UNIVERSITY OF TABRIZ

東京工業大学
Tokyo Institute of Technology

Remote Sensing of Vulnerability: Damage Estimation of Kahramanmaras Earthquake in Turkiye, 2023

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CONTENT

- Remote Sensing: principles
- Review of past earthquakes studied by remote sensing
- Sentinel Asia mission for emergency response
- Kahramanmaras earthquake, damage mapping and field displacement

REMOTE SENSING OF VULNERABILITY

- Remote sensing of vulnerability (tectonic movements)

Earthquake vulnerability mapping through optical and synthetic aperture radar (SAR) imageries

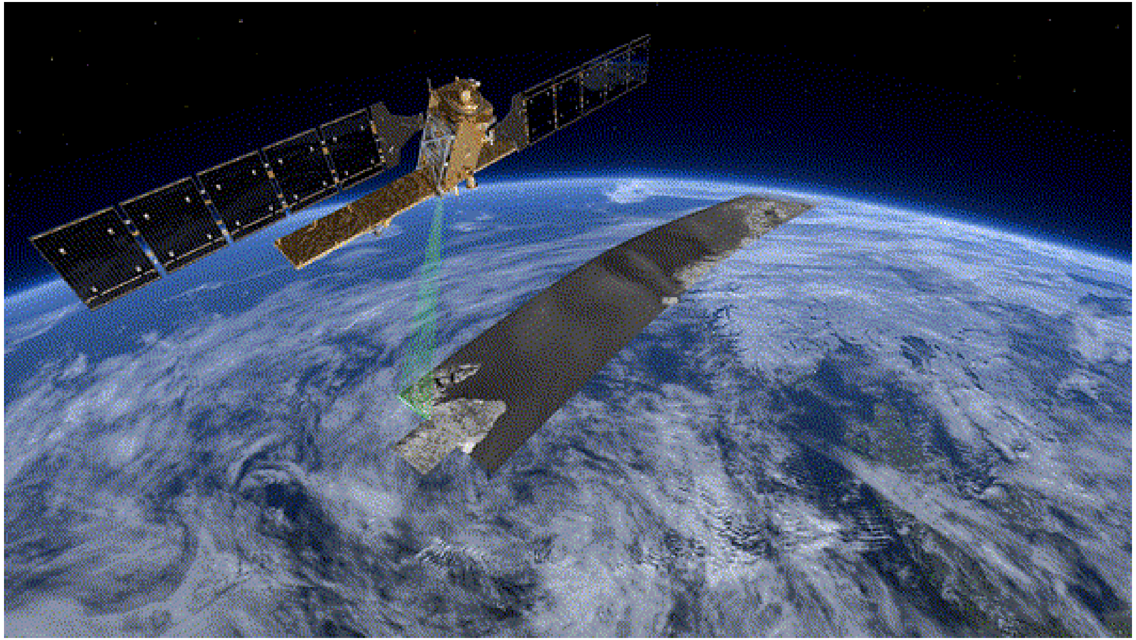
- Remote sensing of vulnerability (non-tectonic movements)

Soil consolidation

Land subsidence

REMOTE SENSING FOR MONITORING

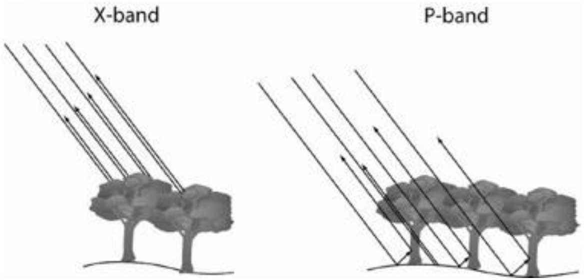
- High performance
- Fast actions
- Low labor work
- Cheaper

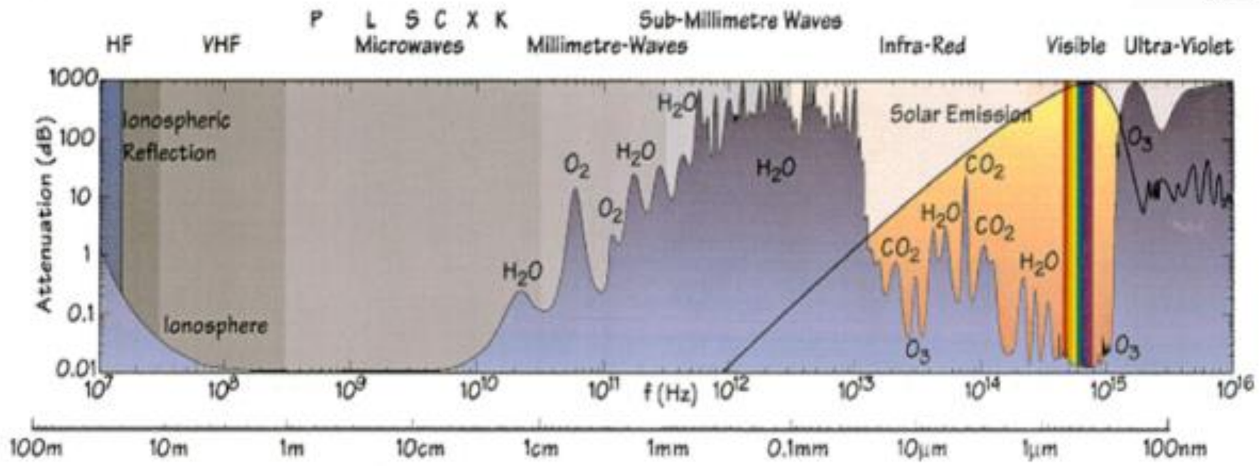


© ESA; Sentinel-1 image

ELECTROMAGNETIC WAVELENGTH OF OPTICAL AND SAR SENSORS

- **Radar wavelengths are considerably longer than visible wavelengths**
- **SAR sensors can be used in all-weather conditions**
- **Several different frequencies are used for radar**





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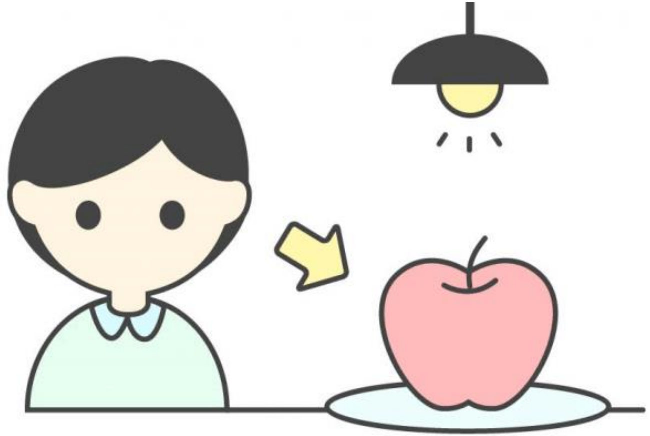
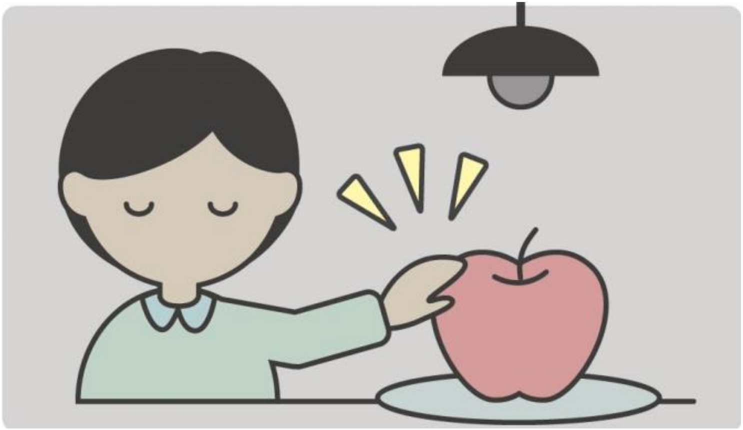
BEING PASSIVE OR ACTIVE!

Passive (Optical Imagery)



Active (SAR Imagery)



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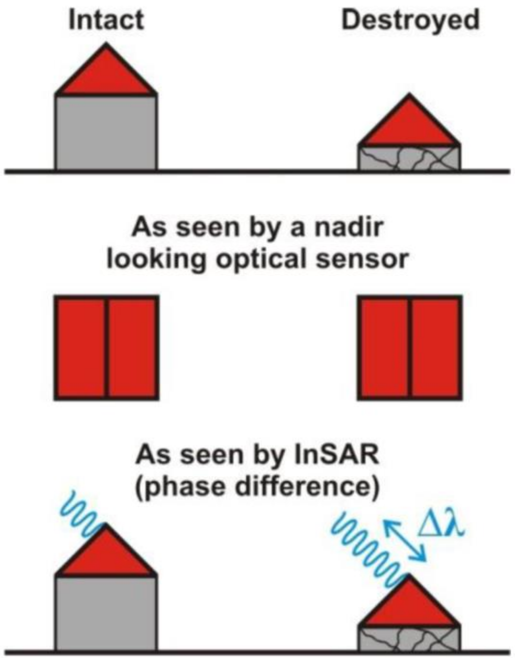
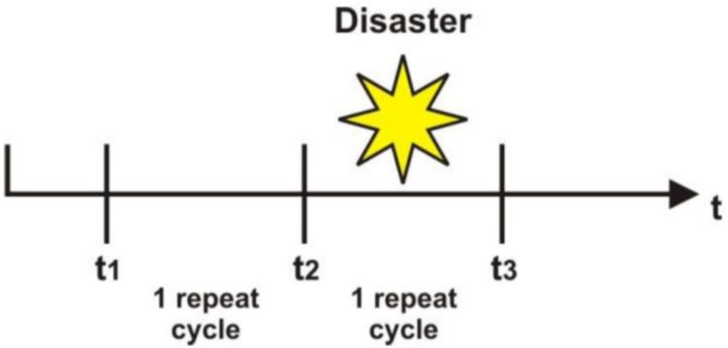
SAR DAMAGE ASSESSMENT CONCEPT





