2017 Final Symposium of J-RAPID Kumamoto EQ
March 4, 2017, Kumamoto, Japan

Damage assessment and vulnerability modeling of structures in the 2016 Kumamoto earthquake based on the data acquired from field investigation and remote sensing

現地調査とリモートセンシングを融合した熊本地震による構造物の被害把握と被害予測モデル構築

March 4, 2017

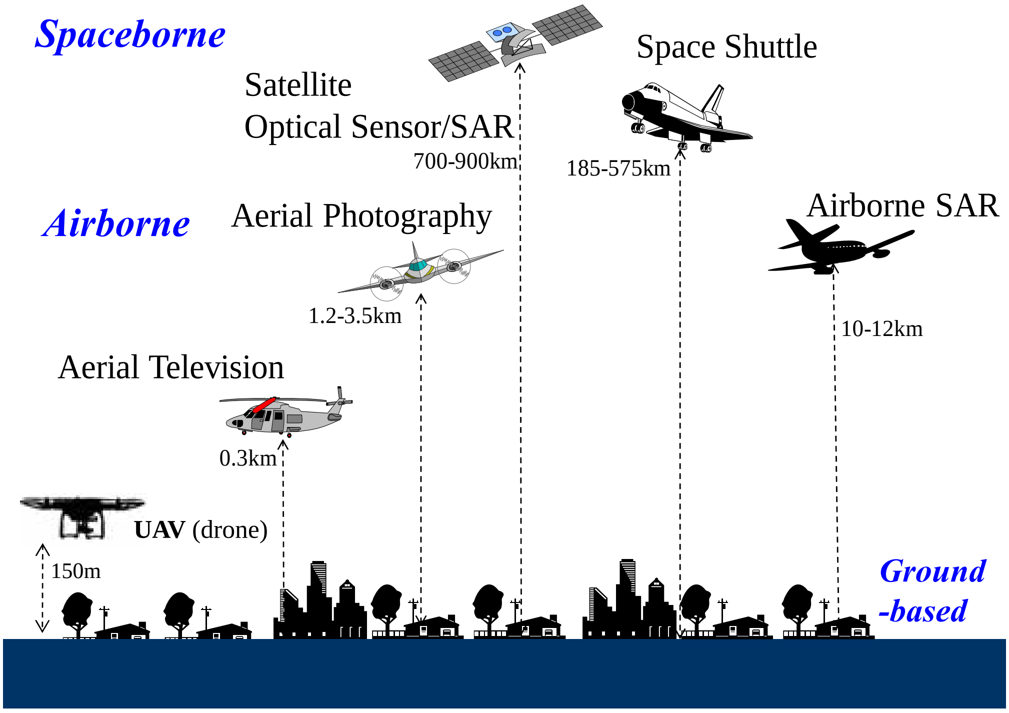
Fumio Yamazaki

CHIBA UNIVERSITY

Professor, Chiba University, Japan

Platforms of Remote Sensing

- **Satellite**: near-polar orbit, geo-stationary, Space Shuttle
- **Airborne platform**: airplane, helicopter, UAV
- **Ground-based**: balloon, tall building, crane, ladder, car

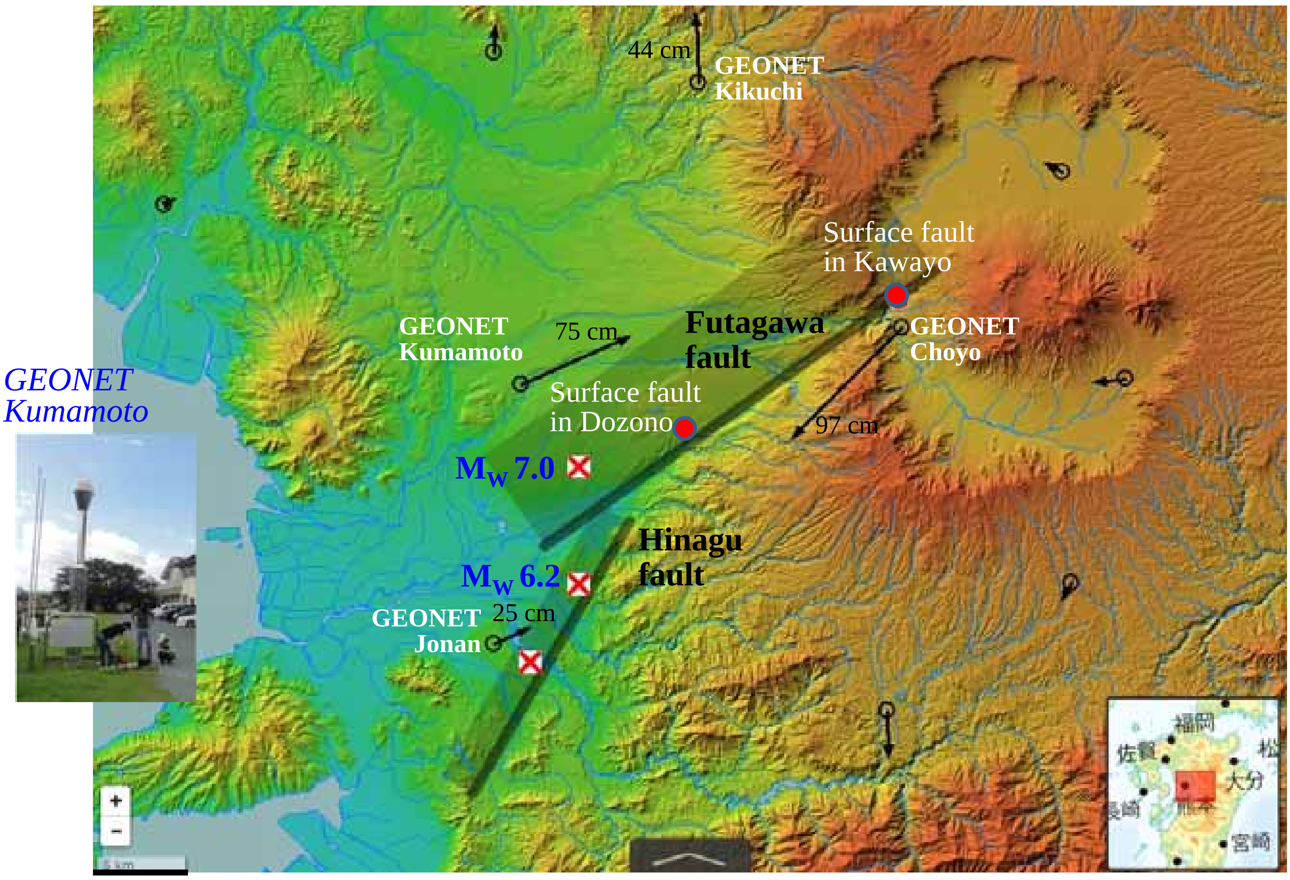


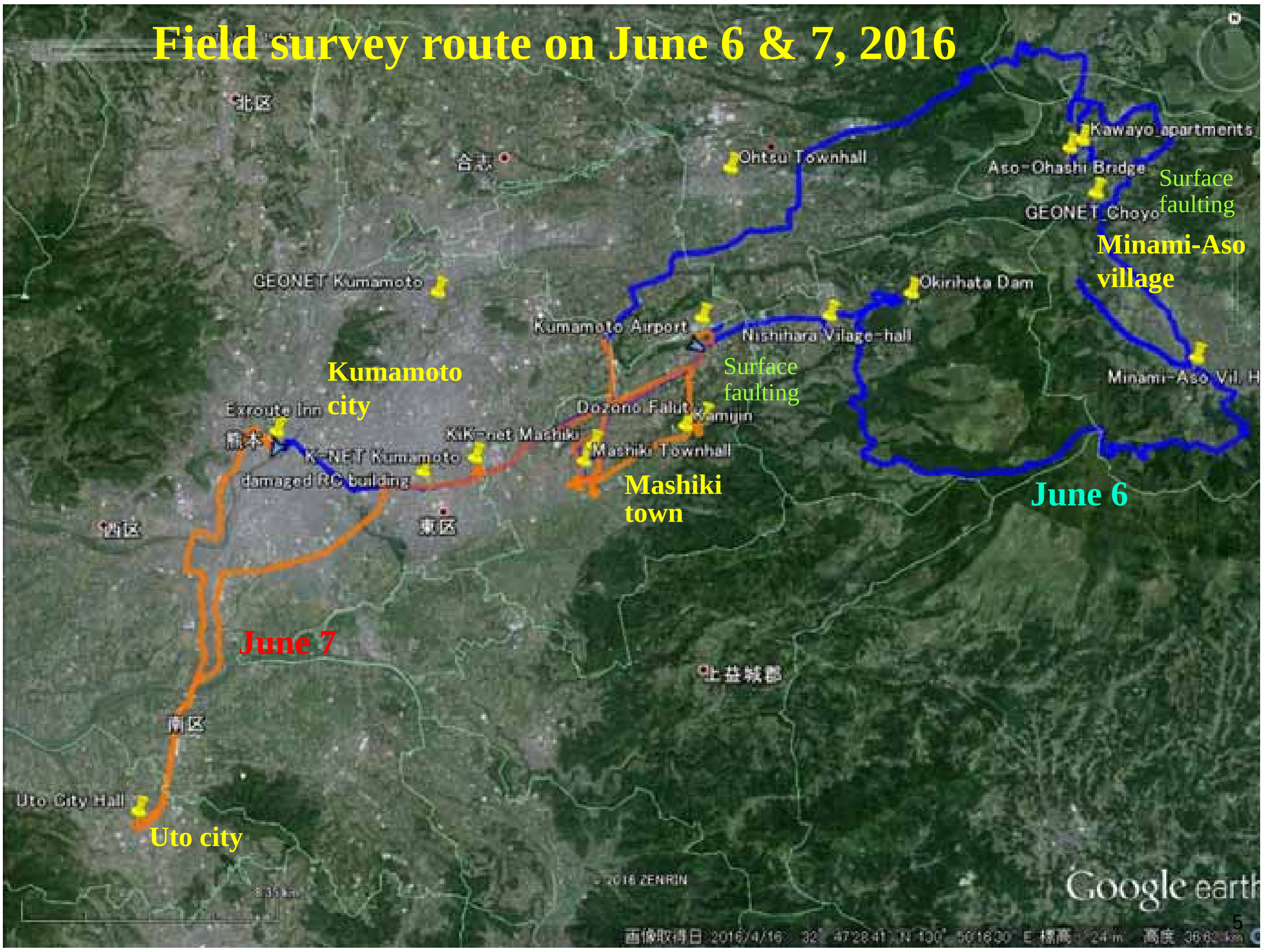
Acquisition condition of various sensors and platforms in disaster response

Platform /Sensor	Satellite ◎ Large coverage	Airborne ○ Mod. coverage	Ground Based △ Low coverage
Optical Sensor	△ Day, Fixed time △ No cloud	○Day, Any time ○ No low cloud	◎ Day, Any time
LiDAR	△	○ All day, Any time ○ No low cloud ◎ High accuracy	◎ Day, Any time
Thermal Infrared	○All day, Fixed time △ No cloud △ Low resolution	◎ All day, Any time ○ No low cloud ○ Mod. resolution	◎All day, Any time ◎ High resolution
SAR	○ All day, Fixed time ◎ All weather	◎ All day, Any time ◎ All weather △ R & D stage	△ Ground penetration Radar

Epicenters, faults, and GPS stations in the 2016 Kumamoto EQ

GEONET Kumamoto





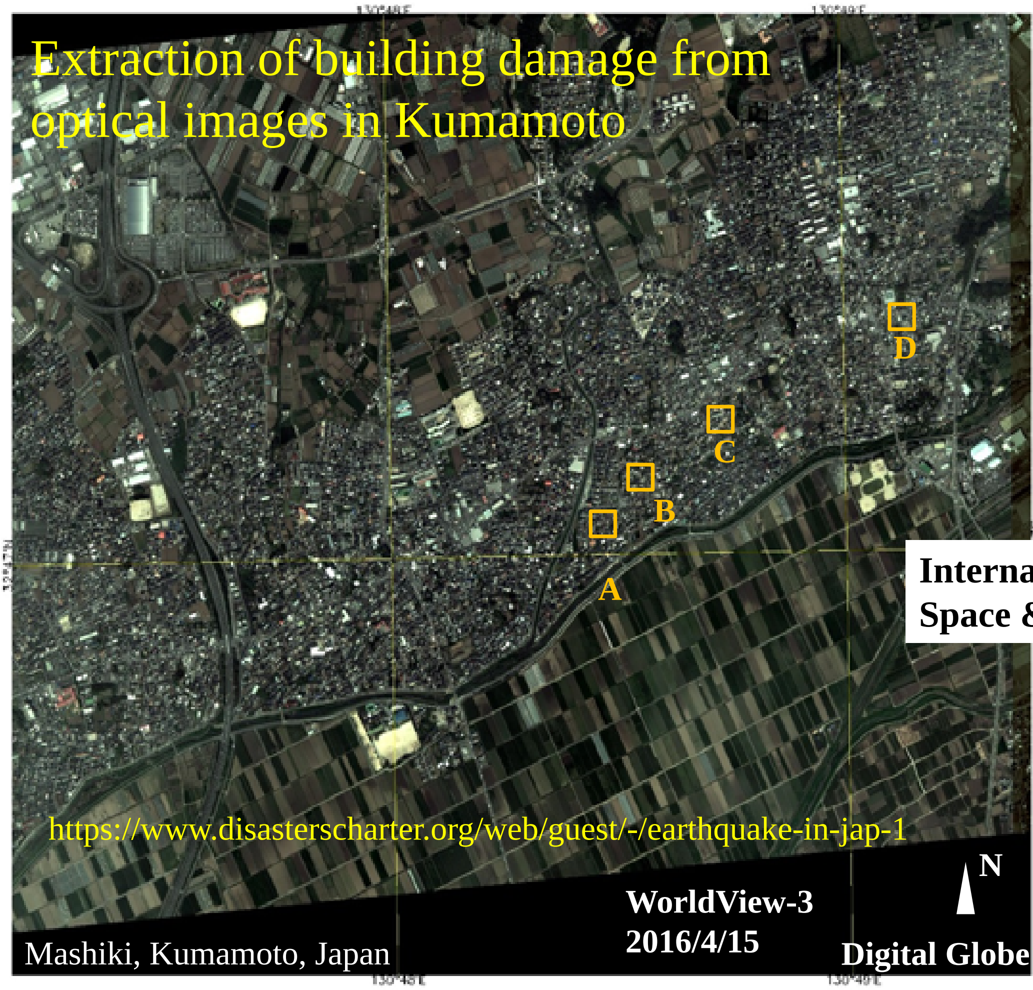
Surface faulting in Mashiki town

April 17

Building damage in Mashiki Town

April 16

Extraction of building damage from optical images in Kumamoto



International Charter – Space & Major Disasters

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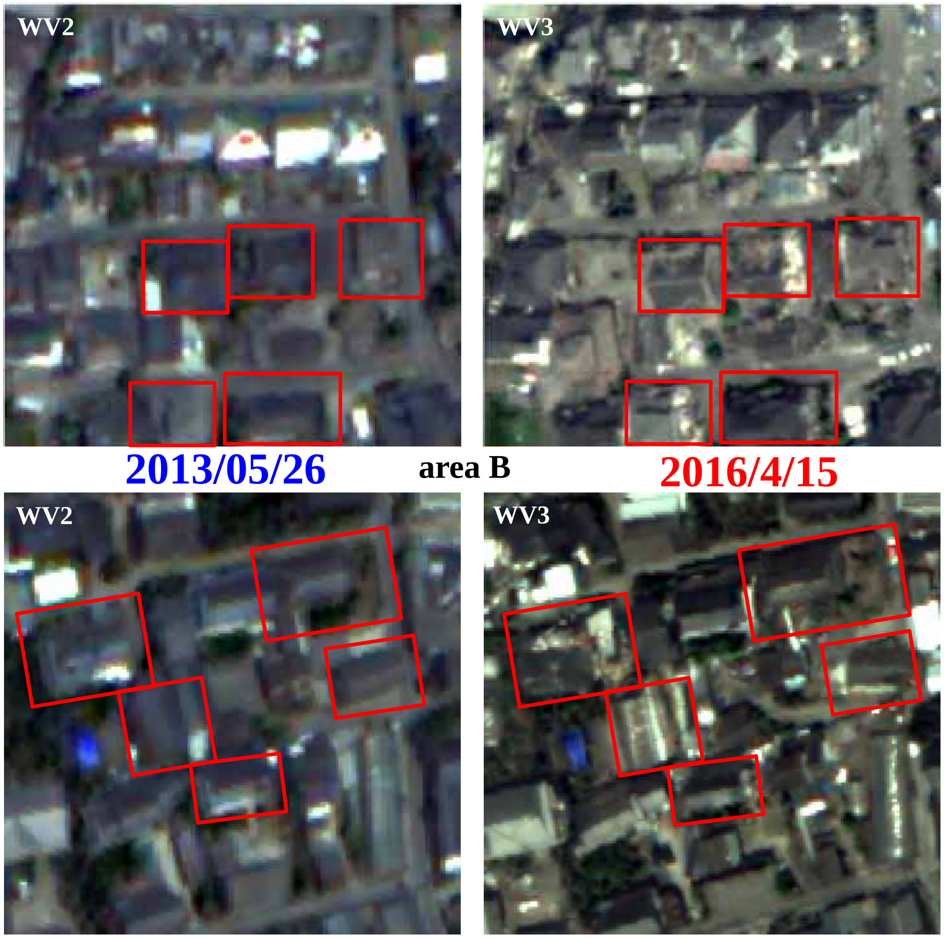
USGS science for a changing world

