Development of Advanced Microwave Sensor For Maritime Surveillance

Prof. Josaphat Tetuko Sri Sumantyo, Ph.D

Josaphat Microwave Remote Sensing Laboratory (JMRSL)
Center for Environmental Remote Sensing, Chiba University
1-33 Yayoi, Inage, Chiba 263-8522 Japan Tel. +81 (0)43 290 3840 / Fax 3857
Email jtetukoss@faculty.chiba-u.jp Website http://www2.cr.chiba-u.jp/jmrsl/

JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

Synthetic Aperture Radar (SAR)

Flight direction

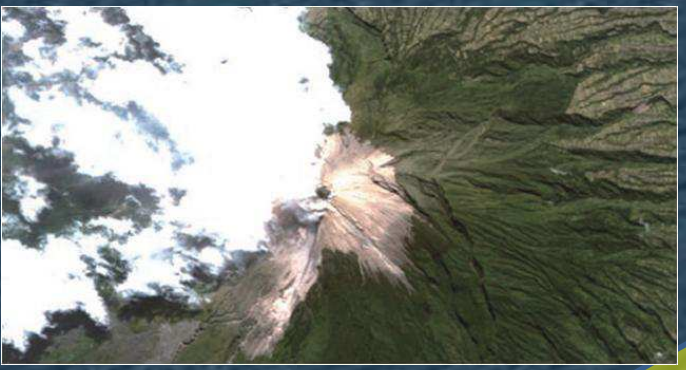
Cloud/haze/fog

Foot print

SAR image

Other names
- **Side looking radar**
- **Microwave radar**
- **Imaging radar**

Optic Sensor



Eruption of volcano of Indonesia Merapi
2006/Apr/26th
(Up)Optical ©AVNIR-2/JAXA
(Right)SAR ©PALSAR/JAXA, METI

Synthetic Aperture Radar (SAR)

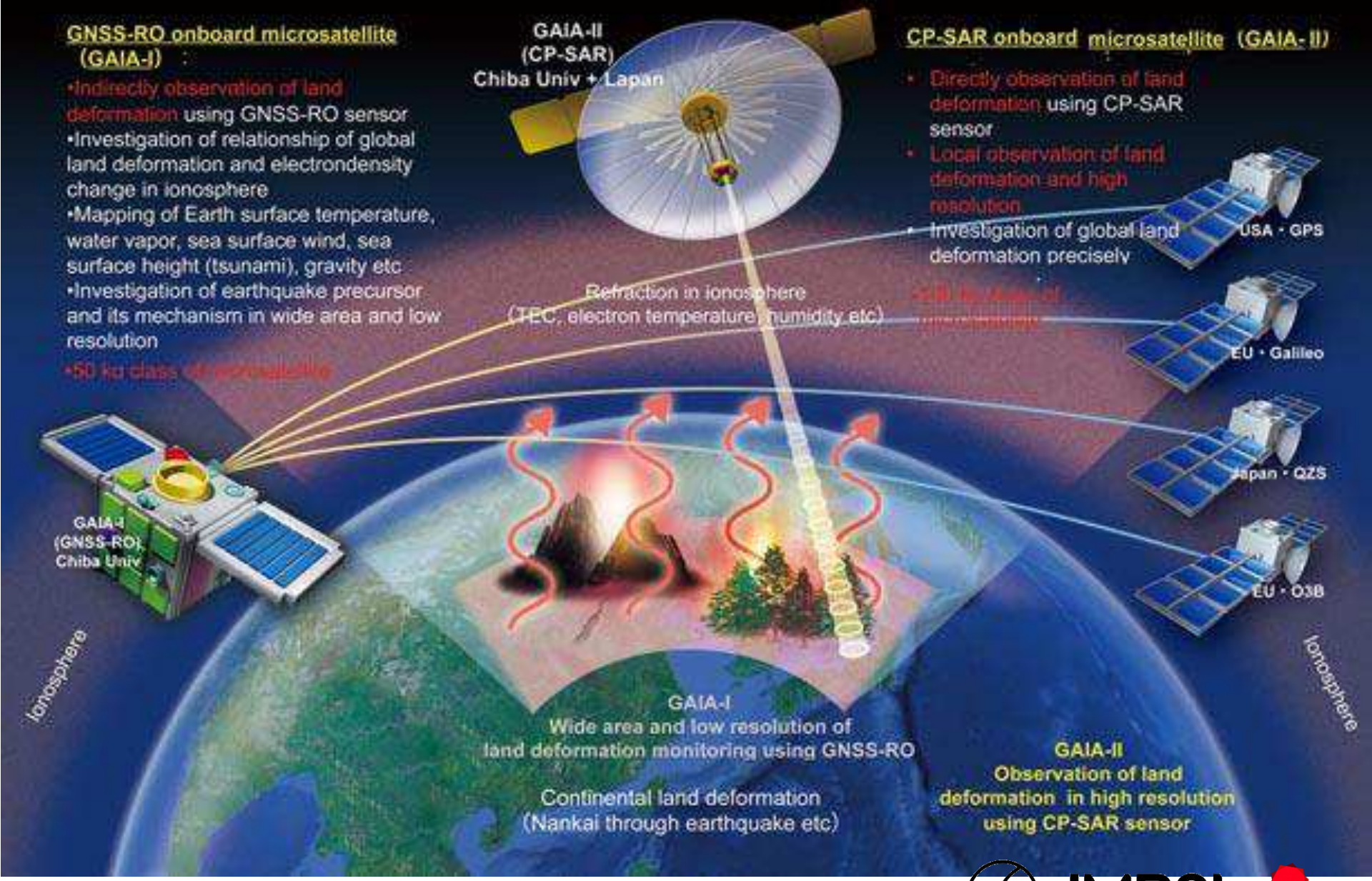
JMRSL
Japan-first Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