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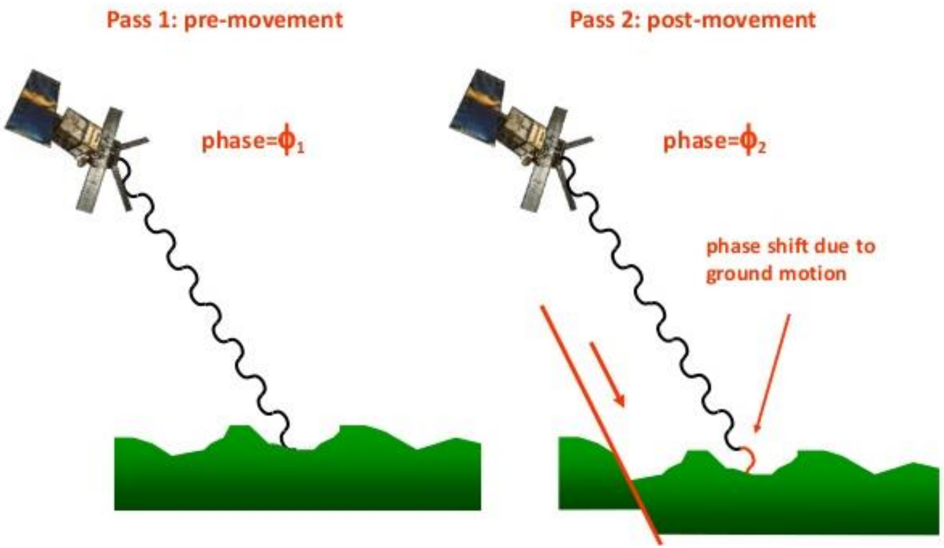
INTERFEROMETRIC SYNTHETIC APERTURE RADAR (INSAR)

- **All-weather tool**
- **Independent of day and night**
- **Useful tool to study geophysical events**
- **A practical tool for building damage estimation**



Phase correlation

Coherence

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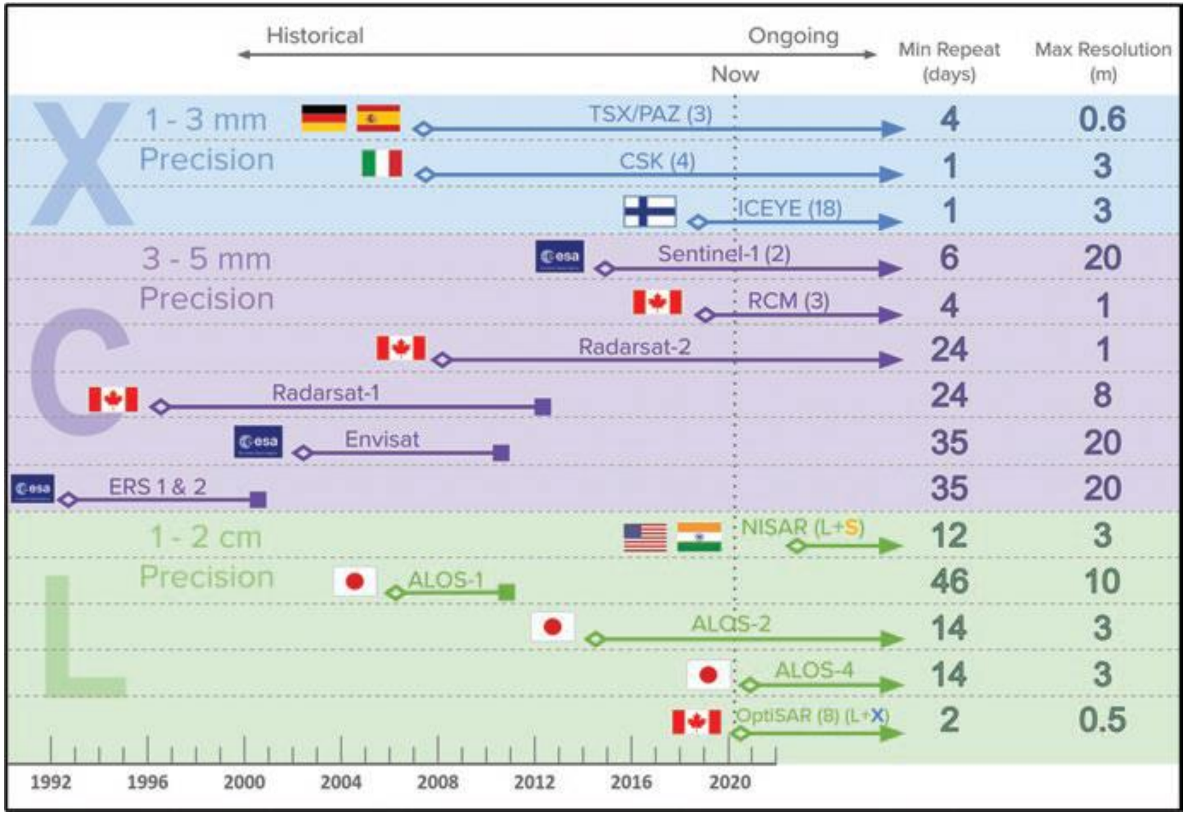
30 YEARS SAR MISSIONS!



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SAR REMOTE SENSING OF VULNERABILITY UNTIL 2011

Year	Earthquake	Country	Studies
1995	Kobe/Hyogokon-Nanbu	Japan	Ito *et al.* 2000 [95], Yonezawa and Takeuchi 1999 [76], Yonezawa and Takeuchi 2001 [84], Ito and Hosokawa 2002 [96], Matsuoka and Yamazaki 1999 [97], Matsuoka and Yamazaki 2000 [73], Yonezawa *et al.* 2002 [98], Matsuoka and Yamazaki 2004 [99], Matsuoka and Yamazaki 2005 [101], Matsuoka and Nojima 2010 [101]
1999	Kocaeli/Gölcük	Turkey	Matsuoka and Yamazaki 2000 [73], Matsuoka and Yamazaki 2002 [102], Ito *et al.* 2003 [103], Trianni *et al.* 2010 [104]
1999	Izmit	Turkey	Bignami *et al.* 2004 [7], Stramondo *et al.* 2006 [78], Trianni and Gamba 2009 [105], Trianni *et al.* 2010 [104]
1999	Chi-Chi/Great Taiwan	Taiwan	Takeuchi *et al.* 2000 [77], Suga *et al.* 2001 [92]
2001	Gujarat	India	Matsuoka and Yamazaki 2002 [102], Yonezawa *et al.* 2002 [98]
2003	Boumerdes	Algeria	Trianni and Gamba 2008 [2]
2003	Bam	Iran	Bignami *et al.* 2004 [7], Arciniegas 2005 [106], Fielding *et al.* 2005 [107], Matsuoka and Yamazaki 2005 [100], Stramondo *et al.* 2006 [78], Arciniegas *et al.* 2007 [8], Gamba *et al.* 2007 [94], Hoffmann 2007 [74], Brunner *et al.* 2010 [108], Trianni *et al.* 2010 [104]
2004	Sumatra	Indonesia	Chini *et al.* 2008 [9]
2006	Mid Java	Indonesia	Matsuoka and Yamazaki 2004 [99], Matsuoka and Yamazaki 2006 [109], Brunner *et al.* 2010 [108]
2007	Pisco	Peru	Trianni and Gamba 2008 [2]
2007	Chincha	Peru	Matsuoka and Nojima 2010 [101]
2008	Wenchuan	China	Balz *et al.* 2009 [110], Wang and Jin 2009 [111], Balz and Lia 2010 [112], Pan and Tang 2010 [113]
2009	L'Aquila	Italy	Guida *et al.* 2010 [114], Dell'Acqua *et al.* 2011 [115], Cossu *et al.* 2012 [116], Dell'Acqua and Gamba 2012 [24], Dell'Acqua *et al.* 2013 [117], Brett and Guida 2013 [118]
2009	Sumatra	Indonesia	Christophe *et al.* 2010 [21], Kawamura *et al.* 2011 [119]
2010	Haiti	Haiti	Uprety and Yamazaki 2012 [10], Brett and Guida 2013 [118]
2010	Yushu County	China	Jin *et al.* 2011 [120]
2011	Tohoku	Japan	Chini *et al.* 2013 [121]

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SAR REMOTE SENSING FOR VULNERABILITY (2011-2021)

- My personal research activity

Year	Earthquake	Country	Studies
2012	Ahar-Varzaghan	Iran	Karimzadeh et al., 2017
2016	Amatrice	Italy	Karimzadeh and Matsuoka 2017; Karimzadeh and Matsuoka 2018
2016	Kumamoto	Japan	Hajeb et al., 2019
2017	Kermanshah	Iran	Karimzadeh et al., 2018; Hajeb et al., 2020; Omarzadeh et al., 2021;
2018	Eastern Iburi	Japan	Karimzadeh and Matsuoka 2018
2020	Petrinja	Croatia	Karimzadeh and Matsuoka 2021

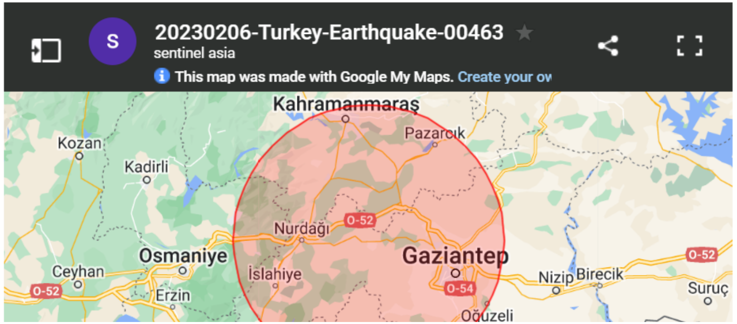
DAMAGE MAPPING IN COLLABORATION WITH SENTINEL ASIA

Sentinel Asia

2023-02-06

Earthquake in Turkey on 06 February, 2023

Emergency Obs. Request Information



Disaster Type: Earthquake

Country: Turkey

Occurrence Date (UTC): 06 February, 2023

SA activation Date(UTC): 06 February, 2023

Requester: Disaster & Emergency Management Presidency of Turkey (AFAD)

