Post-Storm Satellite Images to Trace Tornado Damage Path from the Wind Borne Debris Deposits

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GCOE Program TPU
New Frontier of Education and Research in Wind Engineering

KOGEI TOKYO POLYTECHNIC UNIVERSITY

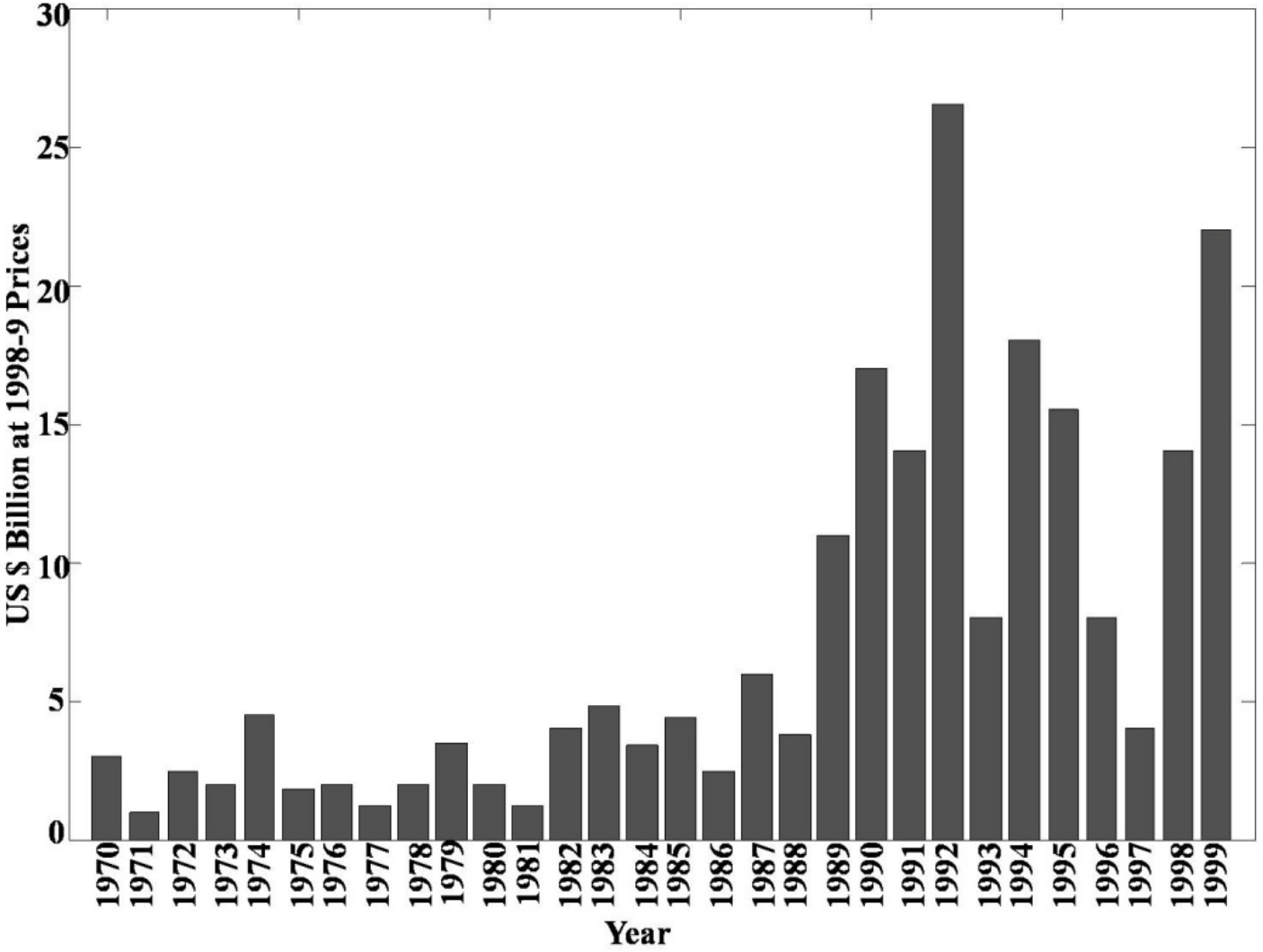
AIM

To identify the Tornado damage path from the Post-storm Satellite/Aerial Imageries alone, by using Texture-Wavelet analysis on the scattered wind borne debris

NATURAL DISASTER: STRONG WINDS

Tornadoes

Tropical Cyclones



Bar chart showing the World insurance losses from major natural disasters (1970-1999) Source: Swiss Reinsurance Company

Field investigation

SATELLITE IMAGES

QuickBird Multi-spectral Satellite imagery of 2.44 m/pixel Resolution

PAST RESEARCHES

- Tornado track identification from pre- and post-storm satellite imageries by Soe et al 2008 and Thomas et al 2002 by change detection

- Cyclone damages to buildings were estimated from pre- and post-storm satellite imageries by Womble et al 2007

PAST RESEARCHES

Difficulties

- Capturing the exact pre-storm location as that of the post-storm
- Complicated and time consuming image-registration procedure
- Cost
- Generalization

SOLUTIONS

- **Texture-Wavelet analysis**

  (2D biorthogonal spline wavelet)

  → More Accurate

- **Post-storm satellite/aerial image alone**

  → Faster damage identification

Save more lives and more building structures can be restored faster.

IMAGE PROCESSING: TEXTURE WAVELET ANALYSIS

WHY TEXTURE–WAVELET ANALYSIS?

1. **Particular Texture** *(Wind Borne Debris)*

→ Texture Analysis

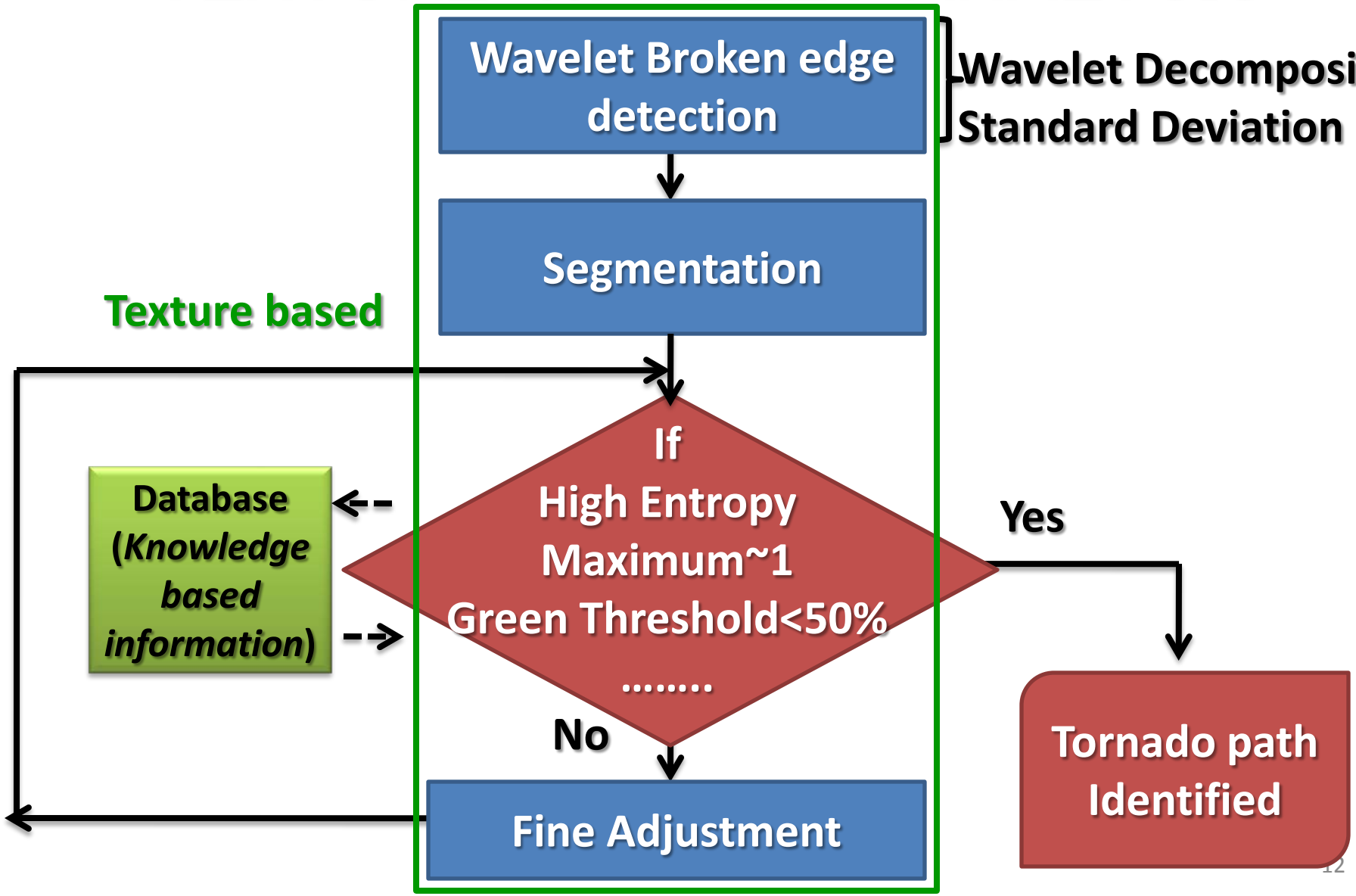
2. **Sharp Broken Edges**
3. **Irregularly arranges pixels**

(High Pass information)