area A



Building Damage in Mashiki Town on April 15, 2016

■ Damaged buildings

Damaged buildings by visual interpretation from the pan-sharpened pre- and post-event optical images.

Pre-event: **WorldView-2**
2013/05/26
11:42:00 (JST)

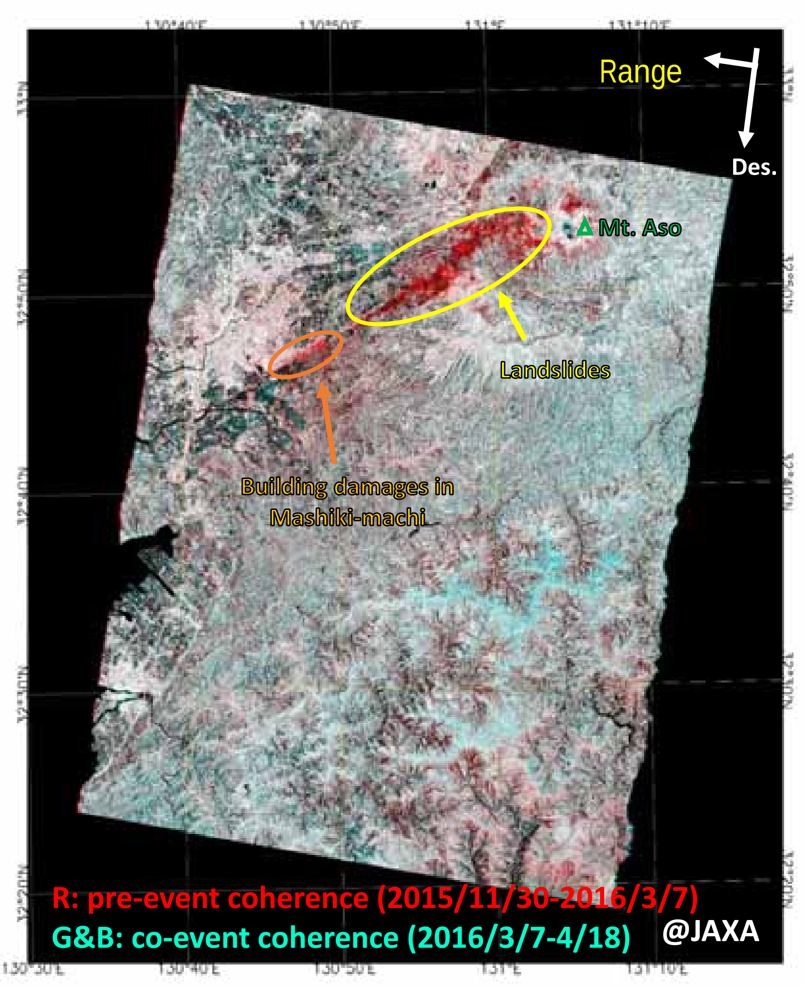
Post-event: **WorldView-3**
2016/4/15
11:08:13 (JST)
Resolution: 0.5-m

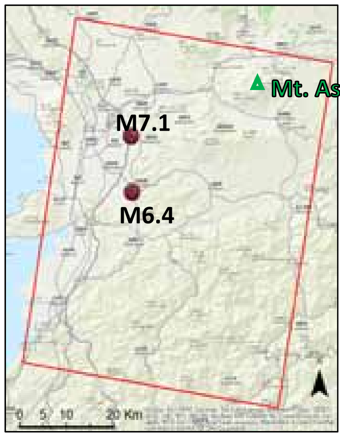
WV2 and WV3 images are owned by Digital Globe and provided by USGS.

Monitoring of evacuation sites by VHR optical satellite images

a. Hiroyasu-Nishi Primary School
益城町 広安西小学校

Color composite of the pre- and co-event PALSAR-2 coherence





Pre-event: 2015/11/30, 2016/03/07
Post-event: 2016/04/18
Off-nadir angle: 32.4 °
Mode: StripMap
Polarization: HH

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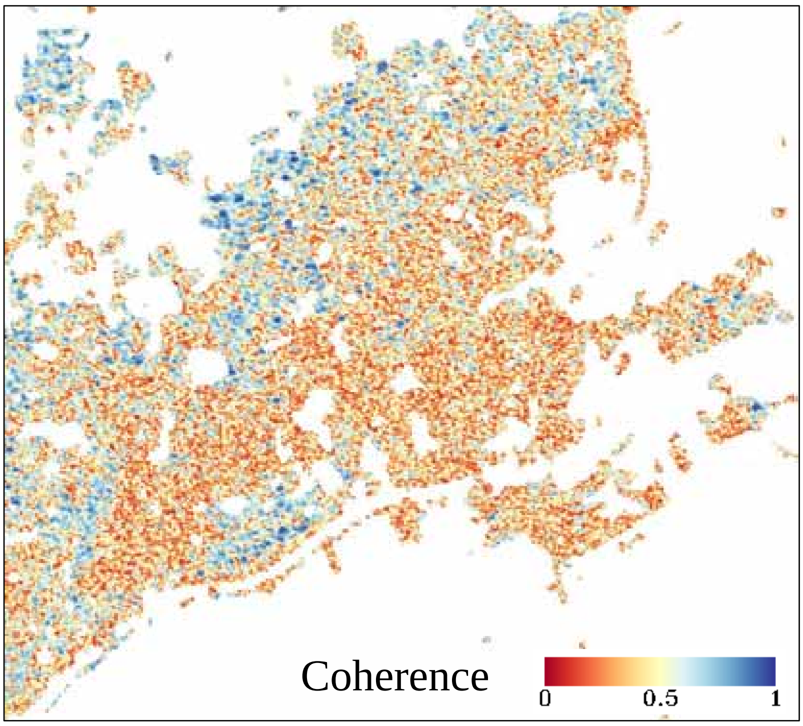
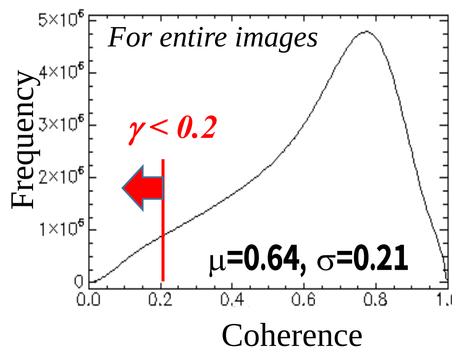
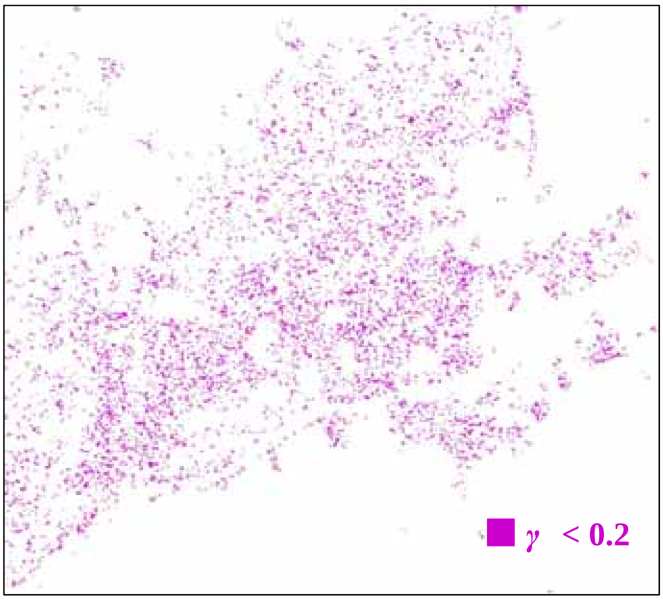
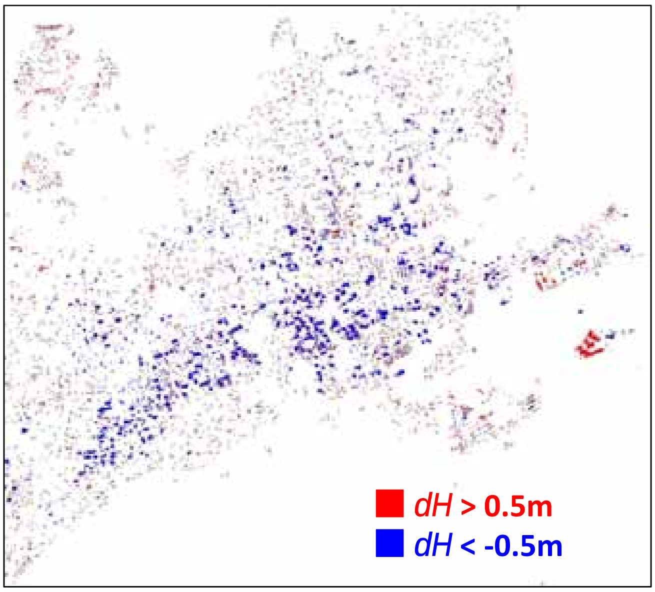
Coherence between the two PALSAR-2 images (2016/4/15 vs 2016/4/29) for the urban land-cover in the central Mashiki Town





Changed areas extracted by low coherence (γ < 0.2) (a); and extracted by DSM height-difference (abs. (dH) > 0.5 m) (b)

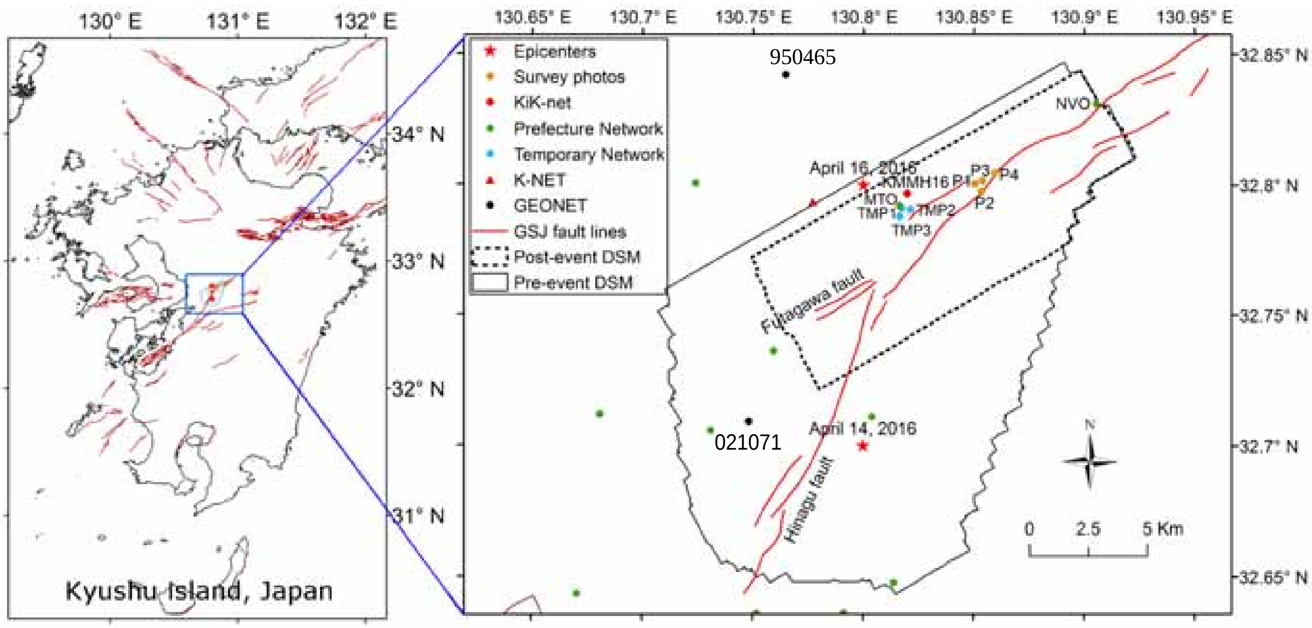




(a) Low coherence from SAR pair (γ < 0.2)

