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

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Summary

Recent earthquakes like the 1994 Northridge and the 1995 Kobe earthquakes, highlight the importance of obtaining damage information of built-up areas at an early stage in order to help resuming normal activities and for future recovery planning. Synthetic aperture radar (SAR) has a remarkable capability to record the physical values of the earth's surface, regardless of weather conditions or the amount of sunlight. A strong earthquake (Mw 6.6) occurred in the middle region of Niigata prefecture (Japan), in the evening of October 23, 2004 (Figure 1). A large number of wooden houses collapsed in the town of Kawaguchi by this earthquake. Damage to lifelines, such as roads, highways, railroads, electrical power, gas, and water, was also significant. A very large number of landslides occurred in the upland village of Yamakoshi, destroying the entire village. Aerial photographs and a high-resolution satellite (IKONOS) captured the damaged areas on the next day of the earthquake. Canadian SAR satellite, Radarsat, also monitored the area by the fine beam-mode, which acquires the earth surface with approximately 8 m resolution, on 2 days after the event (Figure 2).

Building damage detection technique has been successfully applied to past earthquakes such as 1995 Kobe and 2003 Bam, by using the “*z*” index, which is a value derived from the correlation and difference in intensities between pre- and post-event images. This technique was applied to the affected areas due to the 2004 Niigata earthquake by using one pair of Radarsat images taken after the earthquake (October 25, 2004) and before the earthquake (October 1, 2004). However, it was not possible to identify any significant distribution of damaged buildings. The main reason is because the severely damaged building areas of the Niigata earthquake and its distribution were rather small in comparison with those by the Kobe and Bam earthquakes.

In this study, we propose a new technique by using two pairs of SAR images, to identify smaller building damage ratios compared to previous techniques. The main idea is to minimize the effect of signal noise and temporal changes of the earth’s surface, on building damage estimation, by calculating the difference and/or ratio values from the two pre-event images and one post-event image. First, we should evaluate the variation of indices such as *z* value, correlation coefficient, and complex coherence in SAR images to estimate the effect of signal noise and stationary temporal changes, using a pair of pre-event images (October 1 and September 7, 2004). The difference between the *z* value of the two pre-event images and that of the pre- and post-event images is used to evaluate the variation in *z* index. The variation in correlation coefficient is the ratio of the correlation between the pre- and post-event images with respect to the correlation between the two pre-event images.

The city of Ojiya, which was one of the most affected areas by the Niigata earthquake,

carried out a field survey of damaged buildings, and compiled the data into a GIS system. The distribution of the severely-damaged (approximately Grade-4 to 5 in the EMS scale) buildings ratio at a city-block level is shown in Figure 3. The comparison between the building damage from the field survey and the variation indices of *z* value, correlation coefficient, and complex coherence is shown in Figure 4. As the damage level increases, the difference in *z* value seems to increase and the ratios of correlation coefficient and coherence seem to decrease, though the standard deviations vary widely. According to the variance analysis, the correlation coefficient ratio was selected as a suitable index to reflect the building damage level. The distribution of the correlation coefficient ratio overlaid on SAR intensity image is shown in Figure 5. In a macroscopic point of view, the distribution of low correlation coefficient ratio values in built-up areas is in good agreement to damage by survey reports. In the upland Yamakoshi village, we also could identify large-scale landslides with an accuracy as good as interpretation from aerial photos.

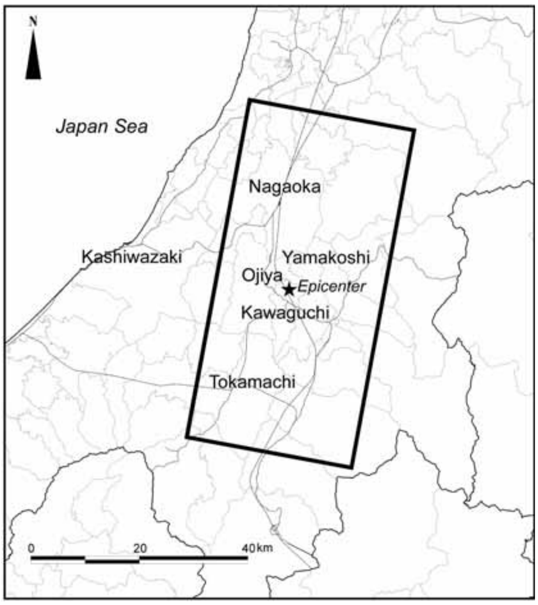


Figure 1. Area of this study.