→Wavelet Analysis

Texture-Wavelet Analysis

TEXTURE–WAVELET ANALYSIS



AN IMAGE PORTION AFTER TORNADO DAMAGE

WAVELET DECOMPOSITION

Part of

Post-Storm Image

$I(x, y)*LD=I_L(x, y)$

$I(x, y)*HD=I_H(x, y)$

Row Convolution

$I_L(x, y)*LD=I_{LL}(x, y)$

$I_L(x, y)*HD=I_{LH}(x, y)$

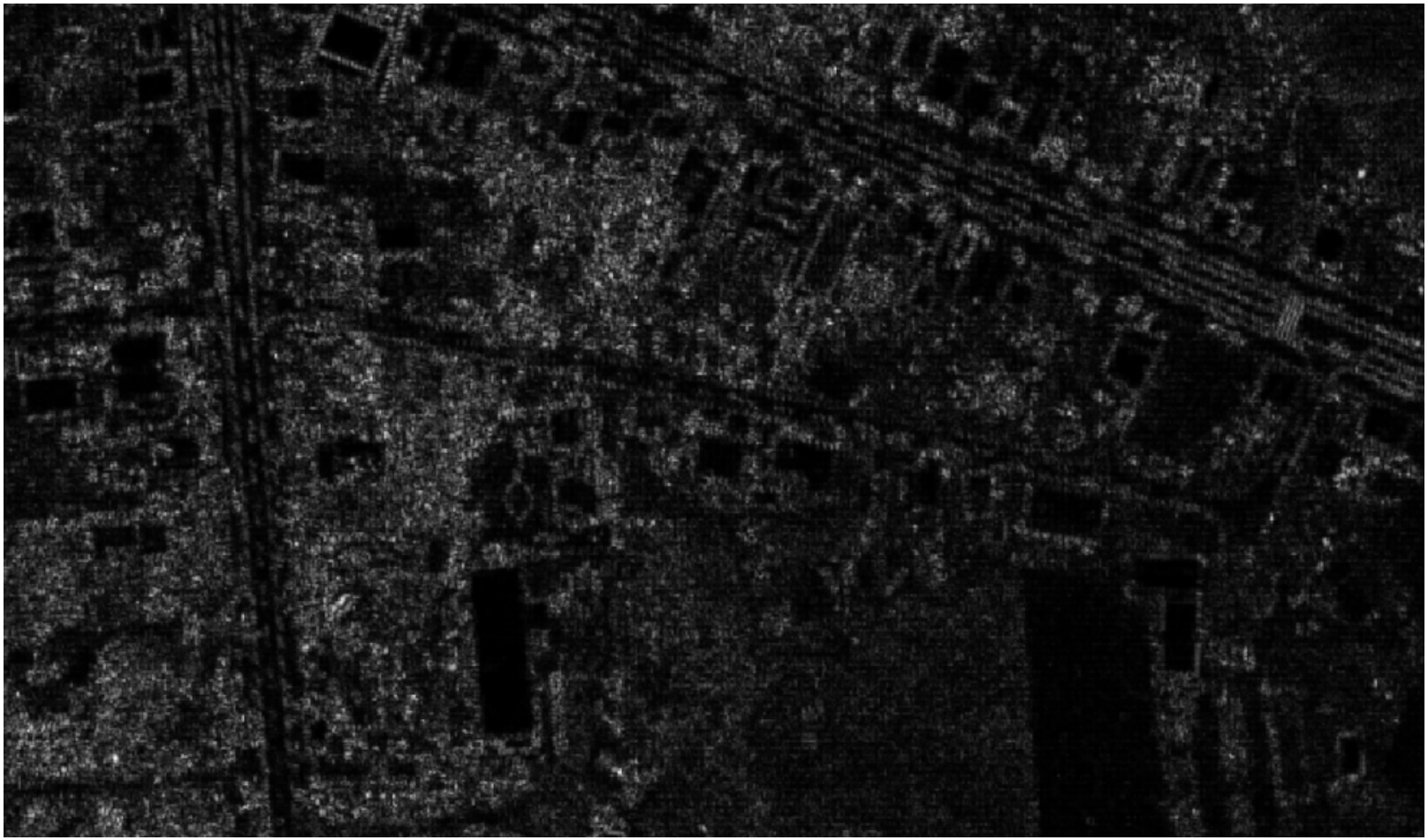
$I_H(x, y)*LD=I_{HL}(x, y)$

$I_H(x, y)*HD=I_{HH}(x, y)$

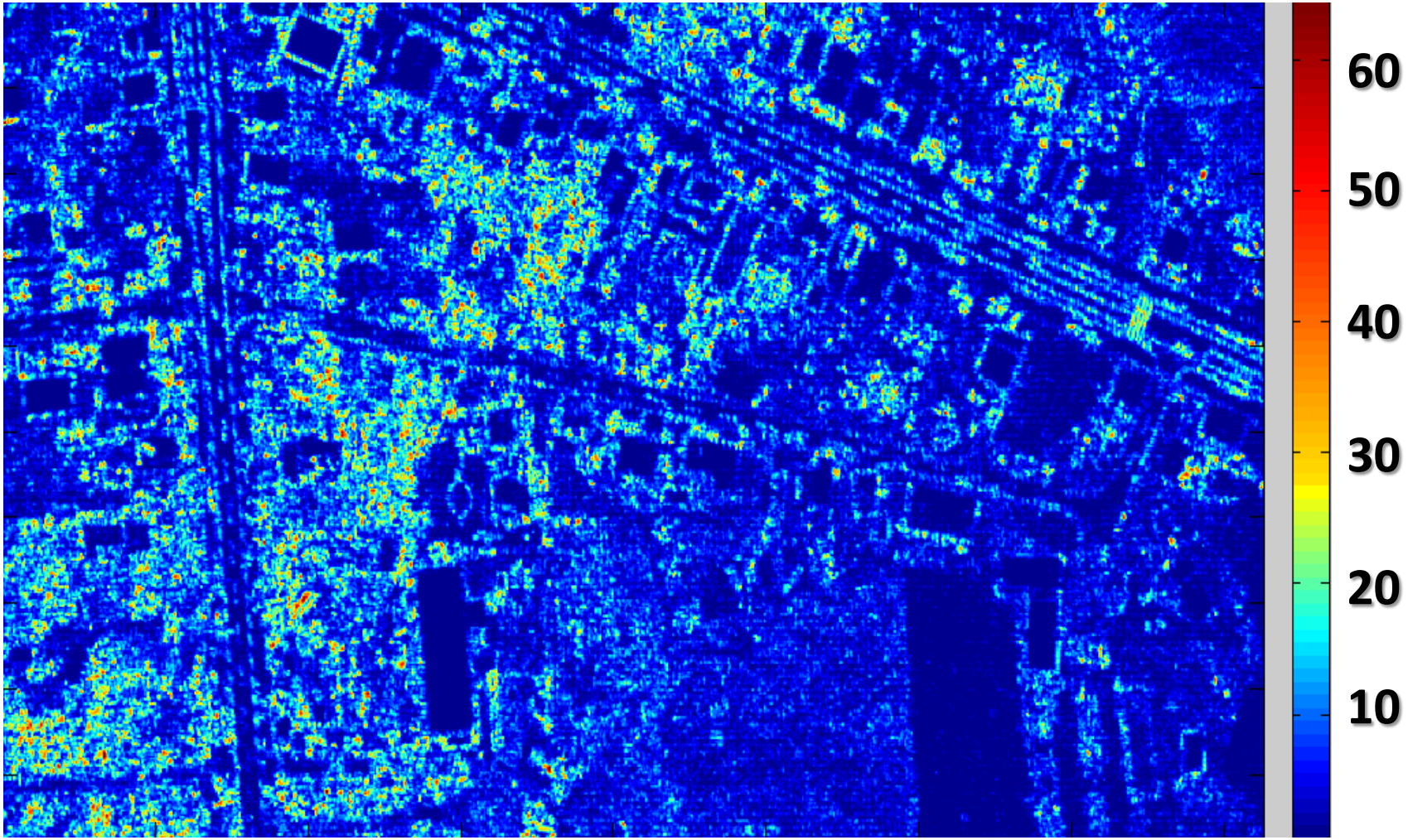
Column Convolution

$$c(n_1, n_2) = \sum_{k_1=-\infty}^{\infty} \sum_{k_2=-\infty}^{\infty} a(k_1, k_2)\, b(n_1 - k_1, n_2 - k_2)$$

