Characteristics of Remote Sensing Images for the 2004 Niigata-ken Chuetsu Earthquake

- Application of SAR imagery for earthquake damage detection -

Masashi Matsuoka[1], Kei Horie[1], Hiroshi Ohkura[2] and Fumio Yamazaki[3]

[1] EDM-NIED, [2] NIED, [3] Chiba Univ.

Objective and Contents

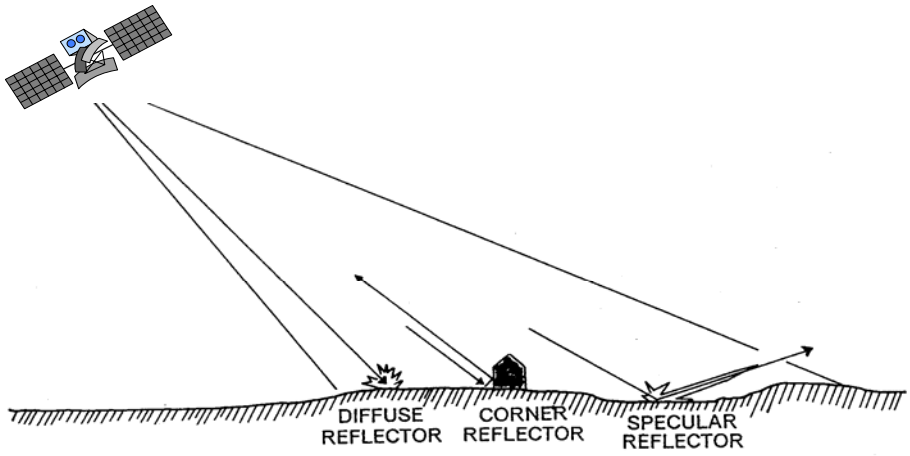
- SAR image characteristics of affected areas due to the 2004 Niigata-ken Chuetsu earthquake and damage detection.

1. Application of our damage detection method developed from the Kobe and Bam studies, to Niigata area, using a pair of pre- and post-earthquake images.
2. An attempt by using two pre-earthquake and one post-earthquake images, to identify smaller building-damage areas compared to the above method.

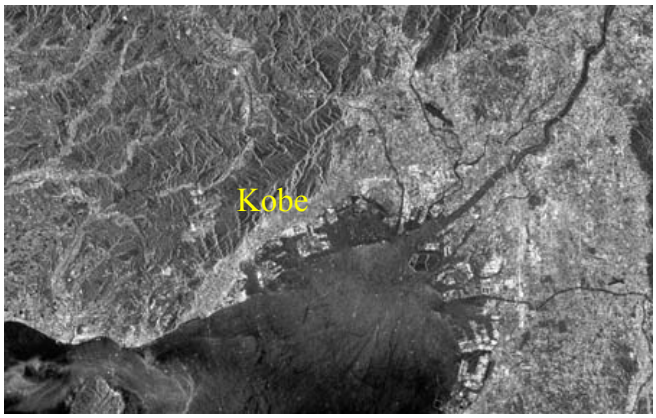
Satellite SAR

SAR: Synthetic Aperture Radar
(Active Microwave Sensor)

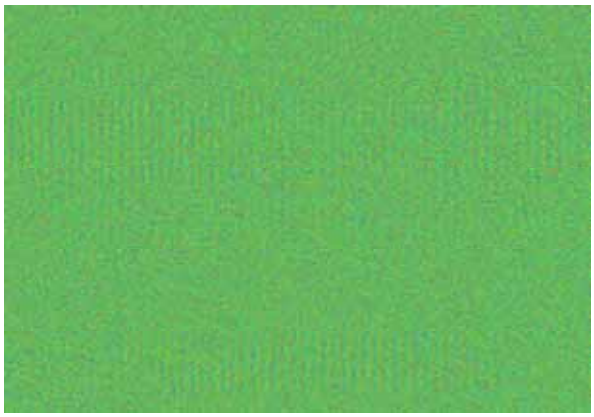
Transmitting a microwave signal, then receiving its reflection (amplitude, phase) from objects on earth's surface



SAR Images



Amplitude Image
Backscattering Coefficient [dB]

