

平成 22 年度 第 5 回災害リモートセンシング技術の標準化と高度化に関する研究委員会

話題提供資料

- ・「高解像度 SAR 画像を用いた変化抽出」(山崎文雄)
- ・「リモートセンシングデータによる被害検出手法について」(三浦弘之)

以上

高解像度SAR画像を用いた変化抽出

2010年7月15日

山崎 文雄
千葉大学 大学院工学研究科

1

研究内容

■地震や津波，風水害について，災害前後の衛星SAR画像(TerraSAR-X, ALOS/PALSAR等)と衛星光学センサ画像・空中写真を入手する．

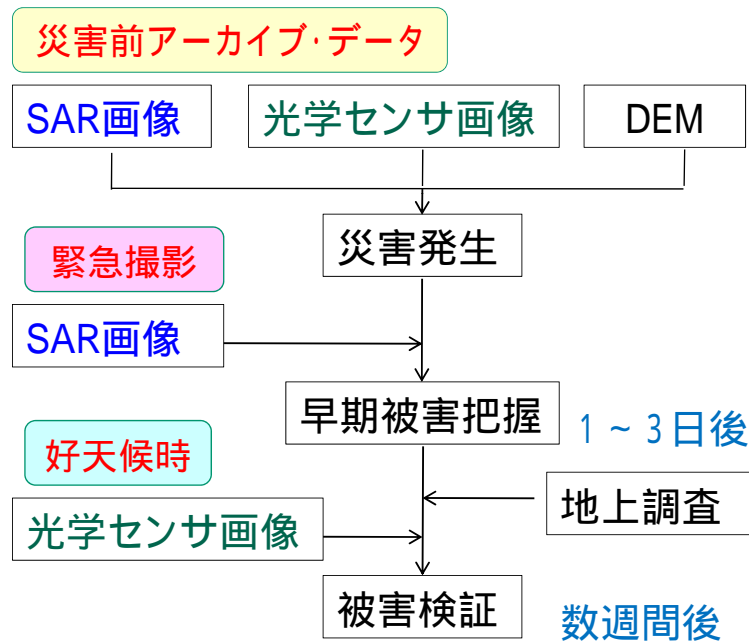
■市街地や中山間地において，マイクロ波の波長，偏波，解像度，照射方向などによる，土地被覆，地形を考慮した後方散乱特性を把握する．

■災害前後のSAR強度画像から，相関と強度差を用いて変化(被害)抽出を行う．



2

本研究で提案する衛星画像と被害把握の流れ



3

発表項目

- 高解像度SAR画像を用いた**建物被害の把握**
2009年イタリア・ラクイラ地震
- 高解像度SAR画像を用いた**市街地変化の把握**
東京・横浜

4

L'Aquila Earthquake



www.nowpublic.net

Location

Central Italy
42.423 ° N, 13.395 ° E

Time:

Monday, April 06, 2009
at 03:32:42 AM (local time)

Magnitude: 6.3
Depth: 10 km

Death: 307
Injury: 15,000
Homeless 65,000



acquisition mode : "SM" / "strip_011" / "HH" / "R"
product type : "EEC" / "SE"
start time UTC : "2009-02-06T16:58:16.345000"
stop time UTC : "2009-02-06T16:58:24.344770"
orbit cycle / no. / dir. : 55 / 9149 / 131 / "A"



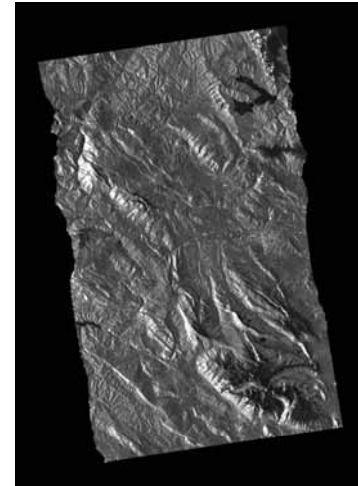
SAR Coverage Area

acquisition mode : "SM" / "strip_011" / "HH" / "R"
product type : "EEC" / "SE"
start time UTC : "2009-04-13T16:58:18.301954"
stop time UTC : "2009-04-13T16:58:26.300939"
orbit cycle / no. / dir. : 61 / 10151 / 131 / "A"

