Preliminary damage mapping following the 2016 Kumamoto Mw7.1 Earthquake using pre- and post-event PALSAR-2 images

http://www.regid.irides.tohoku.ac.jp/response/

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BACKGROUND

- **M_w6.4 earthquake** occurred on **April 14, 2016 21:32 (JST)** in Kumamoto City, Kyushu, Japan. This event was followed by **two big earthquakes** of **M_w6.4** on April 15, 2016 00:09 (JST) and **Mw7.1** on April 16, 2016 01:30 (JST). It was reported that the **latest event generated** most of the **damage in Kumamoto city and surrounding areas**.

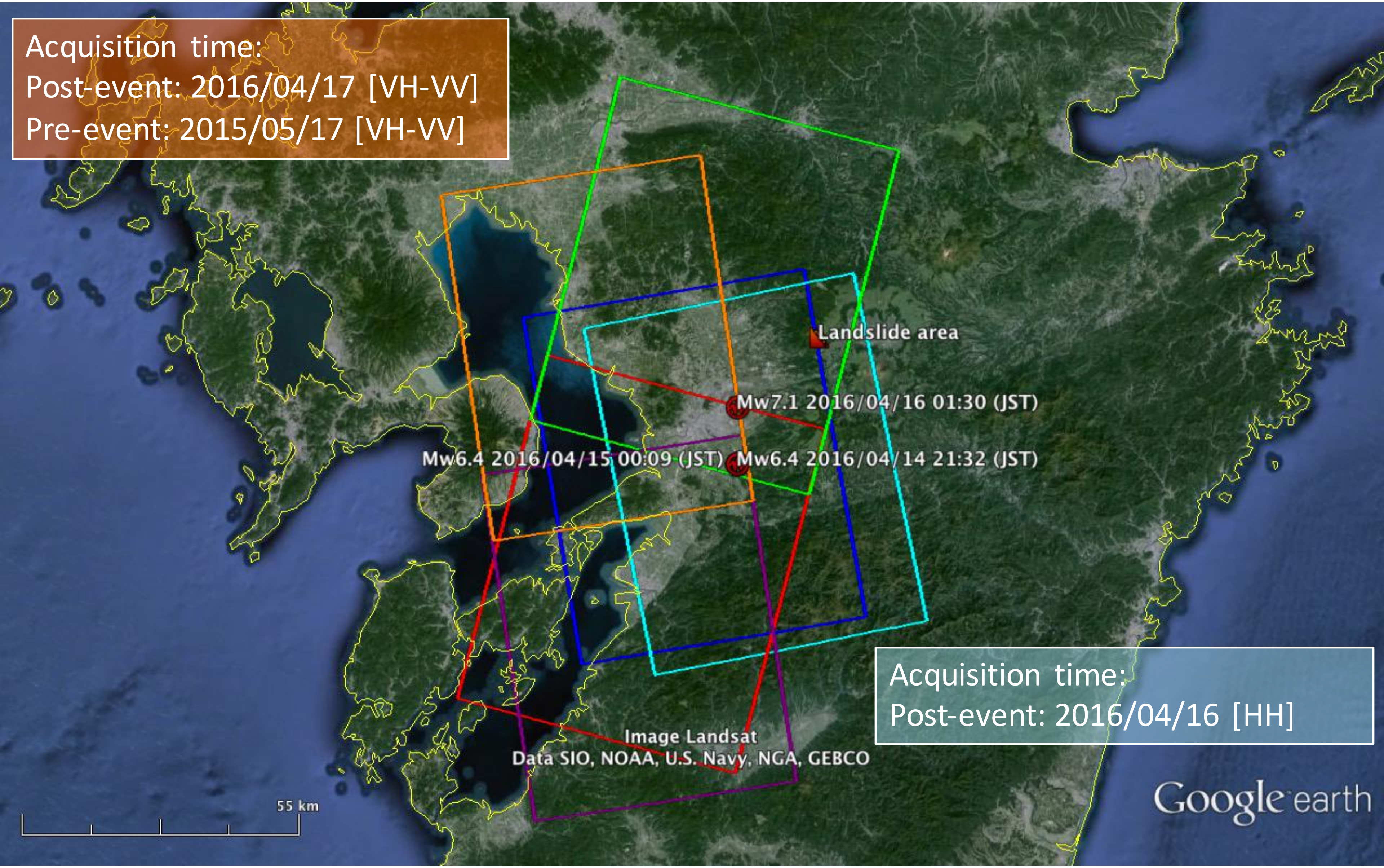
- The ReGiD Lab. (Laboratory of Remote Sensing and Geo-informatics for Disaster Management), IRIDeS, Tohoku University conducted a **preliminary building damage estimation** using two different approaches. **First, conventional change detection approach** using pre- and post-event Synthetic Aperture Radar (SAR) images (Liu et al., 2013). **Second**, a new approach of machine learning **using only post-event SAR image** (Bai at at., 2016).

- In this preliminary damage assessment, we employed a **two post-event SAR images** acquired after the main shock of Mw 7.1 (third significant earthquake) on **16th April**. The image from Kumamoto city was acquired by the Advanced Land Observing Satellite 2 (**ALOS-2**) / L-band Synthetic Aperture Radar (**PALSAR-2**) of JAXA.

