# 3-1

## 題名（和文）：先端リモートセンシング技術・地殻変動観測用長期間継続的差分干渉合成開口レーダの開発

## 題名（英文）：**Development of Advance Remote Sensed Technology and Long-term Consecutive DInSAR for Land Deformation Monitoring**

著者（和文）：ヨサファット テトォコ スリ スマンティヨ・ルフル バユアジ（千葉大）

著者（英文）：Josaphat Tetuko SRI SUMANTYO, Luhur BAYUAJI (Chiba Univ.)

図. 1. 当研究室で開発されている CP-SAR 搭載小型衛星と無人航空機 JX-1

要旨.

合成開口レーダ（SAR）が昼夜また全天候型センサの地球表面観測用のセンサである。本研究室では、現在地球表面における物理情報を観測するために、新型マイクロ波センサである円偏波合成開口レーダ（CP-SAR）搭載の無人航空機と小型衛星を開発している（図1）。この円偏波または楕円偏波情報より軸比画像、楕円率画像、チルト角画像など、様々な新たな SAR 画像を抽出できる。またこのセンサが電離層におけるファラデー回転の影響を軽減できると期待する。

SAR センサの応用研究では、近年、東京都をはじめ、ジャカルタ市などにおける地表面の沈下、地下水面の深化など、様々な都市問題が発生した。図 2 と図 3 はジャカルタ市内における地盤沈下による被害の様子を示す。この地盤沈下の原因として、都市開発、地下水の大量使用などである。この現象が長期間にわたって微少変化しているので、本研究では長期間継続的な差分干渉合成開口レーダ（DInSAR）手法を使用して、主に東京都とジャカルタ市における地盤沈下の把握を高精度かつ広域観測を行った。今まで、本研究室では TerraSAR-X、Envisat ASAR、ERS-1/2 SAR、JERS-1 SAR、ALOS PALSAR データを使用して、東南アジアと東アジア地域における大都会における地殻変動の観測を行っており、特に、ここで大都会における地盤沈下に注目をした。これによって、現地における住宅レベルまでの被害地図を把握し、地盤沈下による体積変化の抽出もできた。

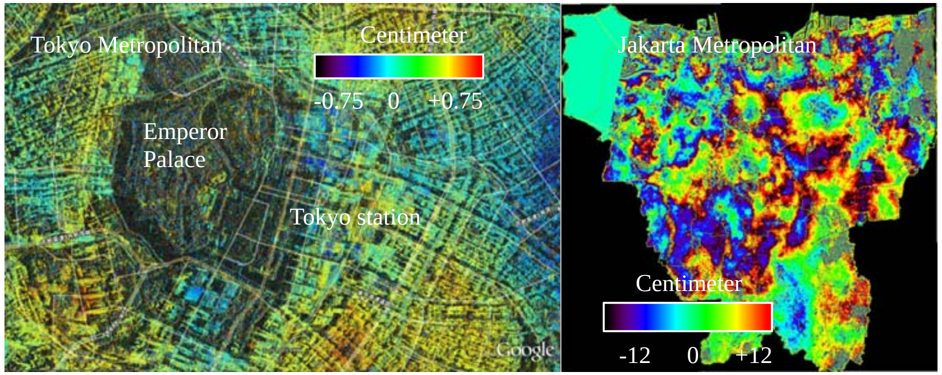
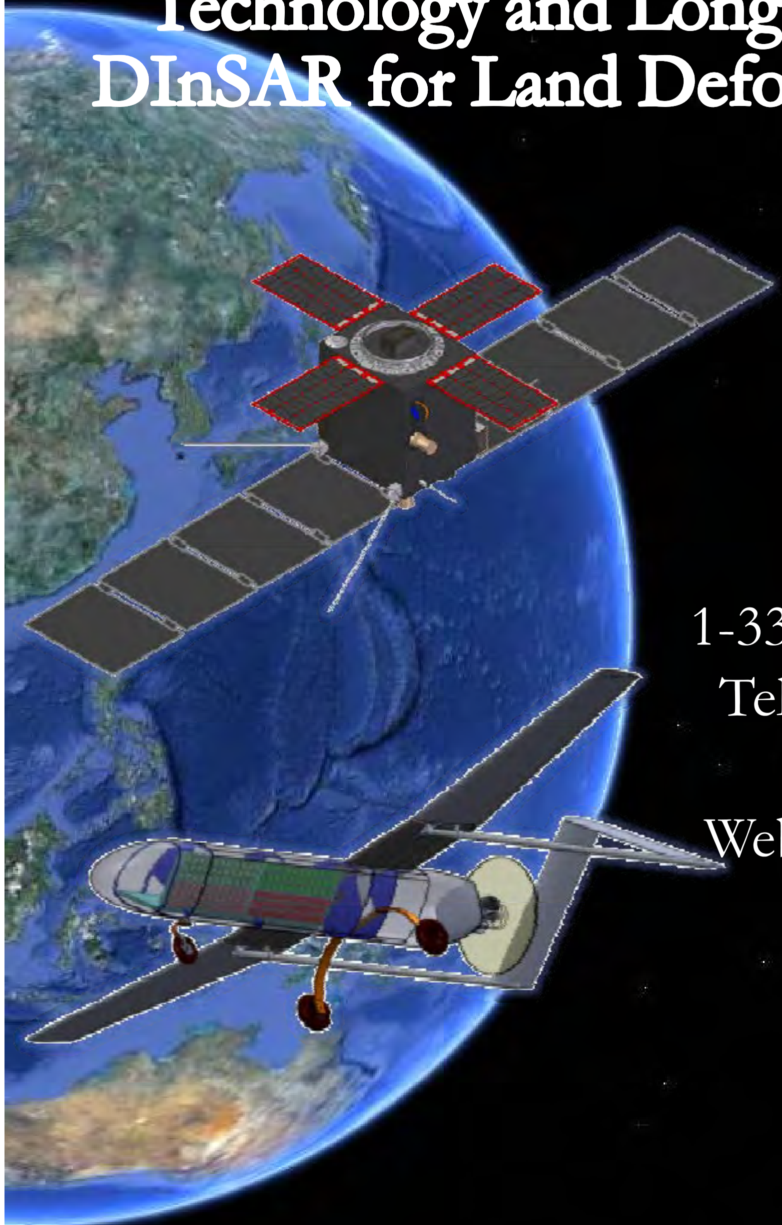



図 2. TerraSAR-X による東京都とジャカルタ市内における地盤沈下の観測

図 3. ジャカルタ市内における地盤沈下の被害状況：(左) Kapuk Dalam 通りの大洪水、(中) Mangga dua 地域に地盤沈下、（右）Ancol 市に崩落した高速道路

# Development of Advance Remote Sensed Technology and Long-term Consecutive DInSAR for Land Deformation Monitoring



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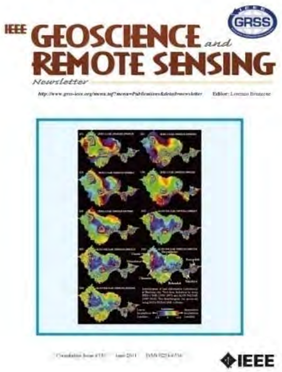
Josaphat Microwave Remote Sensing Laboratory
Center for Environmental Remote Sensing, Chiba University

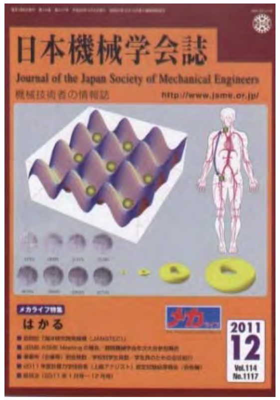
# Contents :

- Background and Objectives
- Introduction of Josaphat Laboratory Research Activity
- Synthetic Aperture Radar onboard Microsatellite Development
- Josaphat Laboratory Experimental Unmanned Aerial Vehicle (JX-1)
- Application of Synthetic Aperture Radar Image Processing (DInSAR) :
  - Volume estimation of eruption of Merapi Volcano
  - Subsidence of Bandung city
  - Subsidence of Jakarta Megapolitan
  - Subsidence of Tokyo Megapolitan
  - Active fault of Kualalumpur
- Summary & Future Research

Articles related CP-SAR UAV and Microsatellite :




IEEE GRS Newsletter Issue June 2011







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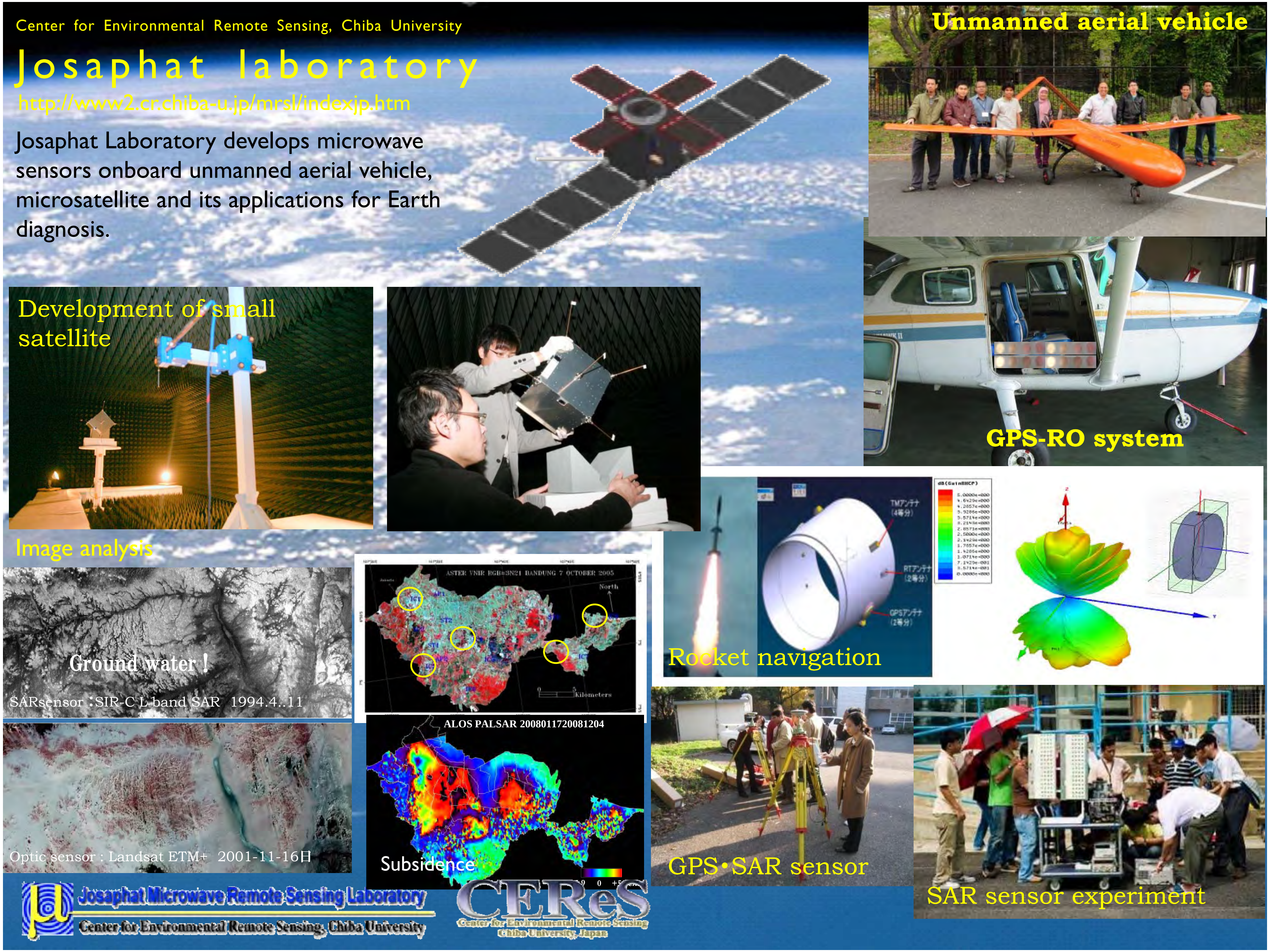
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Josaphat laboratory
http://www2.cr.chiba-u.jp/mrsl/indexjp.htm
Josaphat Laboratory develops microwave sensors onboard unmanned aerial vehicle, microsatellite and its applications for Earth diagnosis.
Unmanned aerial vehicle
GPS-RO system
Development of small satellite
Image analysis
Ground water !
SARsensor：SIR-C L-band SAR 1994.4..11
Optic sensor : Landsat ETM+ 2001-11-16日
ASTER VNIR RGB=3N21 BANDUNG 7 OCTOBER 2005
ALOS PALSAR 2008011720081204
Subsidence
Rocket navigation
GPS•SAR sensor
SAR sensor experiment
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## Background

- Increasing full-polarimetric spaceborne SAR demand in the world.
- Circular Polarizations are effective for ionospheric Faraday rotation correction in low frequency (i.e. P band, L band) of spaceborne SAR data and some applications of Earth observation.
- Lack of SAR onboard microsatellite developers in the world, expecially Asia-Pacific region.
- Little of University's laboratory that has knowledge to design, manufacture, measure, operate and implement the spaceborne SAR.

## Objectives

- Propose a L band full polarimetric spaceborne SAR using Circularly Polarization to reduce the ionosphereic Faraday rotation and new image types for Earth observation.
- Promoting one stop spaceborne SAR laboratory in University for research and education focused on microwave remote sensing technology.


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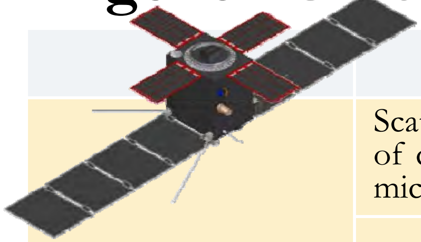
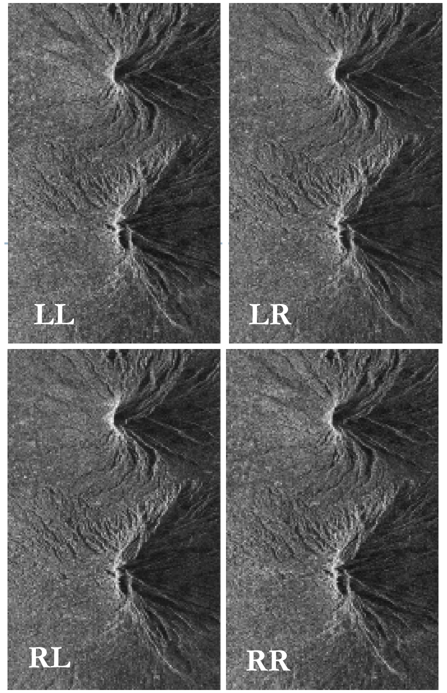
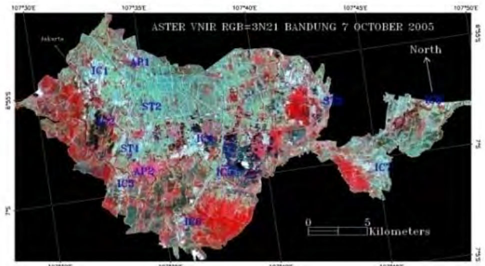
# Target of CP-SAR onboard Microsatellite Mission

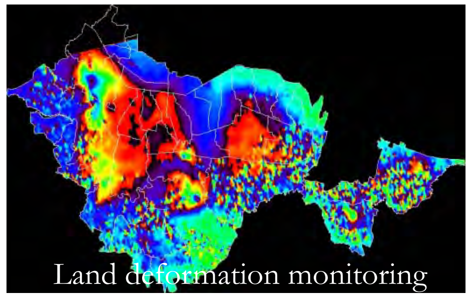


| | Items | Details |
|---|---|---|
| **Basic experiment** | Scattering mechanism of circularly polarized microwave | Scattering mechanism from vegetations, cryosphere, soil and rocks, desert etc |
| | Interferometry | • Linear vs Circular Polarization Interferometry SAR<br>• DEM extraction by CP wave |
| | Axial ratio image (ARI) | Vegetation, geologic, cryosphere etc mapping by using ARI |
| **Applications** | Landcover mapping | • Forest – non forest area classification<br>• Tree height estimation<br>• Paddy field extraction<br>• Wetland extraction<br>• Mangrove area mapping<br>• Snow – ice berg detection |
| | Disaster monitoring | Earthquake, volcano eruption, flood, forest fire etc |
| | Cryosphere monitoring | Ice berg, glacier, artic route etc |
| | Ocean monitoring | Oil spill, ocean wave etc |




Circular Polarimetric SAR





Differential Interferometric SAR

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# Josaphat Laboratory Experimental Unmanned Aerial Vehicle (JX-1)

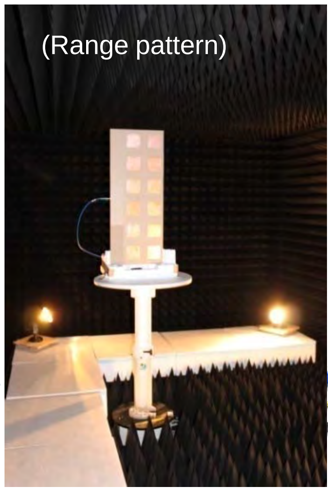
## Weight of JX-1 Parts

| Items | Weight |
|---|---|
| Main body (including battery, tank etc) | 48.0 |
| Centre / main wing 1 unit | 16.0 |
| Wing (2 unit x @ 10 kg) | 20.0 |
| Ladder (2 unit x @ 7 kg) | 14.0 |
| Other instrument (bow etc) | 7.5 |
| Gasoline (20 liters) | 16.0 |
| Payload (CP-SAR, camera etc) | 25.0 |
| Total | 146.5 |

**IMU : IMU440**
76 x 95 x 64 mm 540 gr

| Parameters | Specification |
|---|---|
| Altitude | 1 ～ 4 km |
| Central frequency (CP-SAR sensor) | 1.27 GHz |
| Pulse width | 3.9 ～ 23.87 μs |
| Pulse bandwidth | 16.04 ～ 245.89 MHz |
| Polarizations | RHCP+LHCP |
| Off nadir angle | 40° ～ 60° |
| Resolution | 1 ～ 10 m |
| Observation width | 10 km |
| Antenna size | 0.75 m x 0.4 m x 4 panels |
| Azimuth beamwidth | 7.94° |
| Range beamwidth | 29.78° |
| Antenna efficiency | 80% |
| PRF | 1,000 Hz |
| Peak power | 5.27 ～ 17.46 W |
| Average power | 20.59 ～ 416.62 mW |
| SNR | 15 dB |
| Observation time | 2.81 ～31.70 minutes |
| Payload | 25 kg |

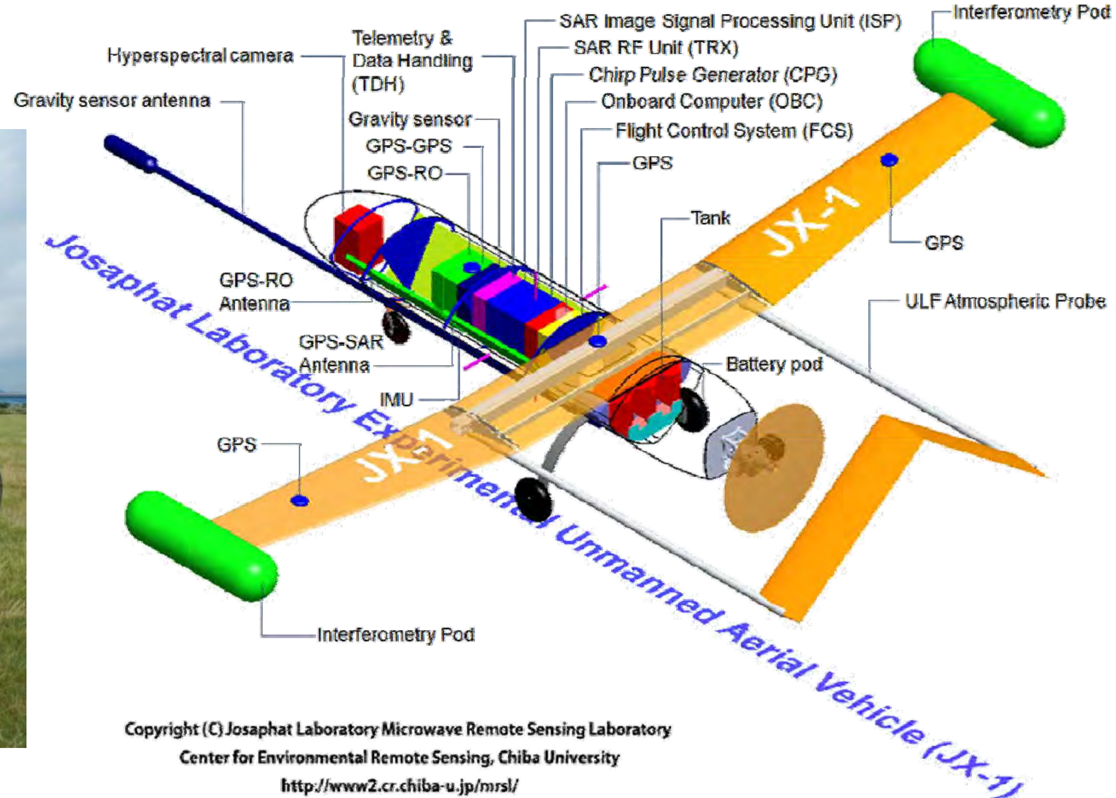

Patch array antenna for CP-SAR system at Josaphat Laboratory Anechoic Chamber (Azimuth pattern)


(Range pattern)

Josaphat Laboratory Unmanned Aerial Vehicle Taxing Test at Otone Airport

# Josaphat Laboratory Experimental Unmanned Aerial Vehicle (JX-1)

## Detail Parts



After successful First Flight of Josapat Laboratory Unmanned Aerial Vehicle (JX-1) at Fujikawa Airport on 7 June 2012

http://www.youtube.com/watch?v=o_a7HoMe2cI


First Flight, Fujikawa Airfield, 7 June 2012

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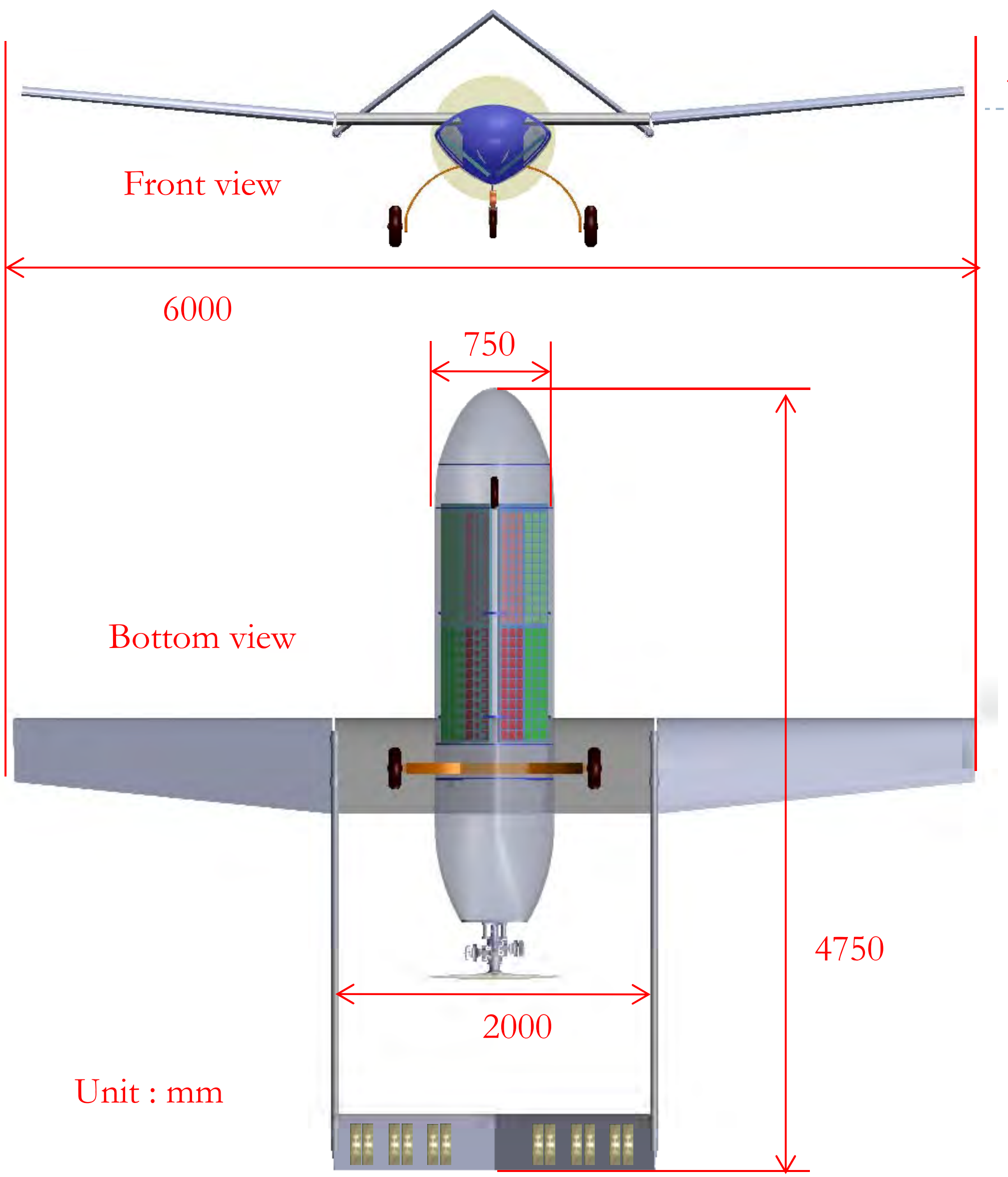
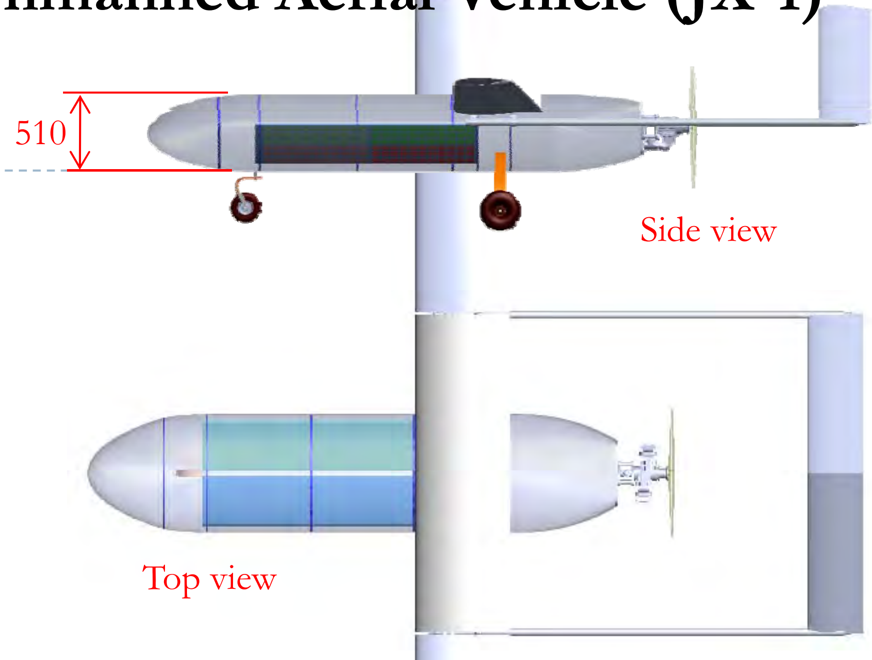
# Josaphat Laboratory Experimental Unmanned Aerial Vehicle (JX-1)