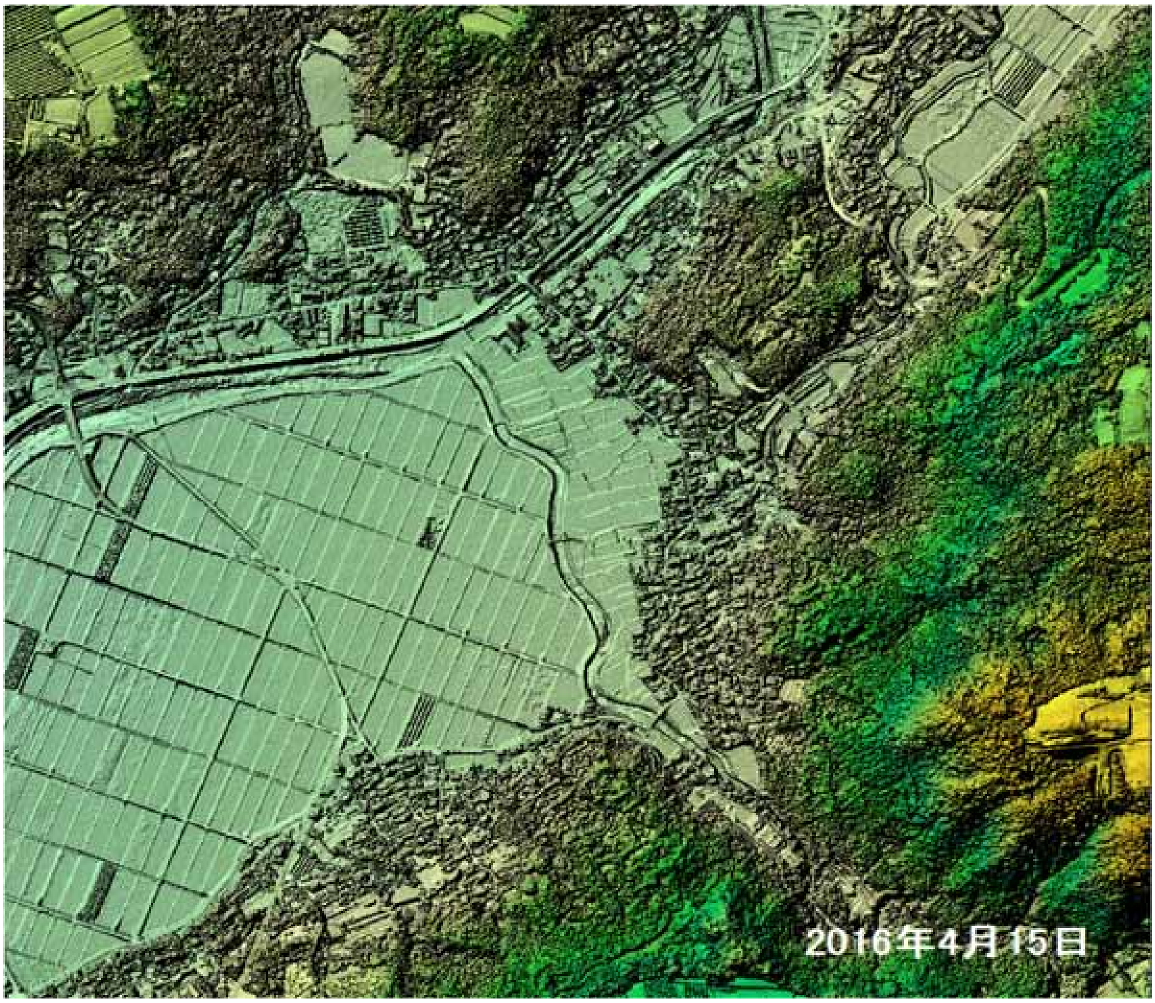
(b) LiDAR DSM height-difference (abs. (dH) > 0.5 m)

LiDAR Surveying Flights by Asia Air Survey Co.

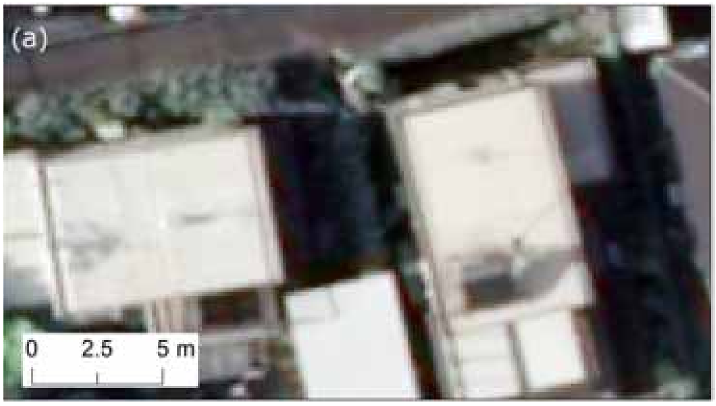


- Pre-event DSM: April 15 (1 day after the foreshock, 2 points/m^2).
- Post-event DSM: April 23 (7 days after the mainshock, 4 points/m^2).
- Six strong-motion are located within the study area.

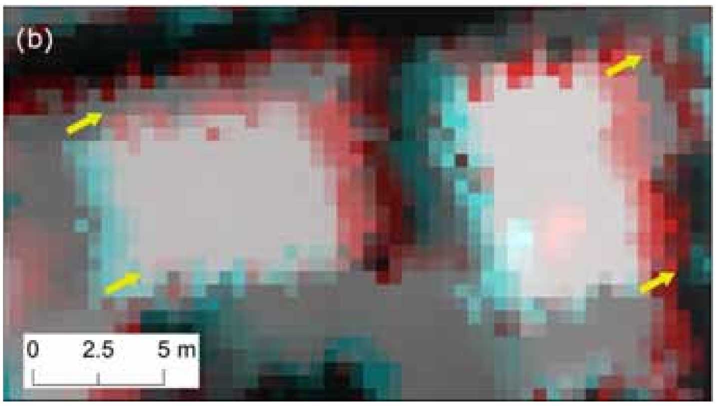
ASIA AIR SURVEY CO.,LTD.



Color composite of the pre- and post-event LiDAR DSMs



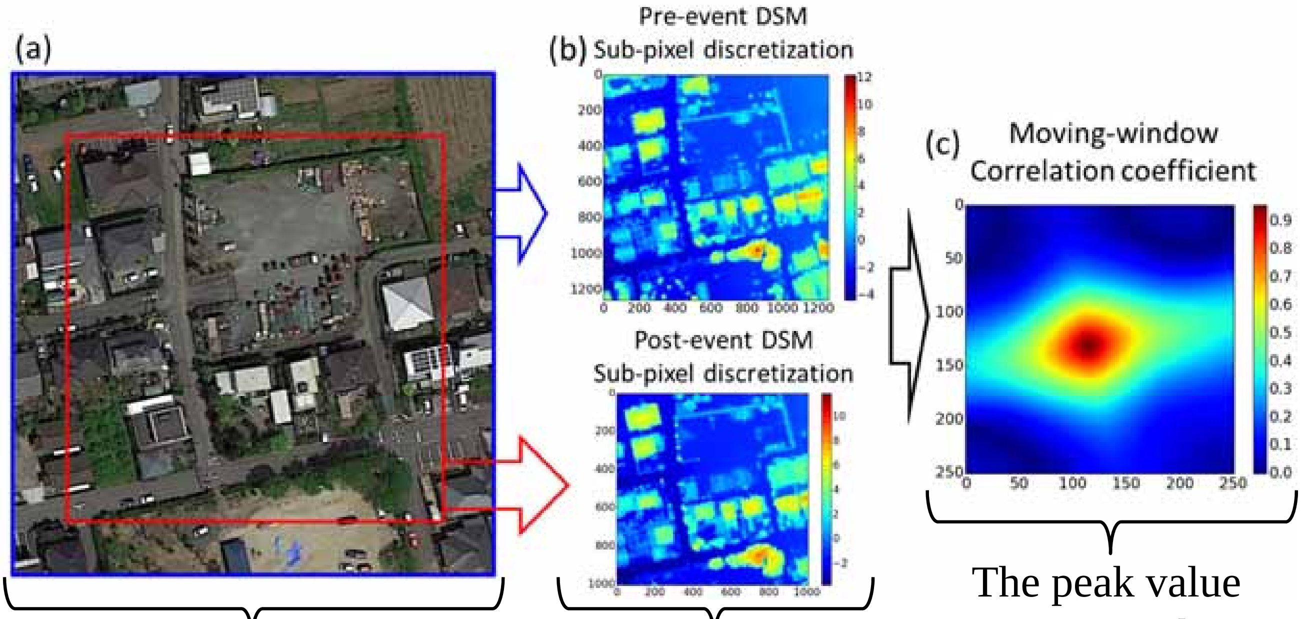
Aerial image of buildings in Mashiki town



Crustal movement is observed as the shift of the DSM

Cyan pixels:
Pre-event DSM > post-event DSM
Red pixels:
Pre-event DSM < post-event DSM
Gray pixels:
Pre-event DSM = post-event DSM

Scheme of the Maximum Correlation Search



Big enough to include several objects such as houses

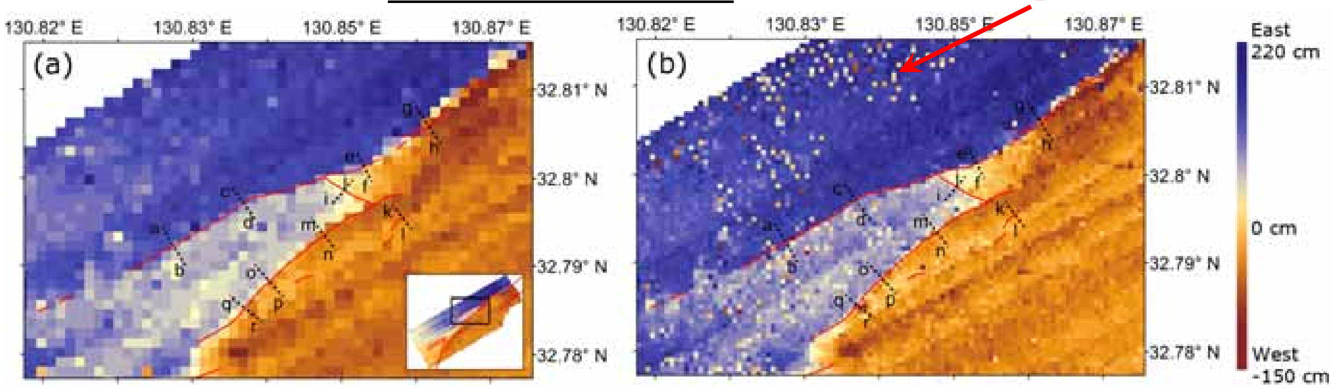
Reduction of the pixel size by cubic convolution

The peak value represent the horizontal displacement

Window Size for Correlation Calculation

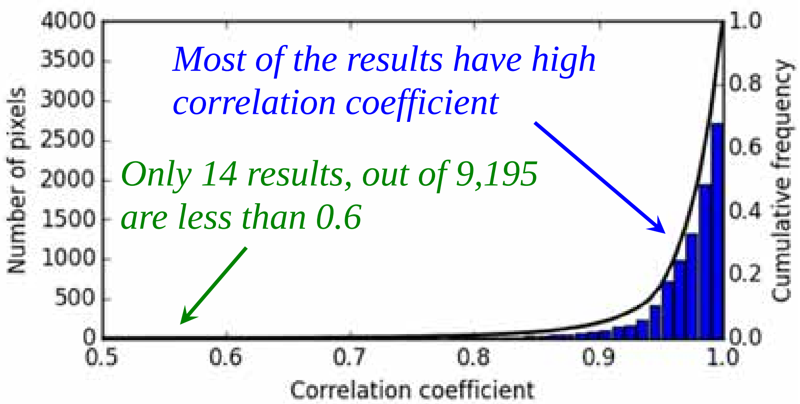
East-West direction

Flat areas produce noise

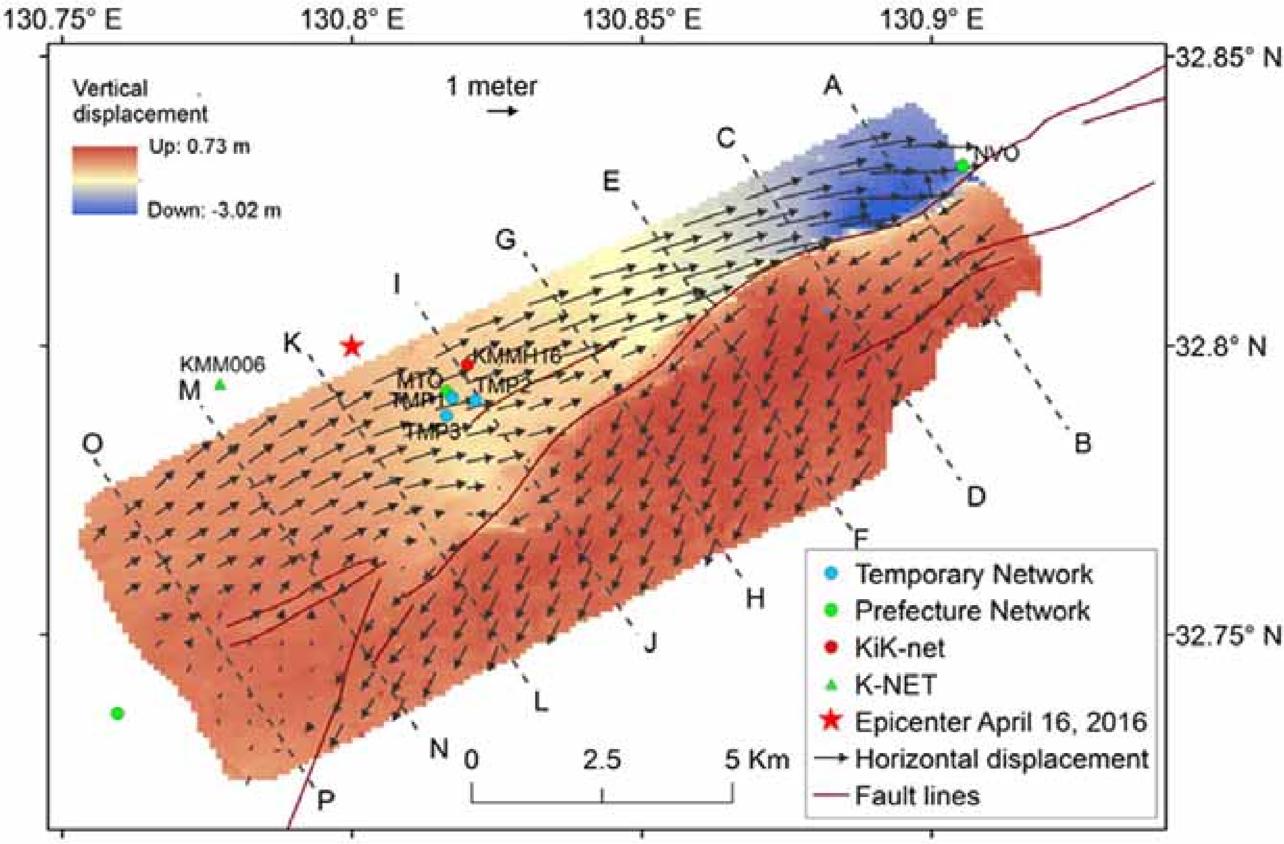


201 x 201 (100m grid)

101 x 101 (50m grid)

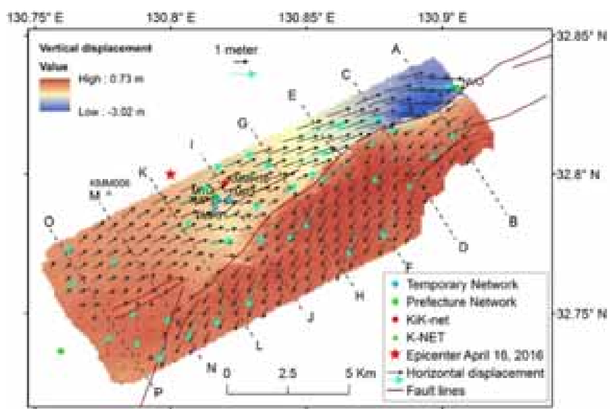


Estimated 3D coseismic displacement from LiDAR DSMs in the main-shock of the Kumamoto EQ