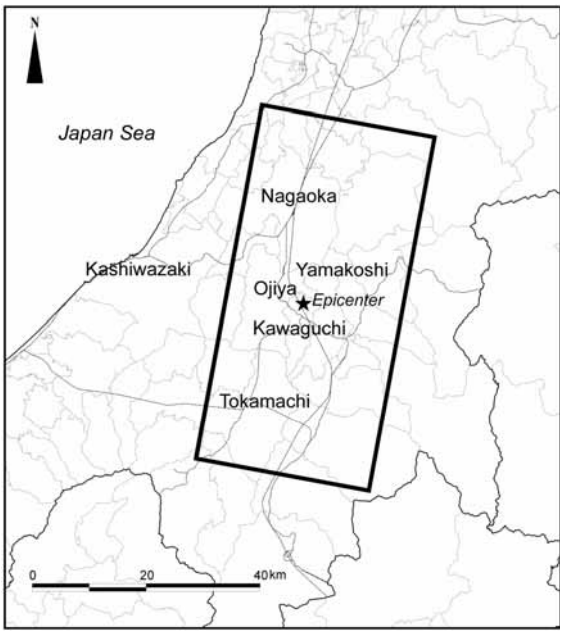


Phase Image
$-\pi \sim \pi$ [rad]

ERS image taken on 1995/5/23

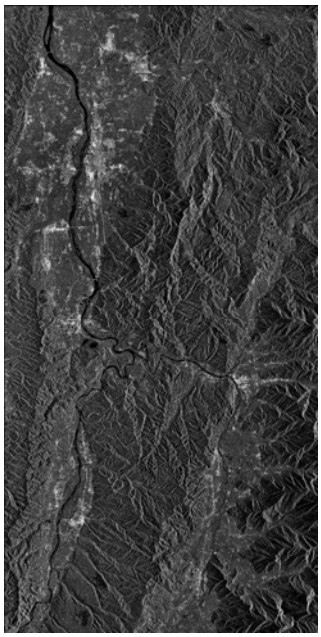
Niigata Chuetsu Earthquake

October 23, 2004
Mw 6.6

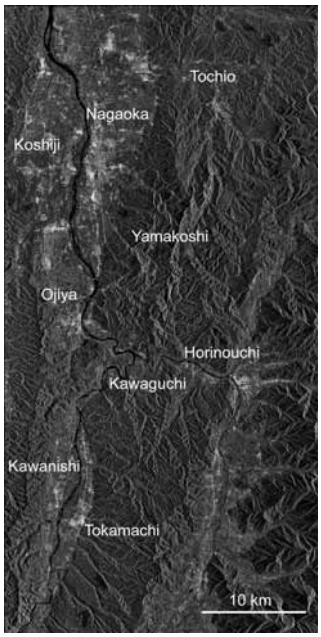


The area of this study

Radarsat/Fine, resolution:9m

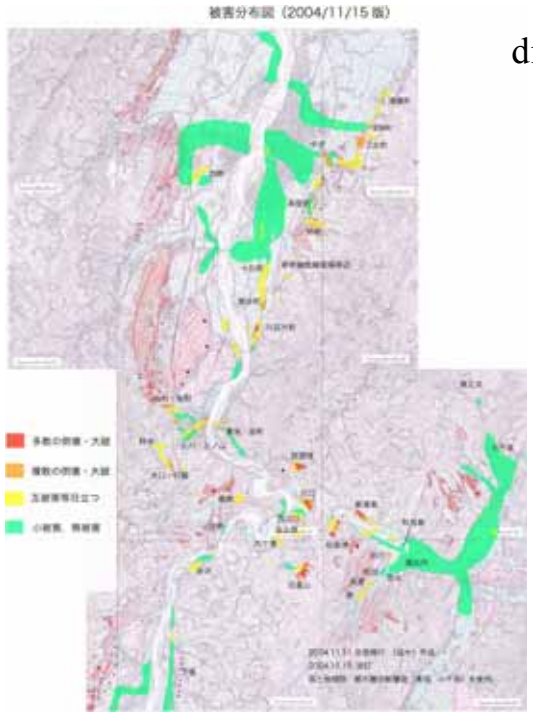


Oct. 1, 2004



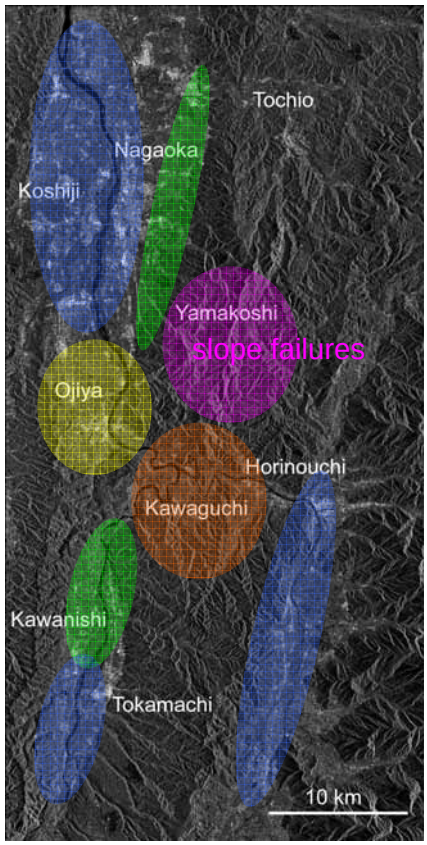
Oct. 25, 2004

Building-Damage Distribution from Field Surveys

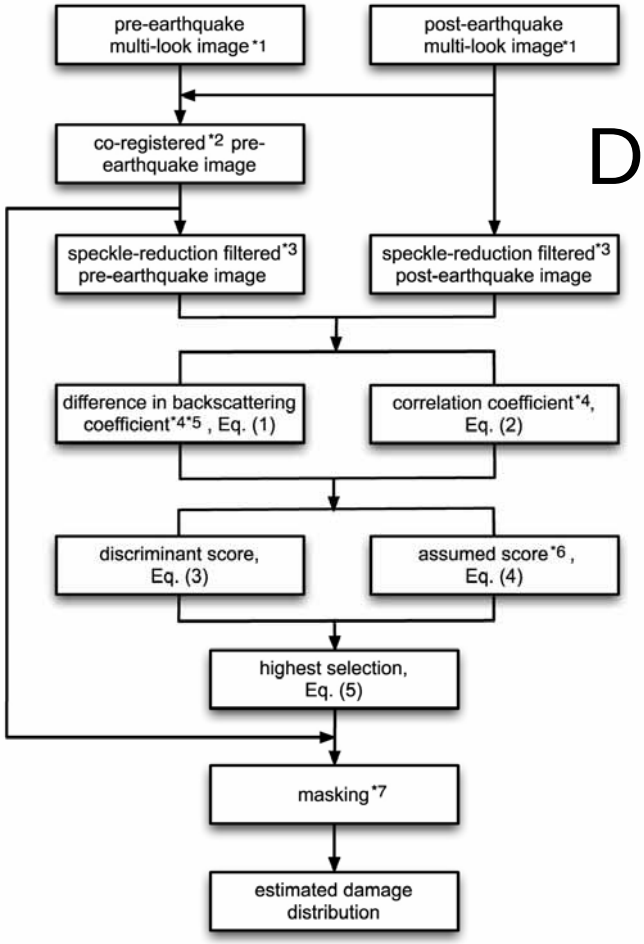


Quick survey result (Yoshimi, 2004)

Schematic distribution of damage