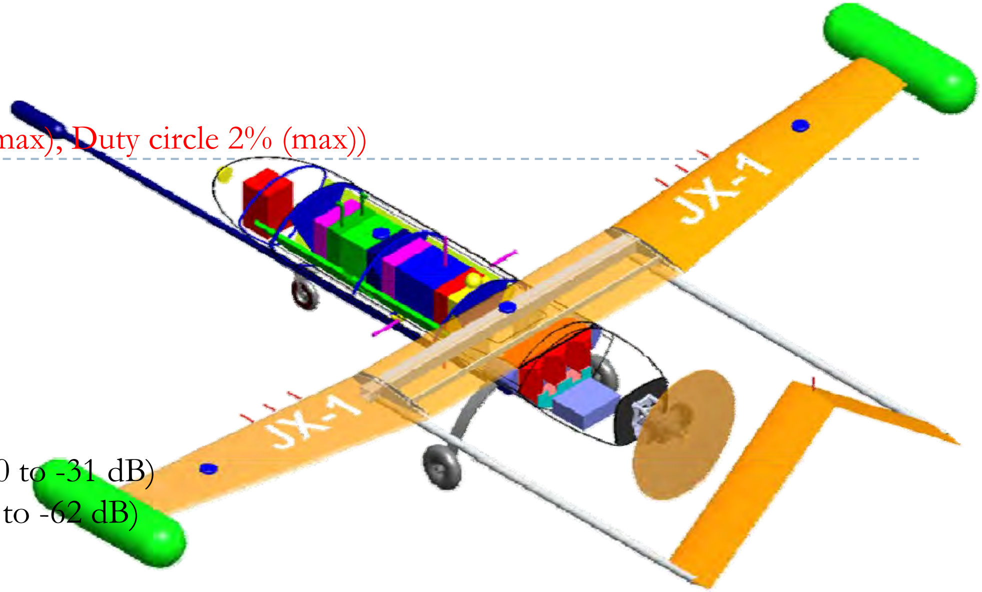


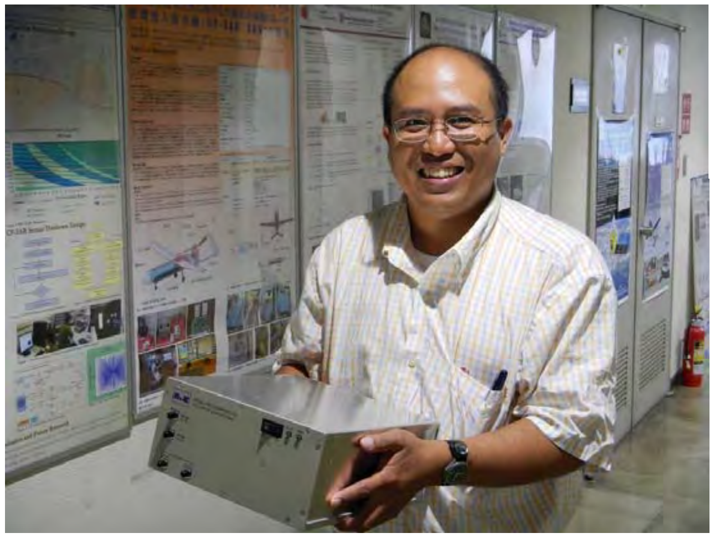




Assembling the Josapat Laboratory Unmanned Aerial Vehicle (JX-1) at Otone Airport for Taxing Test

# CP-SAR Specification for Unmanned Aerial Vehicle

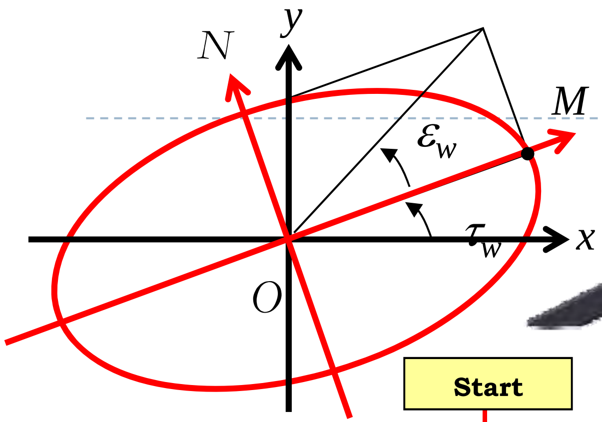
- Transmission frequency range : 1270 MHz ± 150 MHz
- Baseband range : DC to 150 MHz
- Pulse transmission output power : 50 W (Pulse width 10 μs (max), Duty circle 2% (max))
- Transmission system gain : + 47 dB (min)
- Receiver system gain : + 60 dB (min)
- Gain flatness : ± 1.5 dB (max)
- Receiver noise ratio : 3.5 dB (max) @+25°C
- Modulator : (RX and TX) QPSK
- Output higher harmonic wave : -30 dBc (max)
- Output spurious : -60 dBc (max)
- Transmission system gain tuning function : 1/2/3/8/16 dB (0 to -31 dB)
- Receiver system gain tuning function : 1/2/3/8/16 dB x 2 (0 to -62 dB)
- Impedance : 50 Ω
- Transmission system output VSWR : 1.5 : 1 (typ.)
- Receiver system input VSWR : 1.5 : 1 (typ)
- Transmission system antenna switching speed : 1μs (typ.) / 2 μs (max)
- Receiver system antenna switching speed : 1μs (typ.) / 2 μs (max)
- Transmission system On/Off speed : 100 ns (max)
- Receiver system On/Off speed : 100 ns (max)
- Power voltage : DC +28 V (DC +25 to + 35 V switchable)
- Current consumption : 5A (max)
- Temperature : +0°C to 45°C
- Saving temperature : -20°C to 80°C
- RF connector : SMA-Female
- Power connector : N/MS3102A10SL-3P
- Control connector : D-Sub-37P
- Weight : 10 kg (max)
- Size : W 250mm x H 100mm x D 300mm

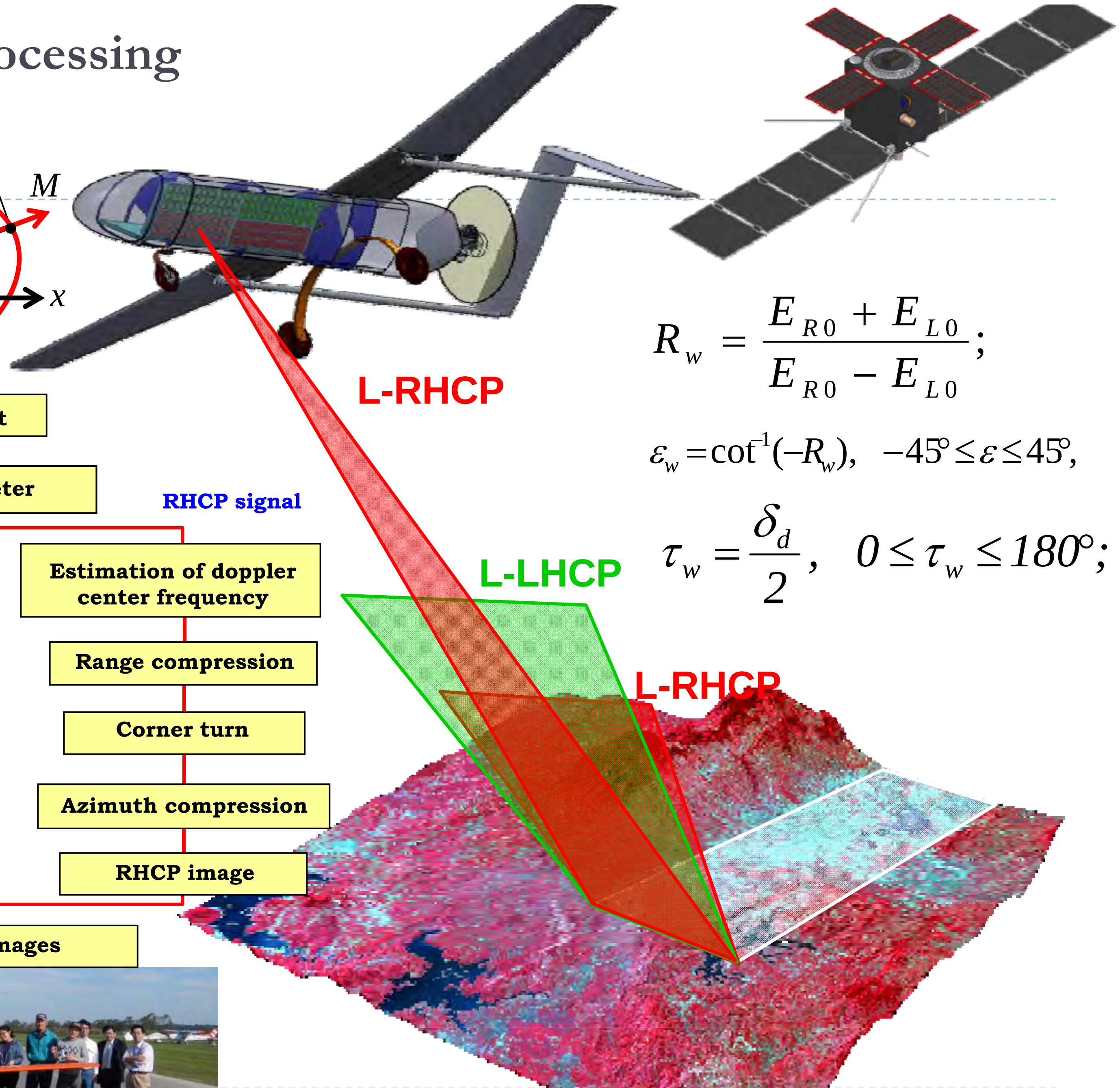


Compact L Band SAR System developed by Josaphat Laboratory

# CP-SAR Image Processing

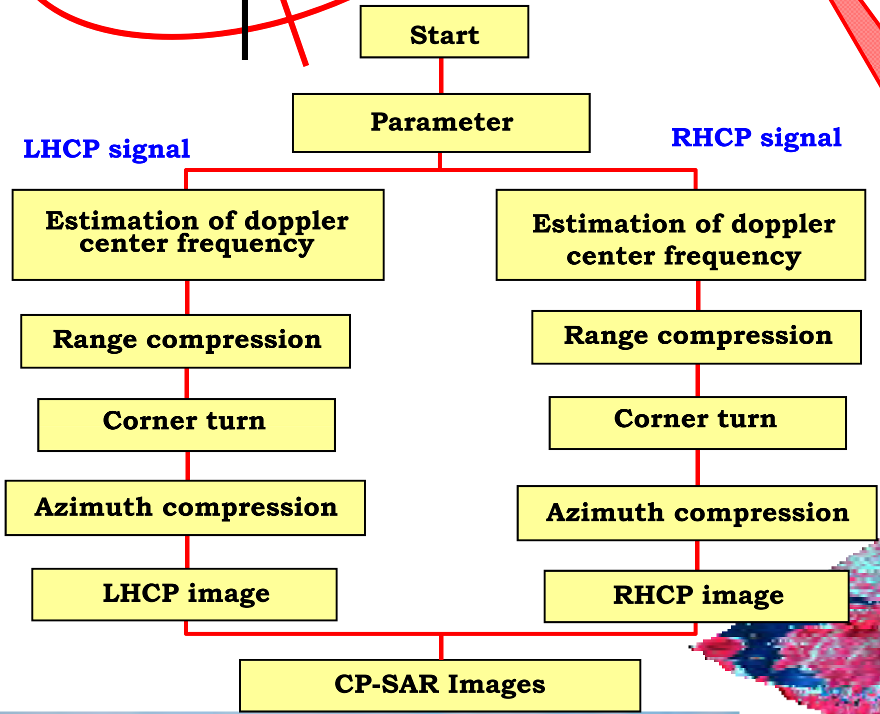



$$R_w = \frac{E_{R0} + E_{L0}}{E_{R0} - E_{L0}};$$

$$\varepsilon_w = \cot^{-1}(-R_w), \quad -45^\circ \le \varepsilon \le 45^\circ,$$

$$\tau_w = \frac{\delta_d}{2}, \quad 0 \le \tau_w \le 180^\circ;$$

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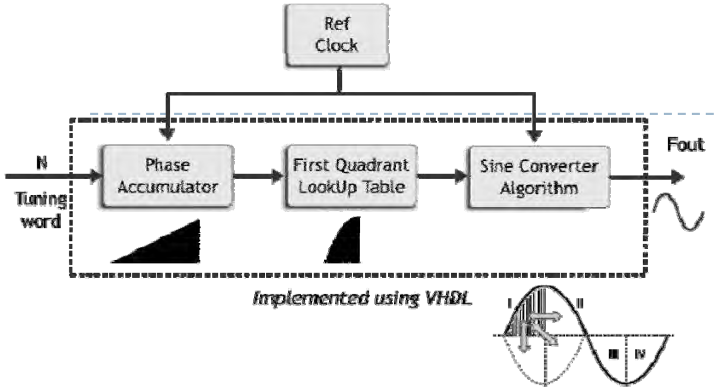
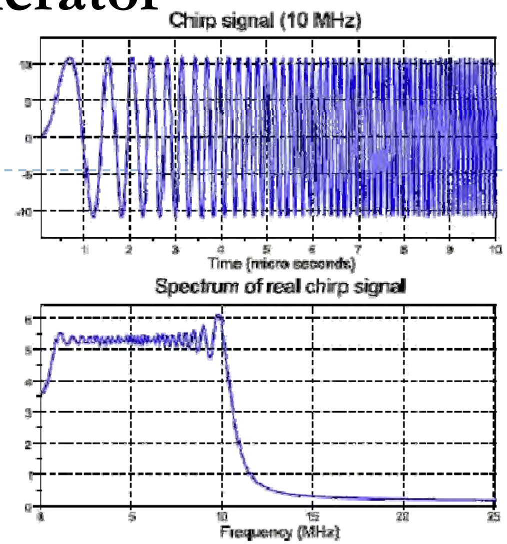
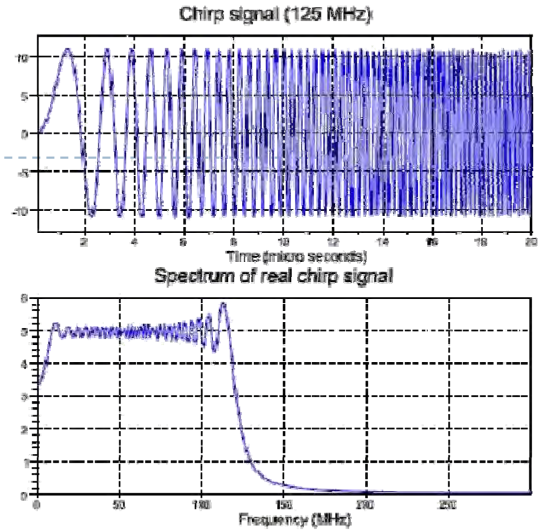
# CP-SAR : Chirp Pulse Generator

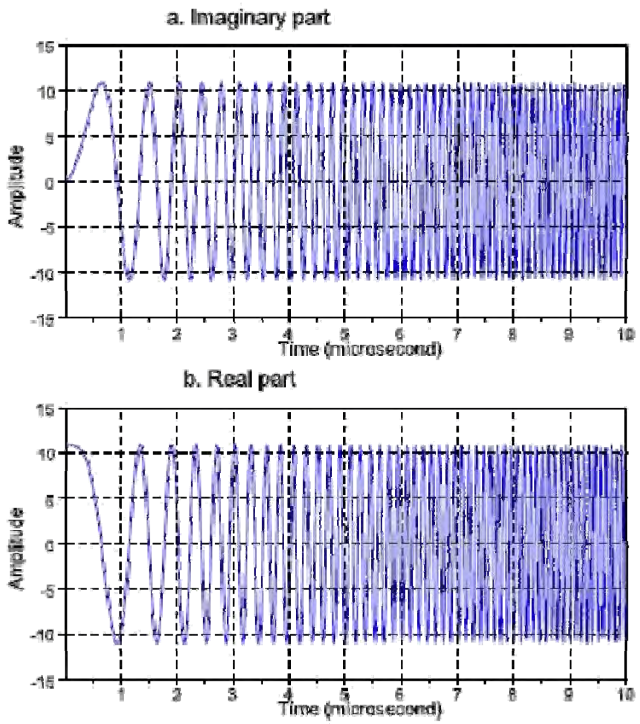



Microsatellite




Unmanned aerial vehicle



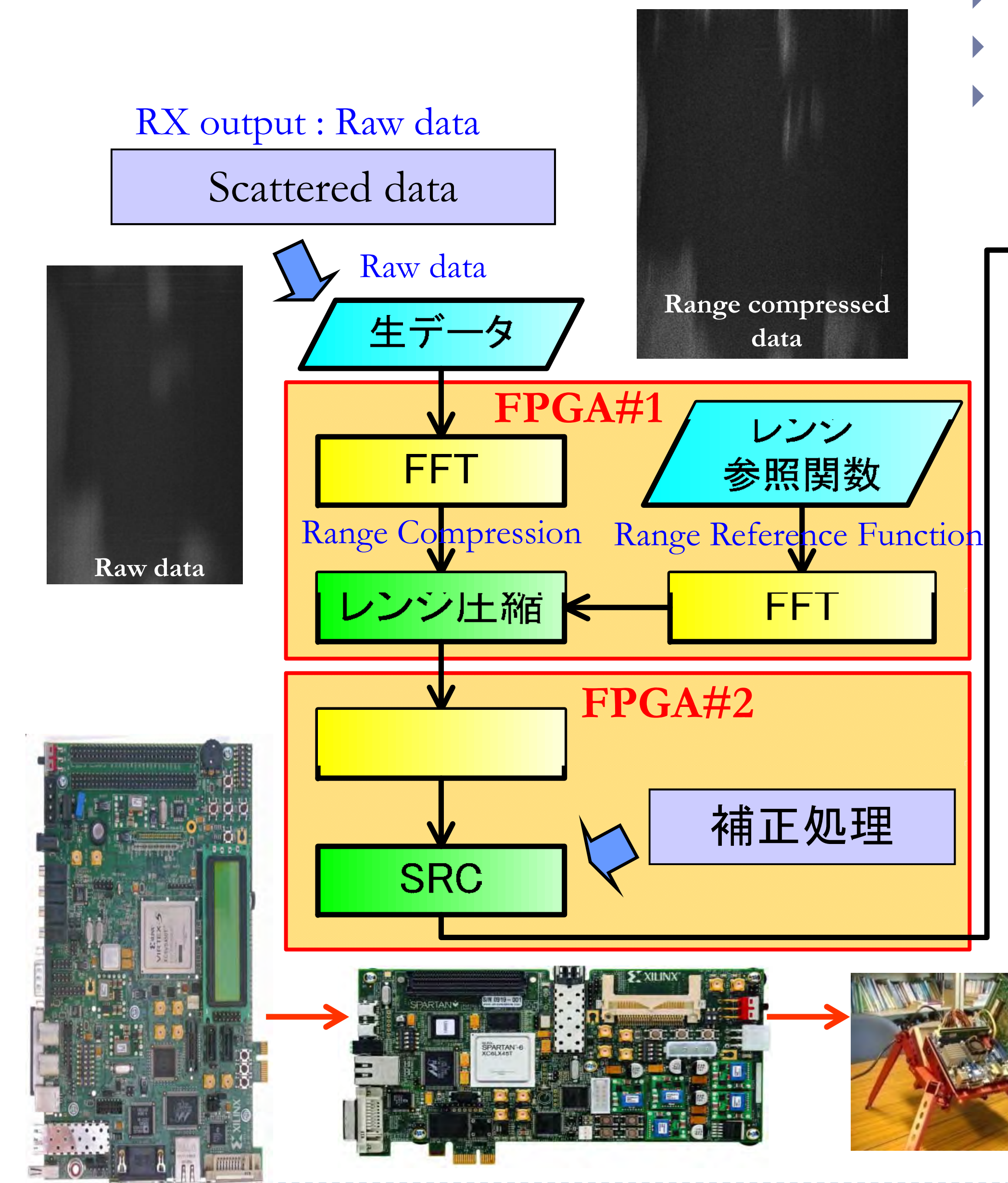



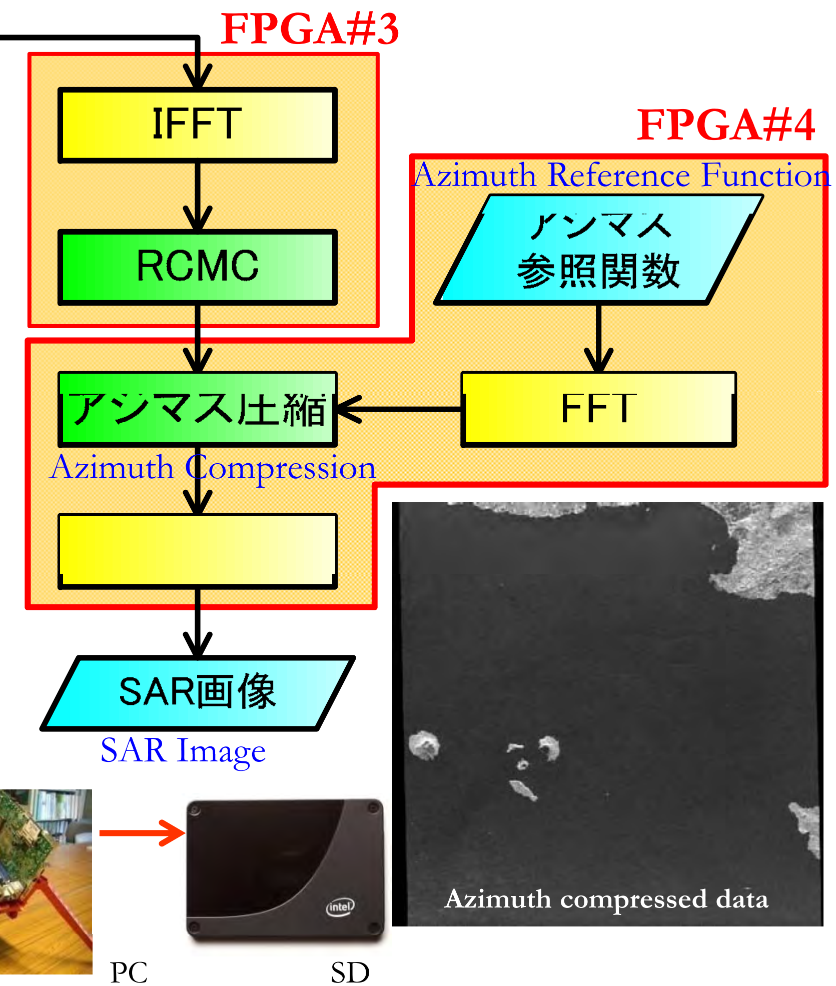

Quadrature (Q) → TX Input

Inphase (I) → TX Input

# CP-SAR Image Processing

- SAR Signal Processing using FPGA
- Compressed data is saved in SSD
- High speed data transfer from FPGA to SSD



