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.)

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. 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

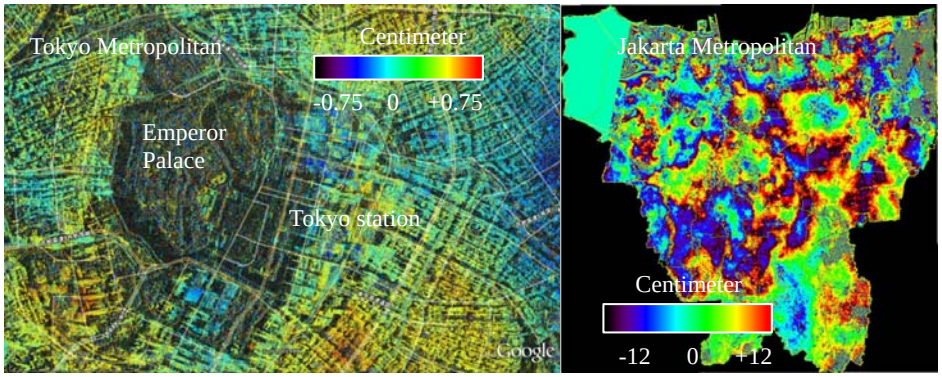
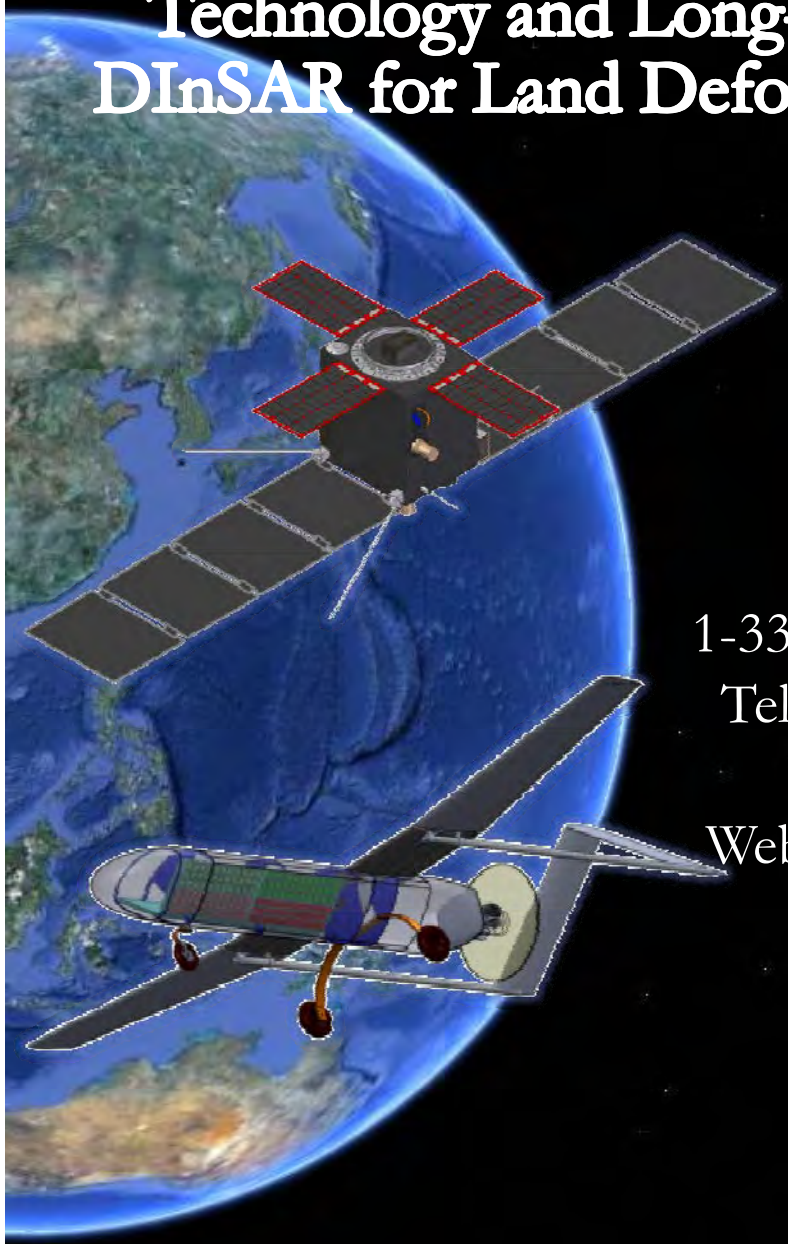


図 2. TerraSAR-X による東京都とジャカルタ市内における地盤沈下の観測

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

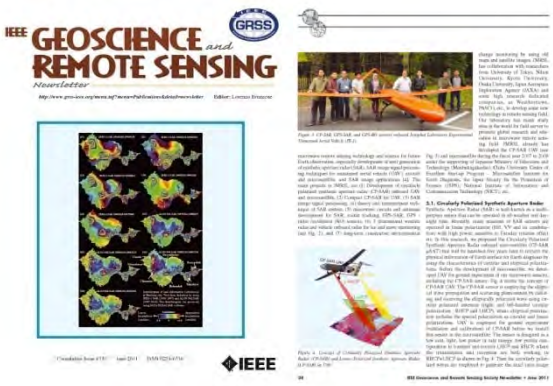
Center for Environmental Remote Sensing, Chiba University

CEReS

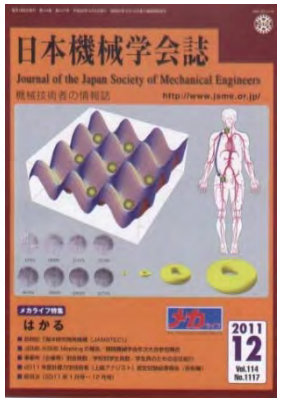
Contents :

- 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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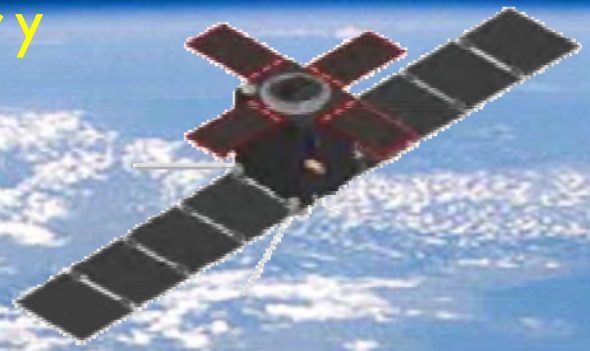
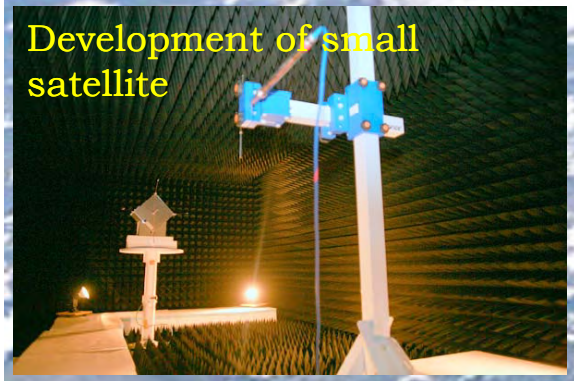
Josaphat laboratory

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.





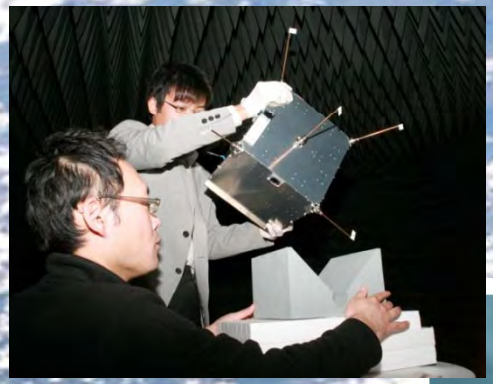
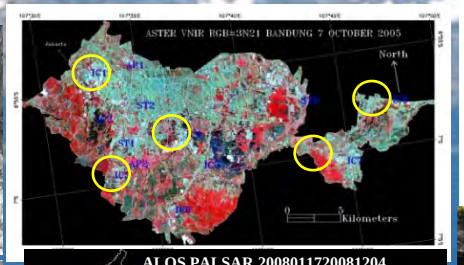
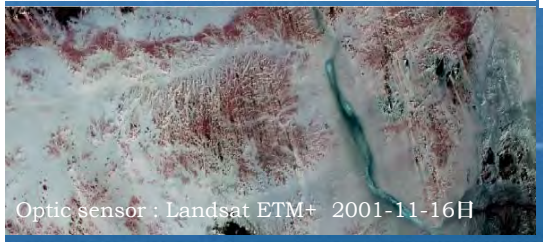
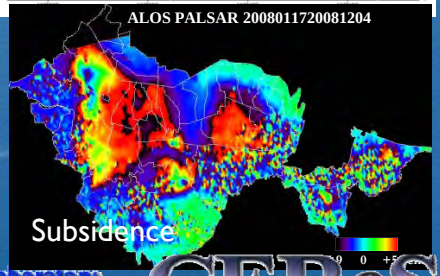
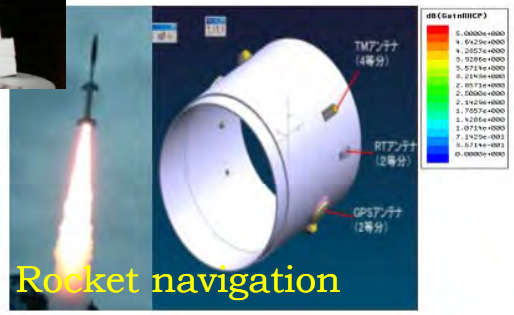


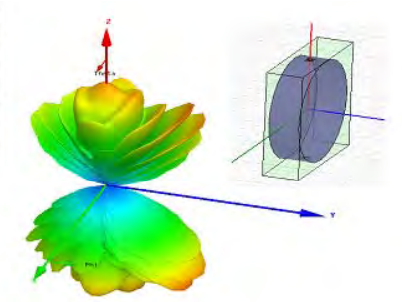
Image analysis

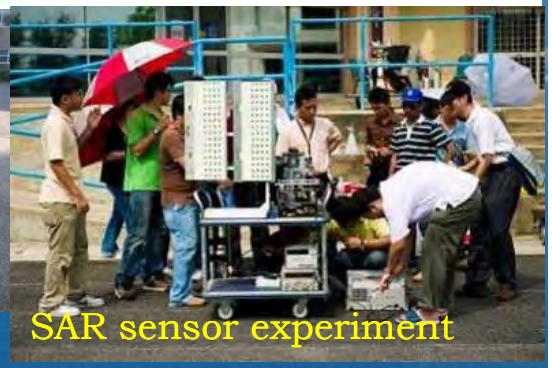












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Chiba University, Japan

Background

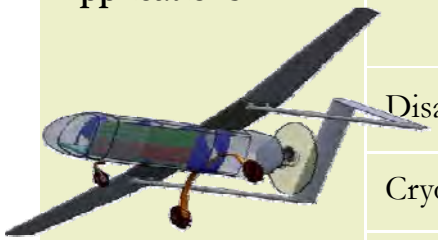
- Increasing full-polarimetric spaceborne SAR demand in the world.
- Circular Polarizations are effective for ionospheric Faraday rotation correction in low frequency (i.e. P band, L band) of spaceborne SAR data and some applications of Earth observation.
- Lack of SAR onboard microsatellite developers 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.

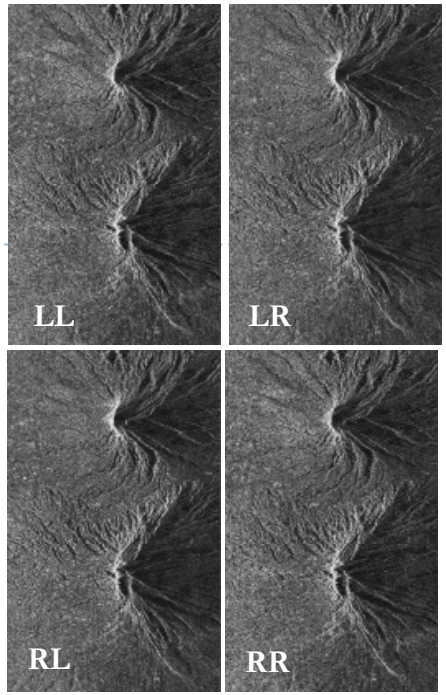
Objectives

- 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.

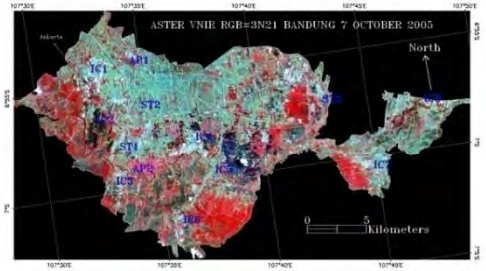
Target of CP-SAR onboard Microsatellite Mission

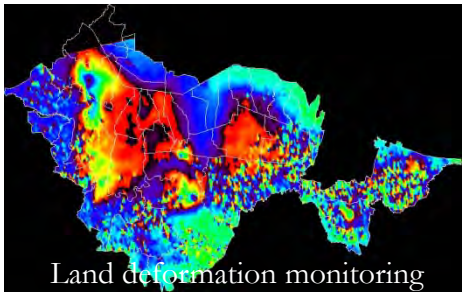
	Items	Details
Basic experiment	Scattering mechanism of circularly polarized microwave	Scattering mechanism from vegetations, cryosphere, soil and rocks, desert etc
	Interferometry	• Linear vs Circular Polarization Interferometry SAR • DEM extraction by CP wave
	Axial ratio image (ARI)	Vegetation, geologic, cryosphere etc mapping by using ARI
Applications	Landcover mapping	• Forest – non forest area classification • Tree height estimation • Paddy field extraction • Wetland extraction • Mangrove area mapping • 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



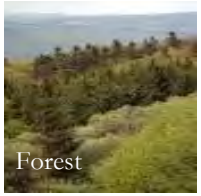


Circular Polarimetric SAR





Differential Interferometric SAR



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Josaphat Laboratory Experimental Unmanned Aerial Vehicle (JX-1)

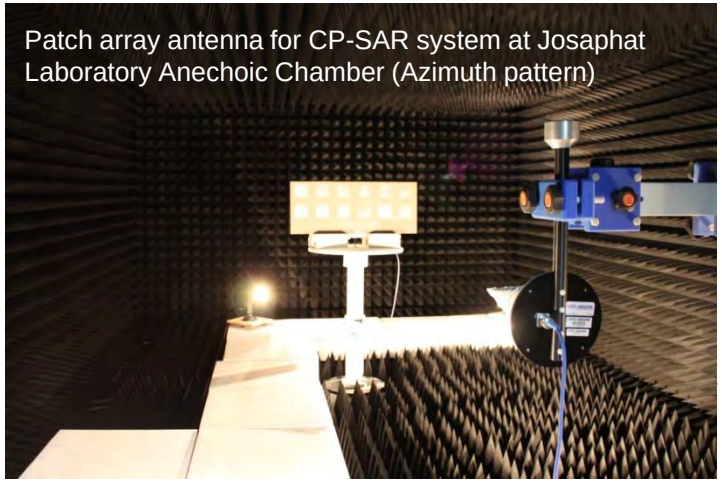
Weight of JX-1 Parts

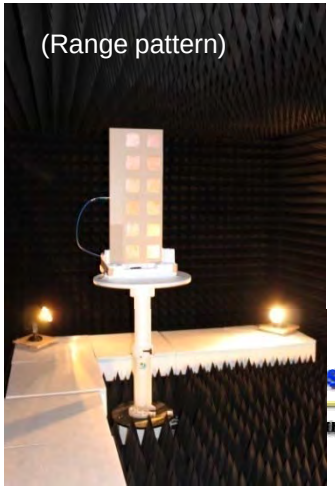
Items	Weight
Main body (including battery, tank etc)	48.0
Centre / main wing 1 unit	16.0
Wing (2 unit x @ 10 kg)	20.0
Ladder (2 unit x @ 7 kg)	14.0
Other instrument (bow etc)	7.5
Gasoline (20 liters)	16.0
Payload (CP-SAR, camera etc)	25.0
Total	146.5

IMU : IMU440

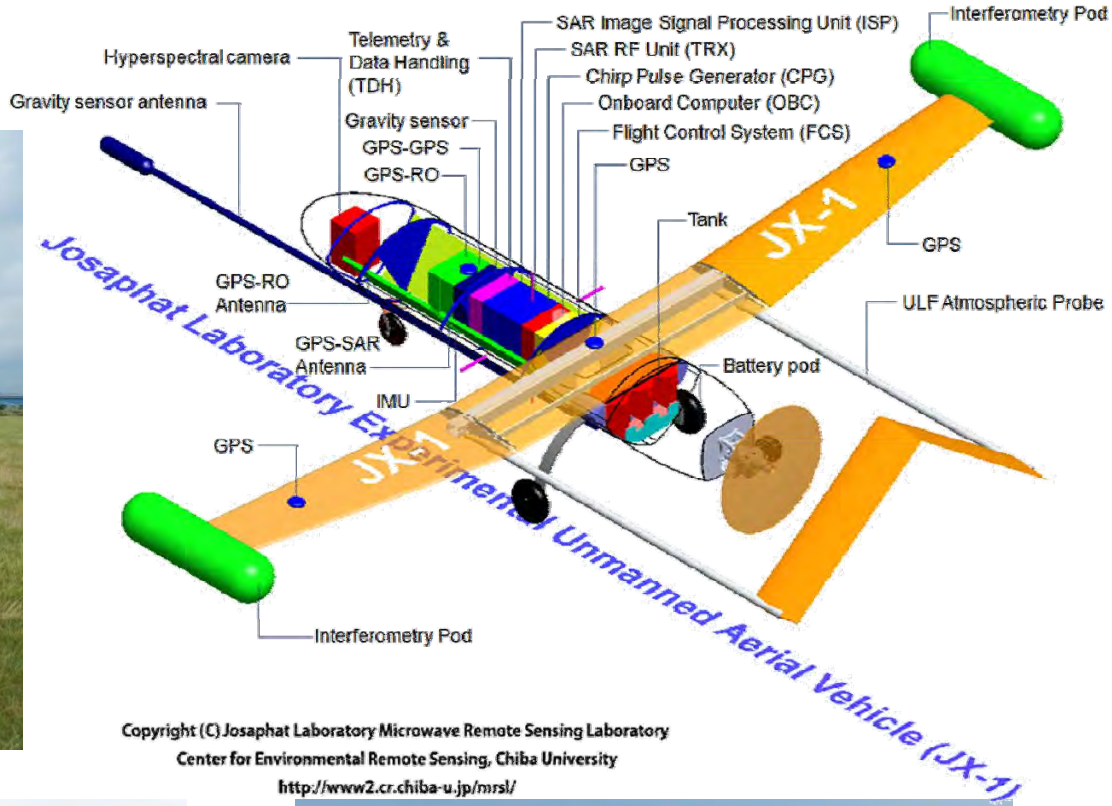
76 x 95 x 64 mm 540 gr

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 Experimental Unmanned Aerial Vehicle (JX-1) Detail Parts

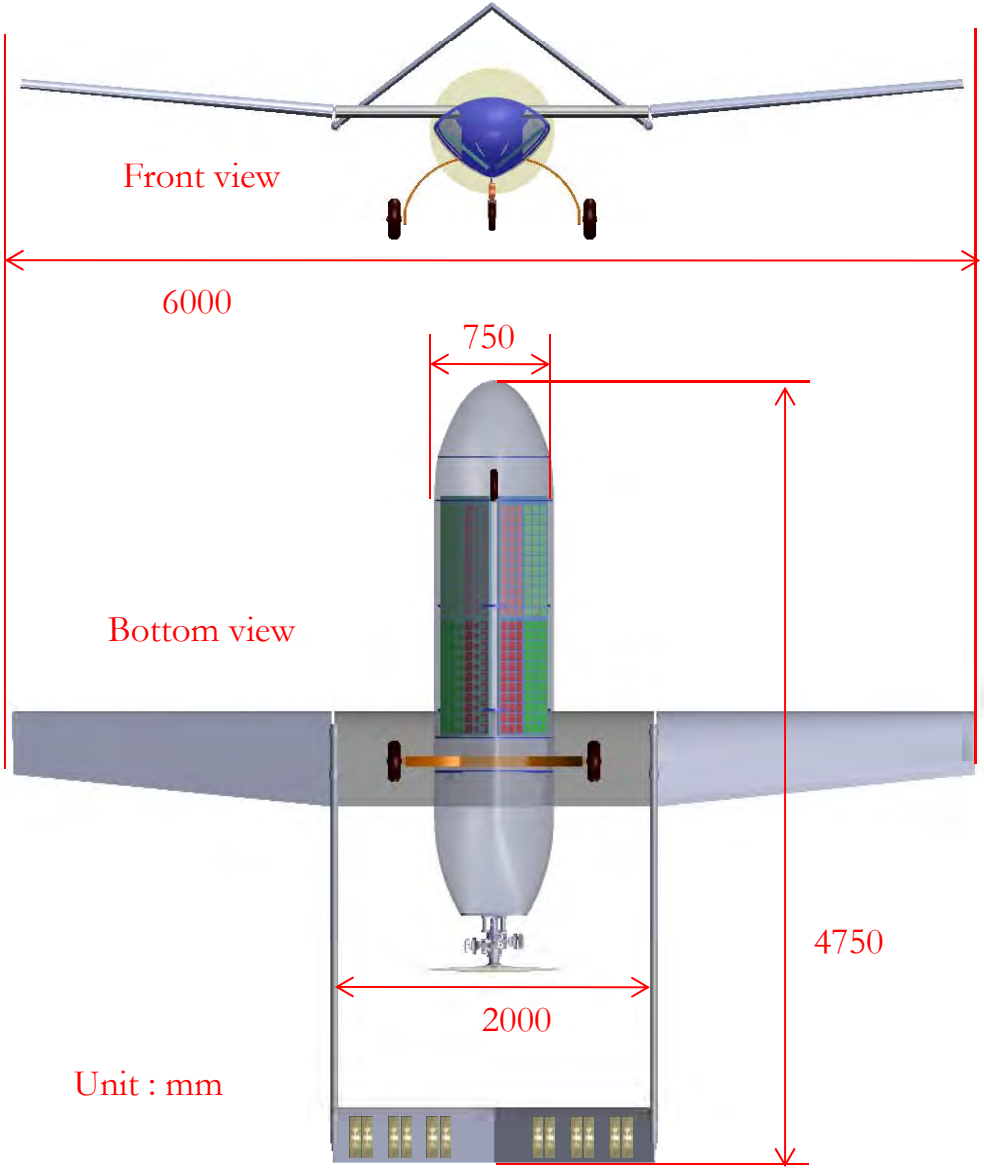


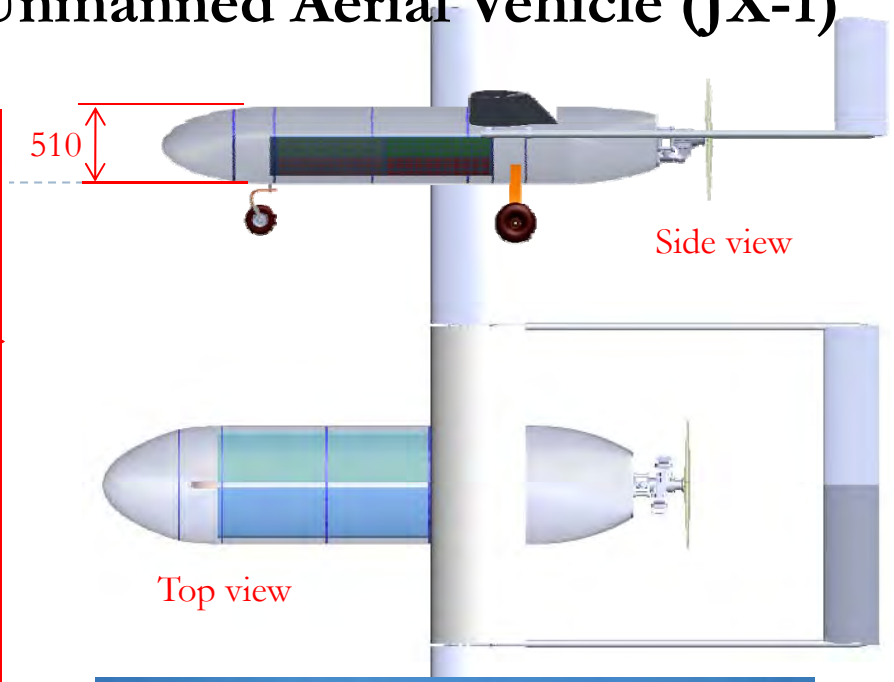
After successful First Flight of Josapat Laboratory Unmanned Aerial Vehicle (JX-1) at Fujikawa Airport on 7 June 2012

