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Estimation of Natural Hazard Damages by Fusion of Change Maps Obtained from Optical and Radar Earth Observations

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Framework of the methodology

- Objectives:

  Estimation of Flood and Tsunami Damages using Object and Fusion based Change Detection (CD) Algorithm

- Instruments:

  Optical and Radar Remote Sensing Imageries

Motivation

MITIGATION	PREPAREDNESS	RESCUE	RECOVERY	SATELLITES USED
Mapping flood-prone areas; delineating flood-plains; land-use mapping.	Flood detection; early warning; rainfall mapping.	Flood mapping; evacuation planning; damage assessment.	Damage assessment; spatial planning.	Tropical Rainfall Monitoring Mission; AMSR-E; KALPANA I;

(Tsunami Sendai, Japan 2011)

Potential of Remote Sensing Data

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P: 15m, TM: 30m
TIR: 60 m

ESA : ERS-2 ENVISAT RADARSAT-1,2

GSD: 10-30m
Swath width: 100 km
SAR imagery

FB: 9 m
SB: 28 m
Swath width: 50 to 500 km
SAR imagery

IRS-1C/D

P: 5.8 m
LISS-3: 23.5 m
Swath width: 70 km (P)
141 km (L-3)

QuickBird-2

P: 0.6 m
MS: 2.4 m
Swath width: 16.5 km

IKONOS-2

P: 1 m
MS: 4 m
HighRes
Swath width: 11.5 km

OrbView-3

P: 1 m
MS: 4 m
HighRes
Swath width: 8 km

FORMOSAT-2

P: 2 m
MS: 8 m
Swath width: 24 km

SPOT-1 to 7

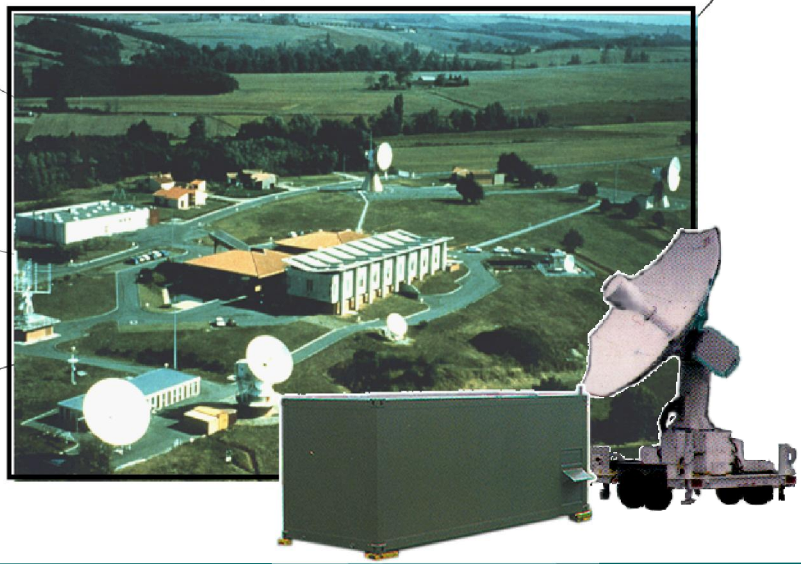
HRV-P: 10m
xS: 20m
HRG-P: 5m
xS: 10m

THR-P: 2.5m

Swath width: 60 km

LANDSAT-5 to 8

P: 15m, TM: 30m
TIR: 60 m
Swath width: 185 km



Sentinel 1

C band: 5-40 m
Period: 12 day
Swath width: 20-400 km

Sentinel 2

SWIR: 20 m
MS: 10 m
Swath width: 290 km
Period: 5 day

TerraSAR-X (Infoterra) 2006

SAR imagery
High Res

SLM: 1 m
SMM: 2 m
SSM: 16m
Swath width: 15 to 100 km

Problem Definition

- Limitation of Existing CD Method
  - ✓ Such methods may be efficient for broad-scale images or large-scale changes for reason that noise caused by registration errors and radiometric variation can be restricted to low level compared to real changes by preprocessing or other means
  - ✓ For high resolution images, there are many new problems to be concerned in design of change detection algorithms