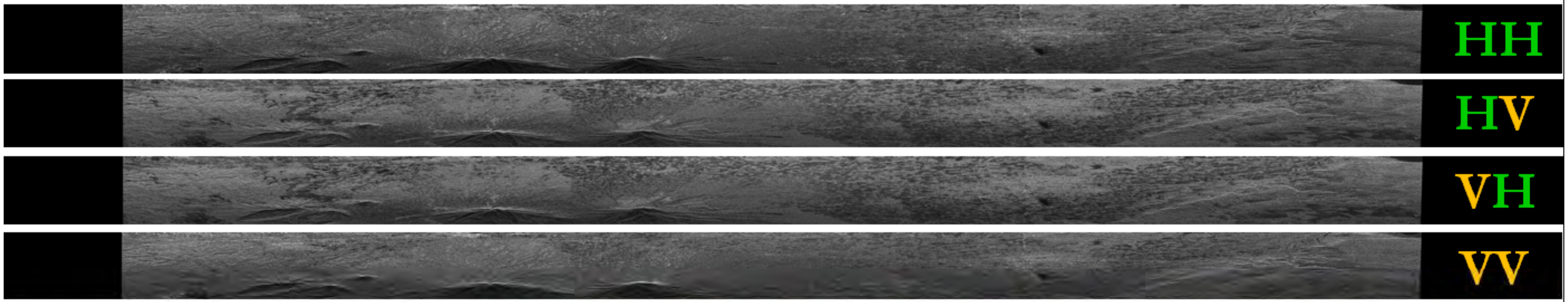

Xilinx FPGA Virtex-5 SX50 ML506 (4 units)

Xilinx SP605 FPGA 2.5 Gbps

# CP-SAR Image Processing : Single Look Complex

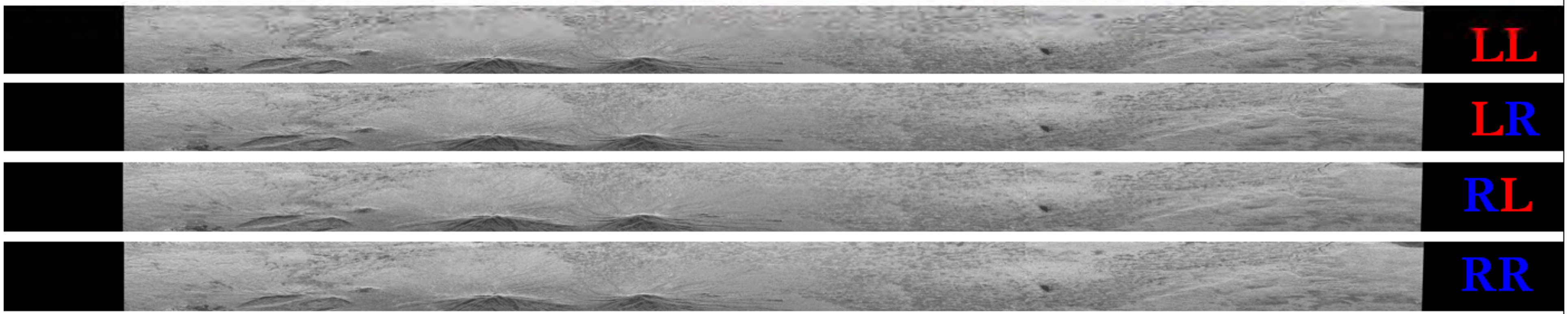
## Linear Polarization

H : Horizontal Polarization V : Vertical Polarization




## Circular Polarization

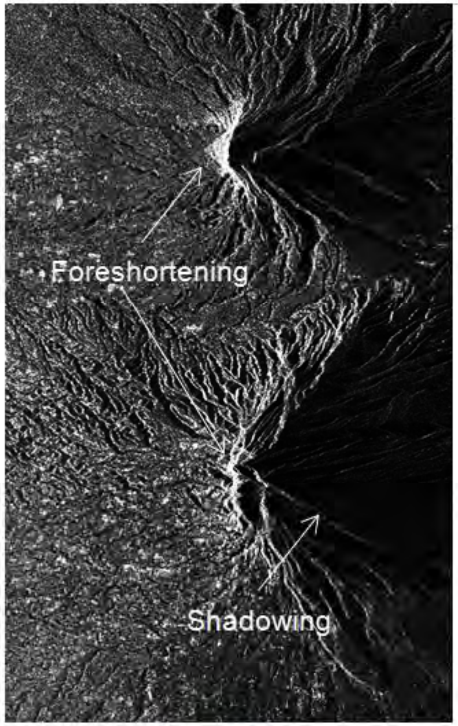
L : Left Handed Circular Polarization R : Right Handed Circular Polarization




Merapi and Merbabu mountain, Java Island, Indonesia
Acquisition date : June 2009
Raw data : ALOS PALSAR : AIST – ERSDAC Format
Simulated by Josaphat Laboratory

# CP-SAR Image Processing (Linear vs Circular Polarized Images)

## Linear Polarization




HH

HV

VH

VV

**H : Horizontal Polarization** **V : Vertical Polarization**

Merapi and Merbabu mountain, Java Island, Indonesia

Acquisition date : June 2009

Raw data : ALOS PALSAR : AIST – ERSDAC Format

Simulated by Josaphat Laboratory

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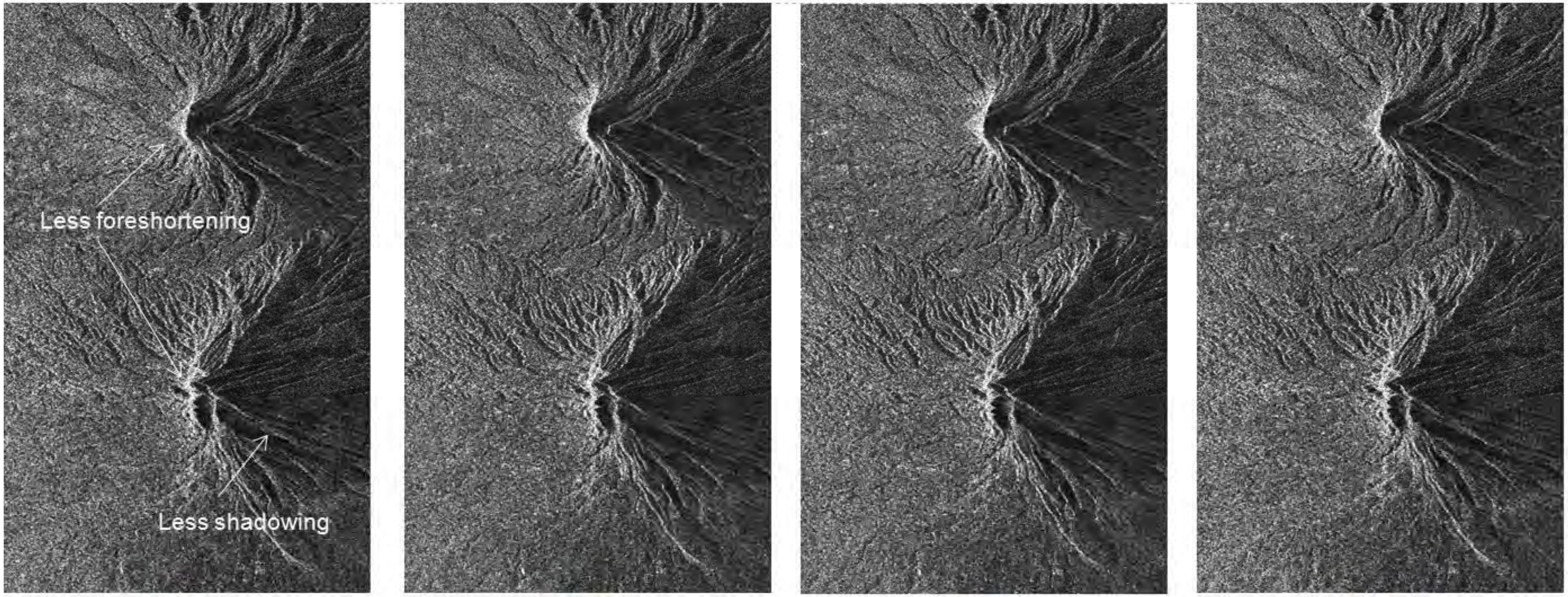
# CP-SAR Image Processing (Linear vs Circular Polarized Images)

## Circular Polarization (Simulated)




**LL** **LR** **RL** **RR**

L : Left Handed Circular Polarization R : Right Handed Circular Polarization

Merapi and Merbabu mountain, Java Island, Indonesia

Acquisition date : June 2009

Raw data : ALOS PALSAR : AIST – ERSDAC Format

Simulated by Josaphat Laboratory

# DInSAR Technique for Retrieving The Volume Estimation of Volcanic Materials Erupted by Merapi Volcano


NASA MODIS 13 November 2010

Josaphat Tetuko Sri Sumantyo, Masanobu Shimada, Pierre-Philippe Mathieu, Junun Sartohadi, Ratih Fitria Putri, "DINSAR TECHNIQUE FOR RETRIEVING THE VOLUME OF VOLCANIC MATERIALS ERUPTED BY MERAPI VOLCANO", Dynamics of Earth Processes and Climate Change: Geosphere Session, TU1.14: DInSAR Applications, Tuesday, July 24, IEEE International Geoscience and Remote Sensing Symposium, 22-27 July 2012 (Munich : Germany)


*Josaphat Tetuko Sri Sumantyo[1], Member, IEEE, Masanobu Shimada[2], Fellow, IEEE, Pierre-Phillippe Mathieu[3], Junun Sartohadi[4], and Ratih Fitria Putri[4]*

1) Chiba University, Japan 2) JAXA, Japan 3) ESA, Italy 4) Gadjah Mada University, Indonesia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# Background

Mt. Merapi, Indonesia erupted on October 26 and November 4-5, 2010. These eruptions killed 94 people and 218 lost, and destroyed Magelang, Boyolali, Klaten and Sleman districs with estimated damage and losses about 4.23 trillion rupiah or 5,288 billion USD.

Need to retrieve the damage area accurately

# Objective

- Employing the DInSAR technique to retrieve the damage area (Indonesia : 129 active volcanoes)
- Assessment of L band Spaceborne ALOS PALSAR to estimate thickness and volume of volcanic material (sand, rock and ash) and damage area in the study area.

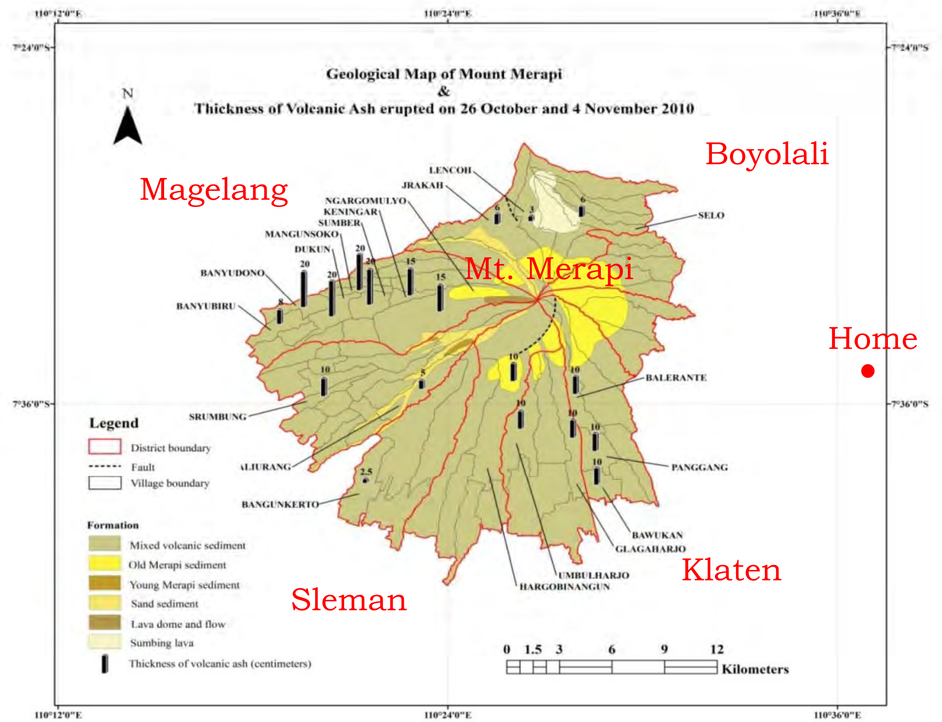

Ground survey photographs

# Study Area : Mt. Merapi, Central Java, Indonesia

- Location :

  Mt. Merapi is located on boundary of Central Java province and Yogyakarta provinces, Indonesia. This area is covered by Magelang, Boyolali, Klaten and Sleman districts.
- Geographical position :

  7° 32’ 21” S, 110° 27’00” E
- Elevation : about 2,900 m asl
- Mt. Merapi has large eruption about 68 times since 1548.

# Study Area : Mt. Merapi eruption on 4-5 November 2010

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# Study Area : Mt. Merapi eruption MODIS data



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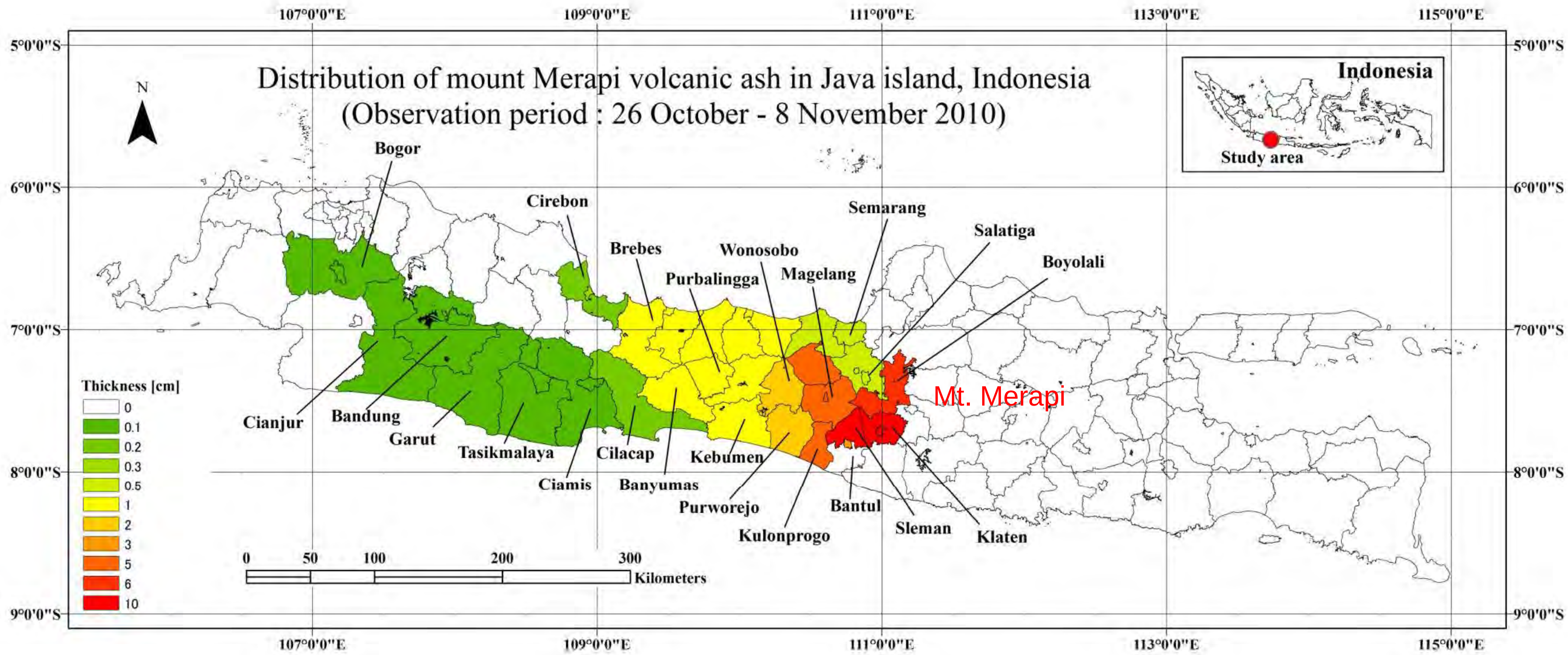
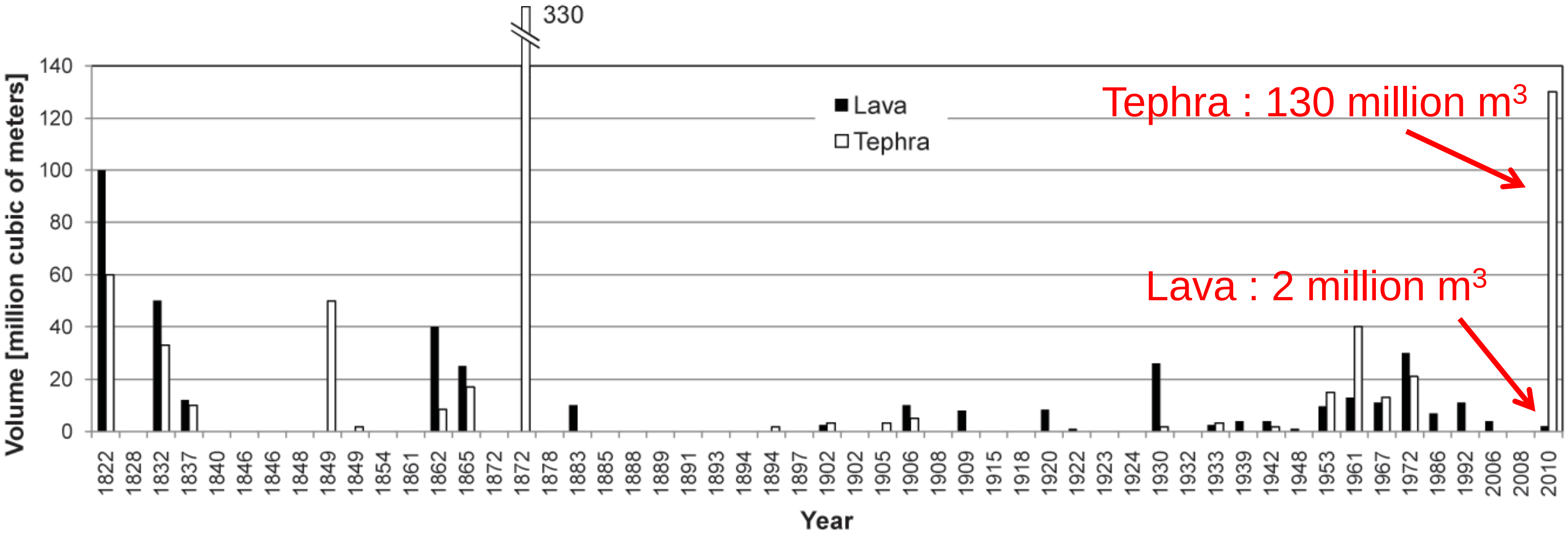
# Study Area :
# Ground data - Mt. Merapi Volcanic Ash Distribution




Ground data (volcanic ash thickness) is collected and analyzed by Josaphat Tetuko Sri Sumantyo –
Center for Environmental Remote Sensing (CEReS), Chiba University

# Volume of volcanic sediment (lava) and erupted volcanic ash (tephra) of Mount Merapi since 1822 to 2010




Modified source :

Global Volcanism Program, Smithsonian National Museum of Natural History

http://www.volcano.si.edu/world/volcano.cfm?vnum=0603-25=&volpage=erupt (accessed 17 July 2011)

# Study Area :
# Ground data - Mt. Merapi Hot Lava Flow



# Study Area :
# Area destroyed by Mt. Merapi Hot Lava Flow

Simo, Boyolali

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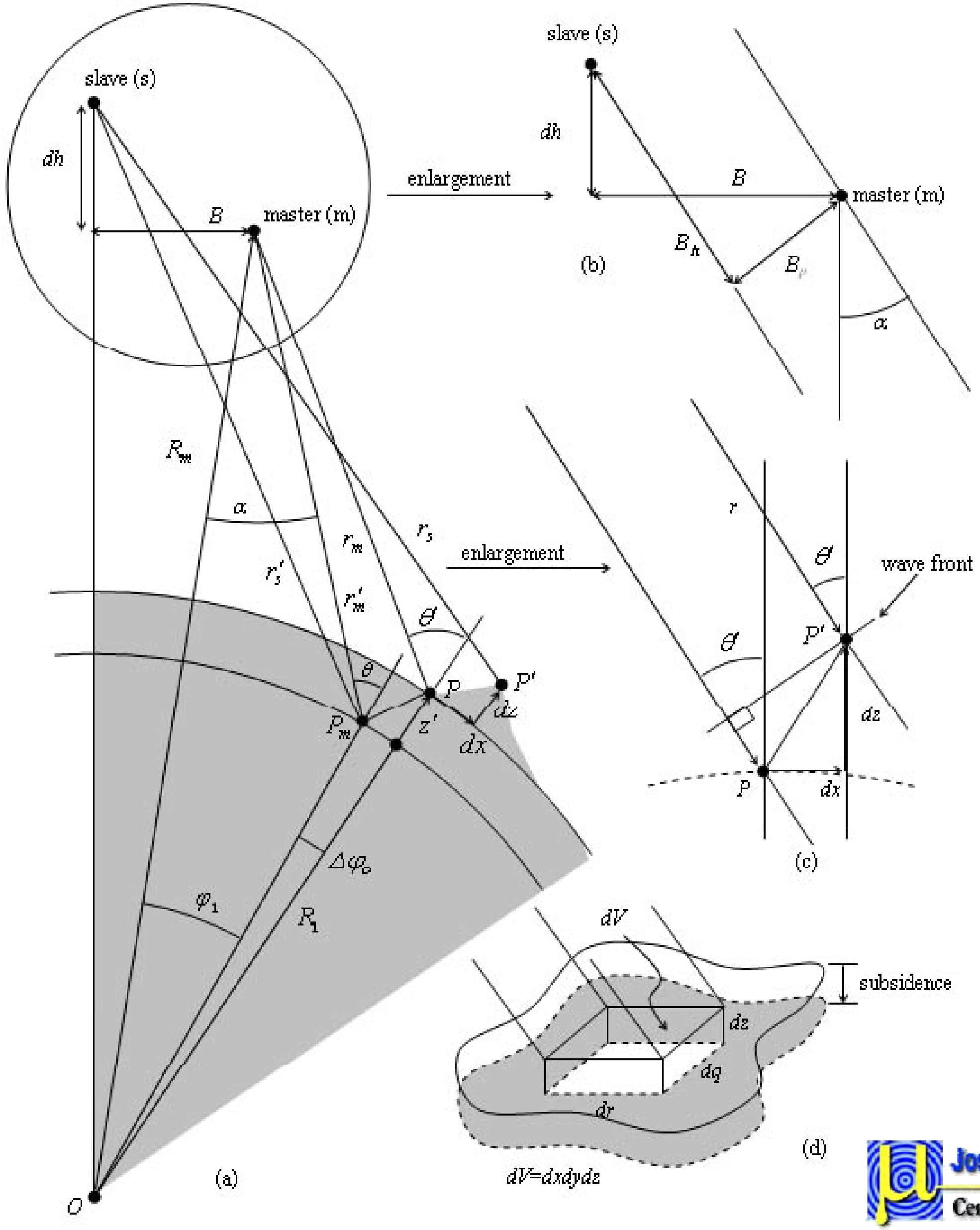
Chiba University, Japan