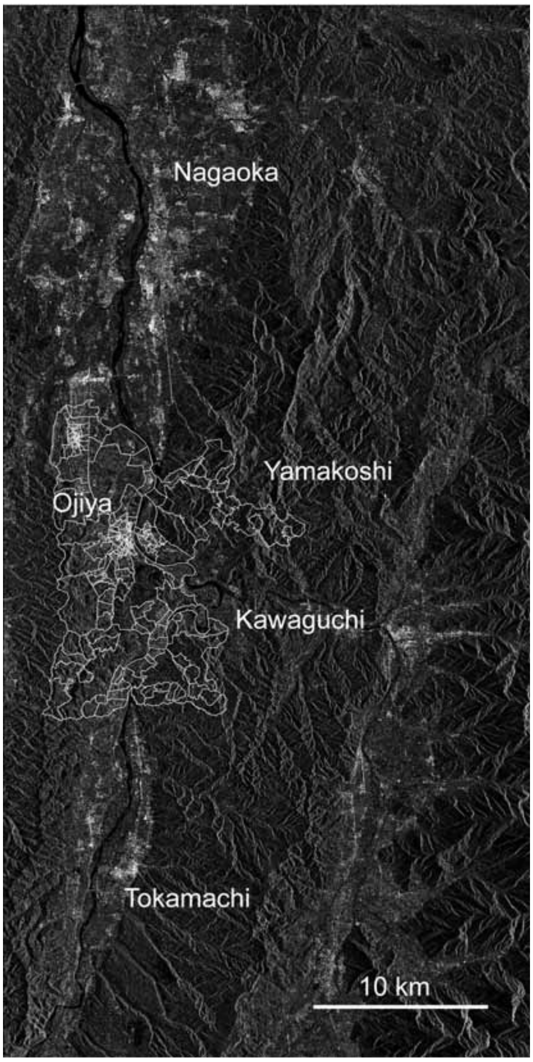


Figure 2. Radarsat fine mode image of Mid-Niigata region acquired on 2 days after the 2004 Niigata-ken Chuetsu earthquake. White line indicates the boundary and city-block of Ojiya city.

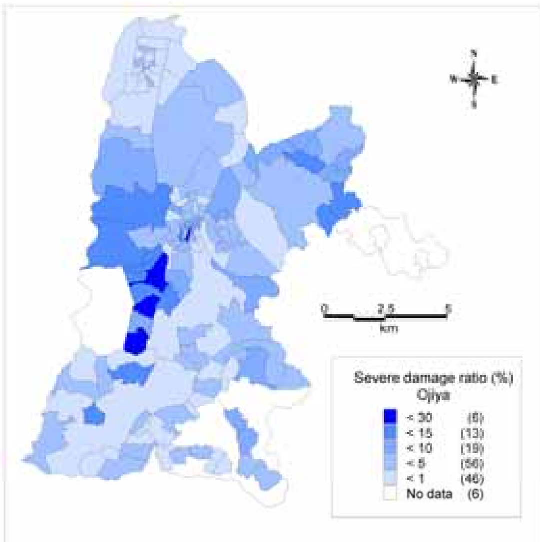
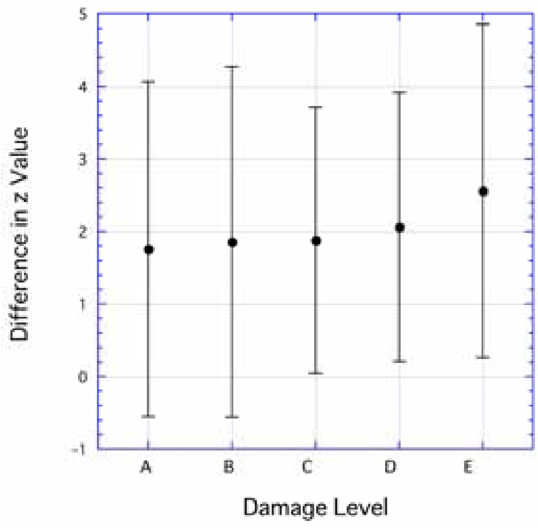
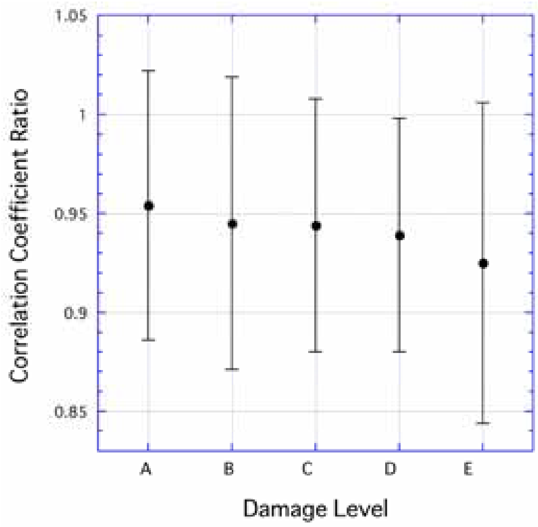