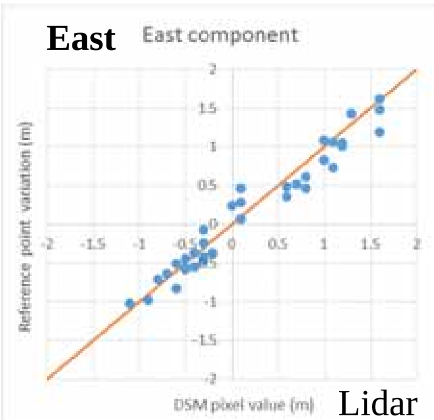


Comparison of LiDAR displacements with GSI's measurement

GSI's measurement
on August 30，2016

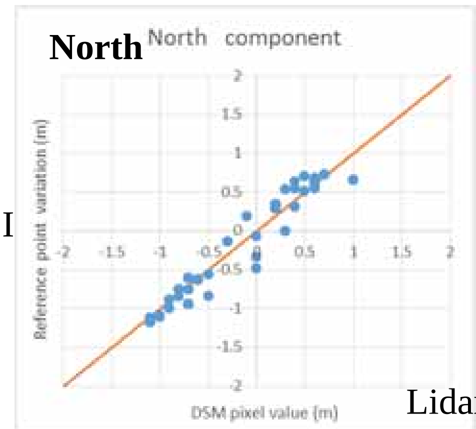


GSI



Lidar

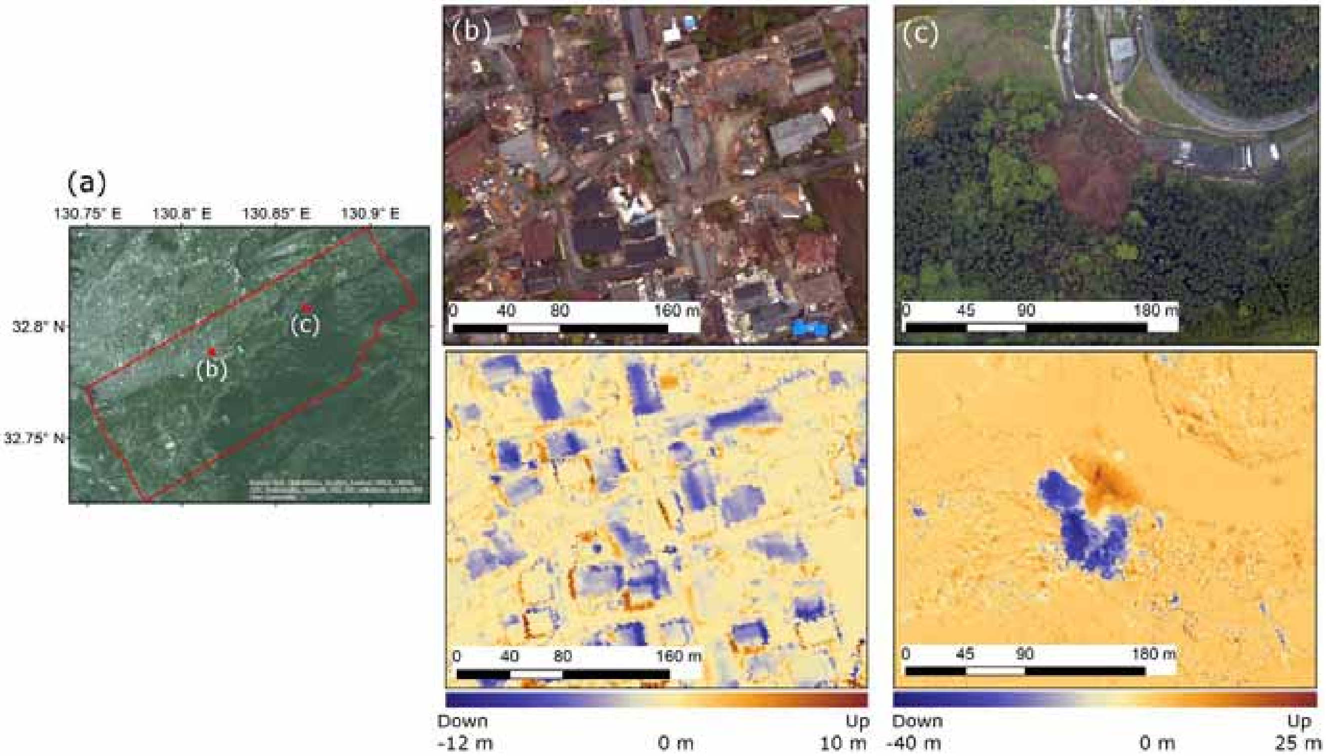
GSI



Lidar

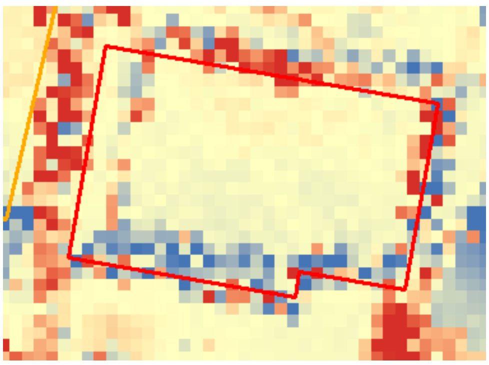
http://www.gsi.go.jp/sokuchikijun/sokuchikijun60019.html

Extraction of **collapsed buildings** and **landslide** by the difference of **LiDAR** Digital Surface Models (DSMs)

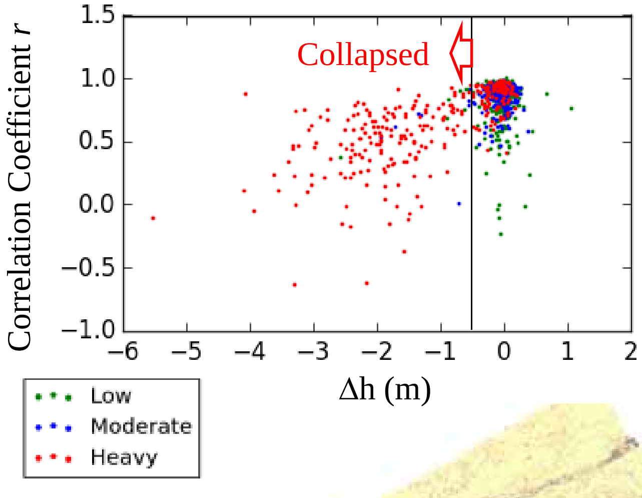


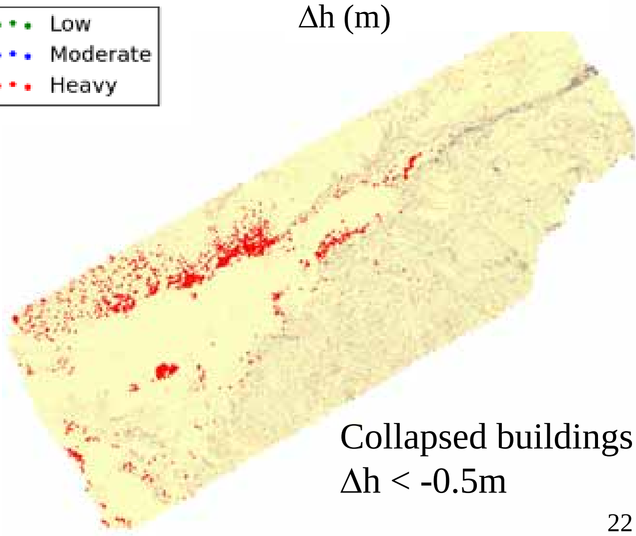
Moya, L., F. Yamazaki, W. Liu, T. Chiba, Estimation of coseismic displacement in the 2016 Kumamoto earthquake from Lidar data, ***6ACEE***, 2016.

Estimation of collapsed buildings from the height change in the footprint



Δh = -0.17m σ = 0.77m r = 0.857





Collapsed buildings
$\Delta h < -0.5$m

Summary

- Application of remote sensing technologies to disaster response was discussed for the 2016 Kumamoto, Japan earthquake.
- Optical satellite images were used under the framework of International Charter..
- Satellite SAR sensors were used to extract landslides and building damage.
- LiDAR DSMs were used to estimate detailed coseismic displacements, building damage and landslides.

References:

L. Moya, F. Yamazaki, W. Liu, T. Chiba, Calculation of coseismic displacement from Lidar data in the 2016 Kumamoto, Japan, earthquake, *Natural Hazards and Earth System Sciences*, 17, 143-156, 2017.

W. Liu, F. Yamazaki, Extraction of collapsed buildings due to the 2016 Kumamoto earthquake based on multi-temporal PALSAR-2 data, *Journal of Disaster Research*, 12(2), 2017.

F. Yamazaki, W. Liu, Remote sensing technologies for post-earthquake damage assessment: A case study on the 2016 Kumamoto earthquake, Keynote Lecture, *6th Asia Conference on Earthquake Engineering*, Cebu City, Philippines, 2016.

Symposium on J-Rapid-Kumamoto

04 March 2017, Kumamoto University

Recent Earthquakes in Nepal, Thailand, and Japan

My impression about building vulnerability and ground motion

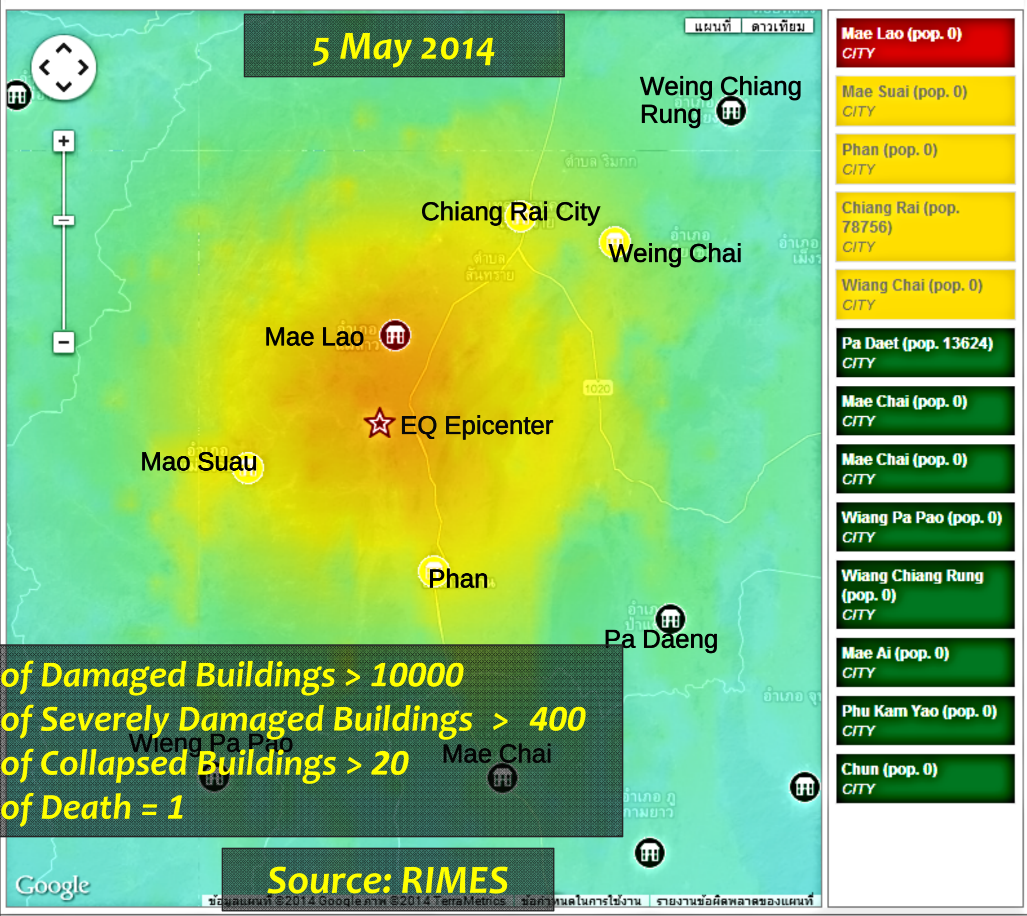
Pennung Warnitchai

Professor of Structural Engineering

Asian Institute of Technology

Ground Shaking Intensity Map of the M6.3 Chiang Rai Earthquake

5 May 2014

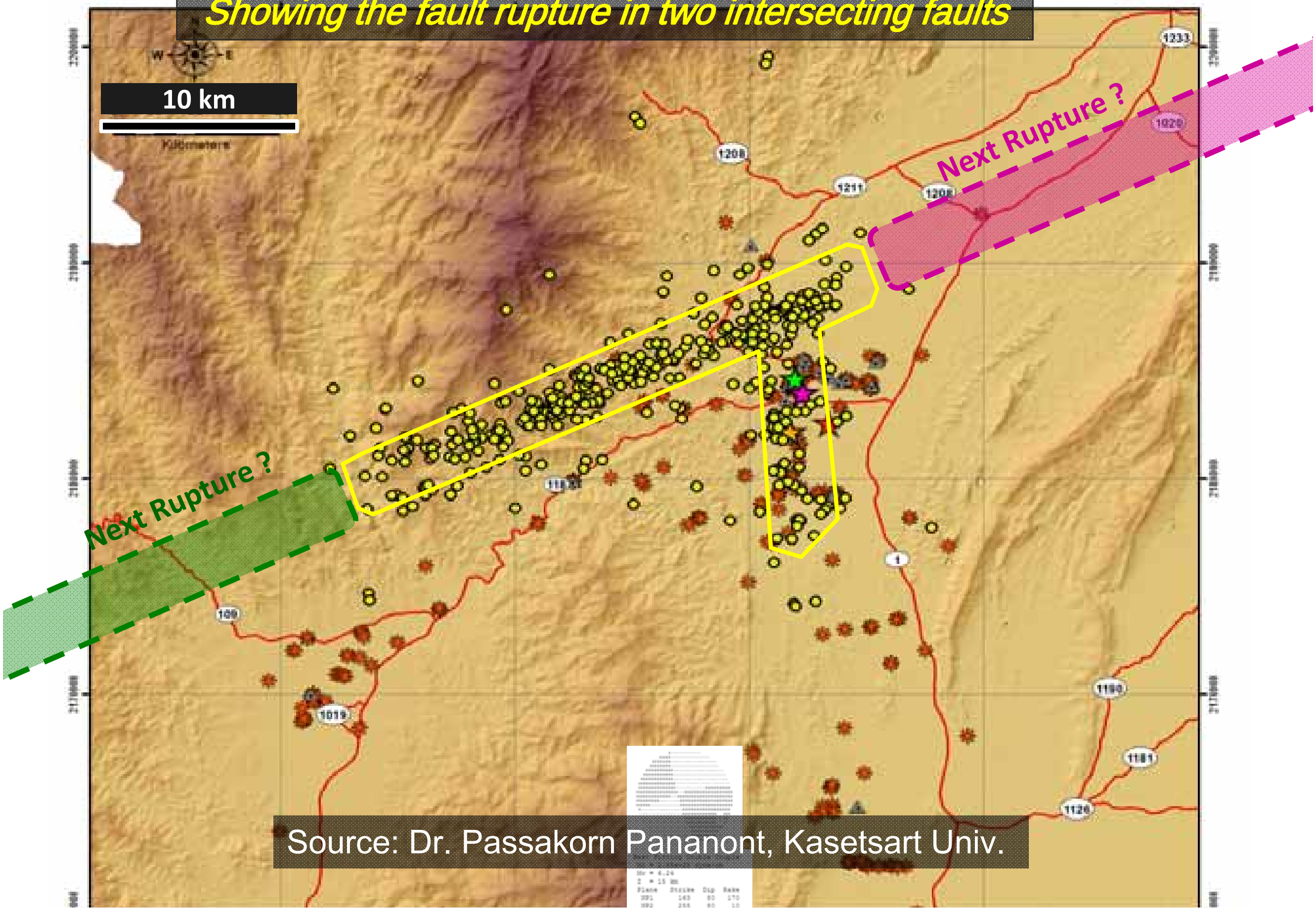


Number of Damaged Buildings > 10000
Number of Severely Damaged Buildings > 400
Number of Collapsed Buildings > 20
Number of Death = 1

Source: RIMES

Distribution of Aftershocks

Showing the fault rupture in two intersecting faults



Source: Dr. Passakorn Pananont, Kasetsart Univ.