Problem Definition

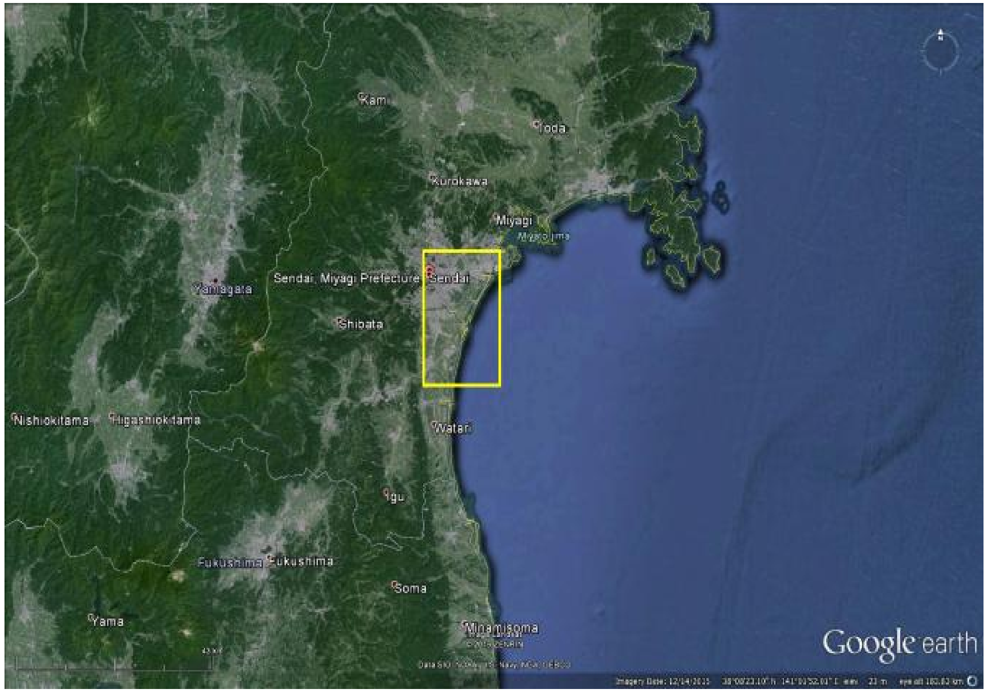
- Limitation of Existing CD Method
  - ✓ Accurate registration of different images is not easily achieved.
  - ✓ Variations of lighting and environmental conditions are rather locally and diversified between different images
  - ✓ Users desire to detect small size changes including lines, buildings, bridges and other man-made targets.

Problem Definition

- Limitation of Existing CD Method
  - ✓ The performances of current change detection methods are not satisfying for high spatial resolution remote sensing images in both effect, efficiency and false alarm rates are relatively high.
- Proposed Solution
  - ✓ An object-level and kernel-based change detection method based on the integration of object-based image analysis (OBIA) and support vector data description (SVDD) method
  - ✓ Fusion of change maps obtained from multi-sensor data