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

First Flight, Fujikawa Airfield, 7 June 2012

Josaphat Laboratory Experimental Unmanned Aerial Vehicle (JX-1)





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

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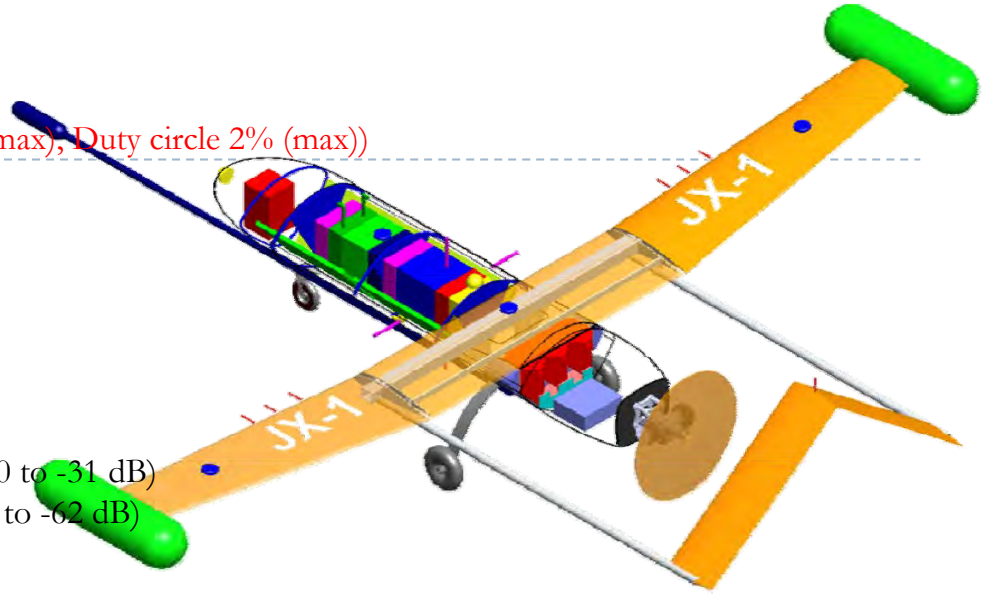
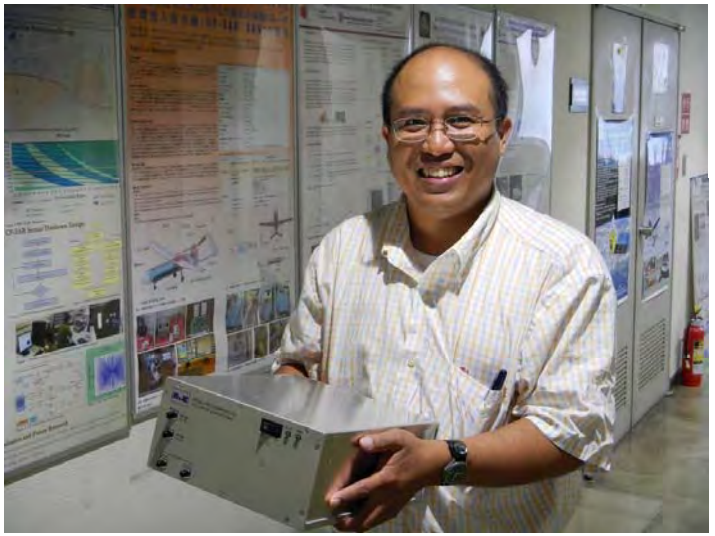
CP-SAR Specification for Unmanned Aerial Vehicle

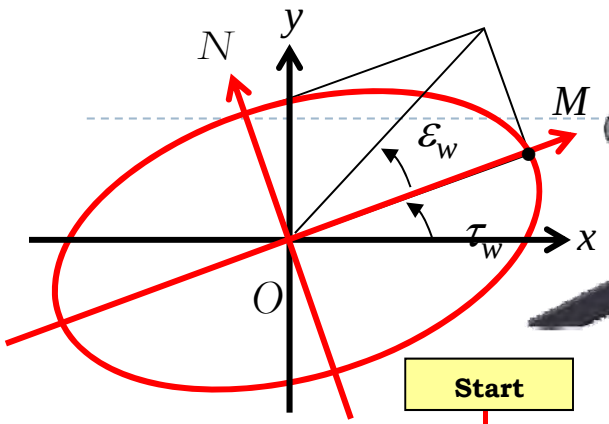
- Transmission frequency range : 1270 MHz ± 150 MHz
- Baseband range : DC to 150 MHz
- Pulse transmission output power : 50 W (Pulse width 10 μs (max), Duty circle 2% (max))
- Transmission system gain : + 47 dB (min)
- Receiver system gain : + 60 dB (min)
- Gain flatness : ± 1.5 dB (max)
- Receiver noise 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

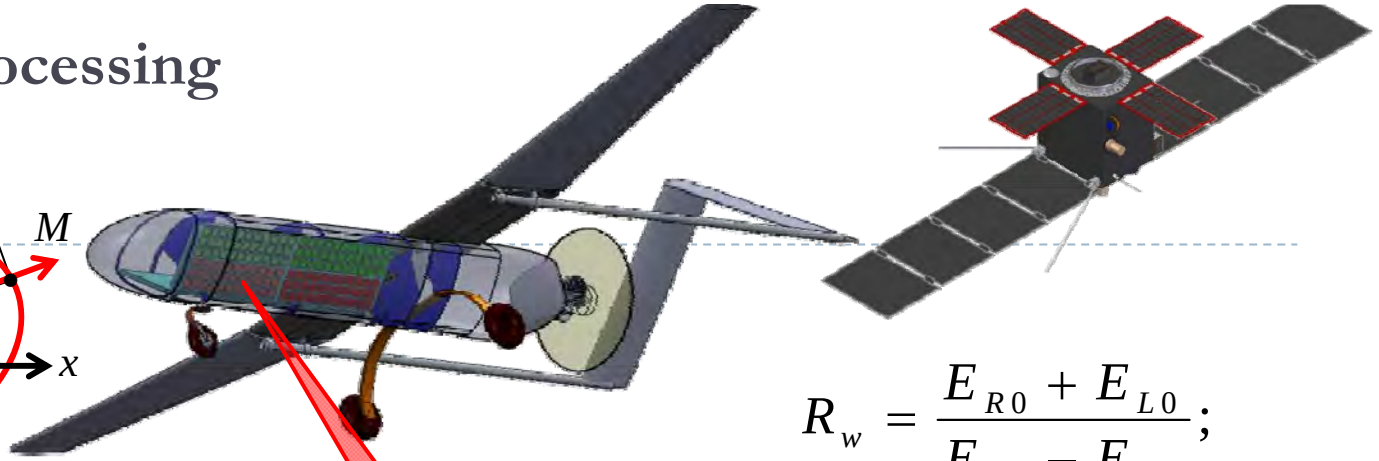




Compact L Band SAR System developed by Josaphat Laboratory

CP-SAR Image Processing



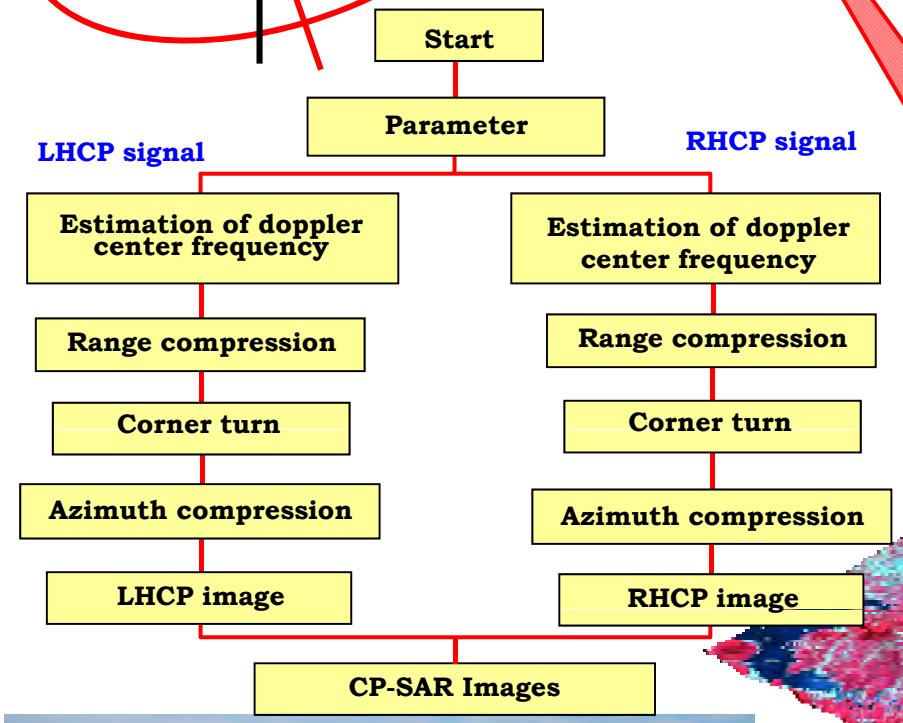


L-RHCP

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

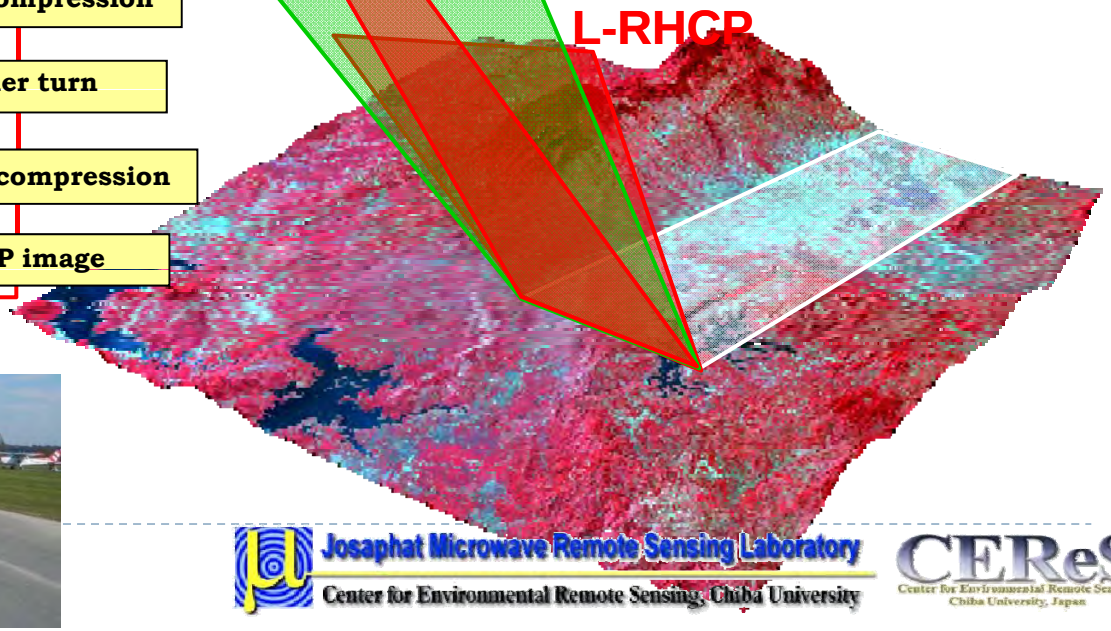
$$\varepsilon_w = \cot^{-1}(-R_w), \quad -45° \le \varepsilon \le 45°,$$

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



L-LHCP

L-RHCP



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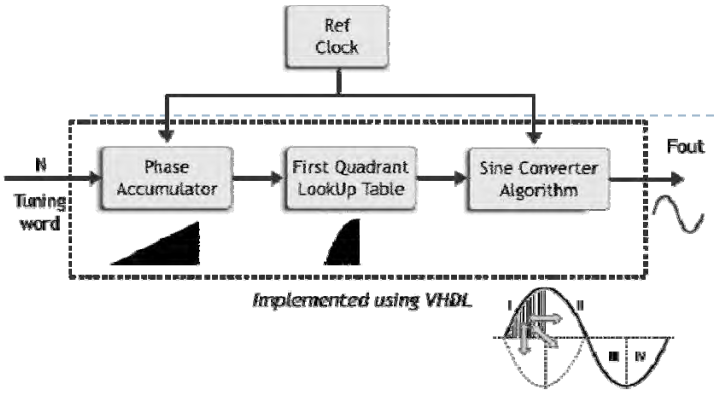
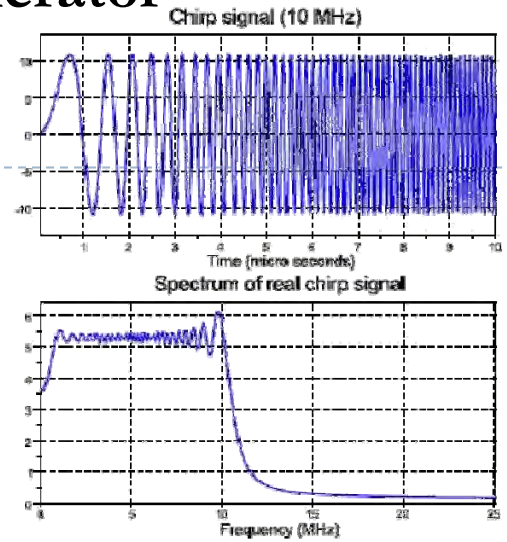
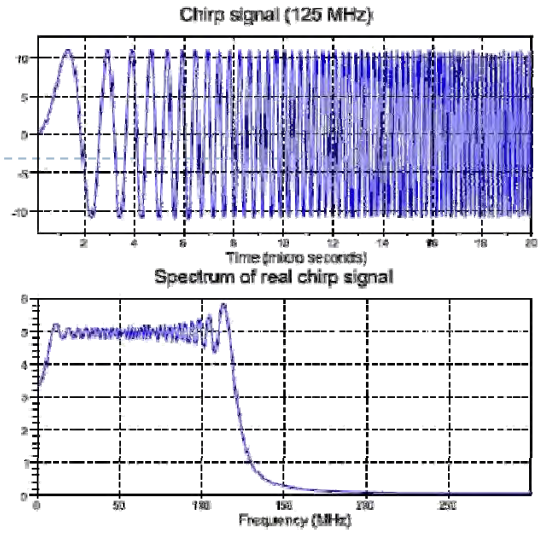
CP-SAR : Chirp Pulse Generator

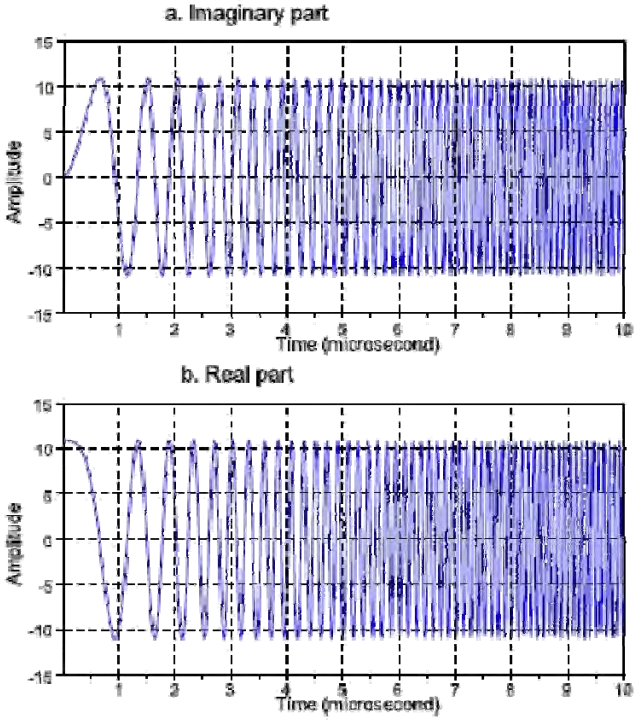
Microsatellite

Unmanned aerial vehicle



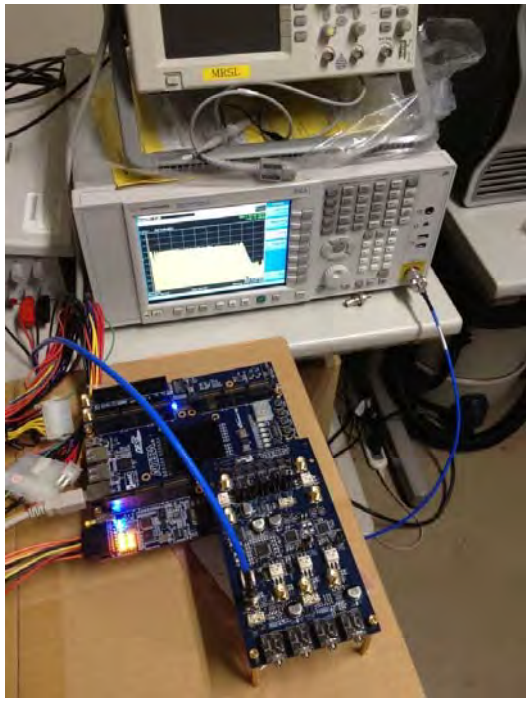






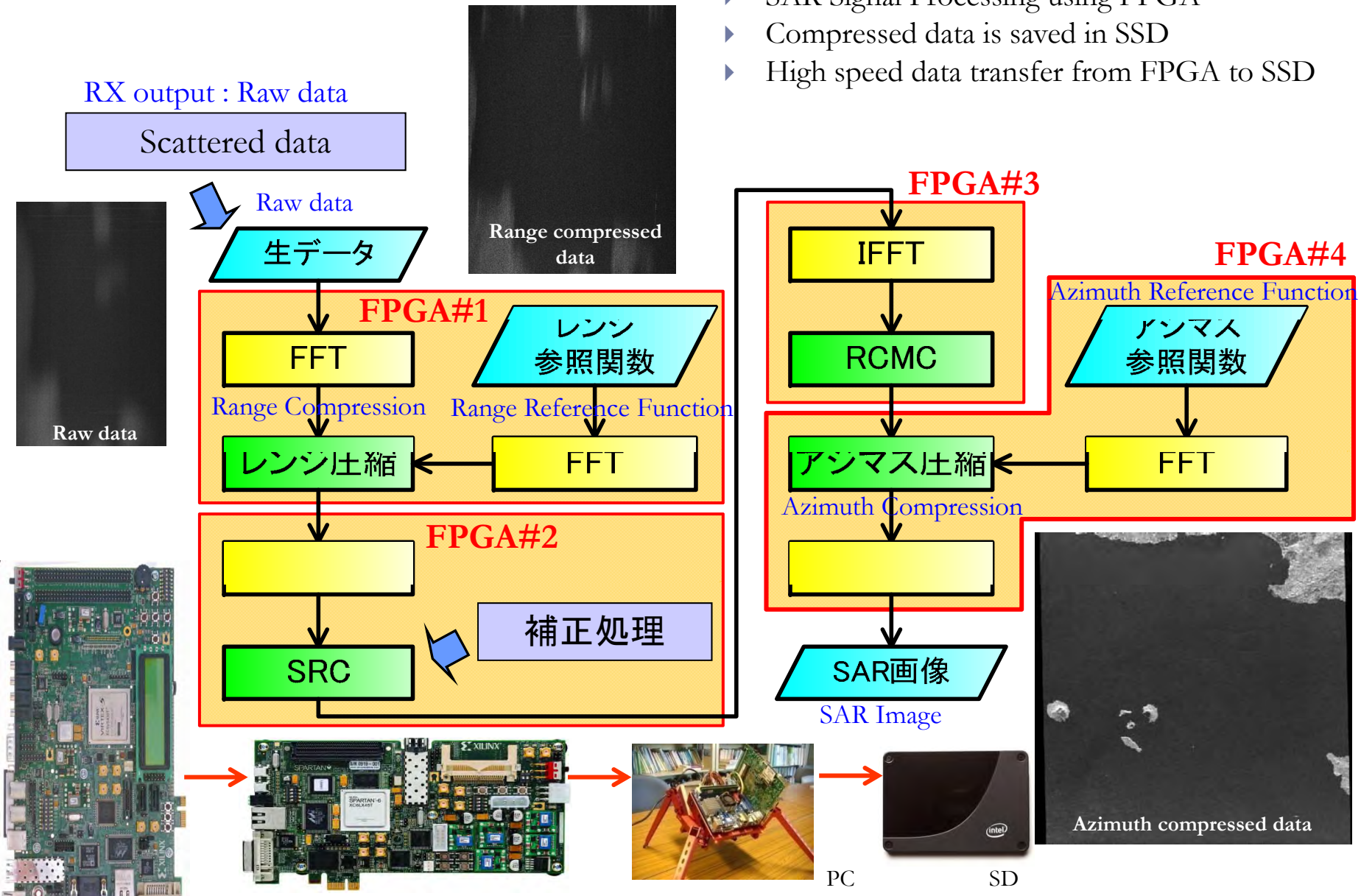
Quadrature (Q) → TX Input

Inphase (I) → TX Input



CP-SAR Image Processing

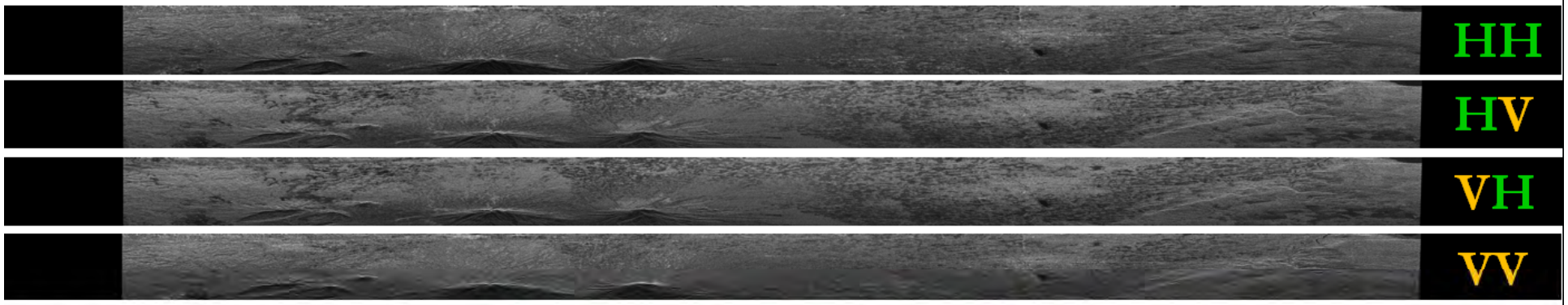
- SAR Signal Processing using FPGA
- Compressed data is saved in SSD
- High speed data transfer from FPGA to SSD