JAXA ALOS-2/PALSAR-2 Data Acquisition

Area	PALSAR-2 data	Acquisition	Type	Polarization	Indecent angle
	Post-event	**20160417**	**L1.5**	**VH-VV**	**45.1**
	Pre-event	20150517	L1.5	VH-VV	45.1
	Post-event	**20160417**	**L1.5**	**HH**	**45.1**
	Pre-event	20150517	L1.5	HH	45.1
	Post-event	**20160415**	**L1.5**	**HH**	**28.7**
	Pre-event	20141114	L1.5	HH	28.7
	Post-event	**20160417**	**L1.5**	**VH-VV**	**28.8**
	Pre-event	20141114	L1.5	VH-VV	28.7
	Post-event	**20160416**	**L1.1**	**HH**	**18.8**
	~~Pre-event~~	~~20160330~~	~~L1.1~~	~~HH~~	~~38.2~~

JAXA ALOS-2/PALSAR-2 Data Coverage



Change Detection Approach

Change Detection Approach

Pre-processing

- ❖ The PALSAR-2 data was converted from digital number to backscattering coefficient (sigma-naught [dB]) using the equation provided by JAXA website (http://www.eorc.jaxa.jp). Then, the PALSAR-2 data was filtered using a Lee filter (Lee 1980) using a 3 x 3 pixel window.

Damage estimation

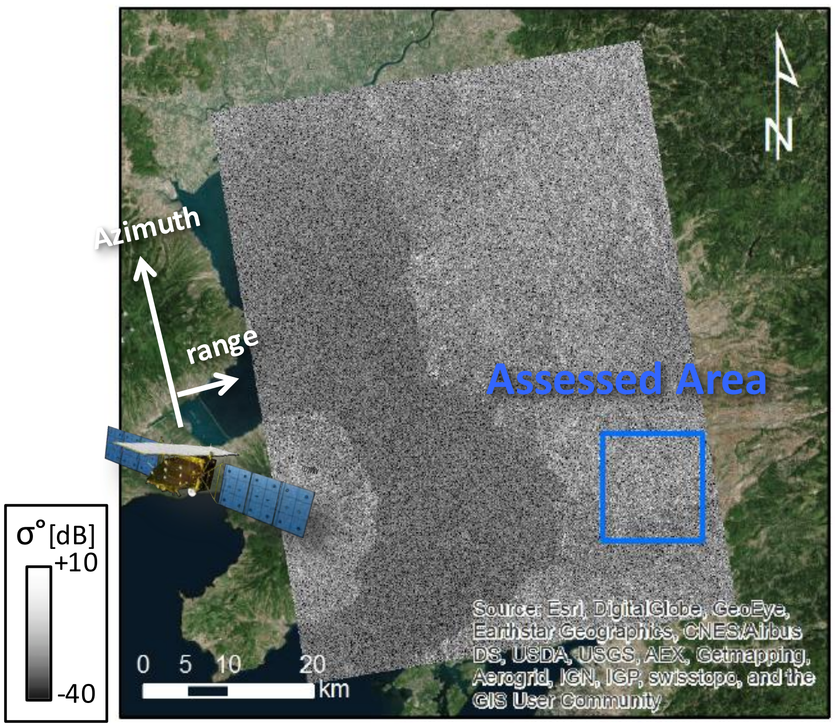
1. First, using the available VH-polarization images, we calculated the difference in backscattering and correlation coefficients using a 15 x 15 pixel window (37.5m x 37.5m) (Matsuoka et al., 2004).
2. The change detection was conducted using the Change Factor (*z*-coefficient) introduced by Liu et al., (2013). Theoretically, high values of *z*-coefficient indicates high probability of changes (Liu et al., 2013).

PALSAR-2 Post-event Images

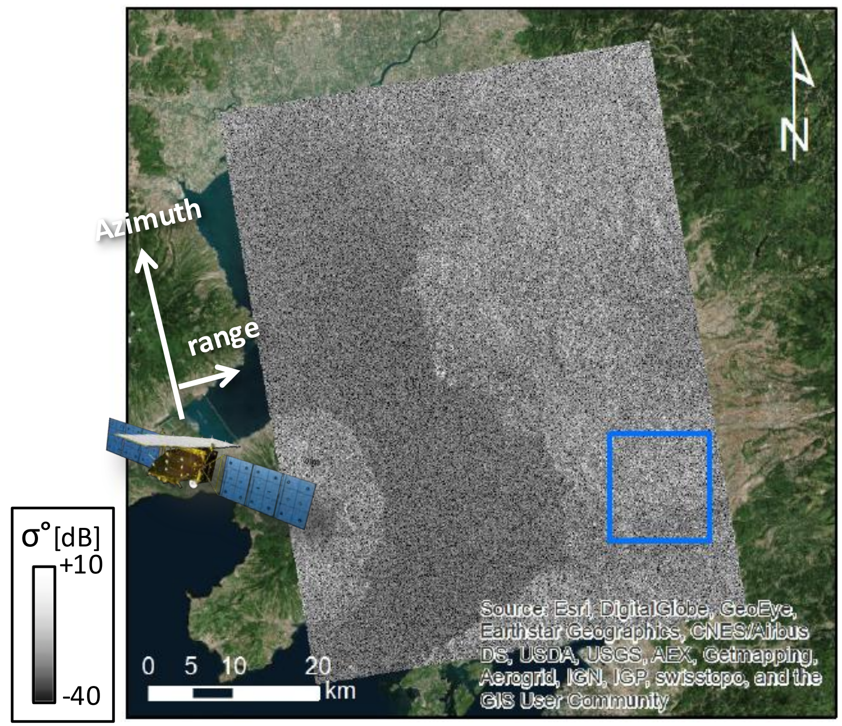
Sigma-naught (σ°) images

- Acquisition mode: StripMap (SM1)
- Ascending Orbit direction (azimuth)/ Right side observation (range)
- VH- and VV-polarizations
- Data format Level 1.1 / Pixel Spacing: 2.5 m