Building collapse by the failure of all columns in the first story

(Ban Tamao, Mae Lao District, Chiang Rai: Epicentral Region)

No strong motion records in this area.

Peak Ground Acceleration (PGA) is estimated to be about 0.2 g to 0.3+g.

Most existing buildings are not designed & constructed for earthquake resistance

Phan Pithayakom School: a 4-story RC Building
(Phan District, Chiang Rai)

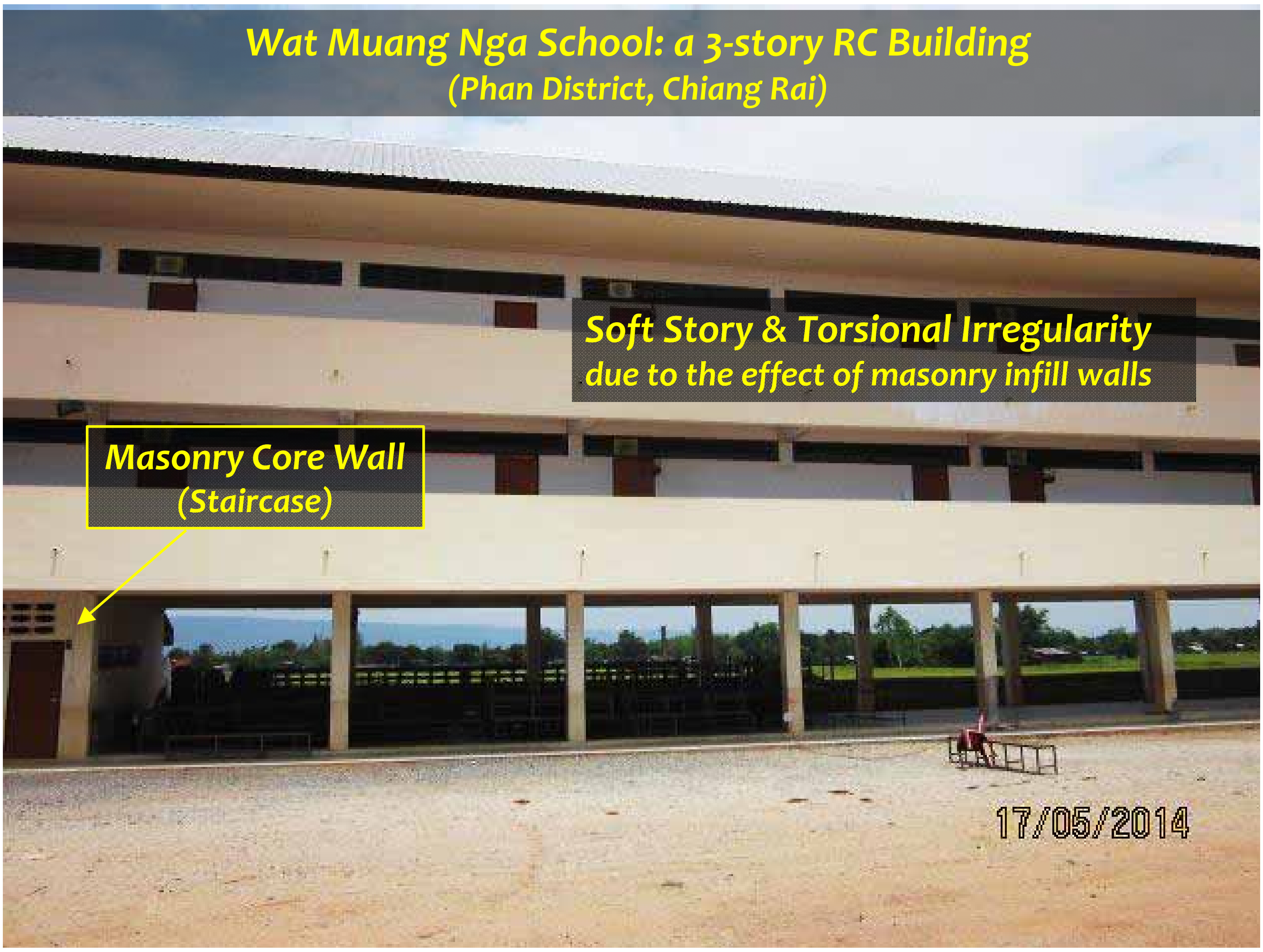
Extensive shear failure in the first-story columns

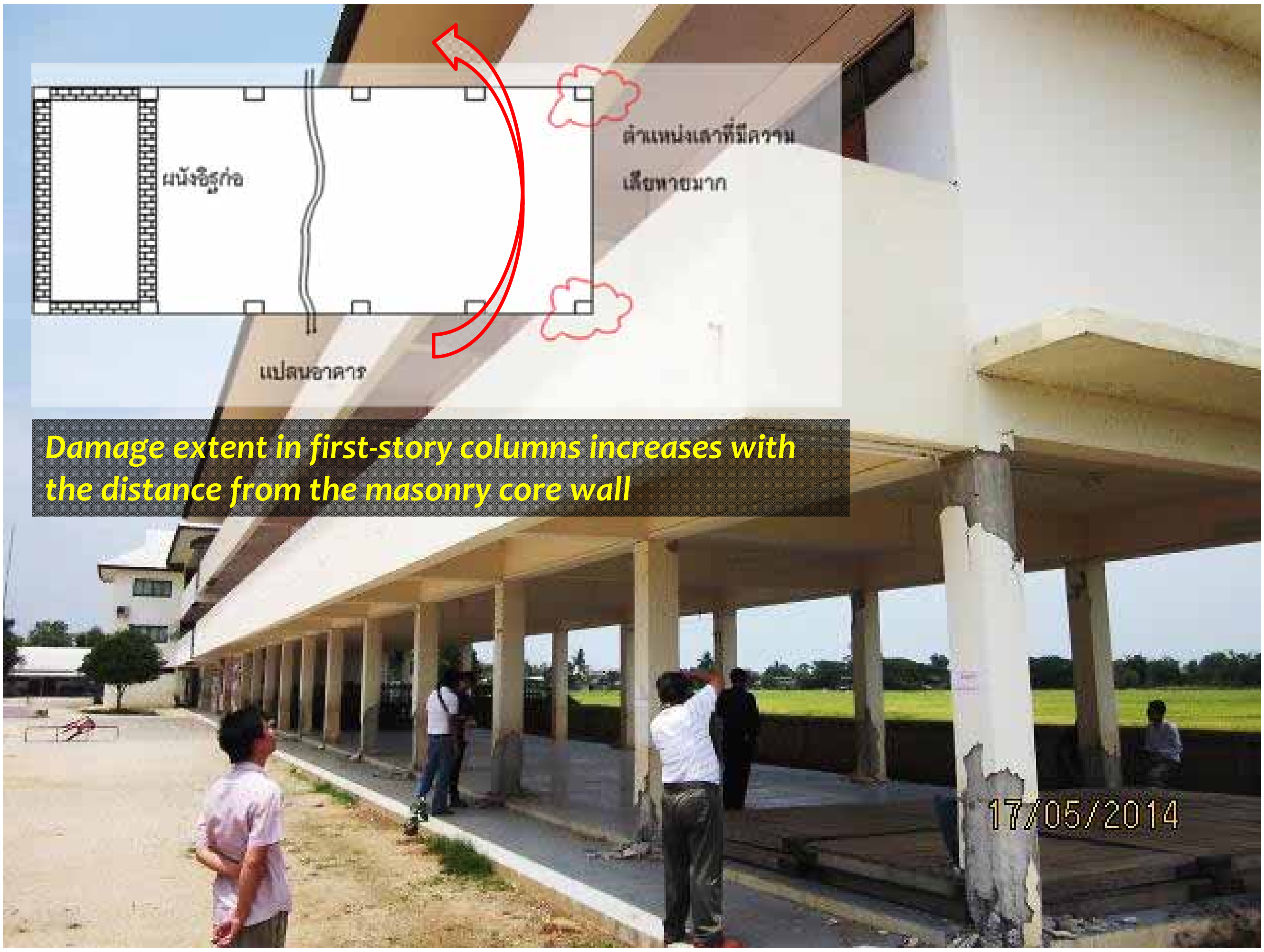
No seismic detailing—low amount of transverse reinforcement & wide spacing

Failure location is just above the infill walls


Collapse of Masonry Infill Walls inside the Building


Collapse of Masonry Infill Walls inside the Building
Building occupants could be injured by the failure of non-structural components.


Wat Muang Nga School: a 3-story RC Building
(Phan District, Chiang Rai)
Soft Story & Torsional Irregularity
due to the effect of masonry infill walls
Masonry Core Wall
(Staircase)
17/05/2014

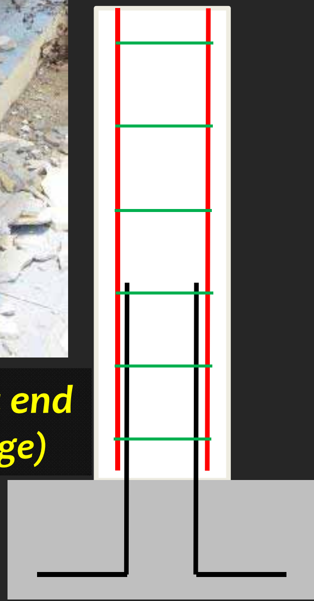

ผนังอิฐก่อ
ตำแหน่งเสาที่มีความ
เสียหายมาก
แปลนอาคาร
Damage extent in first-story columns increases with
the distance from the masonry core wall
17/05/2014

Failure Mode: Lap-splice Failure

Column near core wall (no damage)

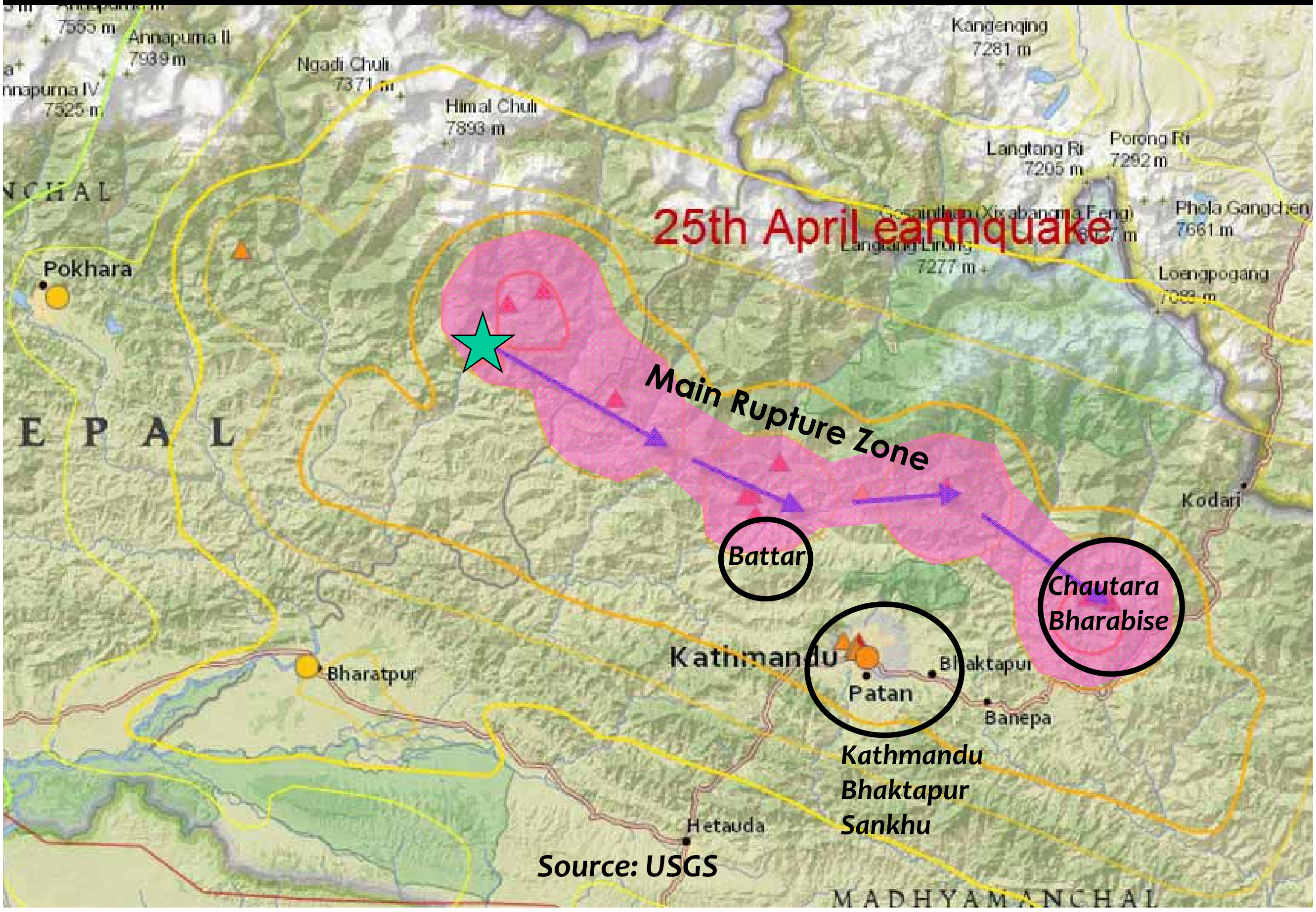
Column at center (moderately damage)

Column at right end (severely damage)