CP-SAR Image Processing : Single Look Complex

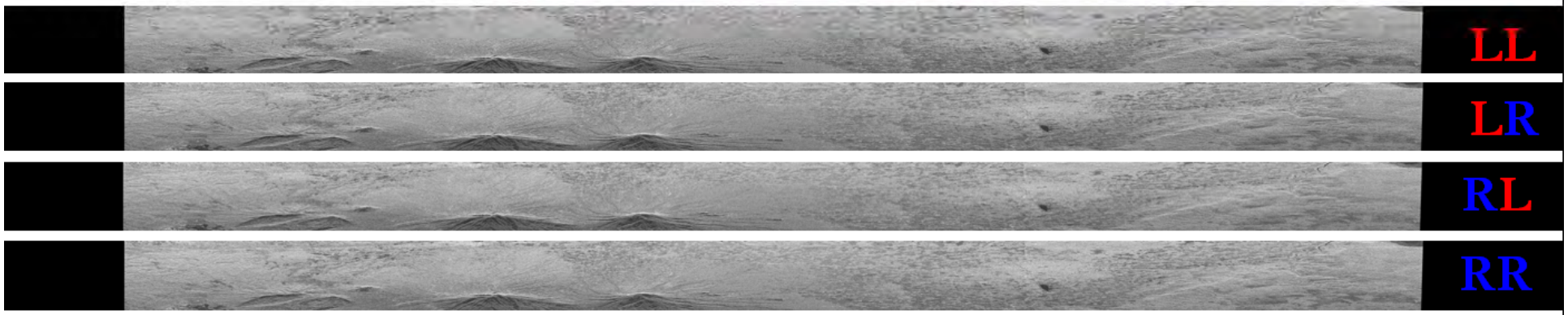
Linear Polarization

H : Horizontal Polarization V : Vertical Polarization



Circular Polarization

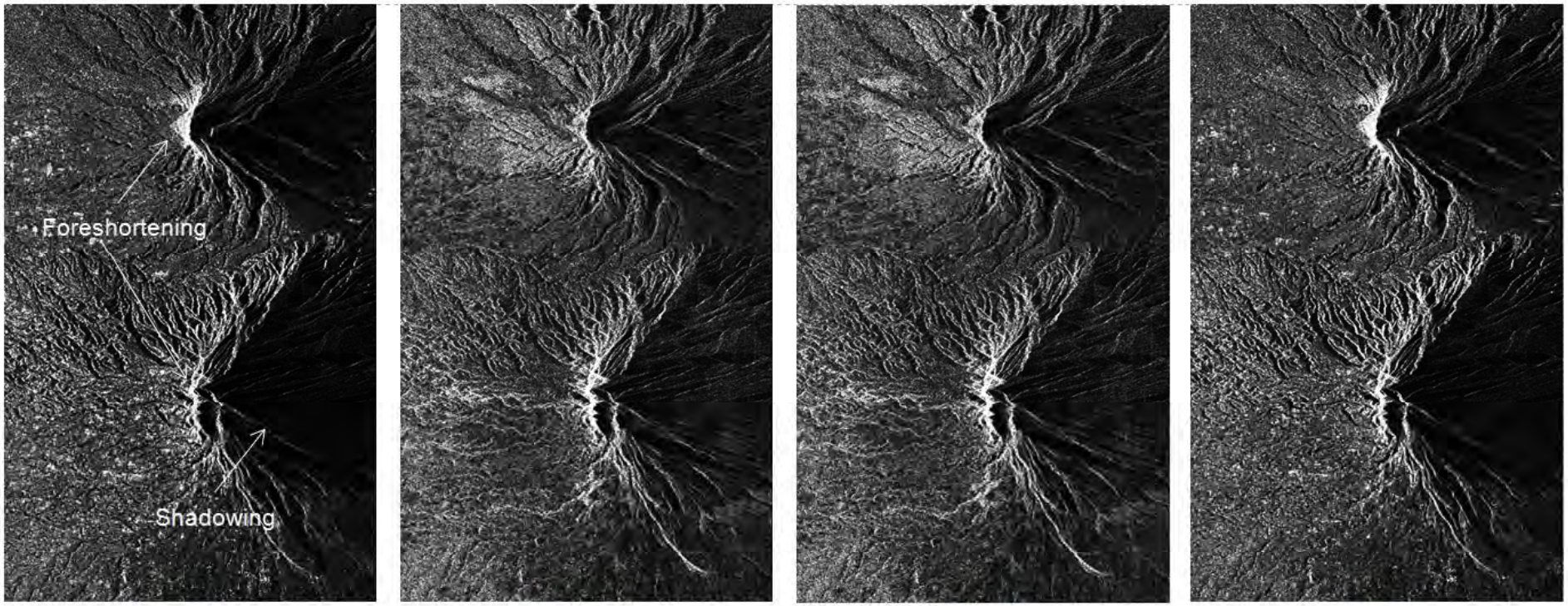
L : Left Handed Circular Polarization R : Right Handed Circular Polarization



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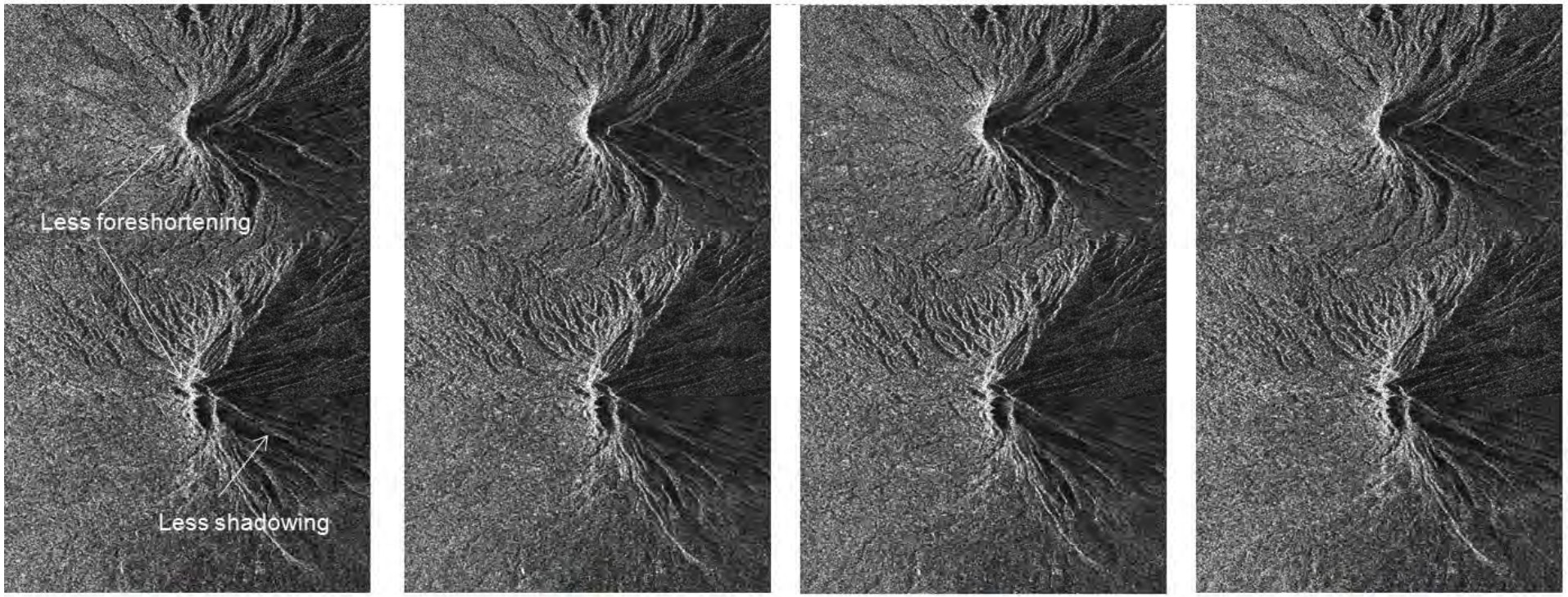
CP-SAR Image Processing (Linear vs Circular Polarized Images)

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

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

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 districts 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 :

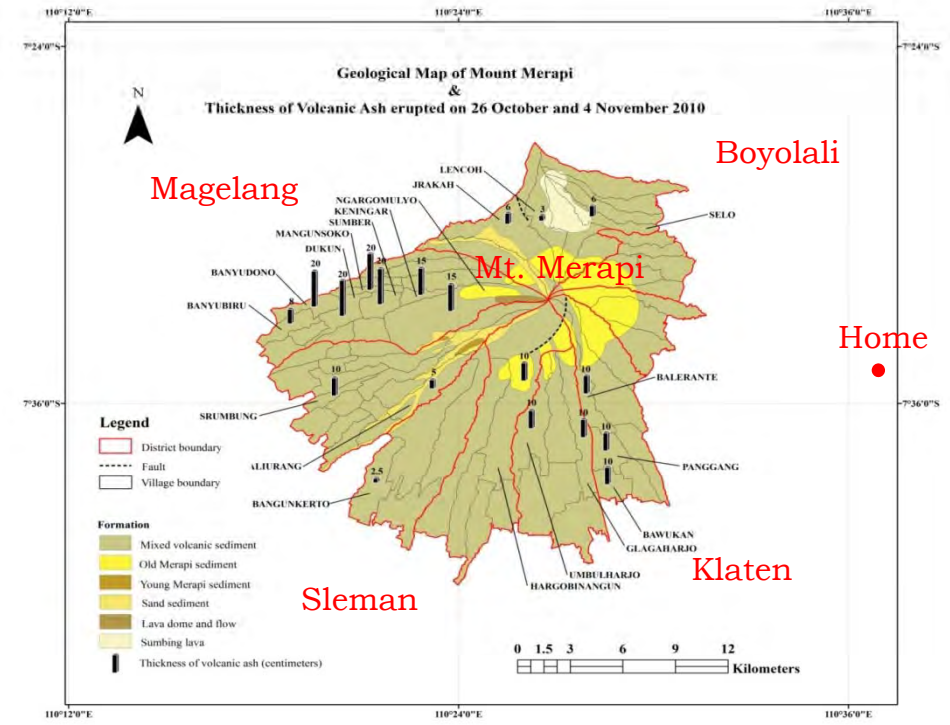
  Mt. Merapi is located on boundary of Central Java province and Yogyakarta provinces, Indonesia. This area is covered by Magelang, Boyolali, Klaten and Sleman districts.

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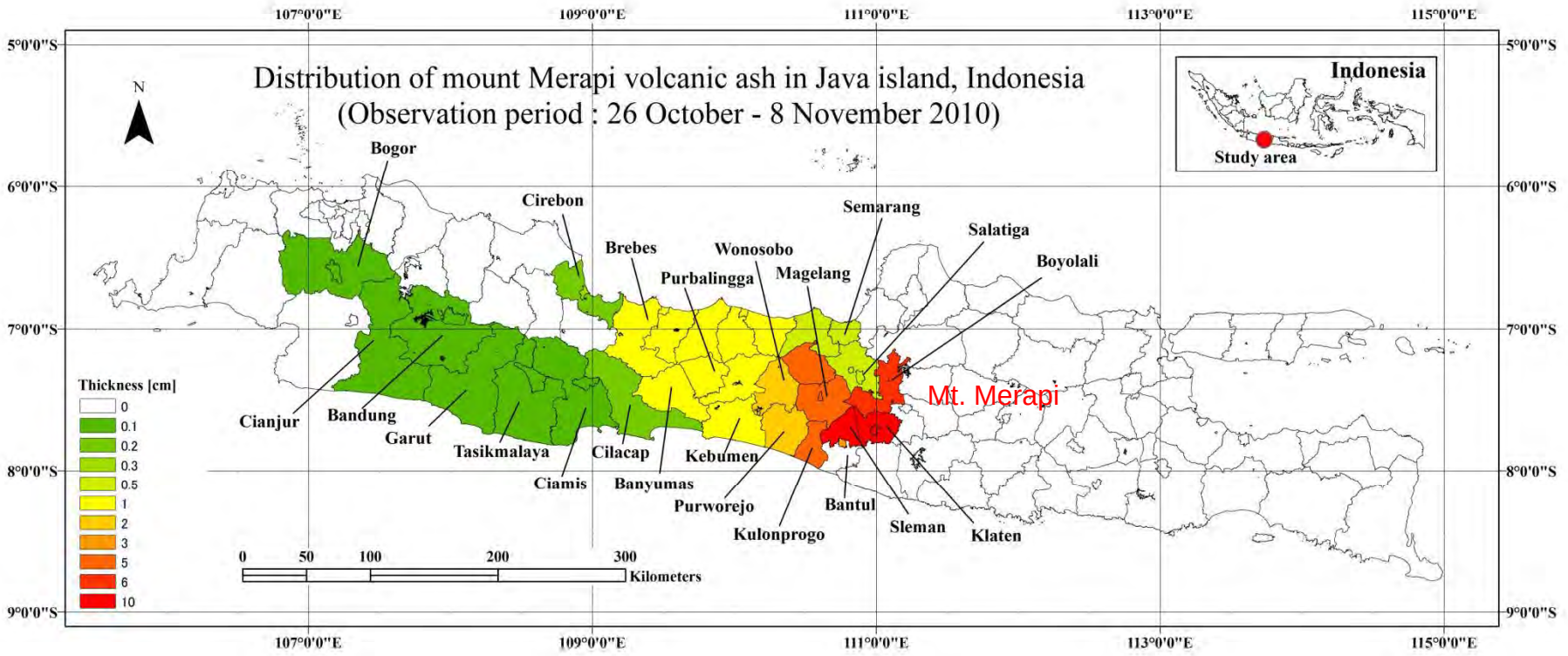
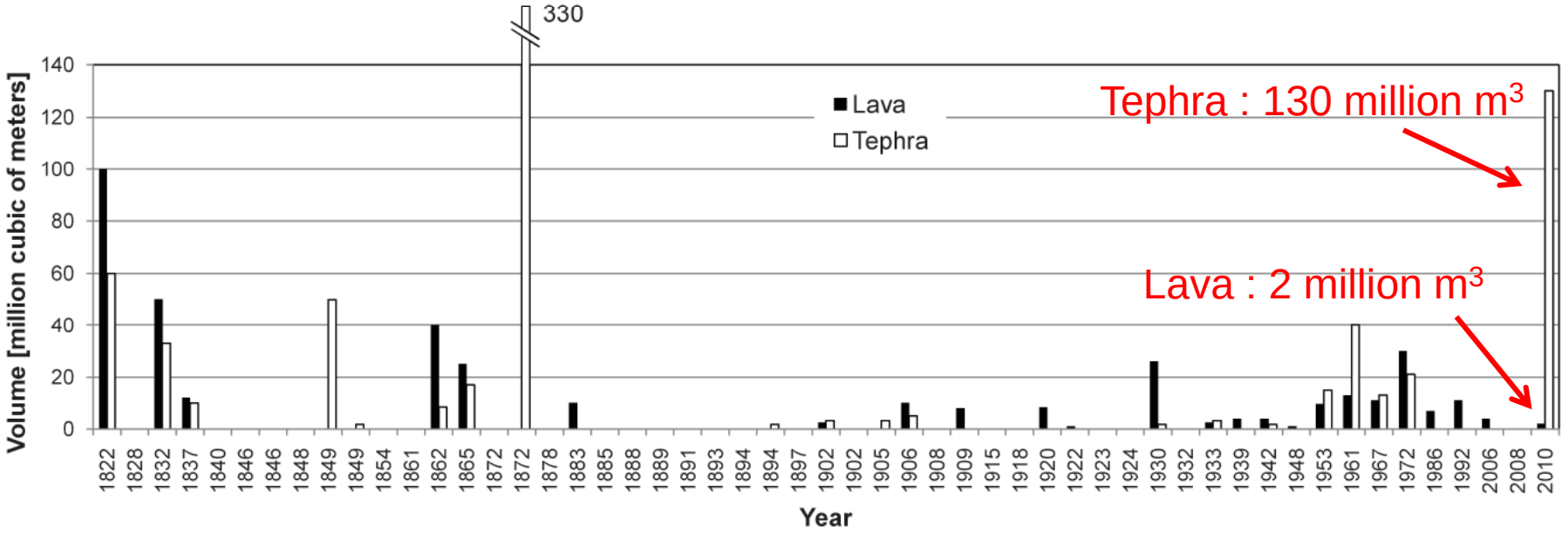
Study Area :
Ground data - Mt. Merapi Volcanic Ash Distribution



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

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

Cangkringan, Sleman

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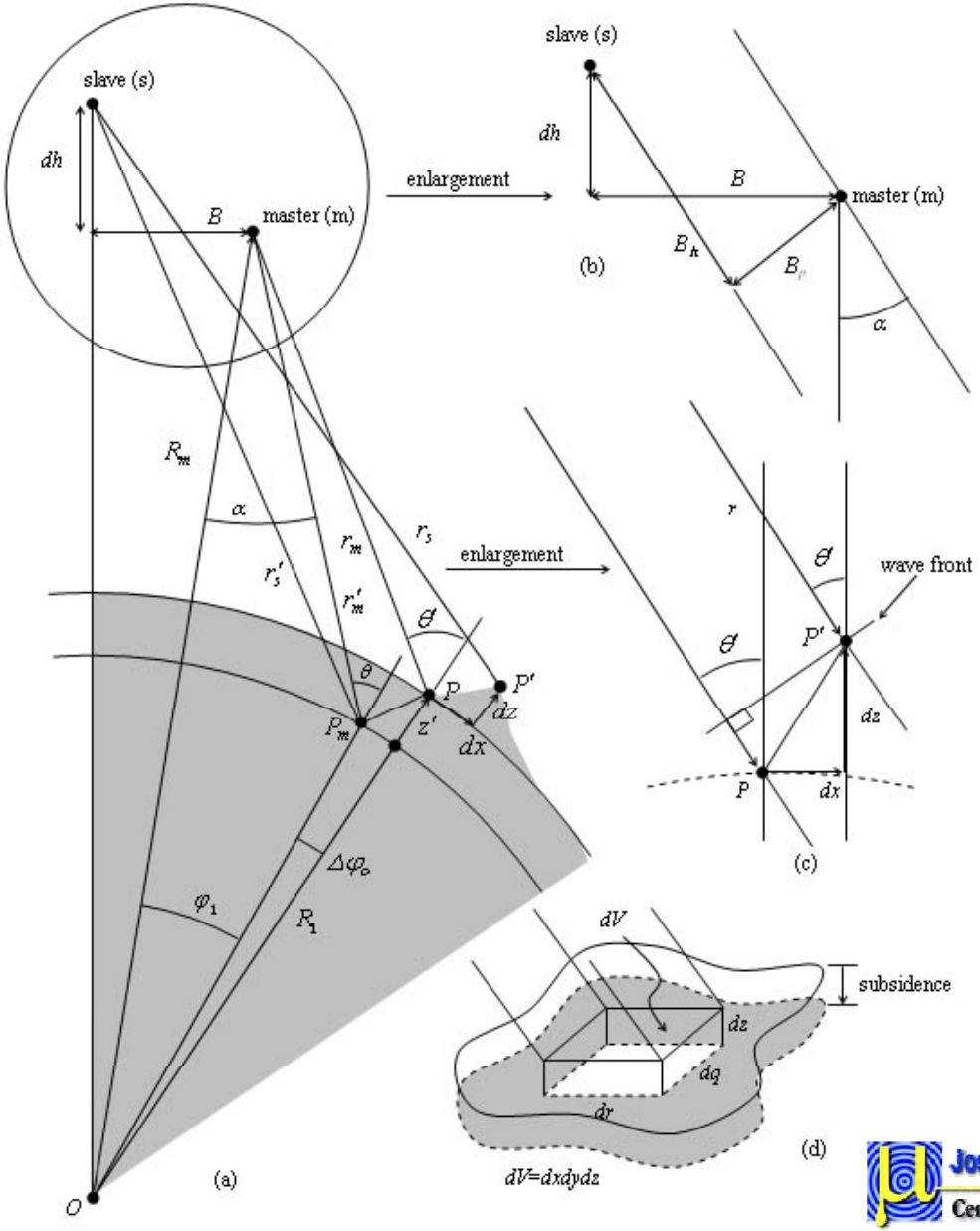
Differential Interferometric SAR (DInSAR) Technique



Phase difference ϕ :