Escalation to the International Charter: No

GLIDE Number: EQ-2023-000015-TUR

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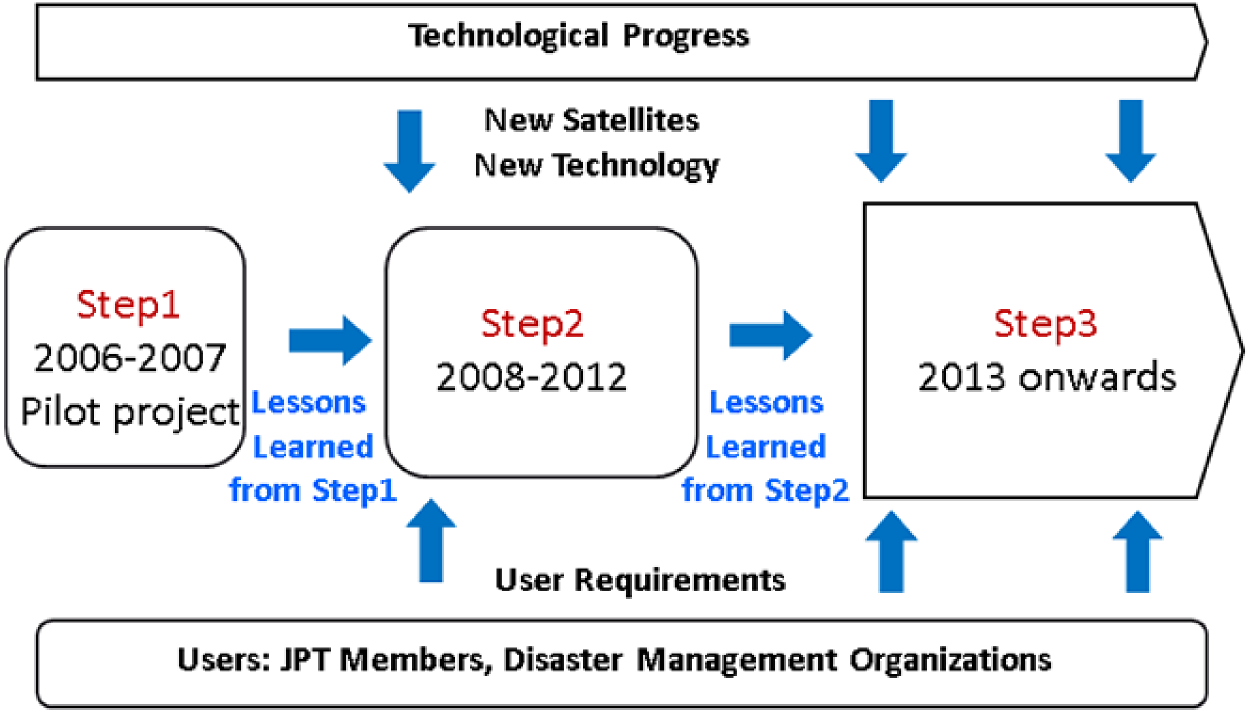
SENTINEL ASIA FRAMEWORK



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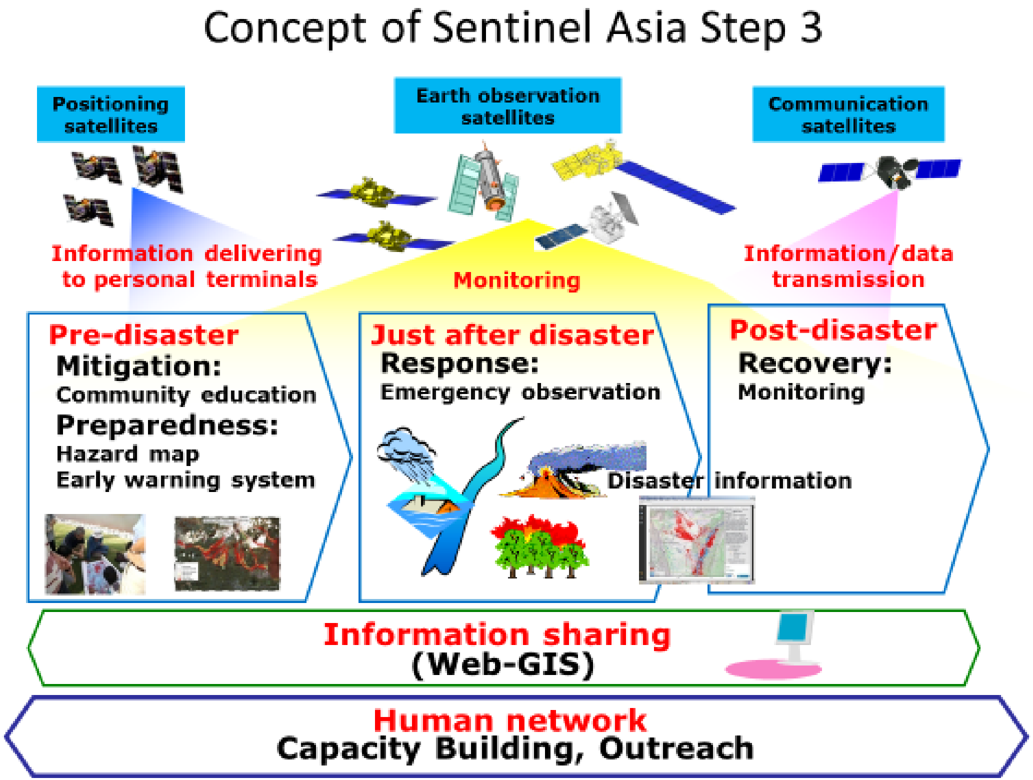
SENTINEL ASIA FRAMEWORK



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BACKGROUND AND OBJECTIVE-1

- The earthquakes that struck southeastern Turkey on February 6, 2023, caused extensive damage in Turkey and Syria. Because of the large extent of the damage, the damage information reported from the affected areas after the earthquake did not provide a complete picture of the damage situation, and observation images from satellites equipped with high-resolution optical sensors only cover a limited number of cities. The images are affected by weather conditions, and therefore, the damage situation could not be grasped uniformly.
- One of the observation modes of the weather-independent synthetic aperture radar (SAR)-equipped satellites is the wide-area observation function (ScanSAR). Since the affected areas were observed on February 17 and 20 after the earthquake, we examine here whether the damage to buildings could be estimated from PALSAR-2 ScanSAR imagery whose spatial resolution is rather coarse (approx. 30 m).
- Although these images were taken more than 10 days after the earthquake and include not only the immediate post-earthquake situation but also disaster relief activities, we believe that the results provide basic data to demonstrate the effectiveness of the wide-area observation mode in understanding huge disasters such as this event.

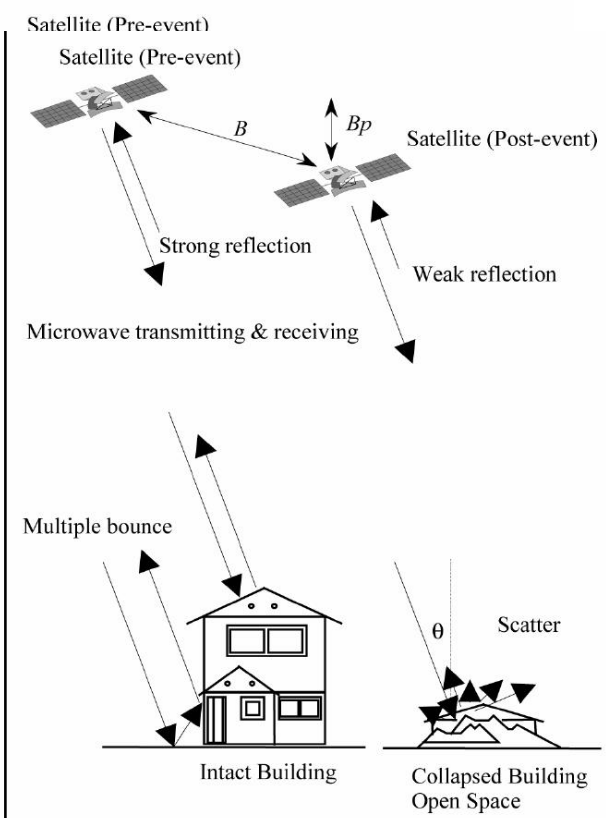
BASIC APPROACH FOR DAMAGE ESTIMATION FROM SAR INTENSITY

- ✓ Image matching
- ✓ Speckle noise filtering
- ✓ Calculating following indices,
  - ✓ Difference of backscattering coefficient (after – before)

    damage < *no damage*

  - ✓ Correlation coefficient

    damage < *no damage*



BACKGROUND AND OBJECTIVE-2

- We already developed C- and L-bands SAR-based damage estimation models with integration of seismic intensity information based on satellite images observed the 1995 Kobe earthquake and its detailed ground truth data (Nojima et al., 2006; Matsuoka and Nojima, 2010) .

- We also developed a discriminant equation for damage estimation with integration of phase and intensity information and its detailed ground truth data for Amatrice (2016) and Kermanshah (2017) earthquakes (Karimzadeh and Matsuoka 2016; Karimzadeh et al., 2018).

- Since these studies have included models (Likelihood Functions) that estimate severe building damage rates from SAR images only, we applied the L-band SAR model to the in Turkey-Syria earthquakes.

能島暢呂，松岡昌志，杉戸真太，江崎賢一：地震動情報と人工衛星SAR画像情報の統合処理による建物全壊率の定量 的推定手法の開発，土木学会論文集A, Vol.62, No.4, pp.808-821, 2006.10.
Matsuoka, M., Nojima, N.: Building Damage Estimation by Integration of Seismic Intensity Information and Satellite L-band SAR Imagery, Remote Sensing, Vol.2, No.9, pp.2111-2126, 2010.9.

Karimzadeh, S., Matsuoka, M., 2017. Building Damage Assessment Using Multisensor Dual-Polarized Synthetic Aperture Radar Data for the 2016 M 6.2 Amatrice Earthquake, Italy. *Remote Sensing, MDPI,* 9(4). doi: 10.3390/rs9040330.