Airborne SAR Applications

Pi-SAR観測による合成開口レーダの機能と検証, 熊谷博
情報通信研究機構(*NICT*) 宇宙からの地球観測講演会 2005年1月13日

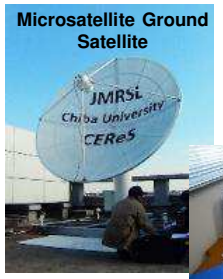
JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

Earth Observation using the GAIA-I and GAIA-II



JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

Roadmap of Synthetic Aperture Radar Development



Strategic priority research promotion program

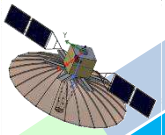
6 Programs

Institute of Global Prominent Research

FY 2015-2022

CHIBA UNIVERSITY

LAPAN-CHIBASat



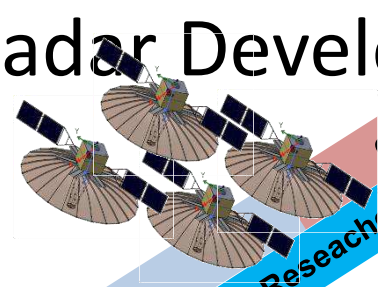
Space Environment

Development of Microsatellite

Advanced Microwave Remote Sensing Research Center : Domestic and International Reseacher Exchange

Calibration & Validation

Operation



~2015

UAV
SAR System
Ground Station
Ground Test
Flight Test
etc

2016

Microsatellite SAR Mission System :
Bus System : Lapan

2017

2018

Microsatellite SAR Mission System :
Bus System : Lapan

2019

2020

Microsatellite SAR Validation and Calibration

Launching

Calibration and validation using Boeing 737-200 and UAV

2021

Microsatellite SAR Applications Development

2022

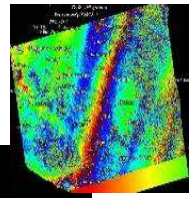
Microsatellite SAR Constellation

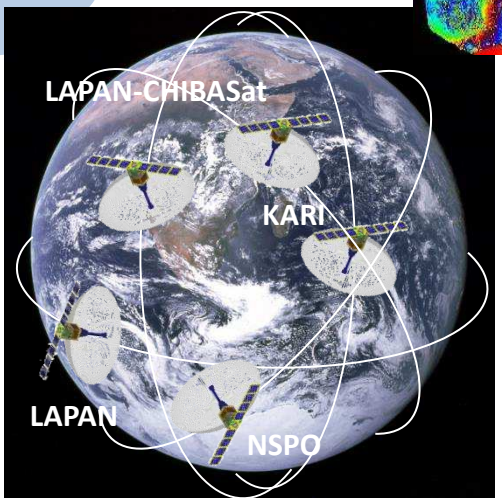
2023

Microsatellite SAR Constellation Global Environment & Land Deformation Monitoring

2024~

mm accuracy of InSAR Technology using Microsatellite SAR





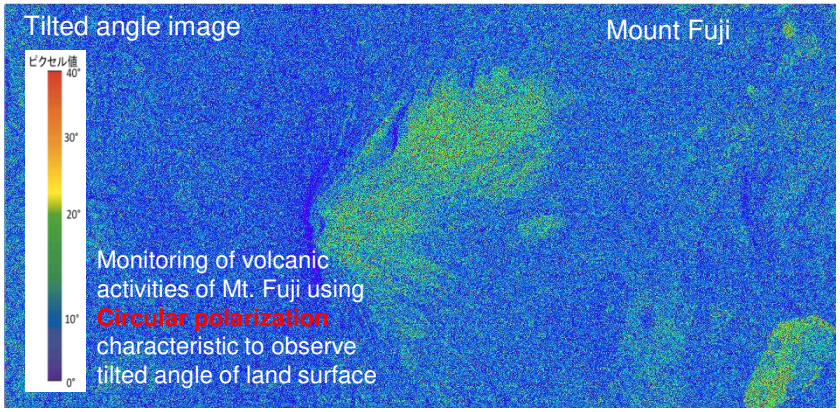
Microsatellite SAR Constellation

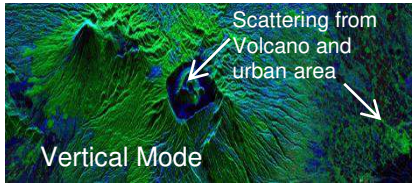
Josaphat Tetuko Sri Sumantyo, Koo Voon Chet, Lim Tien Sze, Takafumi Kawai, Takuji Ebinuma, Yuta Izumi, Mohd Zafri Baharuddin, Steven Gao and Koichi Ito, "Development of circularly polarized synthetic aperture radar onboard UAV JX-1," International Journal of Remote Sensing, Special Issue Papers on Drones, UAVs, RPASs for Environmental Research, online 8 December 2016, printed July 2017 – In press (DOI : 10.1080/01431161.2016.1275057)