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

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

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

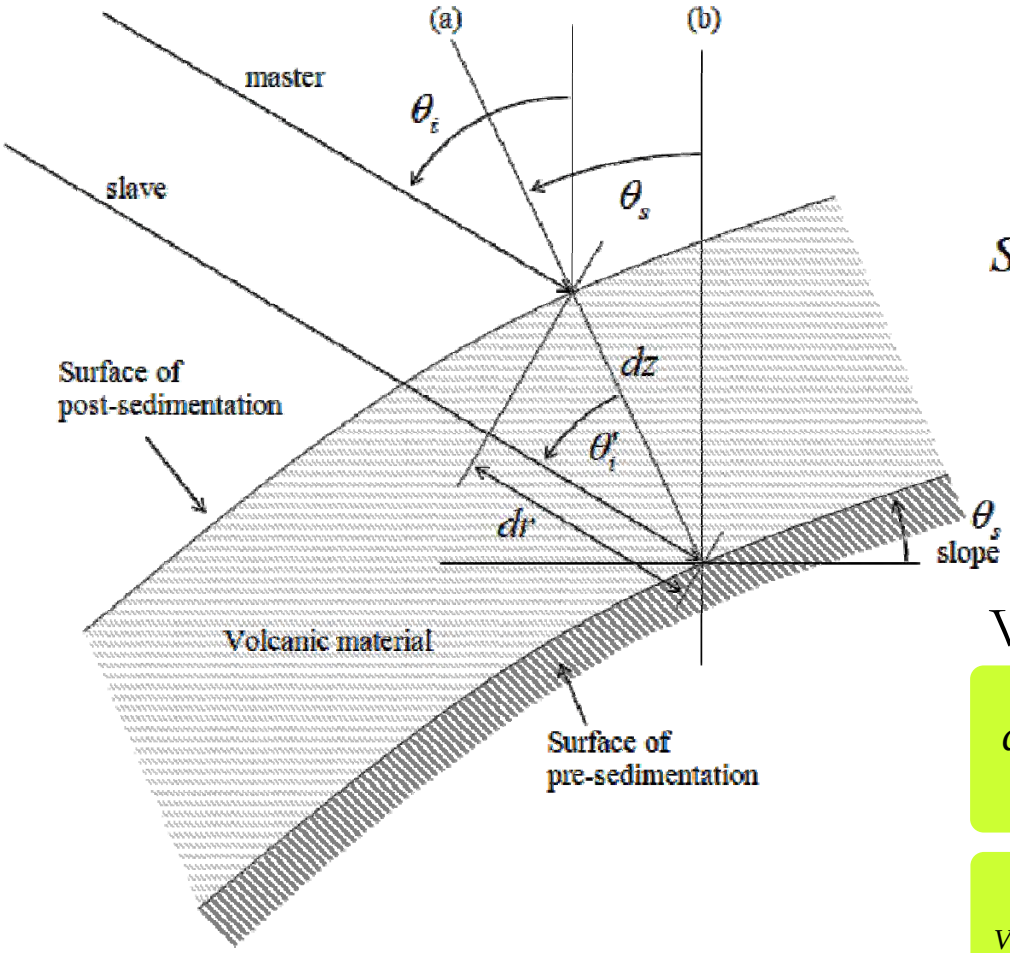
where

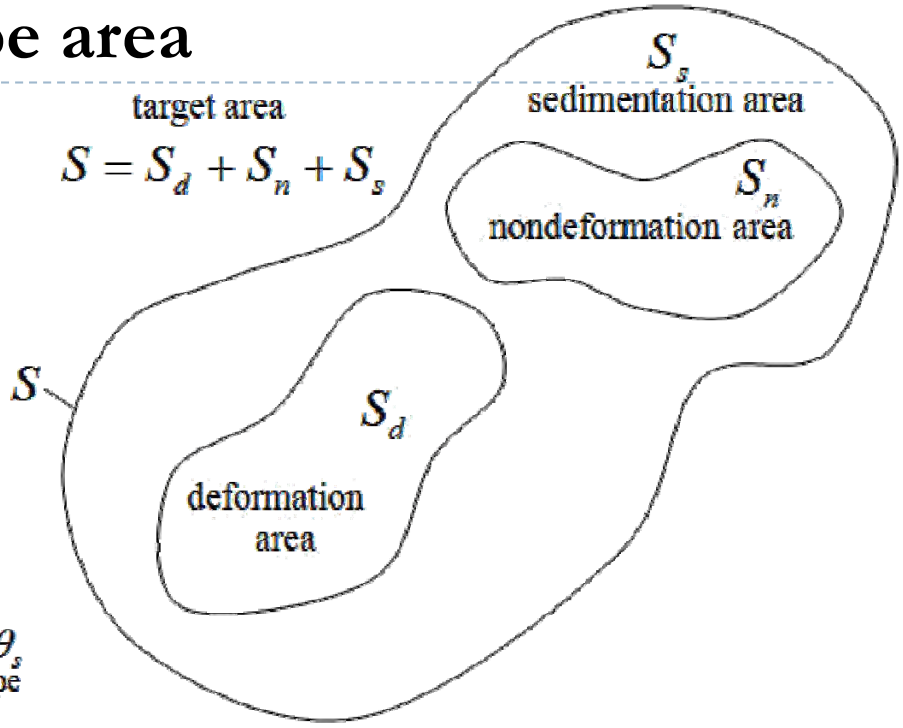
$$B_h = B \cdot \sin\alpha + dh \cdot \cos\alpha$$

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

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

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





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 Center coordinate	(Master) Center date/time Center coordinate	A/D	Path/Row (Frame) FBS/FBD	B (km)	Bp (km)	a (deg)	dh (km)	dh⊥ (km)	dhpr (km)
A1	20100316 15:31:32 -7.543/110.460	20101217 15:28:09 -7.527/110.449	The second eruption : October 26, 2010. A	431/7030 FBS	0.726	-0.654	34.398	0.099	-0.066	-0.328
A2	20100916 15:29:38.853 -7.757/110.568	20101101 15:28:57.075 -7.763/110.571	The first eruption : November 4-5, 2010. A	431/7030 FBD	0.110	-0.095	34.384	0.009	-0.096	-0.054

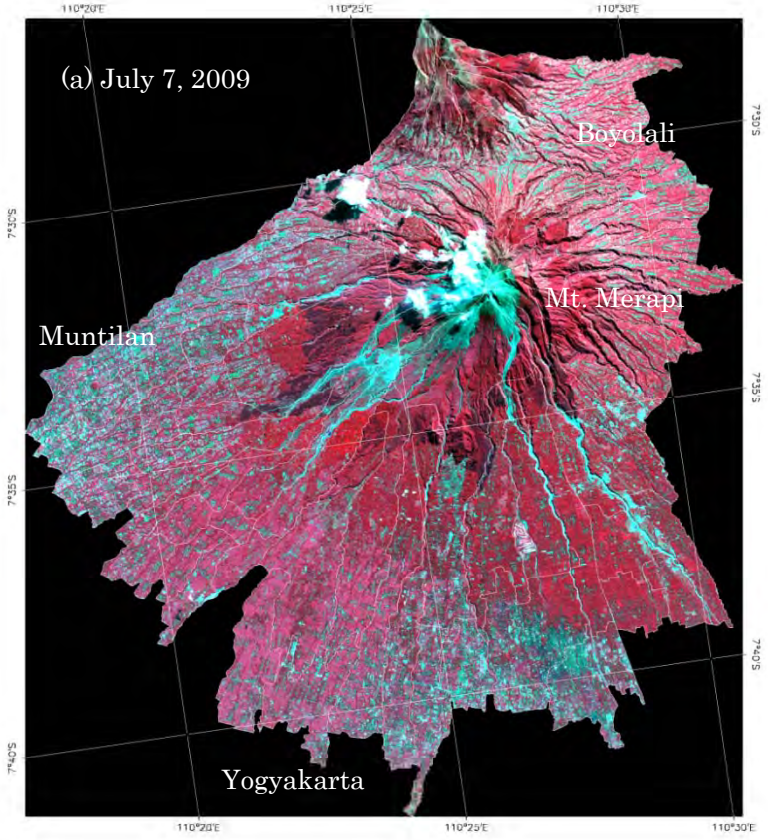
Software :

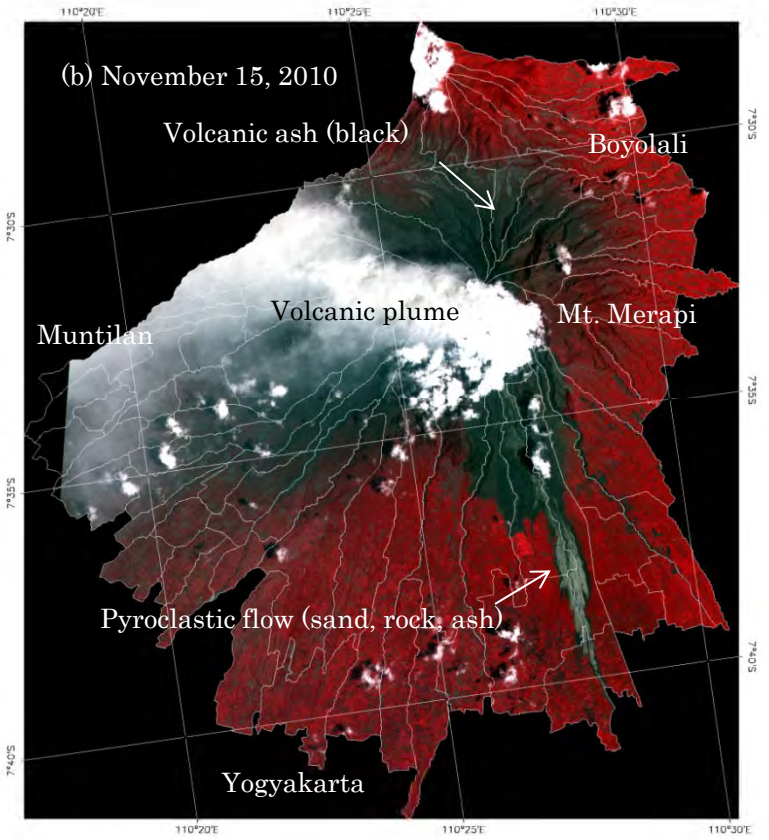
Interferogram and unwraping data is retrieved by JAXA SIGMA-SAR sofware (Shimada Masanobu)

Digital Elevation Model :

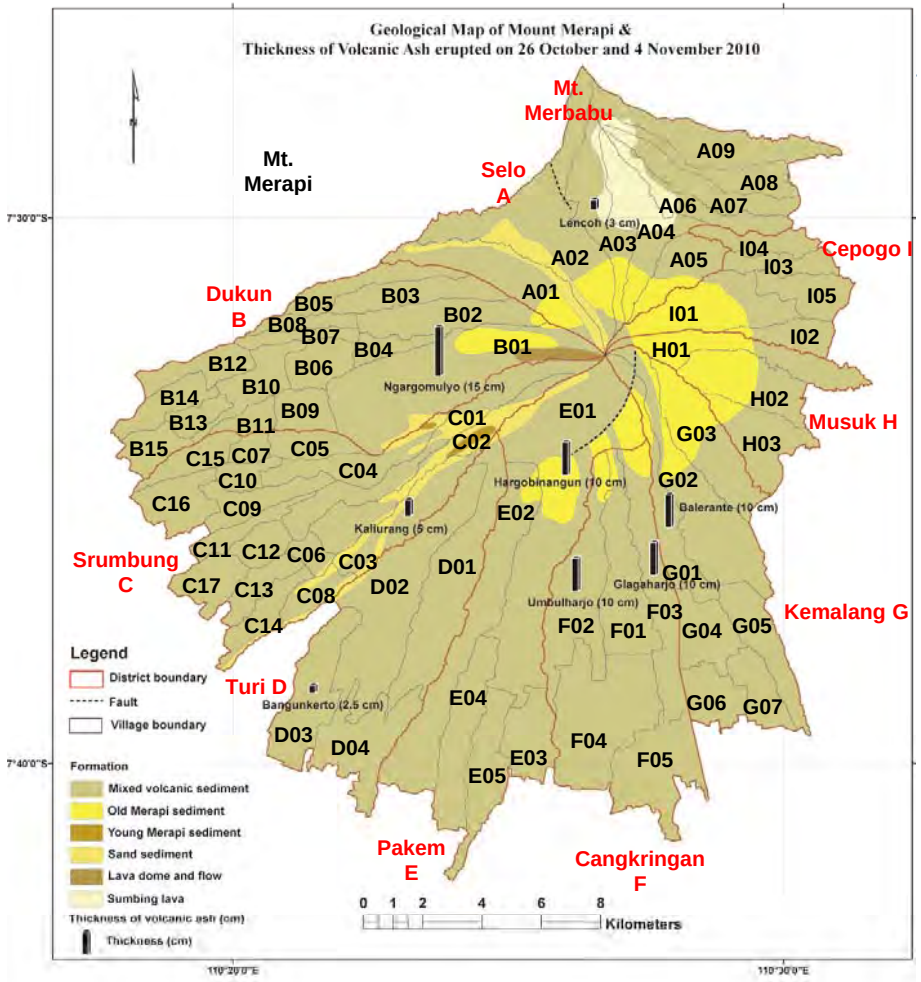
Digital topographic Maps of Indonesia 1:25,000, Bakosurtanal, 2000

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

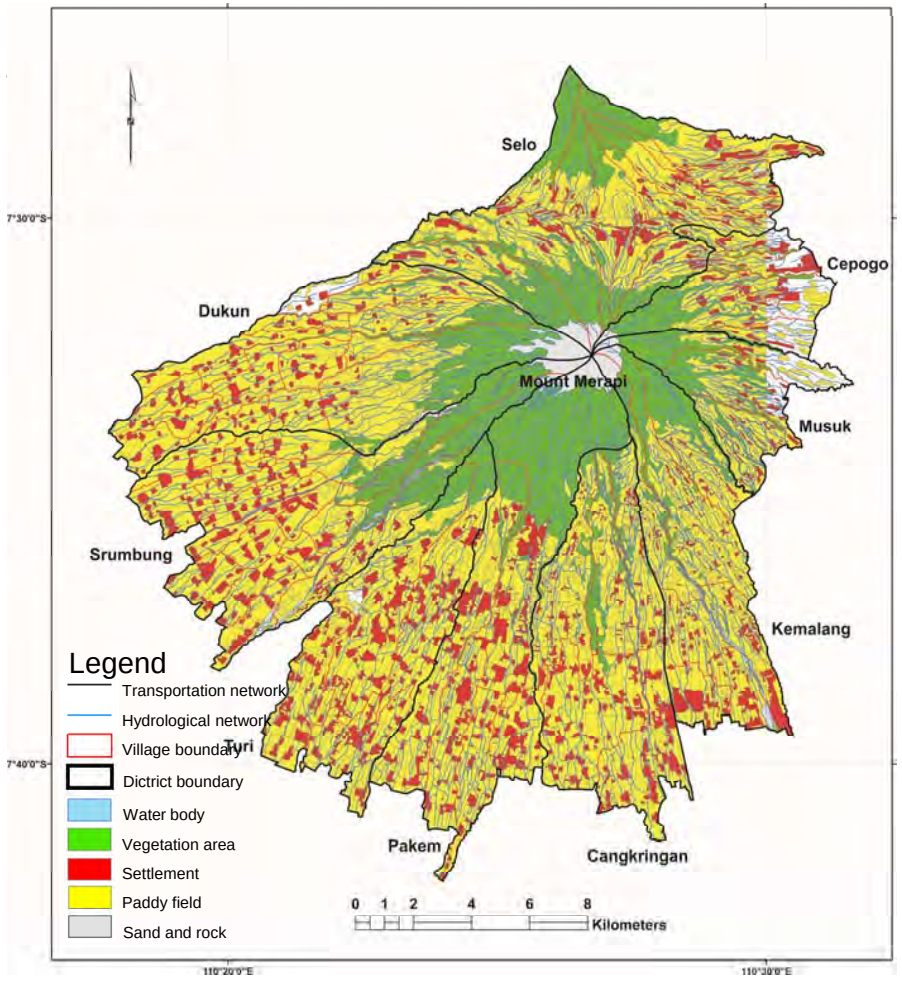




Geological map and Landcover of Mount Merapi



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

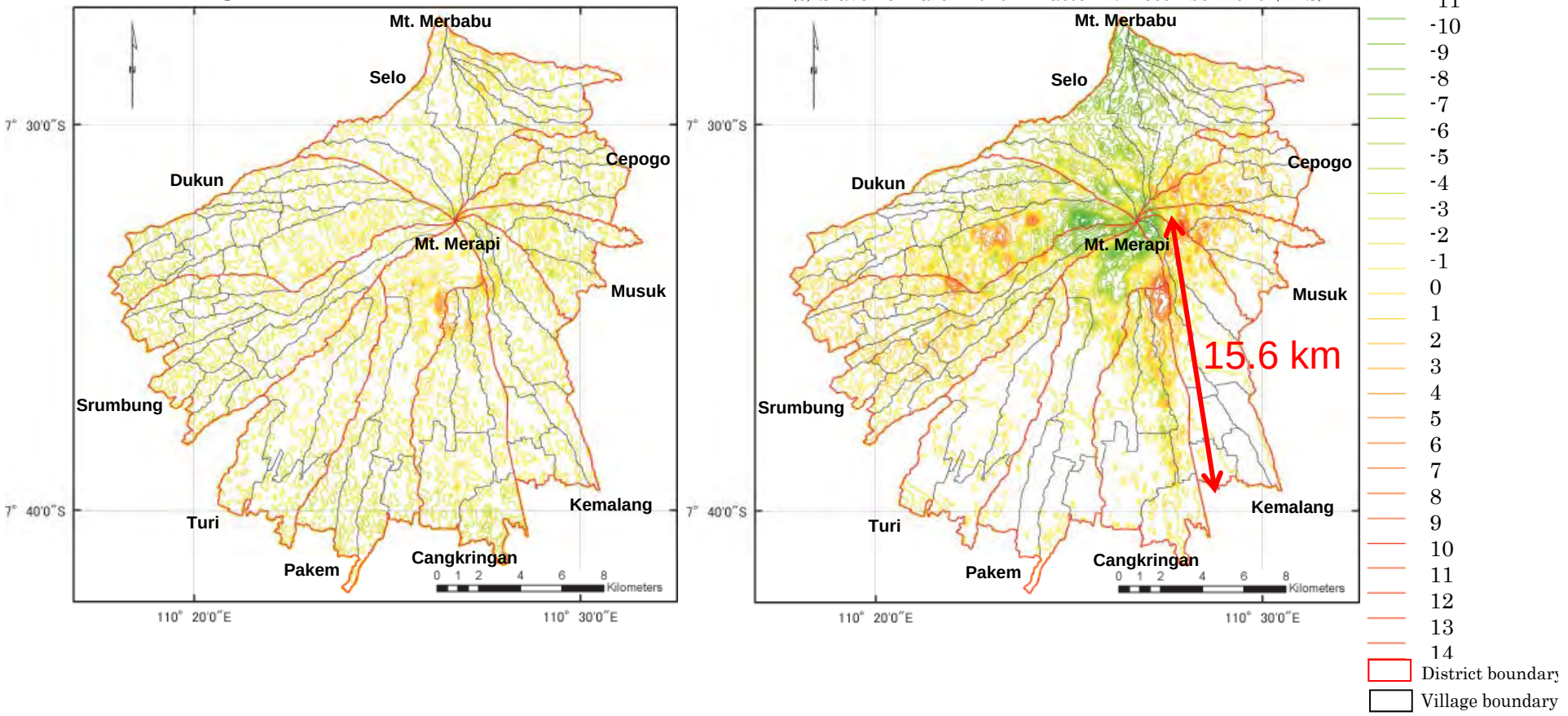


Land cover map of the study area : Digital Topographic Map, 1:25,000, Bakosurtanal, 2000.