BROKEN EDGES DETECTED-WAVELET



STANDARD DEVIATION



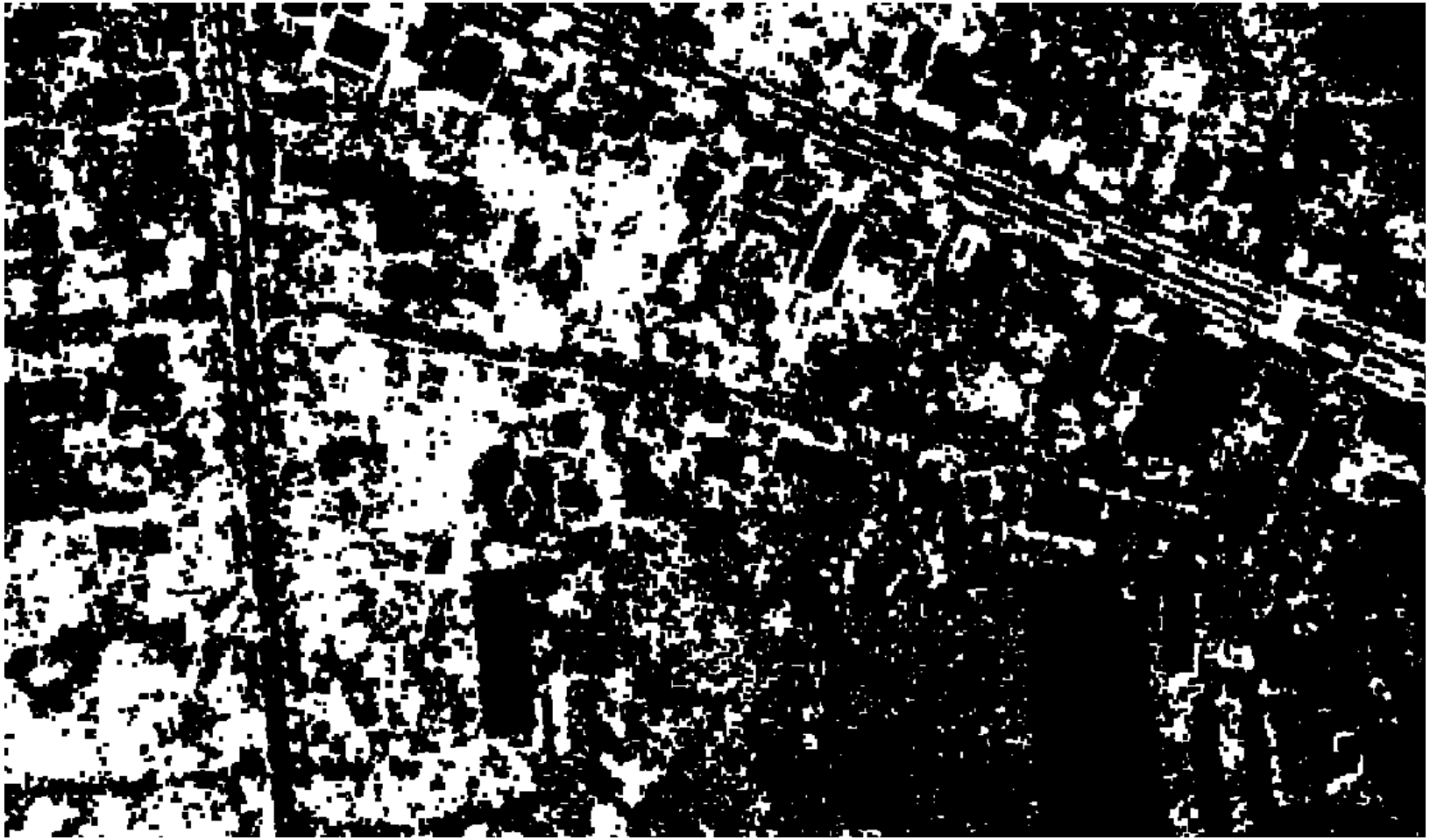
SEGMENTATION

Otsu's thresholding Method

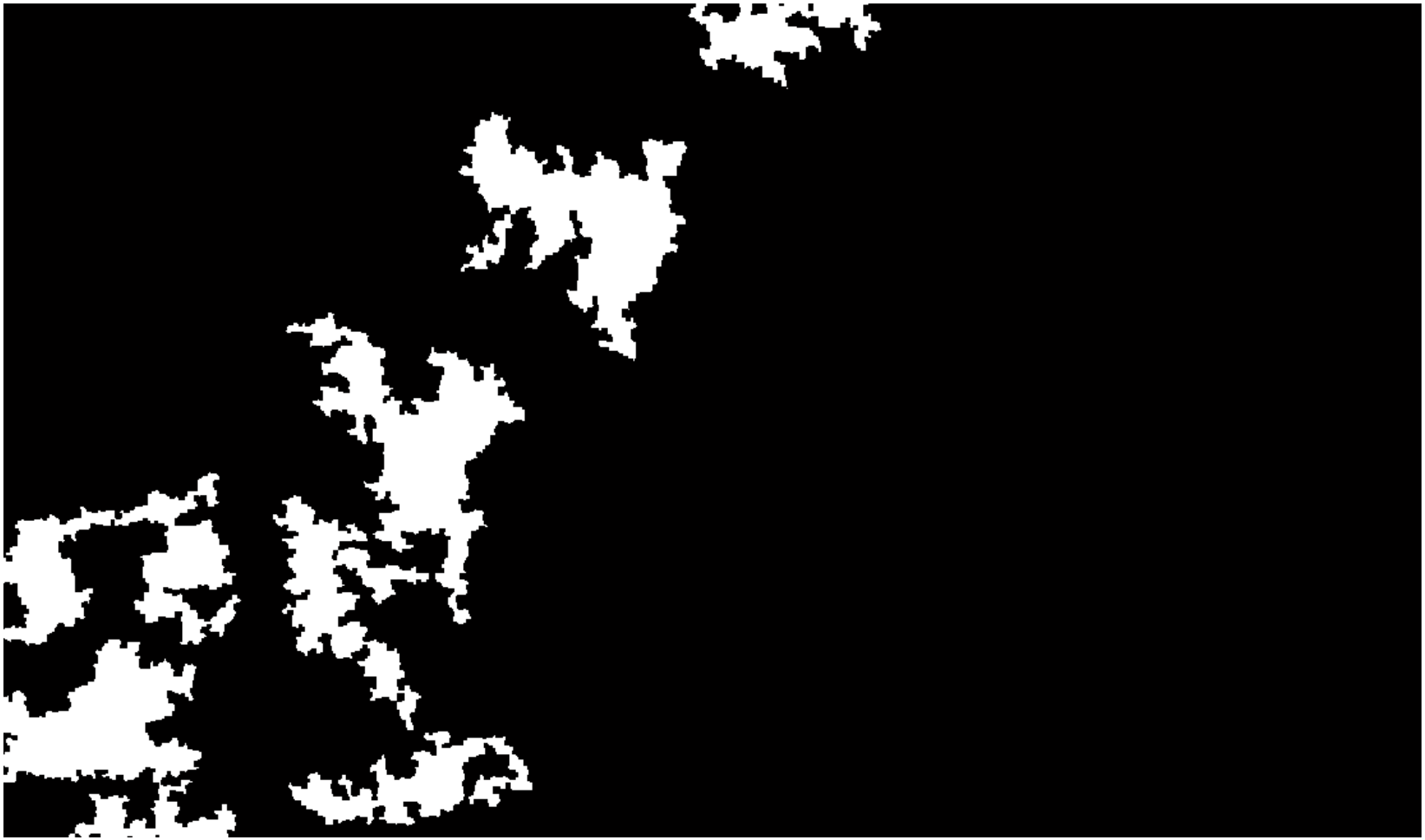
- Object
- Background

- Maximize the separability between two classes
- Calculate the threshold (OTSU 1979)
- Segmentation