Ascending



Before Feb. 6, 2009



After April 13, 2009

5

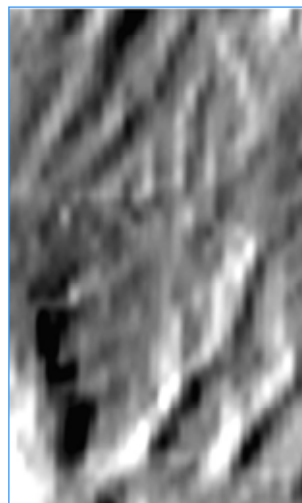
SAR DATA

Feb. 6, 2009

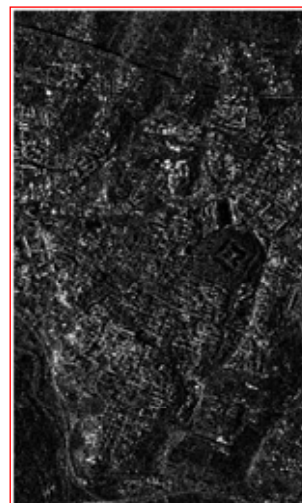
April 13, 2009



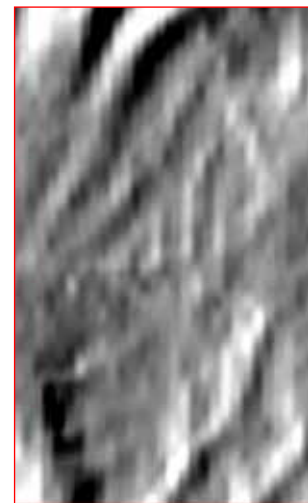
Before **_DN**



GIM **_before**



After **_DN**



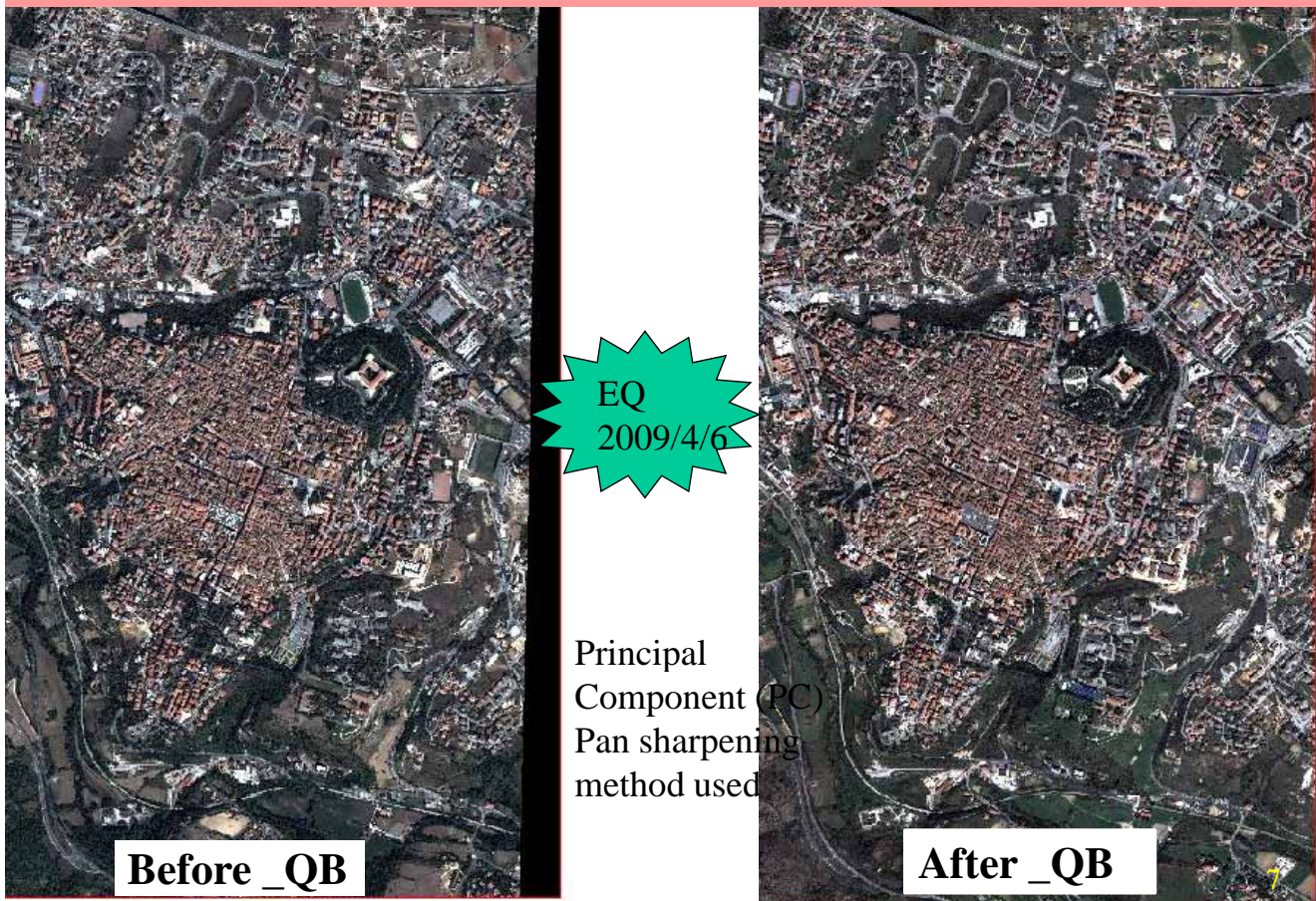
GIM **_after**

DN: Digital Number

GIM: Geocoded Incidence angle mask

6

Pan sharpened QB images (0.6m)



Backscatter

Backscatter → two types

- 1) β_0 = backscatter per unit area in slant range
- 2) σ^0 = backscatter per unit area in ground range (Source;CCRS)

TerraSAR-X product

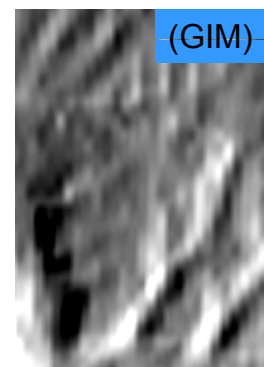
$$\beta_0(\text{db}) = 10\log_{10}(\text{Cal factor} \cdot \text{DN}^2)$$

and Cal factor = 1.043E-05

$$\sigma^0(\text{db}) = \beta_0(\text{db}) + 10\log_{10}(\text{Sin } \theta_{\text{loc}})$$

where,

$$\theta_{\text{loc}} = \frac{GIM - (GIM \text{ mod } 10)}{100}$$



- Geocoded Incidence angle mask (GIM) gives the Local incidence angle >.. angle between the radar beam and the normal to the illuminated surface. GIM mod 10 represents the remainder of the division of GIM by 10. GIM is found in the EEC product folder.
- Cal factor is provided in the XML file.

Change Detection Index from SAR

1. Image matching
2. Speckle noise filtering (*Lee Filter*)
3. Calculating following indices:

✓ **Difference of backscattering coefficient** (after – before)

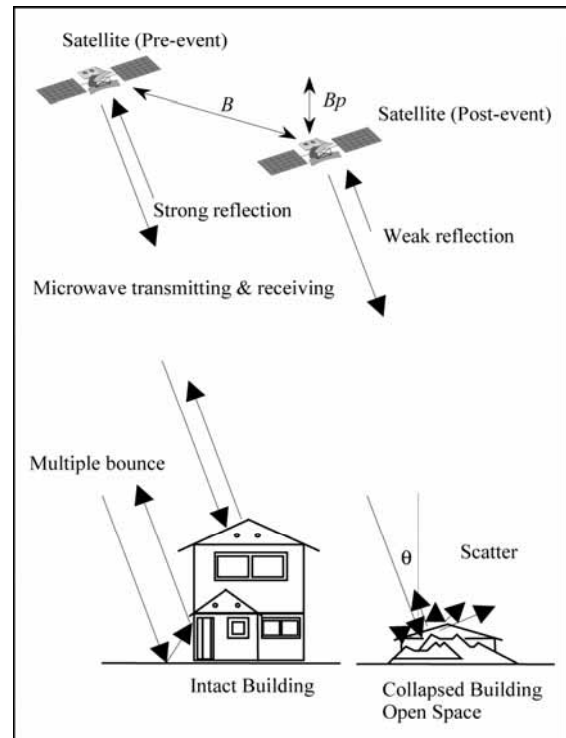
$$d[dB] = 10 \cdot \log_{10} \bar{I}a_i - 10 \cdot \log_{10} \bar{I}b_i$$

✓ **Correlation coefficient**

$$r = \frac{N \sum_{i=1}^N I a_i I b_i - \sum_{i=1}^N I a_i \sum_{i=1}^N I b_i}{\sqrt{\left(N \sum_{i=1}^N I a_i^2 - \left(\sum_{i=1}^N I a_i \right)^2 \right) \cdot \left(N \sum_{i=1}^N I b_i^2 - \left(\sum_{i=1}^N I b_i \right)^2 \right)}}$$

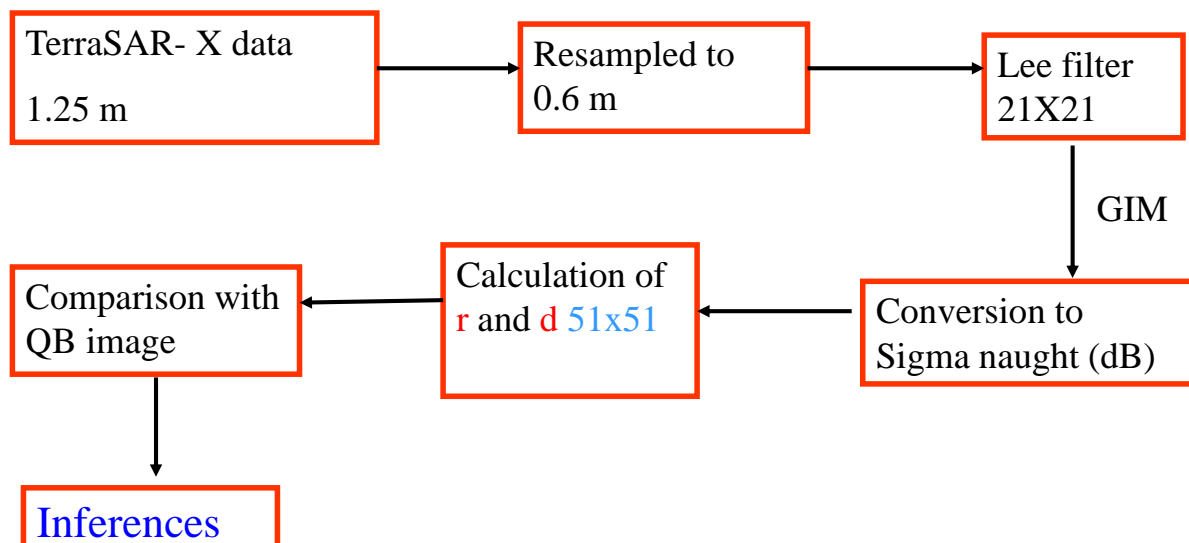
$I a_i$ and $I b_i$ are the digital numbers of the post- and pre-images.

$\bar{I}a_i$ and $\bar{I}b_i$ are the corresponding averaged digital numbers **over the pixel window**.



