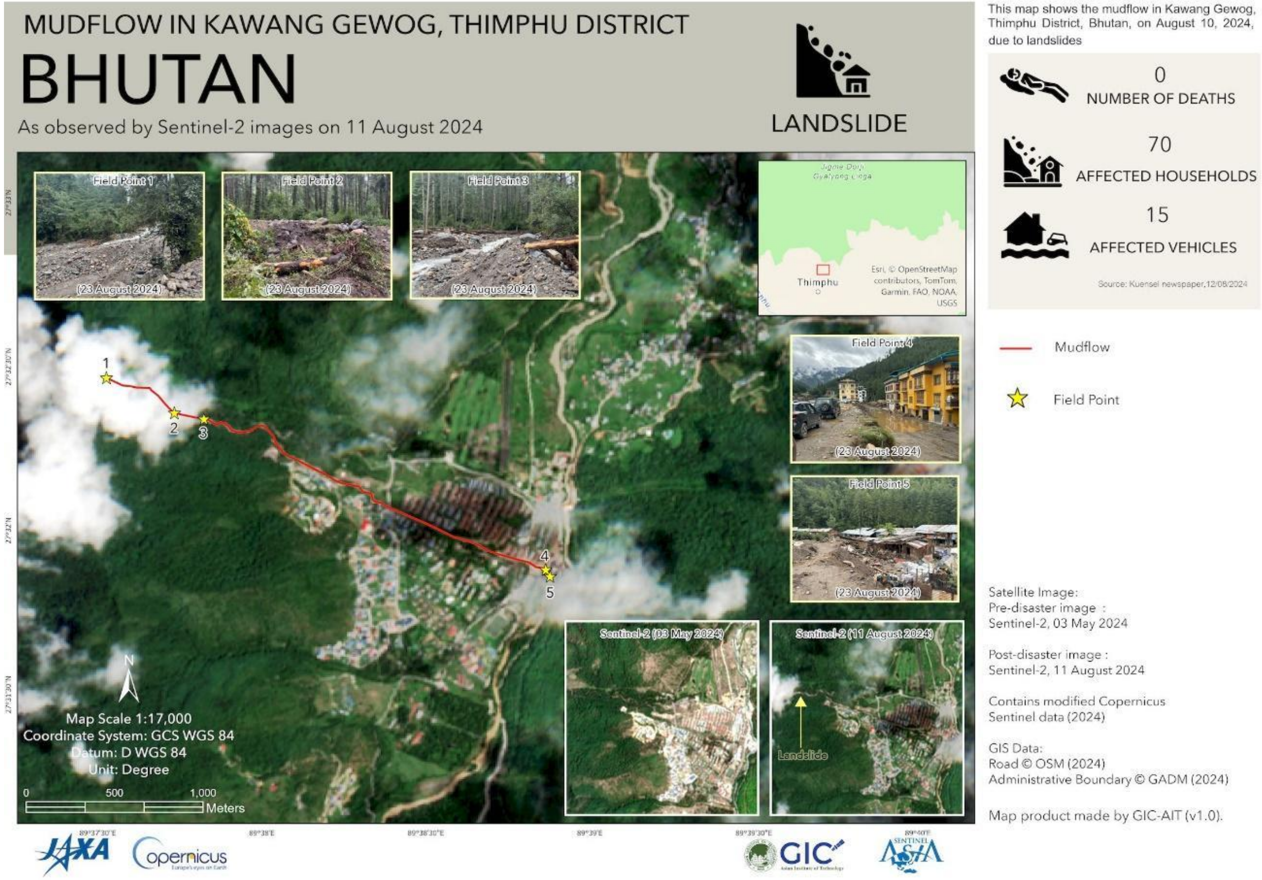
Sentinel Asia activation:

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

Pleiades-1A

(https://disasterscharter.org/activations/mudflow-in-kyrgyzstan-activation-902-)

Case Study – Mudflow in Bhutan (Optical)