2015-05-17

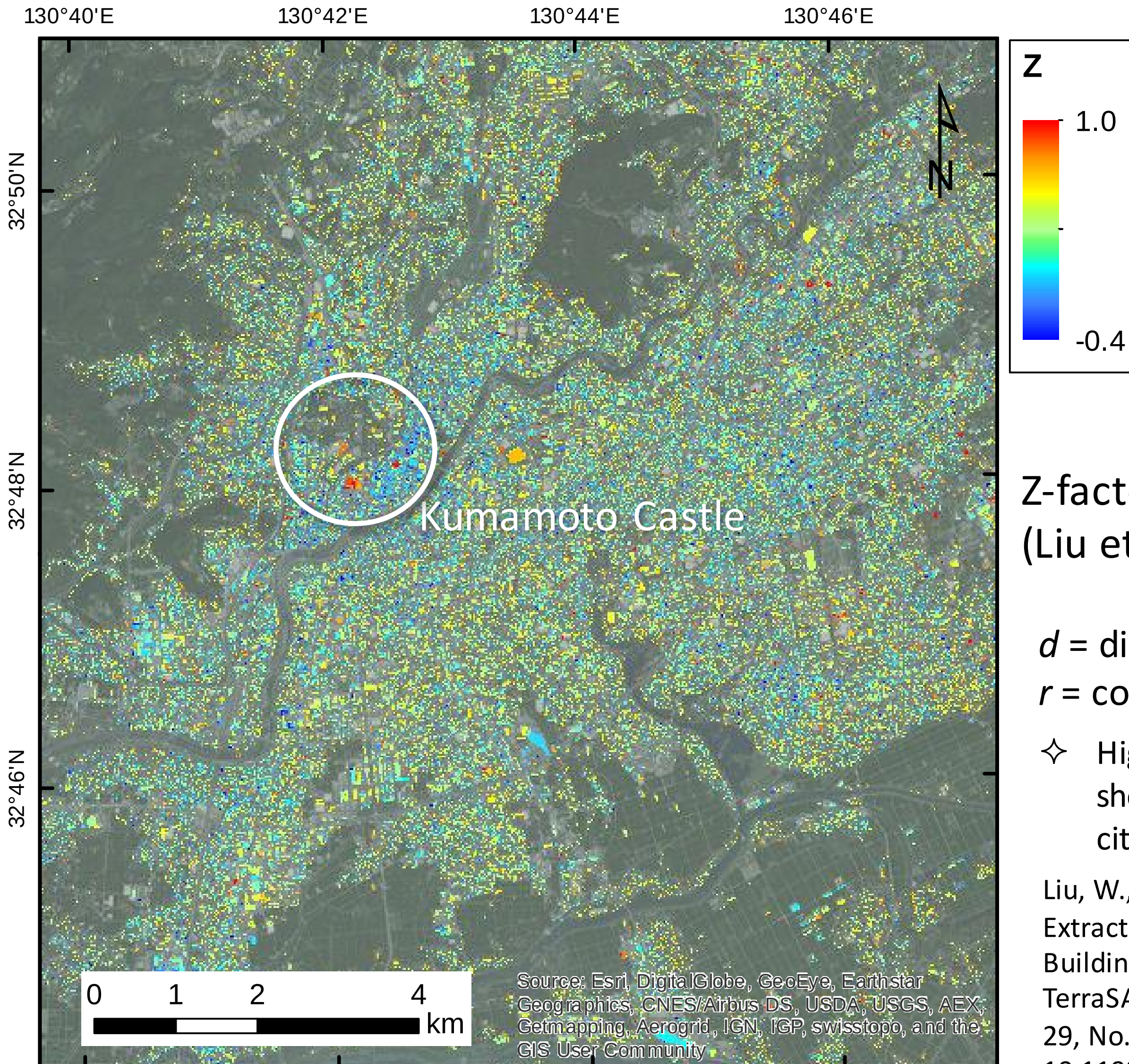


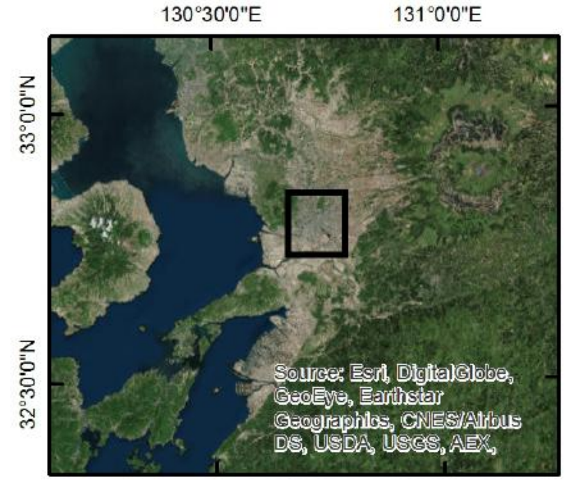
2016-04-17



Preliminary Damage Mapping

Kumamoto city（熊本市）





Z-factor
(Liu et al., 2013)