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

(a) Slave 16 September 2010 – Master 1 November 2010 (FBD)

(b) Slave 16 March 2010 – Master 17 December 2010 (FBS)



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

(a) Umbulharjo village, Cangkringan District

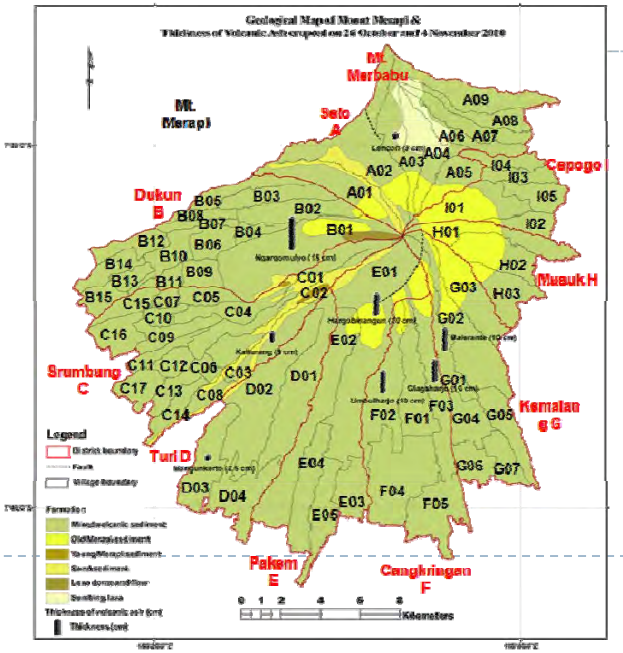
(b) Bakalan village, Cangkringan District

(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



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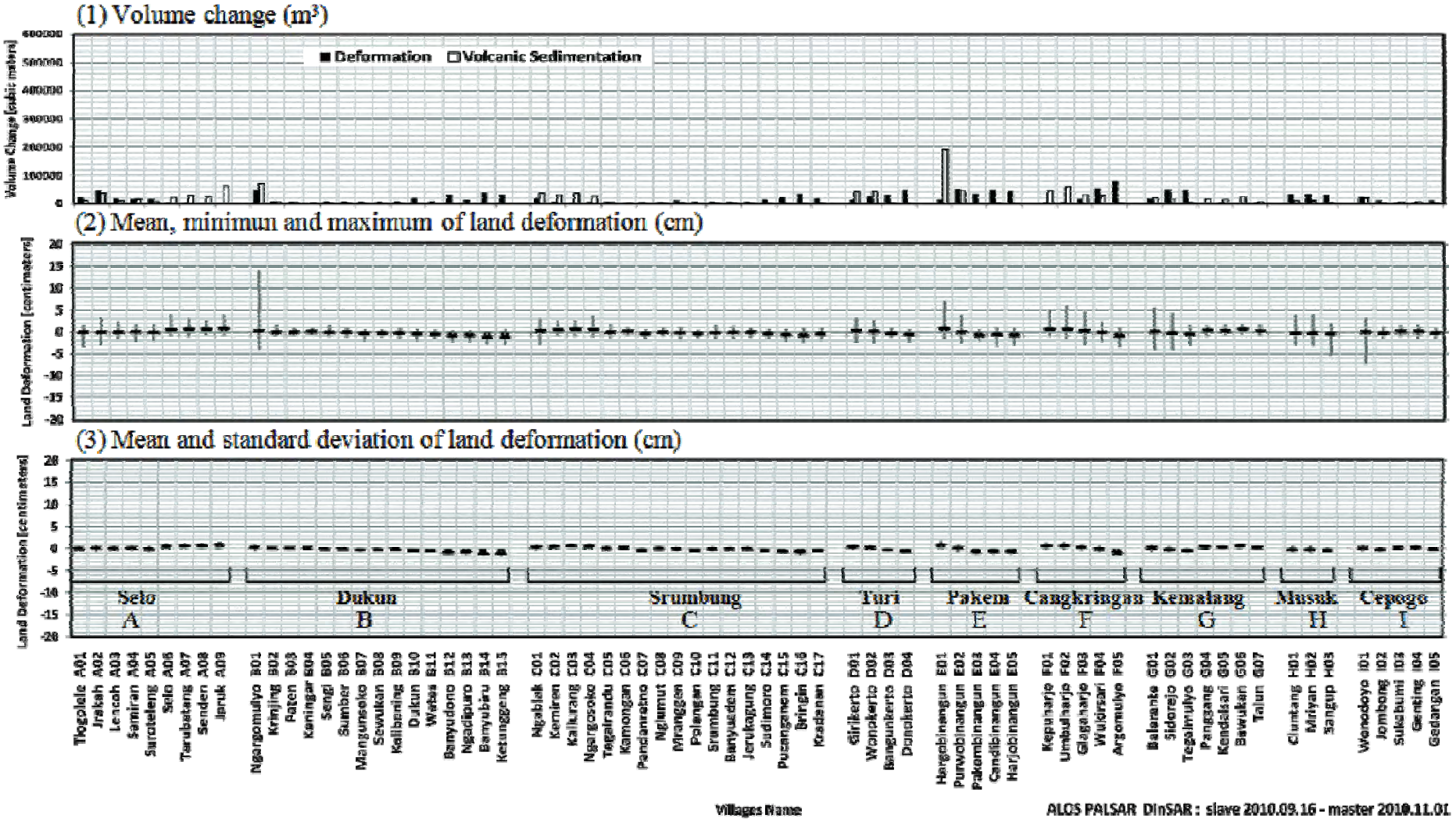
Analysis : Statistical information of land deformation and sedimentation at the study area (1)

Land deformation in Mount Merapi eruption on October 26, 2010



A. Land deformation in Mount Me

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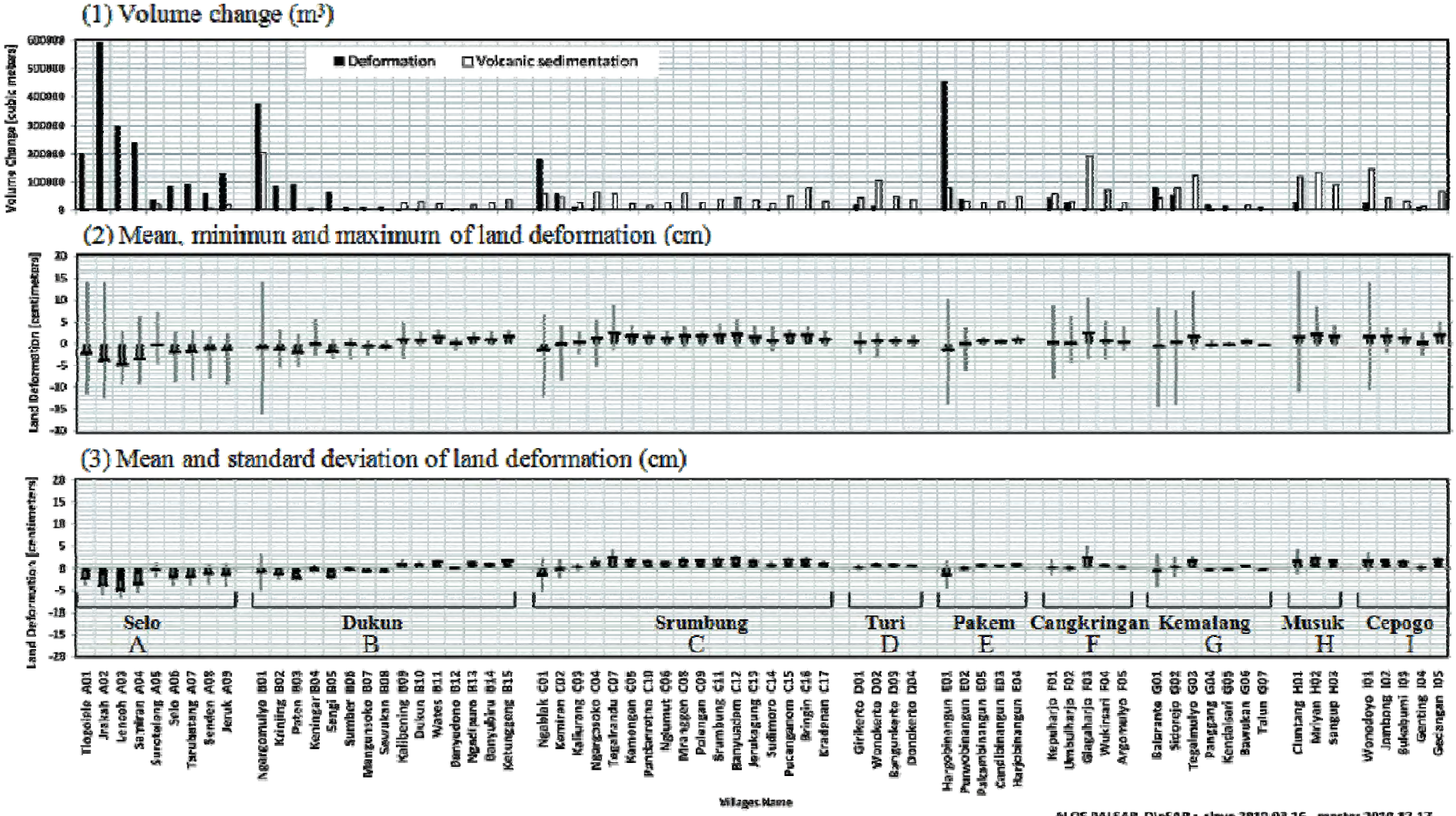
Analysis : Statistical information of land deformation and sedimentation at the study area (2)

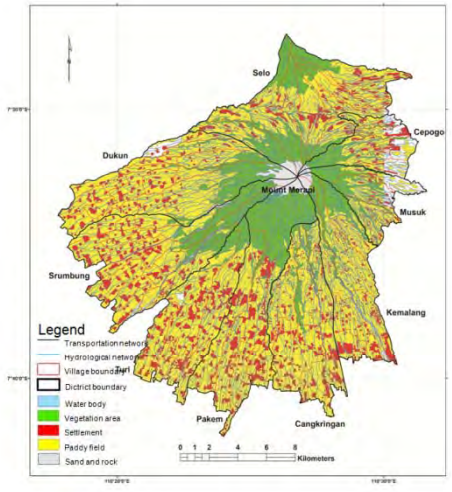
Land deformation in Mount Merapi eruptions on October 26, 2010 and November 4, 2010

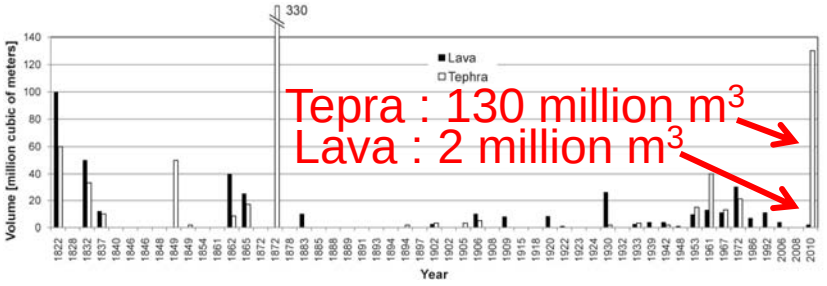


ALOS PALSAR DInSAR : slave 2010.03.16 - master 2010.12.17

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

Classes	Area of Deformation		Area of Sedimention	
	Area (km^2)	Volume (m^3)	Area (km^2)	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.

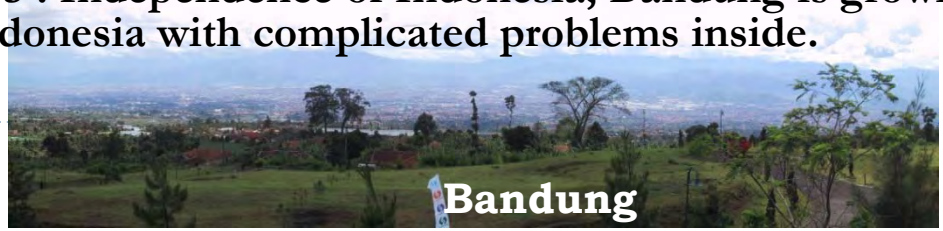
Study area : Bandung city, Indonesia

- 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

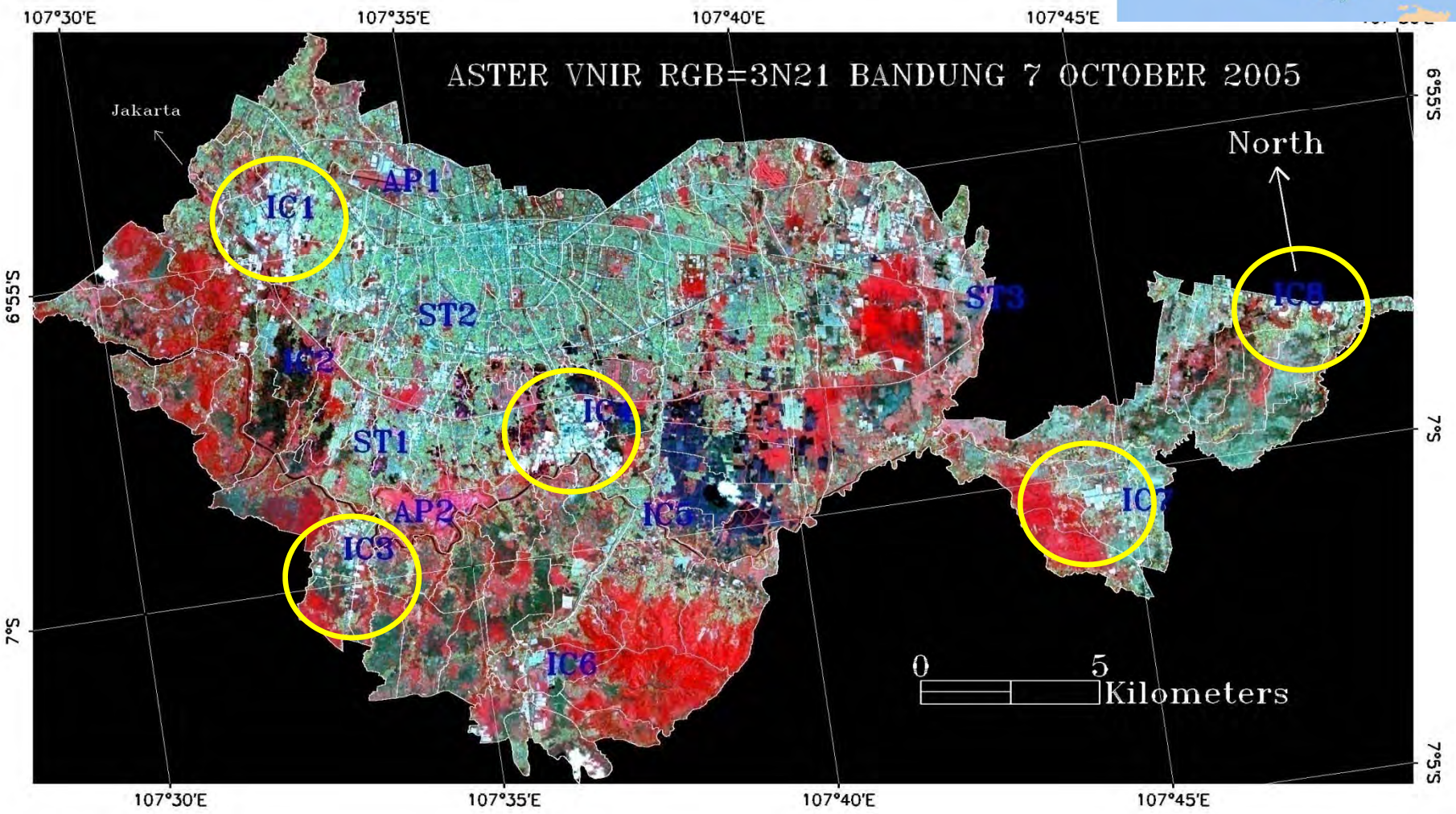
1641 : grown rapidly after the Mataram Kingdom occupied the study area and when the capital moved from Krapyak, Dayeuh Kolot to the area now known as Bandung

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.

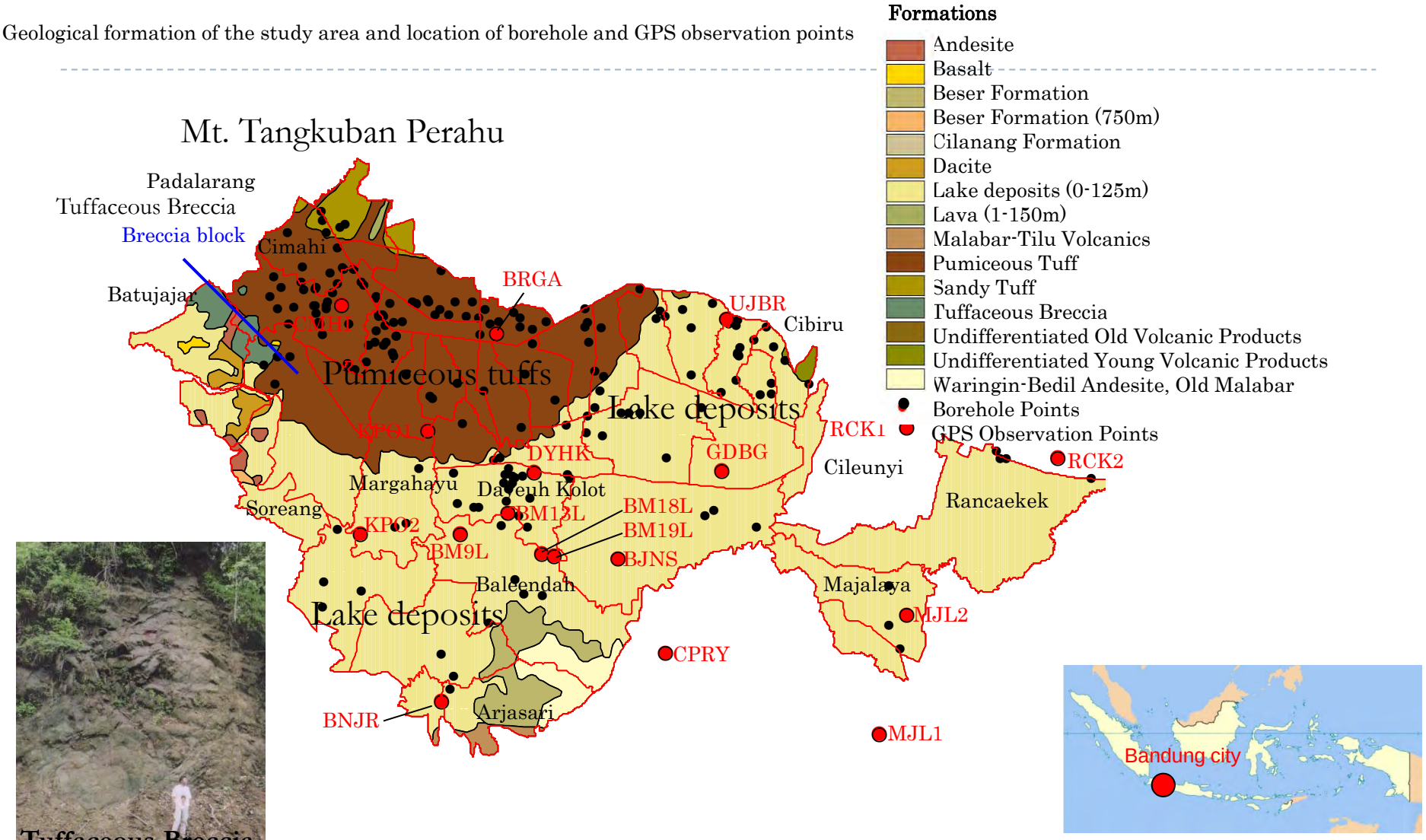


Study area : Bandung city, Indonesia



Study area : Geological history : Main formations

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



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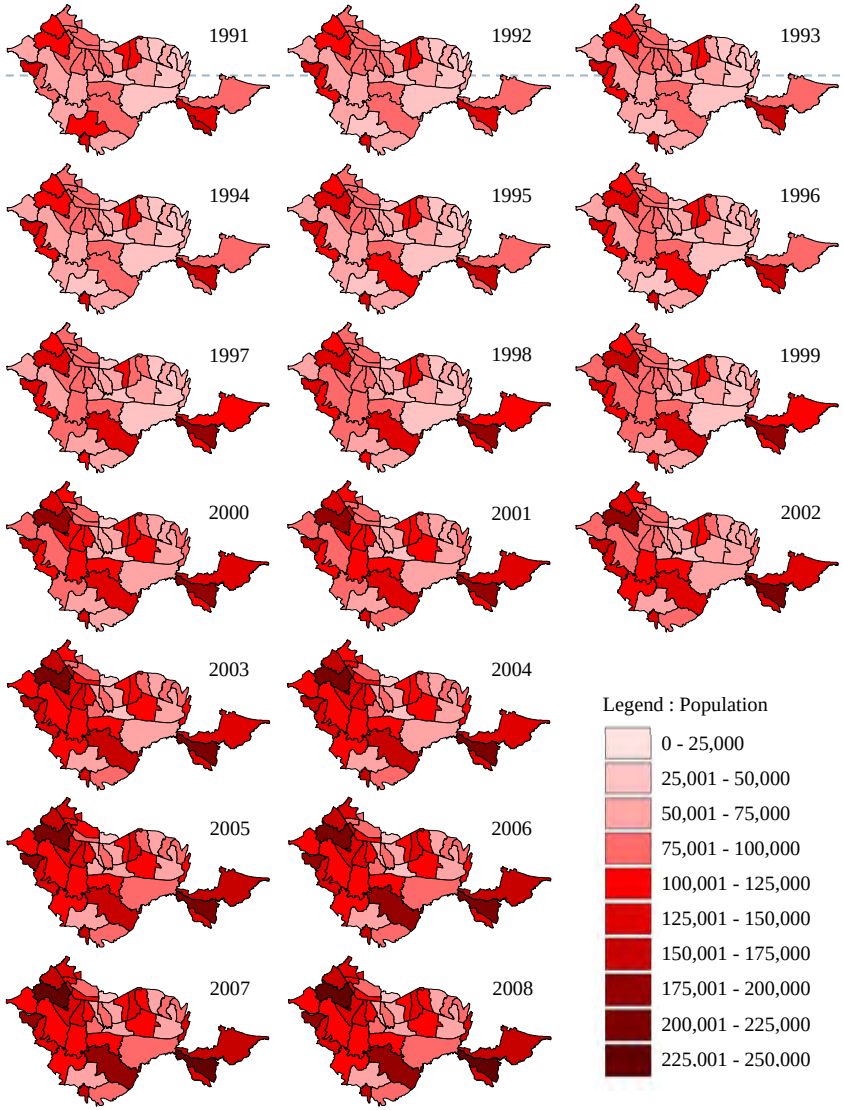
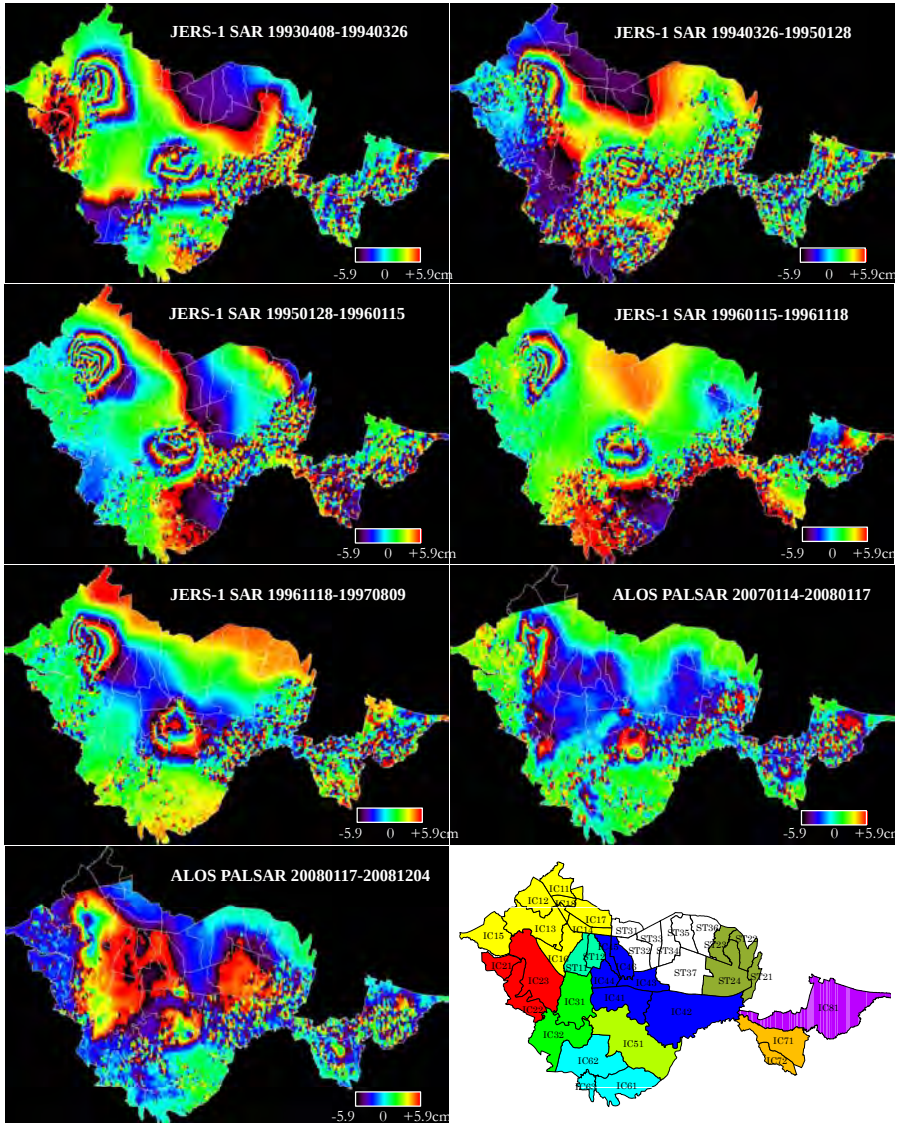
Statistics : Populations