Experiments

- Case Study



The geographical location and the extent of the study area over Sendai, Japan

Experiments

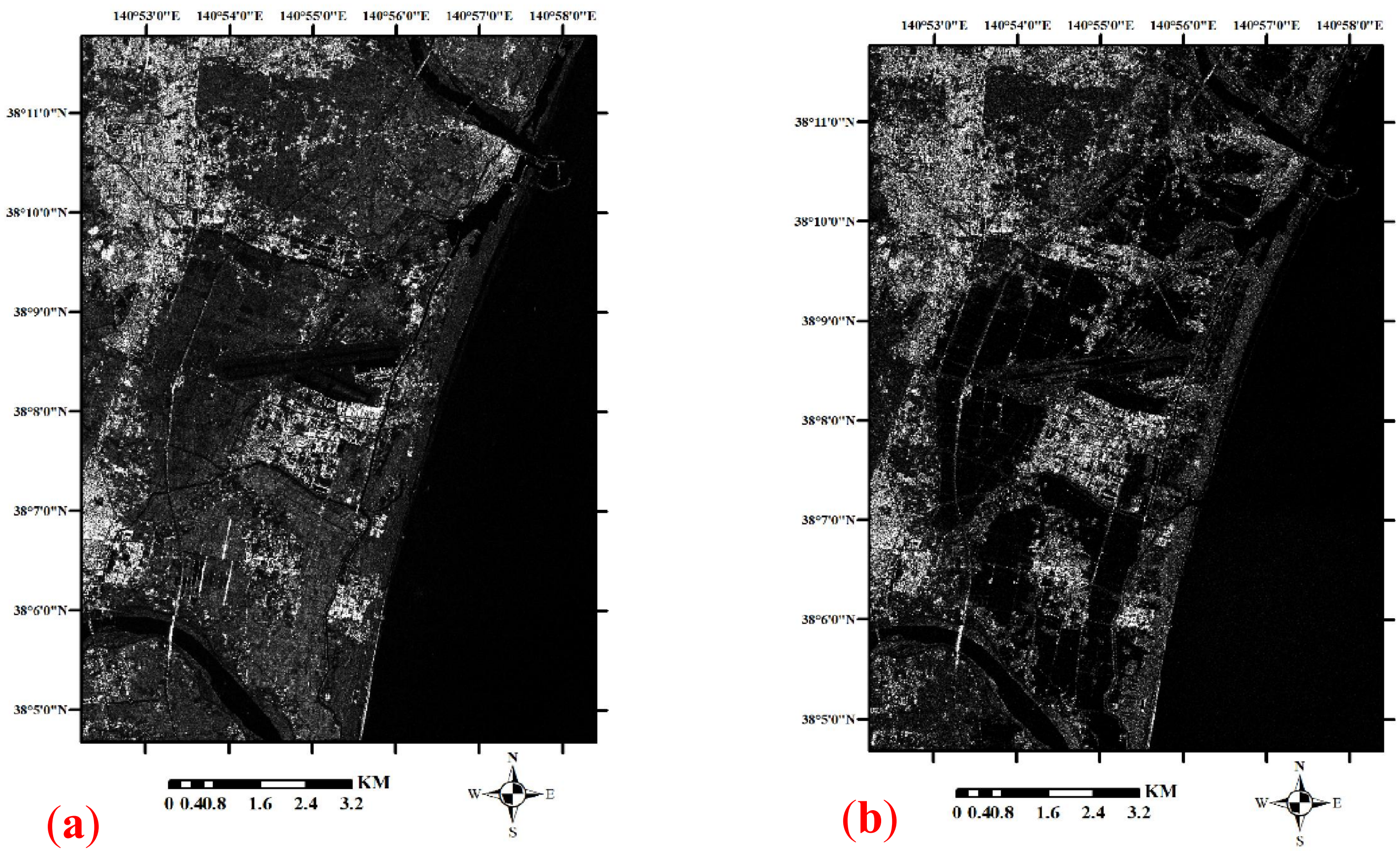
- Remote Sensing Data

Dataset		Pre-change acquisition	Post-event acquisition	Bands Specifications	Spatial Resolution (m)
Sendai, Japan	IKONOS	Dec 11, 2010	Mar 28, 2011	R,G,B, NIR	3.2
	Radarsat-2	Mar 17, 2010	Mar 12, 2011	C-Band (HH)	6.25

The acquisition dates, spectral and spatial resolutions of imageries from Sendai, Japan.

Experiments

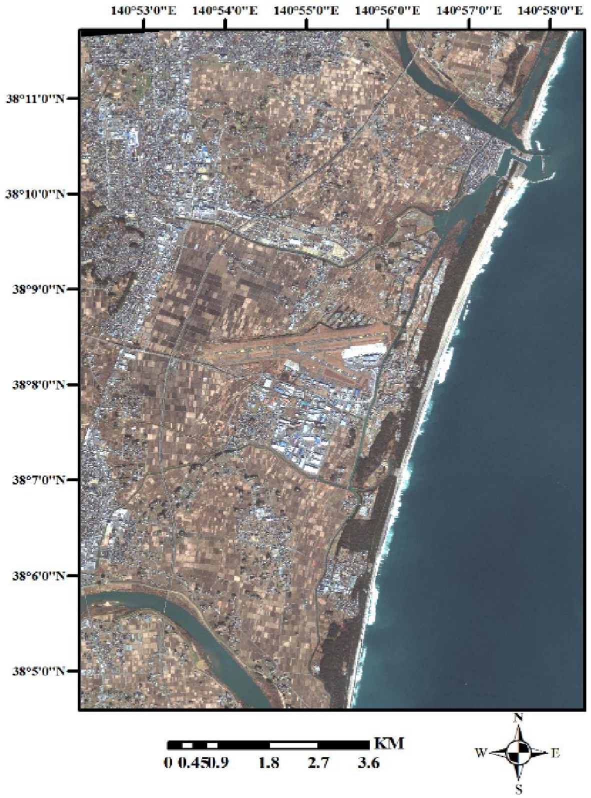
- Remote Sensing Data (Sendai 2011's tsunami)