Karimzadeh, S., Matsuoka, M., Miyajima, M., Adriano, B., Fallahi, A., Karashi, J., 2018. Sequential SAR Coherence Method for the Monitoring of Buildings in Sarpole-Zahab, Iran, *Remote Sensing, MDPI*, 10, 1255, doi:10.3390/rs10081255.

METHODOLOGY

- Variable: SAR intensity difference and correlation

- Procedure: pixel selection for seven damage classes (severe damage ratio) to examine the relationship between indices and damage classes, and proposing following two functions:

– Combined index, *ZR*, (discriminant score) from Regression discriminant function

– Likelihood function (fragility function) to estimate severe damage ratio from *ZR*

DISCRIMINANT SCORE AND LIKELIHOOD FUNCTIONS

ERS-1 (C-band)

Z_R = -1.210 d – 4.360 r

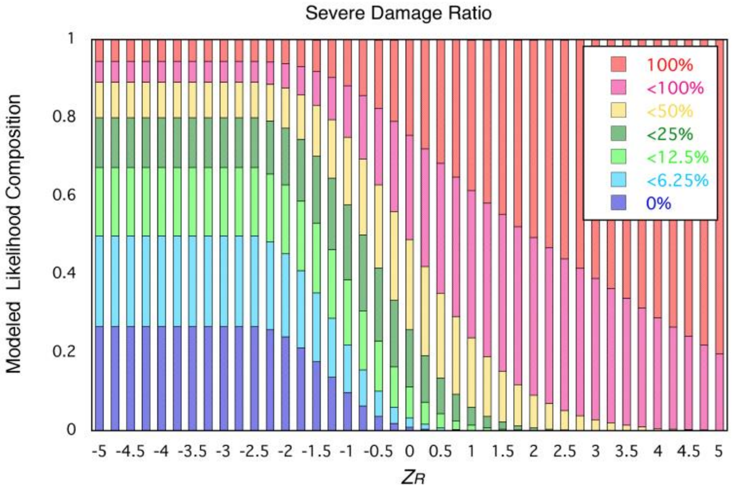
JERS-1 (L-band)

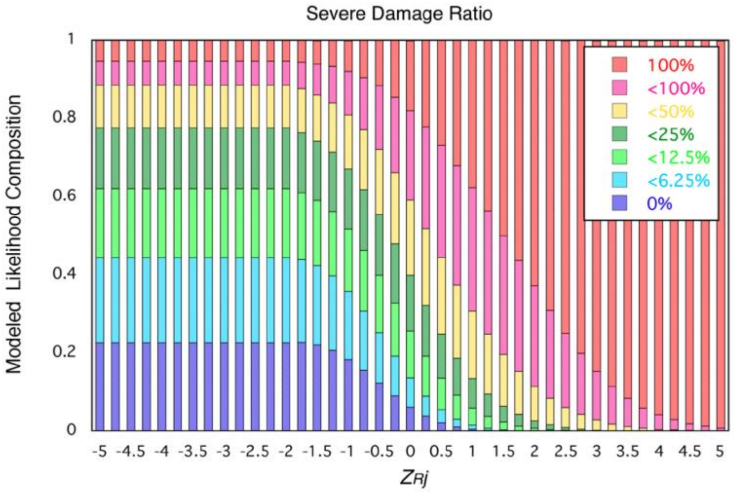
Z_{Rj} = -1.277 d – 2.729 r

Z_R , Z_{Rj} : discriminant score

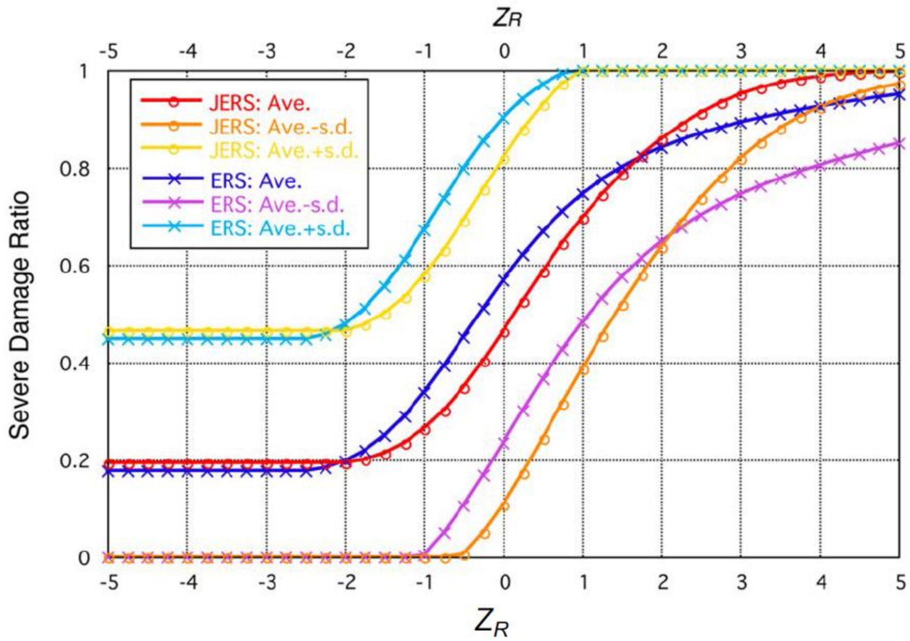
d: intensity difference

r: correlation



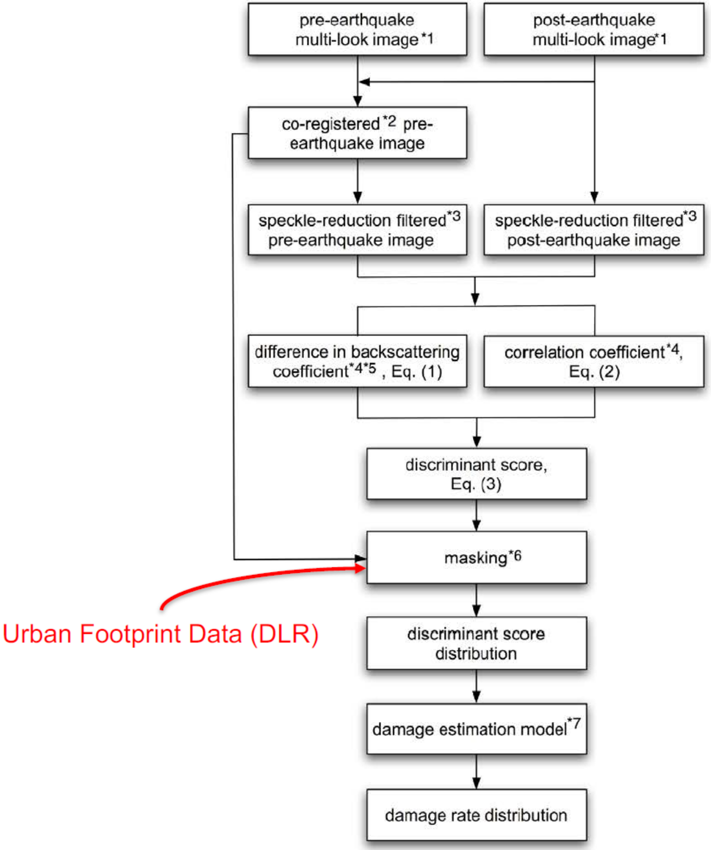


RELATIONSHIP BETWEEN Z_R AND DAMAGE RATIO



This curve is equivalent to the fragility function for damage without seismic intensity information, the severe damage ratio increases with increasing Z_R

FLOWCHART OF DAMAGE ESTIMATION



Equation:

$$d = 10 \cdot \log_{10} \bar{I}a_i - 10 \cdot \log_{10} \bar{I}b_i \qquad (1)$$

$$r = \frac{N\sum_{i=1}^{N} Ia_i Ib_i - \sum_{i=1}^{N} Ia_i \sum_{i=1}^{N} Ib_i}{\sqrt{\left(N\sum_{i=1}^{N} Ia_i^2 - \left(\sum_{i=1}^{N} Ia_i\right)^2\right) \cdot \left(N\sum_{i=1}^{N} Ib_i^2 - \left(\sum_{i=1}^{N} Ib_i\right)^2\right)}} \qquad (2)$$

$$\begin{aligned} z_R &= -1.210\, d - 4.360\, r \quad \textit{for ERS} \\ z_R &= -1.277\, d - 2.729\, r \quad \textit{for JERS} \end{aligned} \qquad (3)$$

where i is the sample number, and Ia_i and Ib_i are the digital numbers of the post- and pre-images, respectively. $\bar{I}a_i$ and $\bar{I}b_i$ are the corresponding averaged digital numbers over the surroundings of pixel i within a 13 × 13 pixel window; the total number of pixels N within this window is 169.