$$z = \left| \frac{d}{\max|d|} \right| - 0.5 \cdot r$$

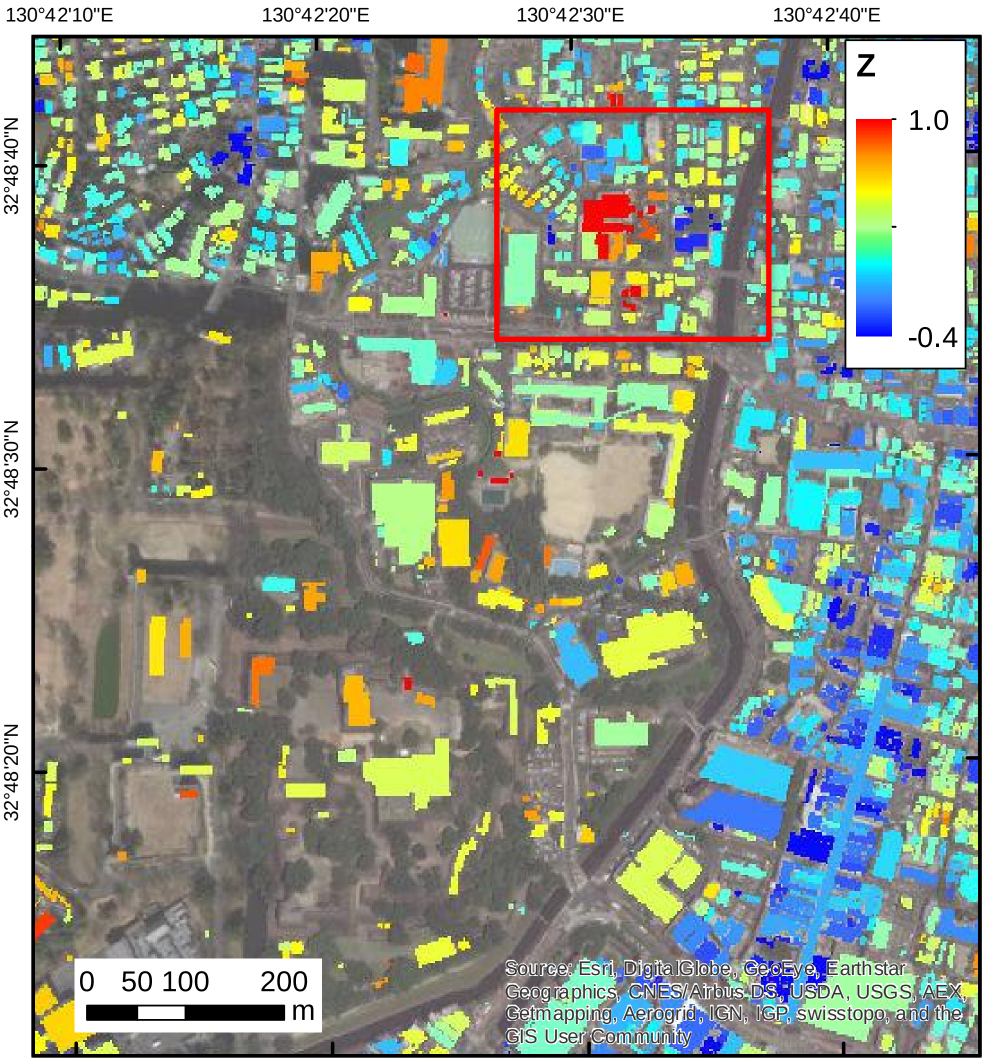
d = difference of backscattering coefficients,
r = correlation coefficient.

✧ High values of the change factor (z ≈ 1.0) show high changes around the Kumamoto city (red spots).

Liu, W., F. Yamazaki, H. Gokon and S. Koshimura, Extraction of Tsunami-Flooded Areas and Damaged Buildings in the 2011 Tohoku-Oki Earthquake from TerraSAR-X Intensity Images, Earthquake Spectra, Vol. 29, No. S1, pp. S183-S200, 2013. doi: 10.1193/1.4000120

Preliminary Damage Mapping

Kumamoto Castle（熊本城）



Pre-event Image (GSI)

Post-event Image (GSI)