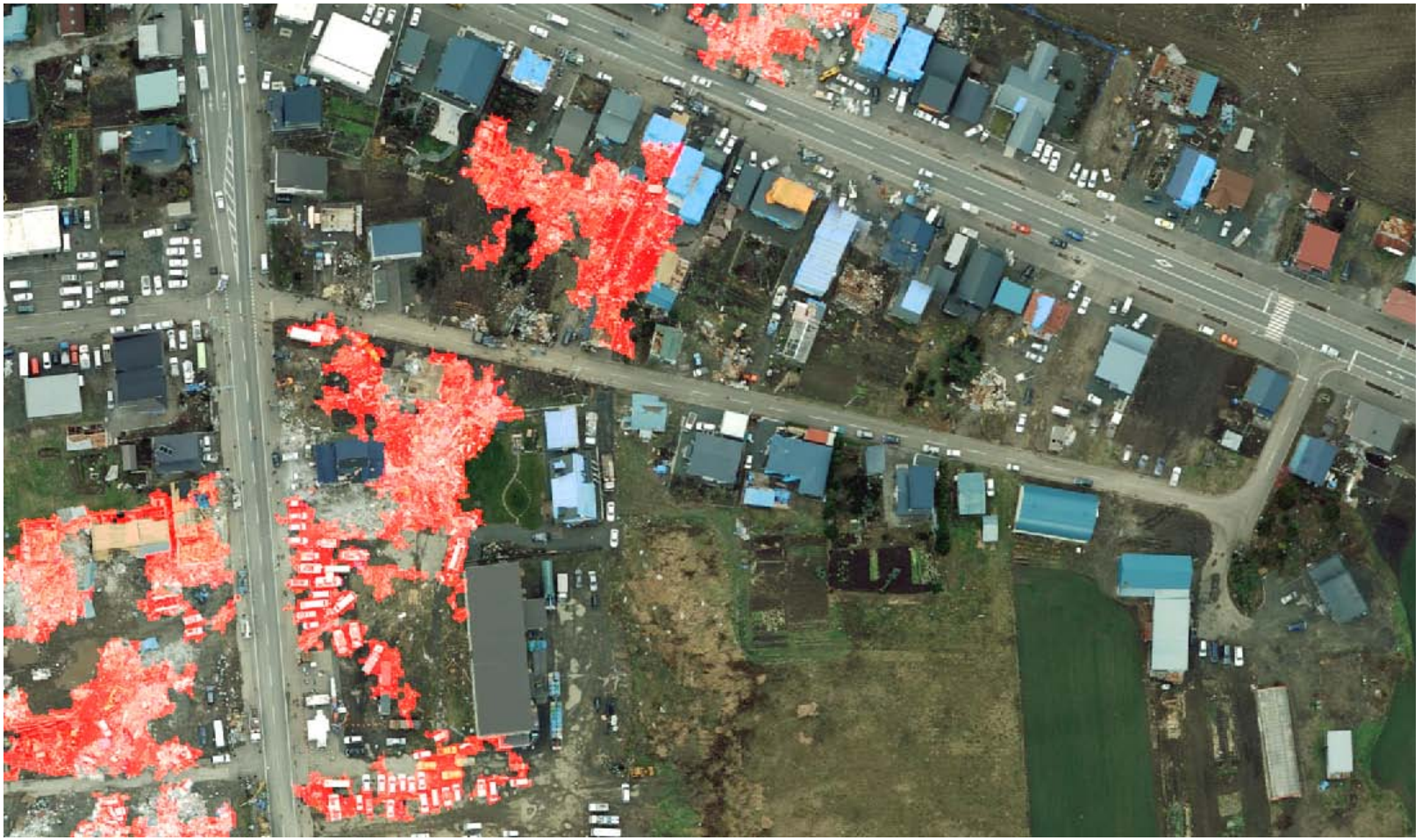
OTSU'S THRESHOLDING METHOD



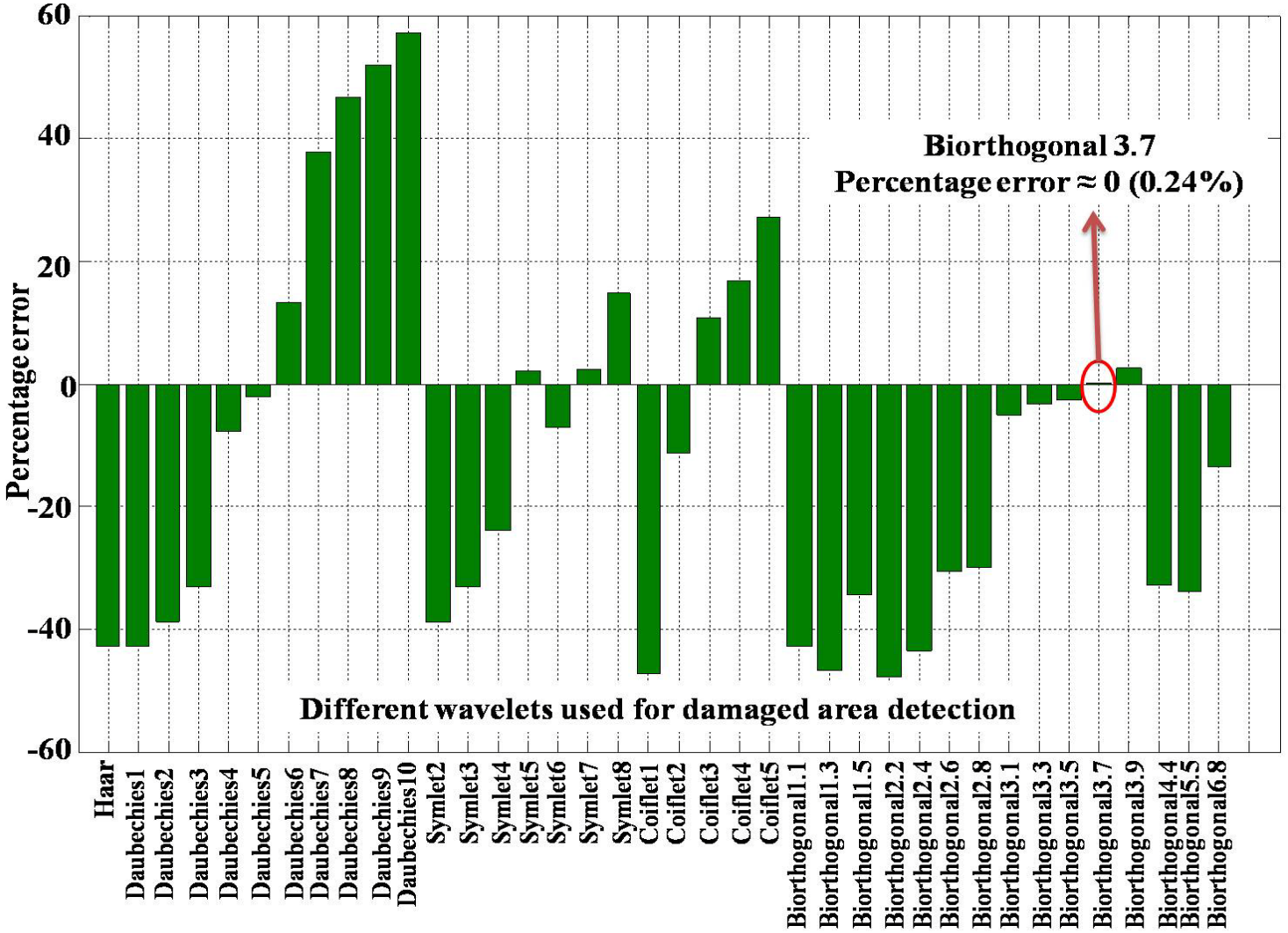
NOISE REMOVAL



DEBRIS MASKED



DEBRIS PATTERN RECOGNITION



SATELLITE AND AERIAL IMAGES

Key words

Image: Multispectral/RGB visible imagery

Resolution: Distance/pixel

SAROMA-CHO TORNADO

LOCATION

On November 7th 2006

at Saroma town

in Hokkaido

Image Courtesy: Kyodo News and Akihiro Takahashi, Northern Regional Building Research Institute

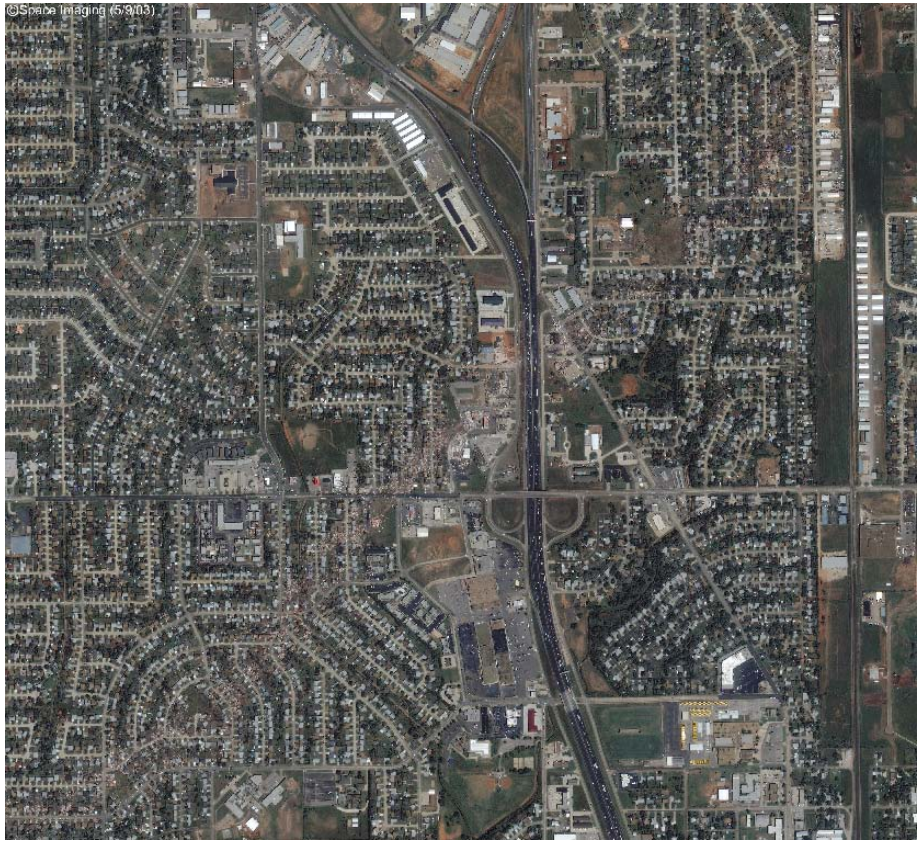
POST-STORM AERIAL IMAGERY

Resolution: 10cm/pixels

Image Courtesy: Shin Engineering Consultants Co. Ltd., Japan

TORNADO FOOT PRINTS IDENTIFIED : Automatically

MOORE, OKLAHOMA, US TORNADO
SATELLITE IMAGERY (1m/pixel)



US Tornado 1999

Image Courtesy: (Image courtesy: Geo eye, source: http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=11470)

MOORE, OKLAHOMA, US TORNADO
SATELLITE IMAGERY (1m/pixel)