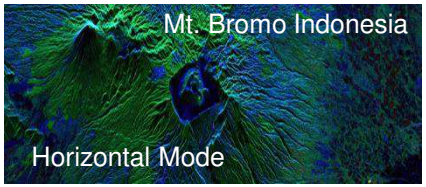
JMRSL
Josaphat Microwave Remote Sensing Laboratory

CHIBA UNIVERSITY

Circularly Polarized Synthetic Aperture Radar（CP-SAR）Terms



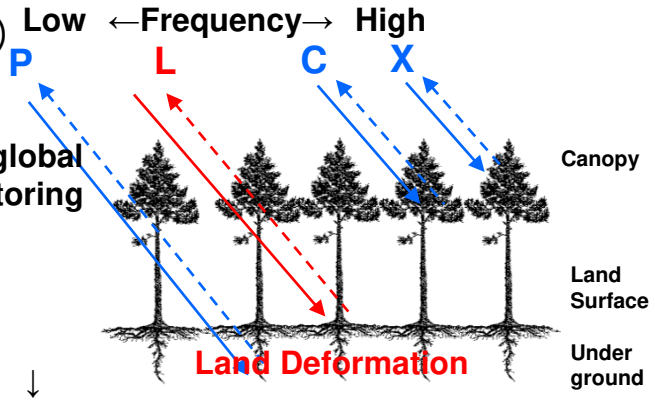


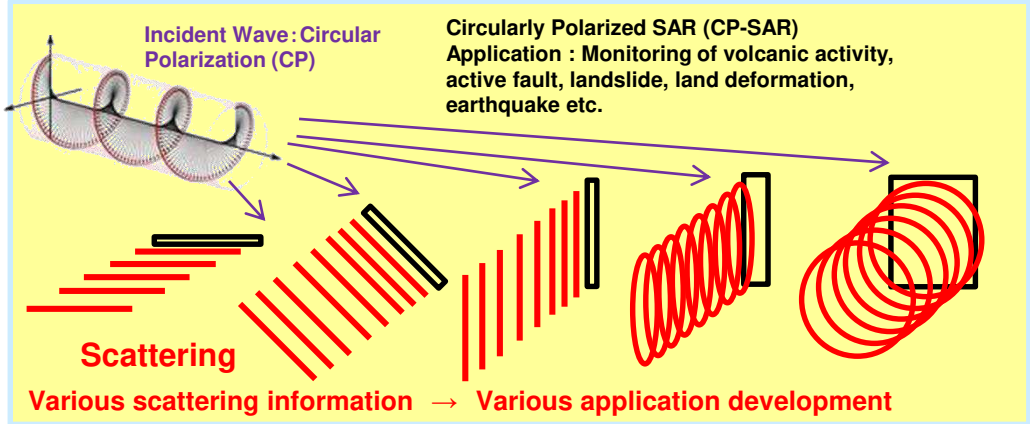


Source : Prof Yosio Yamaguchi

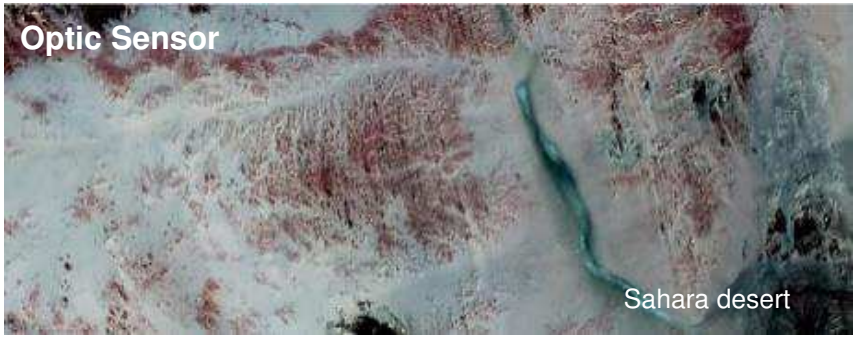
Microsatellite SAR for global land deformation monitoring using L Band →