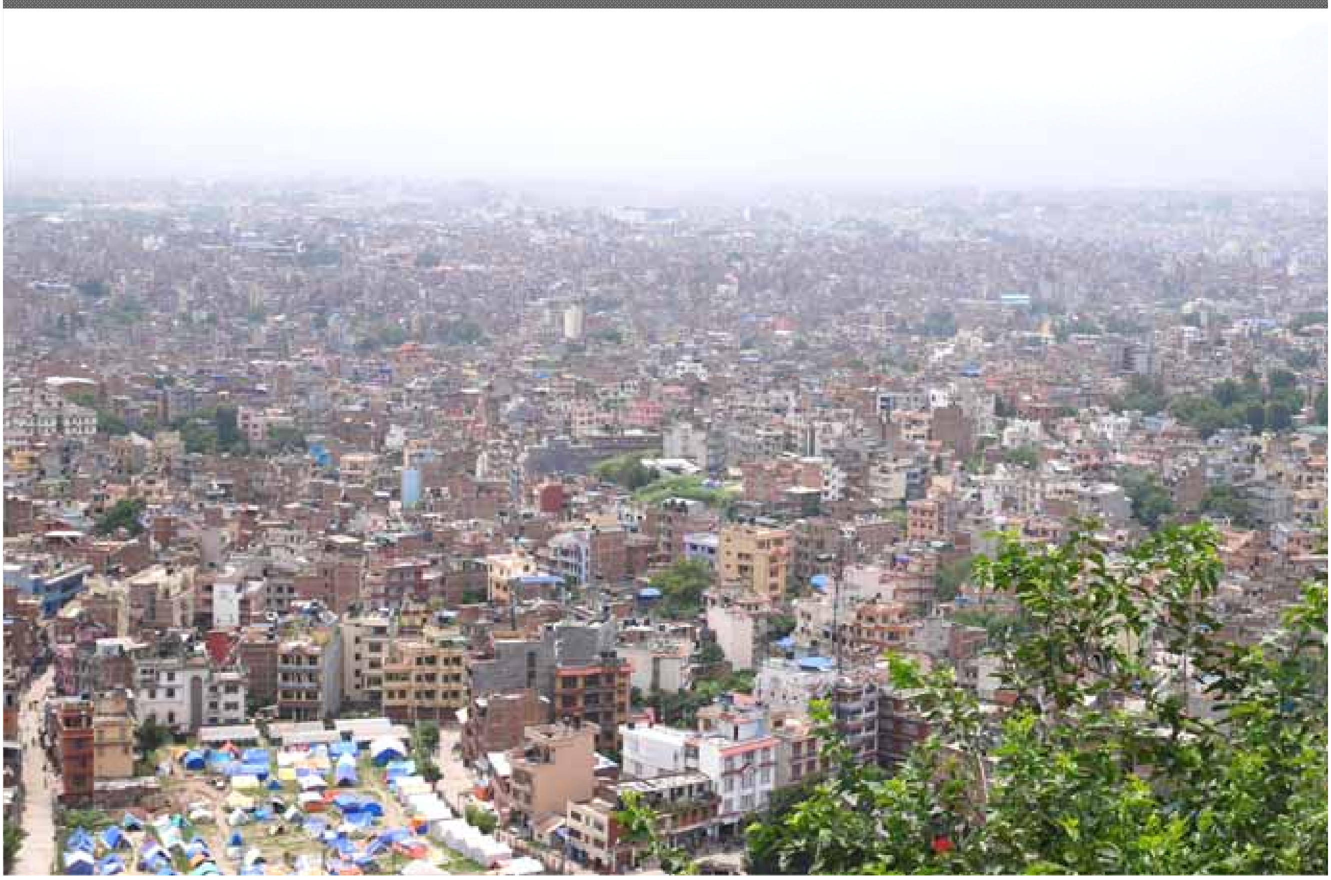
Nepal Earthquake: M 7.8, 25 April 2015

Rupture Mechanism

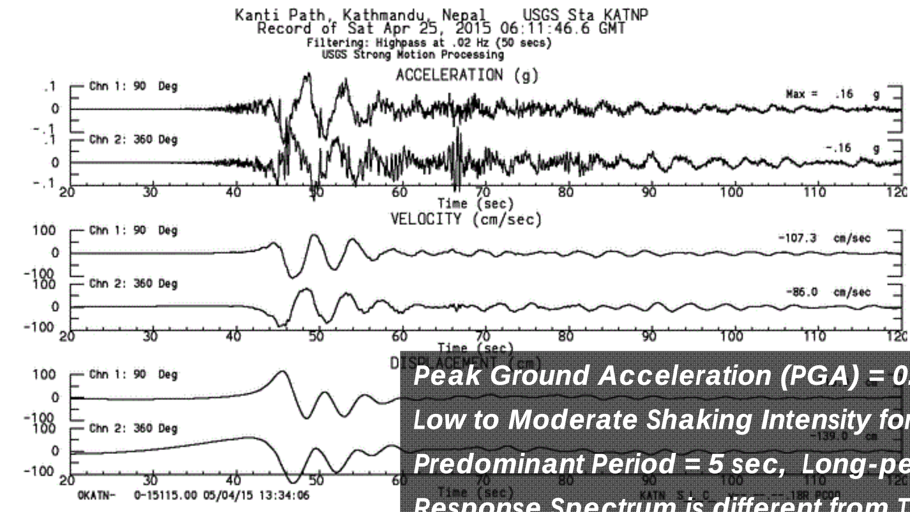


Kathmandu Valley

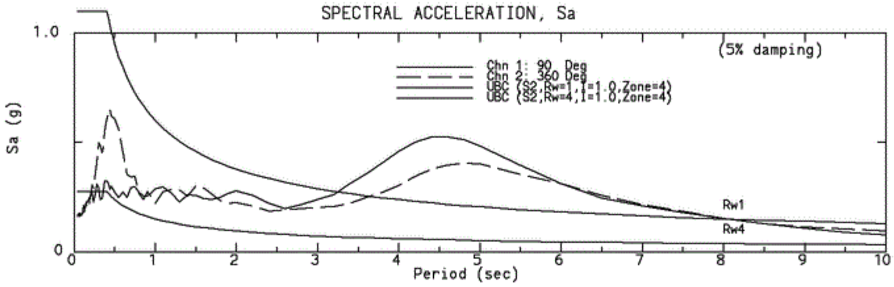
View from Swayambhu Hill Top



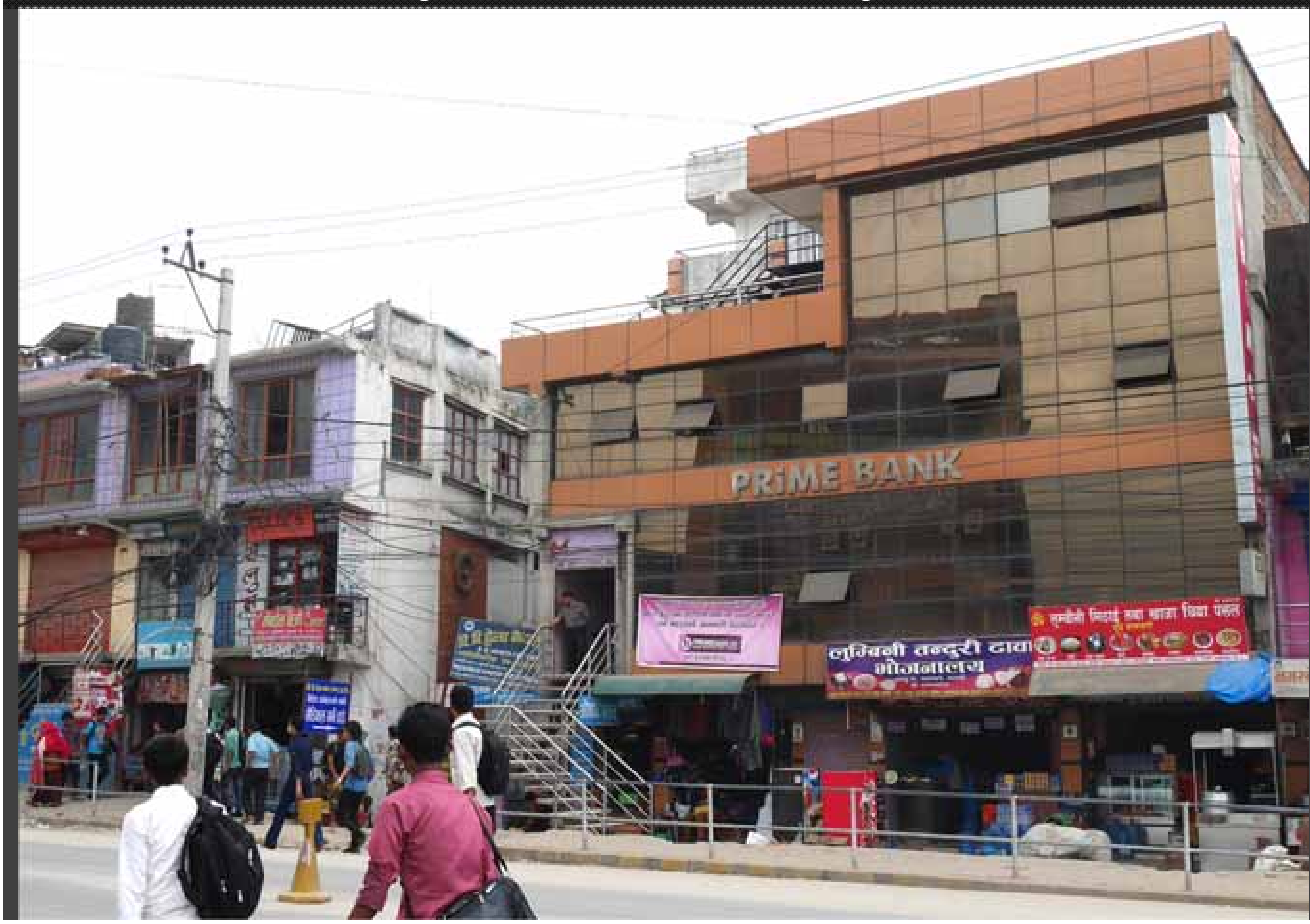
Ground Motion Records in Kathmandu: The 25th April 2015 Earthquake (M_w 7.8)



- Peak Ground Acceleration (PGA) = 0.16 g
- Low to Moderate Shaking Intensity for Low-rise Buildings
- Predominant Period = 5 sec, Long-period Ground Motion!
- Response Spectrum is different from Typical Design Spectrum
- More Damaging Effect to Tall Buildings (Long-period Structures)

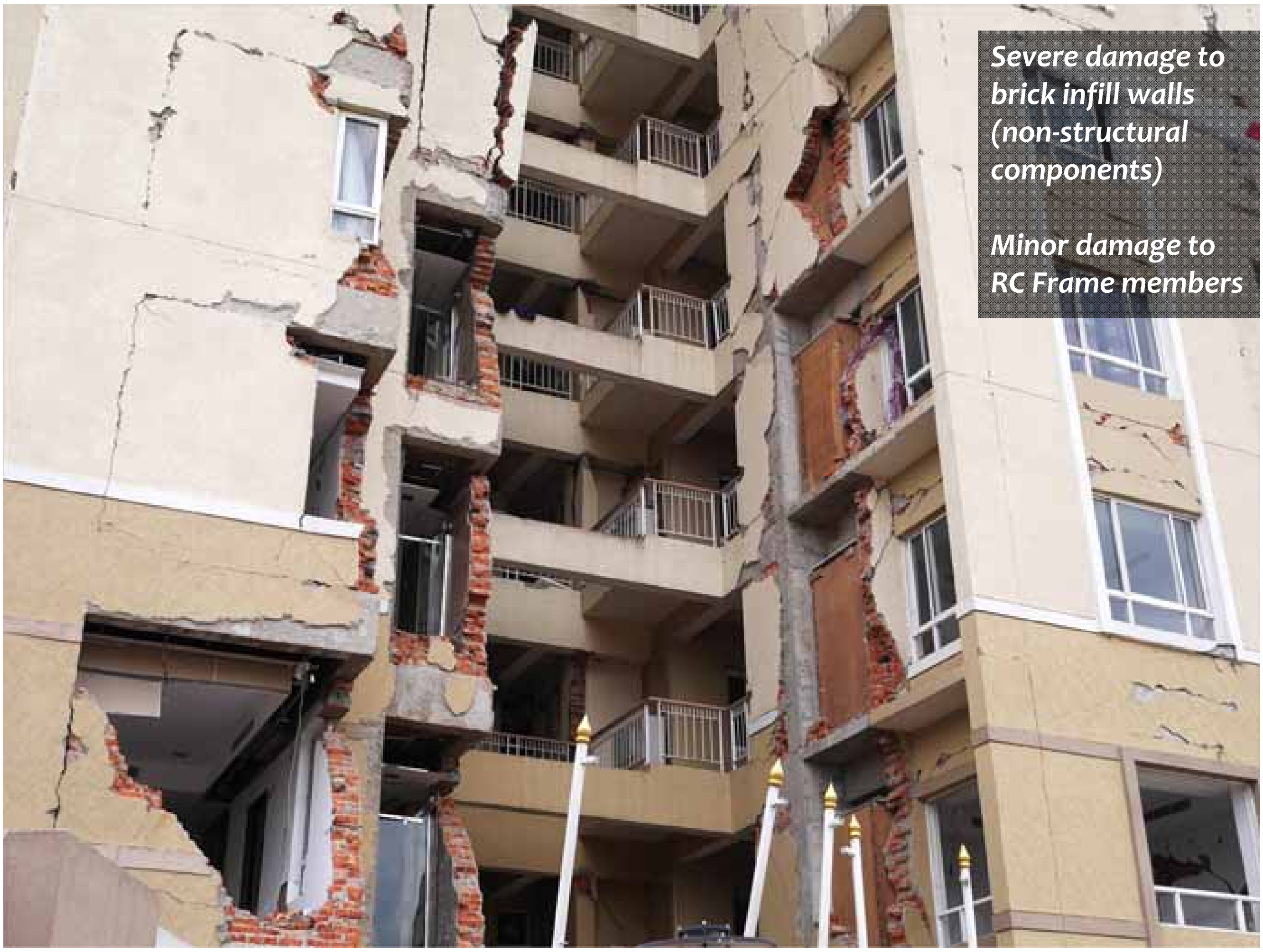


Minor or No Damage to Modern RC Buildings in Kathmandu City



Park View Horizon Apartment
Kathmandu, Nepal

Damaged by the long-period ground motion



Severe damage to brick infill walls (non-structural components)

Minor damage to RC Frame members

Takai *et al. Earth, Planets and Space* (2016) 68:10
DOI 10.1186/s40623-016-0383-7

Earth, Planets and Space
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LETTER **Open Access**

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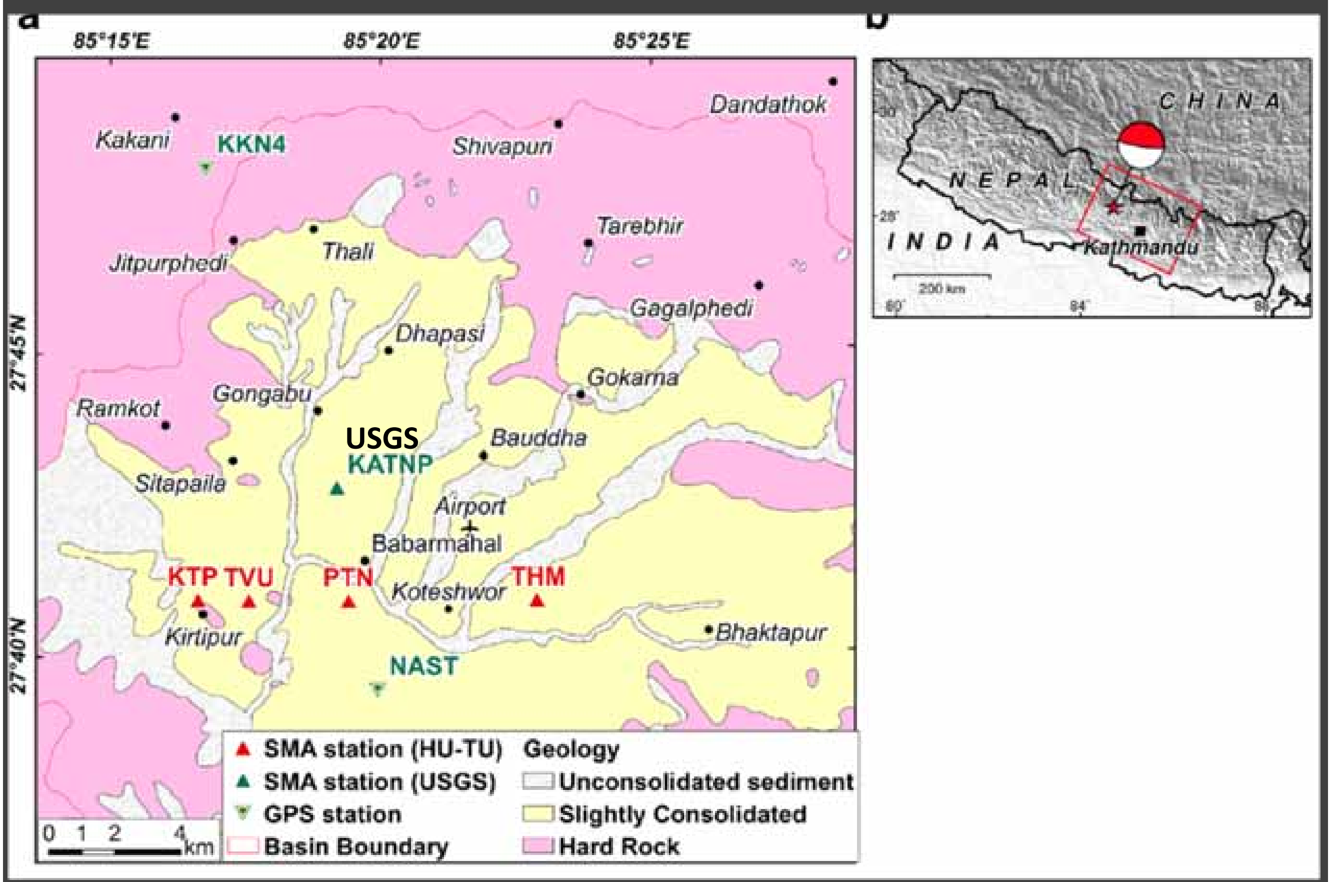
Strong ground motion in the Kathmandu Valley during the 2015 Gorkha, Nepal, earthquake