Damage Detection Method



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
Resampling: Nearest-Neighbor method

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

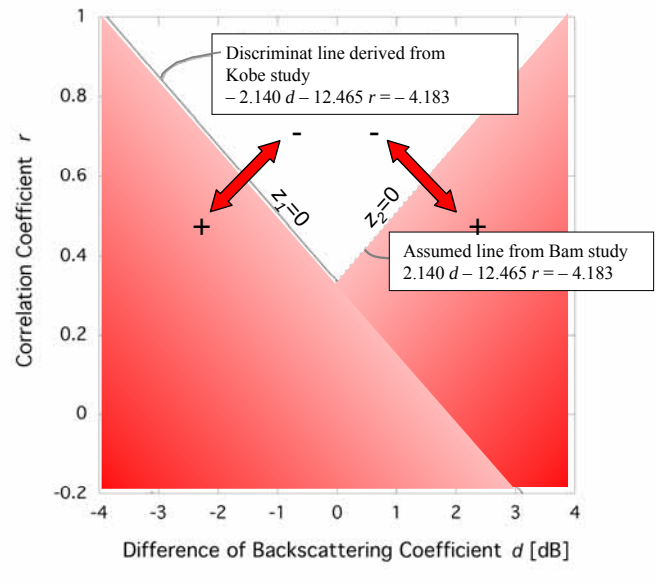
*4 Window size: 13 x 13 pixel

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

*6 Extraction of reverse type of damage:
Set positive value for the coefficient of variable *d* (difference) in Eq.(3)

*7 Threshold value: Depending on incident angle, built environment, etc. (e.g. -5dB)

Damage Detection by *z* Value



A model to estimate damaged areas:

$z_1 = -2.140\,d - 12.465\,r + 4.183$

$z_2 = 2.140\,d - 12.465\,r + 4.183$

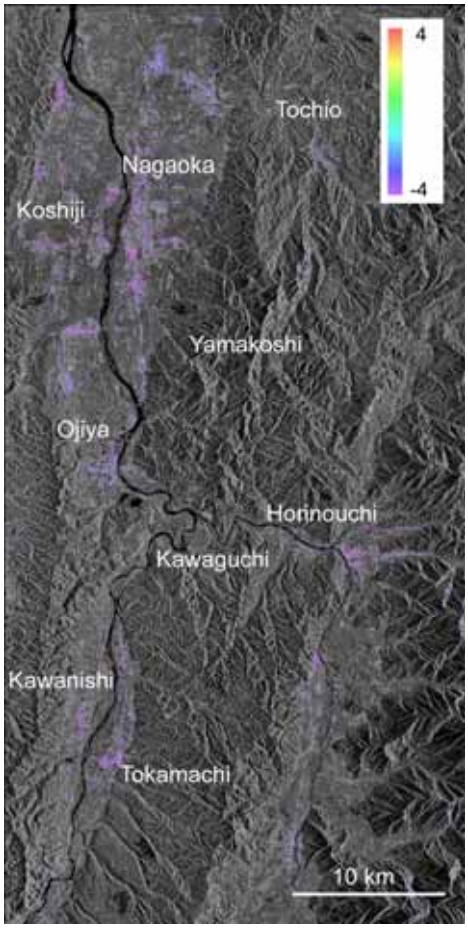
$z = \max(z_1, z_2)$

d : difference in backscattering coefficient(dB)
(after – before)

r : correlation coefficient

Result of Damage Detection for Mid-Niigata Earthquake

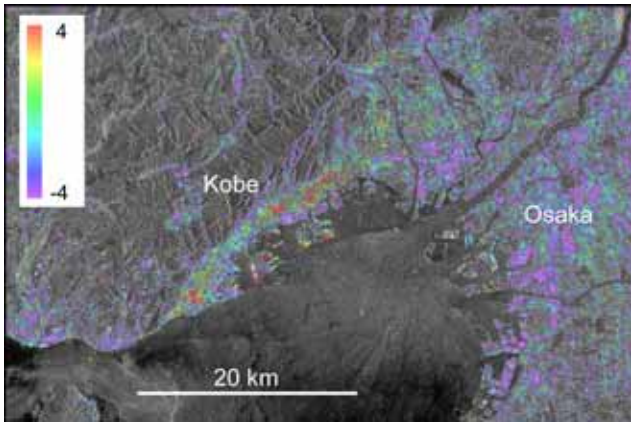
- Low *z*-value areas are spreading



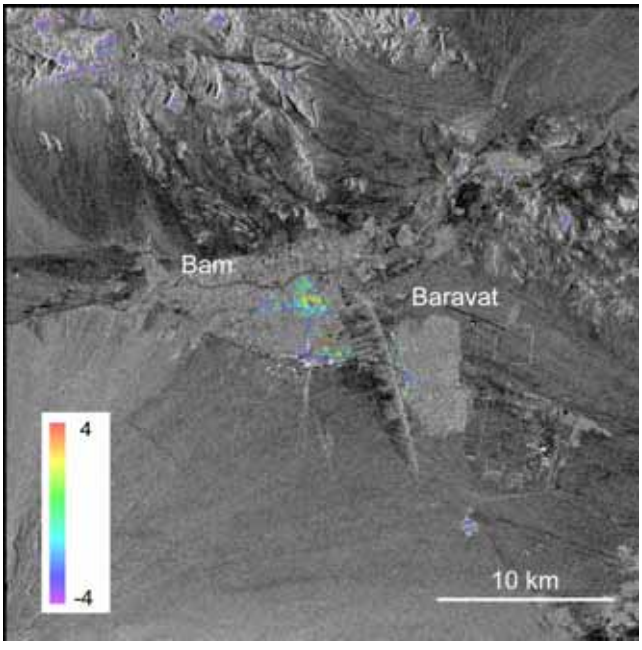
Distribution of *z*-value

Results of Damage Detection for Destructive Earthquakes

- High *z*-value in severely damage areas



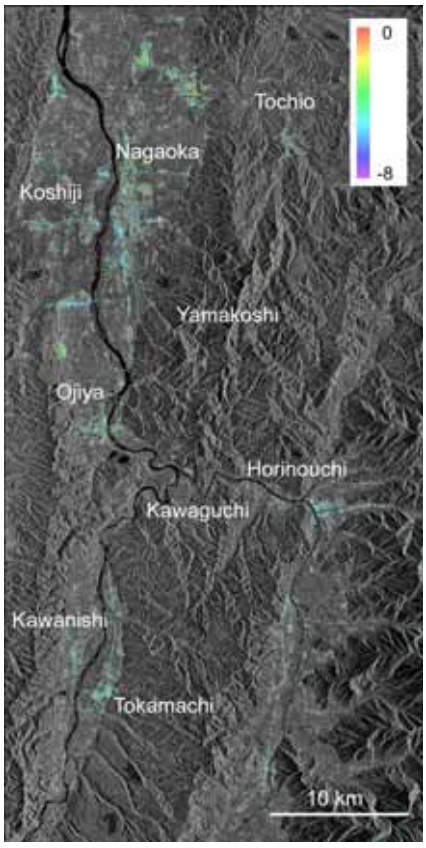
Distribution of *z*-value for
1995 Kobe earthquake (ERS)