Note:

*1 Pixel size: Equal to the size of spatial resolution of satellite's sensor
Pixel value: Power

*2 Tie point selection: Correlation method
Registration: Affine transformation

*3 Filter type: Lee filter
Window size: 21 x 21 pixel

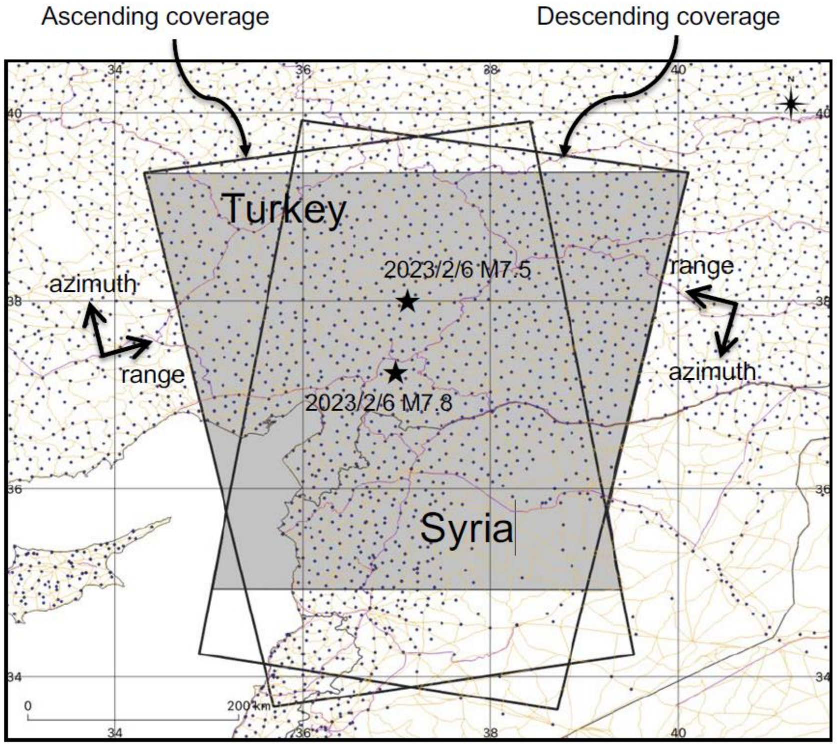
*4 Window size: 13 x 13 pixel

*5 Difference (post - pre): Average value within a window

*6 Threshold: approx. < -5dB of pre-earthquake SAR image

*7 Model: Likelihood functions for building damage estimation based on the dataset from the 1995 Kobe earthquake

PALSAR-2 SCANSAR IMAGERY



Swath width and study area

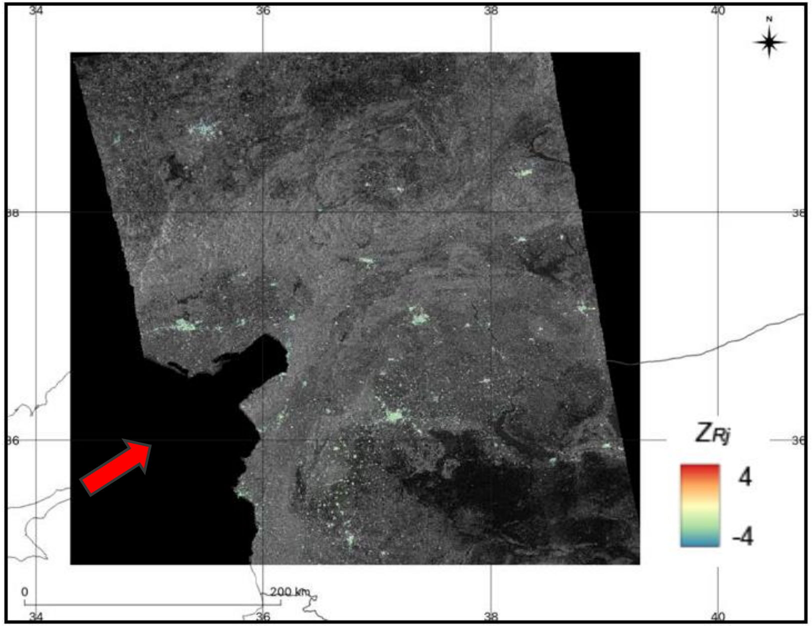
Acquisition date and specifications

Date	Path	Beam	Look	Orbit
2022/9/5	184	W2	R	Asc.
2022/9/16	77	W2	R	Des.
2023/2/17	77	W2	R	Des.
2023/2/20	184	W2	R	Asc.

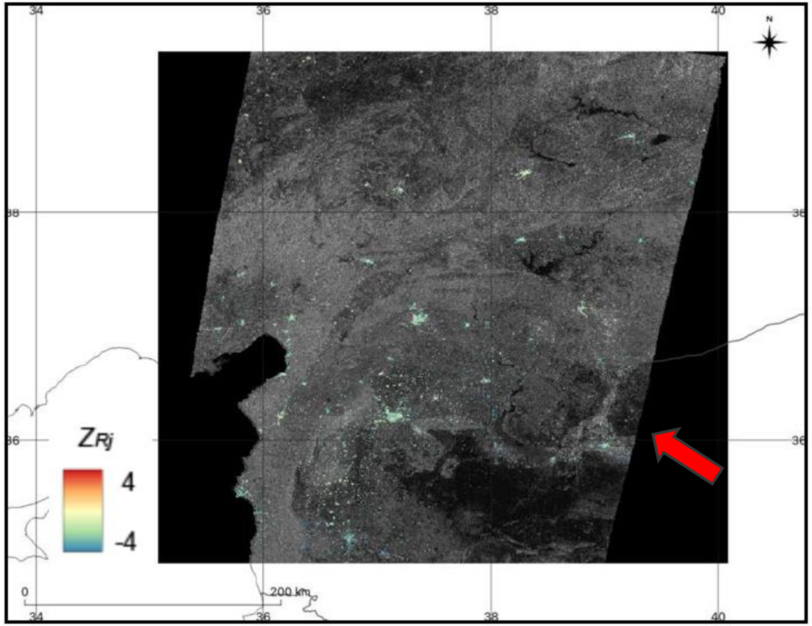
Spatial resolution: approx. 30 m
Polarization: HH

Building damage estimation for each pre- and post-earthquake pair of ascending and descending orbits, respectively.

DISCRIMINANT SCORE Z_{RJ} MAP

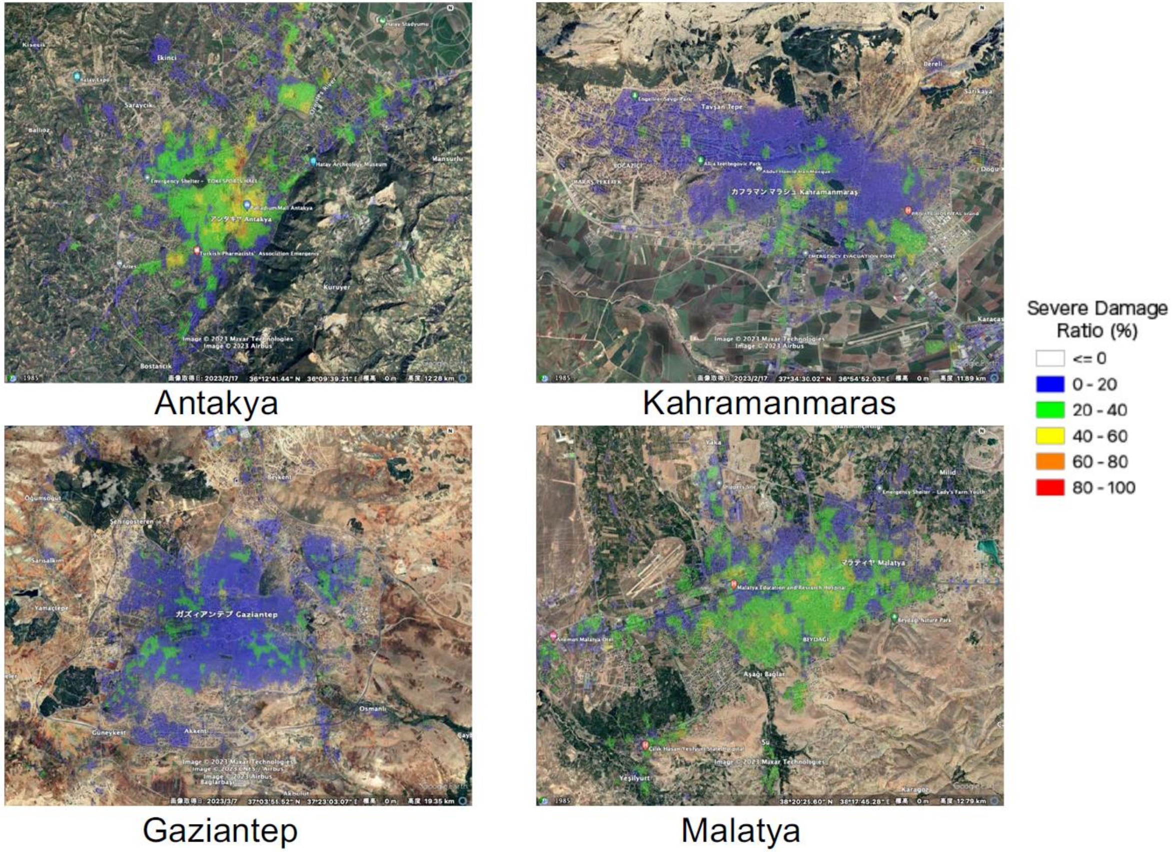


Ascending pair

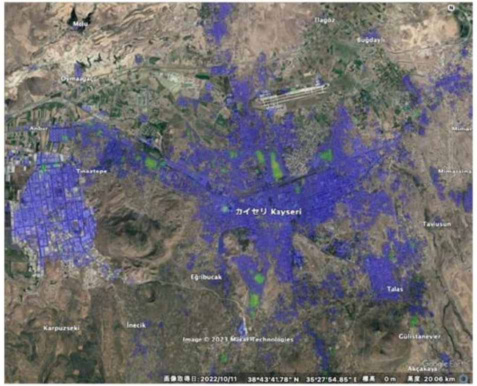


Descending pair

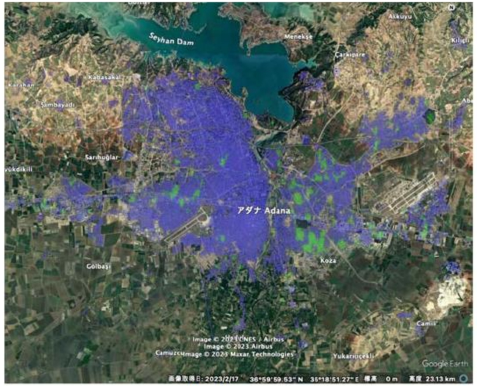
DAMAGE PROXY MAP (DAMAGE RATIO)