9

The flow chart



Correlation & Backscattering difference



Color Composite from DN :
R:post event, G,B:pre-event

Lee Filtered
21x21

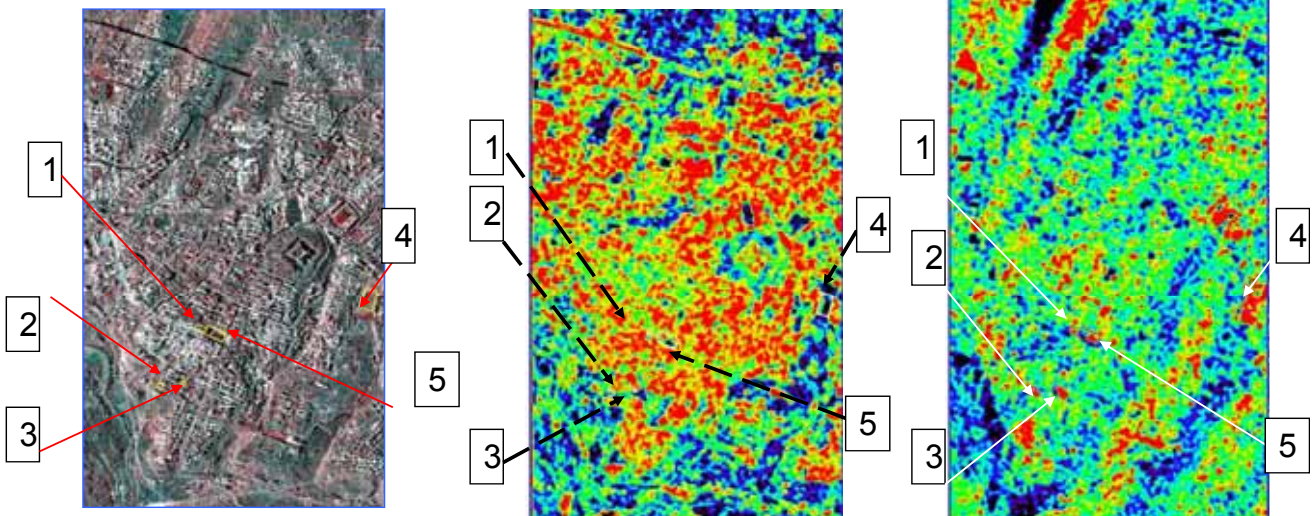


Color Composite from Sigma Naught :
R:post event, G,B:pre-event

$$\sigma^0 \text{ (db)} = \beta_0 \text{ (db)} + 10 \log_{10} (\sin \Theta_{loc})$$

¹¹

Correlation & Backscattering difference



Color Composite :
R:post event, G,B:pre-event

Correlation (r)

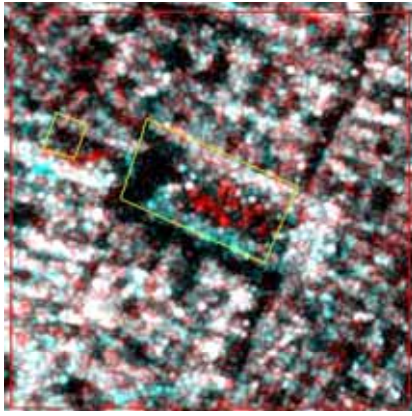
Backscattering difference (d)

$$\sigma^0 \text{ (db)} = \beta_0 \text{ (db)} + 10 \log_{10} (\sin \Theta_{loc})$$

Window size = 51 X 51

Post event-Prevent

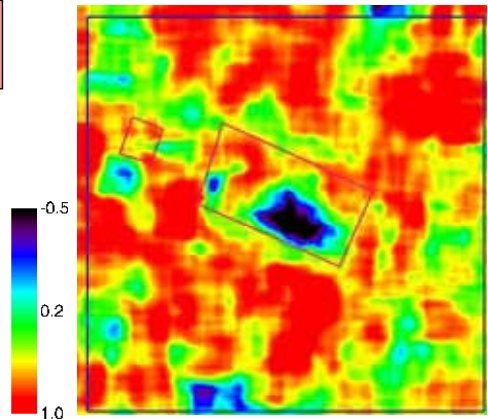
¹²



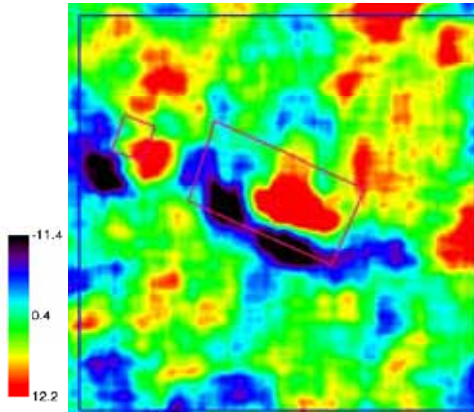
Color Composite:
R:post event, G,B:pre-event

Main Plaza

r and d
calculation from σ_0
51*51 window
(after-before)



Correlation

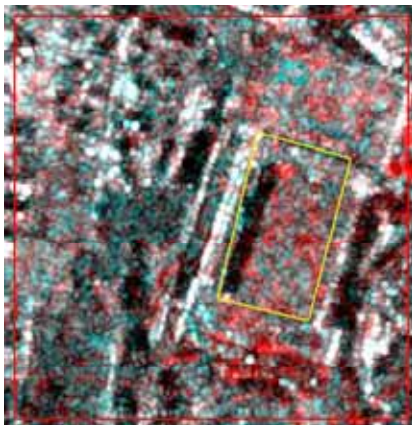


Difference



QB (2009.4.8)

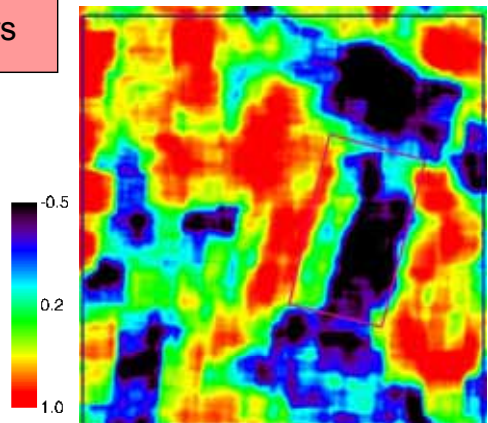
13



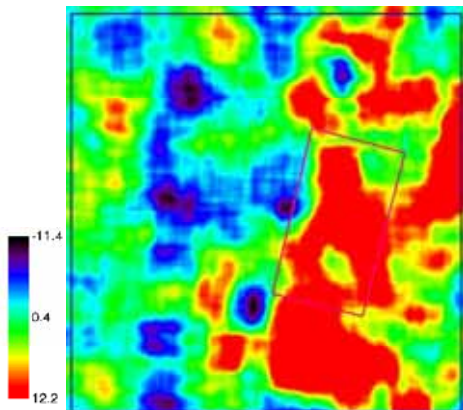
Color Composite:
R:post event, G,B:pre-event

Temporary Shelters

r and d
calculation from σ_0
51*51 window
(after-before)



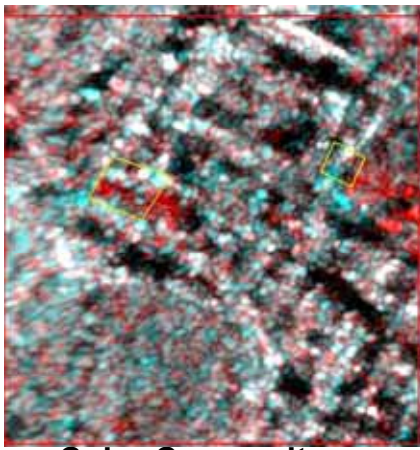
Correlation



Difference



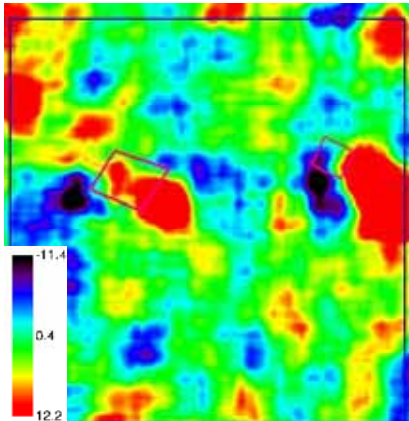
QB (2009.4.8)



Collapsed bldg

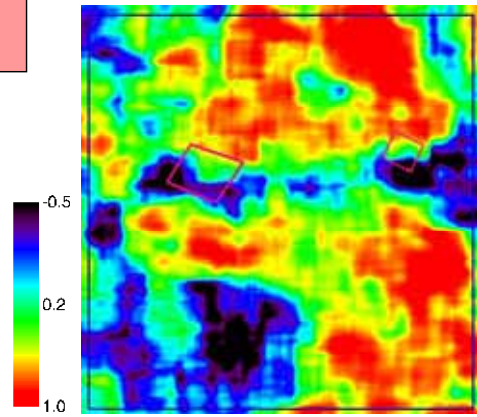
Color Composite:

R:post event, G,B:pre-event



Difference

r and d
calculation from σ_0
51*51 window
(after-before)



Correlation



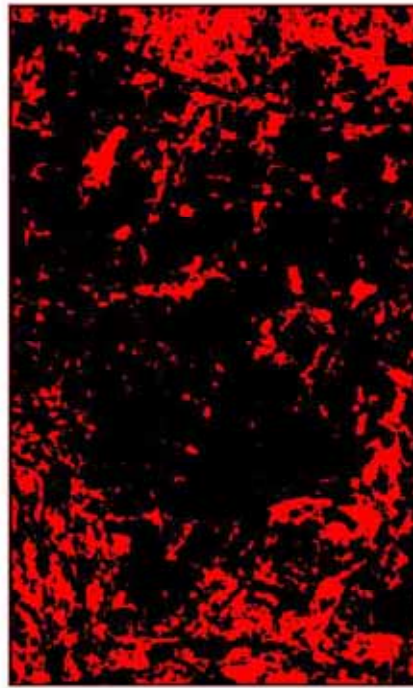
QB (2009.4.8)

(a)QB画像より抽出した人工被覆領域(白色), (b)2時期のTerraSAR-X画像から抽出された低相関領域(赤色), および(c)それらの重ね合わせ.