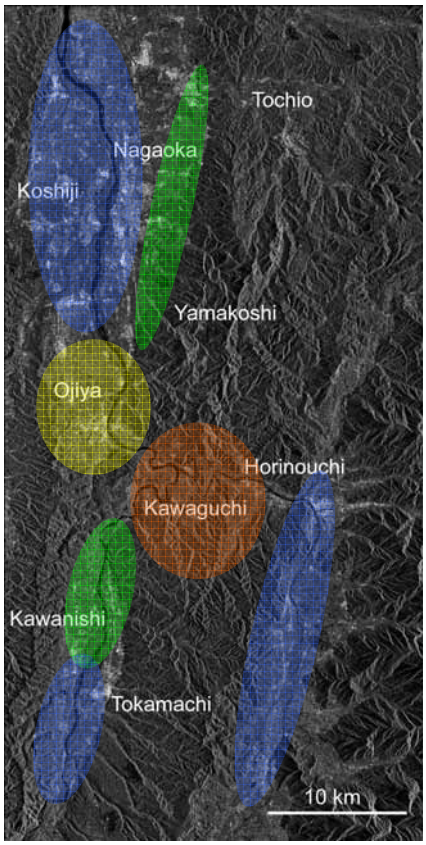
Distribution of *z*-value for
2003 Bam earthquake (Envisat)

Comparison with Actual Damage

- The trend of z-value distribution is not in good agreement to actual damage distribution.
- In the result of the Radarsat images of Mid-Niigata, it was not possible to identify any significant distribution of damaged buildings.



Distribution of z-value (Scale change)



Actual damage distribution

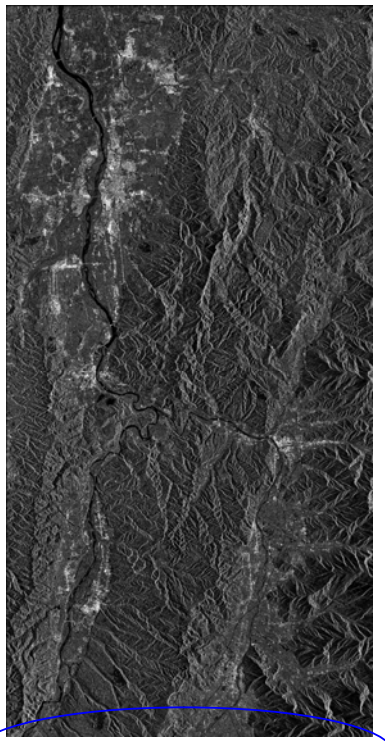
Observation from the Result of Damage Detection (1)

- From field survey reports, the severely-damaged building areas of Niigata earthquake and its distribution were rather small in comparison with those by the Kobe and Bam earthquakes.
- The damage detection method can be applicable to detect the relatively large areas with severely-damage ratio more than approx. 30%.
- The main reason is low signal noise ratio in the area of smaller building-damage ratio.

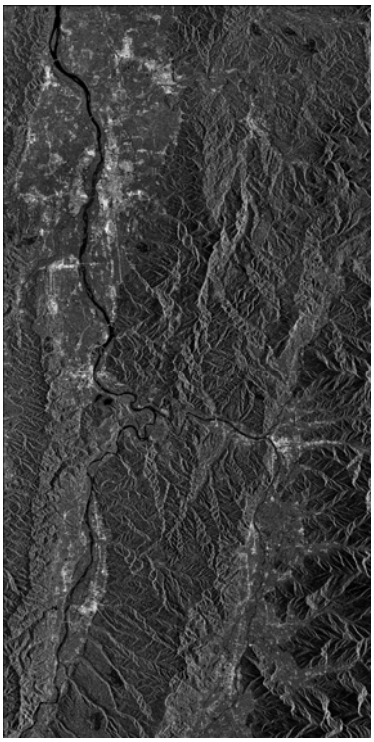
Observation from the Result of Damage Detection (2)

- The noise is likely to be caused by SAR system itself, observation conditions, temporal changes in the earth's surface, etc.
- To minimize the above effects, the understanding of the effect of system noise and stationary temporal surface changes for the indices such as *z*-value and correlation coefficient is needed using a pair of two pre-earthquake images.
- Therefore, we prepared one more pre-earthquake image (Sept. 7, 2004).