# Study Area :
# Area destroyed by Mt. Merapi Hot Lava Flow

# Differential Interferometric SAR (DInSAR) Technique




Phase difference $\phi$ :

$$\phi = -\frac{4\pi}{\lambda}\left(r_m - r_s\right)$$

$$= -\frac{4\pi}{\lambda}\left(r_s' - r_s\right) + \frac{4\pi}{\lambda}\left(r_m' - r_s'\right)$$

$$\cong -\frac{4\pi}{\lambda}\left(\frac{z' B_p}{r_m \sin\theta} + dc_{i,j} - B_h\right)$$

where

$$B_h = B \cdot \sin\alpha + dh \cdot \cos\alpha$$

$$B_p = B \cdot \cos\alpha - dh \cdot \sin\alpha$$

$$dc_{i,j} = -dz_{i,j} \cdot \cos\theta + dx_{i,j} \cdot \sin\theta$$

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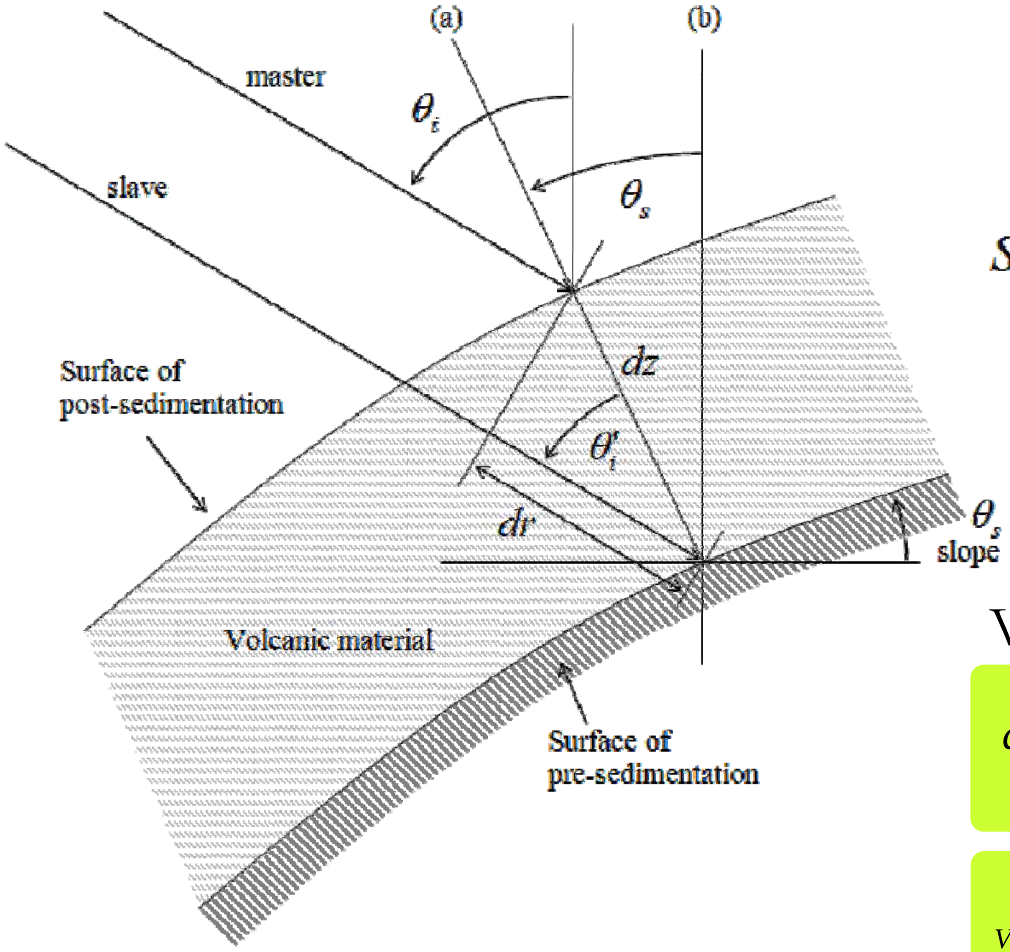
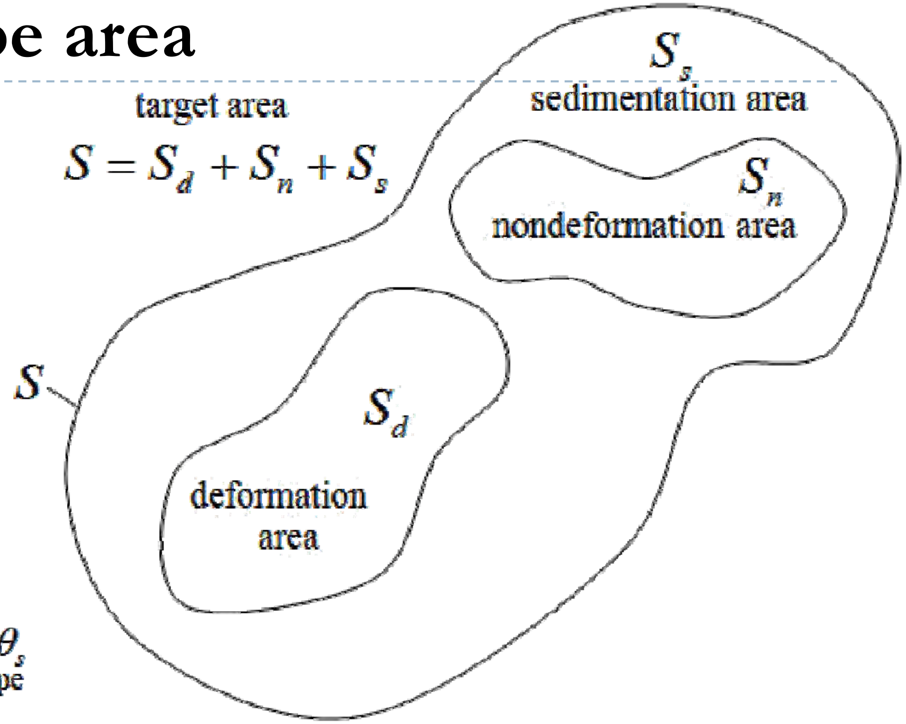
CEReS Center for Environmental Remote Sensing Chiba University, Japan

# Estimation model of thickness and volume change of volcanic material on slope area




target area

$$S = S_d + S_n + S_s$$




Vertical change / deformation :

$$dz = \frac{dr}{\cos(\theta_i - \theta_s)} = \frac{\lambda}{4\cos(\theta_i - \theta_s)/\pi} d\phi$$

$$V_{total} = \int_S dz\, dS \quad \begin{cases} dz < 0 & \rightarrow \text{Deformation} \\ dz = 0 & \rightarrow \text{Non deformation} \\ dz > 0 & \rightarrow \text{Sedimentation} \end{cases}$$

Digital Elevation Model :

Digital topographic Maps of Indonesia 1:25,000, Bakosurtanal, 2000

# Satellite Imageries : ALOS PALSAR

TABLE.  ALOS PALSAR Imageries employed in This Study

| Pair No. | (Slave) Center date/time<br>Center coordinate | (Master) Center date/time<br>Center coordinate | A/D | Path/Row (Frame) FBS/FBD | B (km) | Bp (km) | a (deg) | dh (km) | dh⊥ (km) | dhpr (km) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | The second eruption : October 26, 2010. | | | | | | | |
| A1 | 20100316<br>15:31:32<br>-7.543/110.460 | 20101217<br>15:28:09<br>-7.527/110.449 | A | 431/7030<br>FBS | 0.726 | -0.654 | 34.398 | 0.099 | -0.066 | -0.328 |
| | | | The first eruption : November 4-5, 2010. | | | | | | | |
| A2 | 20100916<br>15:29:38.853<br>-7.757/110.568 | 20101101<br>15:28:57.075<br>-7.763/110.571 | A | 431/7030<br>FBD | 0.110 | -0.095 | 34.384 | 0.009 | -0.096 | -0.054 |

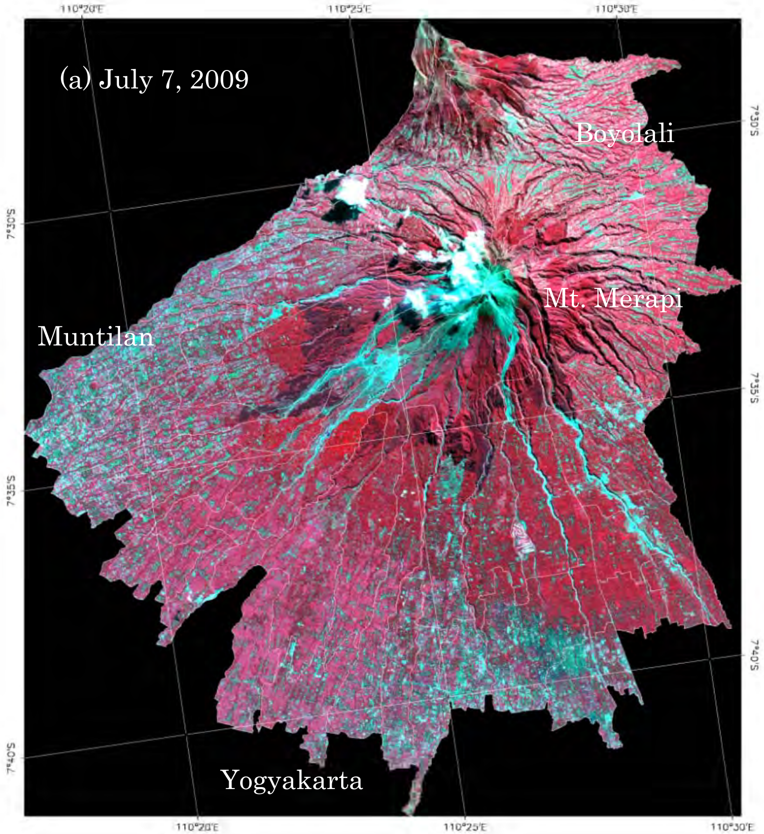
**Software :**

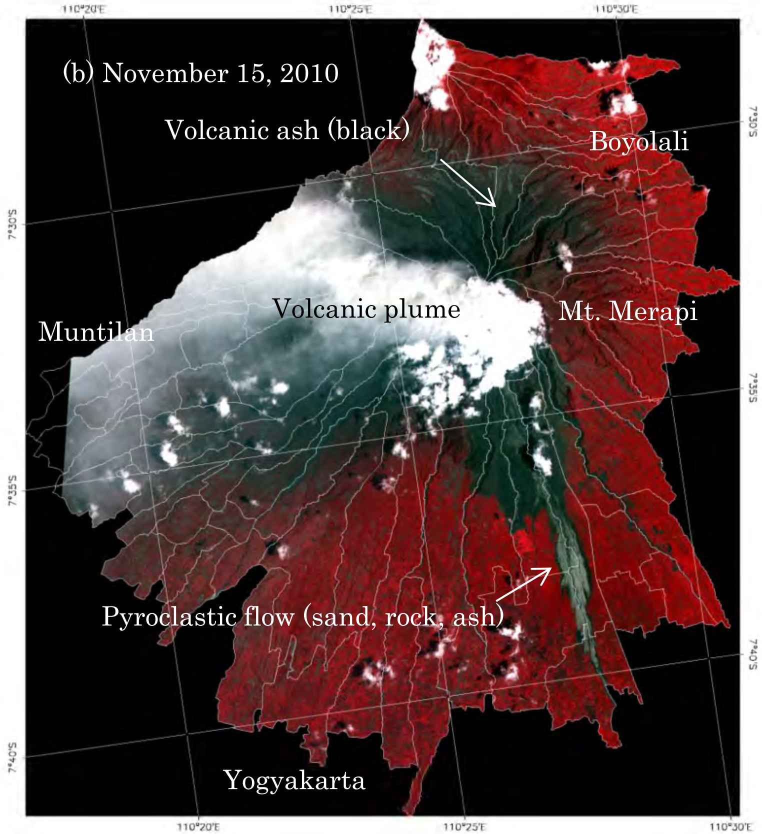
Interferogram and unwraping data is retrieved by JAXA SIGMA-SAR sofware (Shimada Masanobu)

**Digital Elevation Model :**

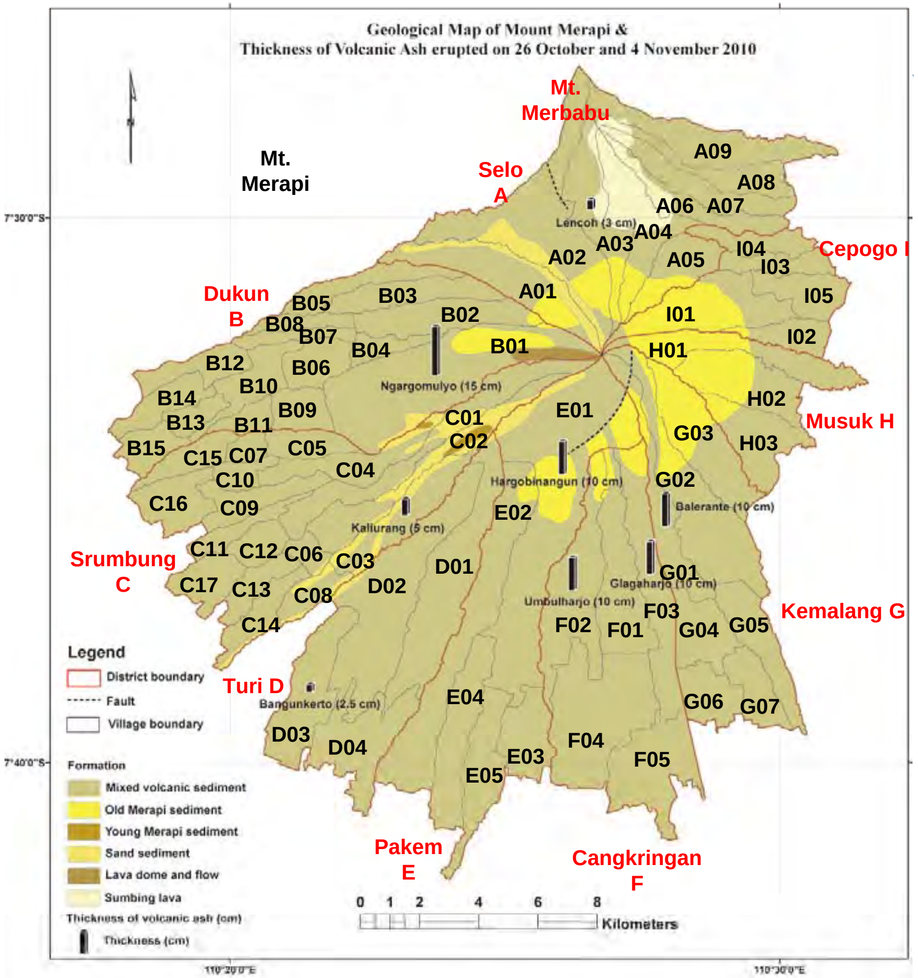
Digital topographic Maps of Indonesia 1:25,000, Bakosurtanal, 2000

# Terra ASTER images of Mount Merapi eruption after (November 15, 2010) and before (July 7, 2009)

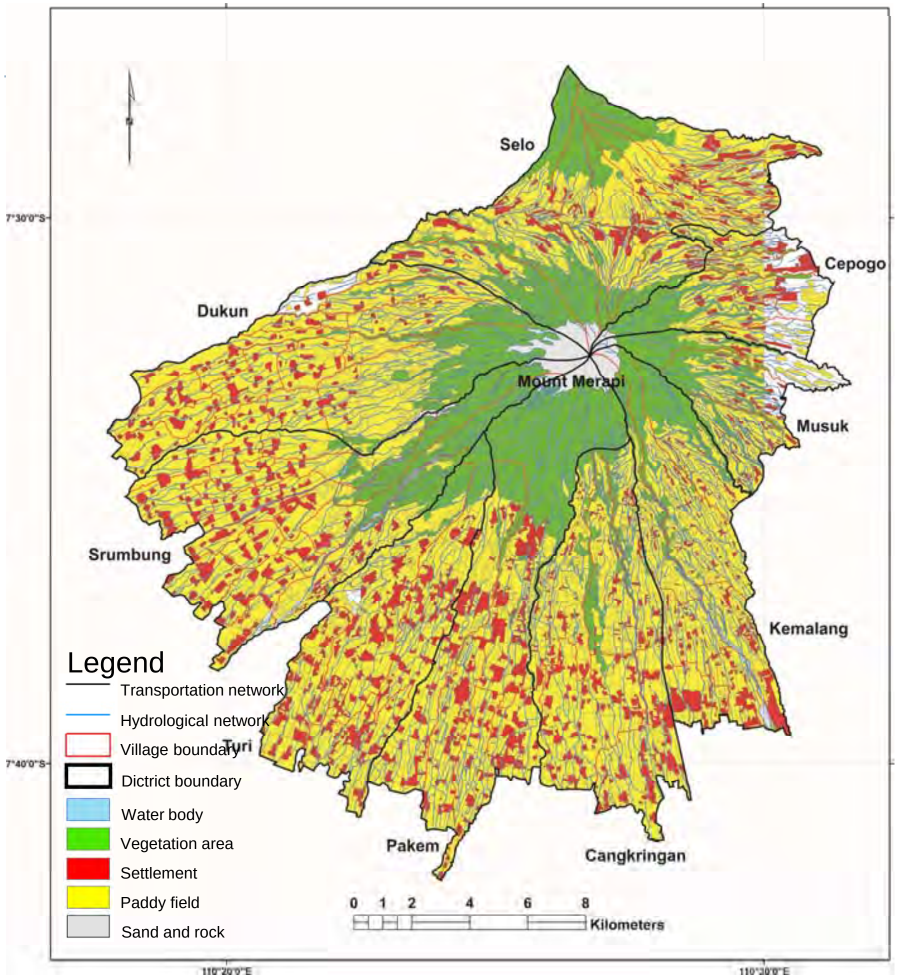


# Geological map and Landcover of Mount Merapi

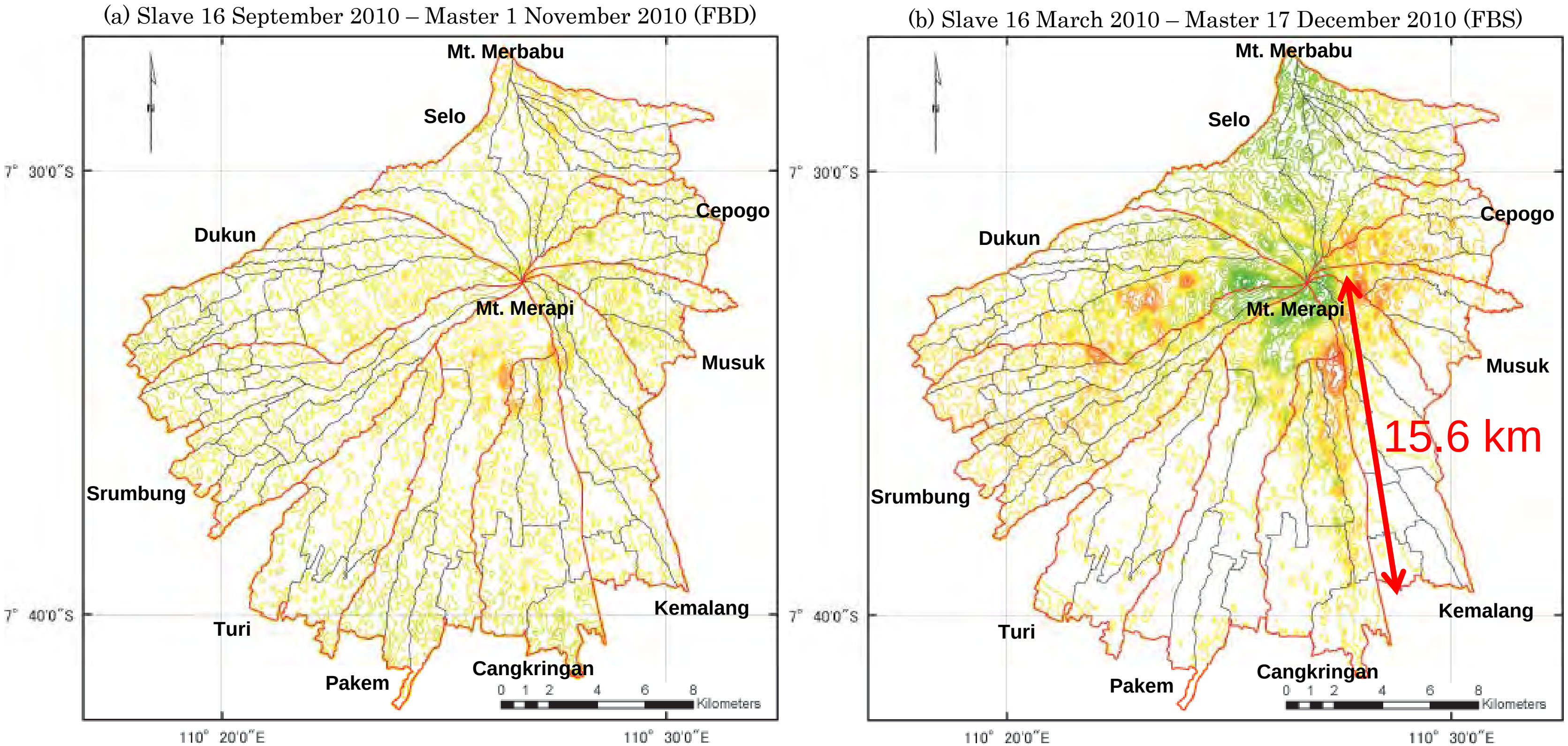


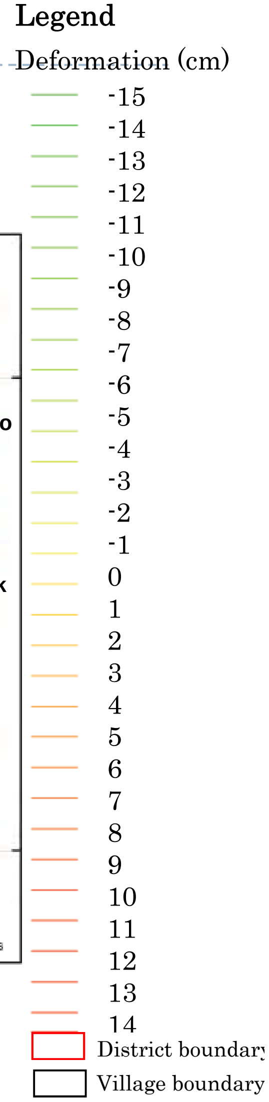

Geological map of Mount Merapi, code of villages and thickness of volcanic ash erupted on October 26 and November 4, 2010




Land cover map of the study area : Digital Topographic Map, 1:25,000, Bakosurtanal, 2000.

# Analysis : Thickness distribution of volcanic ash of Mount Merapi derived by DInSAR technique



# Photographs of volcanic ash coverage and damage area collected in ground survey after Mount Merapi erupted

(a) Umbulharjo village, Cangkringan District

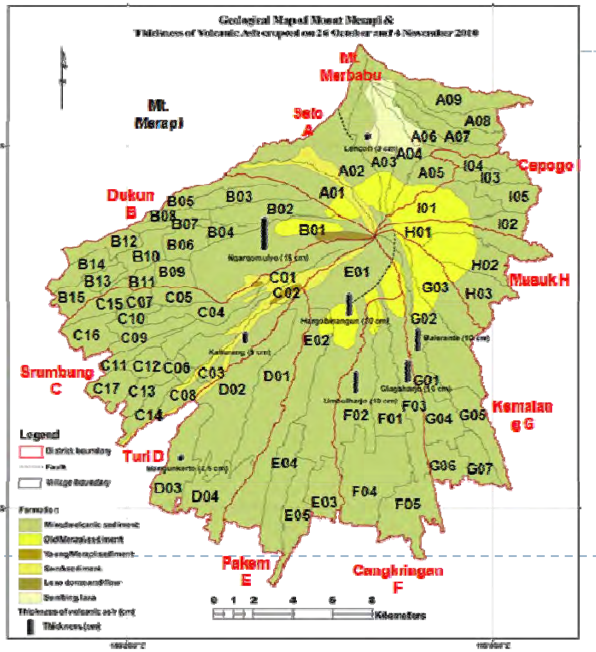

(b) Bakalan village, Cangkringan District

(c) Batang river, Srumbung District

(d) Pucanganom village, Dukun District

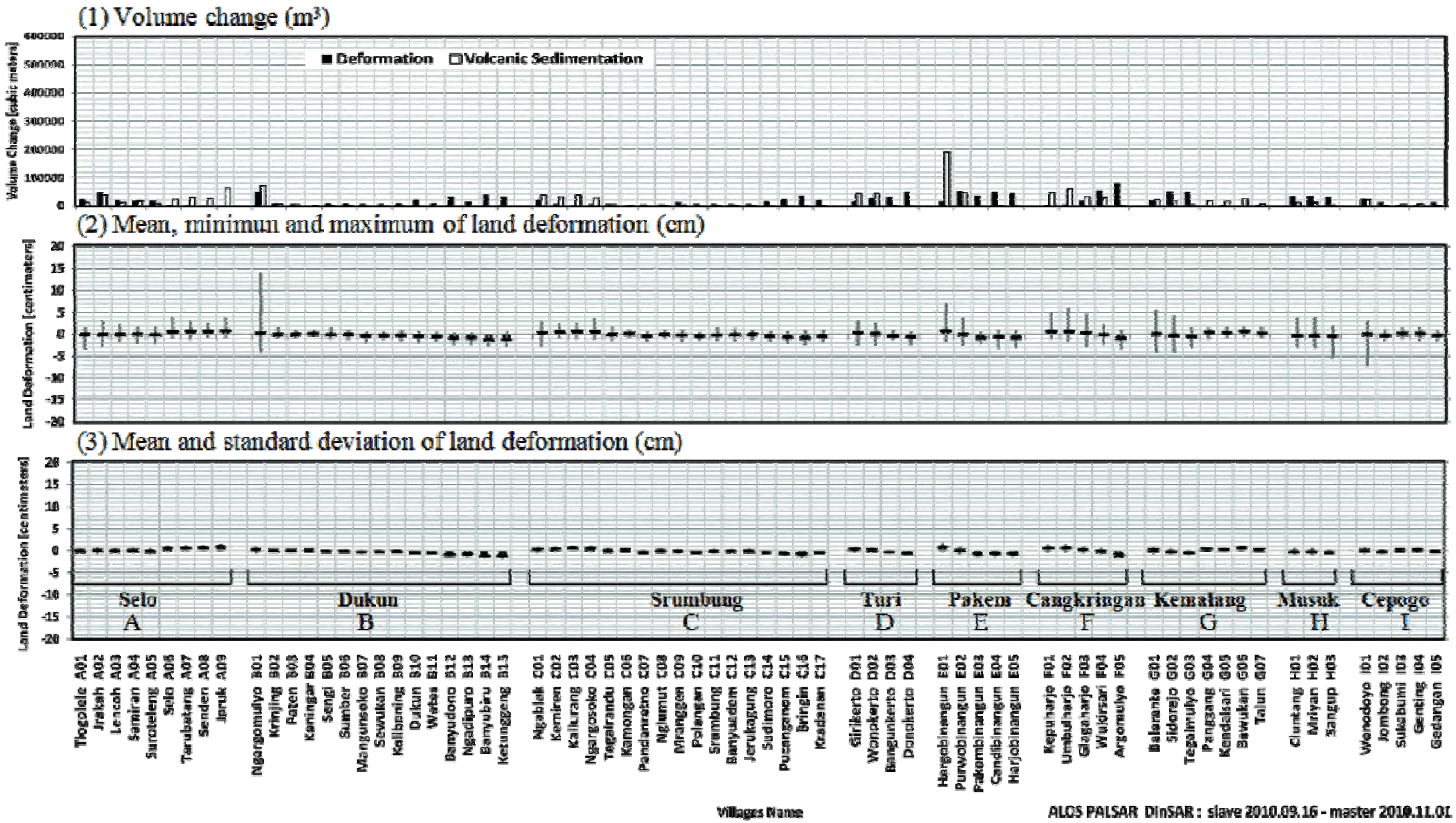
# Analysis : Estimated volcanic sediment thickness in the study area

| No. | Village Names | District Names | Ground data (cm) + standard deviation | DInSAR (cm) + standard deviation | Error ratio (%) |
|---|---|---|---|---|---|
| 1 | Lencoh A03 | Selo A | 3.0 ± 2 | 3.0 ± 1.9 | 1 |
| 2 | Ngargomulyo B01 | Dukun B | 15.0 ± 5 | 14.1 ± 4.2 | 6 |
| 3 | Kaliurang C03 | Srumbung C | 5.0 ± 2 | 3.0 ± 0.8 | 40 |
| 4 | Bangunkerto D03 | Turi D | 2.5 ± 2 | 1.7 ± 0.5 | 34 |
| 5 | Hargobinangun E01 | Pakem E | 10.0 ± 3 | 10.3 ± 3.2 | 3 |
| 6 | Glagaharjo F01 | Cangkringan F | 10.0 ± 3 | 10.6 ± 2.7 | 5 |
| 7 | Umbulharjo F03 | Cangkringan F | 10.0 ± 2 | 6.3 ± 0.9 | 37 |
| 8 | Balerante G01 | Kemalang G | 10.0 ± 3 | 8.3 ± 3.8 | 17 |
| | | | | Average error : | 20 |