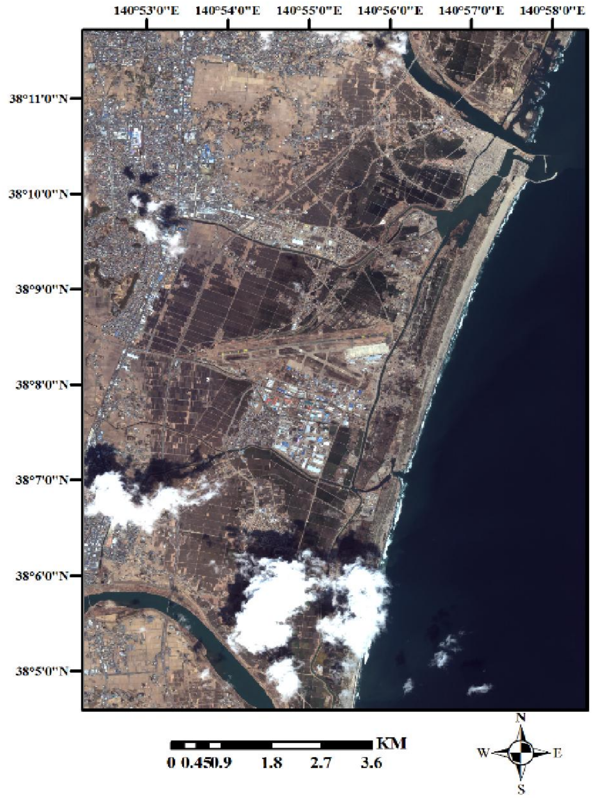
The sigma0 images provided by Radarsat-2 imagery from (a) before and (b) after of Sendai 2011's tsunami.

Experiments

- Remote Sensing Data (Sendai 2011's tsunami)



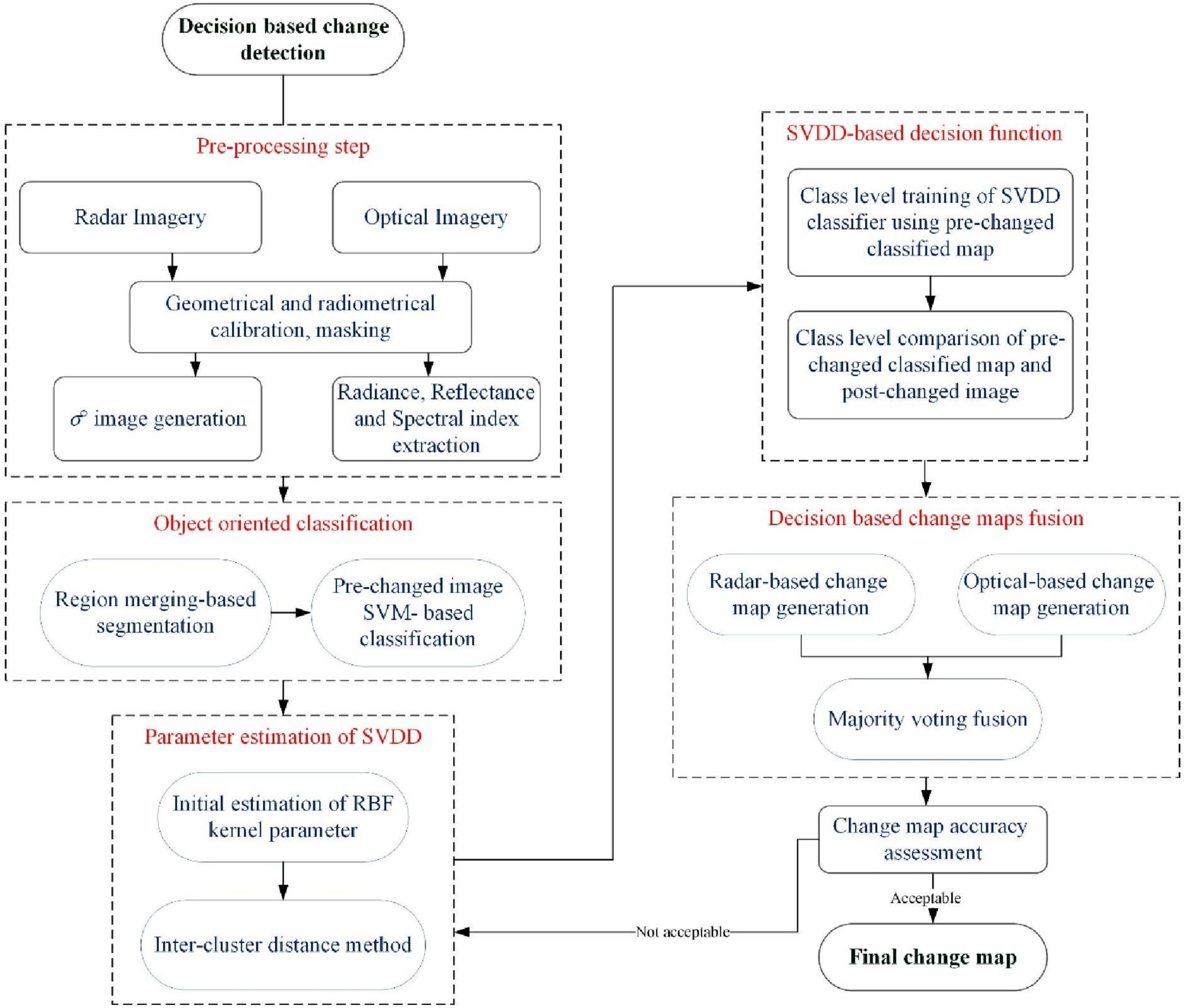
(a)