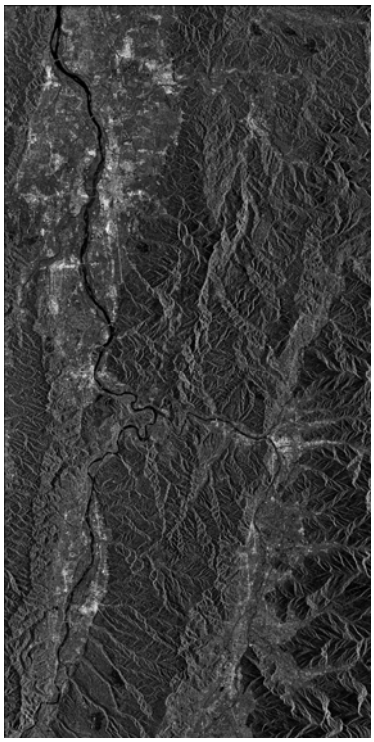
Dataset of SAR Images



Sept. 7, 2004 (before)



Oct. 1, 2004 (before)



Oct. 25, 2004 (after)

Calculating Variations

- To minimize the effect of system noise and stationary temporal surface changes, the variations of the indices (correlation, complex coherence, and *z*-value) were calculated by the following equations,

Correlation coefficient ratio: $(r_{ab} + 1) / (r_{bb} + 1)$

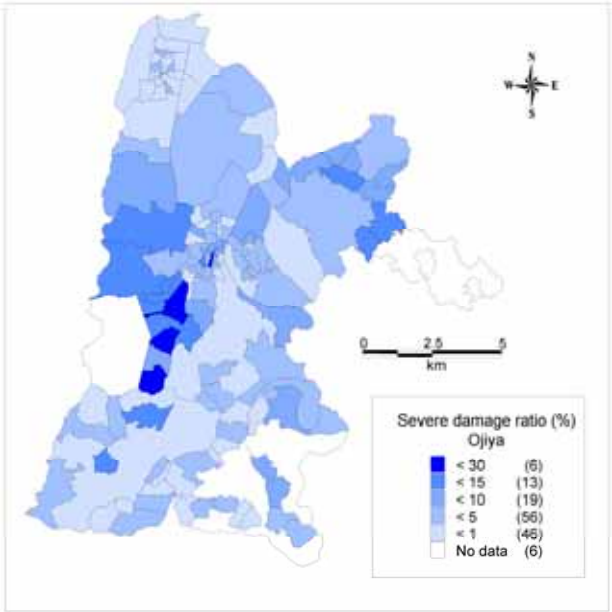
Coherence ratio: ρ_{ab} / ρ_{bb}

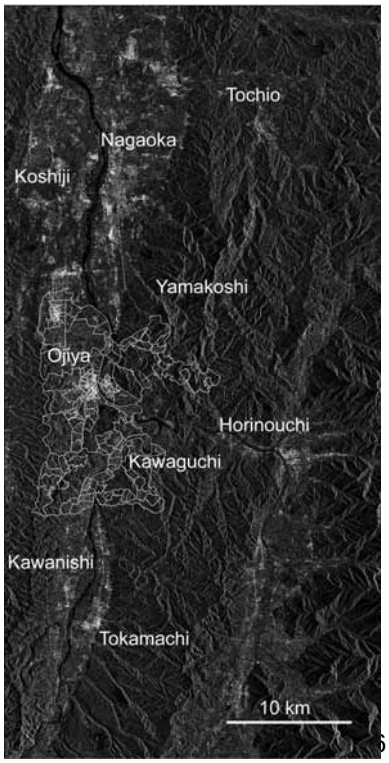
Difference in *z*-value: $z_{ab} - z_{bb}$

ab: after&before, bb: before&before

GIS-based Building Damage Database

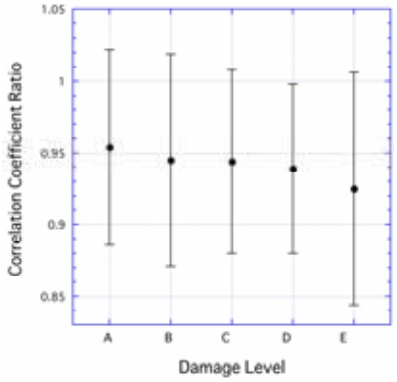
- Overlaying SAR image on GIS database, the relationship between the variations of the indices and damage level.