# Analysis : Statistical information of land deformation and sedimentation at the study area (1)

**Land deformation in Mount Merapi eruption on October 26, 2010**

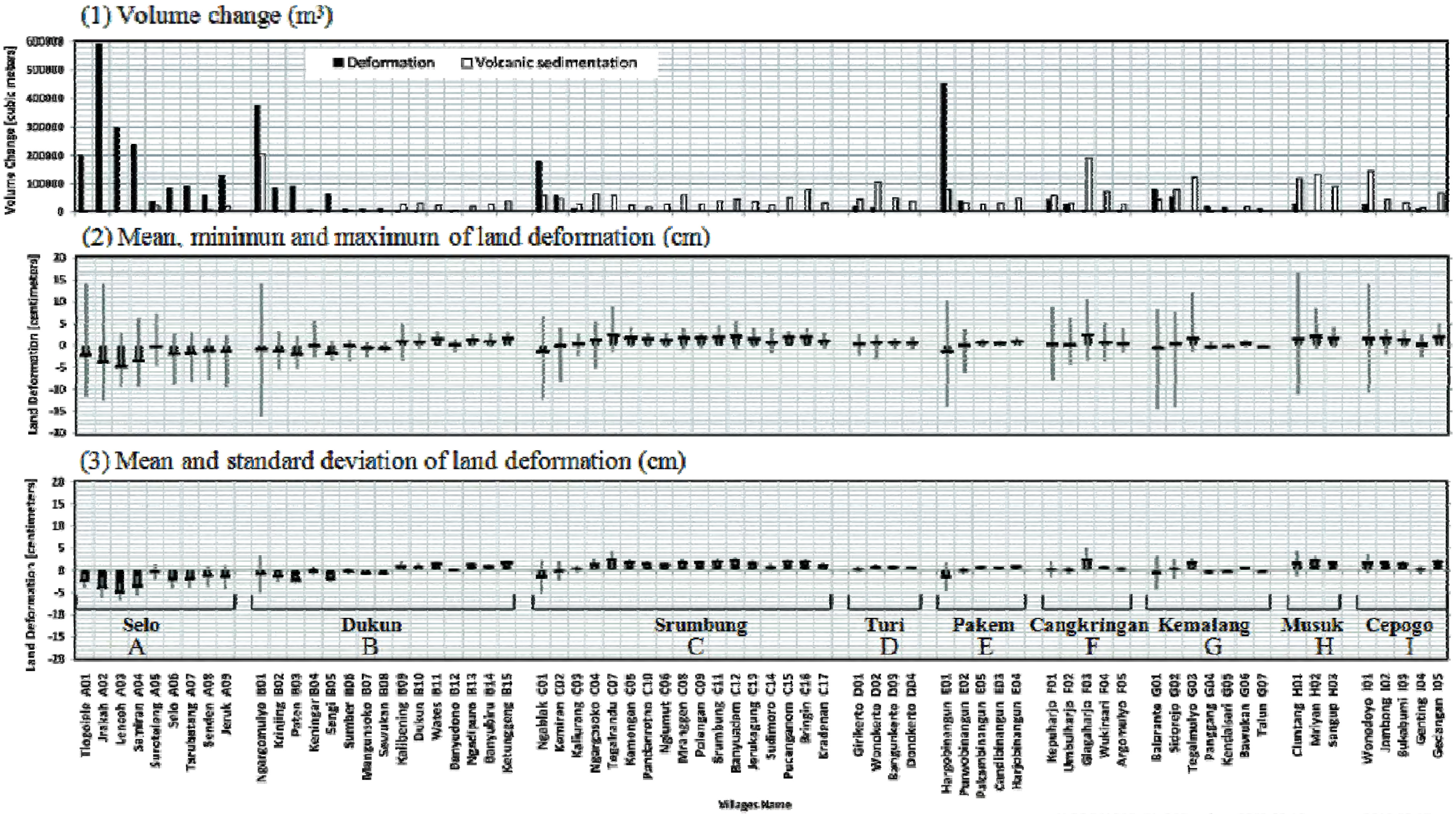





A. Land deformation in Mount Me

# Analysis : Statistical information of land deformation and sedimentation at the study area (2)

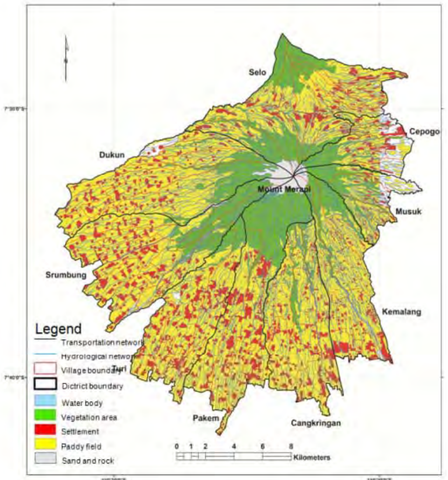
**Land deformation in Mount Merapi eruptions on October 26, 2010 and November 4, 2010**

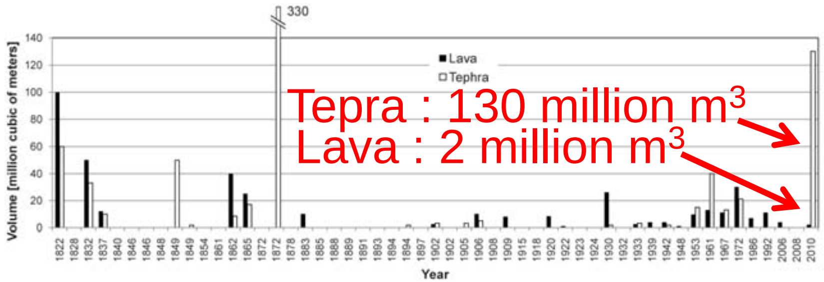



ALOS PALSAR DInSAR : slave 2010.03.16 - master 2010.12.17

# Estimation of Damage Area
# (ALOS PALSAR : Slave 2010.03.16 – Master 2010.12.17)

| Classes | Area of Deformation: Area ($km^2$) | Area of Deformation: Volume ($m^3$) | Area of Sedimention: Area ($km^2$) | Area of Sedimention: Volume ($m^3$) |
|---|---|---|---|---|
| Building | 0.008 | 30 | 0.099 | 846 |
| Settlement area | 14.961 | 193,621 | 37.012 | 344,937 |
| Bush | 33.310 | 10,299 | 25.677 | 5,057 |
| Forest | 10.812 | 3,499 | 2.701 | 346 |
| Grass | 9.551 | 3,884 | 4.096 | 806 |
| Horticulture area | 25.688 | 387,166 | 36.320 | 473,909 |
| Irrigated paddy field | 18.971 | 193,526 | 77.938 | 817,704 |
| Seasonal paddy field | 1.890 | 39,142 | 1.911 | 9,350 |
| Dry paddy field | 38.854 | 602,134 | 37.895 | 520,693 |
| Total : | 154.045 | 1,433,301 | 223.649 | **2,173,648** |




Modified source :
Global Volcanism Program, Smithsonian National Museum of Natural History http://www.volcano.si.edu/world/volcano.cfm?vnum=0603-25=&volpage=erupt (accessed 17 July 2011)

# Other disaster monitoring using DInSAR : Bandung Subsidence Monitoring

J. T. Sri Sumantyo, M. Shimada, P.P. Mathieu, and H.Z. Abidin , "Long-term Consecutive DInSAR for Volume Change Estimation of Land Deformation," IEEE Transactions on Geoscience and Remote Sensing, Vol. 50, No. 1, pp. 259 - 270, January 2012.

# Study area : Bandung city, Indonesia

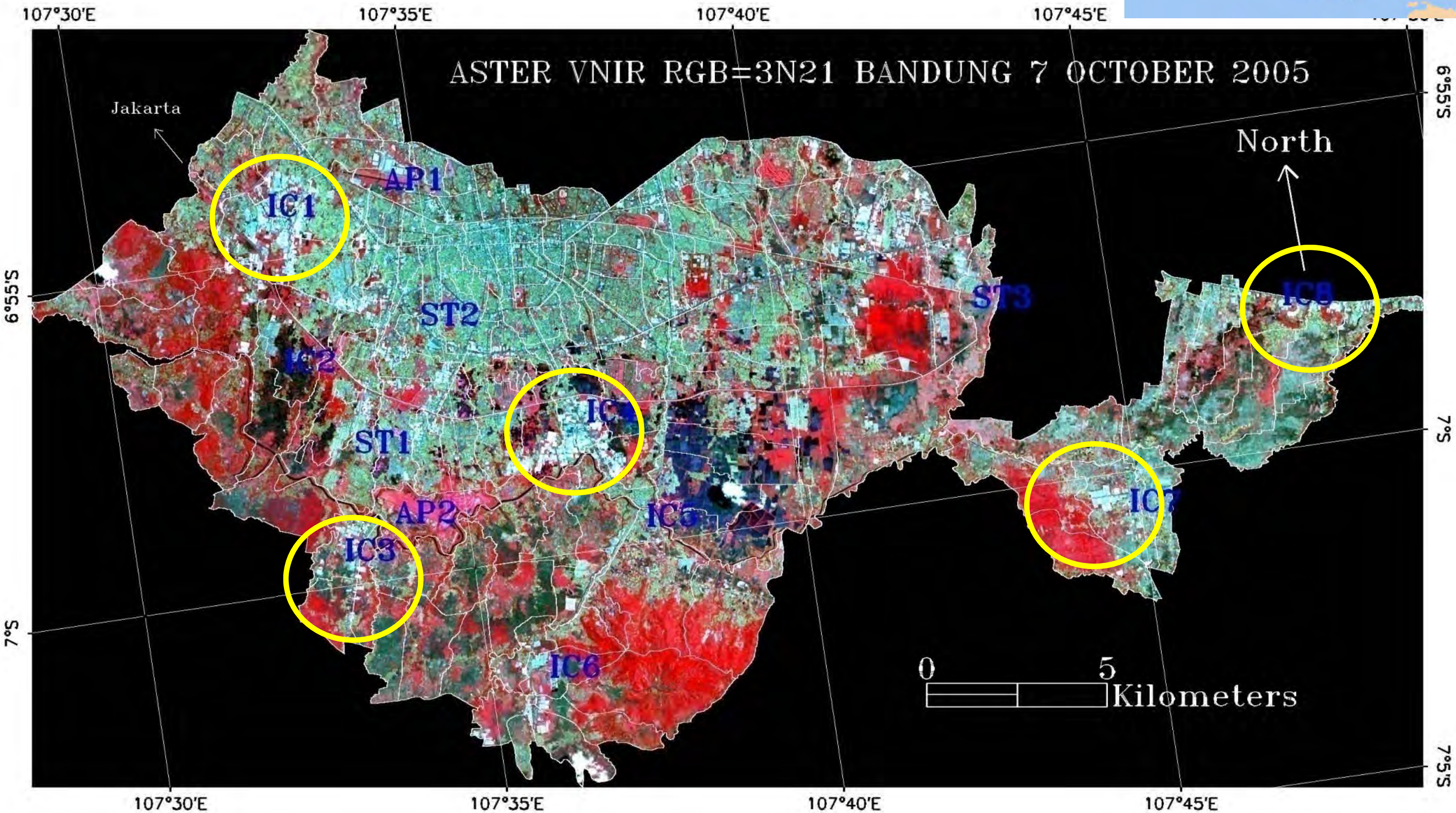
- Capital of West Java Province
- Location : 107°36' and 6°55'S
- Elevation : 675 m ～ 1,050 m
  (Volcanoes range)
- Population (in 2006) : 4,399,482
  (Density : 1,431 people/km$^2$)
  Most densed area : Margahayu
  (10,861 people/km$^2$)
- Geological information :
  Pumiceous tuff and ancient lake deposit or sediment formations
- Temperature : 24～25°C (October)
- Weather : Rainy and Dry
- Coverage : 345 km$^2$
- History

1641 : grown rapidly after the Mataram Kingdom occupied the study area and when the capital moved from Krapyak, Dayeuh Kolot to the area now known as Bandung

18 century : Colonial period when the Dutch first Major, Coopman developed this city as modern city

1945 : Independence of Indonesia, Bandung is growing fastly as the third big city on Indonesia with complicated problems inside.


# Study area : Bandung city, Indonesia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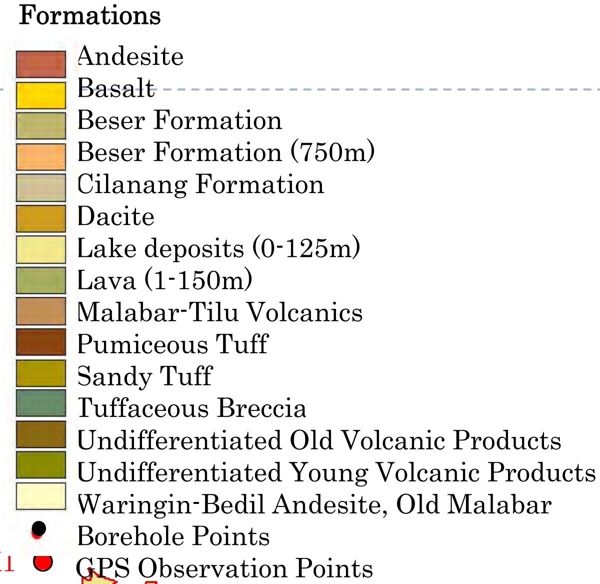
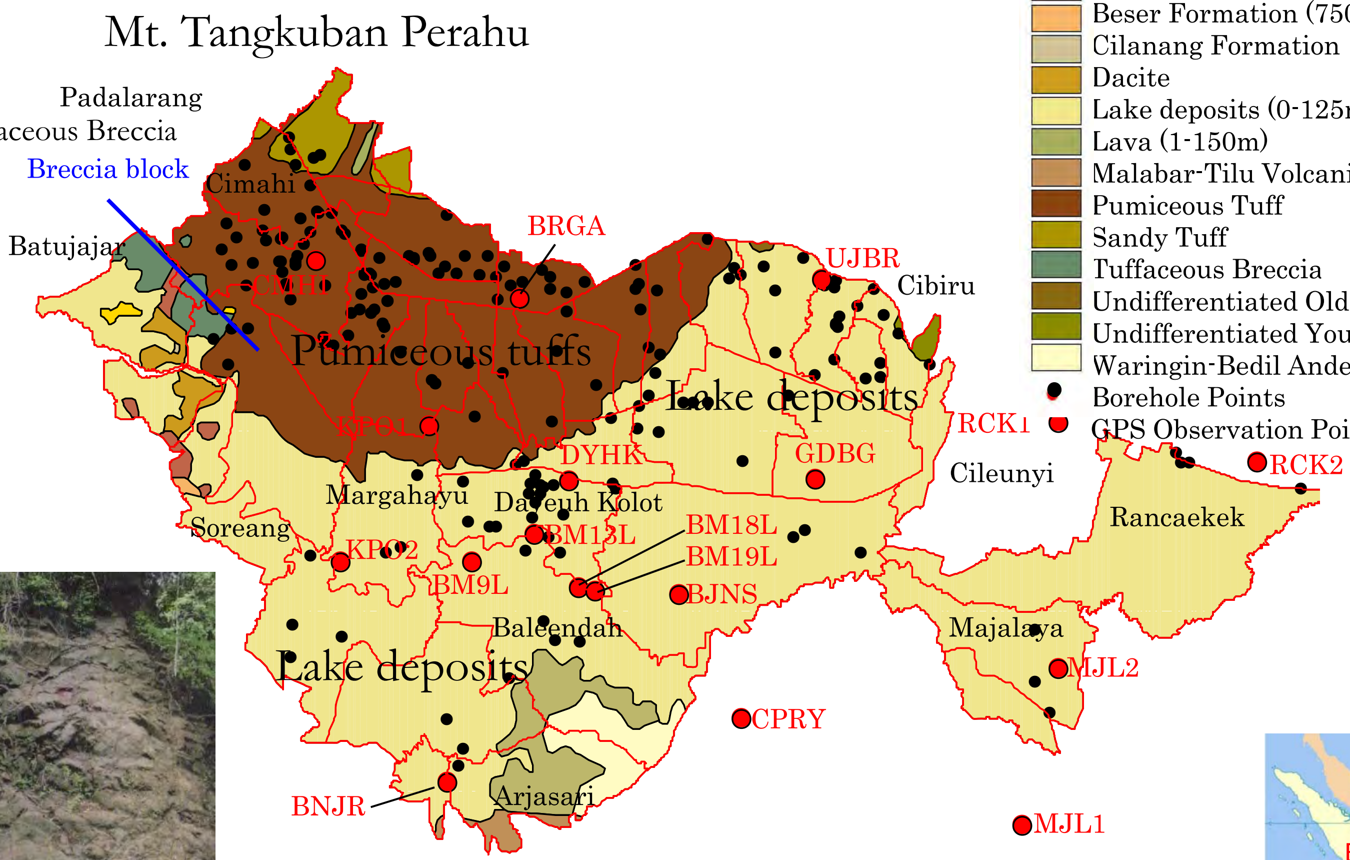
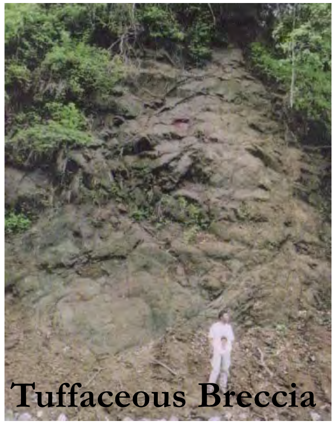
# Study area : Geological history : Main formations

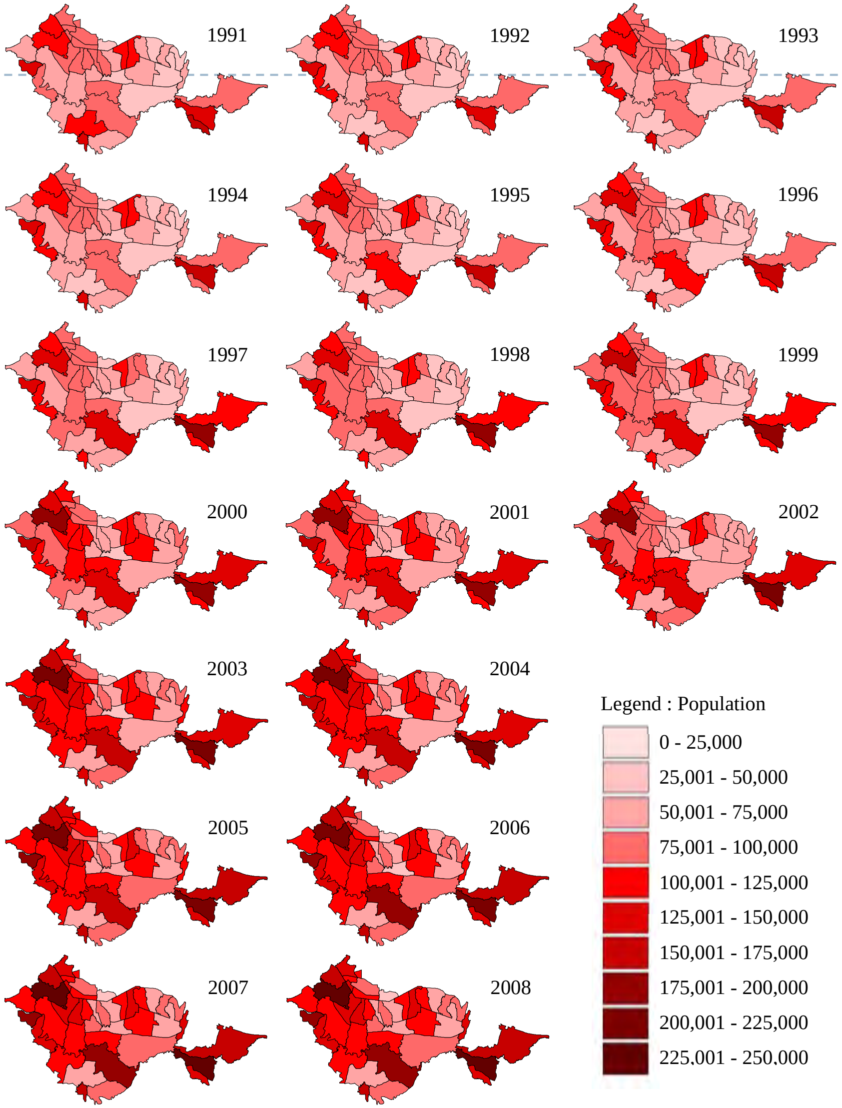
Geological formation of the study area and location of borehole and GPS observation points