(b)

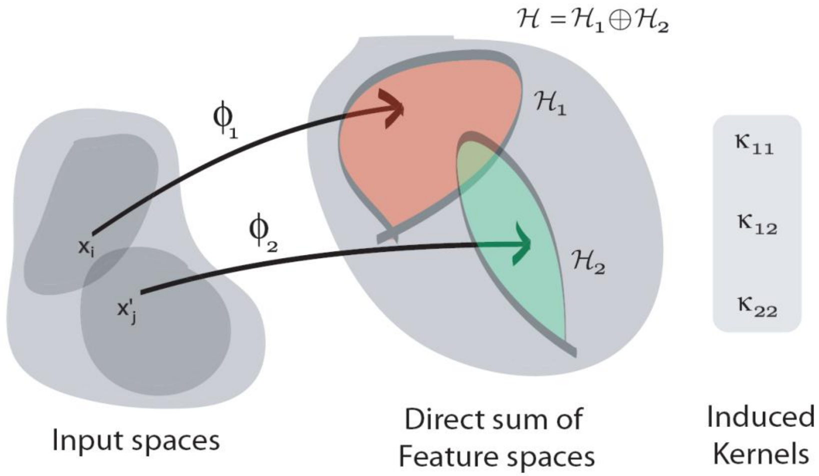
The sigma0 images provided by IKONOS imagery from (a) before and (b) after of Sendai 2011's tsunami.