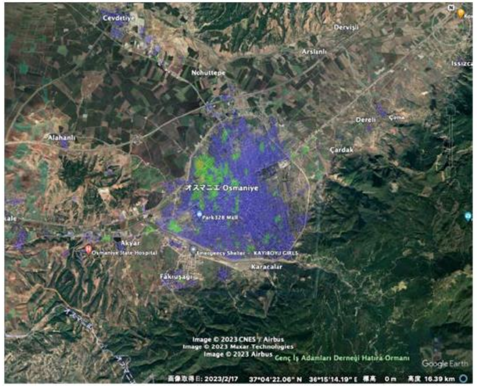
DAMAGE PROXY MAP (DAMAGE RATIO)



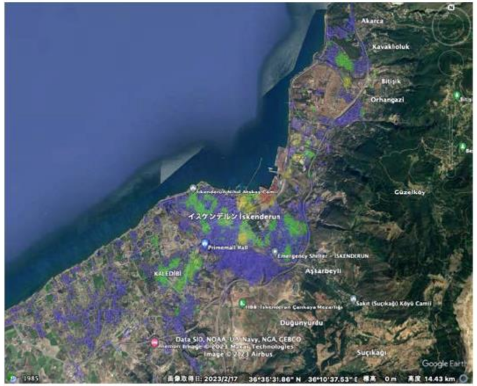
Kayseri



Adana



Osmaniye

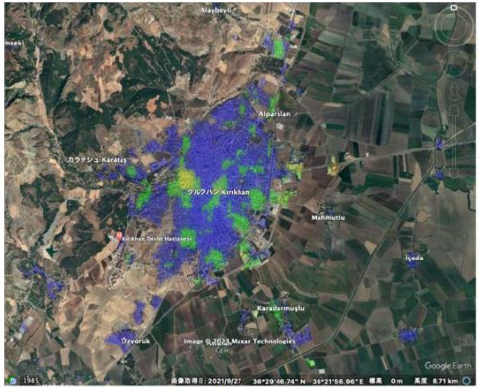


Iskenderun

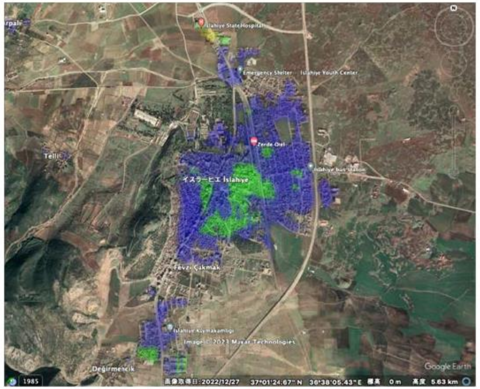
Severe Damage Ratio (%)

- <= 0
- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100

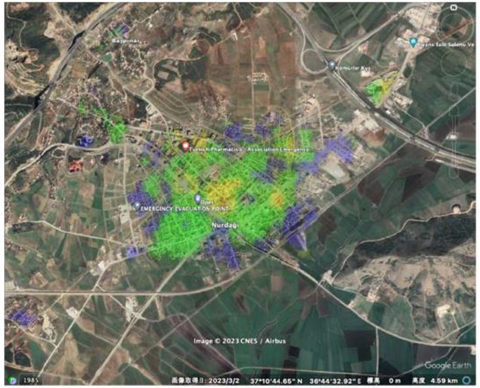
DAMAGE PROXY MAP (DAMAGE RATIO)



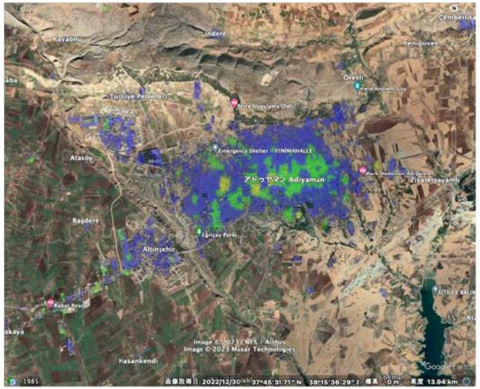
Kirikhan



Islahiye



Nurdagi

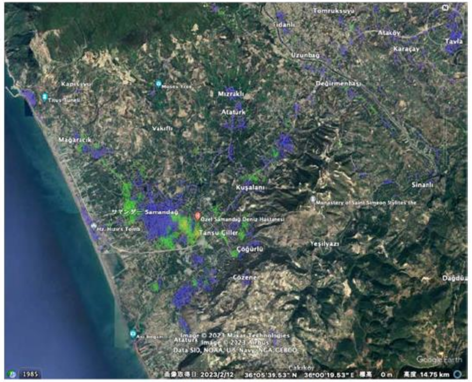


Adiyaman

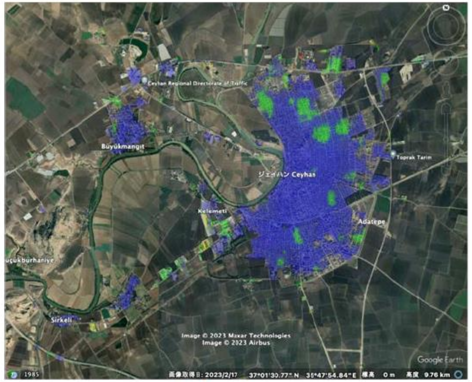
Severe Damage Ratio (%)

- <= 0
- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100

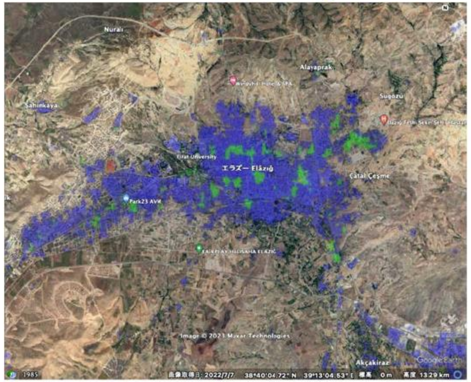
DAMAGE PROXY MAP (DAMAGE RATIO)



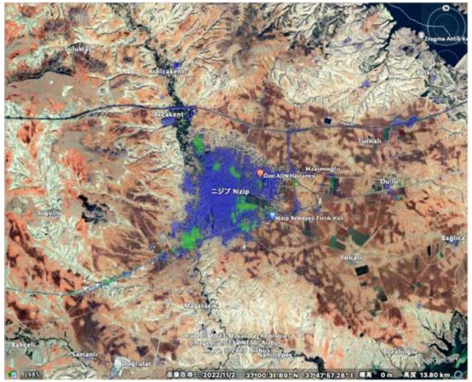
Samandag



Ceyhan



Elazig

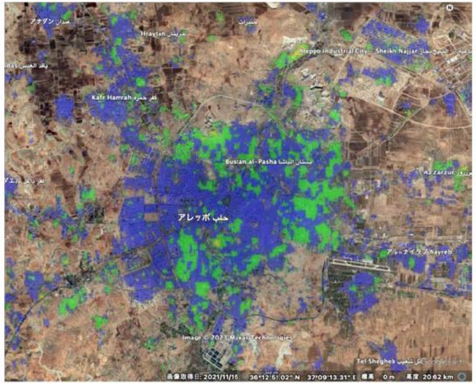


Nizip

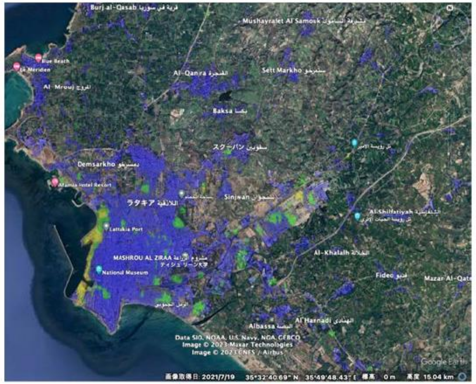
Severe Damage Ratio (%)

- <= 0
- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100

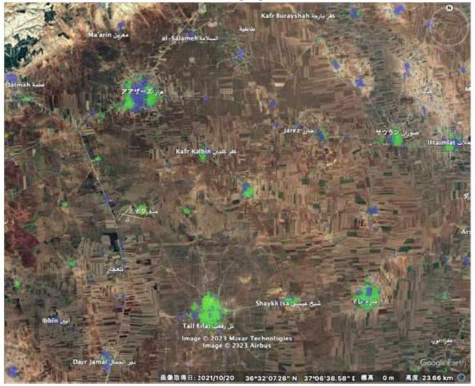
DAMAGE PROXY MAP (DAMAGE RATIO)



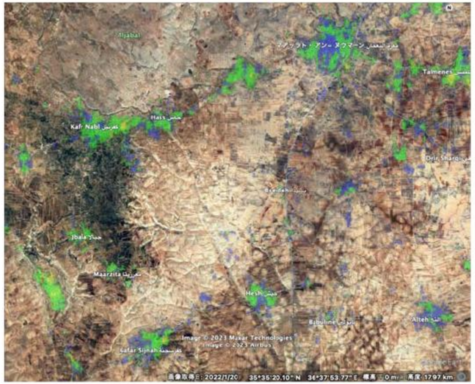
Aleppo



Latakia



Northern area of Aleppo



Eastern arae of Latakia

Syria

Severe Damage Ratio (%)

- <= 0
- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100

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WIDE-AREA DAMAGE PROXY MAPPING BY ALOS-2 SCANSAR IMAGERY ACQUIRED AFTER THE 2023 TURKEY EARTHQUAKES