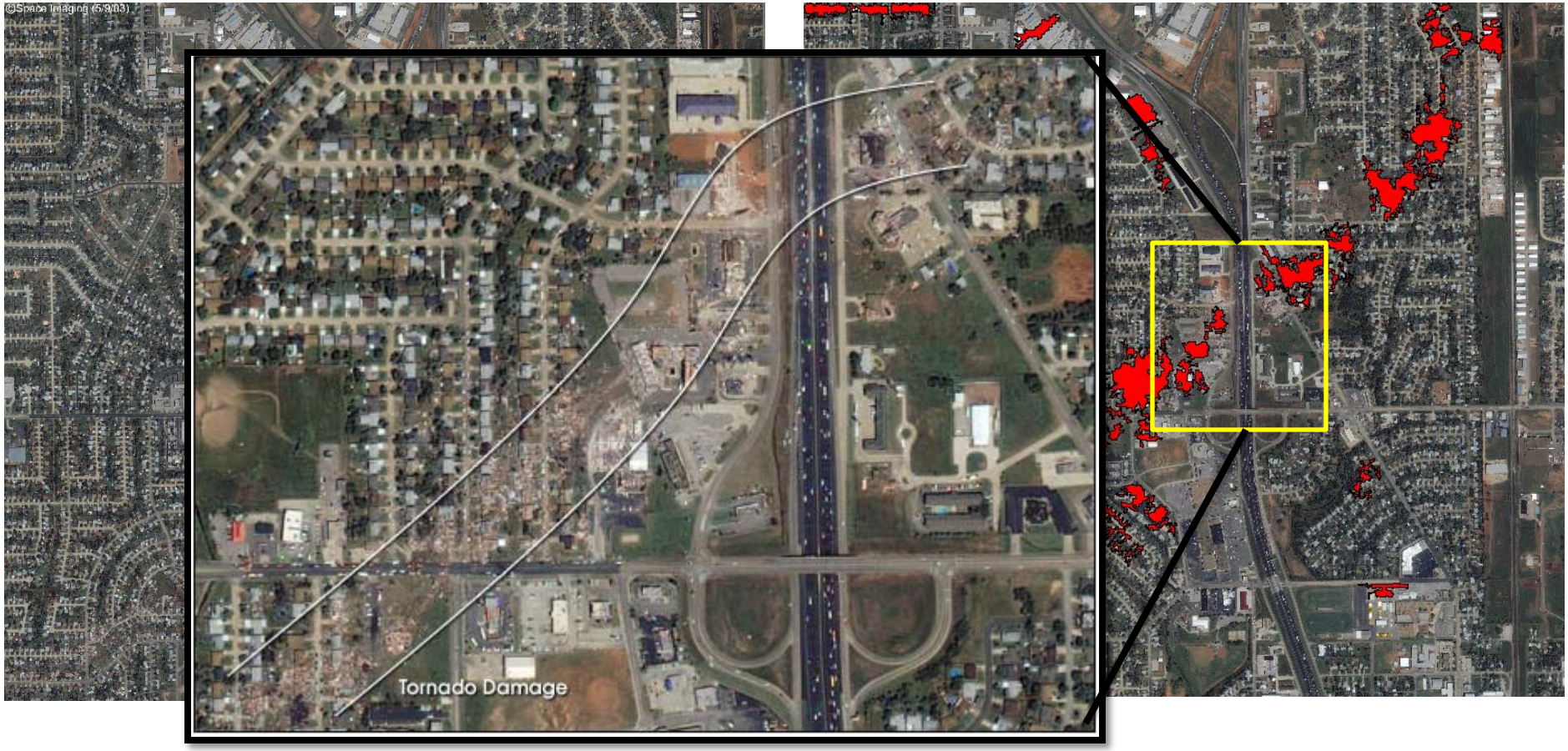


Image Courtesy: (Image courtesy: Geo eye, source: http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=11470)

TUSCALOOSA , ALABAMA, TORNADO

SATELLITE IMAGERY (30m/pixel)

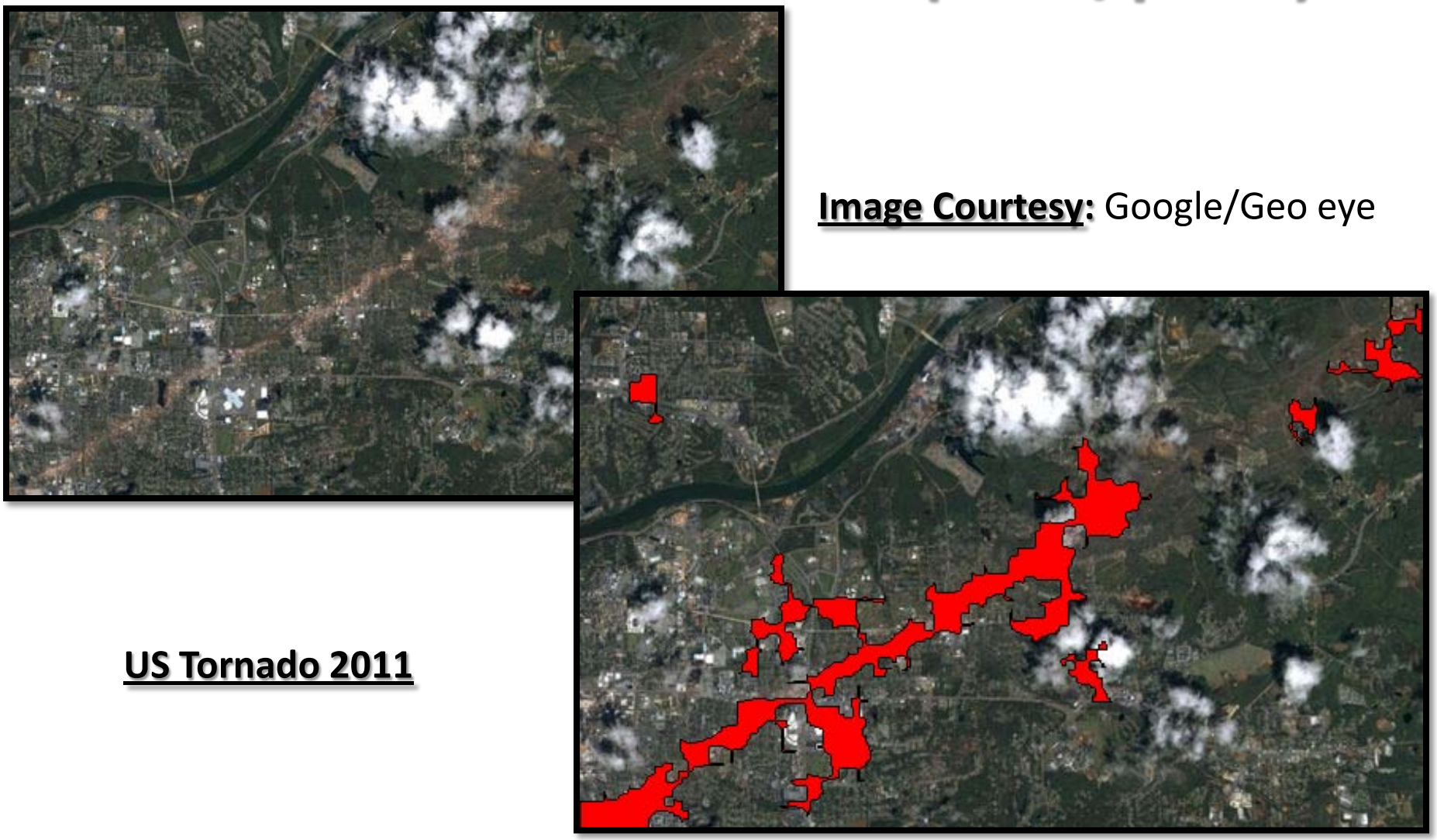


Image Courtesy: Google/Geo eye

US Tornado 2011

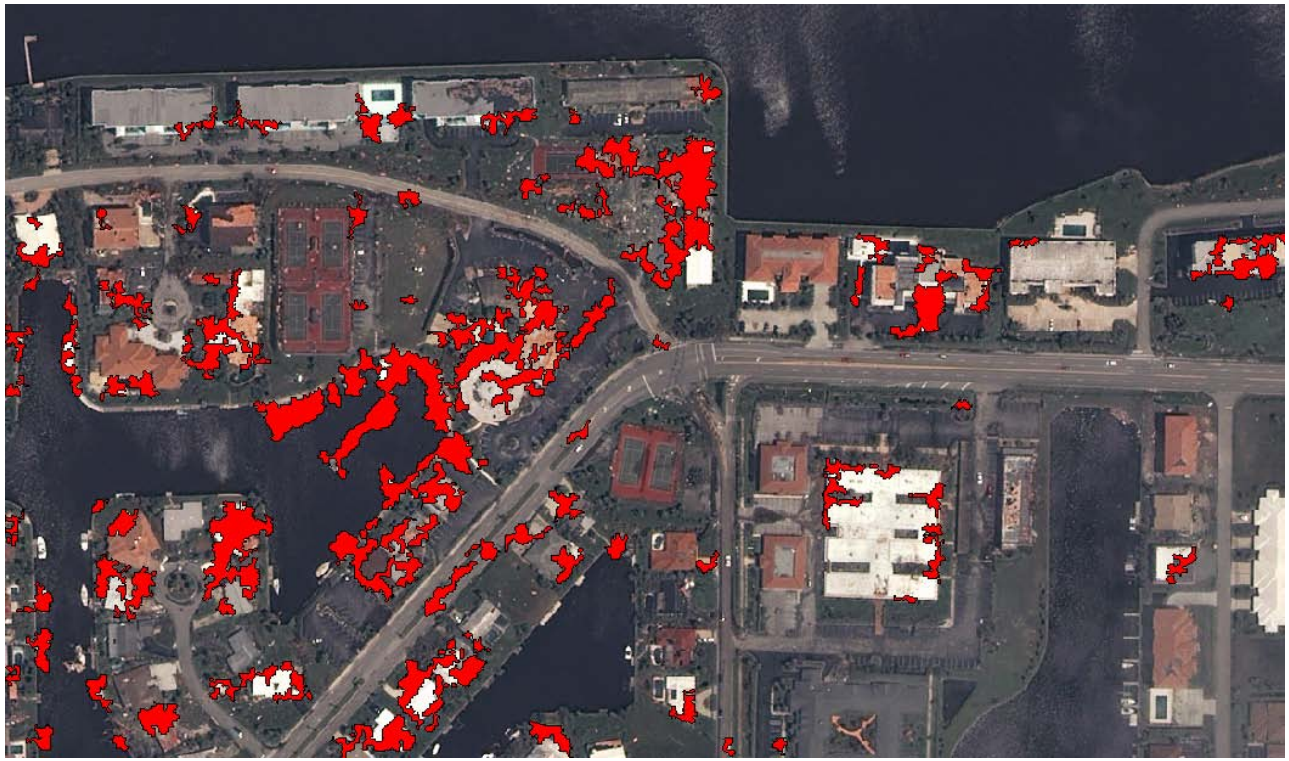
TOKUNOSHIMA, KAGOSHIMA TORNADO
AERIAL IMAGERY