Machine learning approach

Machine Learning Approach

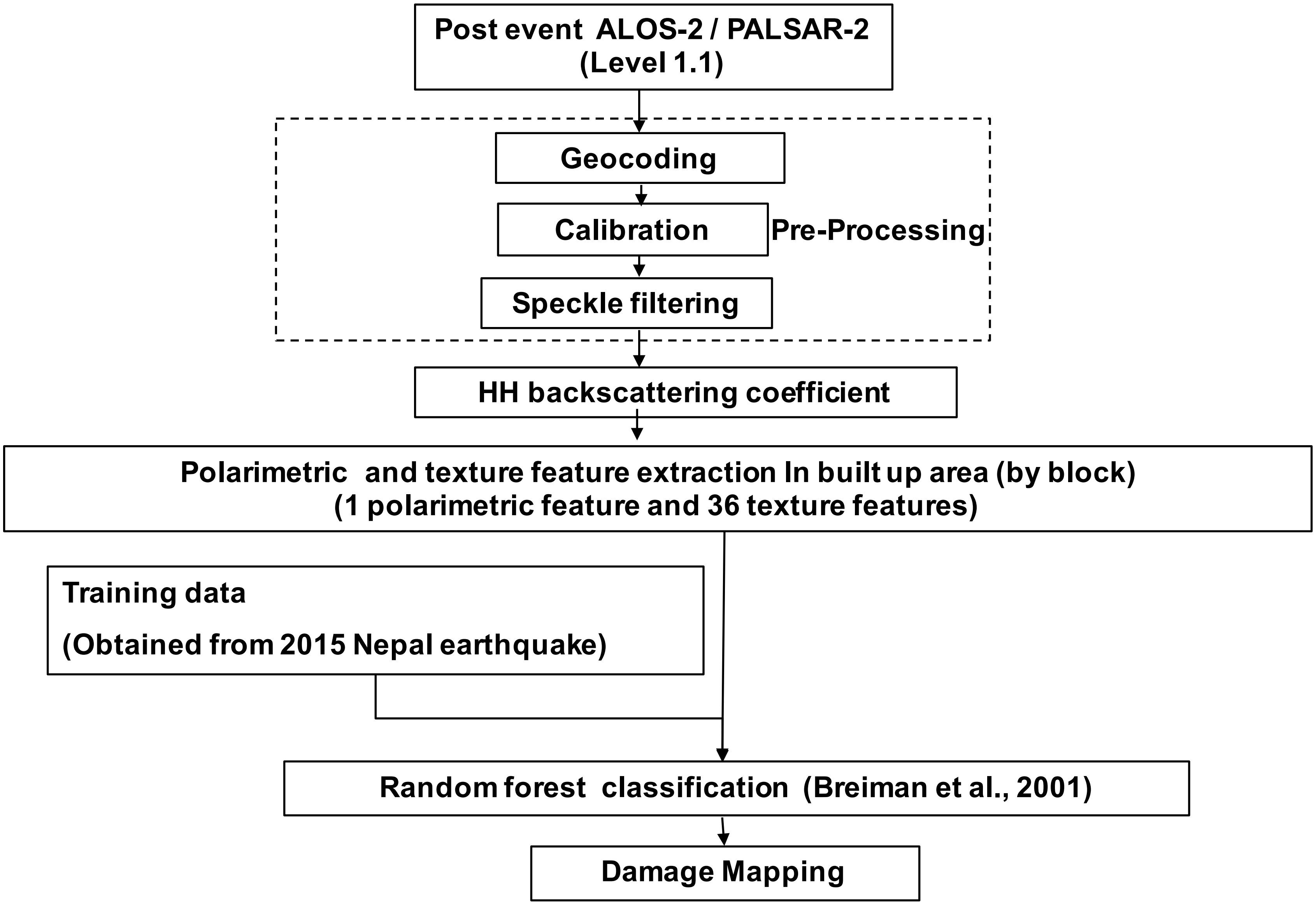
Pre-processing

- ❖ The PALSAR-2 data was converted from digital number to backscattering coefficient (sigma-naught [dB]) using the equation provided by JAXA website(1). Then, the PALSAR-2 data was filtered using a Lee filter (Lee 1980) using a 3 x 3 pixel window.