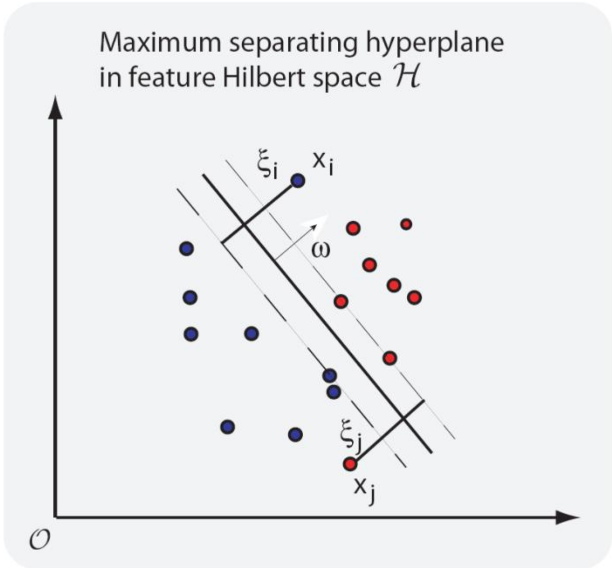
Methodology



The overview of proposed decision fusion based change detection method

Support Vector Machines

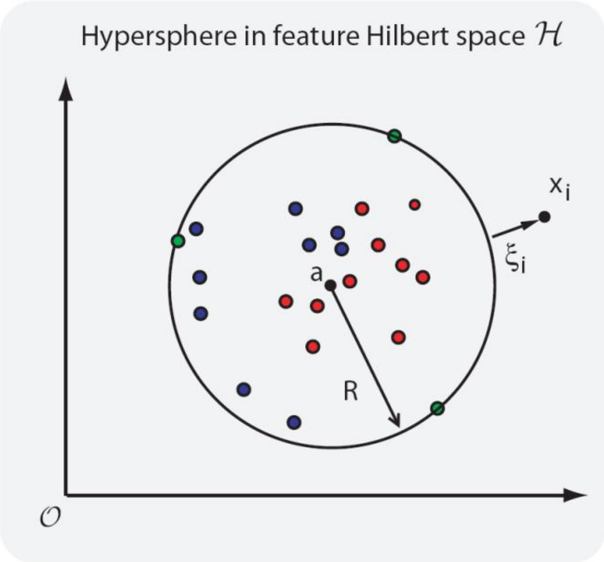




$$
\begin{cases}
\min\limits_{w,b,\xi_1,\dots,\xi_l} \left[\frac{1}{2} |w|^2 + C \sum_{i=1}^{l} \xi_i \right] \\
y_i (w.x_i + b) - 1 + \xi_i \geq 0 \qquad i = 1,\dots,l \\
\xi_i \geq 0 \qquad i = 1,\dots,l
\end{cases}
$$

$$
f(x, \lambda_1, \dots, \lambda_l) = \operatorname{sgn}\left(\sum_{i=1}^{l} \lambda_i y_i K(x_i , x) + b \right)
$$

Support Vector Data Description



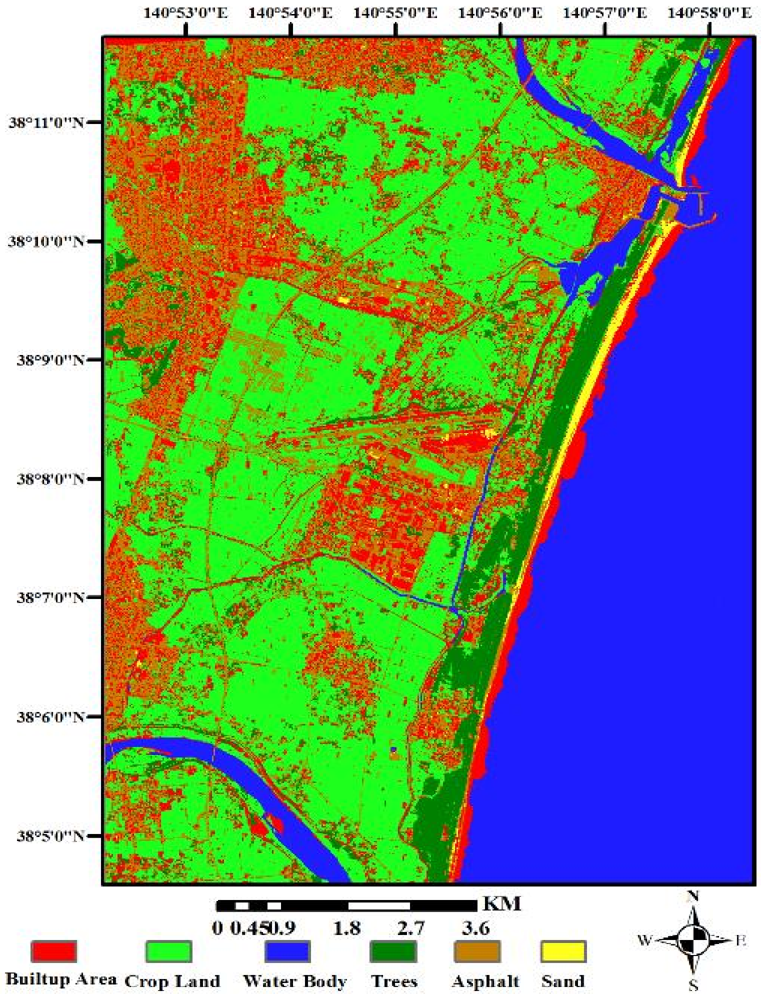
$$\begin{cases} \varepsilon(R,a,\xi) = R^2 + C\sum_i \xi_i \\ \|x_i - a\|^2 \le R^2 + \xi_i, \qquad \forall \xi_i \ge 0, \quad \forall i \end{cases}$$

$$L(R,a,\xi,\alpha,\gamma) = R^2 + C\sum_i \xi_i - \sum_i \gamma_i \xi_i - \sum_i \alpha_i \left\{ R^2 + \xi_i - (x_i.x_i - 2a.x_i + a.a) \right\}$$

$$f_{SVDD}(z;\alpha,R) = I(\|z-a\|^2 \le R^2) = I\left((z.z) - 2\sum_i \alpha_i (z.x_i) + \sum_{i,j} \alpha_i \alpha_j (x_i.x_j) \le R^2 \right)$$