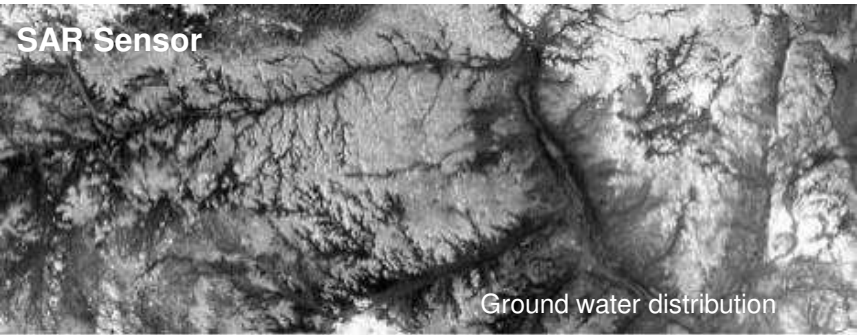
Comparison of Linear Polarized SAR and Circular Polarized SAR ↓

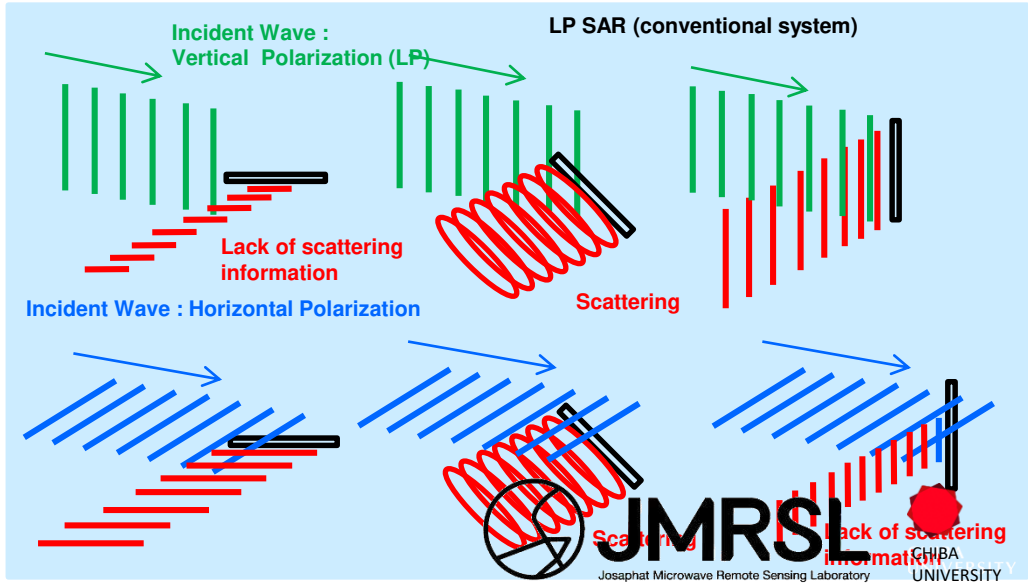