Damage estimation

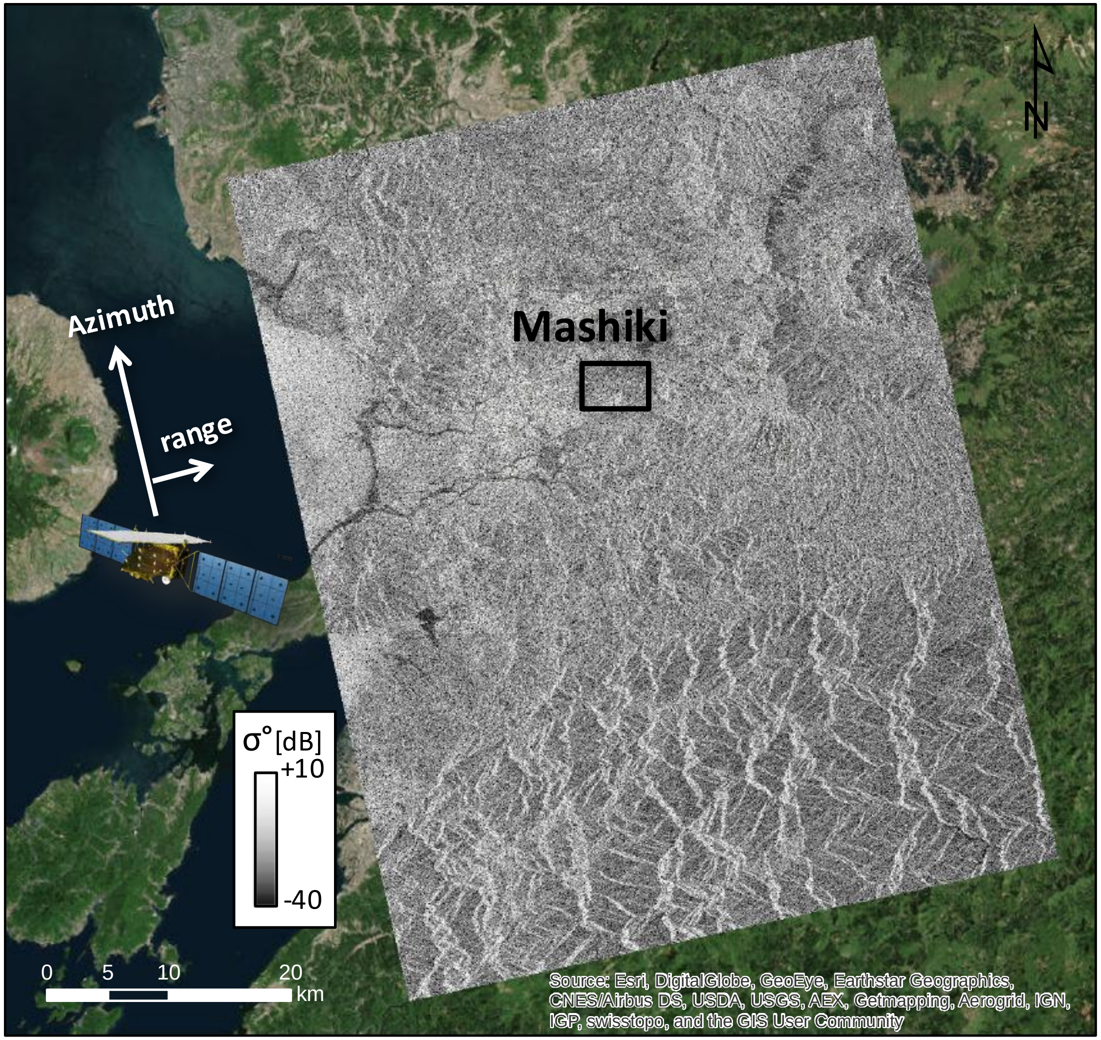
1. We calculated 37 texture parameters based on the Grey-Level Co-occurrence Matrix (Haralick et al., 1973), and the HH-polarization information.
2. We conducted the damage estimation in block-scale of 50 m x 50 m, the average value of each texture parameter is calculated in each block.
3. Finally, using training sample of structural damage observed in the 2015 Nepal earthquake, a random forest algorithm (Breiman et al., 2001) was applied to classify the building damage into two categories in Kumamoto city.

Method (Bai et al., 2015)



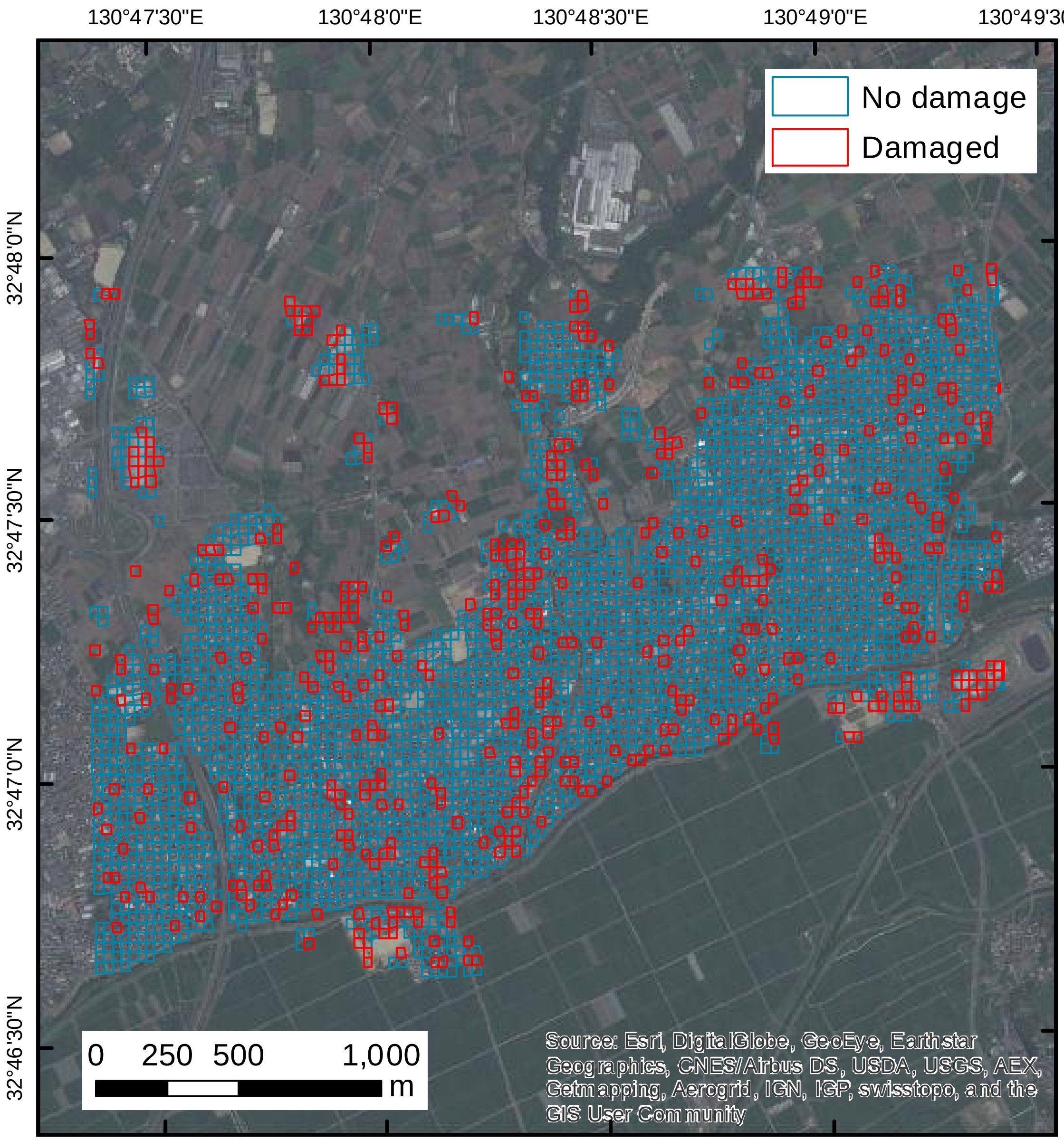
PALSAR-2 Post-event Image (2016/04/16)