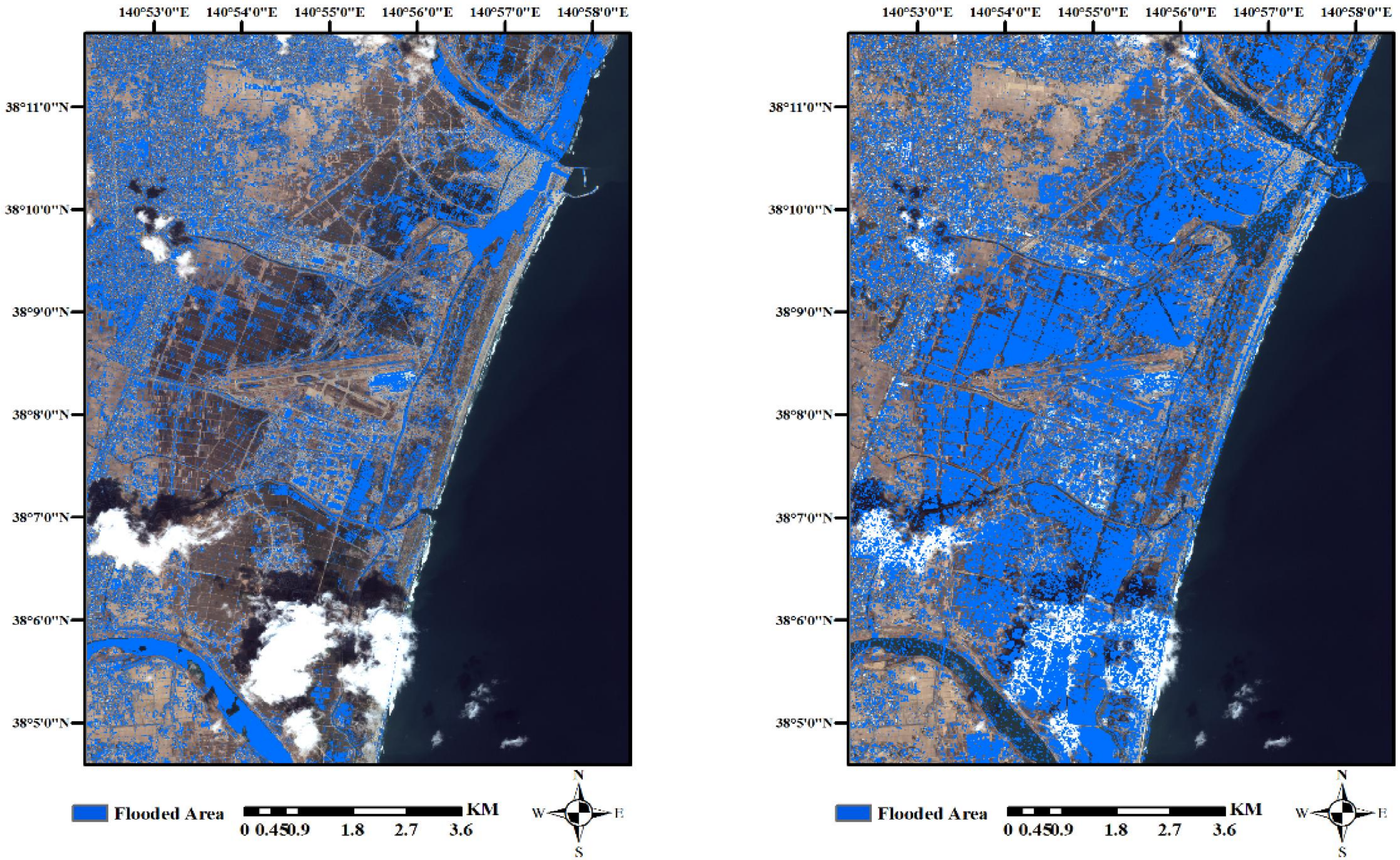
$$I(A) = \begin{cases} 1 & if\ \ A\ \ is\ true \\ 0 & otherwise \end{cases}$$

Results



The pre-change classification map obtained from object-based SVM classification method for IKONOS imagery over the Sendai, Japan, before the tsunami.