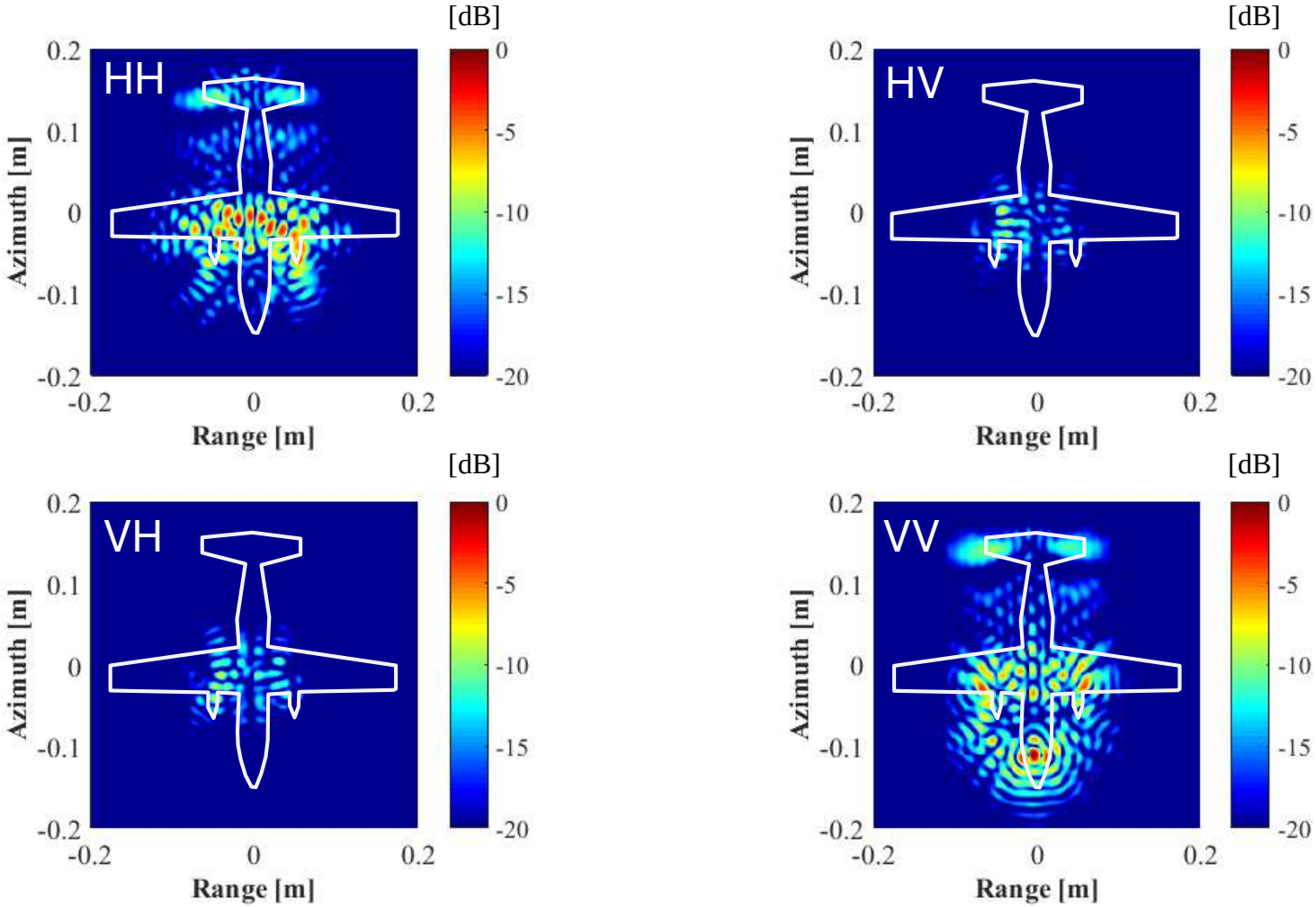
Optic Sensor VS SAR Sensor







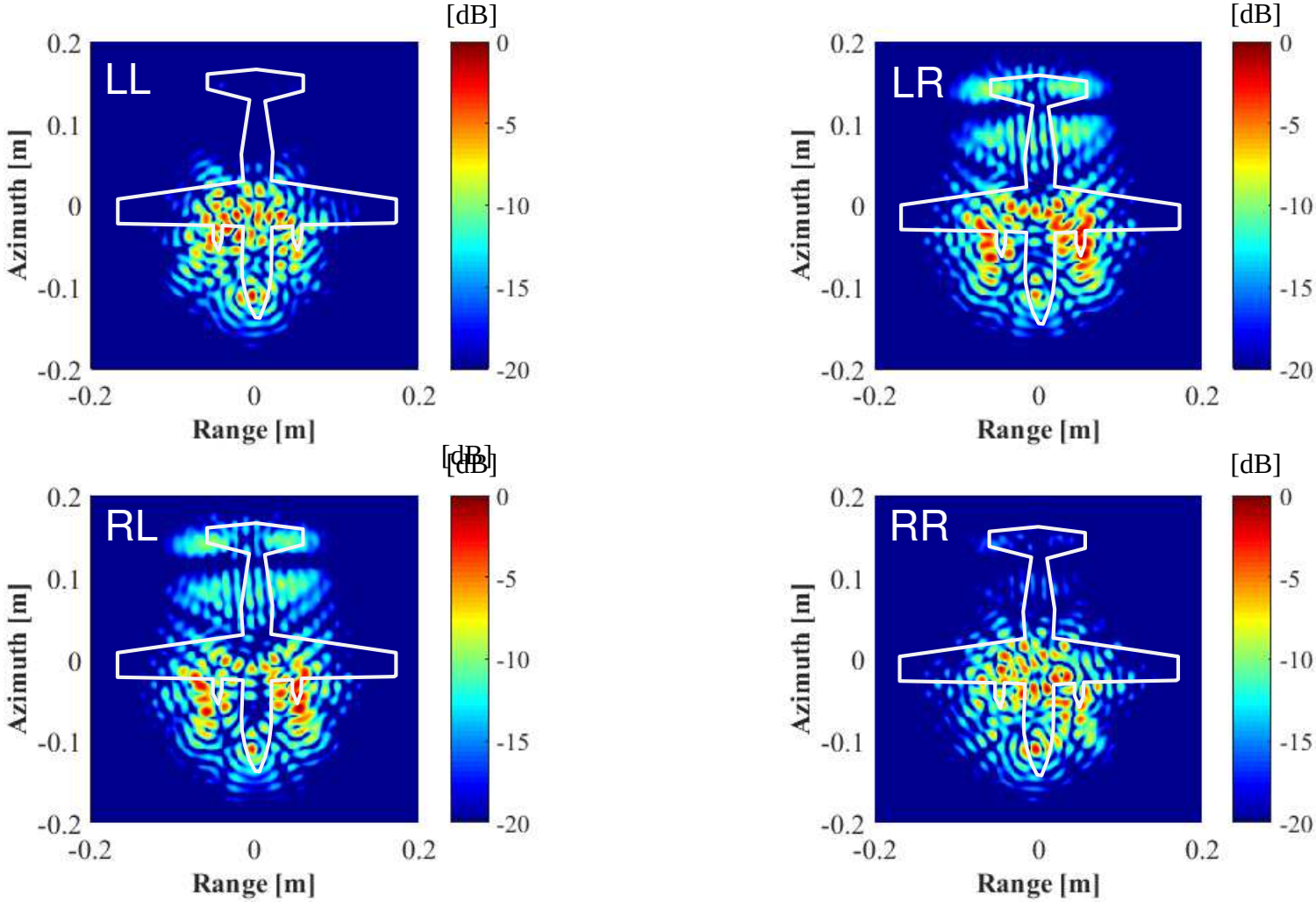
Scattering of Linear Polarization (LP)