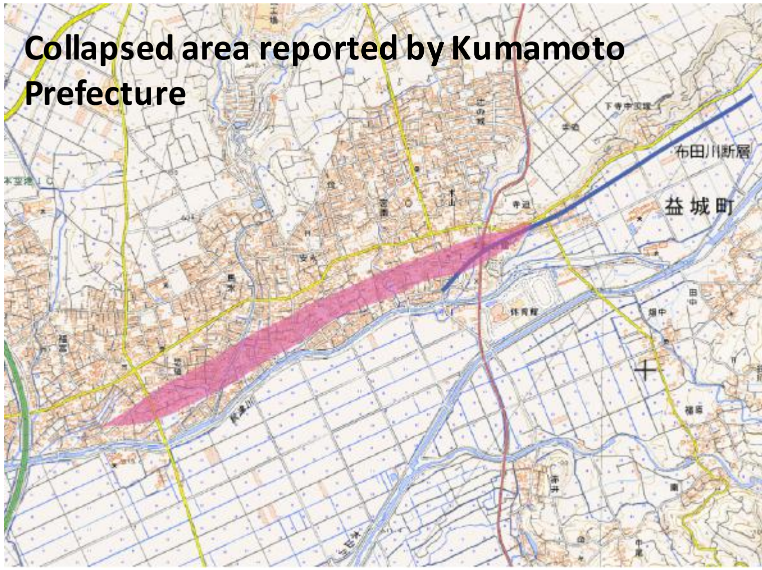
Sigma-naught (σ°) image

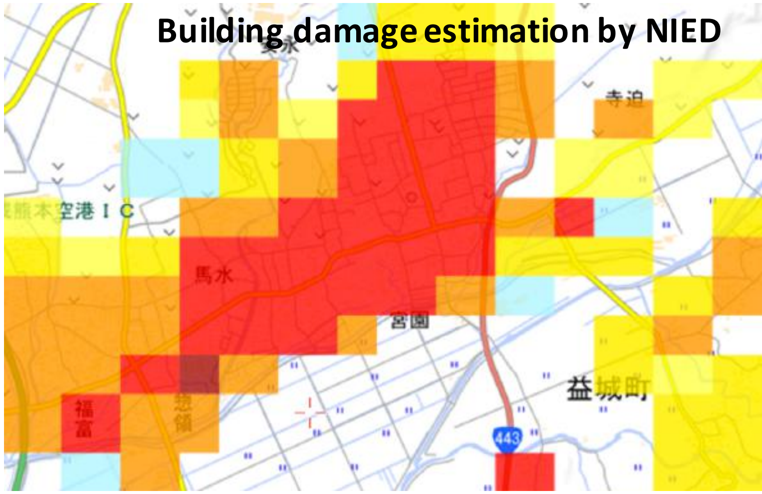


- Acquisition mode: StripMap (SM1)
- Ascending Orbit direction (azimuth)
- Right side observation (range)
- HH-polarization
- Data format Level 1.5
- Pixel Spacing: 2.5 m

Preliminary Damage Mapping (Mashiki town)