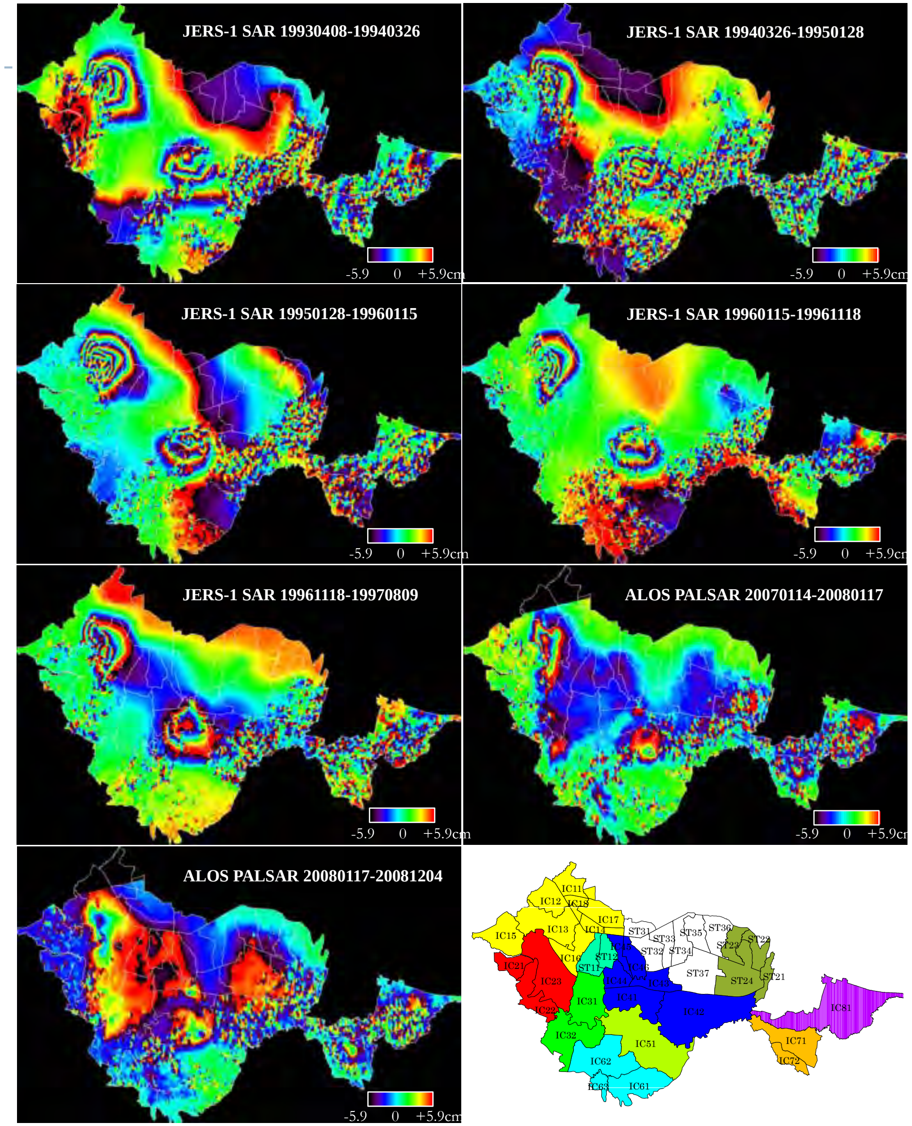



# Statistics : Populations

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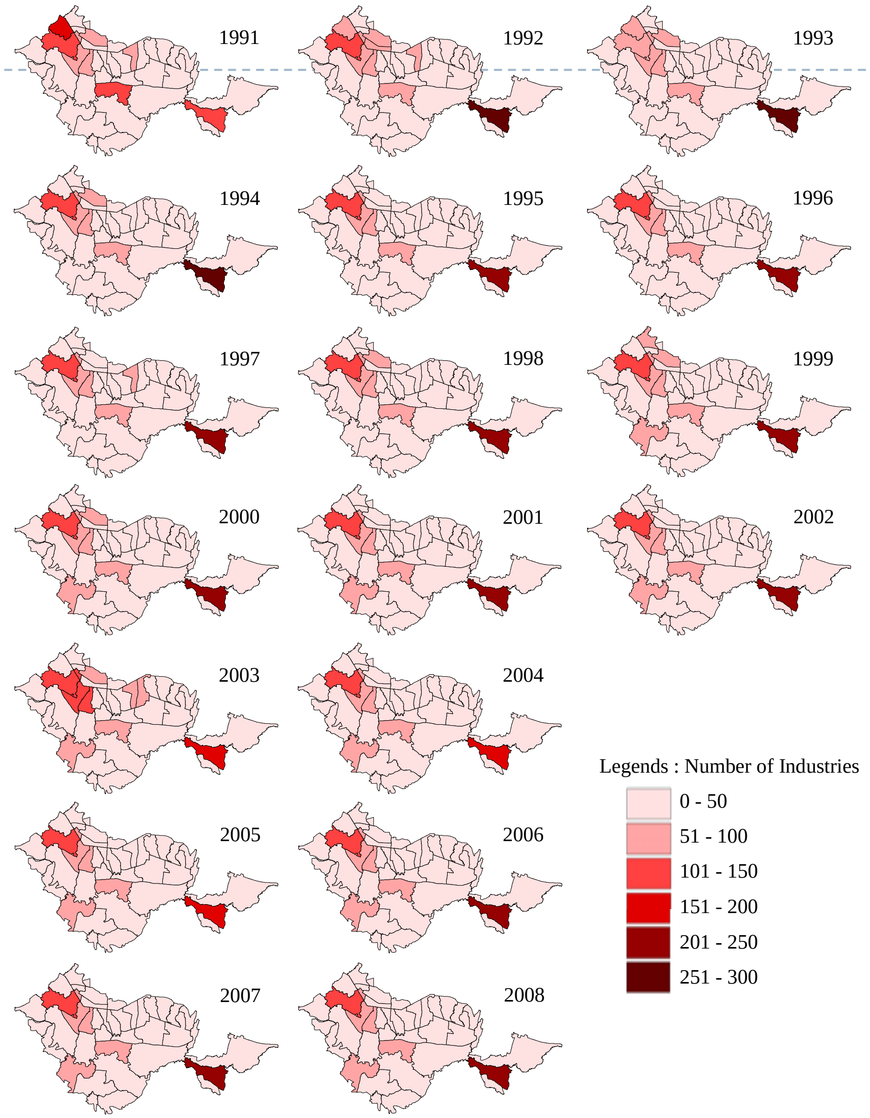
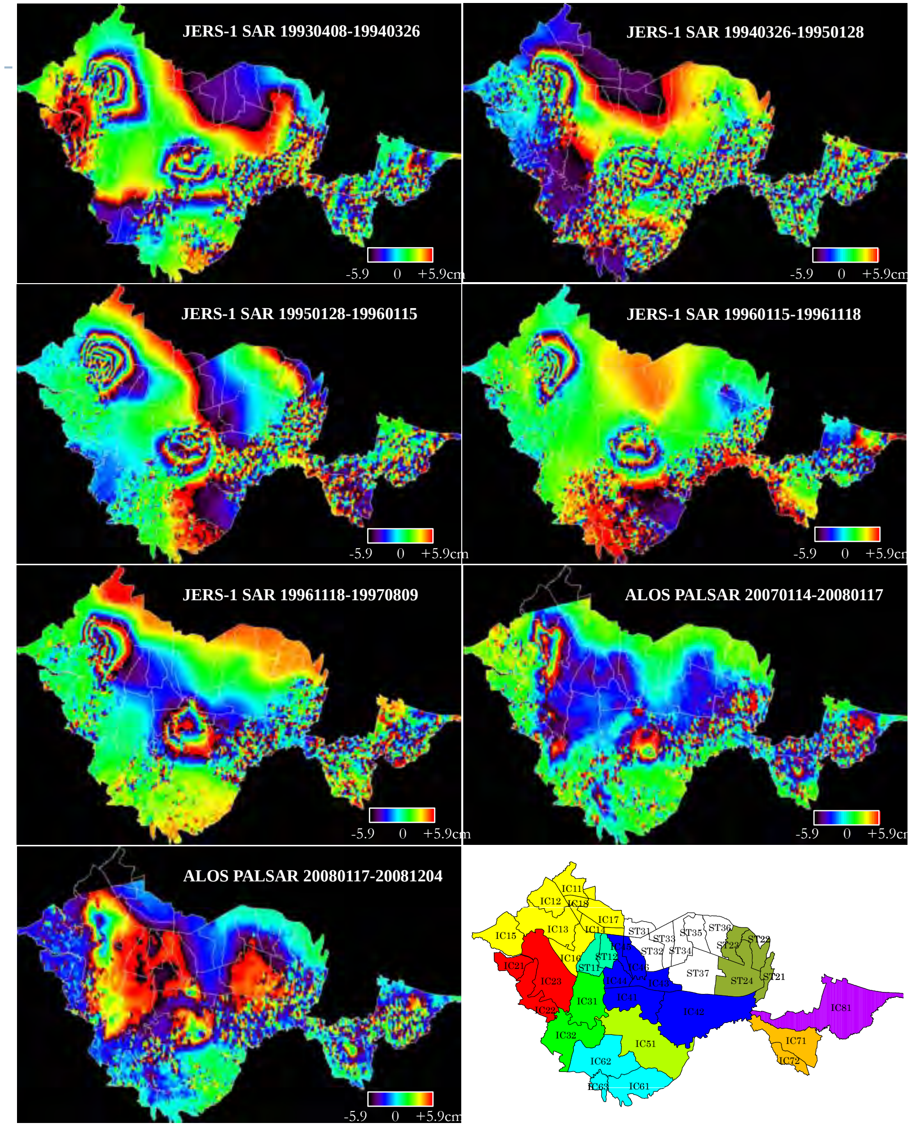
# Statistics : Industries



# Ground Survey Data

(13-14 December 2008, 25-28 February 2009, 4-10 August 2009)

(A) S 6°54'45.7", E 107°33'1.7"

(B) S 6°55'23.0", E 107°33'4.0"

(C) S 6°55'31.3", E 107°33'1.1"

(D) S 6°58'29.1", E 107°36'30.3"

(E) S 6°58'13.7", E 107°36'38.8"

(F) S 6°58'15.4", E 107°36'38.2"

(G) S 6°59'35.5", E 107°37'35.3"

(H) S 6°58'8.1", E 107°36'39.9"

(I) S 6°58'17.6", E 107°36'40.5"

# Estimation Result by using VolSAR

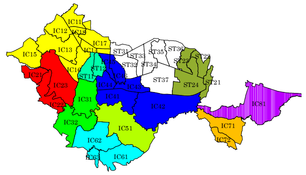


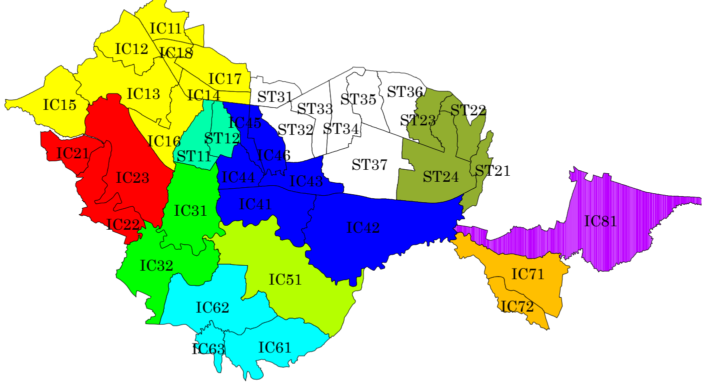
TABLE. Estimation of Subsidence (Maximum Value in Centimeters) and Volume (in Cubic Meters) of The Study Area

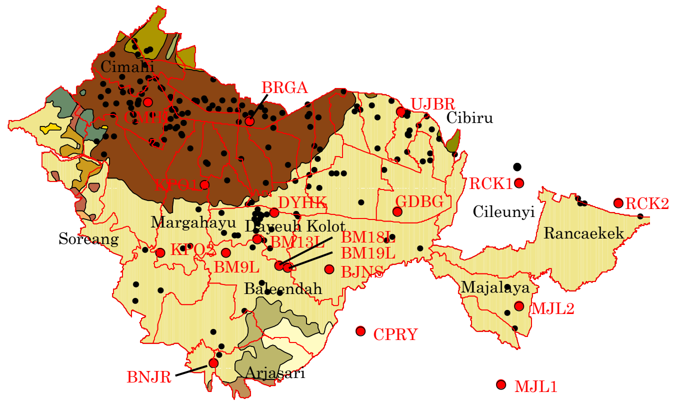
| District Codes | District Name | Sensor Name and Data Combination (Slave-Master) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | JERS-1 19930408-19940326 | JERS-1 19940326-19950128 | JERS-1 19950128-19960115 | JERS-1 19960115-19961118 | JERS-1 19961118-1997080 | ALOS 20070114-20080117 | ALOS 20080117-20081204 |
| **Industrial Complexes** | | | | | | | | |
| IC1 | Cimahi | 55 (8,112,500) | 45 (4,432,500) | 57 (8,635,500) | 47 (4,935,000) | 36 (3,852,000) | 21 (1,701,000) | 14 (1,862,000) |
| IC2 | Cililin | 12 ( 918,000) | 0 ( 0) | 0 ( 0) | 0 ( 0) | 0 (0) | 12 ( 222,000) | 12 ( 756,000) |
| IC3 | Margahayu | 0 ( 0) | 0 ( 0) | 0 ( 0) | 0 ( 0) | 0 (0) | 9 ( 81,000) | 12 ( 732,000) |
| IC4 | Dayeuhkolot | 9 ( 513,000) | 31 (1,534,500) | 25 (1,100,000) | 16 ( 840,000) | 20 (1,280,000) | 6 ( 75,000) | 12 ( 726,000) |
| IC5 | Baleendah | 12 ( 312,000) | 6 ( 114,000) | 6 ( 255,000) | 6 ( 102,000) | 12 ( 336,000) | 27 ( 351,000) | 19 ( 655,500) |
| IC6 | Arjasari | 6 ( 225,000) | 0 ( 0) | 6 ( 330,000) | 6 ( 708,000) | 3 ( 133,500) | 12 ( 150,000) | 12 ( 192,000) |
| IC7 | Majalaya | 0 ( 0) | 0 ( 0) | 0 ( 0) | 0 ( 0) | 0 (0) | 9 ( 85,500) | 12 ( 168,000) |
| IC8 | Rancaekek | 12 ( 252,000) | 0 ( 0) | 0 ( 0) | 0 ( 0) | 9 ( 220,500) | 9 ( 198,000) | 12 ( 174,000) |
| **Settlement Areas** | | | | | | | | |
| ST1 | Babakan Ciparay | 12 ( 174,000) | 6 ( 66,000) | 6 ( 132,000) | 3 ( 28,500) | 3 ( 90,000) | 3 ( 105,000) | 6 ( 189,000) |
| ST2 | Cileunyi | 9 ( 715,500) | 6 ( 204,000) | 9 ( 67,500) | 4 ( 26,000) | 4 ( 94,000) | 4 ( 78,000) | 6 ( 120,000) |
| ST3 | Sumur Bandung | 9 (1,125,000) | 9 ( 783,000) | 9 ( 495,000) | 4 ( 344,000) | 4 ( 278,000) | 4 ( 420,000) | 6 ( 324,000) |

# GPS Observation

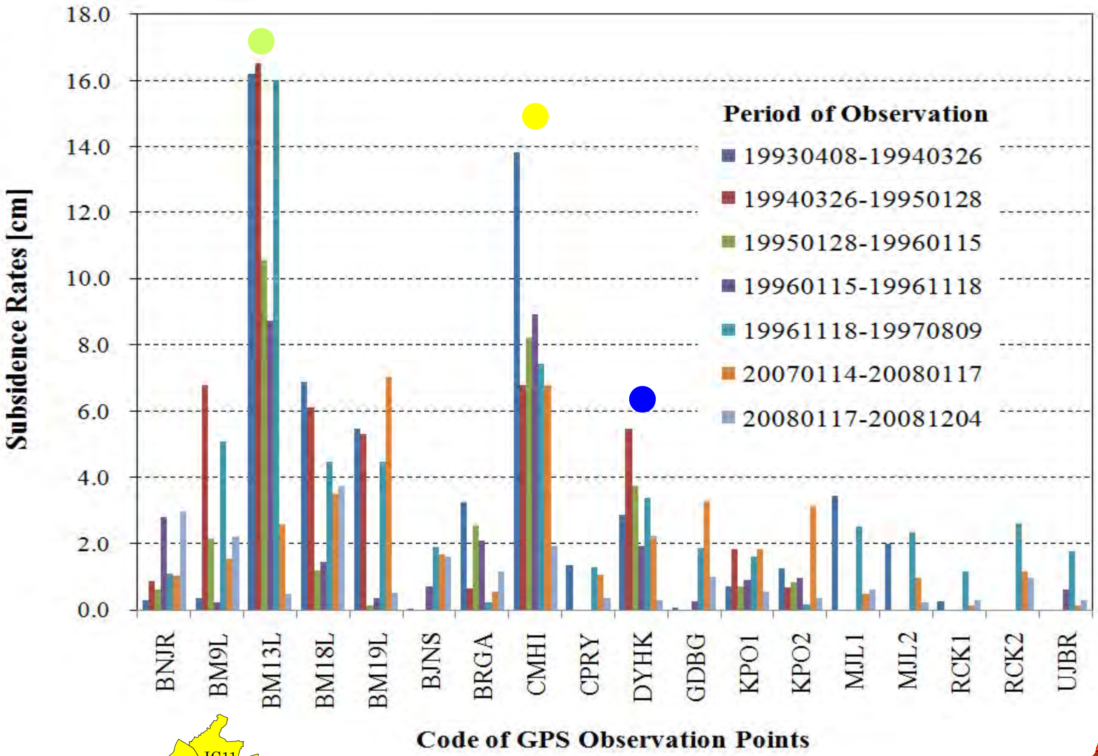
| Location Codes | Location Name | Coordinate | | Period of Observation | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Latitude | Longitude | 200002-200111 | 200111-200207 | 200207-200306 | 200306-200506 | 200506-200808*) |
| BNJR | Banjaran | 7.040 | 107.591 | 8.7 | 3.8 | 3.3 | 6.9 | 5.2 (4.0) |
| BM9L | Bojong Malaka 9 | 6.985 | 107.598 | - | - | 19.1 | - | - (3.8) |
| BM13L | Bojong Malaka 13 | 6.978 | 107.614 | - | - | 5.7 | 10.3 | - (3.1) |
| BM18L | Bojong Malaka 18 | 6.991 | 107.626 | - | - | 15.9 | 10.0 | 8.5 (7.2) |
| BM19L | Bojong Malaka 19 | 6.992 | 107.630 | - | - | 5.6 | - | - (7.5) |
| BJNS | Bojongsoang | 6.993 | 107.652 | 9.2 | 4.2 | 3 | - | - (3.3) |
| BRGA | Braga | 6.919 | 107.610 | - | 11.9 | - | - | - (1.7) |
| CMHI | Cimahi | 6.909 | 107.557 | 22.8 | 17.6 | 15.7 | 4.4 | - (8.7) |
| CPRY | Ciparay | 7.024 | 107.669 | - | 3.0 | - | - | 1.7 (1.4) |
| DYHK | Dayeuhkolot | 6.965 | 107.623 | 18.8 | 18.2 | 4.1 | 8.1 | 10.9 (2.5) |
| GDBG | Gedebage | 6.964 | 107.688 | - | 1.1 | 16.8 | 4.0 | 10.1 (4.3) |
| KPO1 | Kopo 1 | 6.951 | 107.587 | - | - | 7.0 | 1.3 | 7.1 (2.4) |
| KPO2 | Kopo 2 | 6.985 | 107.563 | - | 0.1 | 6.1 | 5.1 | 10.5 (3.5) |
| MJL1 | Majalaya 1 | 7.051 | 107.742 | 8.1 | 2.1 | 8.2 | - | 2.2 (1.1) |
| MJL2 | Majalaya 2 | 7.011 | 107.752 | - | - | 3.4 | 3.7 | 6.5 (1.2) |
| RCK1 | Rancaekek 1 | 6.950 | 107.752 | 12.1 | 5.4 | - | 3.2 | 0.5 (0.4) |
| RCK2 | Rancaekek 2 | 6.960 | 107.804 | 18 | 14.8 | 0.8 | 6.9 | 5.9 (2.1) |
| UJBR | Ujungberung | 6.914 | 107.690 | 3.1 | 1.7 | 6.1 | - | 0.7 (0.4) |

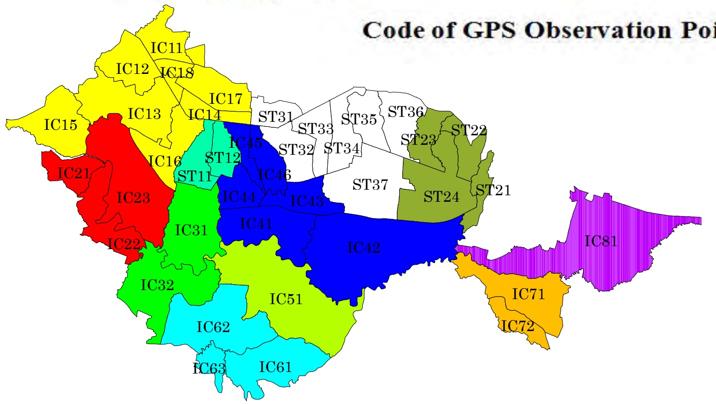
*) Value inside the bracket shows the subsidence rate derived by DInSAR within 14 January 2007 and 4 December 2008