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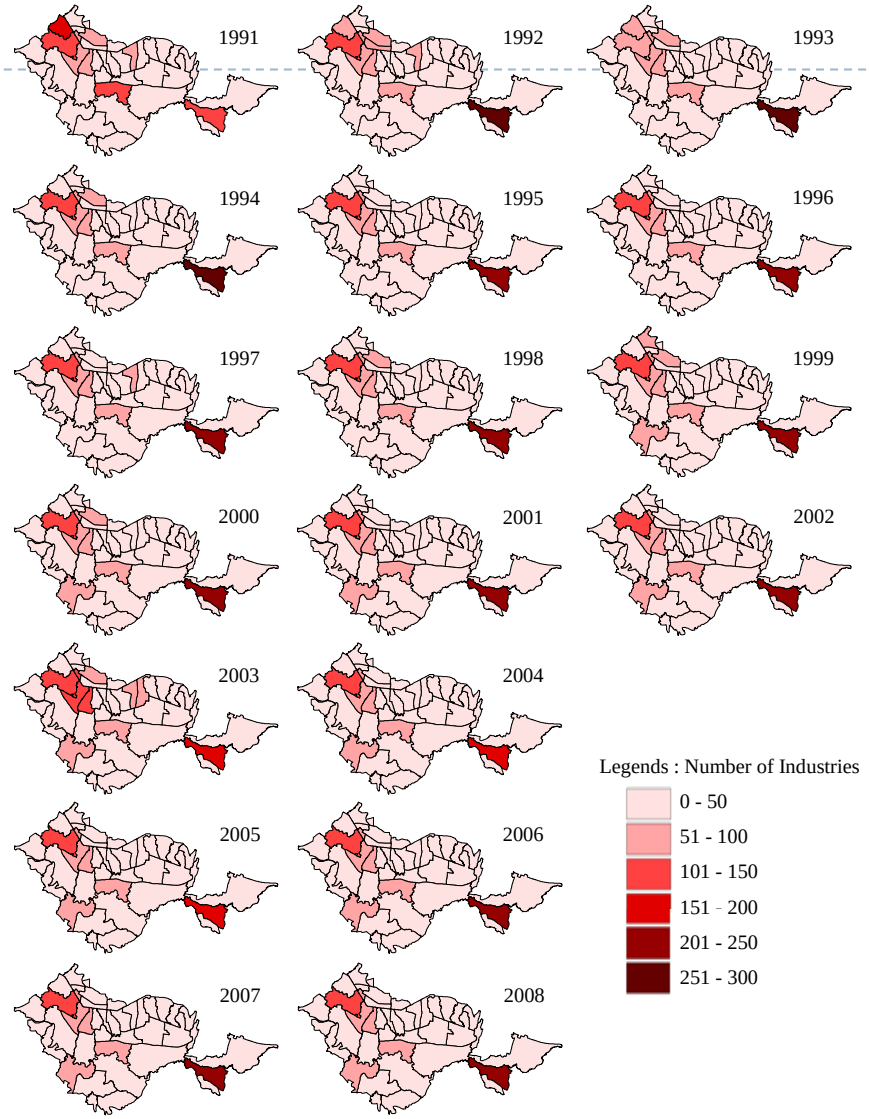
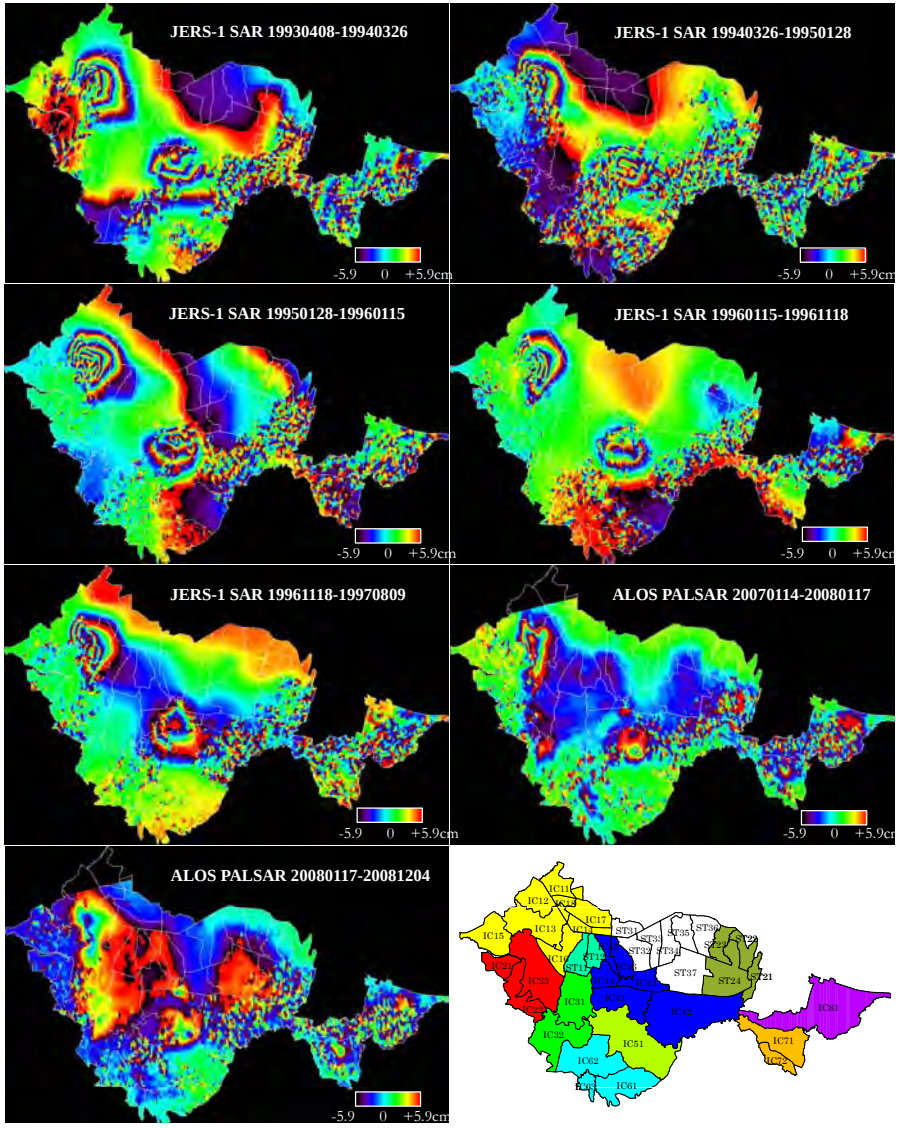
Statistics : Industries





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

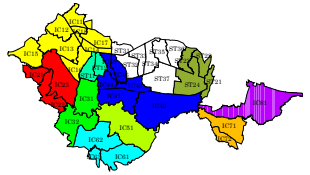


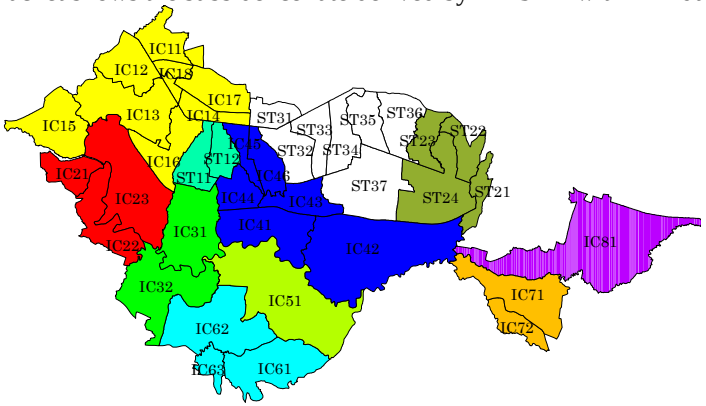
TABLE. Estimation of Subsidence (Maximum Value in Centimeters) and Volume (in Cubic Meters) of The Study Area

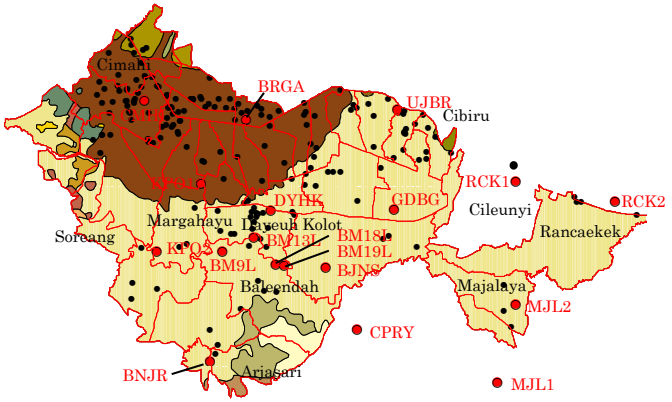
District Codes	District Name	Sensor Name and Data Combination (Slave-Master)						
		JERS-1 19930408-19940326	JERS-1 19940326-19950128	JERS-1 19950128-19960115	JERS-1 19960115-19961118	JERS-1 19961118-1997080	ALOS 20070114-20080117	ALOS 20080117-20081204
Industrial Complexes								
IC1	Cimahi	55 (8,112,500)	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





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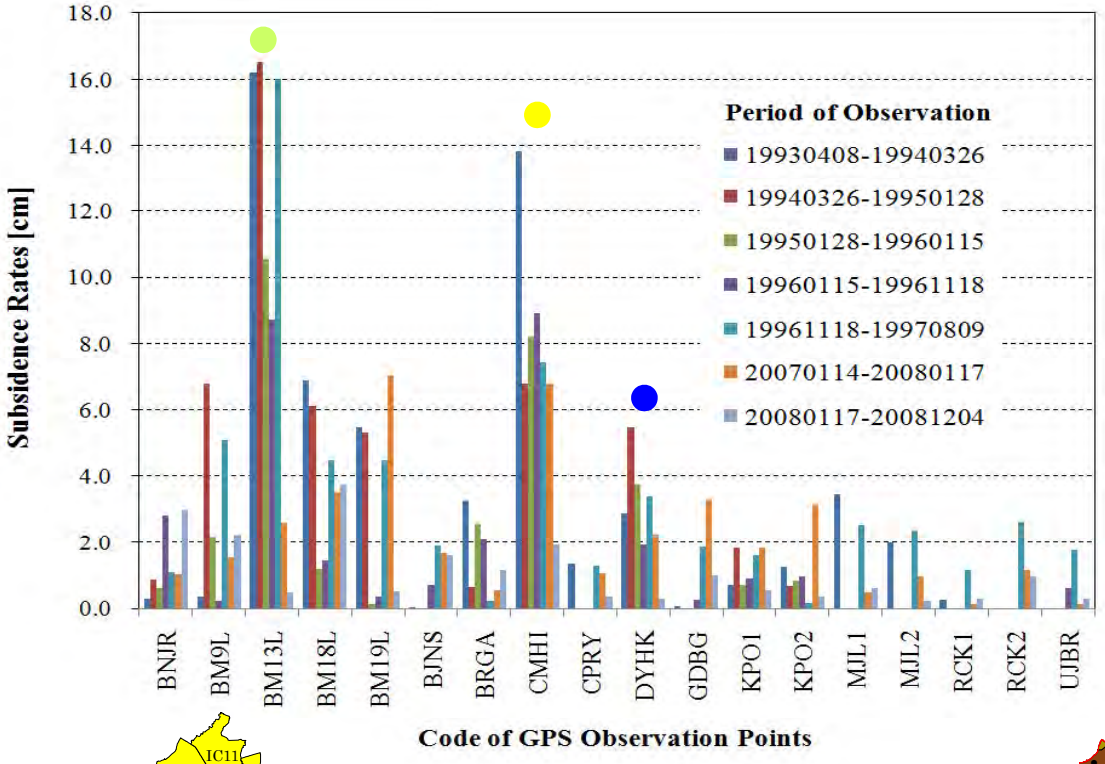
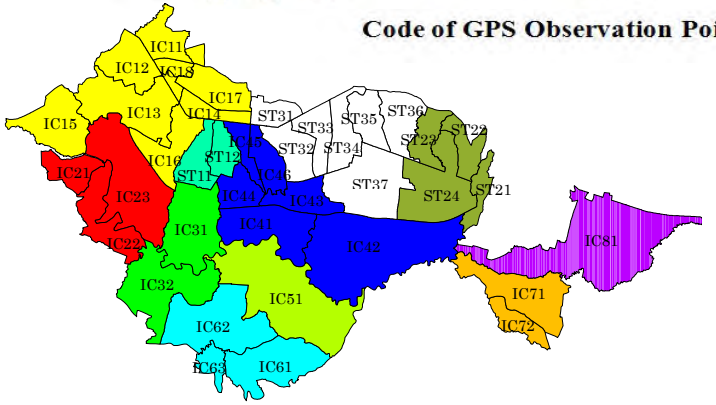
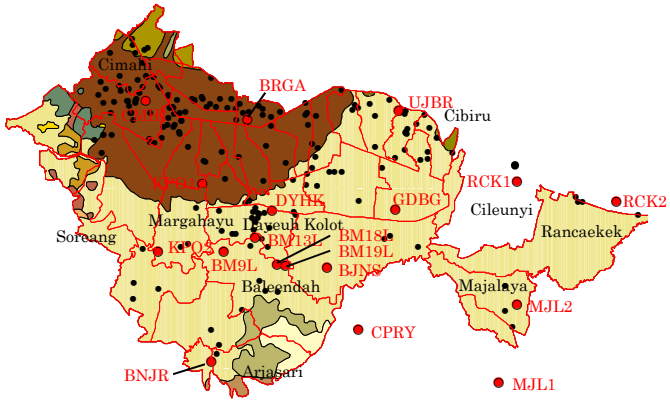
Subsidence Estimation using DInSAR







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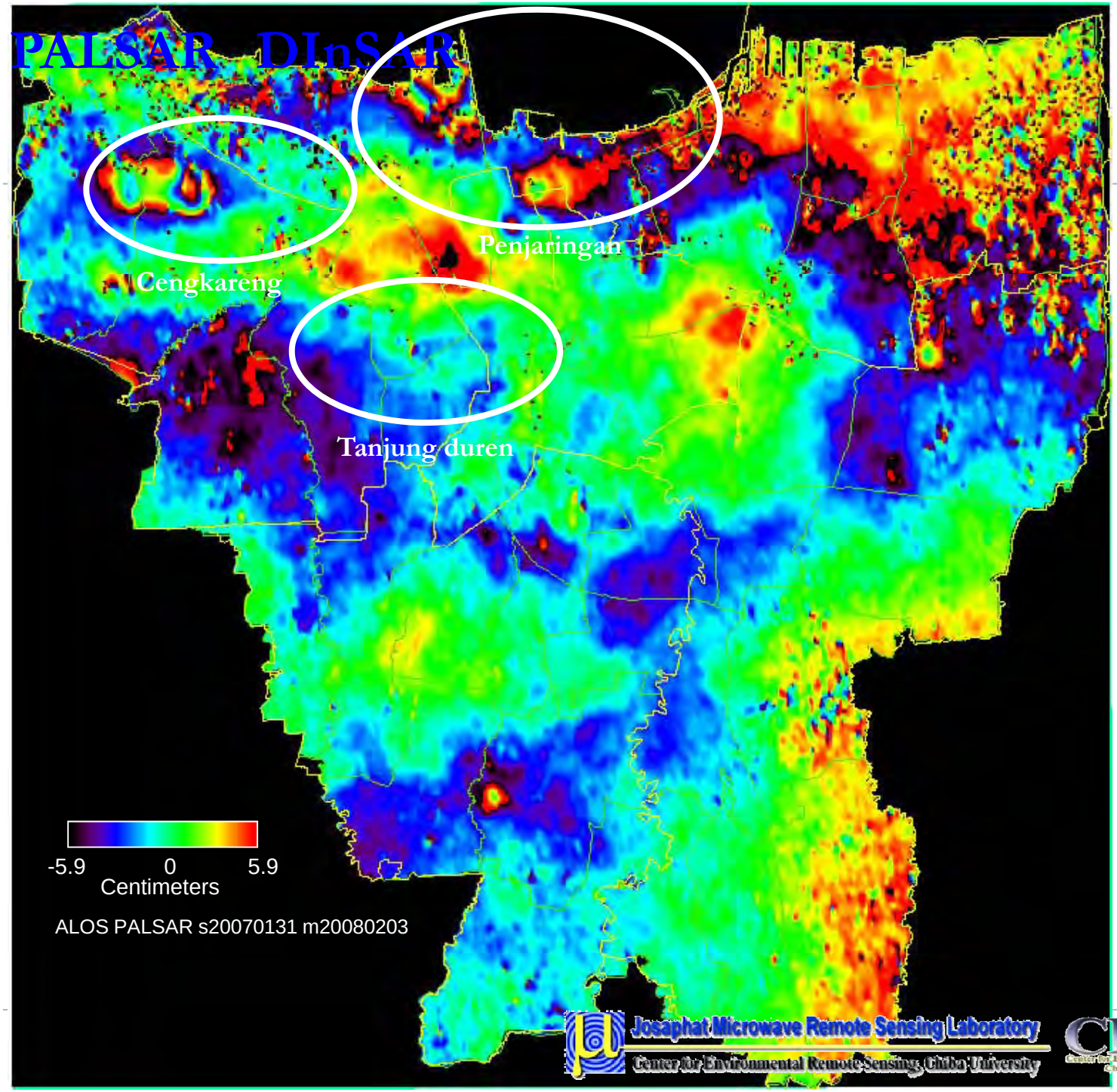
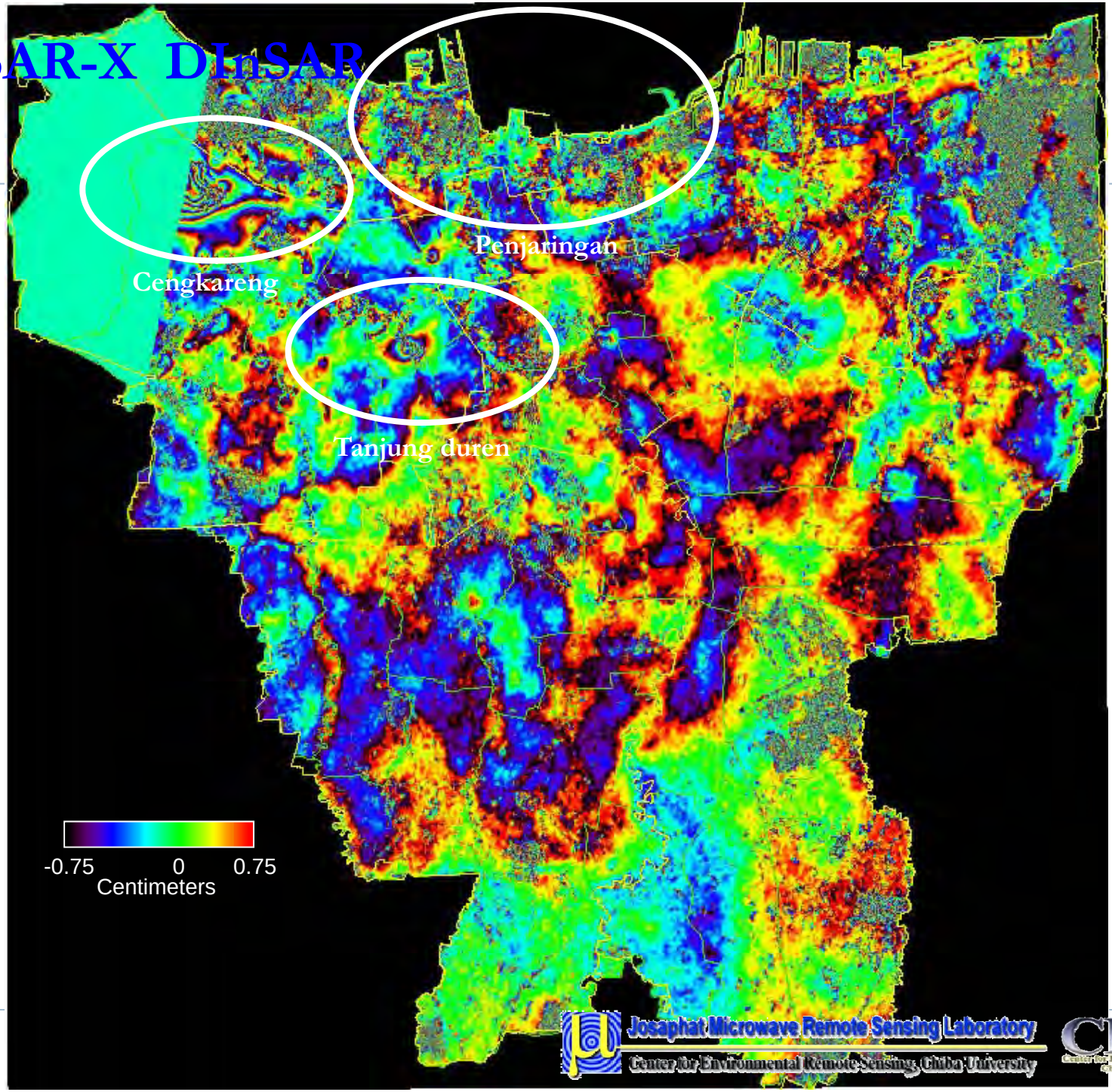
Other disaster monitoring using DInSAR : Subsidence of Jakarta Megapolitan