M. Matsuoka[1], F. Ogushi[2], N. Nojima[3] & S. Karimzadeh[4]

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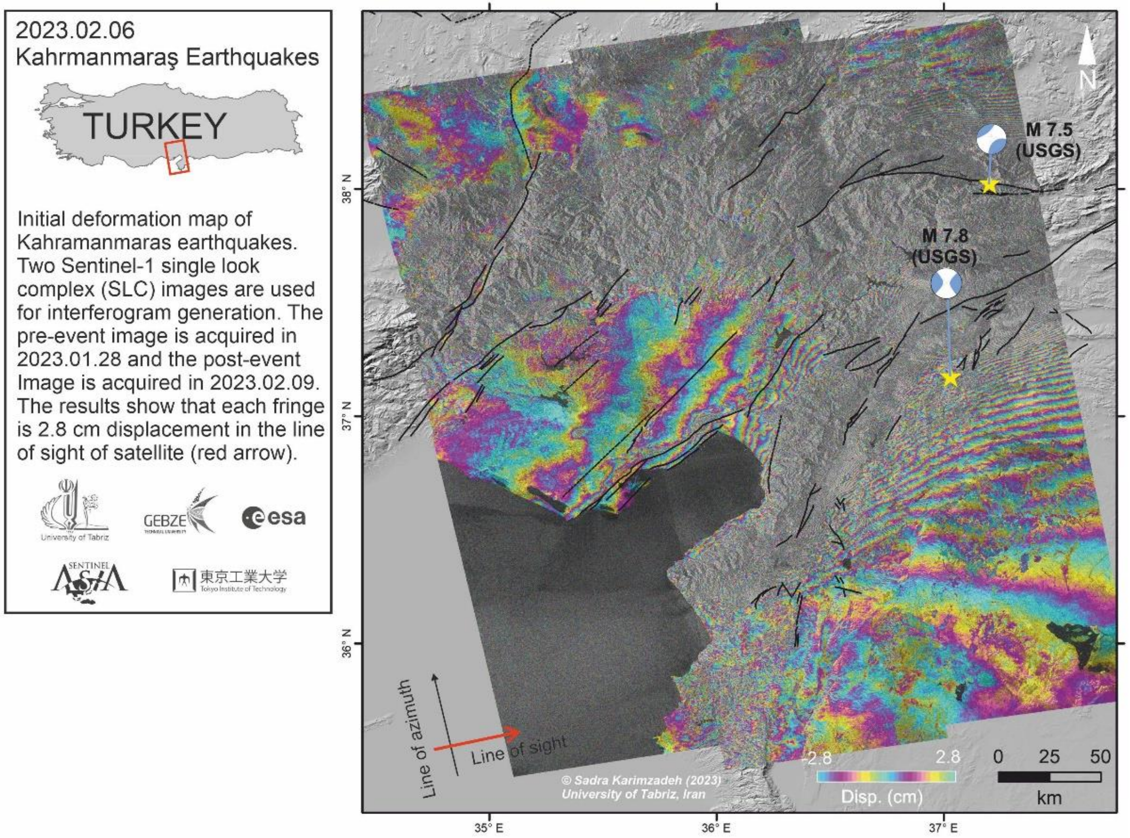
[2] Terra Phase, Inc., Yokohama, Japan