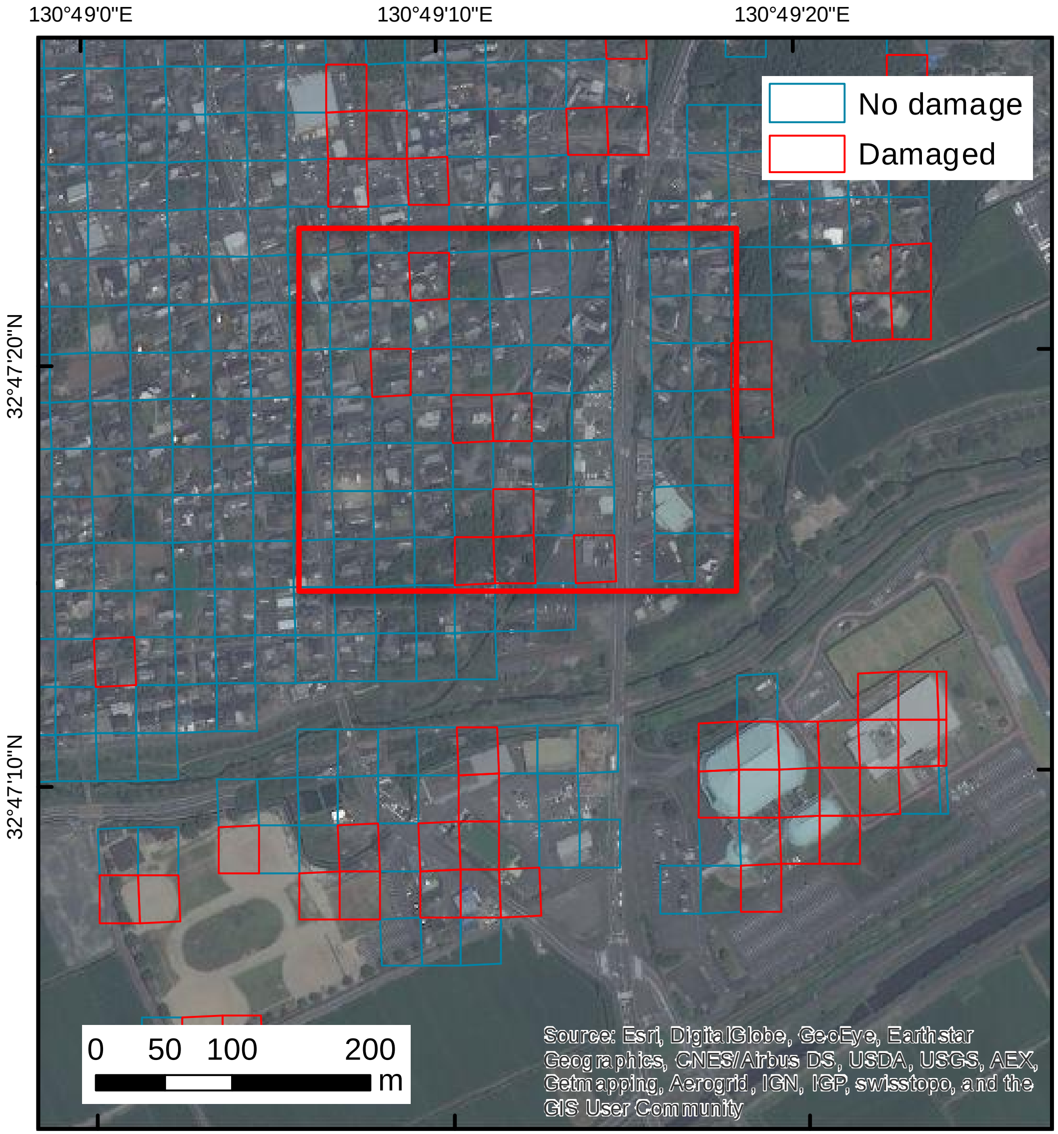


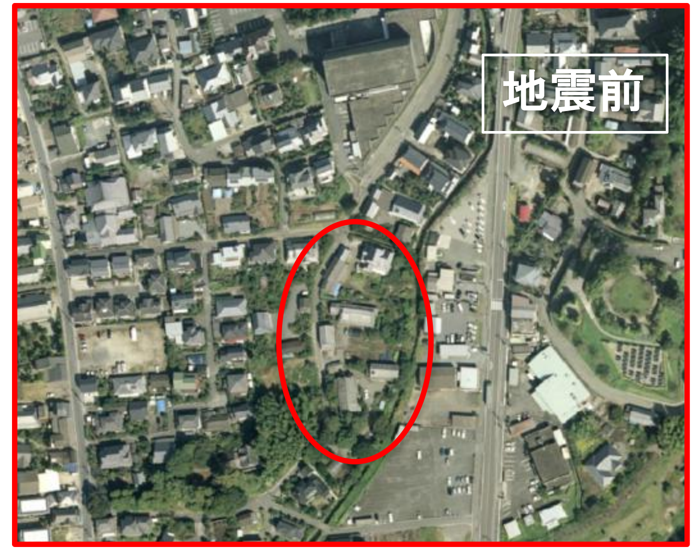




Preliminary Damage Mapping

Mashiki Town（益城町）





Pre-event Image (GSI)

Post-event Image (GSI)

Summary

- We have conducted a preliminary damage mapping in Kumamoto city and Mashiki town using pre- and post-event ALOS-2 images with VH-polarization and post-event HH-polarization, respectively.

- According to damage estimation, the change detection approach applied in Kumamoto city showed spots of high changes, which can be interpreted as damaged buildings . However, several misdetections were due to new construction found in the post-event SAR image.
- However, the change detection analysis successfully detected parts of damages around Kumamoto Castle. Based on the comparison of aerial photos (GSI), these damage is consistent with reported building collapse.

- On the other hand, machine learning approach applied in Mashiki town showed that small 20 % of built-up area were detected as damaged. But the results need to be verified with in-situ data.

Acknowledgement

ALOS-2/PALSAR-2 image is owned by JAXA, and the dataset was provided by JAXA.