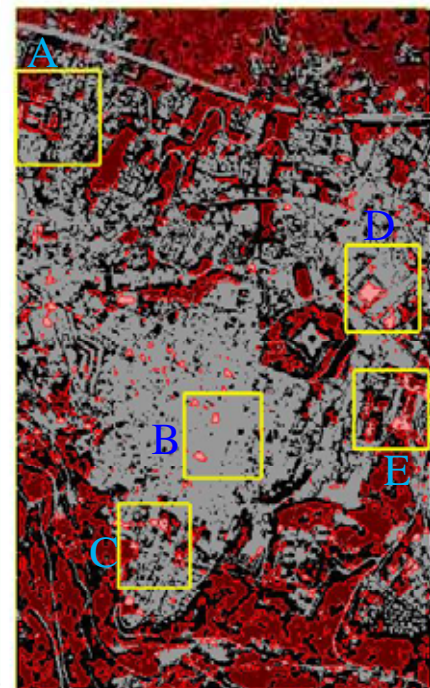
薄赤色の領域が地震前後で変化のあった人工被覆領域.



(a) Area of $NDVI \leq 0.16$
from QB image on 2009/4/8

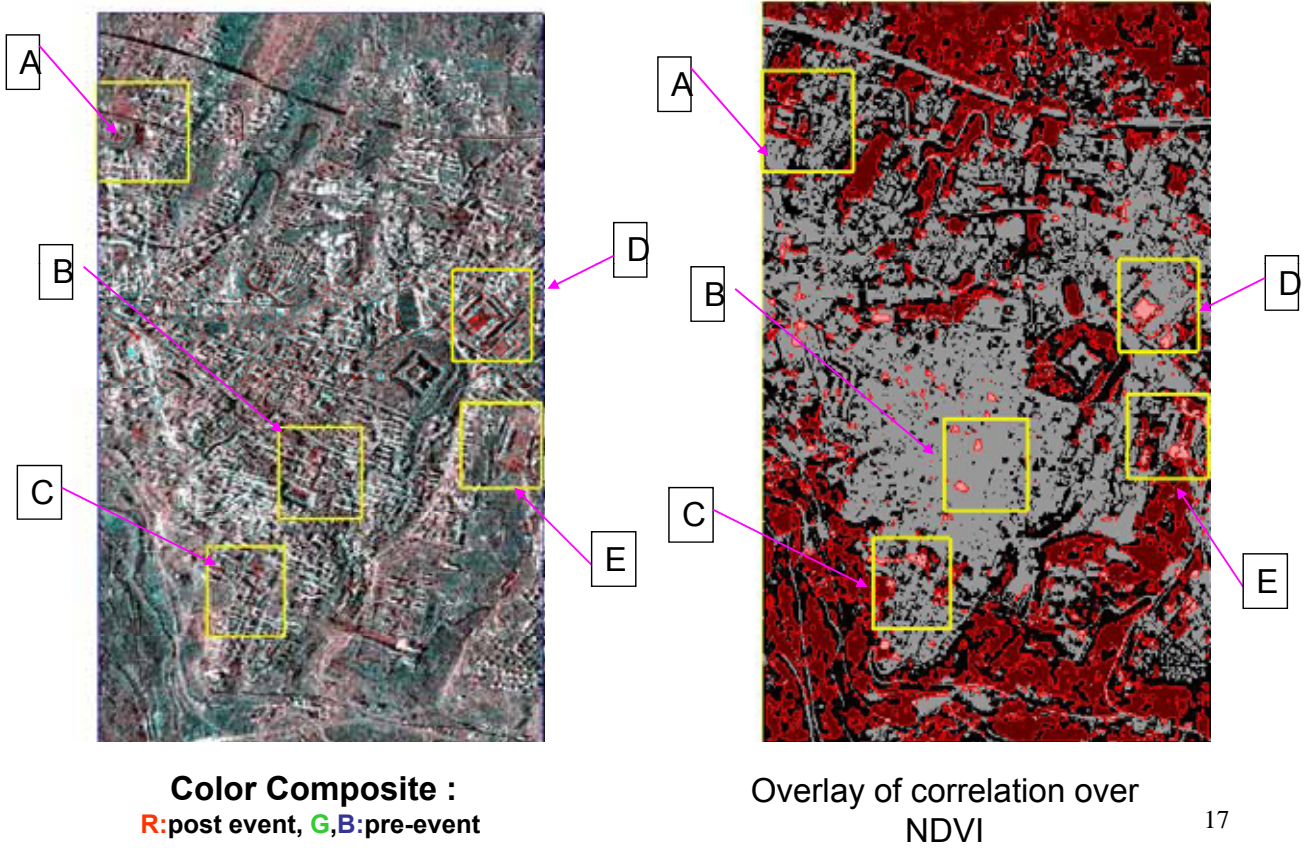


(b) Area of $r \leq 0.3$ from TSX
images on 2009/2/6 & 4/13

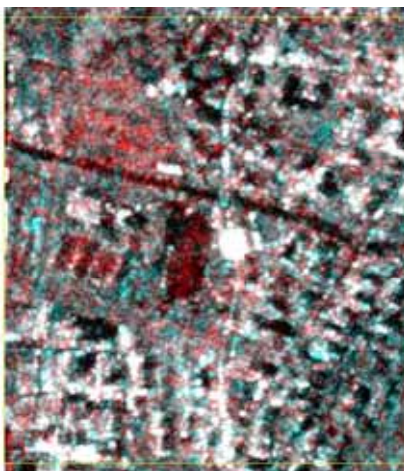


(c) Superposition of the areas
with $NDVI \leq 0.16$ and $r \leq 0.3$

NDVI and Correlation



Area A



Color Composite:
R: post-event, G,B: pre-event

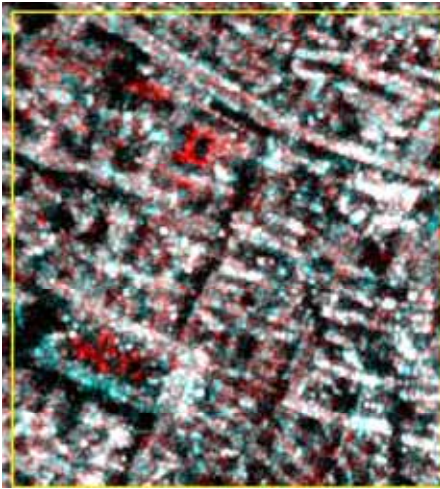


Superposition of the areas
 $NDVI \leq 0.16$ and $r \leq 0.3$

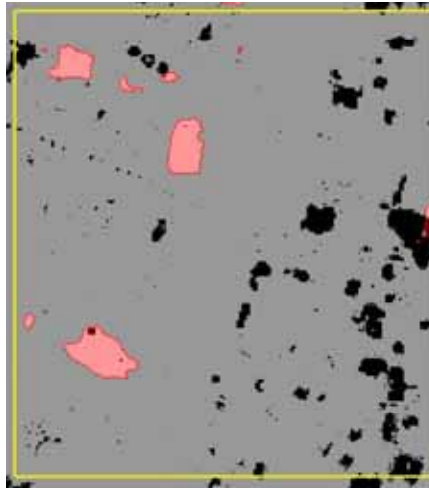


QuickBird
post-event: 2008/4/8

Area B



Color Composite:
R: post-event, G,B: pre-event



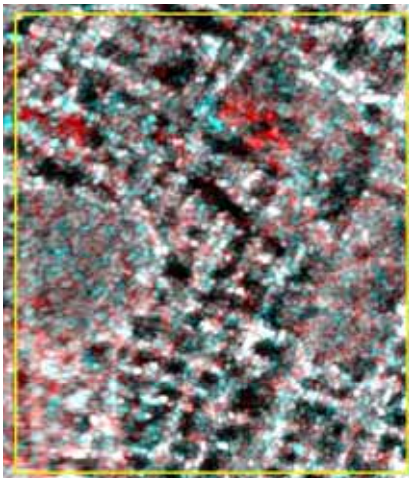
Superposition of the areas
 $NVDI \leq 0.16$ and $r \leq 0.3$