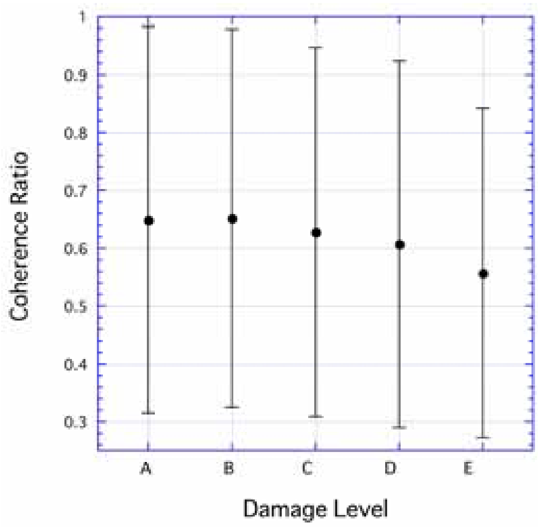
Figure 3. Distribution of severely-damaged building ratio in Ojiya city.



(a) Difference in *z* value



(b) Correlation coefficient ratio



(c) Coherence ratio

Figure 4. Relationship between building damage level and indices from the two pairs of SAR images. The damage level classified into A, B, C, D, and E, correspond to the severely damage ratio of 0-1, 1-5, 5-10, 10-15, and 15-30%, respectively.

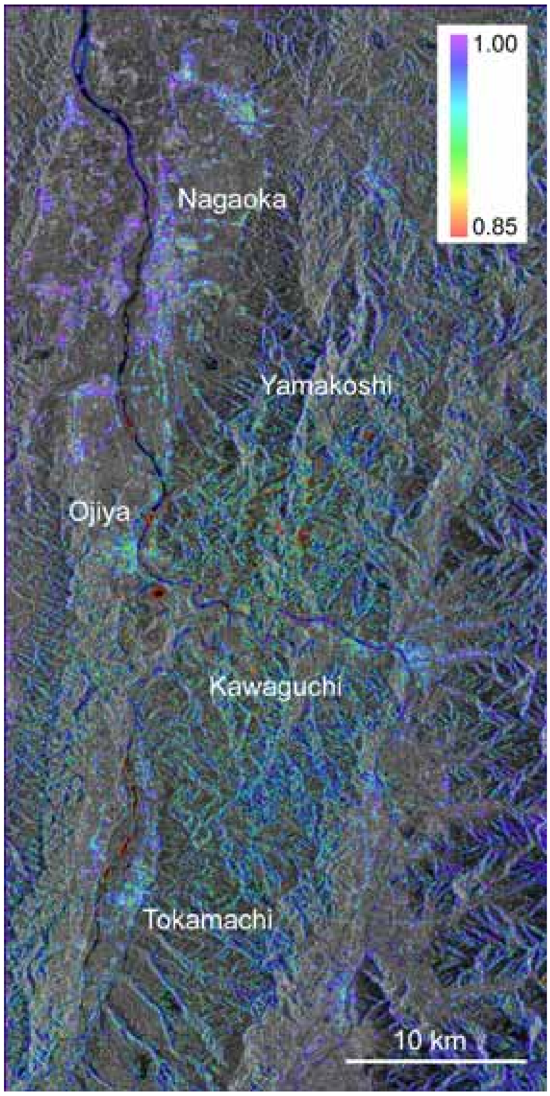


Figure 5. Distribution of correlation coefficient ration overlaid on SAR intensity image.