Nobuo Takai[1*], Michiko Shigefuji[2], Sudhir Rajaure[3], Subeg Bijukchhen[4], Masayoshi Ichiyanagi[2], Megh Raj Dhital[5] and Tsutomu Sasatani[6]

Abstract

On 25 April 2015, a large earthquake of Mw 7.8 occurred along the Main Himalayan Thrust fault in central Nepal. It was caused by a collision of the Indian Plate beneath the Eurasian Plate. The epicenter was near the Gorkha region, 80 km northwest of Kathmandu, and the rupture propagated toward east from the epicentral region passing through the sediment-filled Kathmandu Valley. This event resulted in over 8000 fatalities, mostly in Kathmandu and the adjacent districts. We succeeded in observing strong ground motions at our four observation sites (one rock site and three sedimentary sites) in the Kathmandu Valley during this devastating earthquake. While the observed peak ground acceleration values were smaller than the predicted ones that were derived from the use of a ground motion prediction equation, the observed peak ground velocity values were slightly larger than the predicted ones. The ground velocities observed at the rock site (KTP) showed a simple velocity pulse, resulting in monotonic-step displacements associated with the permanent tectonic offset. The vertical ground velocities observed at the sedimentary sites had the same pulse motions that were observed at the rock site. In contrast, the horizontal

Strong-motion Accelerometer Stations in Kathmandu Valley



Observed Ground Accelerations in Kathmandu

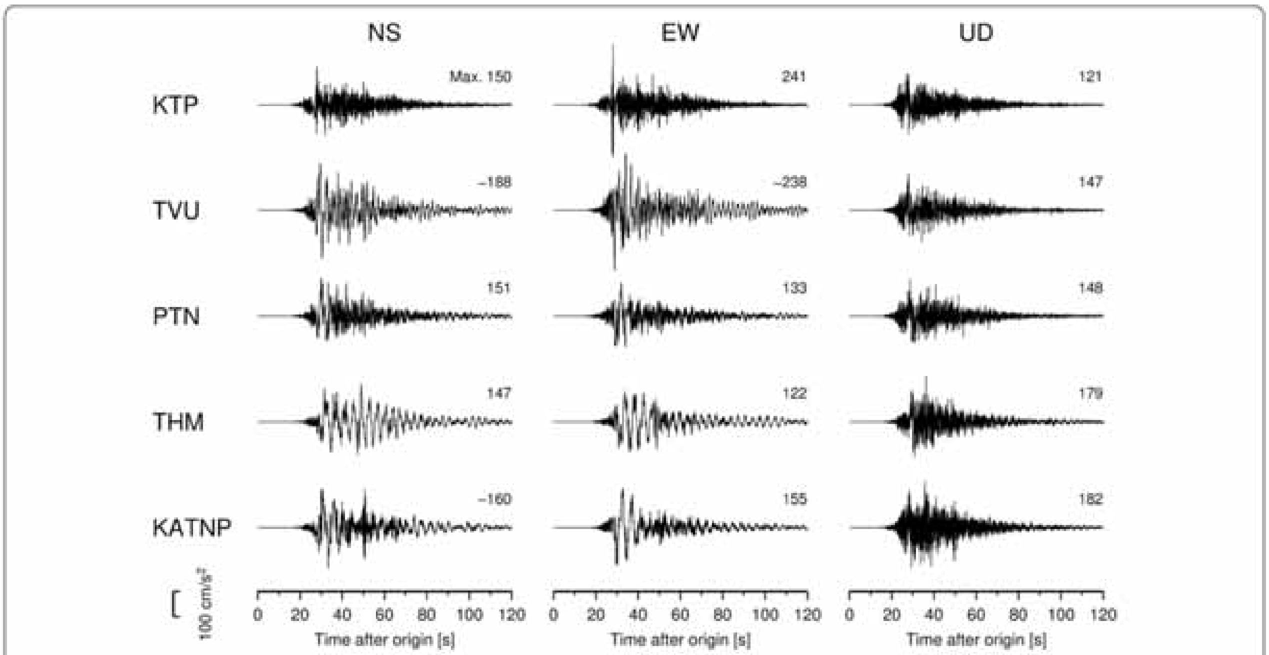
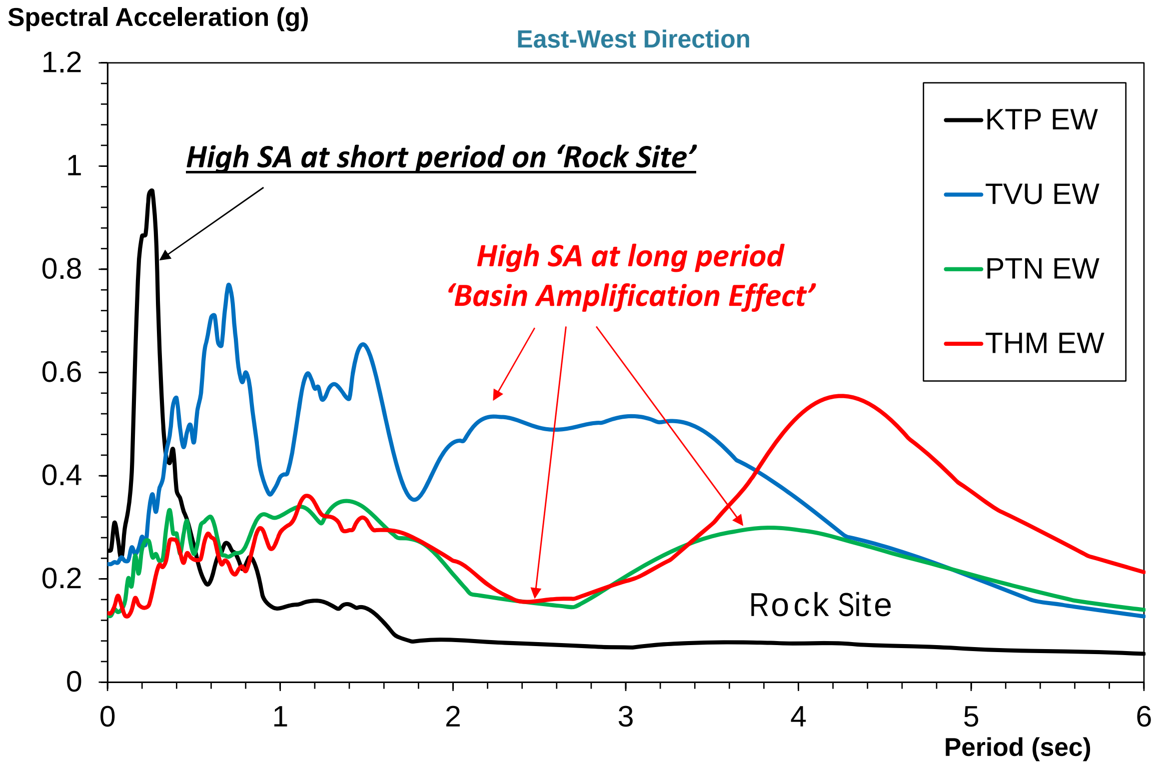


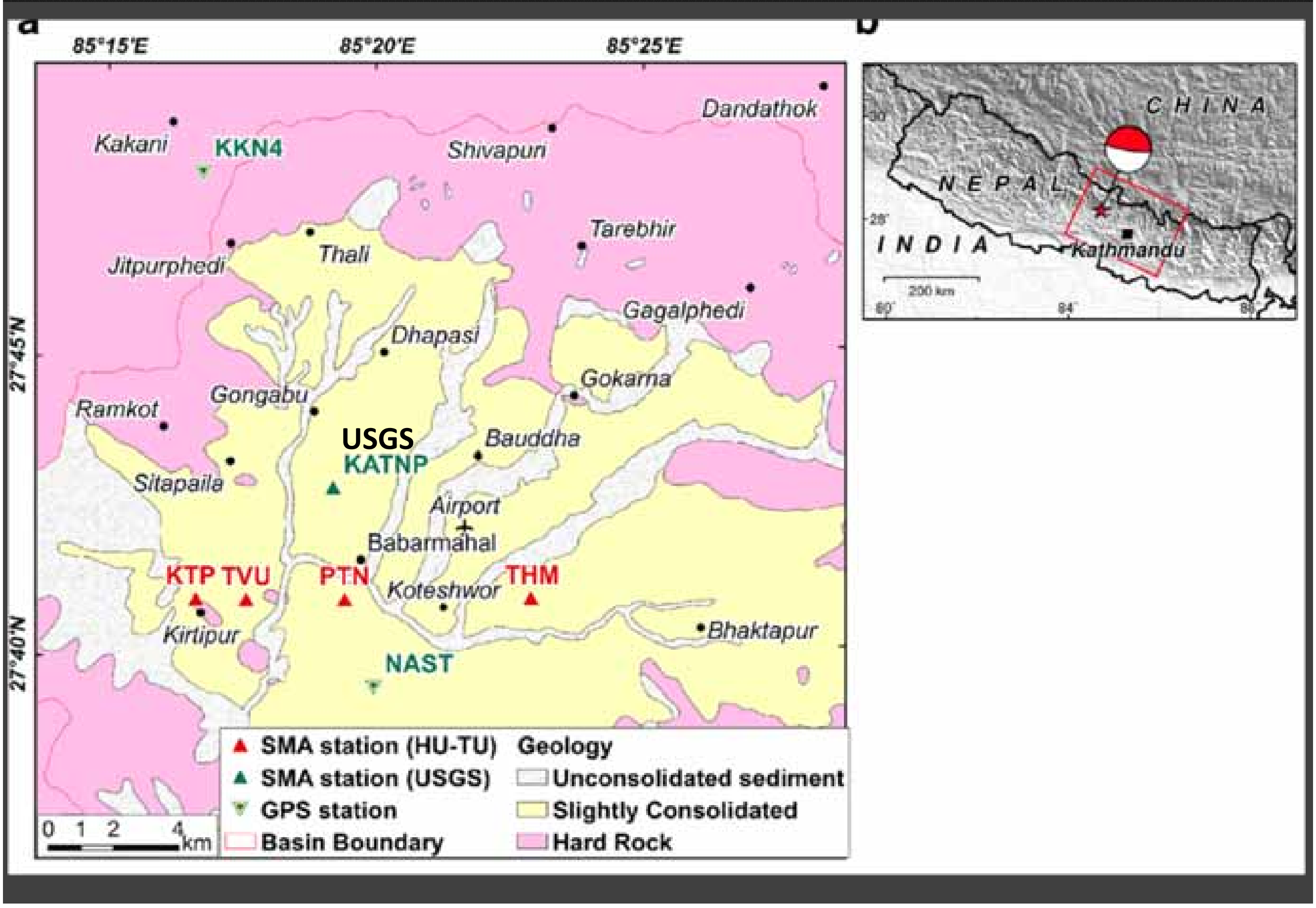
Fig. 2 Observed ground accelerati… soft sedimentary sites. The wavefo… …rock site and the others are

PGA is low—about 0.12g to 0.24g

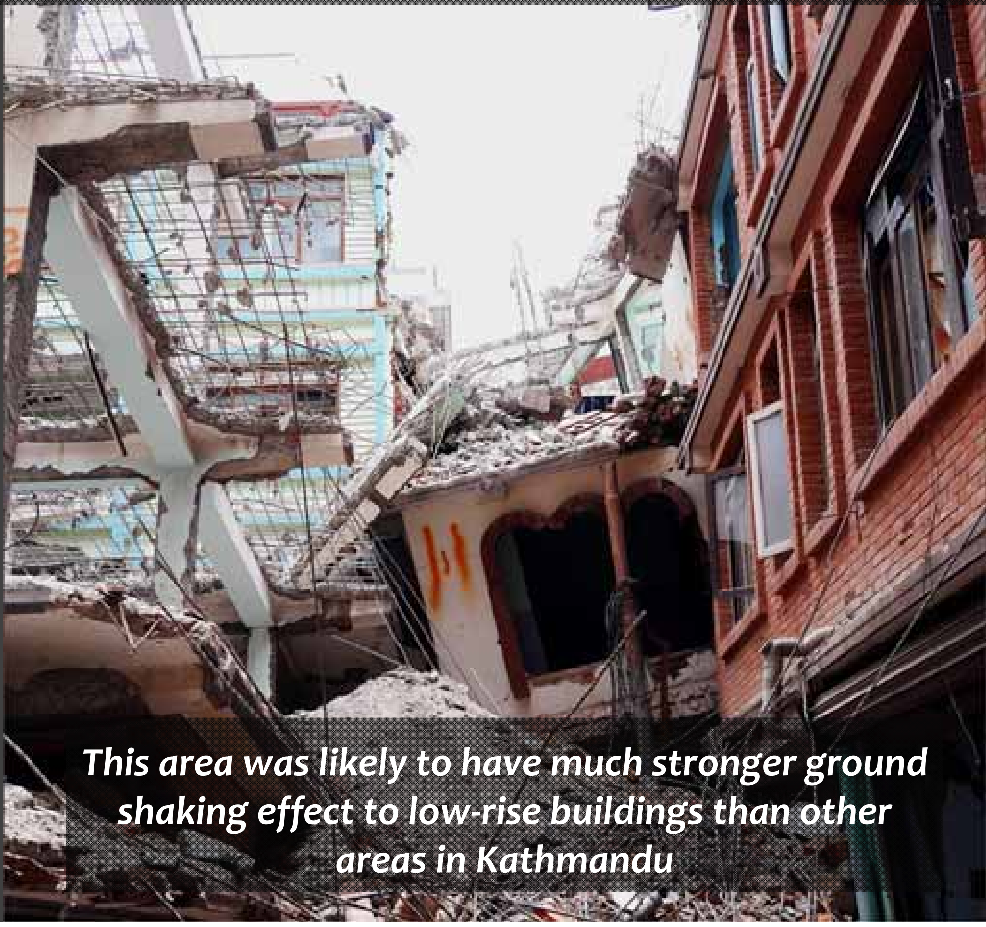
Acceleration Response Spectrum (5% Damped)