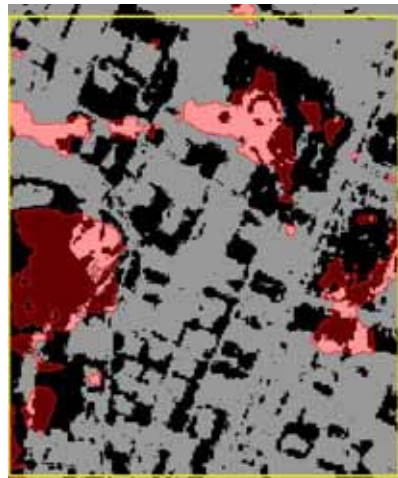
QuickBird
post-event: 2008/4/8

19

Area C



Color Composite:
R: post-event, G,B: pre-event



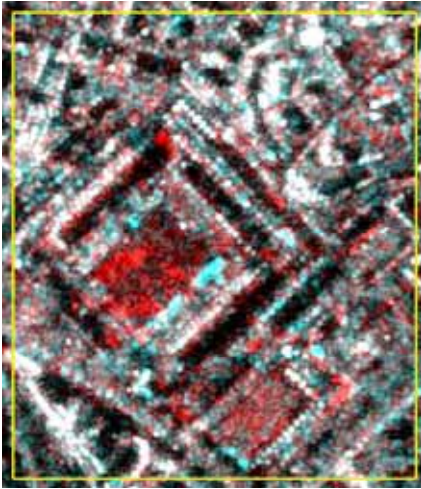
Superposition of the areas
 $NVDI \leq 0.16$ and $r \leq 0.3$



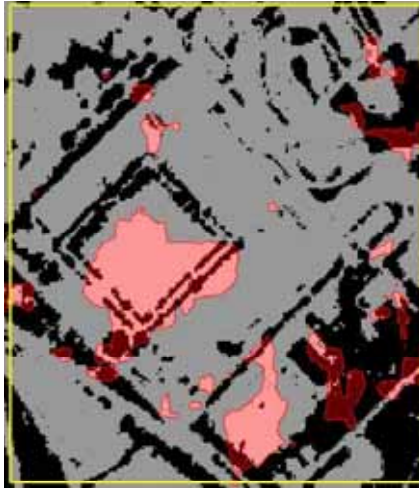
QuickBird
post-event: 2008/4/8

20

Area D



Color Composite:
R: post-event, G,B: pre-event



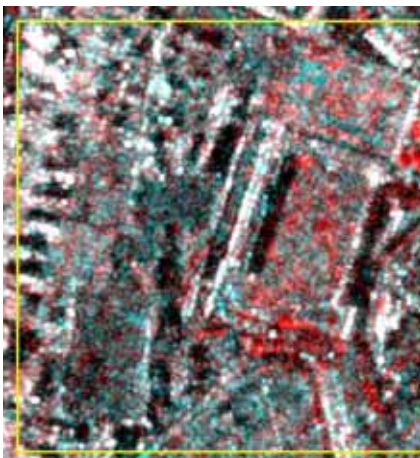
Superposition of the areas
 $NVDI \leq 0.16$ and $r \leq 0.3$



QuickBird
post-event: 2008/4/8

21

Area E



Color Composite:
R: post-event, G,B: pre-event



Superposition of the areas
 $NVDI \leq 0.16$ and $r \leq 0.3$



QuickBird
post-event: 2008/4/8

22

発表項目

■高解像度SAR画像を用いた建物被害の把握

2009年イタリア・ラクイラ地震

■高解像度SAR画像を用いた市街地変化の把握

東京・横浜

Basic research on TerraSAR-X and PALSAR images

23

Study areas



Central Tokyo

The ground surface including urban areas (bridges, roads, buildings), vegetation, water

QuickBird image

Resolution: 0.6m

Time: 2007.03.20



24

TerraSAR-X images

2008.05.23

2009.11.27



Polarimetric: HH
Resolution: 1.25m

Course: Descending
Looks angle: 42.8 °

25

Radiometric calibration of TerraSAR-X

- **Beta Naught (radar brightness ⁰)**

The radar reflectivity per unit area in **slant range**

$$\beta^0_{dB} = 10 \cdot \log_{10}(k_s \cdot |DN|^2)$$

k_s : the calibration factor

- **Sigma Naught (radiometric calibration ⁰)**

The radar reflectivity per unit area in **ground range**

$$\sigma^0_{dB} = \beta^0_{dB} + 10 \cdot \log_{10}(\sin \theta_{loc})$$

$$\theta_{loc} = \frac{(GIM - (GIM \bmod 10))}{100}$$

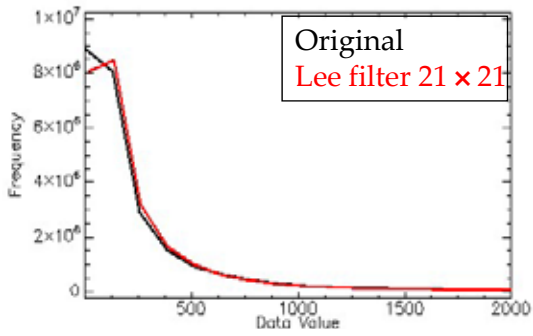
θ_{loc} : the local incidence angle

GIM: the Geocoded Incidence Angle MASK

($GIM \bmod 10$): the remainder of the division of GIM by 10

26

Beta Naught



Lee filter: 21×21

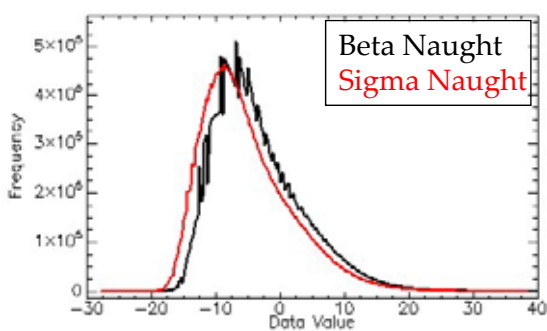
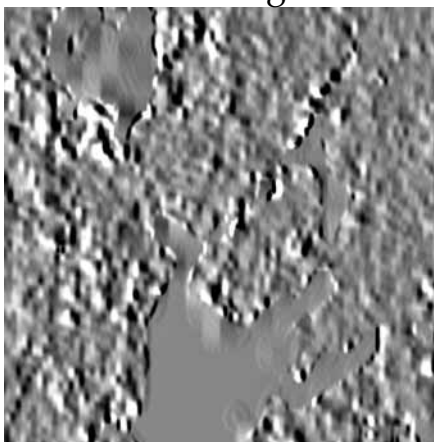


$$\beta^0_{dB} = 10 \cdot \log_{10}(k_s \cdot |DN|^2)$$

$$k_s = 9.7 \times 10^{-6}$$

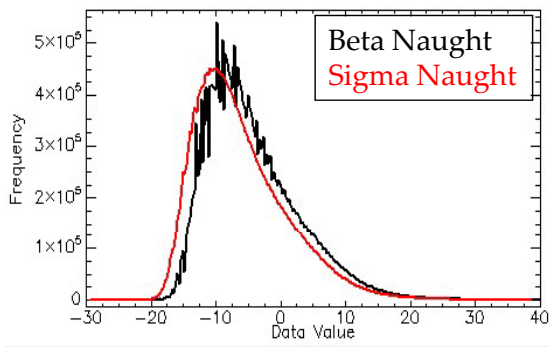
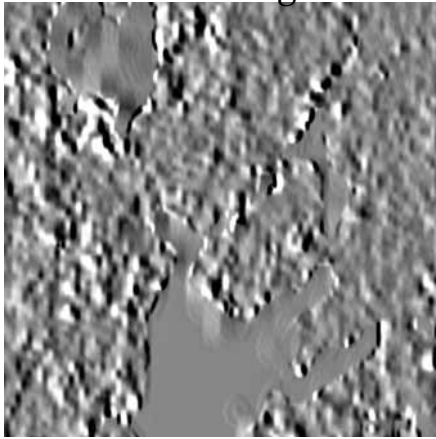
Sigma Naught