Josaphat Tetuko Sri Sumantyo, Koo Voon Chet, Lim Tien Sze, Takafumi Kawai, Takuji Ebinuma, Yuta Izumi, Mohd Zafri Baharuddin, Steven Gao and Koichi Ito, "Development of circularly polarized synthetic aperture radar onboard UAV JX-1," International Journal of Remote Sensing, Special Issue Papers on Drones, UAVs, RPASs for Environmental Research, Vol. 38, No. 8-10, pp.2745-2756, online 8 December 2016, printed July 2017 (DOI : 10.1080/01431161.2016.1275057)

JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

Scattering of Circular Polarization (CP)



Josaphat Tetuko Sri Sumantyo, Koo Voon Chet, Lim Tien Sze, Takafumi Kawai, Takuji Ebinuma, Yuta Izumi, Mohd Zafri Baharuddin, Steven Gao and Koichi Ito, "Development of circularly polarized synthetic aperture radar onboard UAV JX-1," International Journal of Remote Sensing, Special Issue Papers on Drones, UAVs, RPASs for Environmental Research, Vol. 38, No. 8-10, pp.2745-2756, online 8 December 2016, printed July 2017 (DOI : 10.1080/01431161.2016.1275057)

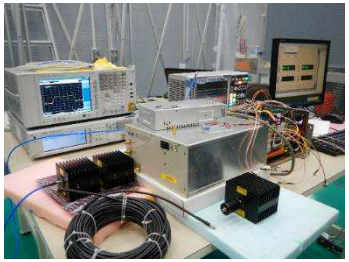
JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

SAR Technology

1. Technology :
   Circularly Polarized Synthetic Aperture Radar (CP-SAR) as improvement of Linear Polarized Synthetic Aperture Radar (LP SAR)

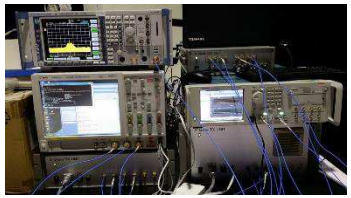
2. Development of SAR System
   - SAR system developing since 2005
   - L, C, X band SAR system
   - UAV, Aircraft and Microsatellite onboard
3. Collaborators :
- Japan government and companies
- Malaysia (MMU, USM, Uniten etc)
- Indonesia government and companies
- Taiwan (NSPO)
- ESA (DIFFERENT)
- ISAS-JAXA
- NASA KARI – KPLO etc

L Band SAR System Microsatellite



L Band SAR System Aircraft / UAV

C Band SAR System Aircraft / UAV



X Band SAR System Aircraft / UAV

JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

Benefit of CP-SAR

- Circular polarizations (CP) performs better than the HH polarization at **lower incidence angles** (off nadir angle) [1-2].
- CP exhibits multiple benefits over linear polarization including CP avoids **polarization losses due to misalignment**
- CP is no need to keep the transmitting and receiving antenna in the same alignment; It has the ability to **decrease interference** between direct and reflected signal due to multipath propagation
- The CP has the advantage of compactness and low power requirement, since the transmission of CP microwave is not affected by the **Faraday rotation effect** in the ionosphere [3]

etc

References

[1] S. Angelliaume, P. Martineau, P. Durand, and T. Cussac, "Ship Detection and Sea Clutter Characterisation Using X&L-Band Full-Polarimetric Airborne SAR Data," *Proceedings of SeaSAR Norway*, 2012, pp. 1-4.

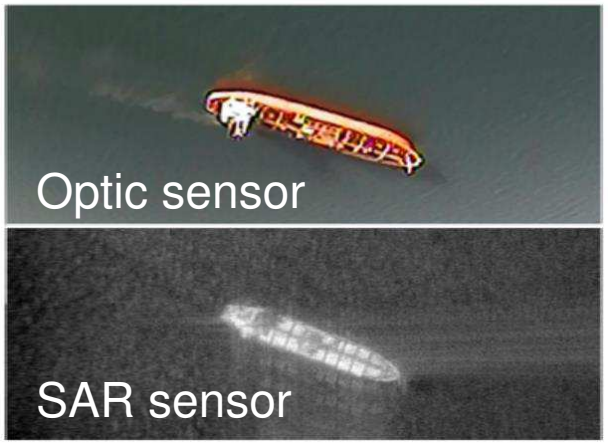
[2] R. Touzi, "On the use of polarimetric SAR data for ship detection," *Proceedings of Geoscience and Remote Sensing Symposium*, vol. 2, 1999, pp. 812-814.