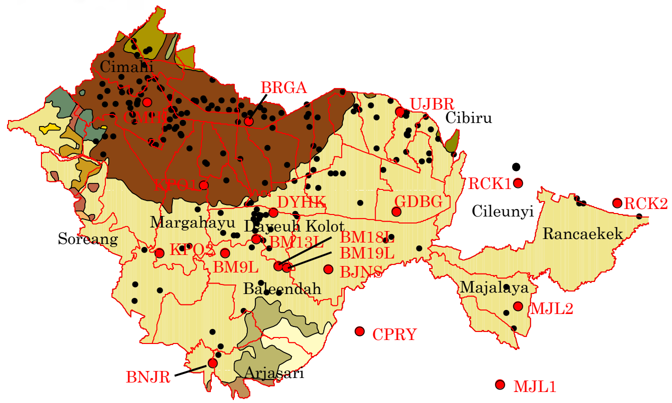


# Subsidence Estimation using DInSAR

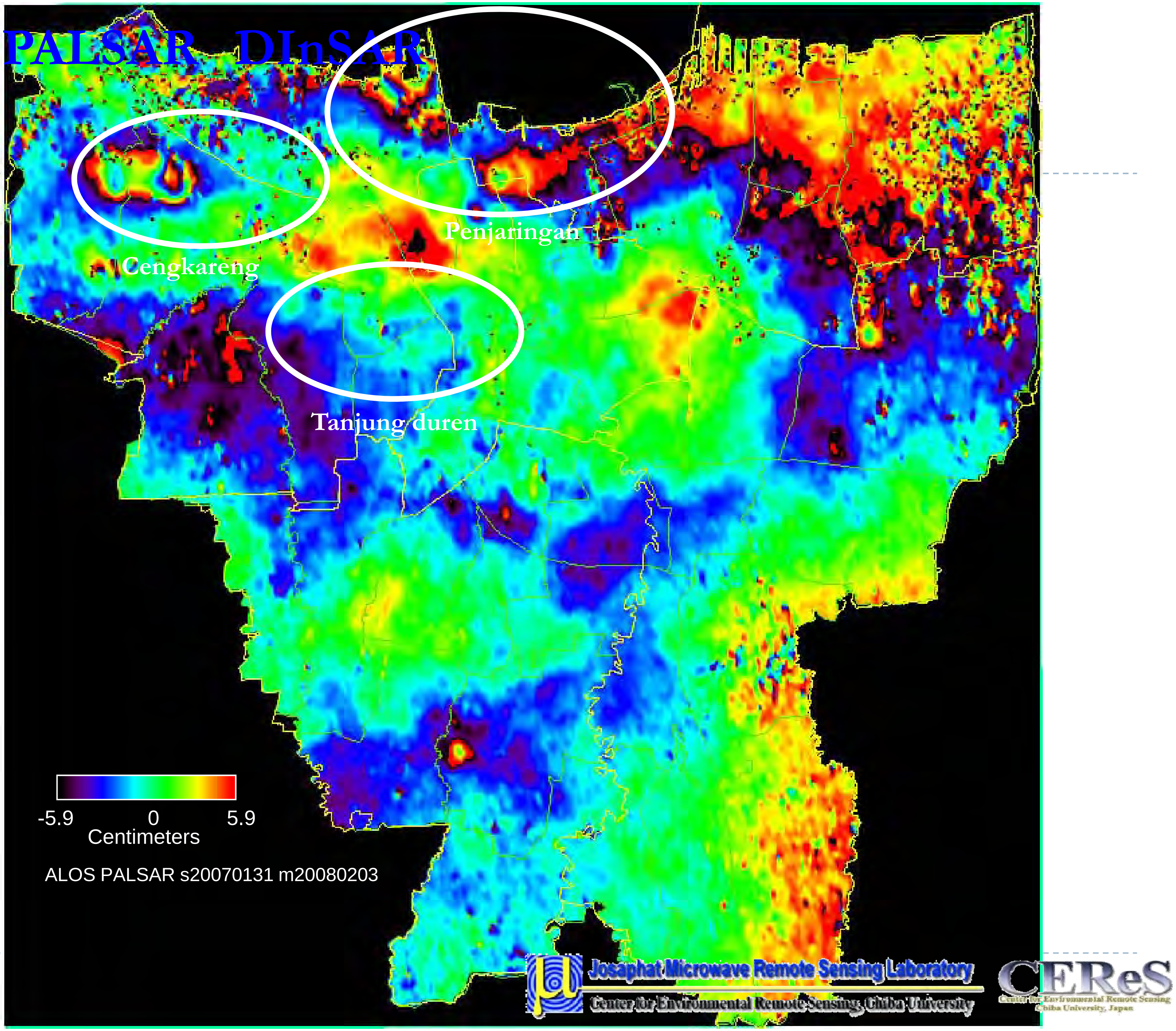


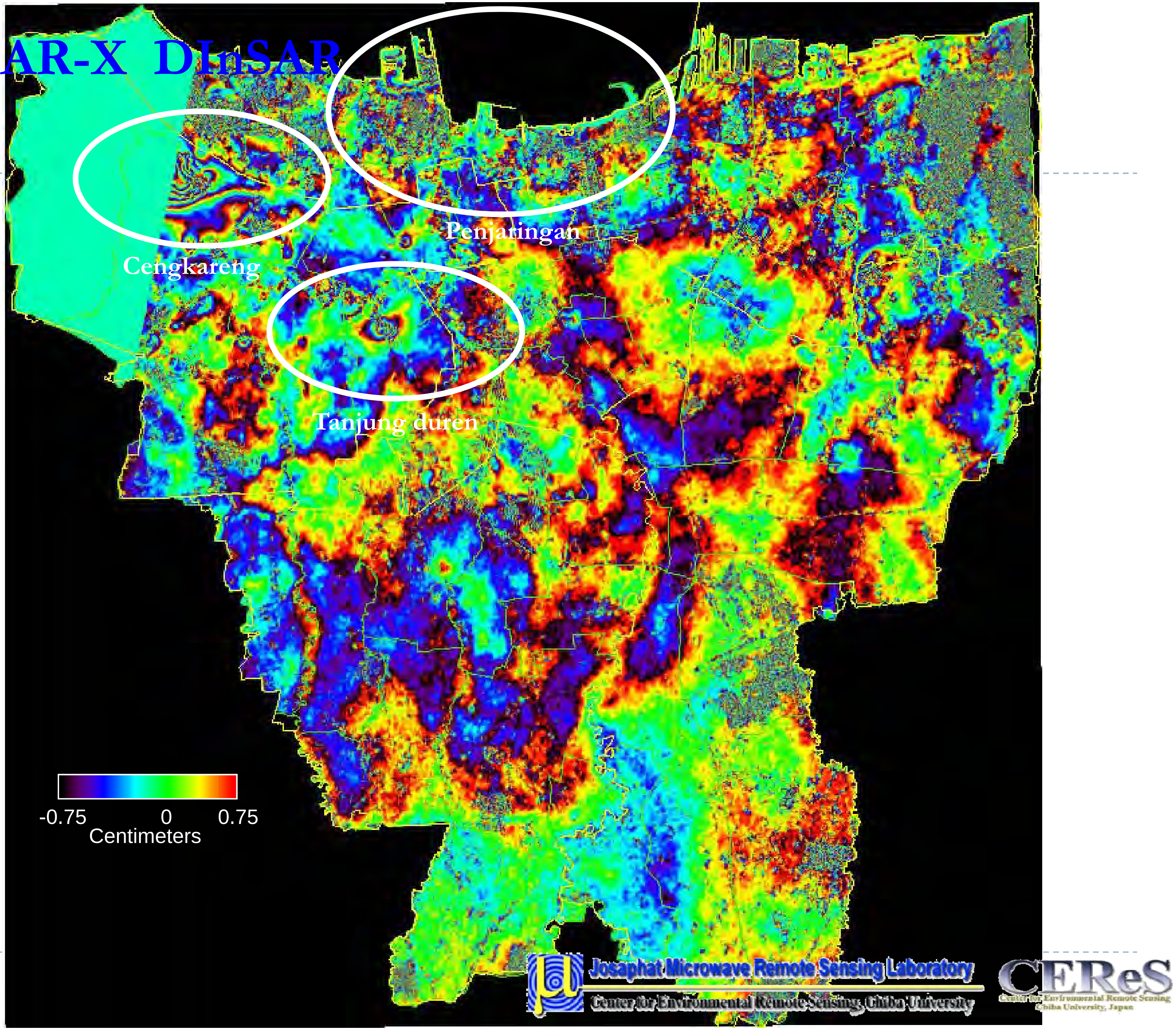



# Other disaster monitoring using DInSAR : Subsidence of Jakarta Megapolitan

# ALOS PALSAR DInSAR

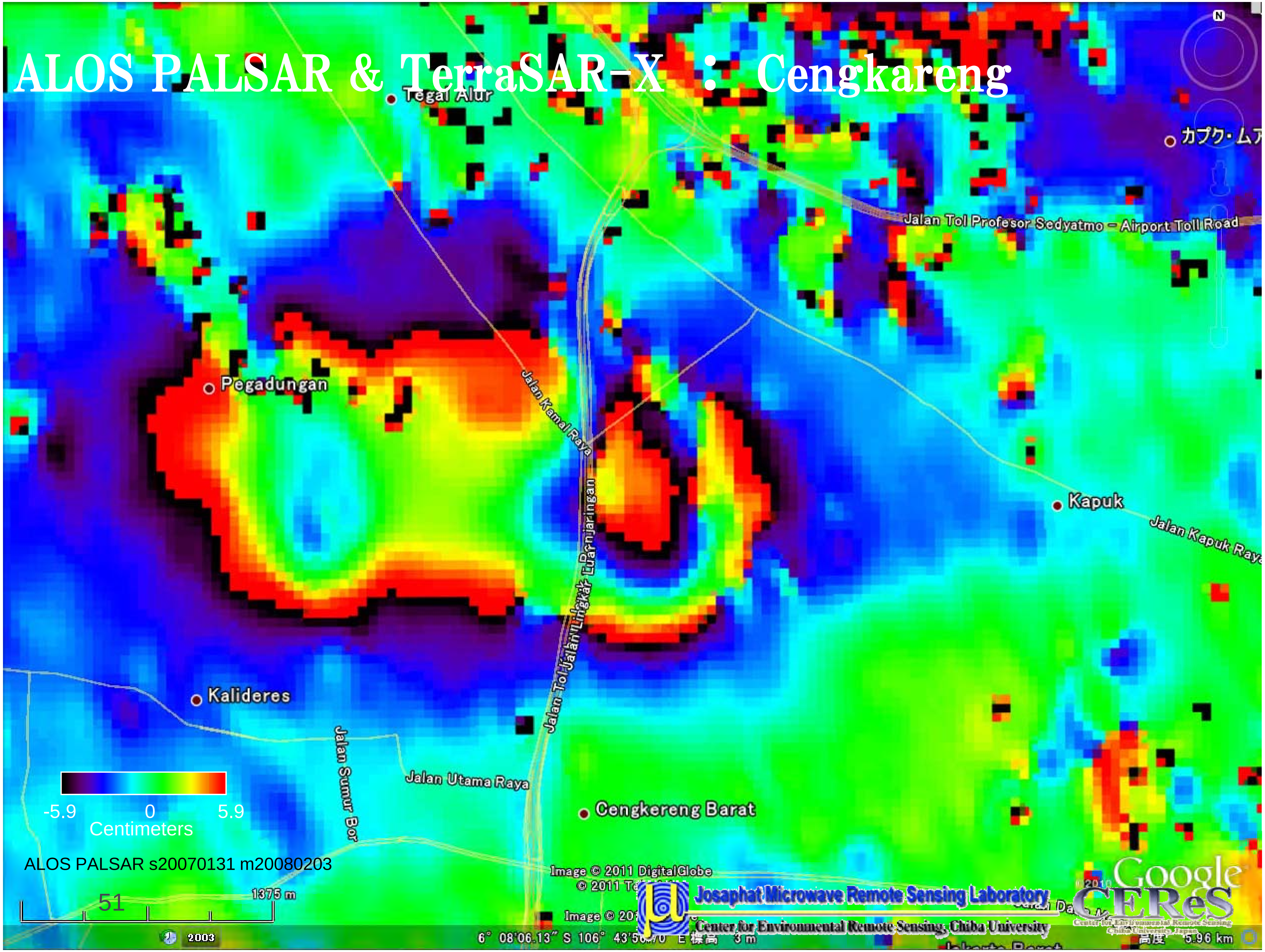


# TerraSAR-X DInSAR

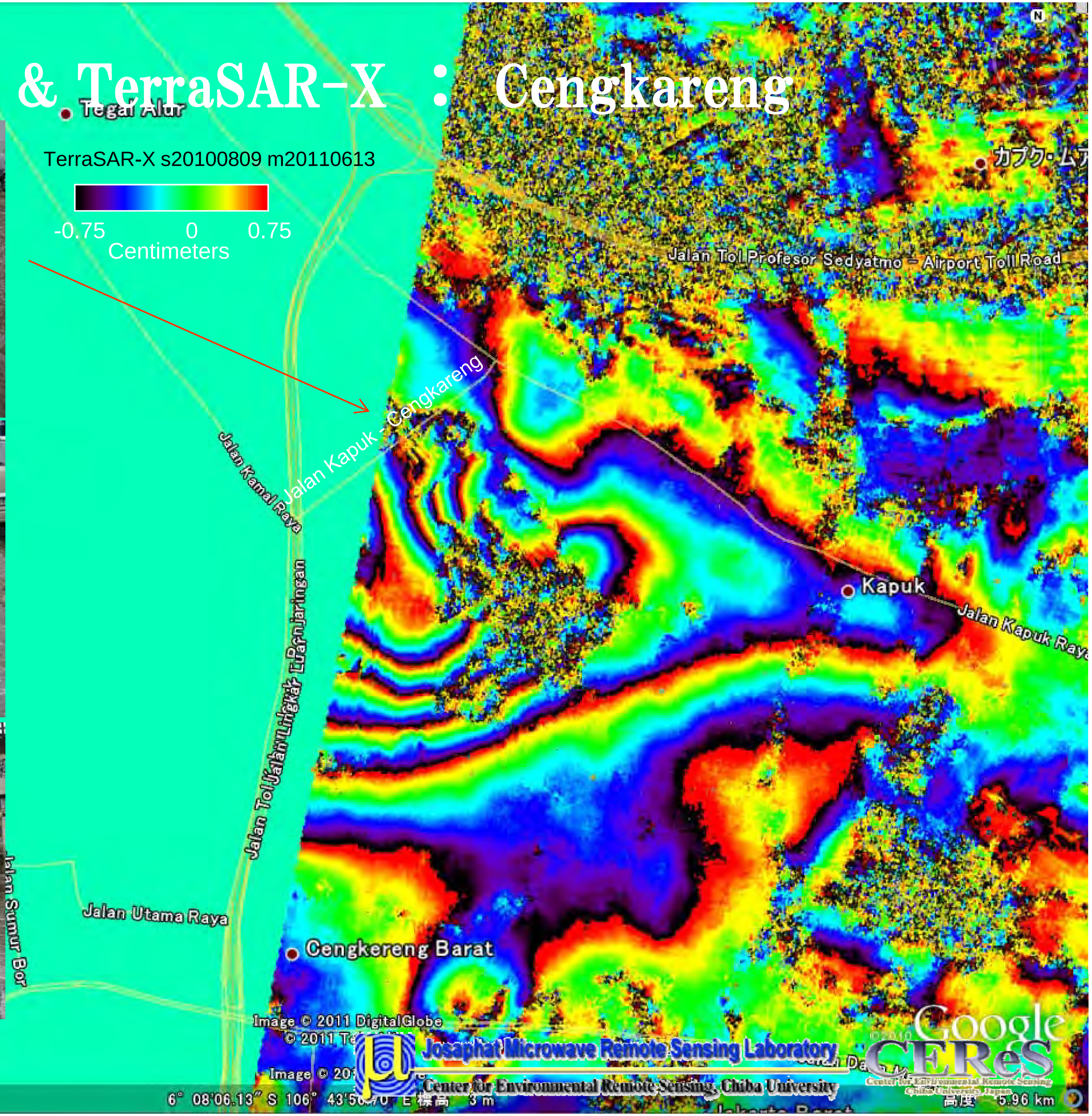


# ALOS PALSAR & TerraSAR-X ： チェンカレング区

# ALOS PALSAR & TerraSAR-X ： Cengkareng

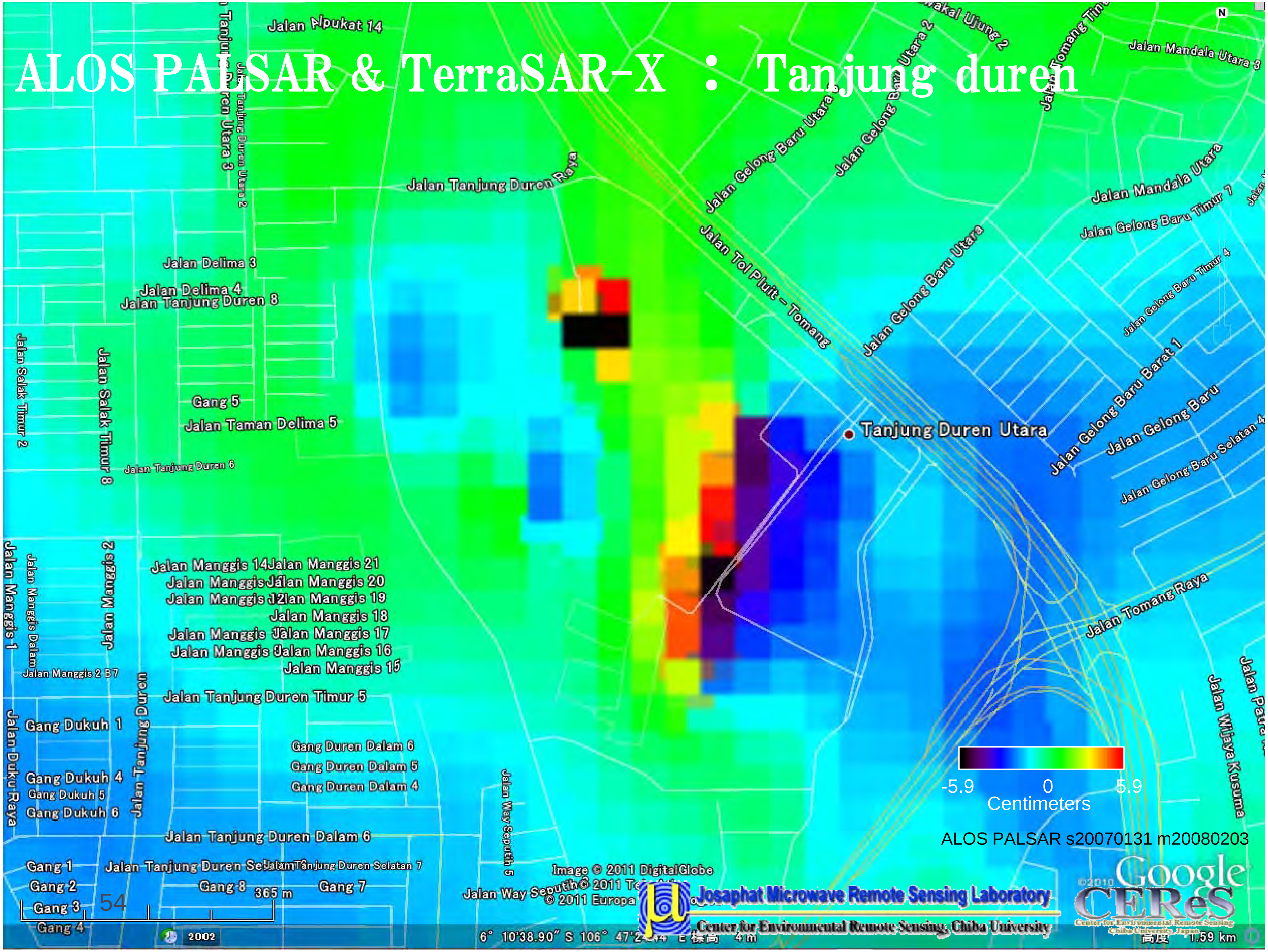


# ALOS PALSAR & TerraSAR-X ： Cengkareng

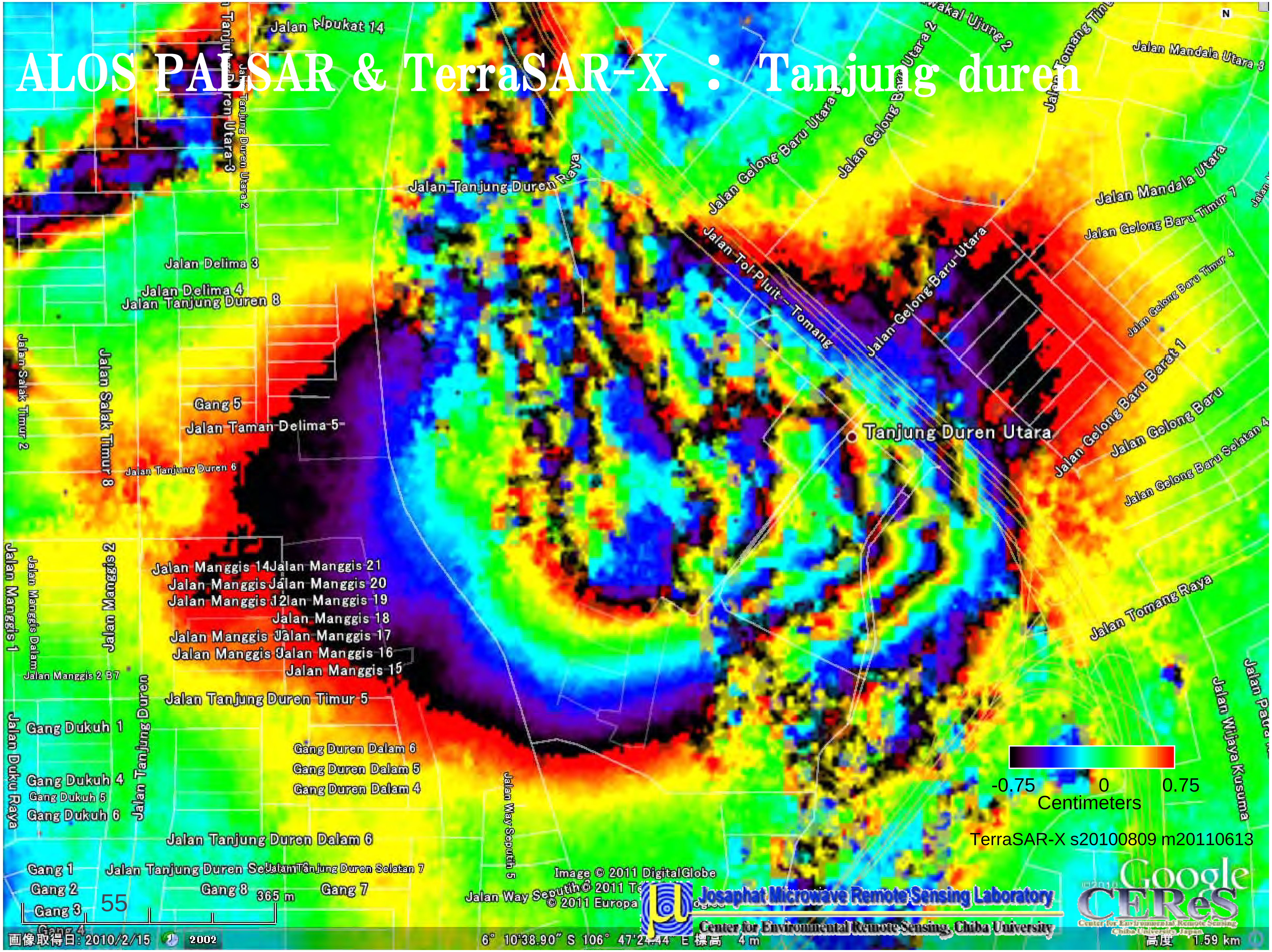



# ALOS PALSAR & TerraSAR-X ： タンジュングドレン区

# ALOS PALSAR & TerraSAR-X ： Tanjung duren

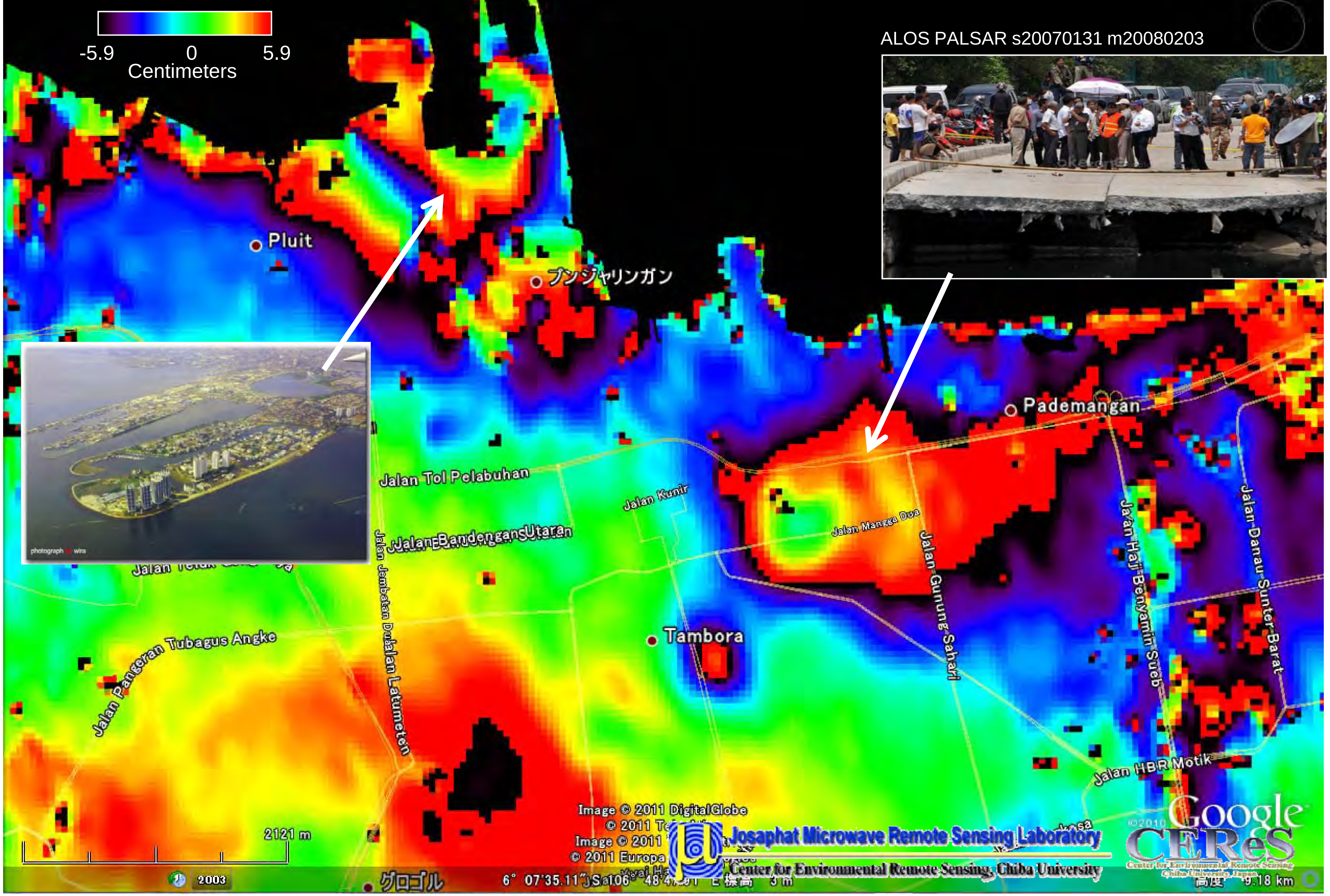


# ALOS PALSAR & TerraSAR-X ： Tanjung duren

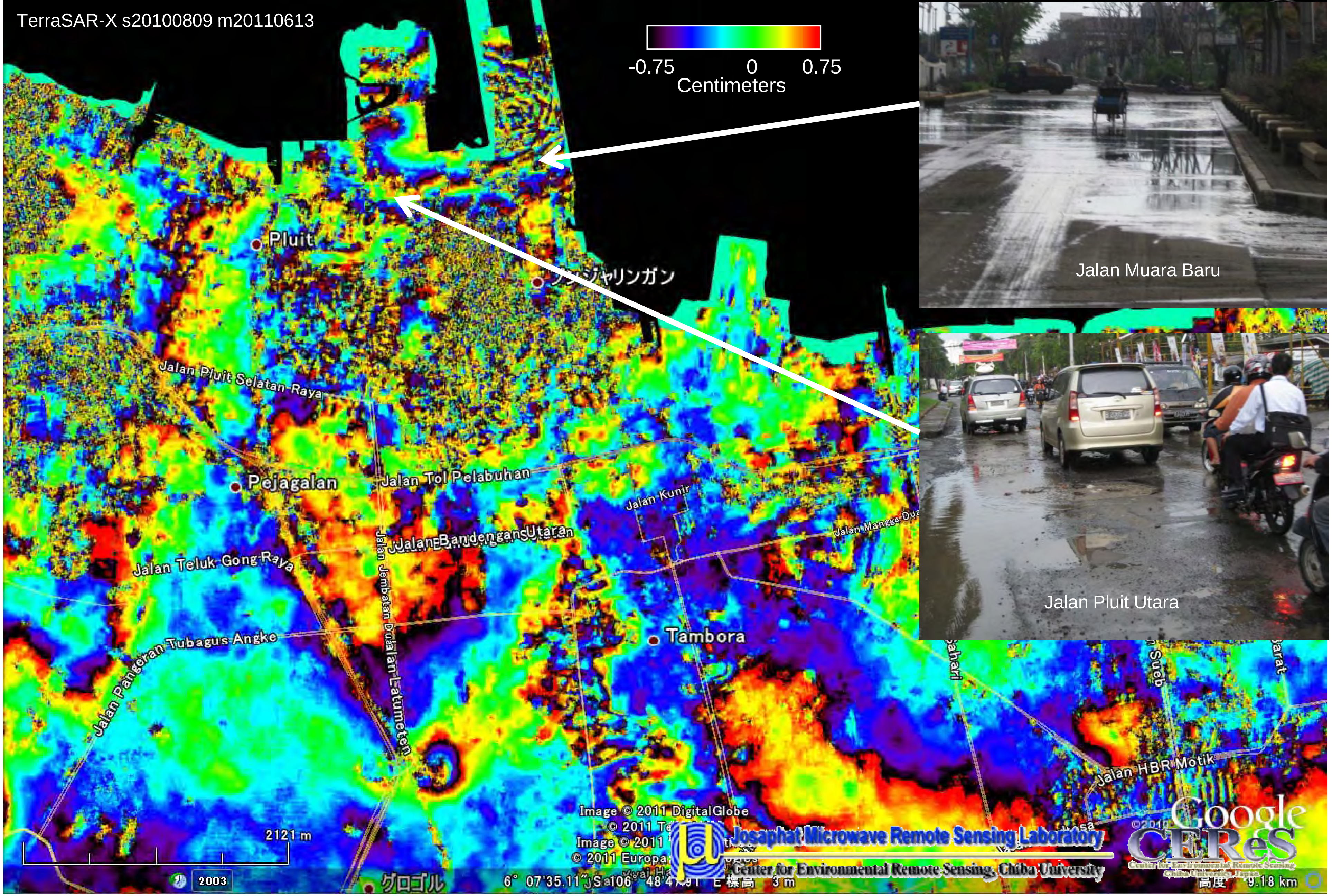


# ALOS PALSAR & TerraSAR-X ： Penjaringan

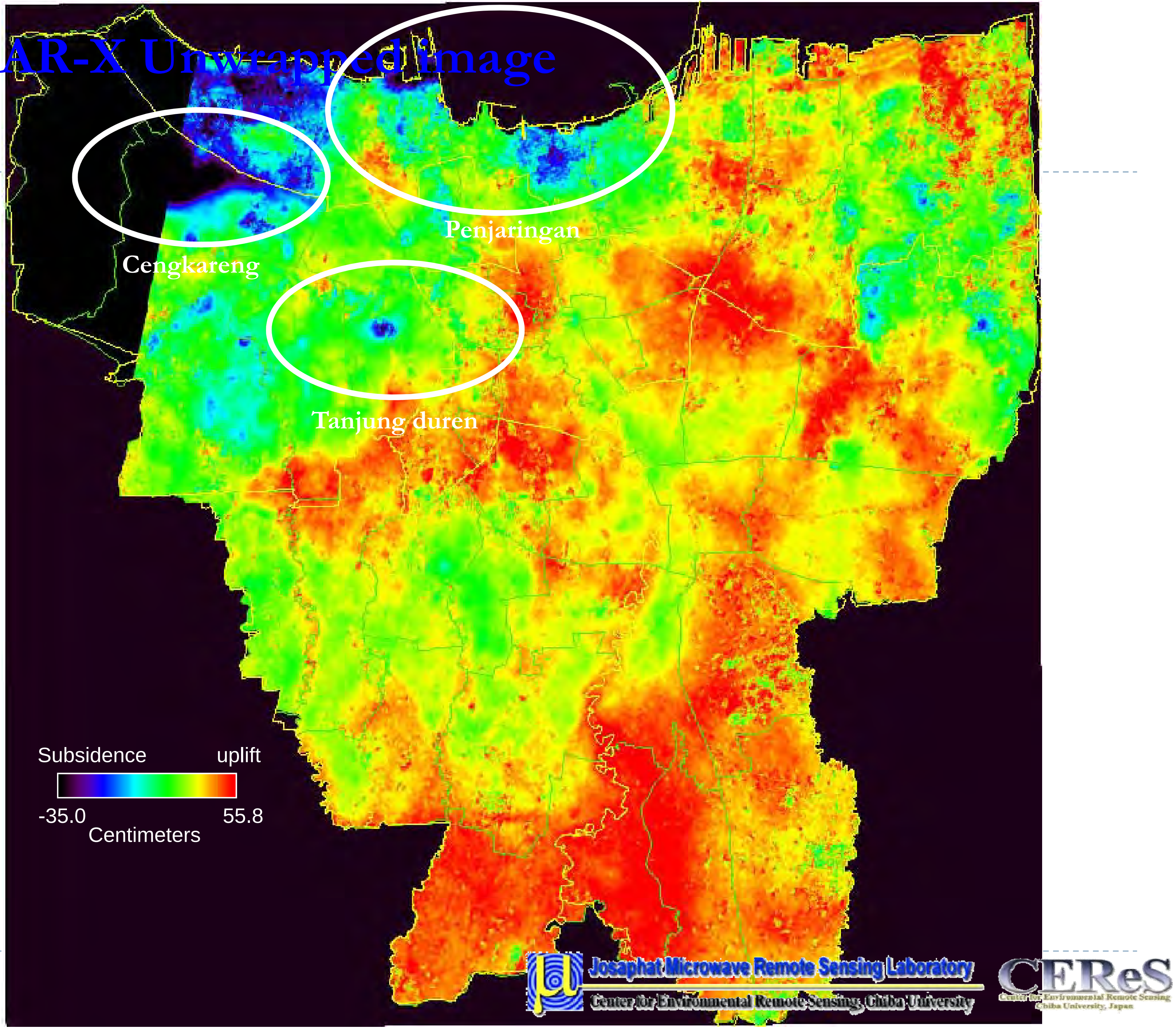
# ALOS PALSAR & TerraSAR-X ： Penjaringan



# ALOS PALSAR & TerraSAR-X ： Penjaringan

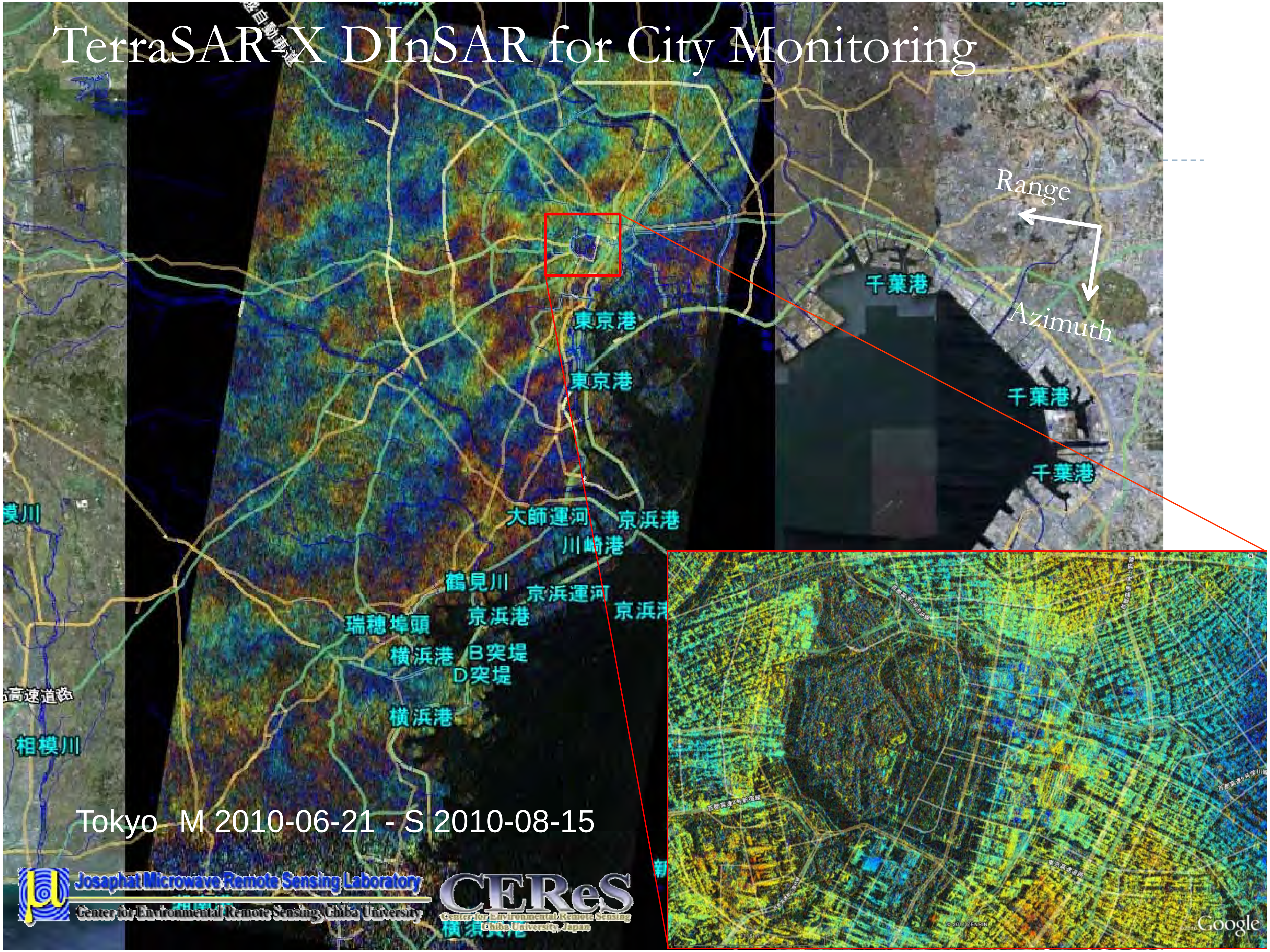


# TerraSAR-X Unwrapped image



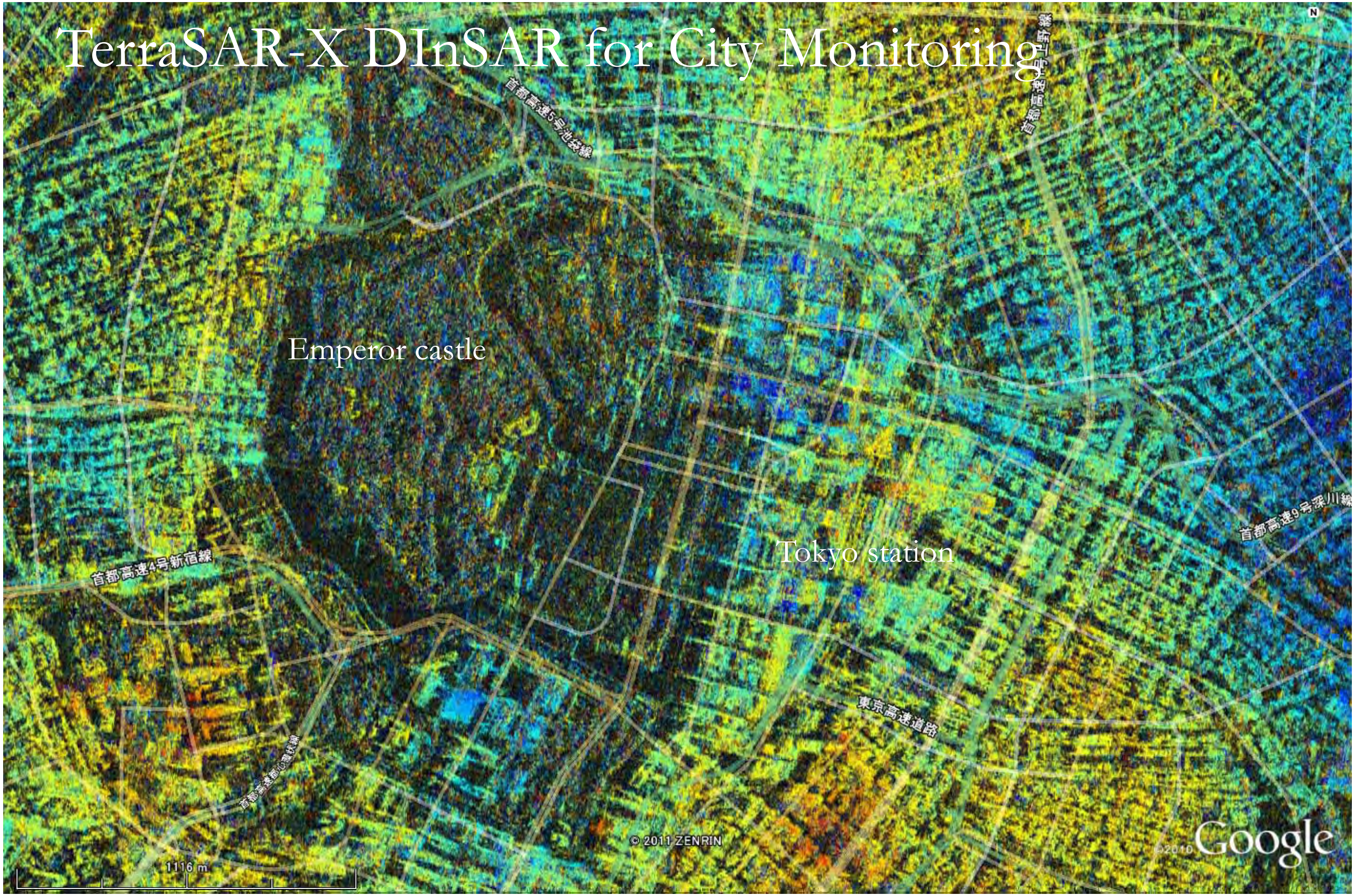
# Other disaster monitoring using DInSAR : Subsidence at Tokyo Megapolitan

# TerraSAR-X DInSAR for City Monitoring

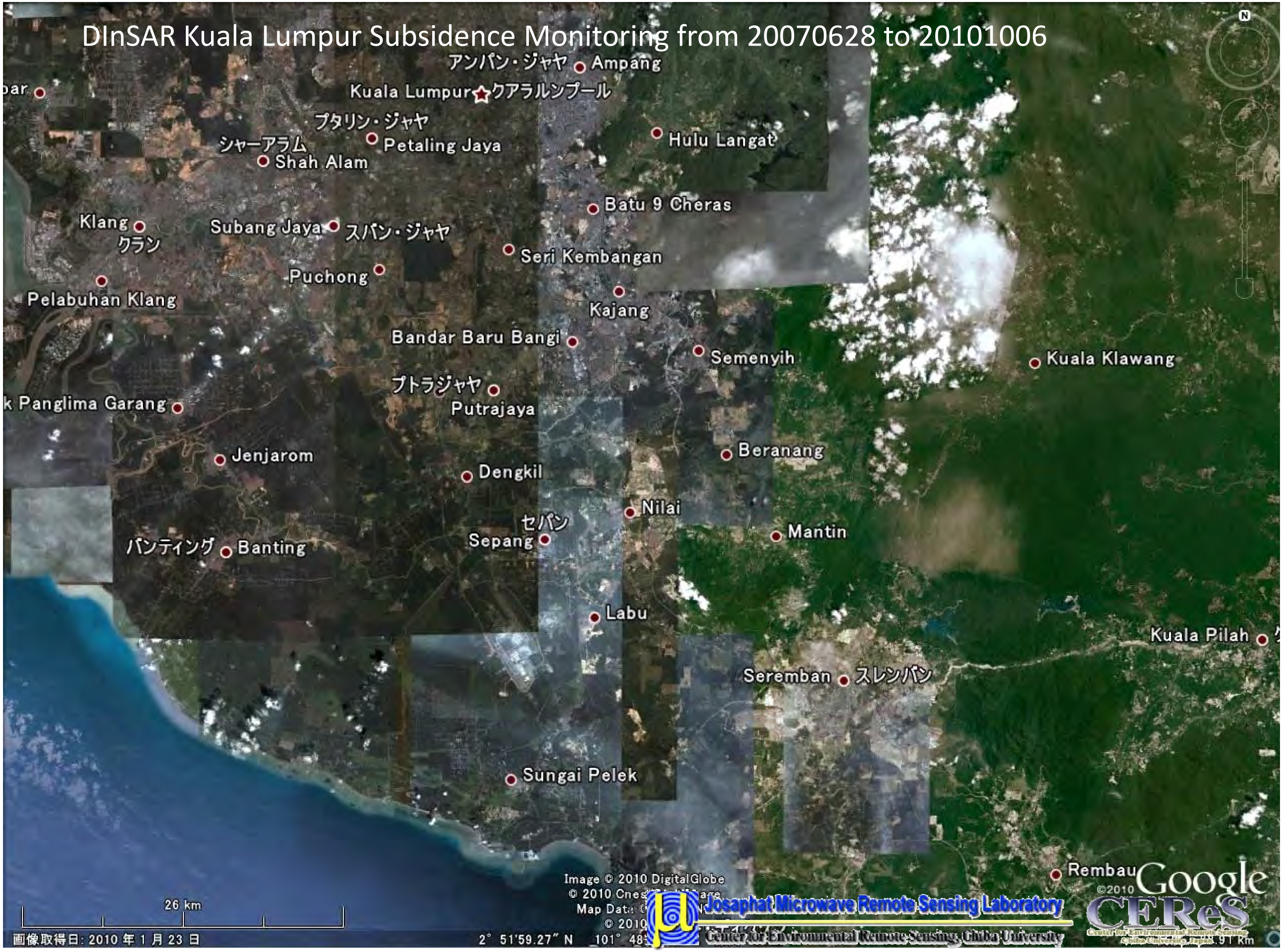


# TerraSAR-X DInSAR for City Monitoring

# TerraSAR-X DInSAR for City Monitoring



# Other disaster monitoring using DInSAR : Active Fault at Kualalumpur, Malaysia


DInSAR Kuala Lumpur Subsidence Monitoring from 20070628 to 20101006
アンパン・ジャヤ
Ampang
Kuala Lumpur
クアラルンプール
プタリン・ジャヤ
Petaling Jaya
シャーアラム
Shah Alam
Hulu Langat
Batu 9 Cheras
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クラン
Subang Jaya
スバン・ジャヤ
Seri Kembangan
Puchong
Pelabuhan Klang
Kajang