GIM images

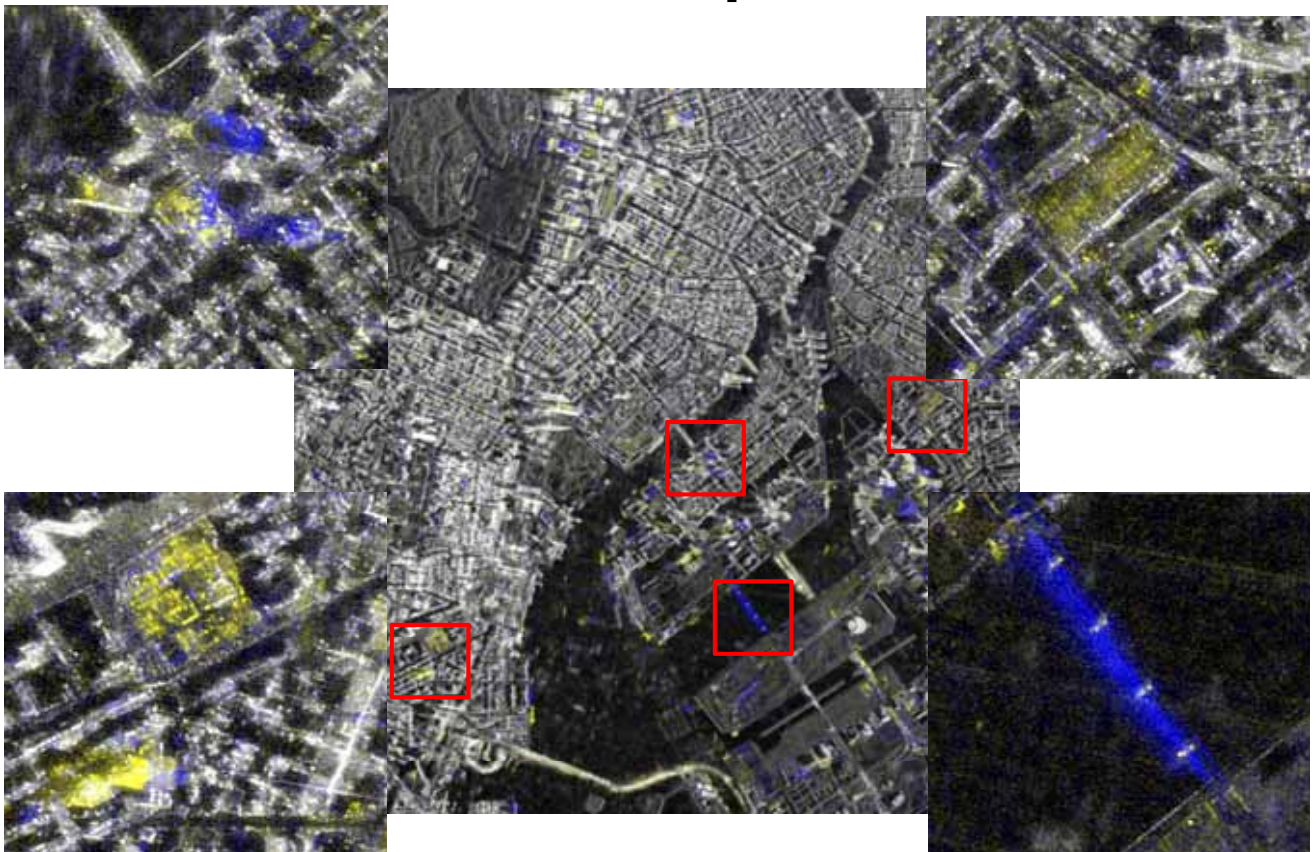


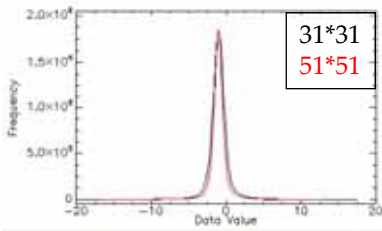
Sigma Naught (08.05.23)

GIM images



Color composite

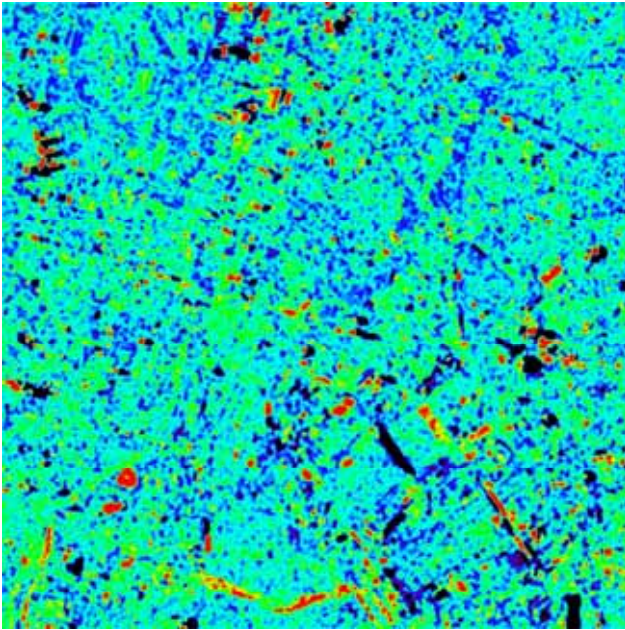




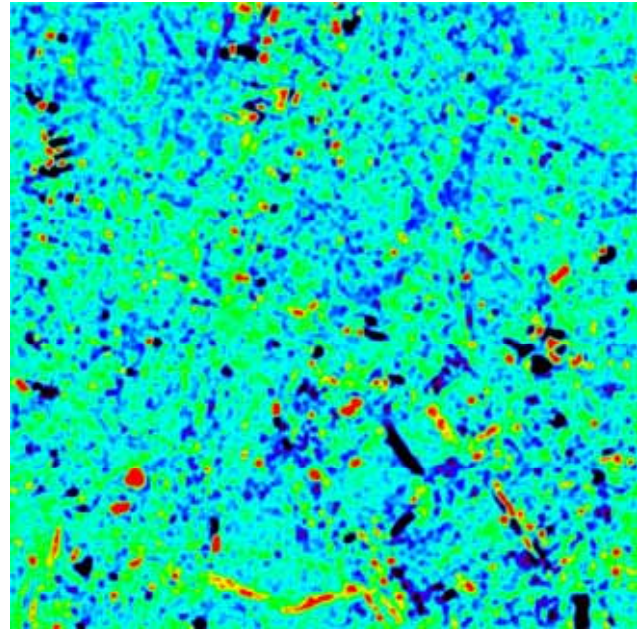
Difference

$$d = \hat{I}a - \hat{I}b$$

$\hat{I}a, b$: The mean of σ^0 within the window

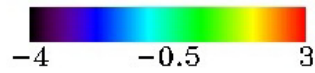


31 × 31 pixels



51 × 51 pixels

31



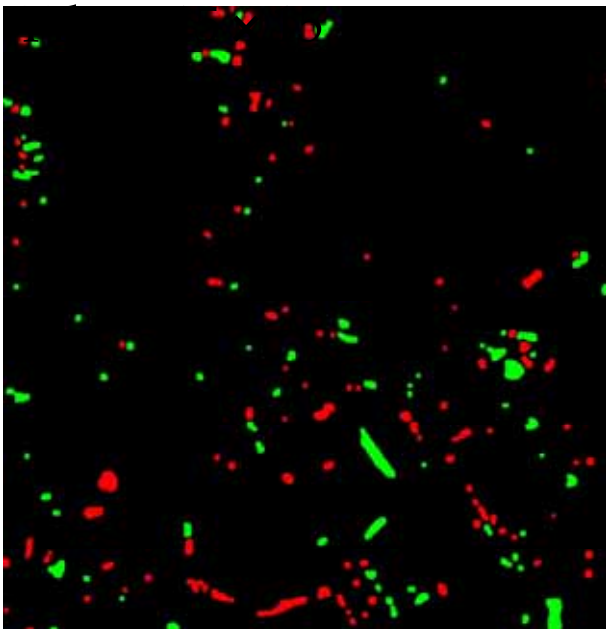
Change detection

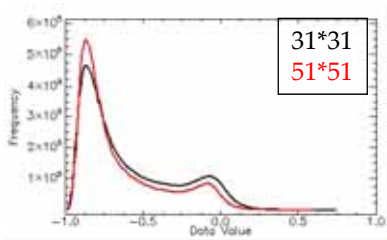
Mean: -0.93 Stdev: 1.19

No change:

Mean \pm 2Stdev

New building
Destroyed building

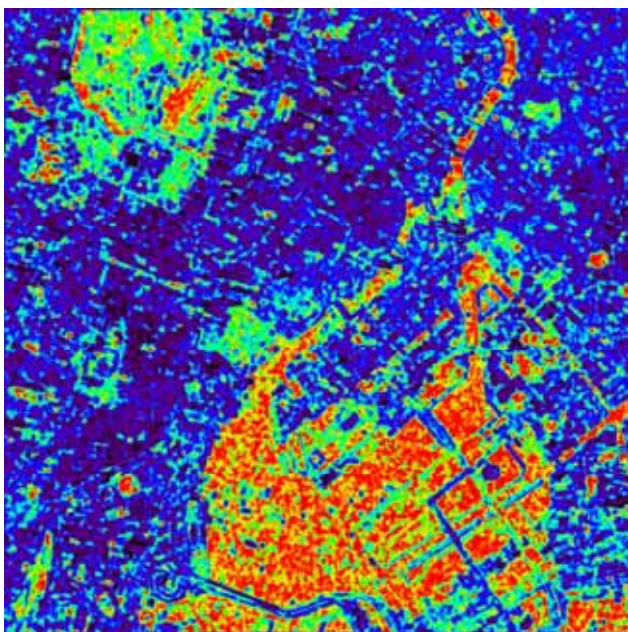




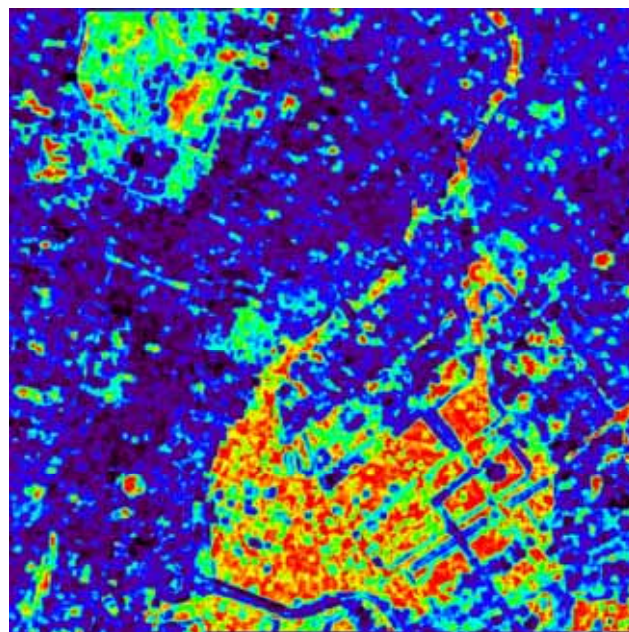
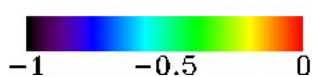
Correlation

$$r = \frac{N \sum_i^n I_a \cdot I_b - \sum_i^n I_a \sum_i^n I_b}{\sqrt{\left(N \sum_i^n I_a^2 - \left(\sum_i^n I_a \right)^2 \right) \left(N \sum_i^n I_b^2 - \left(\sum_i^n I_b \right)^2 \right)}}$$

$I_a, b: \sigma^0$



31 × 31 pixels



51 × 51 pixels

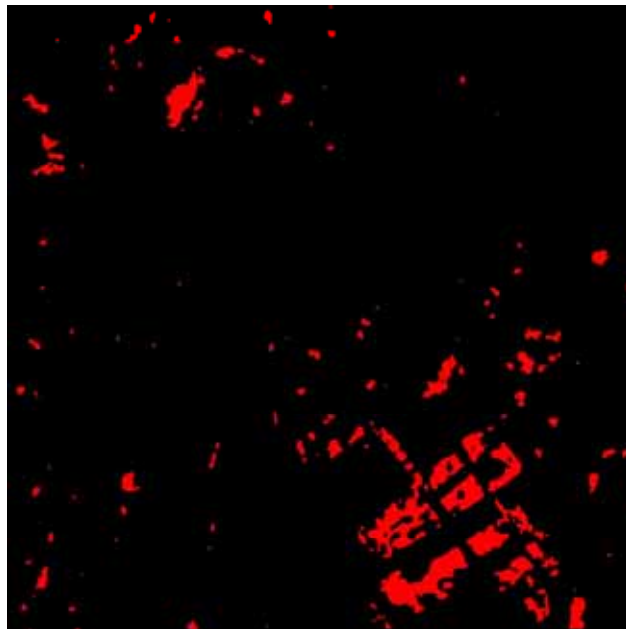
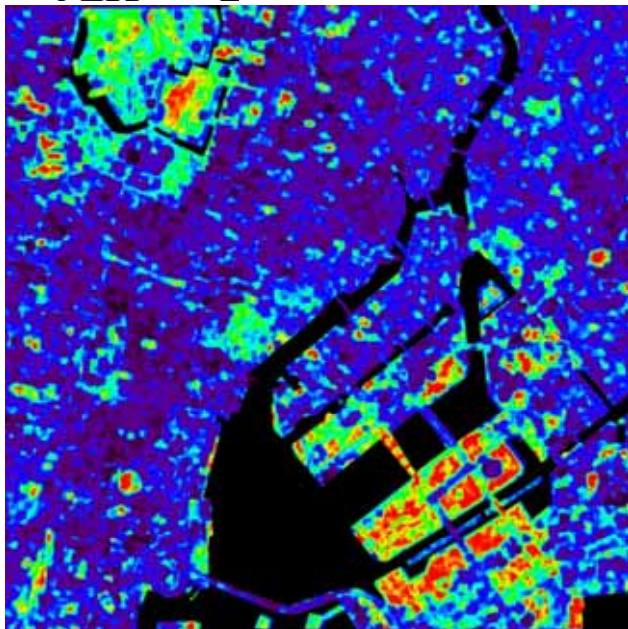
33

Change detection 2



Changes: $r > -0.2$

Filter: 15×15



Results of change detection



New building
Destroyed building
Low correlation

Since high buildings show layover in SAR images, the location of results are at south-eastern of real location.

35

PALSAR



Date: 2009.11.27
Polarimetric: HH
Course: Descending
Resolution: 12.5m
Looks angle: 21.2 °
Wavelength: L-band

•Image is got from GeoGid

36

Radiometric calibration of PALSAR

PALSAR product				
Select Level:	Processing Options:			Output Options:
<input type="radio"/> SSC (Single-look Slant Range Complex) <input type="radio"/> MSA (Multi-look Slant Range Amplitude) <input type="radio"/> MGA (Multi-look Grand Range Amplitude) <input checked="" type="radio"/> MGG (Multi-look Grand Range Geocode) <input type="radio"/> MGO (Multi-look Grand Range Ortho)	Radiometric calibration <input checked="" type="radio"/> None <input type="radio"/> AIST Polarimetric calibration <input type="radio"/> None <input type="radio"/> AIST Unit <input checked="" type="radio"/> Digital Number <input type="radio"/> dB	Map Projection <input type="radio"/> UTM <input checked="" type="radio"/> EQA Pixel Spacing <input checked="" type="radio"/> 12.5 m <input type="radio"/> 15 m <input type="radio"/> 30 m <input type="radio"/> 90 m	Interpolation Method <input type="radio"/> 1/dist <input type="radio"/> Nearest Neighbor <input type="radio"/> SQR (1/dist) <input type="radio"/> Constant <input checked="" type="radio"/> Gaussian	Output Format <input type="radio"/> Flat binary <input checked="" type="radio"/> GeoTIFF Data Type <input checked="" type="radio"/> Float <input type="radio"/> 2 byte Integer Output Directory <input type="text"/>