Image Courtesy: very low resolution image capture from a video taken by Asahi Shimbun

Japan Tornado Nov19, 2011

PUNTA GORDA : HURRICANE CHARLEY

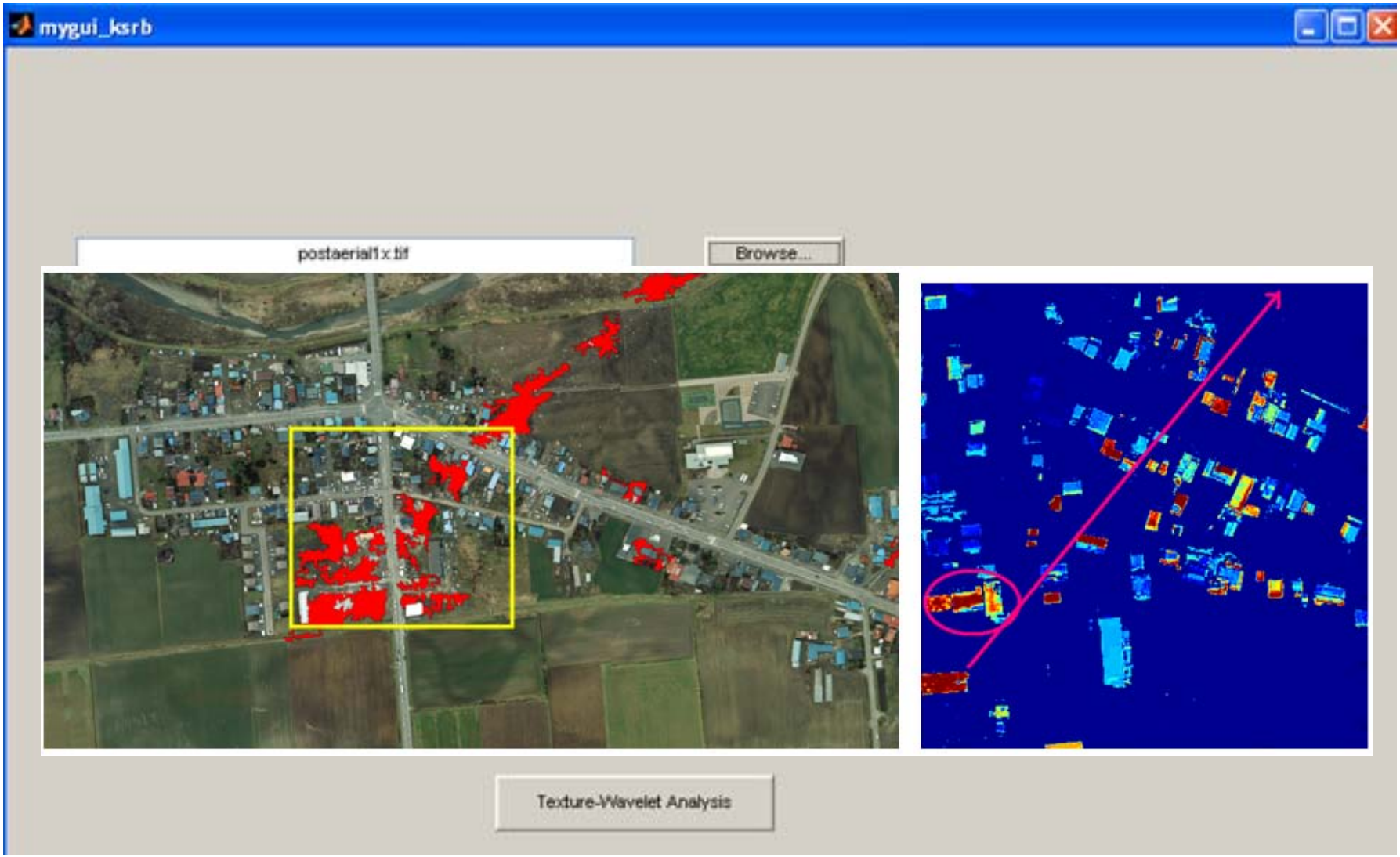
Satellite image (2.44m/pixel)



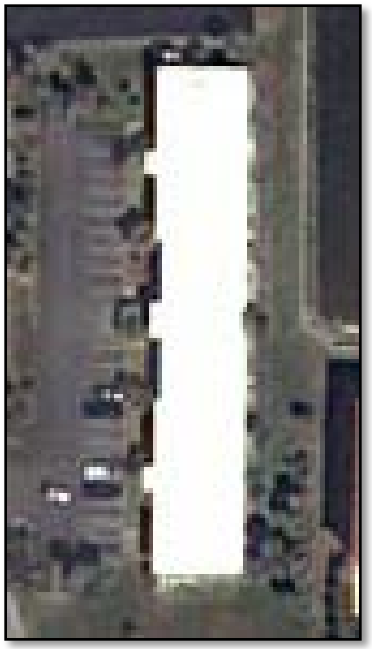
US Hurricane Aug 13th 2004

Image Courtesy: DigitalGlobe$_{TM}$ and were licensed and provided by Remote Sensing Technology Center of Japan (RESTEC)

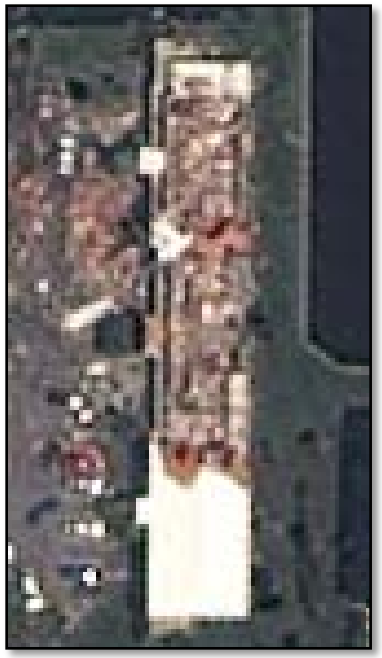
SOFTWARE DESIGNED



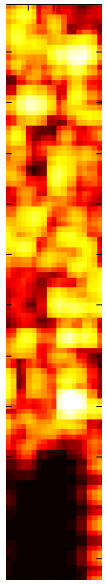
USAGE OF HIGH RESOLUTION IMAGERY FOR BUILDING DAMAGE DETECTION



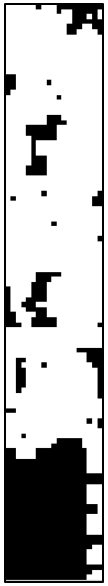
Pre –storm Roof Top



Post-storm Roof Top



Damage Severity

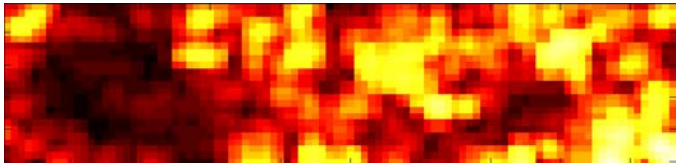


Damaged Area Detected

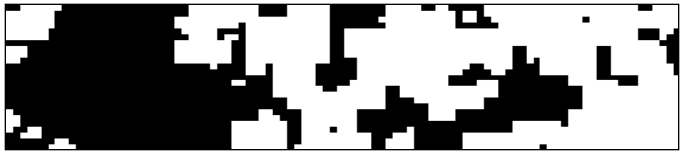
USAGE OF HIGH RESOLUTION IMAGERY FOR BUILDING DAMAGE DETECTION

Pre -storm Roof Top

Post-storm Roof Top

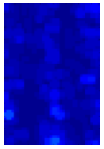
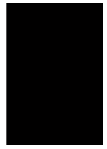
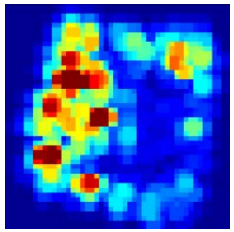
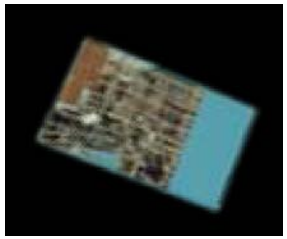
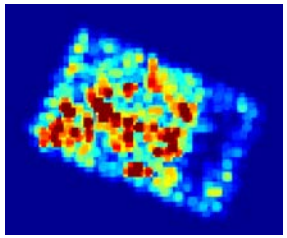
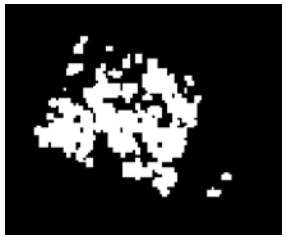
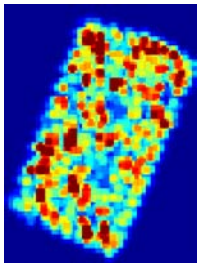