Bandar Baru Bangi
Semenyih
Kuala Klawang
プトラジャヤ
Putrajaya
Panglima Garang
Jenjarom
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Sepang
Mantin
バンティング
Banting
Labu
Kuala Pilah
Seremban
スレンバン
Sungai Pelek
Rembau
Image © 2010 DigitalGlobe
26 km
画像取得日: 2010 年 1 月 23 日
2° 51'59.27" N
Josaphat Microwave Remote Sensing Laboratory
Center for Environmental Remote Sensing, Chiba University
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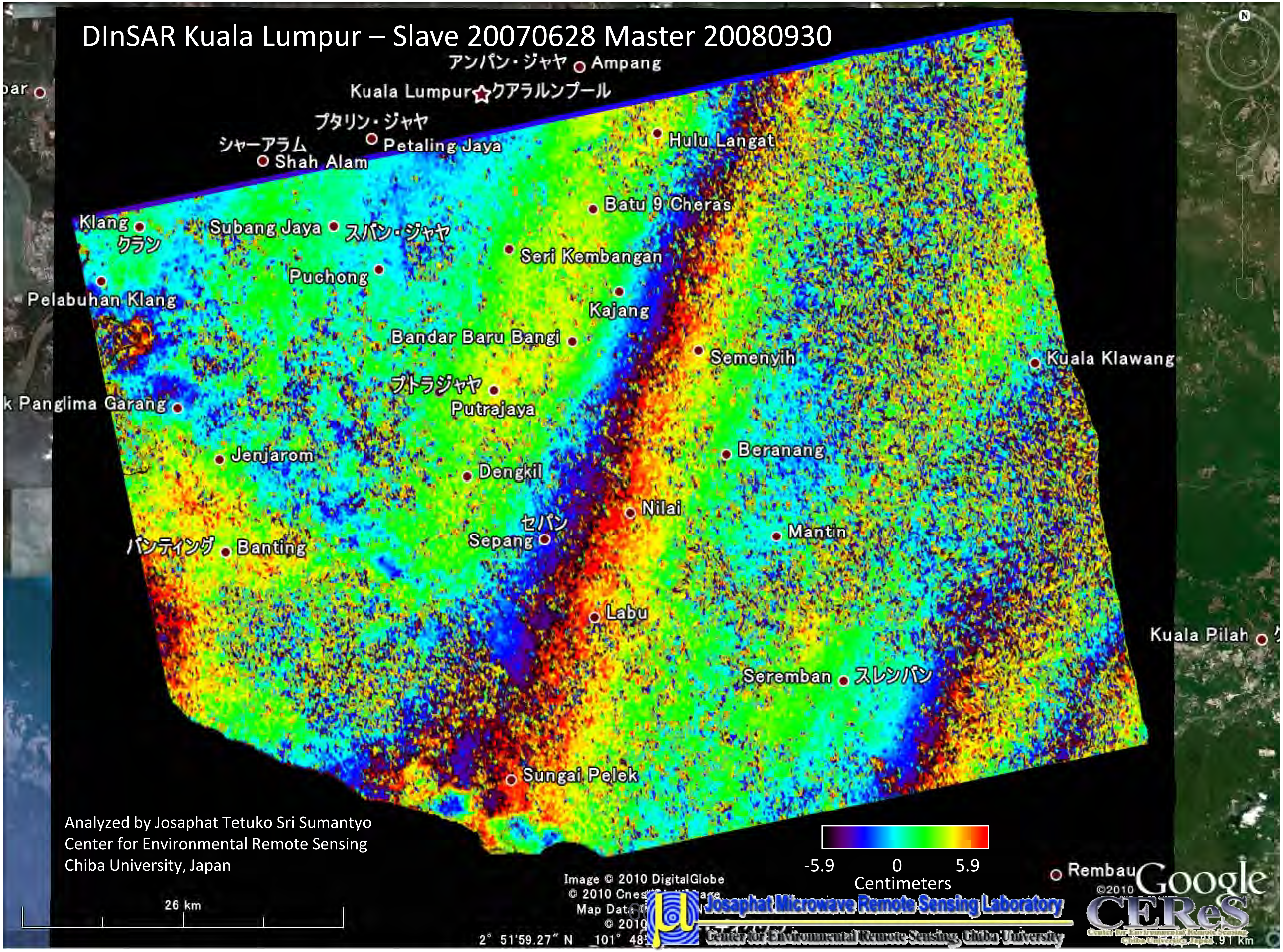
DInSAR Kuala Lumpur – Slave 20070628 Master 20080930
アンパン・ジャヤ Ampang
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Center for Environmental Remote Sensing
Chiba University, Japan
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26 km
Image © 2010 DigitalGlobe
Josaphat Microwave Remote Sensing Laboratory
Center for Environmental Remote Sensing, Chiba University
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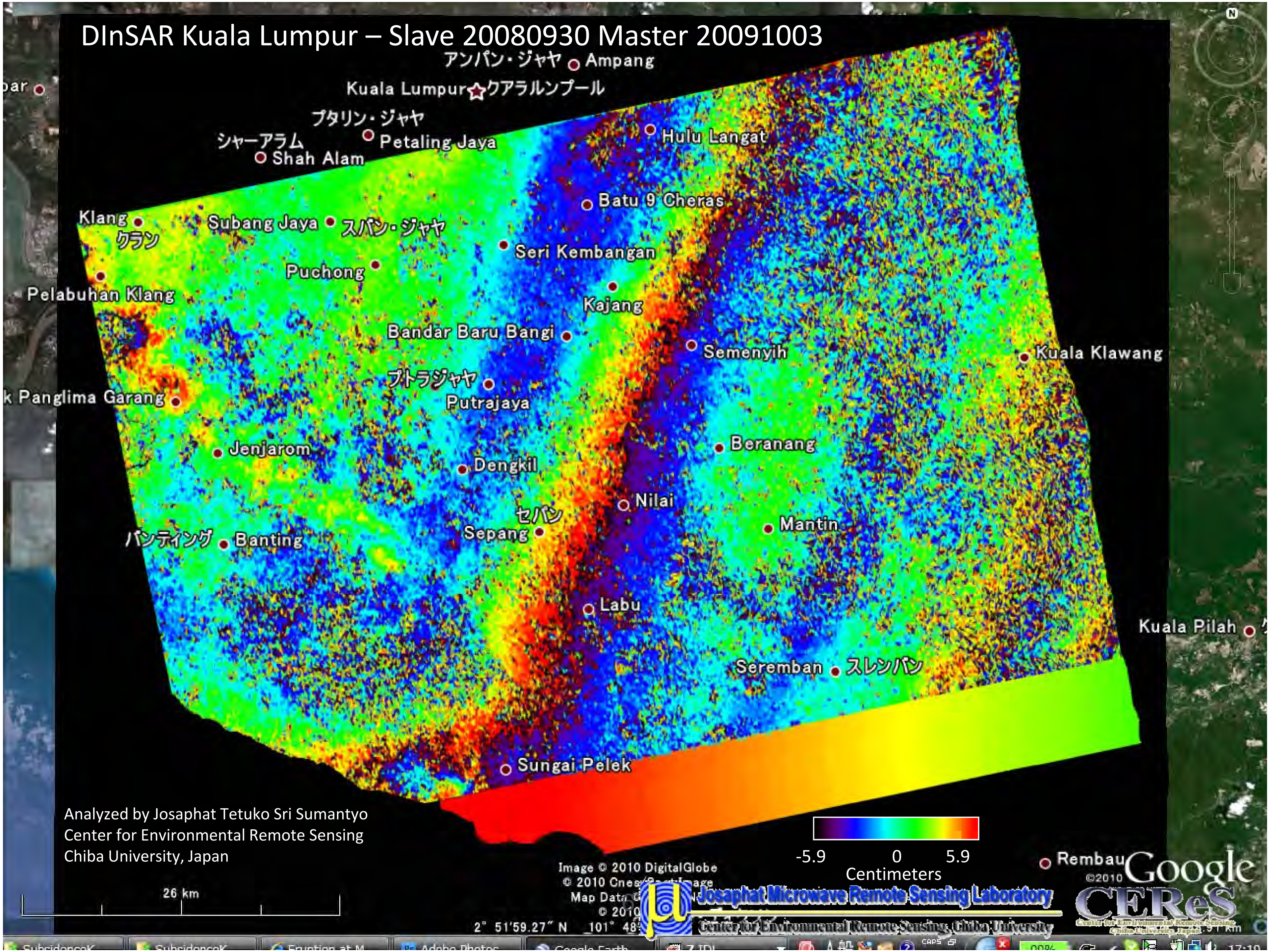
2° 51'59.27" N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アンパン・ジャヤ Ampang
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# Summary and Future Research

- Introduction of our research on CP-SAR onboard Microsatellite and Unmanned Aerial Vehicle (UAV)
- Introduction of our SAR image processing results for disaster monitoring
- We plan to hold some ground test using our UAV SAR in Japan, Malaysia and Indonesia in the near future.


## Acknowledgments

JAXA SIGMA-SAR software was used to generate the interferograms used in the present study.


Articles related CP-SAR UAV and Microsatellite :


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# Thank you for your attentions !

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