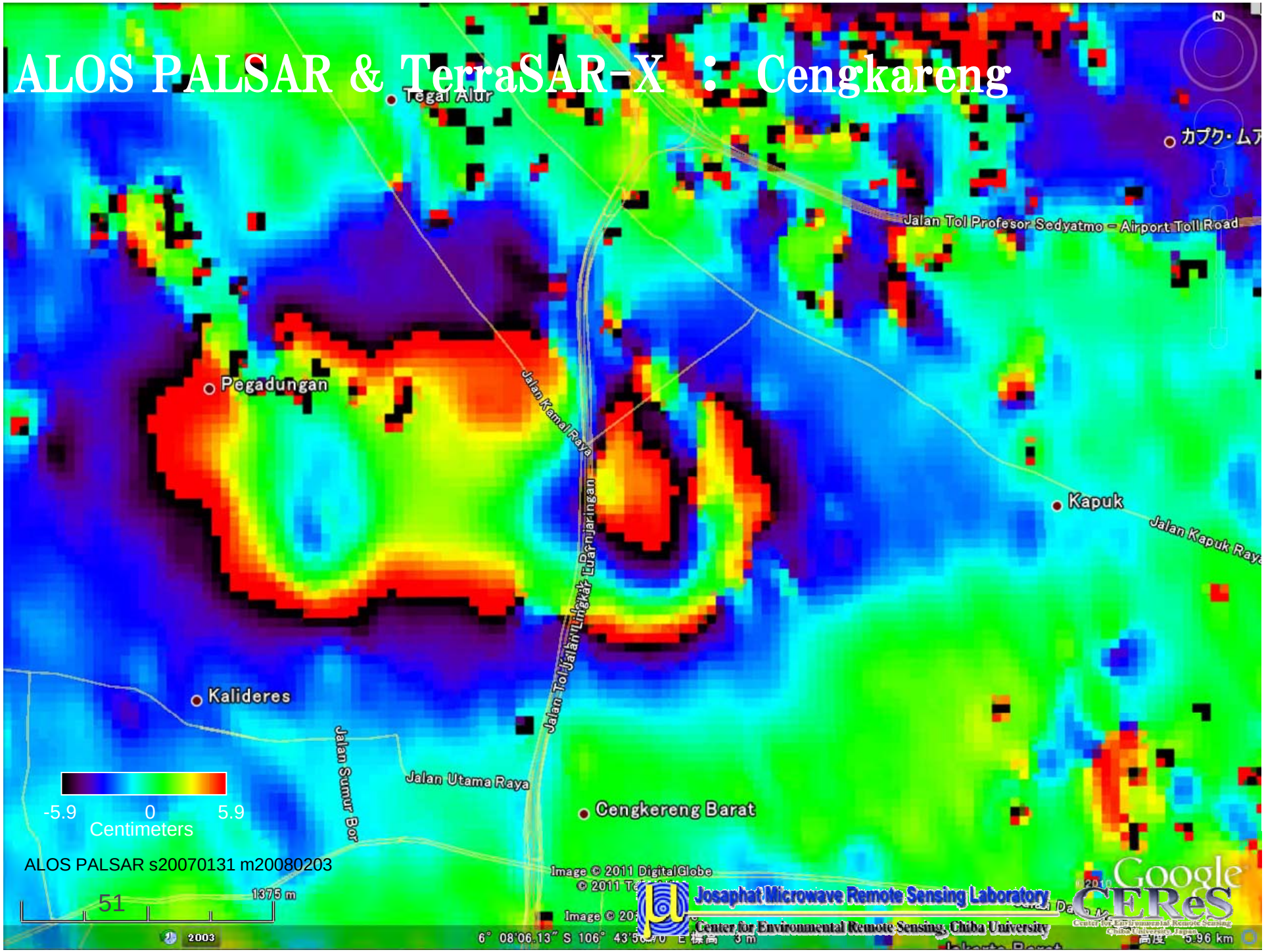
ALOS PALSAR DInSAR



TerraSAR-X DInSAR



ALOS PALSAR & TerraSAR-X ： チェンカレング区


ALOS PALSAR & TerraSAR-X : Cengkareng
Tegal Alur
カプク・ムア
Jalan Tol Profesor Sedyatmo – Airport Toll Road
Pegadungan
Jalan Kamal Raya
Jalan Tol Jalan Lingkar Luar Jakarta
Kapuk
Jalan Kapuk Raya
Kalideres
Jalan Sumur Bor
Jalan Utama Raya
Cengkereng Barat
-5.9
0
5.9
Centimeters
ALOS PALSAR s20070131 m20080203
51
1375 m
2003
Image © 2011 DigitalGlobe
Josaphat Microwave Remote Sensing Laboratory
Center for Environmental Remote Sensing, Chiba University
Google
CERES
6° 08'06.13" S 106° 43'
3 m
5.96 km

ALOS PALSAR & TerraSAR-X : Cengkareng

Jalan Kapuk - Cengkareng

TerraSAR-X s20100809 m20110613

-0.75 0 0.75

Centimeters

Tegal Alur

Jalan Tol Profesor Sedyatmo - Airport Toll Road

Jalan Kamal Raya

Jalan Kapuk - Cengkareng

Jalan Tol Jakarta Lingkar Luar Pondok Jaringan

Kapuk

Jalan Kapuk Raya

Jalan Utama Raya

Cengkereng Barat

Jalan Sumur Bor

Image © 2011 DigitalGlobe

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Center for Environmental Remote Sensing, Chiba University

Google

CERES

52

1375 m

画像取得日: 2010/4/1

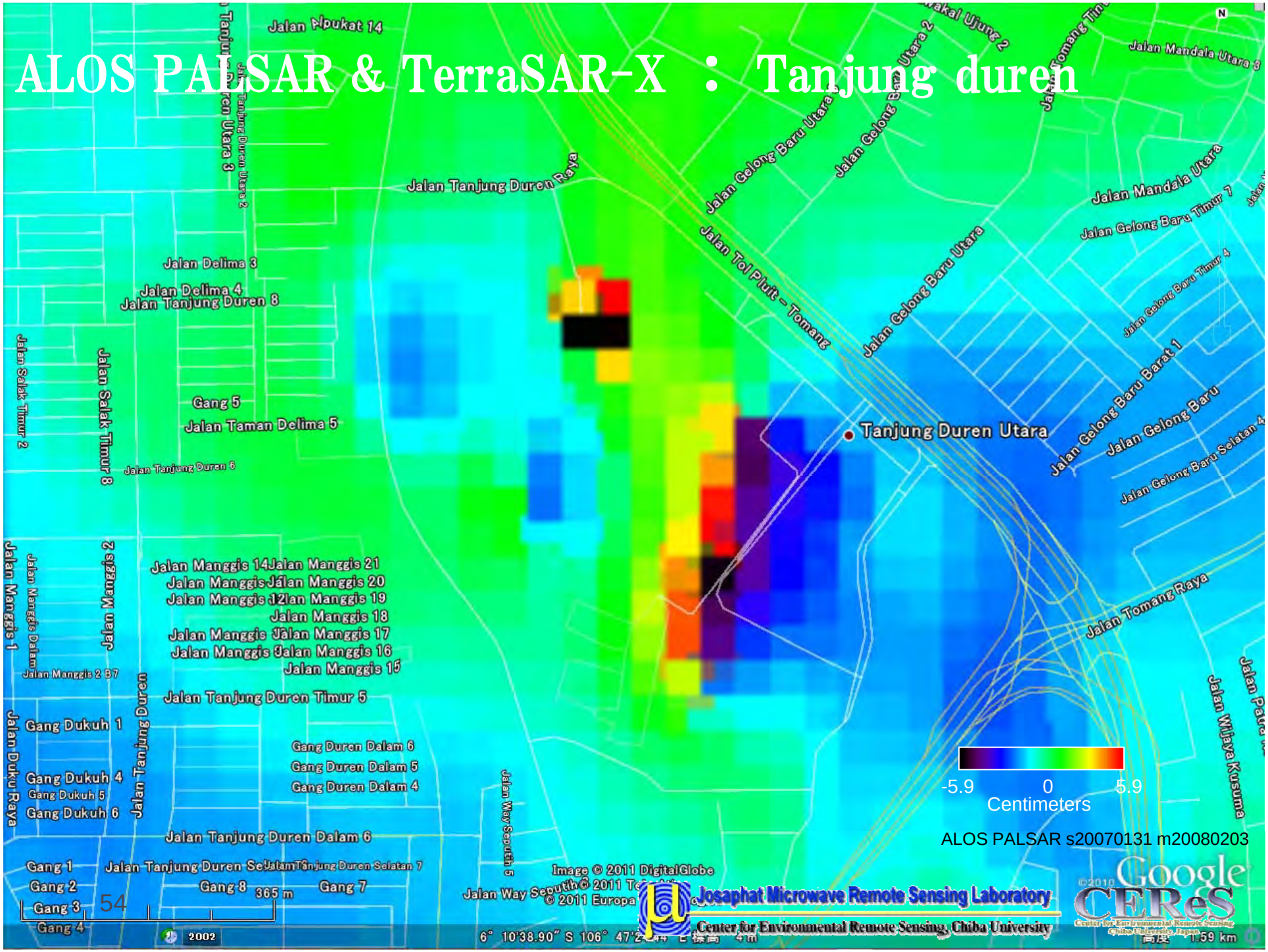
2003

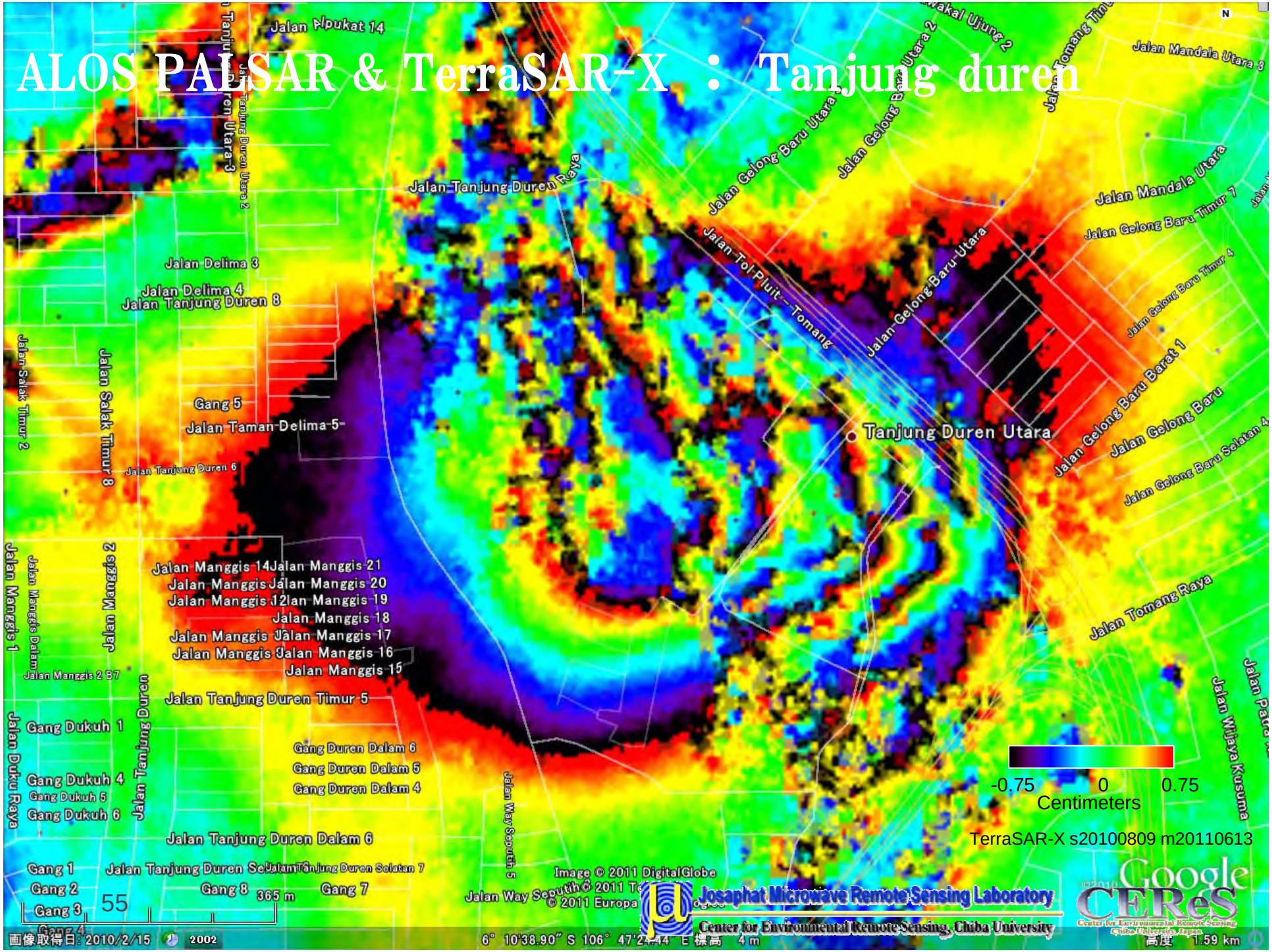
6° 08'06.13" S 106° 43'56.70" E 標高 3 m

高度 5.96 km

ALOS PALSAR & TerraSAR-X ： タンジュングドレン区

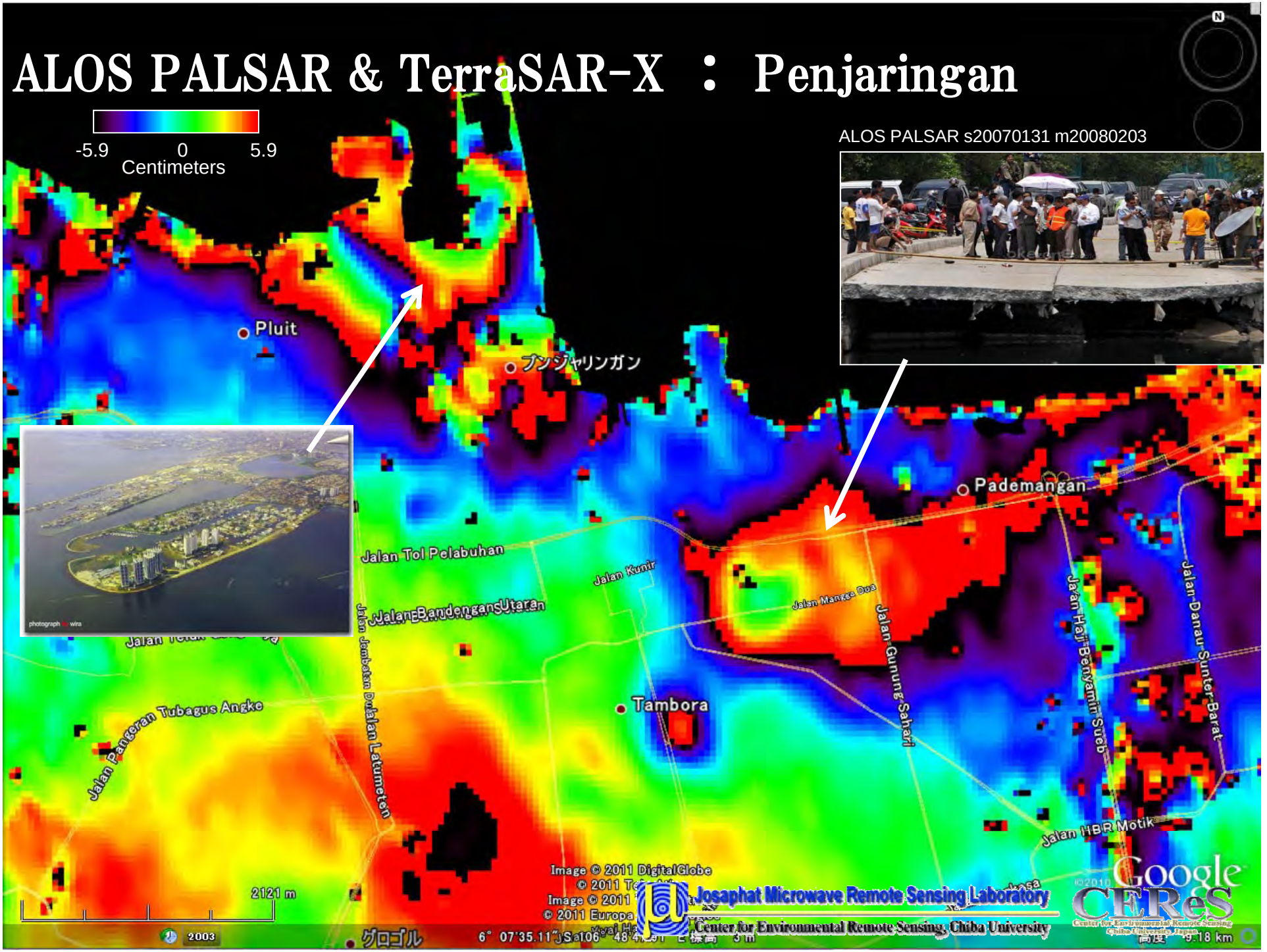
ALOS PALSAR & TerraSAR-X ： Tanjung duren




ALOS PALSAR & TerraSAR-X ： Tanjung duren
Jalan Tanjung Duren Raya
Jalan Tol Pluit - Tomang
Jalan Gelong Baru Utara
Jalan Gelong Baru Timur 7
Jalan Mandala Utara
Jalan Delima 3
Jalan Delima 4
Jalan Tanjung Duren 8
Jalan Salak Timur 8
Jalan Salak Timur 2
Gang 5
Jalan Taman Delima 5
Jalan Tanjung Duren 6
Tanjung Duren Utara
Jalan Gelong Baru Barat 1
Jalan Gelong Baru
Jalan Gelong Baru Selatan 4
Jalan Manggis 14
Jalan Manggis 21
Jalan Manggis 20
Jalan Manggis 12
Jalan Manggis 19
Jalan Manggis 18
Jalan Manggis 17
Jalan Manggis 16
Jalan Manggis 15
Jalan Manggis 1
Jalan Manggis 2
Jalan Manggis 2 37
Jalan Tanjung Duren Timur 5
Jalan Tomang Raya
Jalan Wijaya Kusuma
Gang Dukuh 1
Gang Dukuh 4
Gang Dukuh 5
Gang Dukuh 6
Jalan Duku Raya
Jalan Tanjung Duren
Gang Duren Dalam 6
Gang Duren Dalam 5
Gang Duren Dalam 4
Jalan Tanjung Duren Dalam 6
Jalan Way Seputih 5
Gang 1
Gang 2
Gang 3
Gang 4
Jalan Tanjung Duren Selatan 7
Gang 8
Gang 7
365 m
55
-0.75
0
0.75
Centimeters
TerraSAR-X s20100809 m20110613
Image © 2011 DigitalGlobe
© 2011 Europa
Josaphat Microwave Remote Sensing Laboratory
Center for Environmental Remote Sensing, Chiba University
Google
CERES
画像取得日: 2010/2/15
2002
6° 10'38.90" S 106° 47'24.44" E 標高 4 m
高度 1.59 km