● Beta Naught ⁰

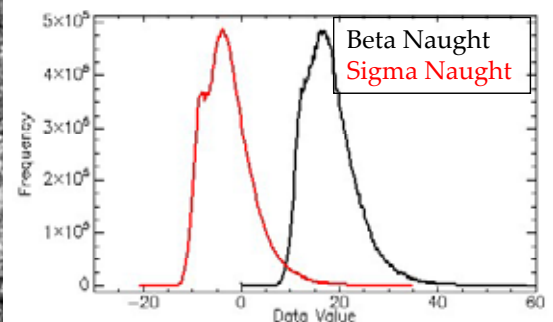
$$\beta^0_{dB} = 10 \cdot \log_{10}(DN^2)$$

● Sigma Naught ⁰

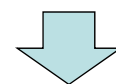
$$\sigma^0_{dB} = \beta^0_{dB} + (-20.76[dB])$$

37

Sigma Naught



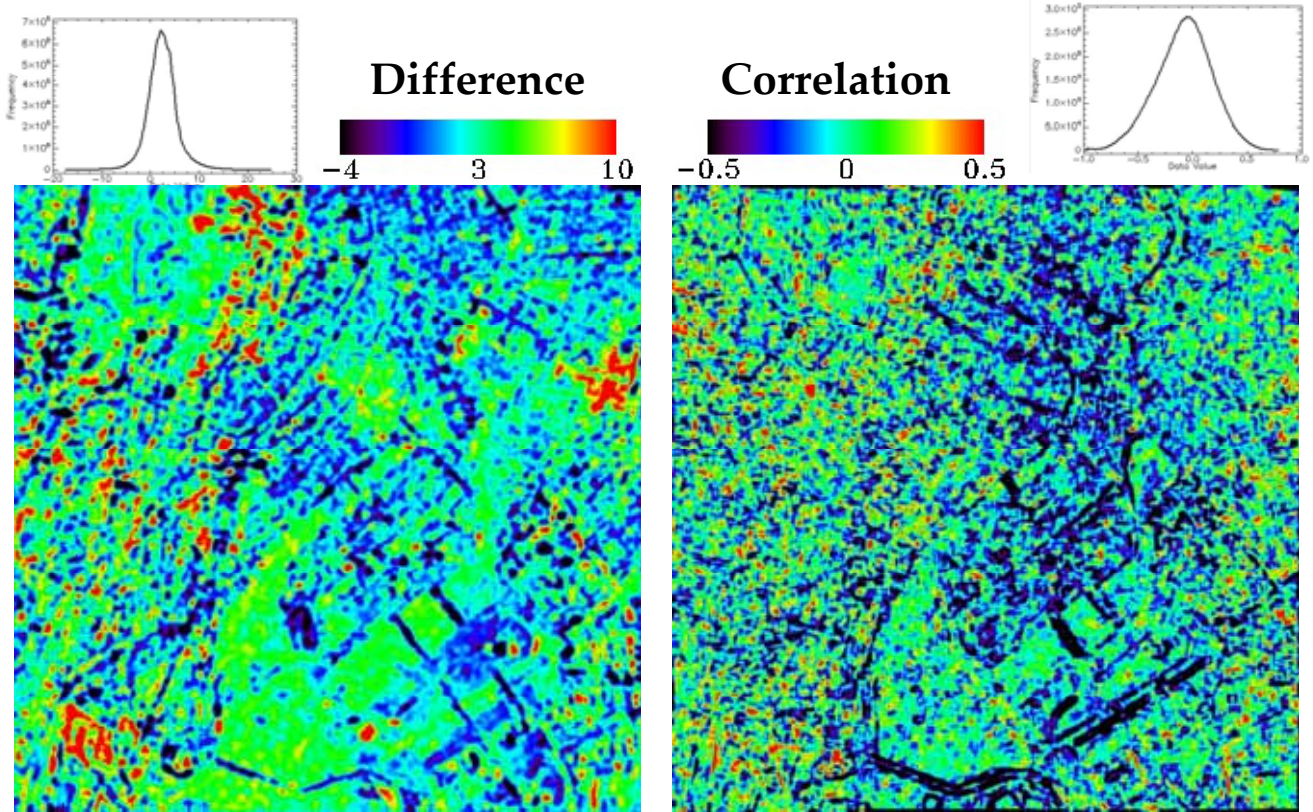
Lee filter: 21 × 21



$$\sigma^0_{dB} = \beta^0_{dB} + (-20.76[dB])$$

38

Difference and correlation between TerraSAR-X and PALSAR



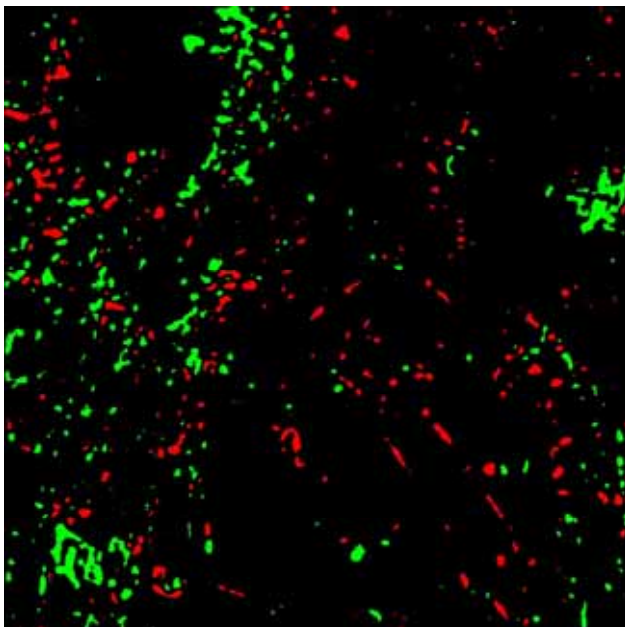
Reflection difference

Mean: 2.5 Stdev: 3.0

No change:

PALSAR dev
TerraSAR-X

- The reflection of bridges are stronger in X-band. And the refraction of big buildings are stronger in L-band.
- The layovers are different because of look angle.



リモートセンシングデータによる 被害検出手法について -建物被害検出手法の標準化へ向けて-

三浦弘之(東京工業大学)

第5回JAEEリモセン委員

主な過去の事例

- 地震(対象;使用したリモセンデータ)
- 1993年北海道南西沖地震(津波;SAR)
- 1995年兵庫県南部地震(建物;SAR, 光学)
- 2003年イラン・バム地震(建物;SAR, 光学)
- 2003年アルジェリア地震(建物;光学)
- 2004年新潟県中越地震(建物, 斜面崩壊;SAR, 光学)
- 2004年スマトラ島沖地震(津波;SAR, 光学)
- 2006年インドネシア・ジャワ島中部地震(建物;光学)
- 2007年新潟県中越沖地震(建物;光学)
- 2007年ペルー・ピスコ地震(建物;光学)
- 2008年岩手・宮城内陸地震(斜面崩壊;SAR, 光学)
- 2008年中国四川地震(建物;SAR, 光学)
- 2010年ハイチ地震(建物;SAR, 光学)
- 2010年チリ・マウレ地震(建物;SAR, 光学)

画像処理による建物被害検出手法

著者名	対象地震	使用した画像	解析方法	長所
松岡・山崎	1995年兵庫県南部など	前後, SAR	後方散乱強度の差分と相関を利用	雲の影響を受けないため, アーカイブがあれば迅速な検出が可能
小杉・他	1995年兵庫県南部など	前後, 光学	輝度やテクスチャの非線形写像法によるマッチング	異なる撮影角度の高分解能画像にも適用可能
三富・他 Thuy et al.	1995年兵庫県南部など	後, 光学	エッジ強度のテクスチャを利用	地震後画像のみで適用可能
Rathje et al.	2003年イラン・バム	後, 光学	DNのテクスチャを利用	地震後画像のみで適用可能
Huyck et al.	2003年イラン・バム	前後, 光学	エッジ強度のテクスチャを利用	異なるセンサの画像間でも適用可能
Kohiyama et al.	2003年イラン・バム	前後, 光学	複数の地震前画像からDNのパラッキを評価した上で, 変化抽出	地震後に顕著に変化した地域を検出可能
三浦・翠川	2006年ジャワ島中部	前後, 光学	既知領域を除去した上で, DNの差分を利用	撮影条件が同じ画像を利用. 手法が簡便

衛星画像による被害把握