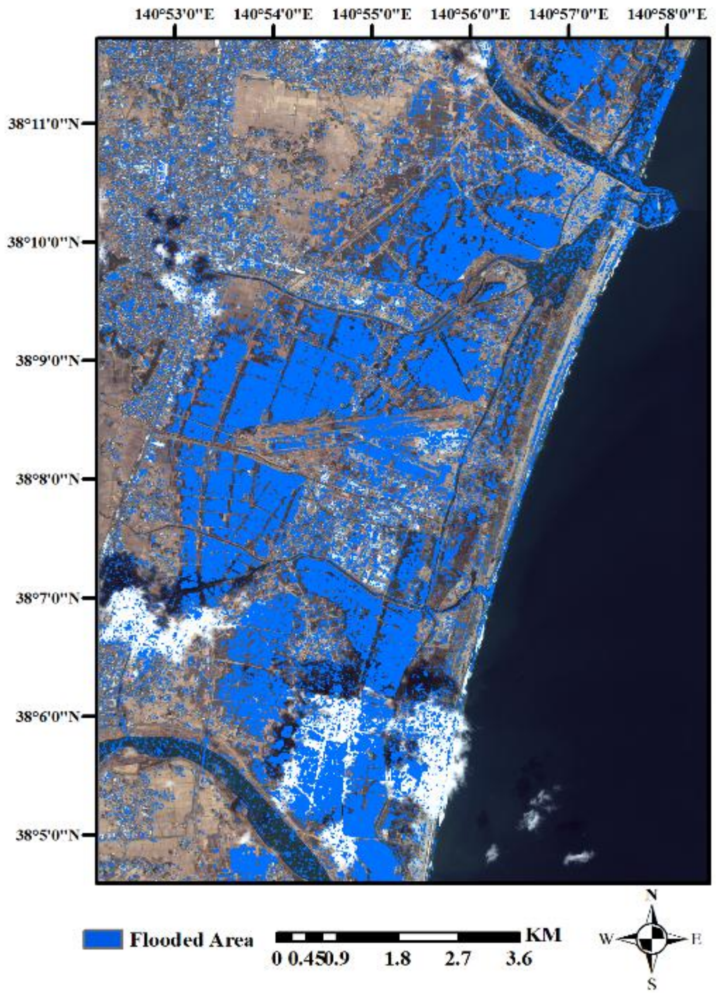
Results



(a) (b)

Change maps obtained from proposed CD method for (a) IKONOS imagery and (b) Radarsat-2 imagery from Sendai, Japan. IKONOS and Radarsat-2 Satellite images, courtesy of the Digital Globe Foundation and MacDonald, Dettwiler and Associates Ltd. Geospatial Service respectively

Results



Change maps obtained from decision fusion based CD methods using IKONOS and Radarsat-2 imageries from Sendai, Japan

Results

The accuracy analysis of proposed CD method on Sendai case study.

Acc. Criteria	**Tsunami, Sendai, Japan**		
	IKONOS	Radarsat-2	Fused change maps
Kappa	0.85	0.82	**0.91**
OA	93.61	92.60	**96.37**

Discussion and Conclusions

- Several conclusions can be deduced
  - ✓ The fusion of change maps obtained from optical and radar imageries always provides better results than without completing the fusion phase.
  - ✓ Preliminary results show that objects may be well suited to quantify changes when only one class of the landscape features is the research emphasis.
  - ✓ Using radar imageries are more appropriate choice. As high resolution optical imageries are a more appropriate choice for extracting the earthquake-affected and flooded-affected in built-up and crop lands areas.

Discussion and Conclusions

- Several conclusions can be deduced
  - ✓ The proposed CD approach leads to an acceptable level of accuracy for both optical and radar imageries.
  - ✓ The microwave signals have high sensitivity to water content of wetland and flooded areas which increase the intensity of the backscatter signal. Consequently, radar sensors have high potential in detecting environmental changes during natural disasters with adverse weather conditions.
  - ✓ In future research, efforts will be on the integration of various remote sensing sensor types using information level and feature level methods for multiple change detetcion.

Thanks for your attention