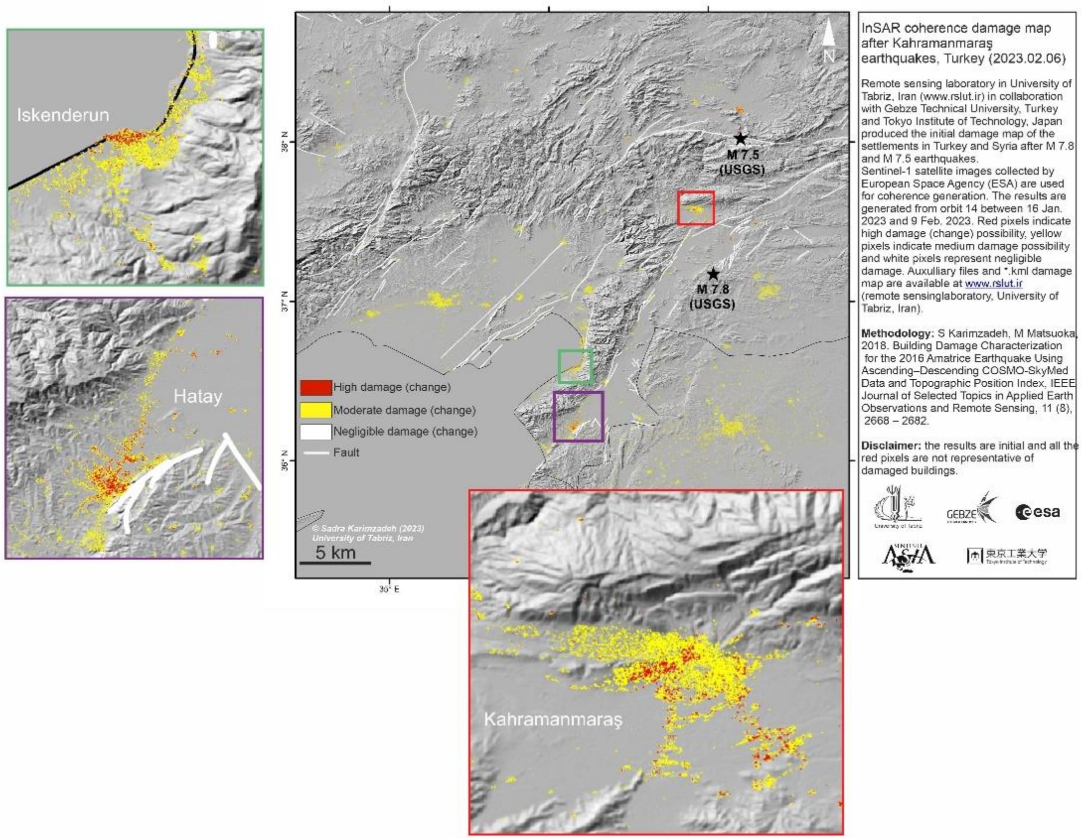
[3] Gifu University, Gifu, Japan

[4] University of Tabriz, Tabriz, Iran

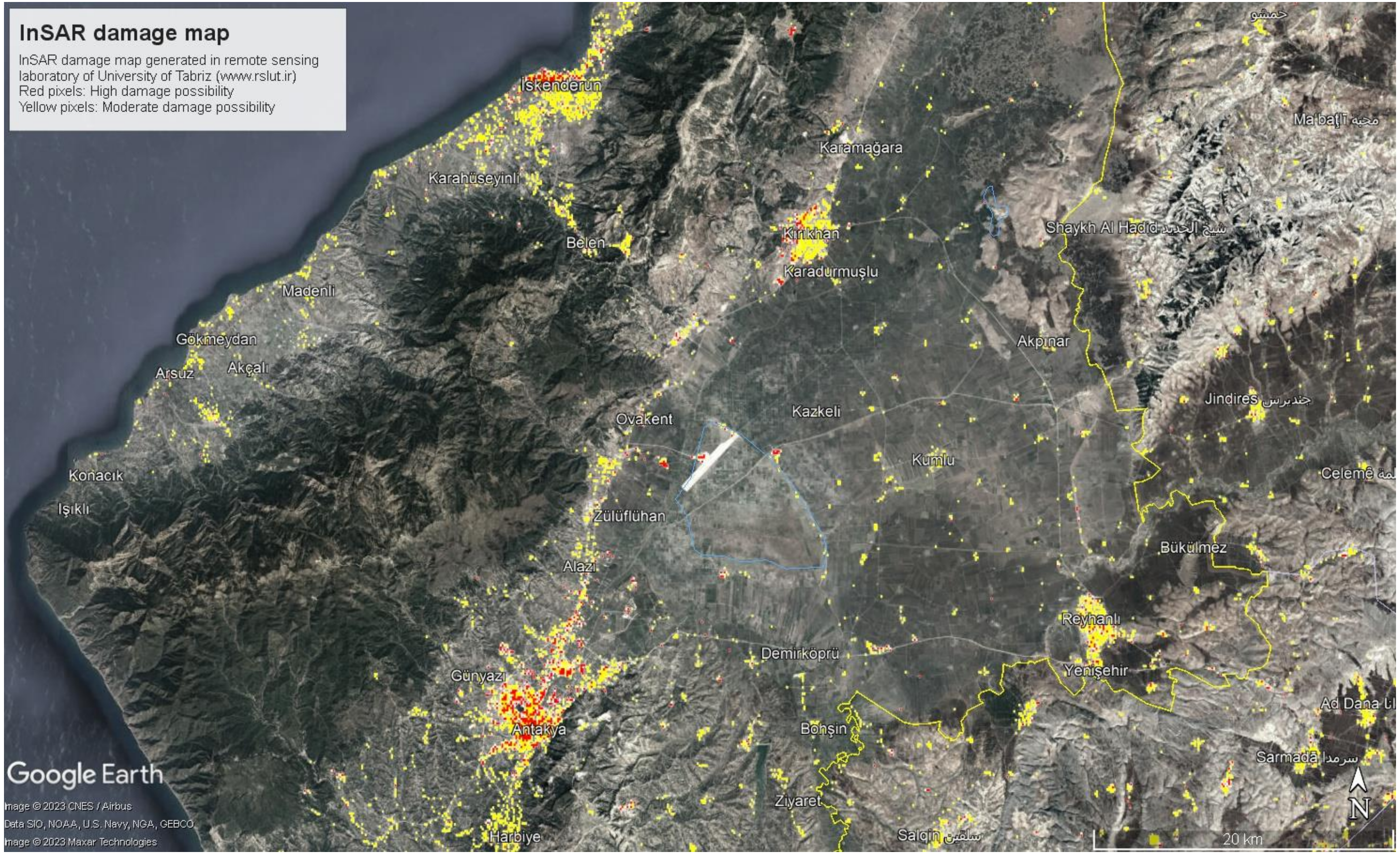
KAHRAMANMARAS SENTINEL-1 INTERFEROGRAM



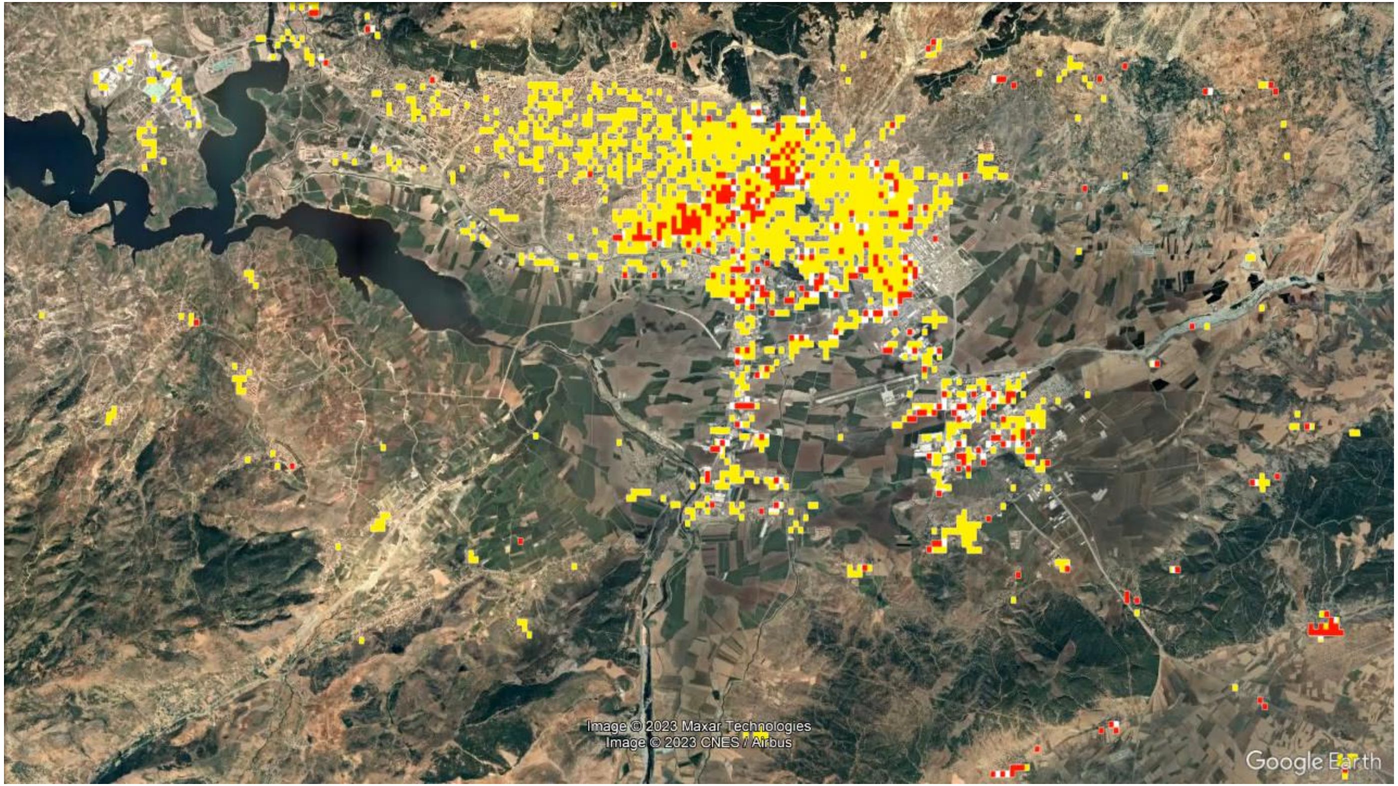
DAMAGE PROXY MAP FROM SENTINEL-1



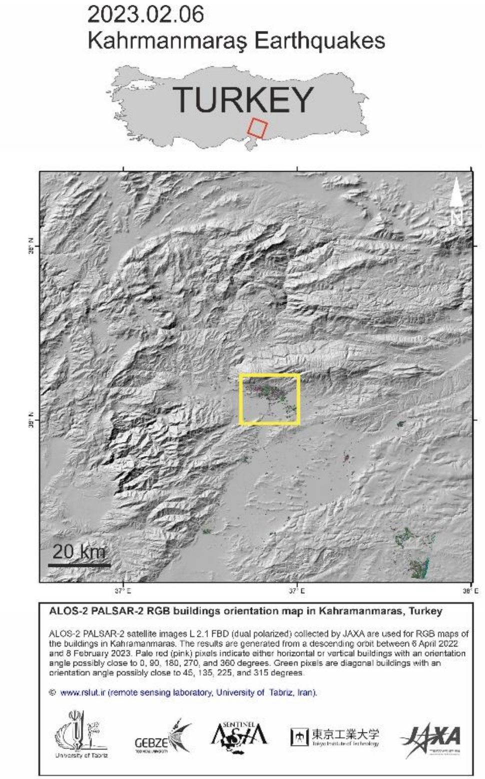
DAMAGE PROXY MAP OVER HATAY

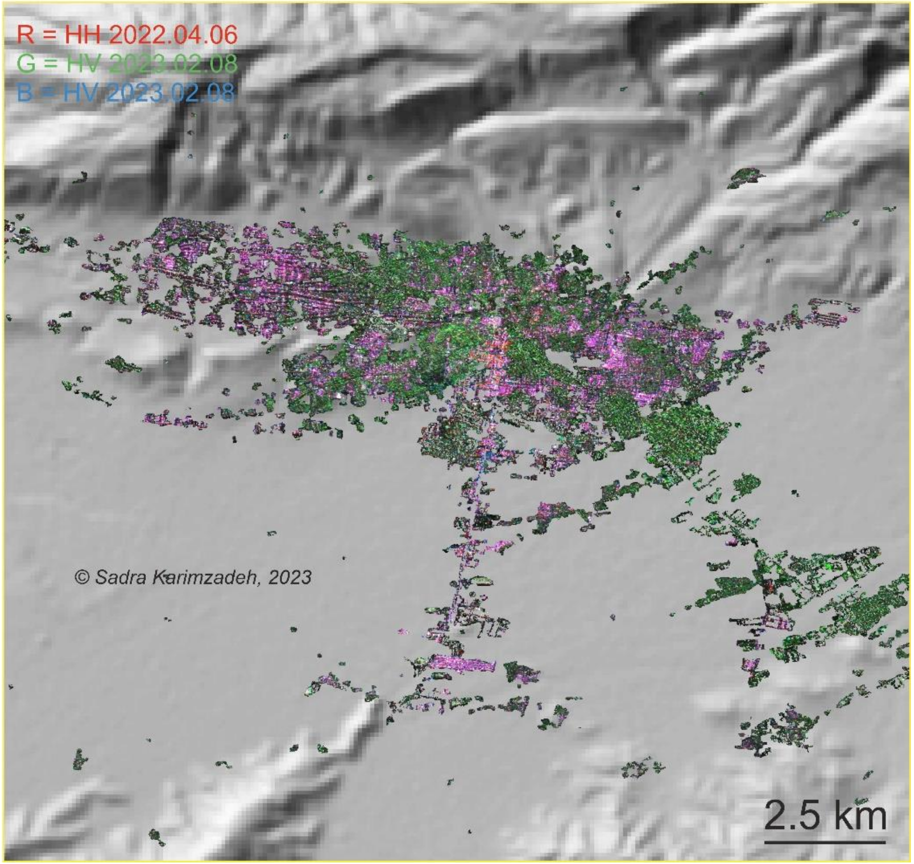


DAMAGE PROXY MAP

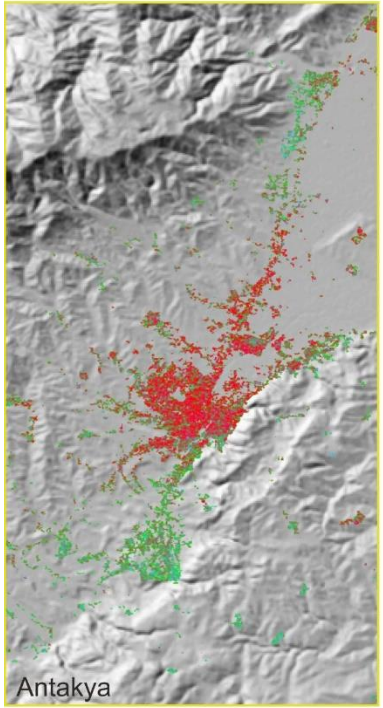


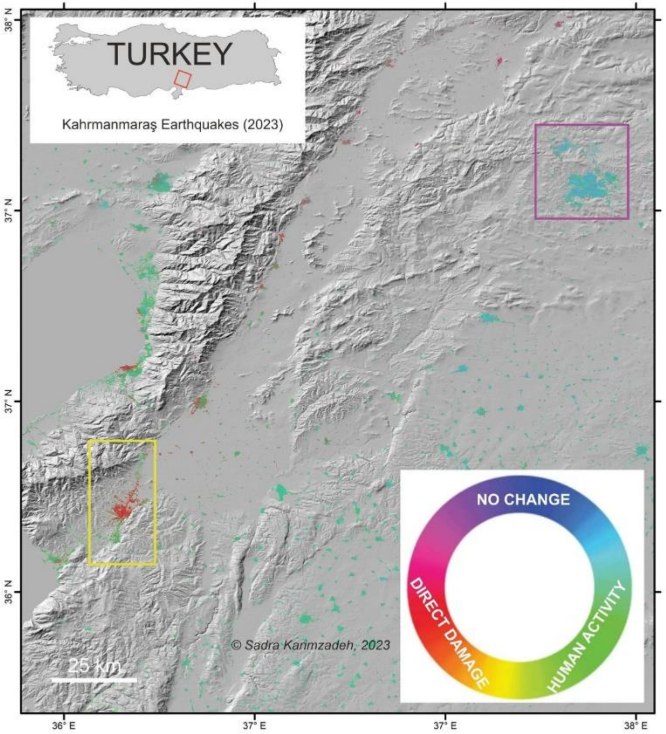
RGB MAP OF KAHRAMANMARAS (PALSAR-2)

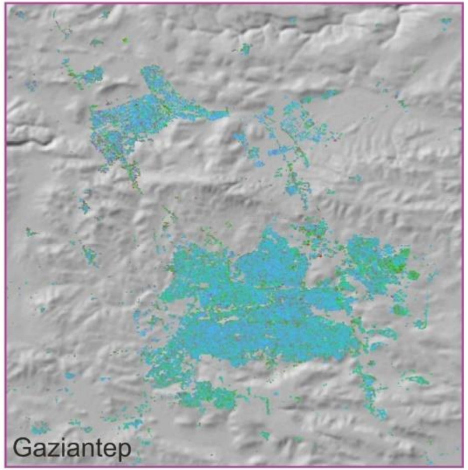




RGB MOOD MAP OF ANTAKYA AND GAZIANTEP







THANK YOU!

Any question?!