Strong-motion Accelerometer Stations in Kathmandu Valley



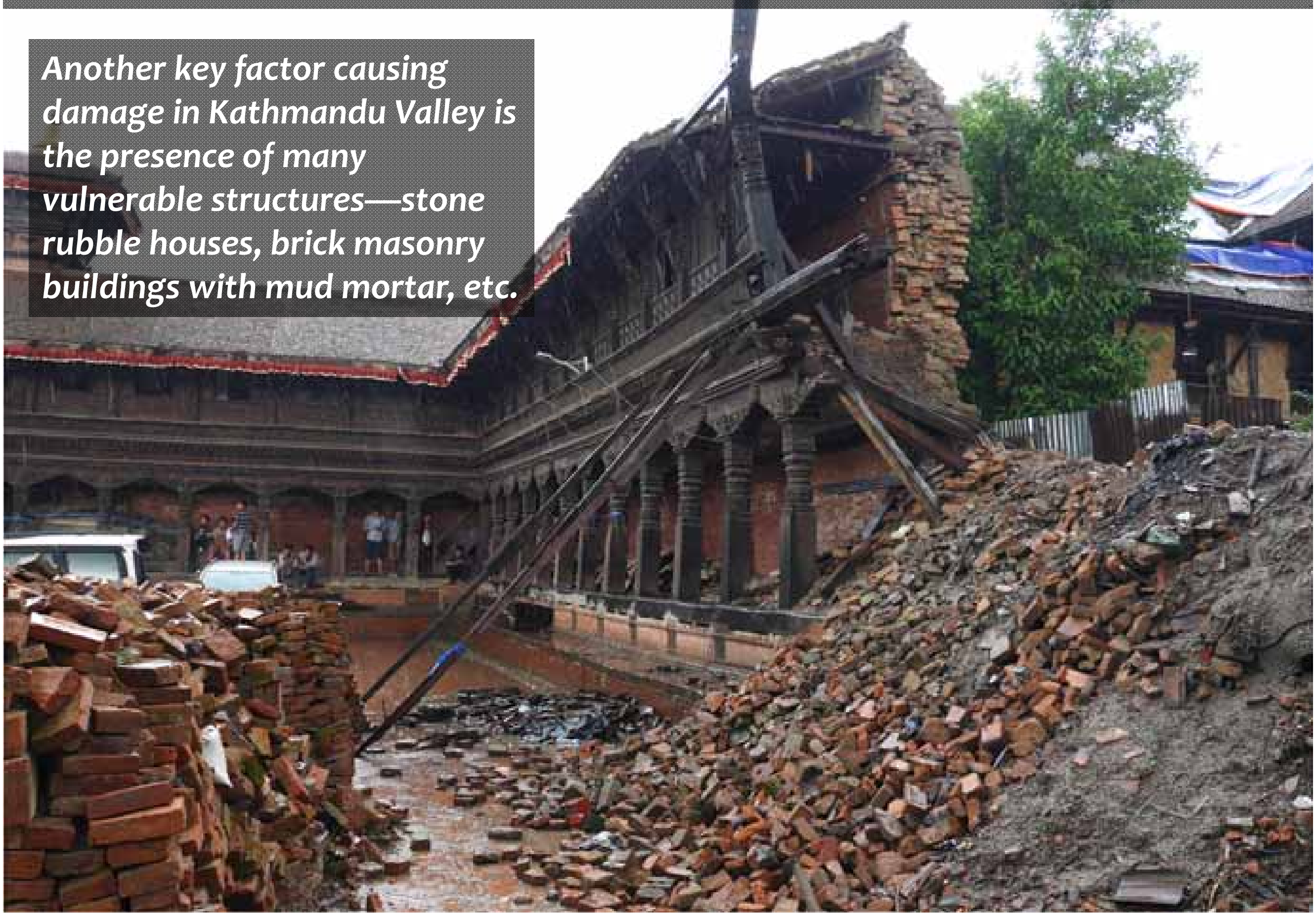
The Concentrated Damage Area in Gongabu, Kathmandu



Collapsed RC Building in Gongabu, Kathmandu

Pancake Collapse in Gongabu, Kathmandu

Bhaktapur—An Ancient City in Kathmandu Valley



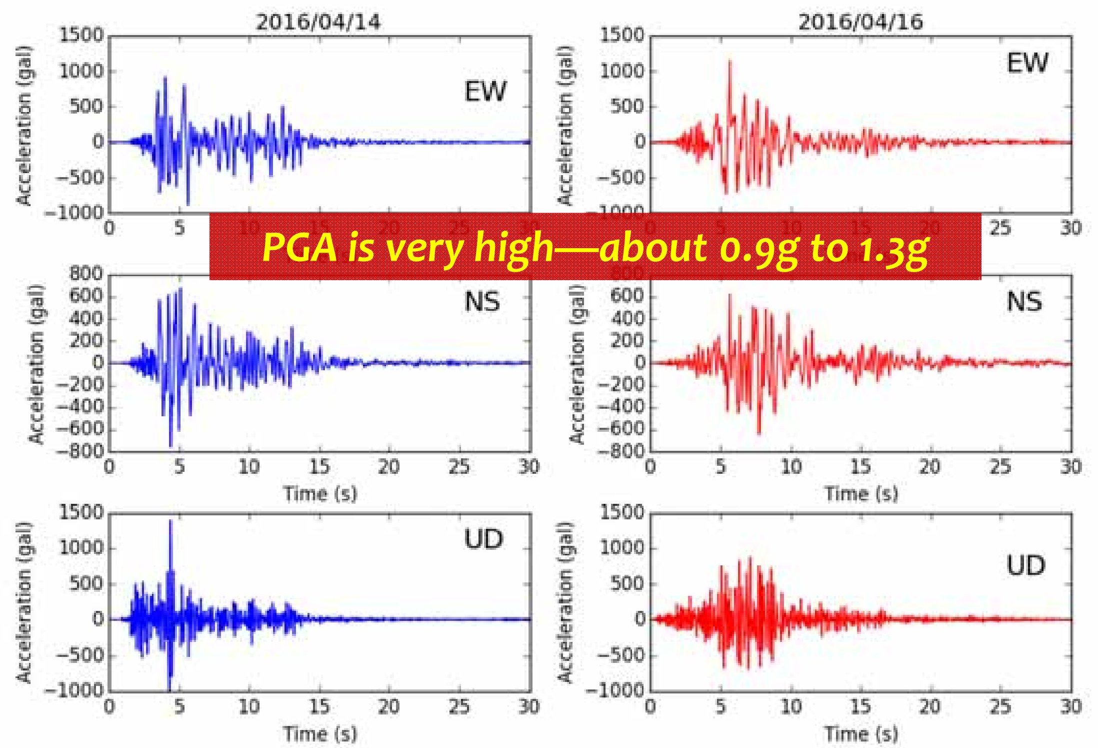
Damage to Cultural Heritage Buildings in Bhaktapur

The Kumamoto Earthquakes: M 6.5 + M7.3, 14 & 16 April 2016

Building Damage by Surface Rupture & Ground Deformation

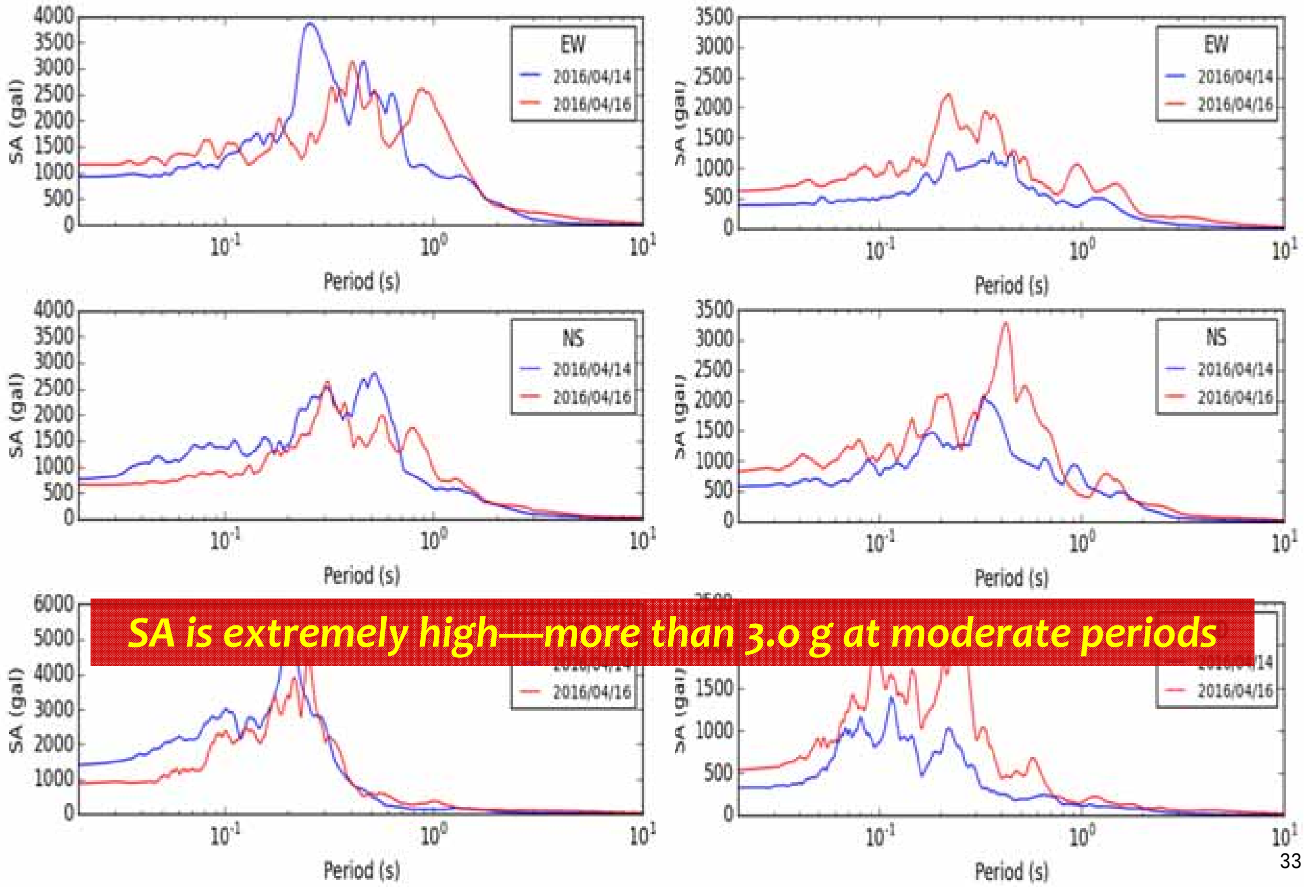
Acceleration records at KiK-net Mashiki (KMMH16)

Event	PGA (cm/s^2)	PGV (cm/s)	I_{JMA}
4/14 21:26	925.0	91.9	6.47
4/16 01:25	1313.8	131.7	6.49



Comparison of Acc. Response Spectra for M6.5 & M7.3 EQs

KiK-net Mashiki K-NET Kumamoto

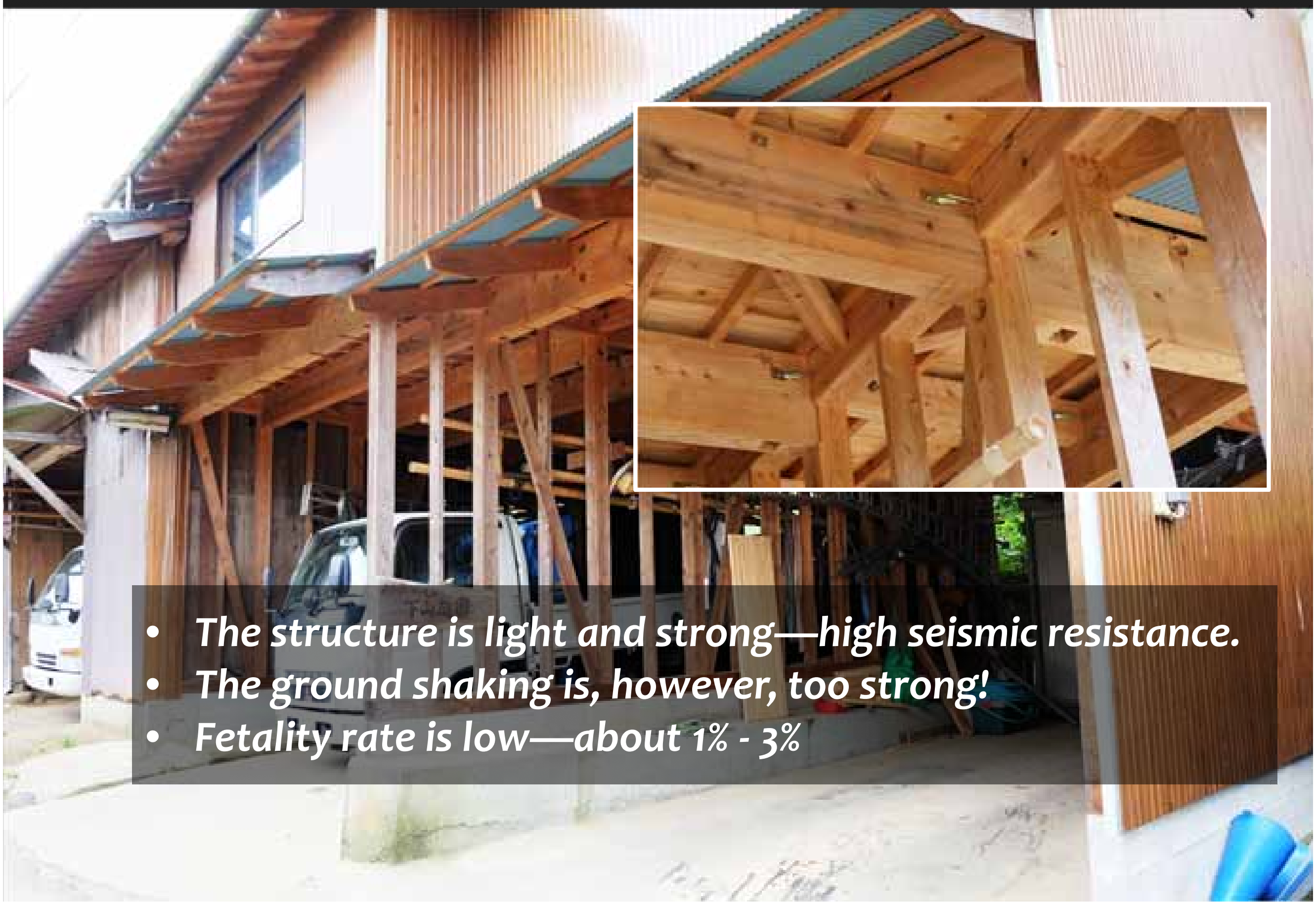


SA is extremely high—more than 3.0 g at moderate periods

Collapse of Wooden Houses in Mashiki Town

Collapse of Wooden Houses in Mashiki Town

Typical Timber Frame & Wooden Panel of Modern Wooden Houses



- *The structure is light and strong—high seismic resistance.*
- *The ground shaking is, however, too strong!*
- *Fetality rate is low—about 1% - 3%*

Minor Damage to Some Wooden Houses in Extremely Severe Shaking Areas