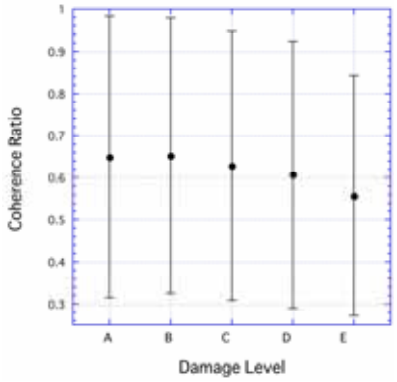


Damage Level vs. Variation Index

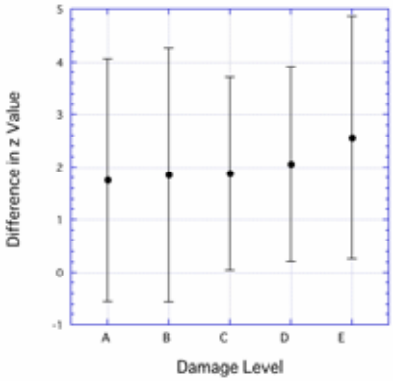
Correlation Coefficient Ratio



Coherence Ratio



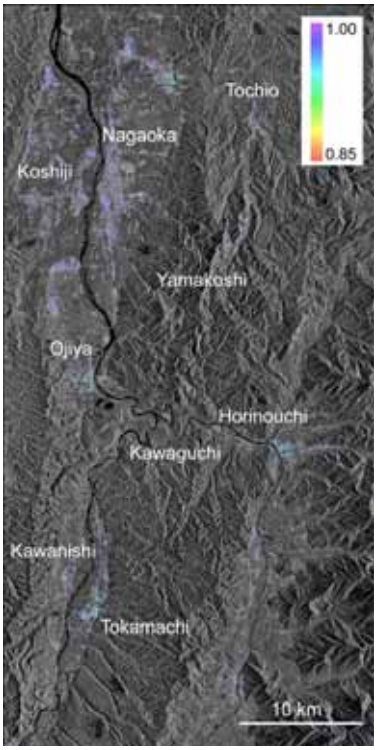
Difference in *z*-value

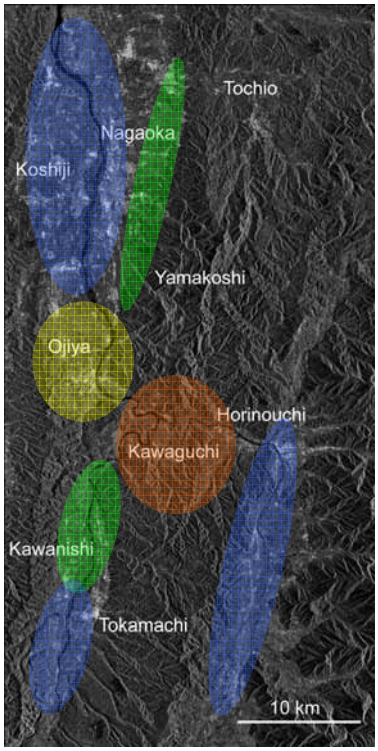


The damage level classified into A, B, C, D, and E, corresponding to the collapsed building ratio of 0-1, 1-5, 5-10, 10-15, and 15-30%, respectively.

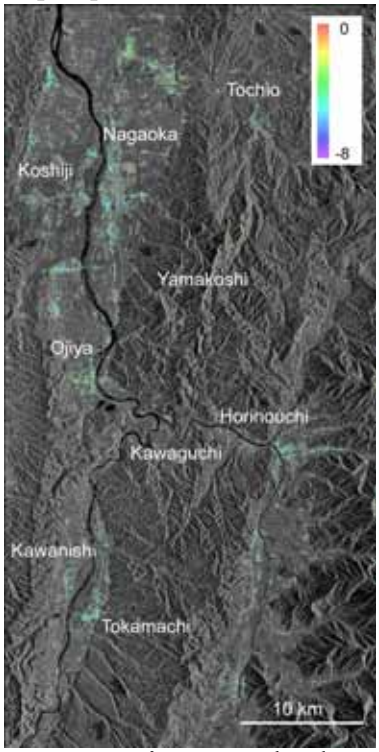
- Though the standard deviations for all indices, according to the variance analysis, the correlation coefficient ratio is selected as a suitable index to reflect the building damage level.

Distribution of Correlation Coefficient Ratio (1)