Damage Severity



Damaged Area Detected

USAGE OF HIGH RESOLUTION IMAGERY FOR BUILDING DAMAGE DETECTION

Post-storm Roof Top	Damage Severity	Damage area Detected	
			% Area of Roof Damage = 0%
			% Area of Roof Damage = 41%
			% Area of Roof Damage = 58%
			% Area of Roof Damage = 89%

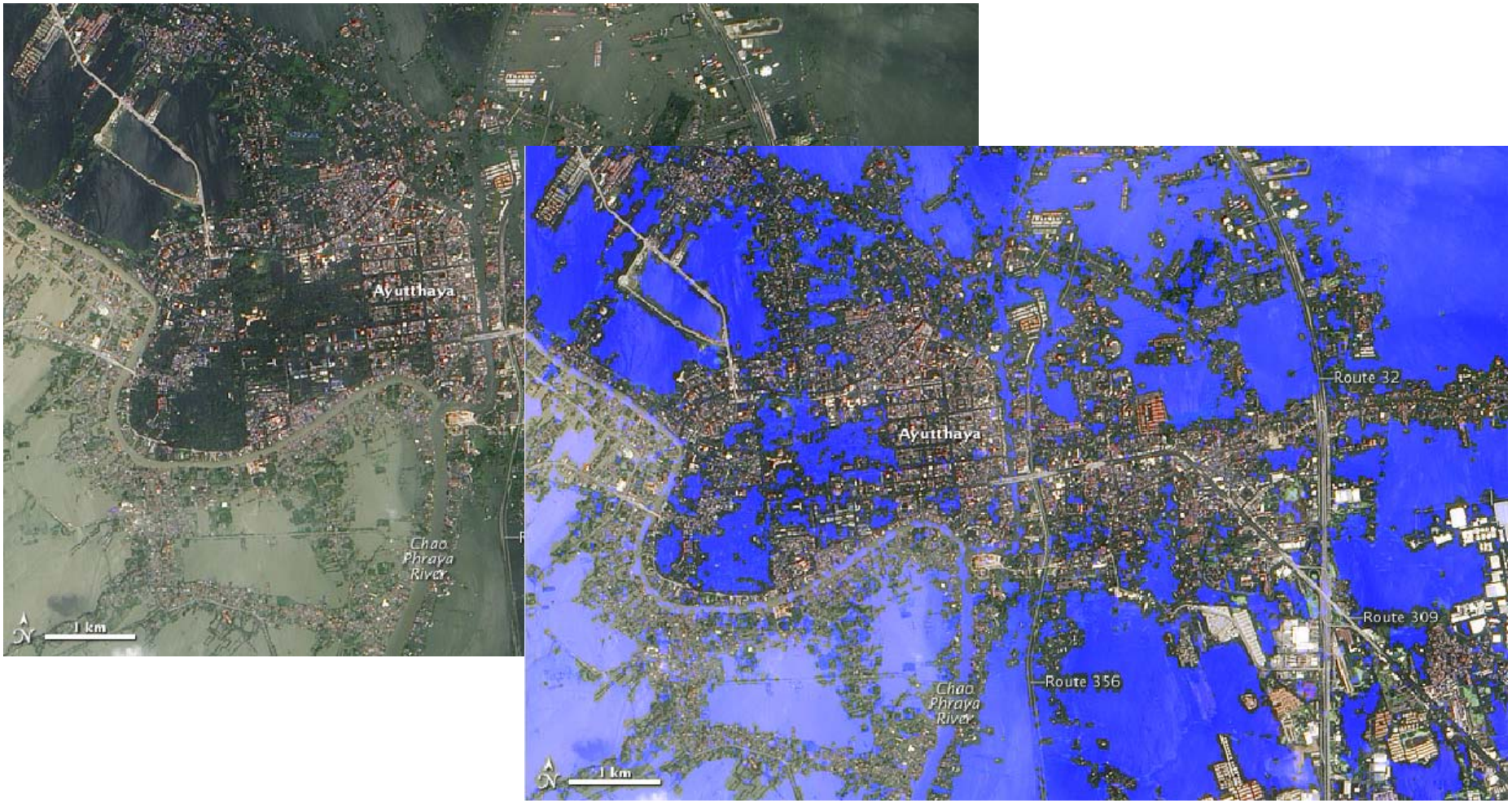
OTHER NATURAL HAZARDS DETECTED FROM SATELLITE IMAGERY