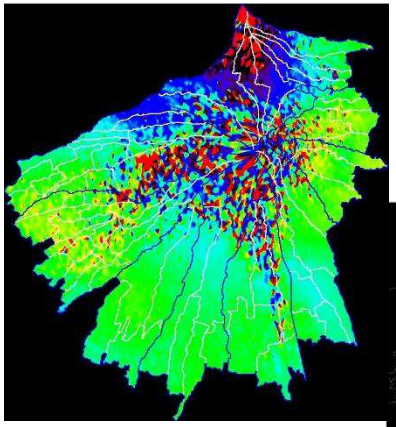
[3] J. T. Sri-Sumantyo, "Development of Circularly Polarized Synthetic Aperture Radar (CP-SAR) Onboard Small Satellite," *PIERS Proceedings, Marrakesh, Morocco,* 2011, pp. 334-341.

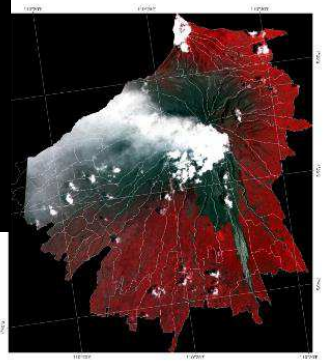
Needs

1. Disaster Monitoring
   Peatland, land deformation
   Fire spot monitoring
   Volcanic and earthquake monitoring
   Landslide precursor
2. Fishery and Maritime
   Illegal fishing and armed fishing ship
   Oil spill monitoring etc
3. Search and Rescue (SAR)
   - Heavy rain and cloud/haze environment
   - Forest
4. Infrastructure Monitoring
   Maintenance of highway, seaport, railway, electricity transmission line, dam, housing etc
5. Research and Education on SAR Technology
   - Development on new SAR technology
   - Development on SAR applications