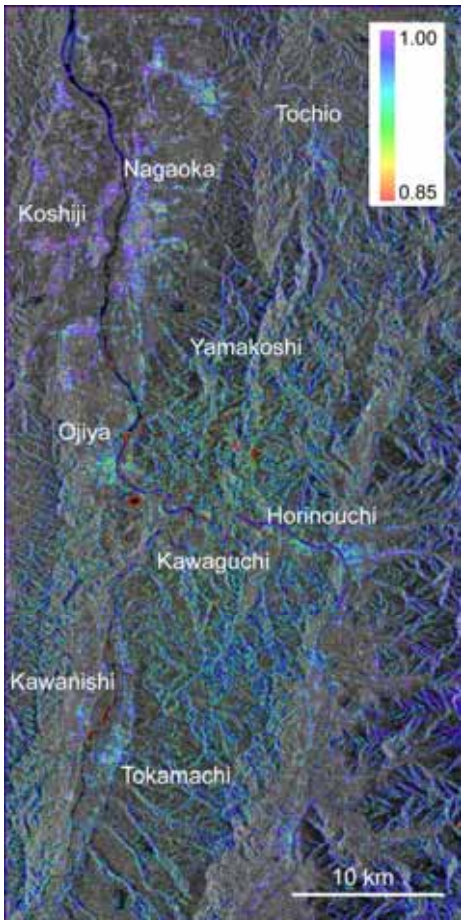




Actual damage distribution



Previous method

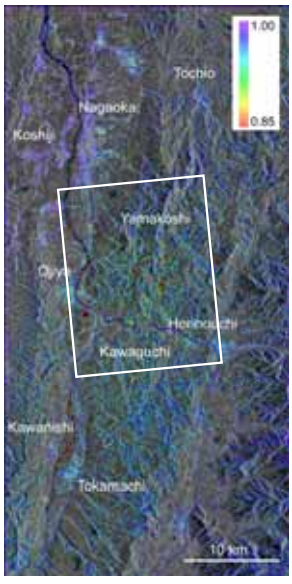


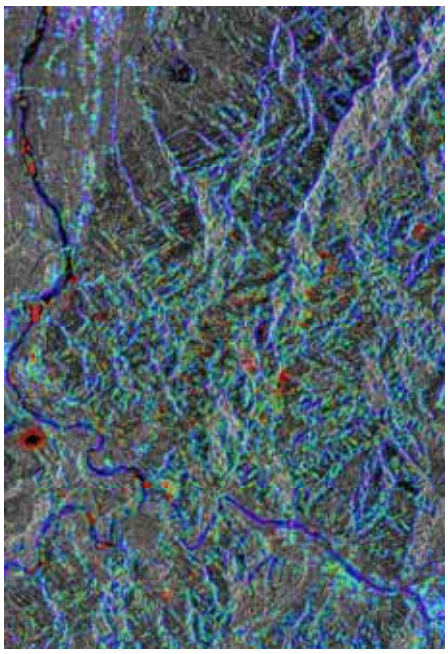
Distribution of Correlation Coefficient Ratio (2)

- Areas selected by correlation coefficient, from a pair of pre-event images, which is more than 0.7.

Distribution of Correlation Coefficient Ratio (3)

- Yamakoshi village (slope failures)



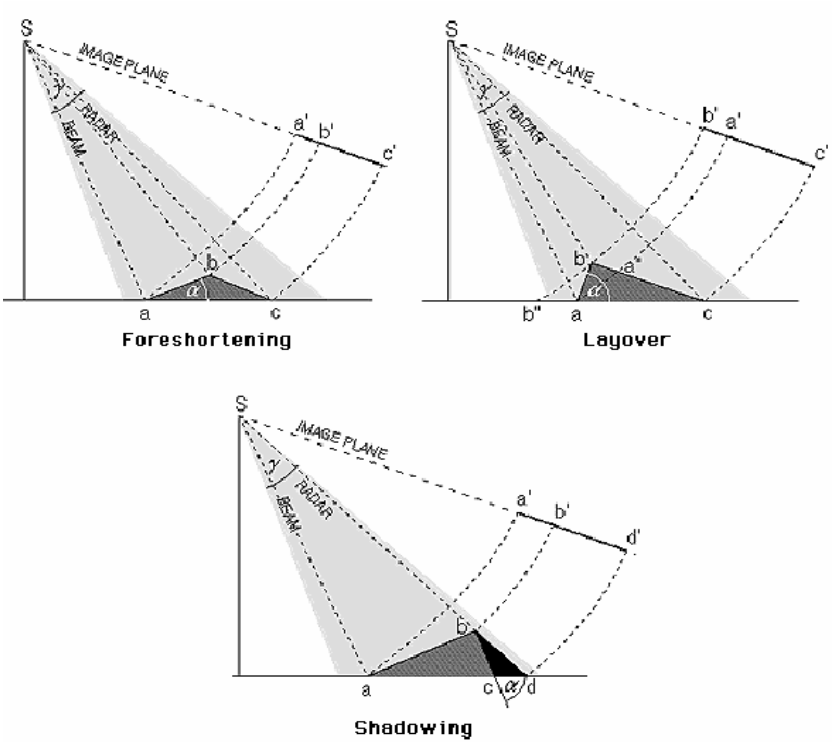


Distribution of CC Ratio

Slope-failures

Geometric Distortion due to Side-looking SAR System

- Foreshortening
- Layover
- Shadowing



Conclusions

- We applied the damage detection method to the affected areas due to the 2004 Niigata-ken Chuetsu earthquake by using a pair of pre- and post-event Radarsat images.
- However, it was not possible to identify any significant distribution of damaged buildings. Because the building damage ratios were rather small.
- A new method to detect the areas of smaller building-damage ratios was proposed by calculating the ratio between the correlation coefficient from a pair of two pre-event images and that from a pair of pre- and post-event images.
- The results of the proposed method showed in relatively good agreement with actual damage survey reports.

Thank you