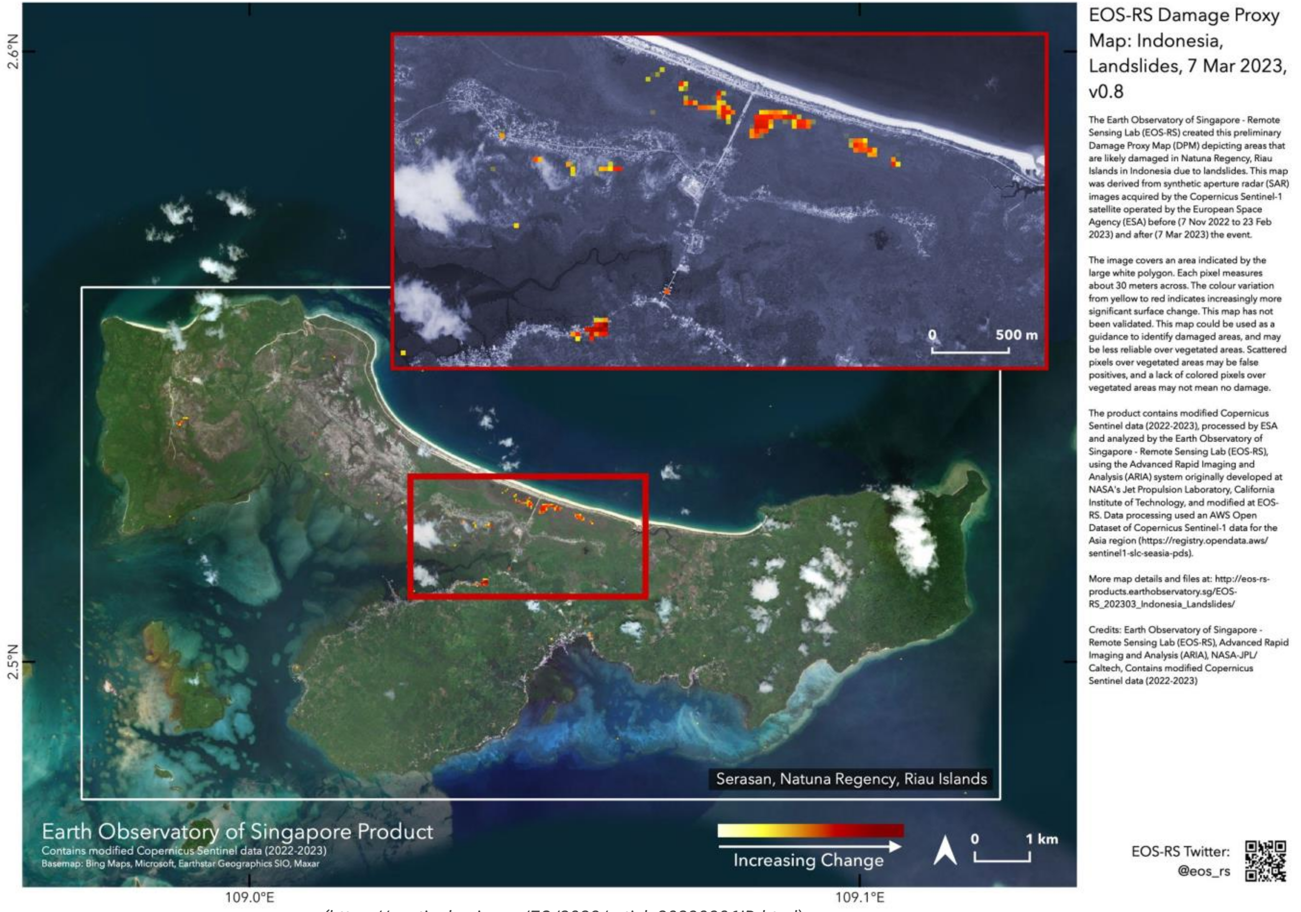
(https://sentinel-asia.org/EO/2024/article20240810BT.html)

Sentinel Asia activation:

Mudflow in Bhutan
(10 August 2024)

Sentinel-2

Case Study – Landslide in Indonesia (SAR)