THAILAND FLOOD
Satellite image 10m/pixel

Ayutthaya, Bangkok, DATE: OCT 23, 2011

Image Courtesy: EarthObservatory, NASA

THAILAND FLOOD
Satellite image 10m/pixel

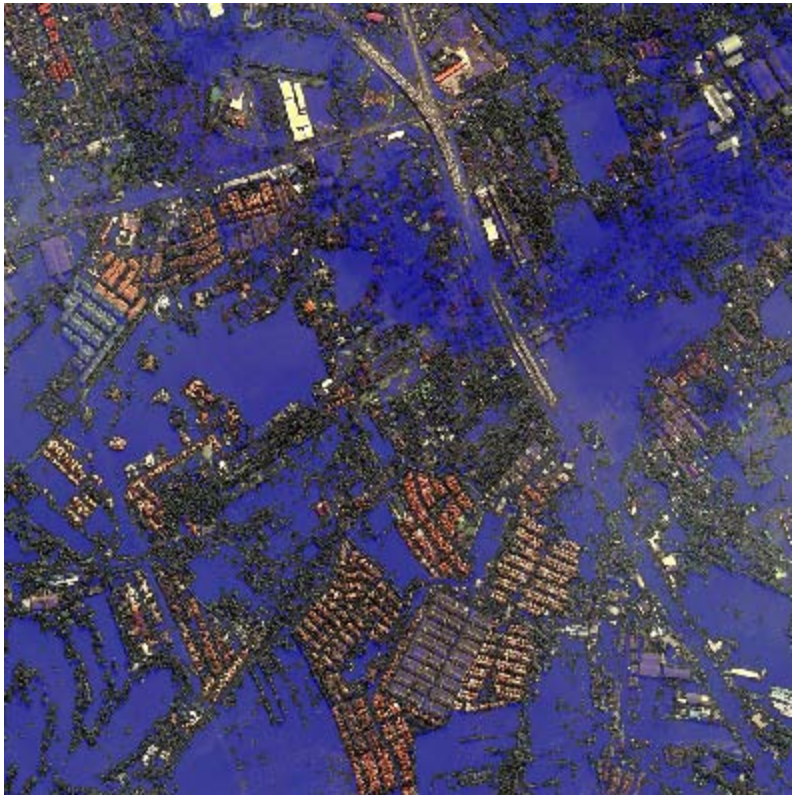


Ayutthaya, Bangkok, DATE: OCT 23, 2011

Image Courtesy: EarthObservatory, NASA

THAILAND FLOOD

Satellite image 2.44m/pixel

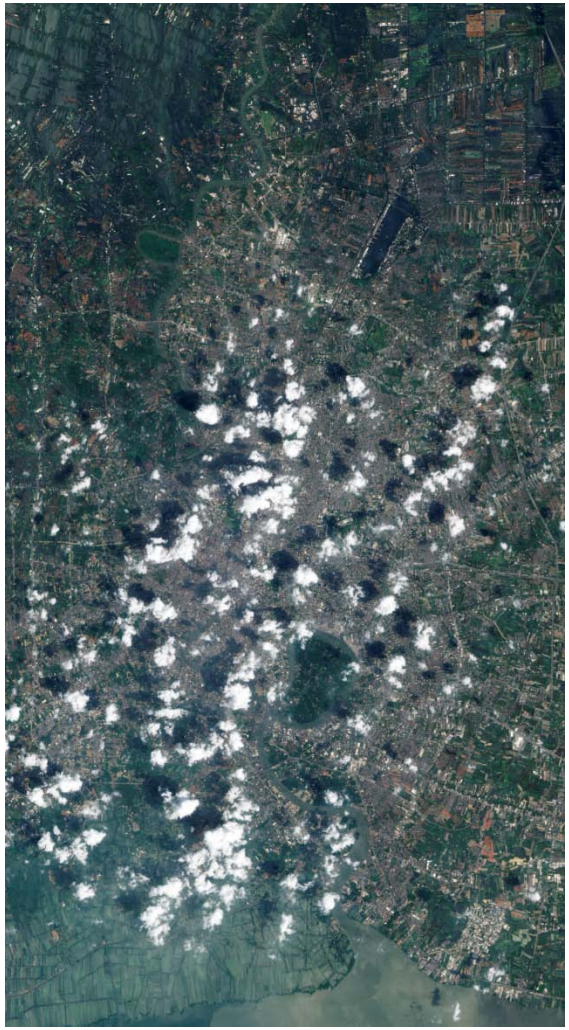


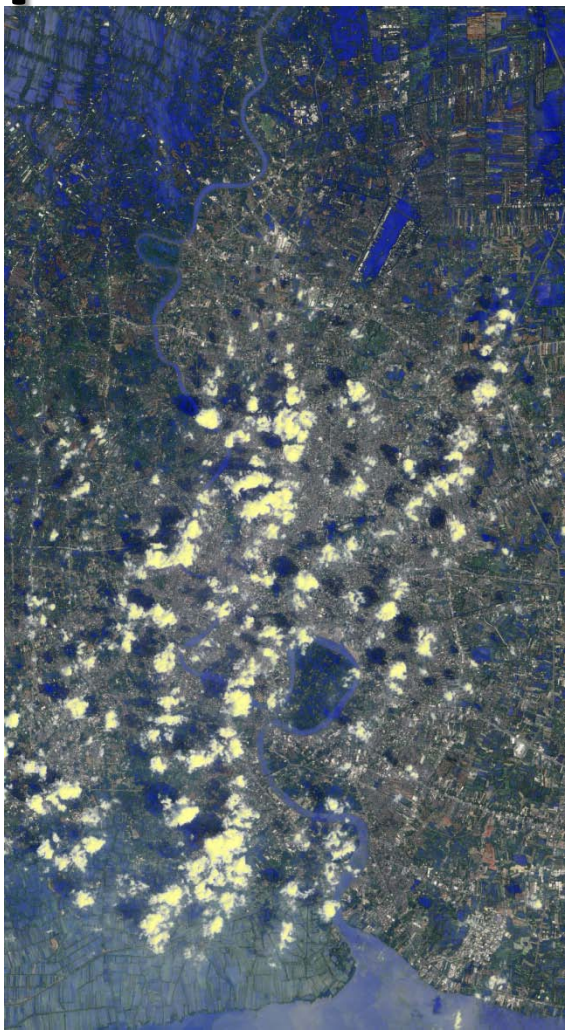
Bangkok, DATE: OCT 25, 2011

Image Courtesy: EarthObservatory, NASA

THAILAND FLOOD

Satellite image 20m/pixel

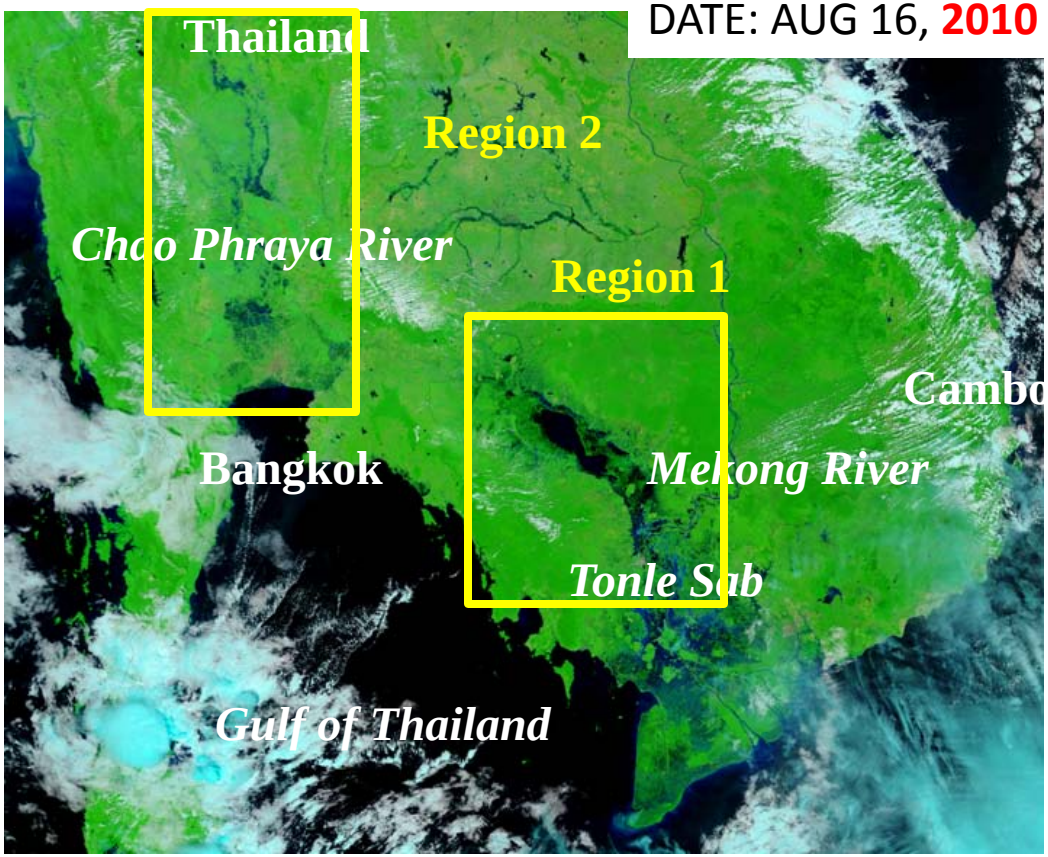




Bangkok DATE: OCT 31, 2011

Image Courtesy: EarthObservatory, NASA

THAILAND FLOOD

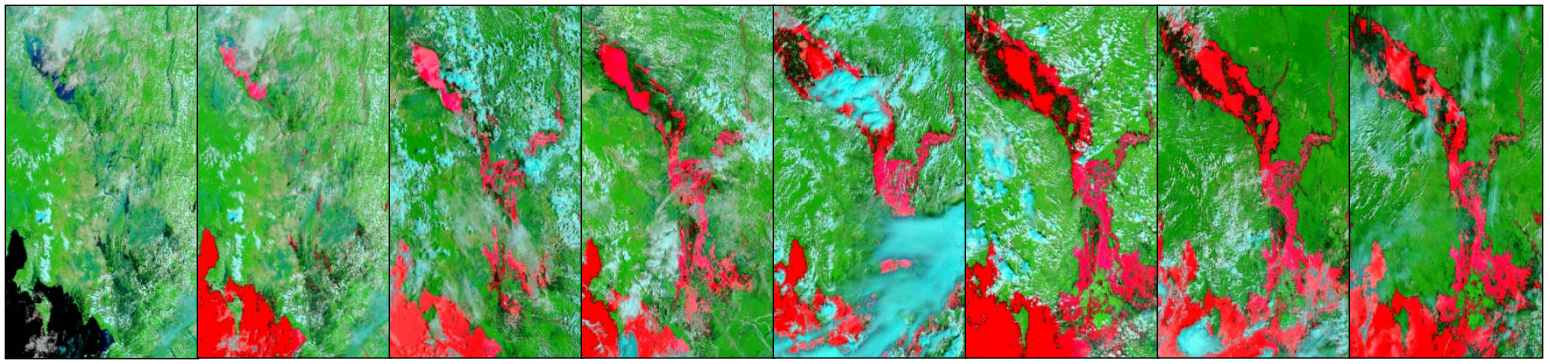


- **Moderate Resolution Imaging Spectroradiometer**
- **combination of visible and infrared light to better distinguish between water and land**

Image Courtesy: EarthObservatory, NASA

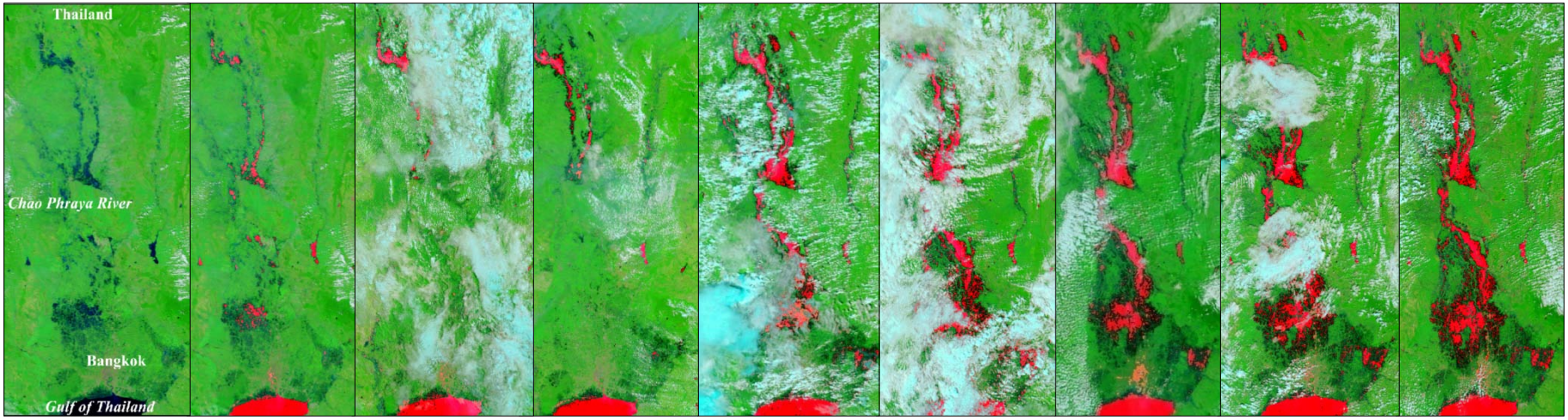
PROGRESS IN THAILAND FLOOD

Region 1 → CAMBODIA



AUG 16 2010 | AUG 16 2010 | AUG 13 2011 | AUG 24 2011 | OCT 11 2011 | OCT 18 2011 | OCT 25 2011 | NOV 1 2011

Region 2 → BANGKOK



AUG 16 2010 | AUG 16 2010 | AUG 13 2011 | AUG 24 2011 | OCT 11 2011 | OCT 18 2011 | OCT 19 2011 | OCT 25 2011 | NOV 1 2011

In search of Satellite images

DEBRIS OF JAPAN TSUNAMI IN PACIFIC OCEAN

Image Courtesy: US Navy in Japan

CONCLUSIONS

1. Tornado foot prints are traced successfully by using Texture-Wavelet Analysis from the debris deposit using post-storm image alone
2. User friendly software is designed for the purpose.
3. Further, once the path is traced **Where exactly building damage is located** can be easily traced

ACKNOWLEDGEMENTS

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THANK YOU VERY MUCH FOR YOUR KIND ATTENTION