ALOS PALSAR & TerraSAR-X ： Penjaringan

ALOS PALSAR & TerraSAR-X ： Penjaringan



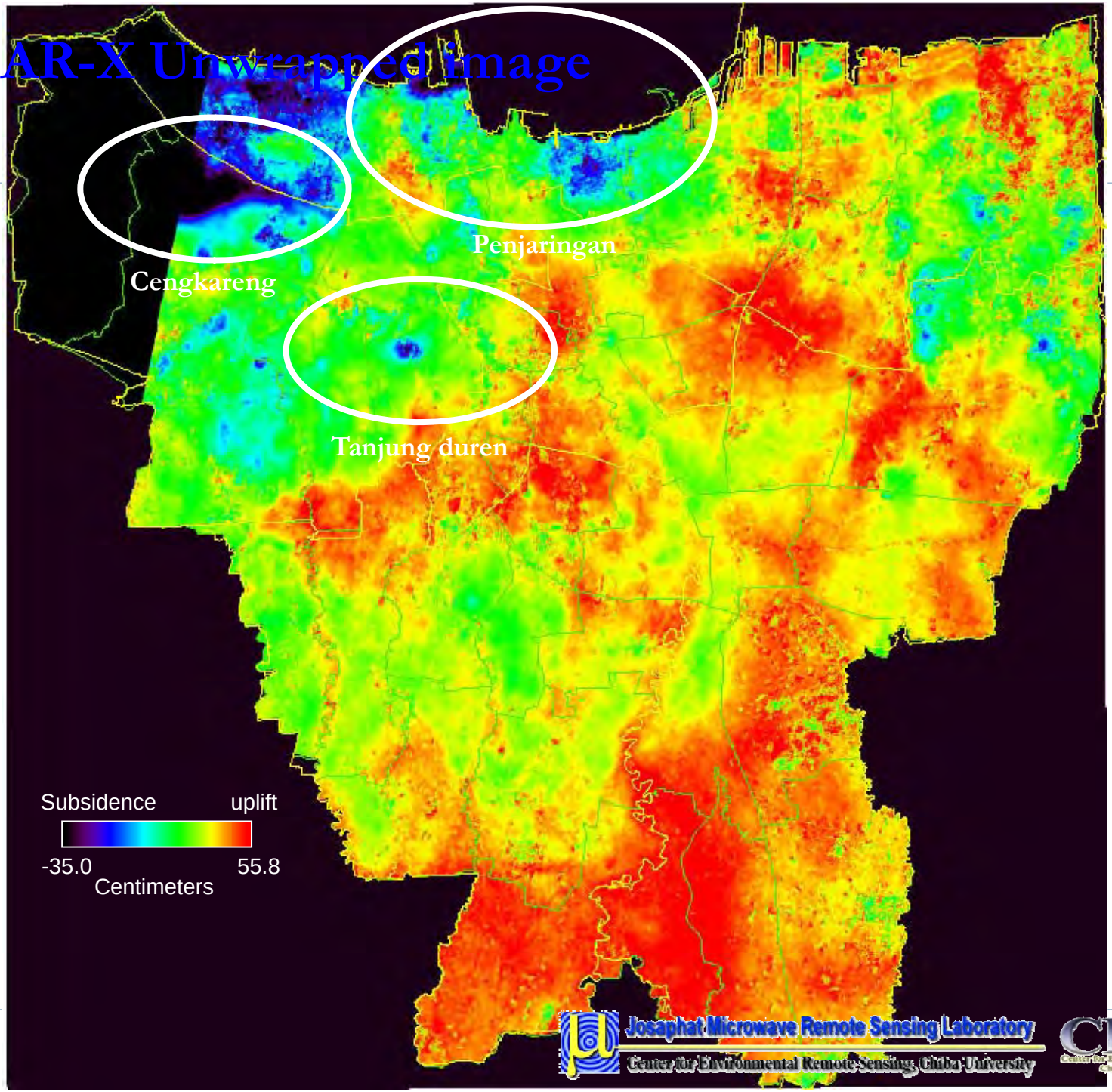
ALOS PALSAR & TerraSAR-X ： Penjaringan

TerraSAR-X s20100809 m20110613

-0.75 0 0.75
Centimeters

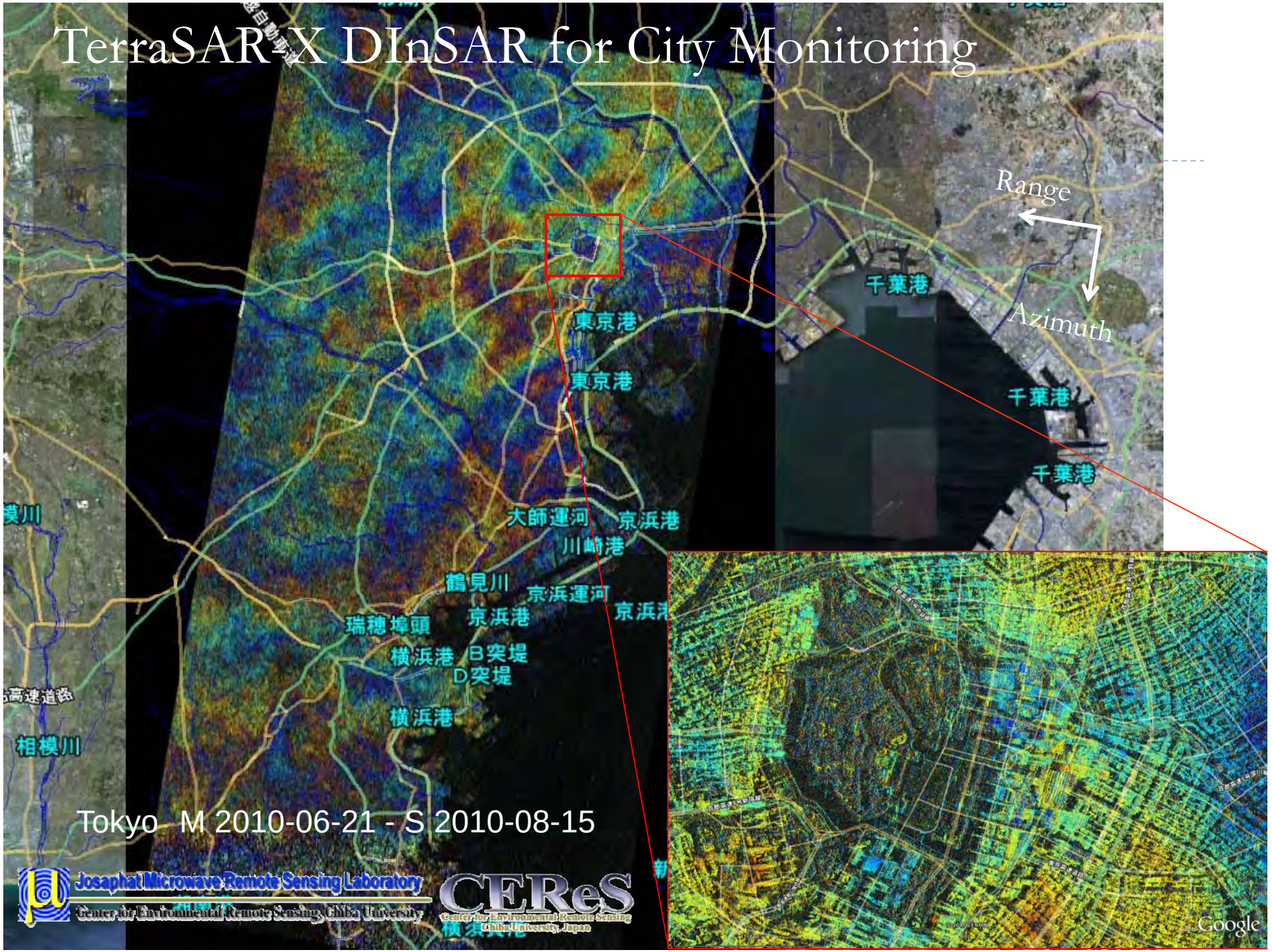
Pluit
ペンジャリンガン
Jalan Pluit Selatan Raya
Pejagalan
Jalan Tol Pelabuhan
Jalan Kunir
Jalan Bandengan Utara
Jalan Teluk Gong Raya
Jalan Jembatan Dua
Jalan Pangeran Tubagus Angke
Jalan Latumeten
Tambora
Jalan HBR Motik
2121 m
2003
グロゴル
Image © 2011 DigitalGlobe
© 2011 Europa
Josaphat Microwave Remote Sensing Laboratory
Center for Environmental Remote Sensing, Chiba University
Google
CERES
6° 07'35.11"S 106° 48'
標高 3 m
高度 9.18 km

TerraSAR-X Unwrapped image



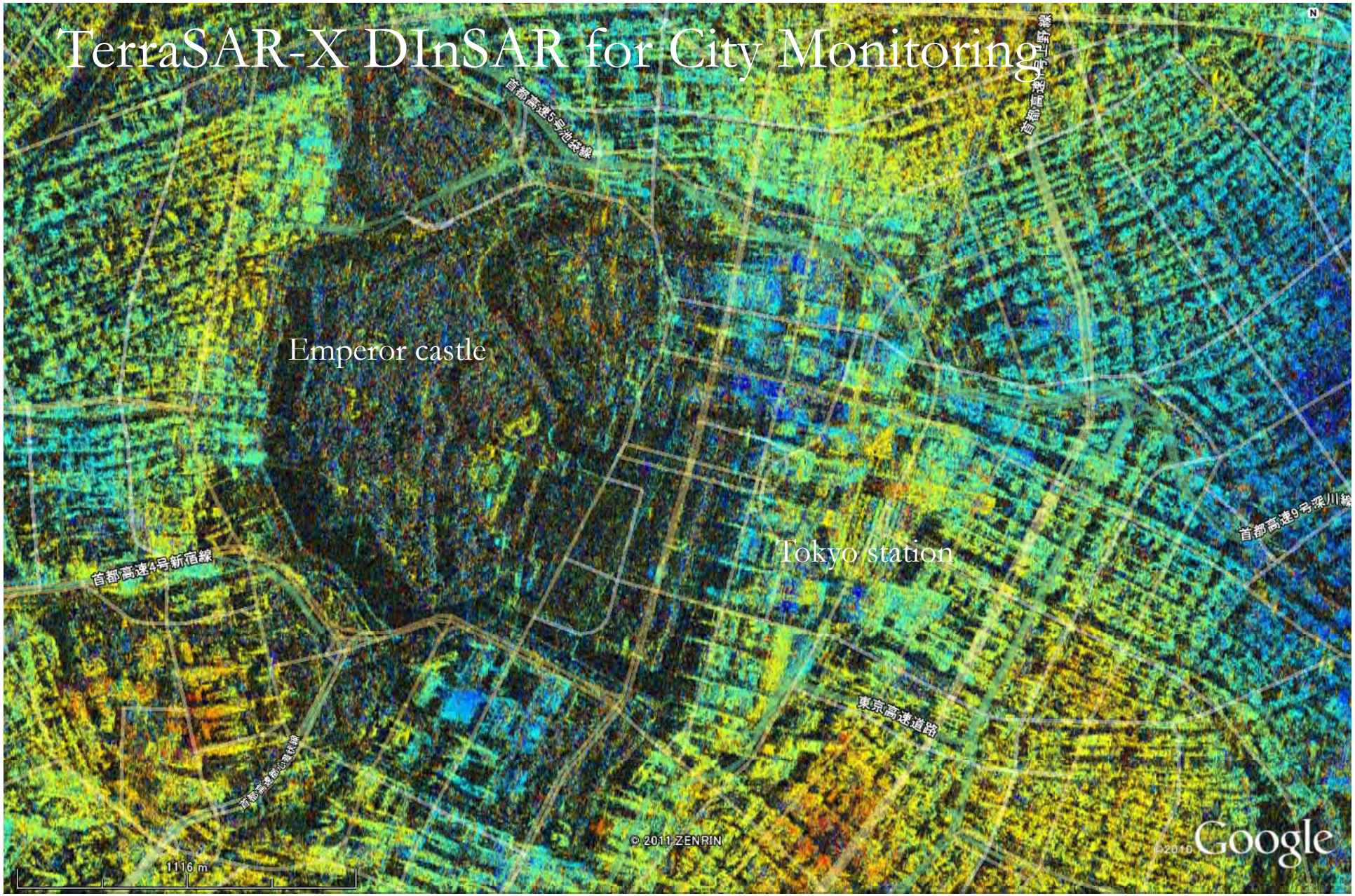
Other disaster monitoring using DInSAR : Subsidence at Tokyo Megapolitan

TerraSAR-X DInSAR for City Monitoring

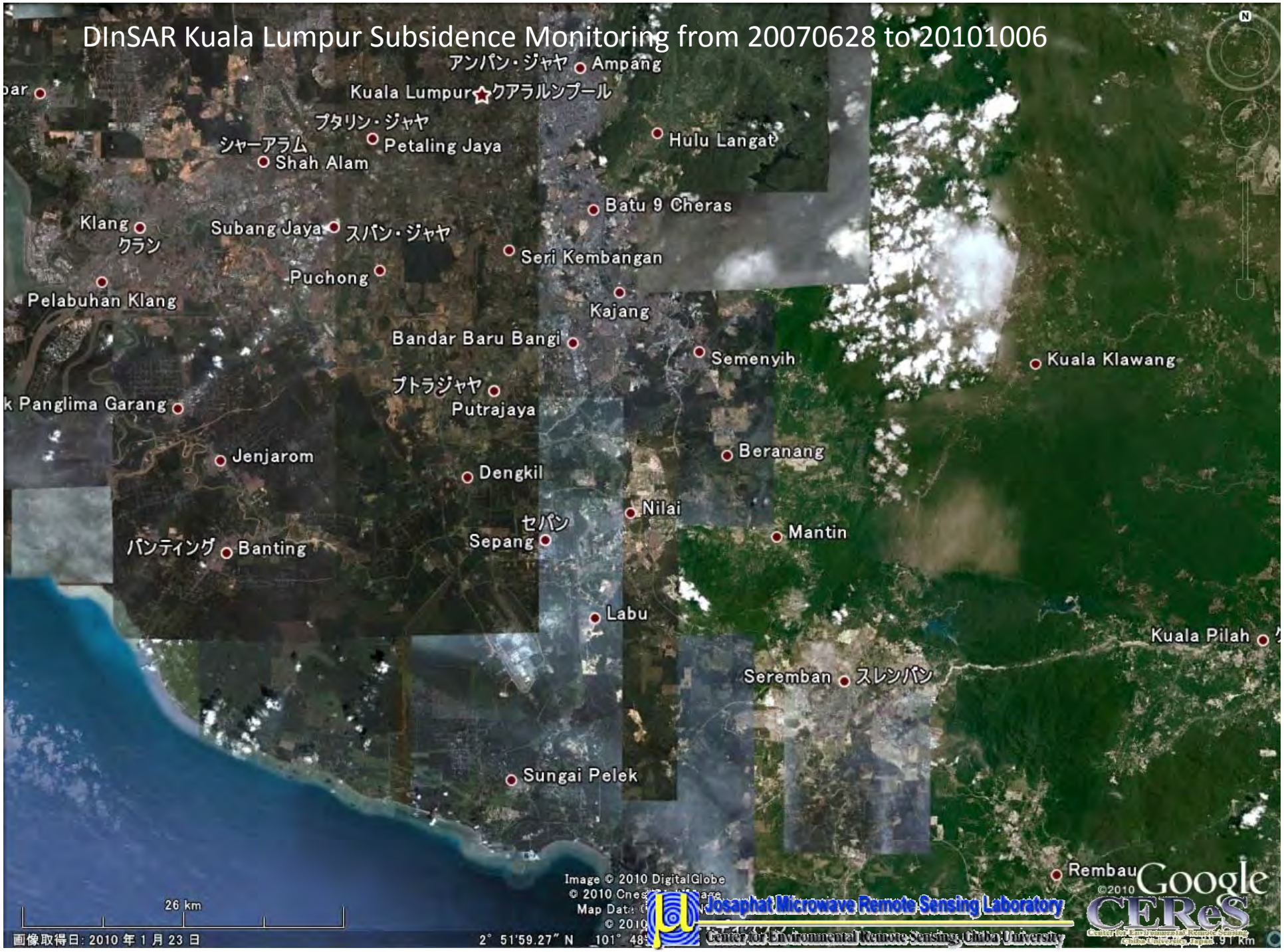


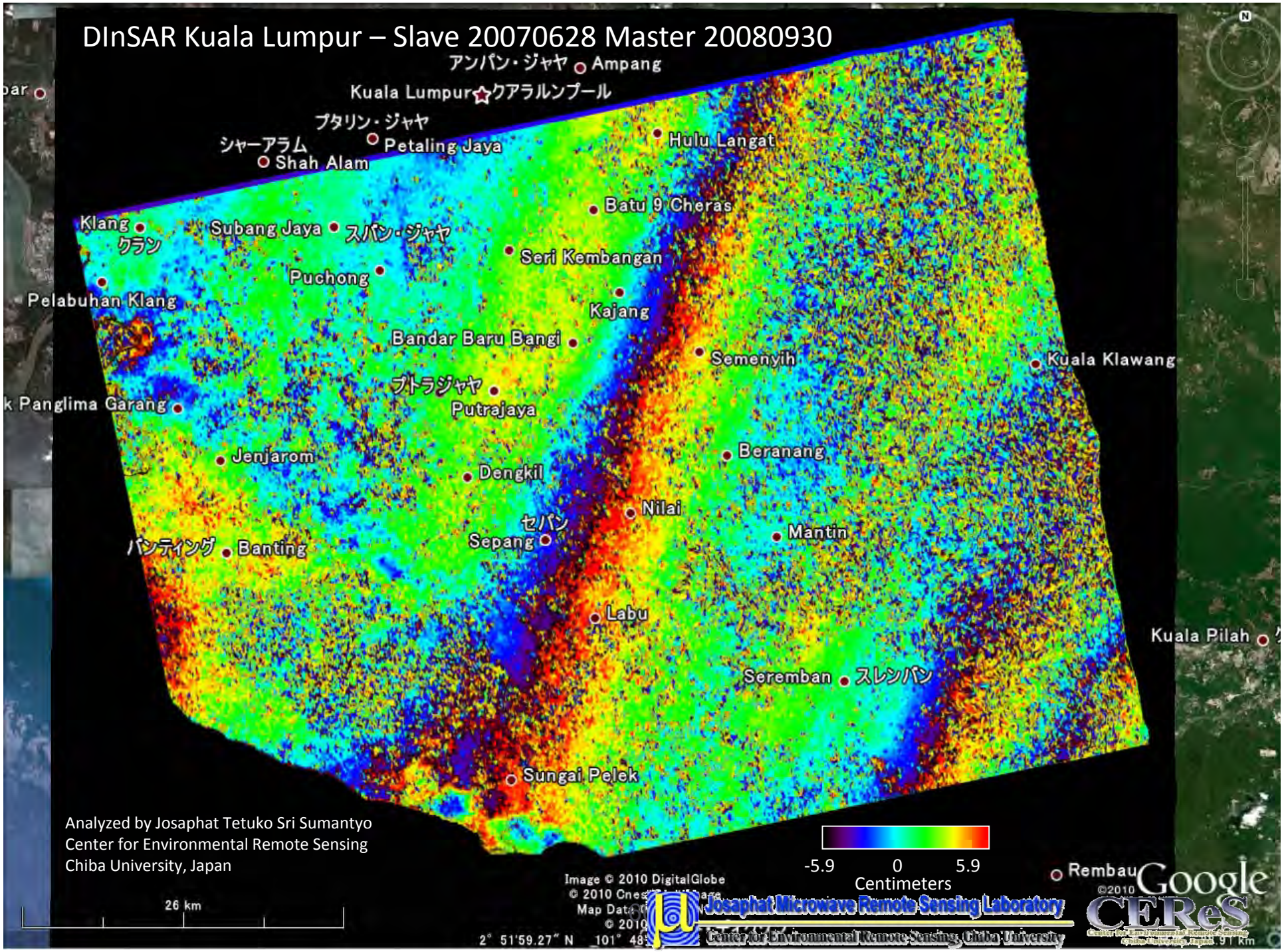
TerraSAR-X DInSAR for City Monitoring

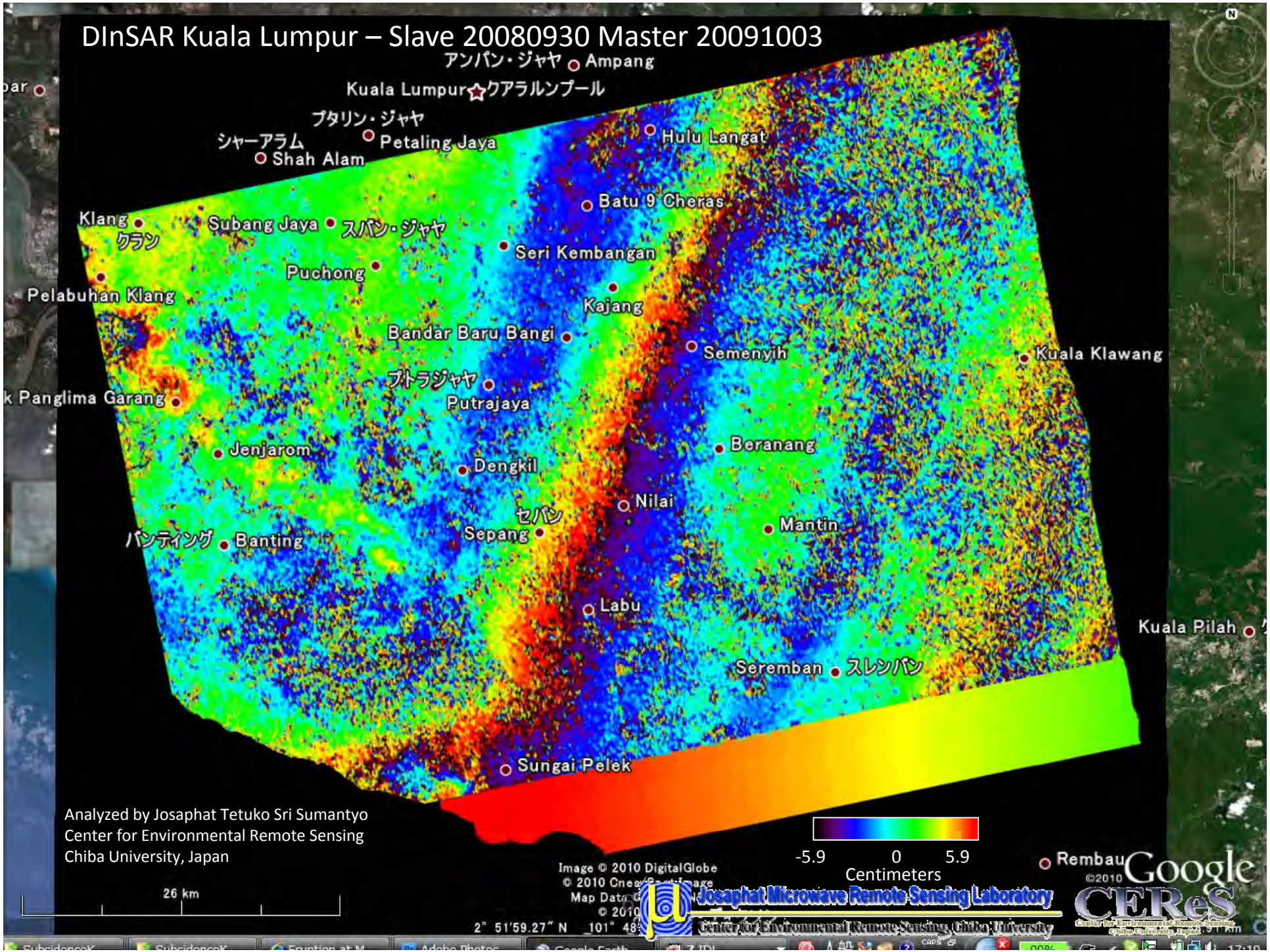
TerraSAR-X DInSAR for City Monitoring



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
Klang
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
Dengkil
Beranang
Nilai
セパン
Sepang
Mantin
バンティング
Banting
Labu
Kuala Pilah
Seremban
スレンバン
Sungai Pelek
Rembau
Image © 2010 DigitalGlobe
© 2010 Cne
Map Data
© 2010
26 km
Josaphat Microwave Remote Sensing Laboratory
Center for Environmental Remote Sensing, Chiba University
Google
©2010
CEReS
画像取得日: 2010 年 1 月 23 日
2° 51'59.27" N
101° 48
91 Km


DInSAR Kuala Lumpur – Slave 20070628 Master 20080930
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
Klang
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
Beranang
Dengkil
Nilai
セパン
Sepang
Mantin
バンティング
Banting
Labu
Kuala Pilah
Seremban
スレンバン
Sungai Pelek
Rembau
-5.9
0
5.9
Centimeters
Analyzed by Josaphat Tetuko Sri Sumantyo
Center for Environmental Remote Sensing
Chiba University, Japan
26 km
Image © 2010 DigitalGlobe
Josaphat Microwave Remote Sensing Laboratory
Center for Environmental Remote Sensing, Chiba University
Google
CERES


DInSAR Kuala Lumpur – Slave 20080930 Master 20091003
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
Klang
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
Dengkil
Beranang
Nilai
セパン
Sepang
Mantin
バンティング
Banting
Labu
Kuala Pilah
Seremban スレンバン
Sungai Pelek
Rembau
Analyzed by Josaphat Tetuko Sri Sumantyo
Center for Environmental Remote Sensing
Chiba University, Japan
-5.9
0
5.9
Centimeters
26 km
Image © 2010 DigitalGlobe
Josaphat Microwave Remote Sensing Laboratory
Center for Environmental Remote Sensing, Chiba University
Google
CEReS

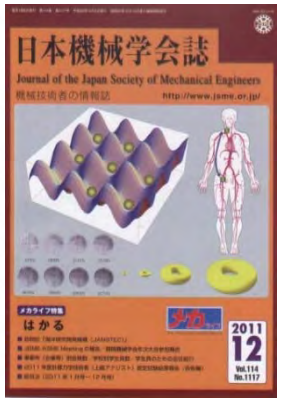
Summary and Future Research

- 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 :



IEEE GRS Newsletter Issue June 2011

Thank you for your attentions !

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Email jtetukoss@faculty.chiba-u.jp
Website http://www2.cr.chiba-u.jp/lab/jtetukoss/