(https://sentinel-asia.org/EO/2023/article20230306ID.html)

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)

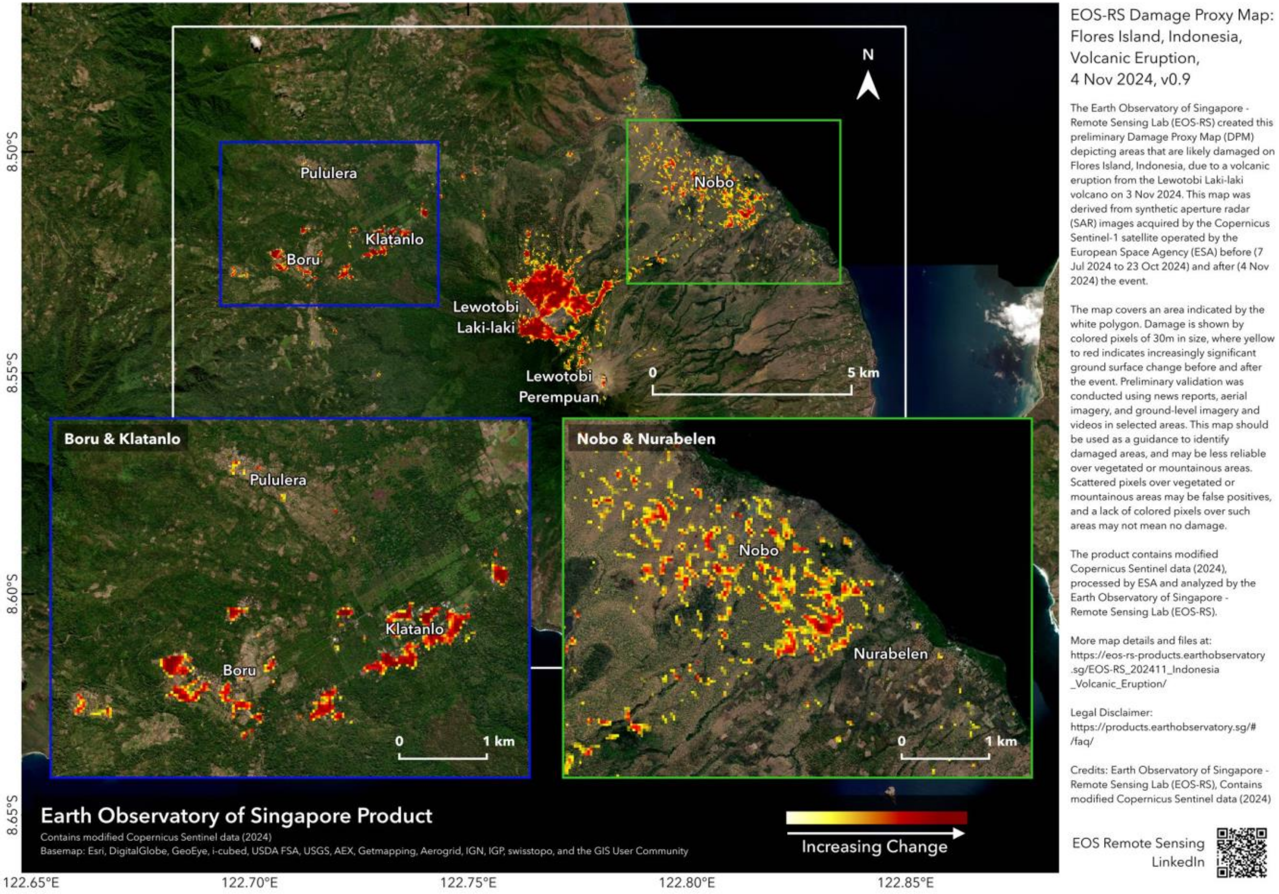
(https://sentinel-asia.org/EO/2024/article20241103ID.html)

Sentinel Asia activation:

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

Sentinel-2

Case Study – Volcano Eruption in Indonesia (SAR)



(https://sentinel-asia.org/EO/2024/article20241103ID.html)

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

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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