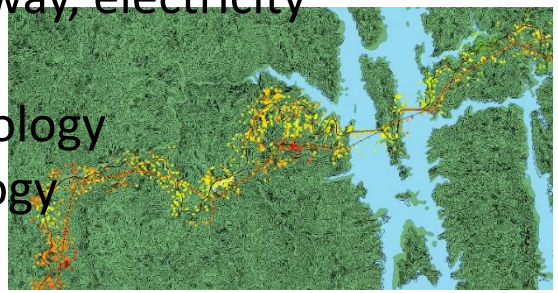
etc







Merapi eruption

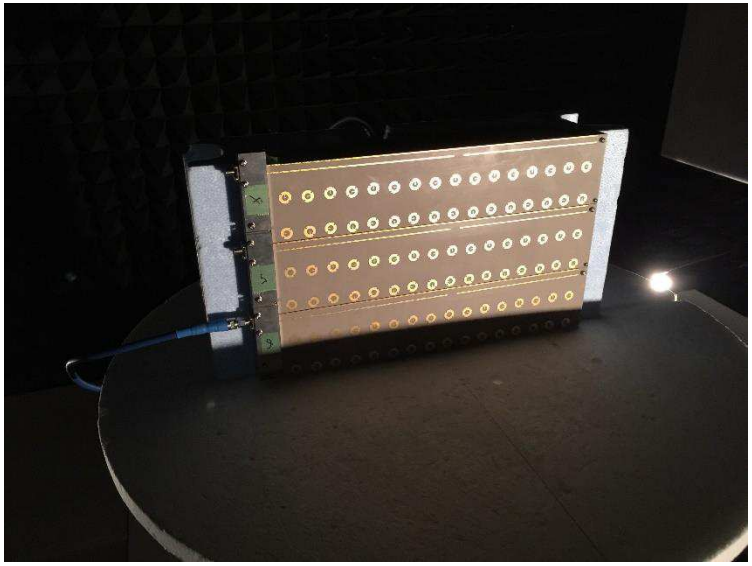


Malaysian highway and electricity infrastructure monitoring

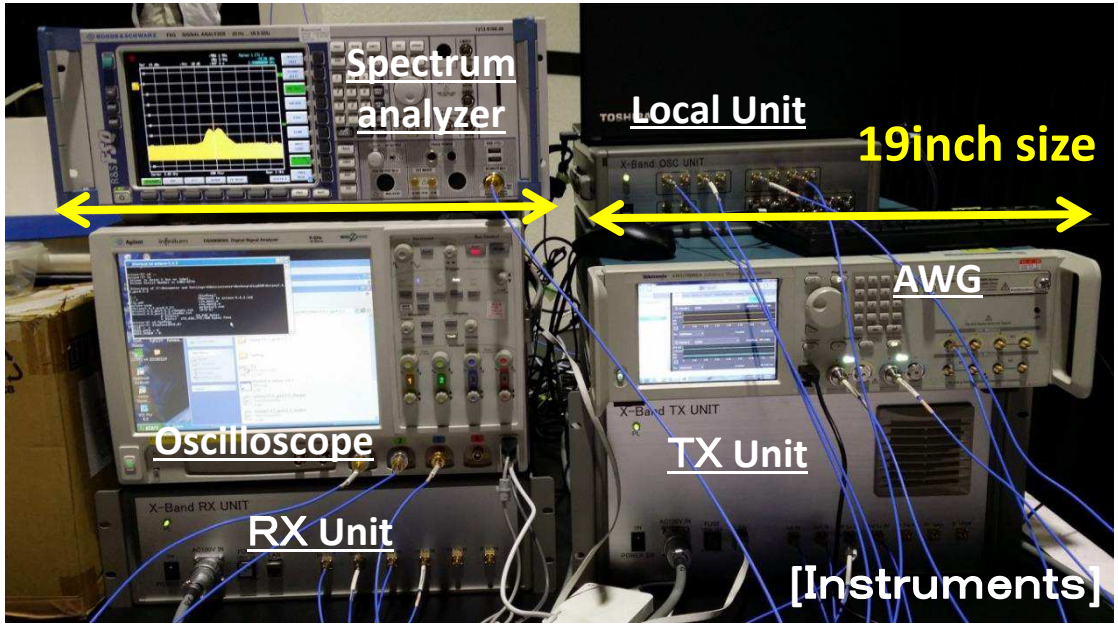
JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

X Band SAR for Boeing 737-200

Items	Spec
Center Frequency	9.4GHz
Frequency Bandwidth	800MHz
Transmit Power	1500W peak
Slant Range Resolution	1m
Azimuth Resolution	5m
Flight Altitude	～5,000m



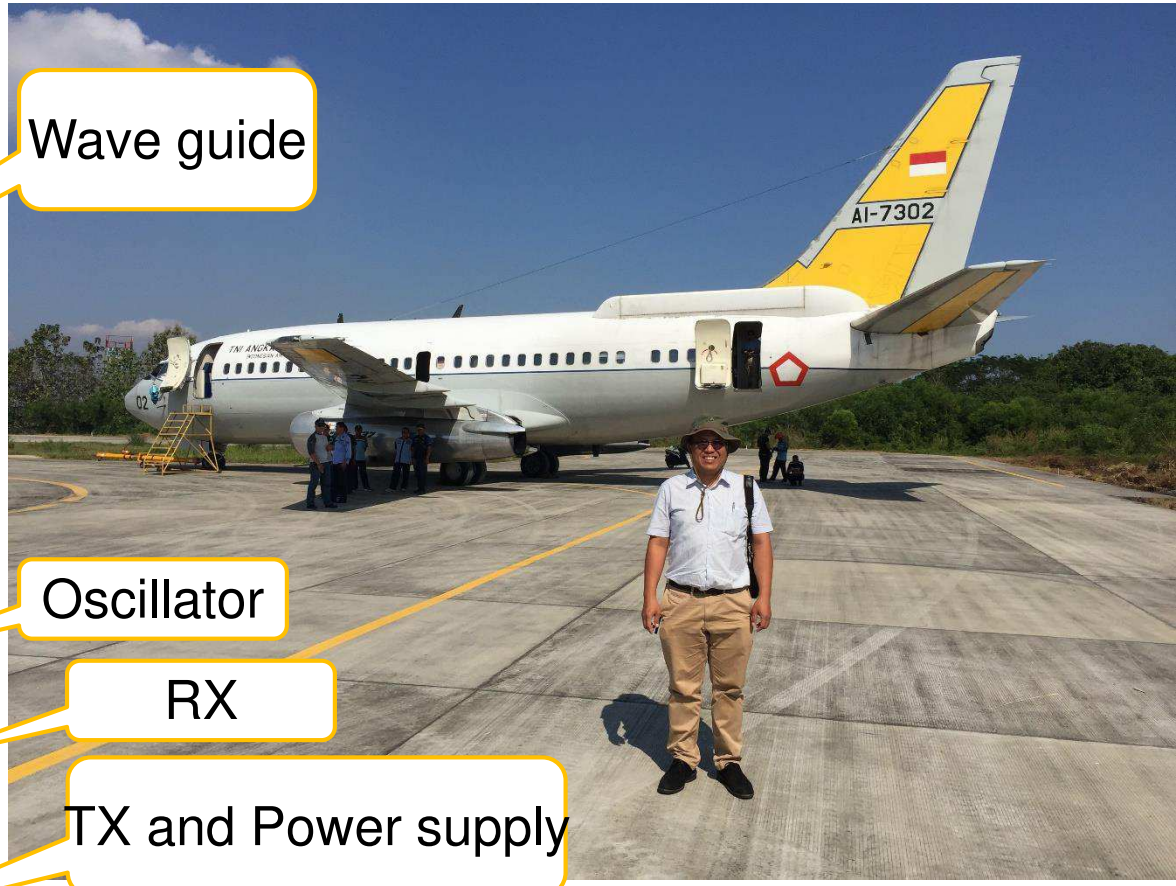
CP-SAR Antenna : Tilted 30 degrees for downward



X Band CP-SAR System

JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

X Band SAR Installation



Wave guide

Oscillator

RX

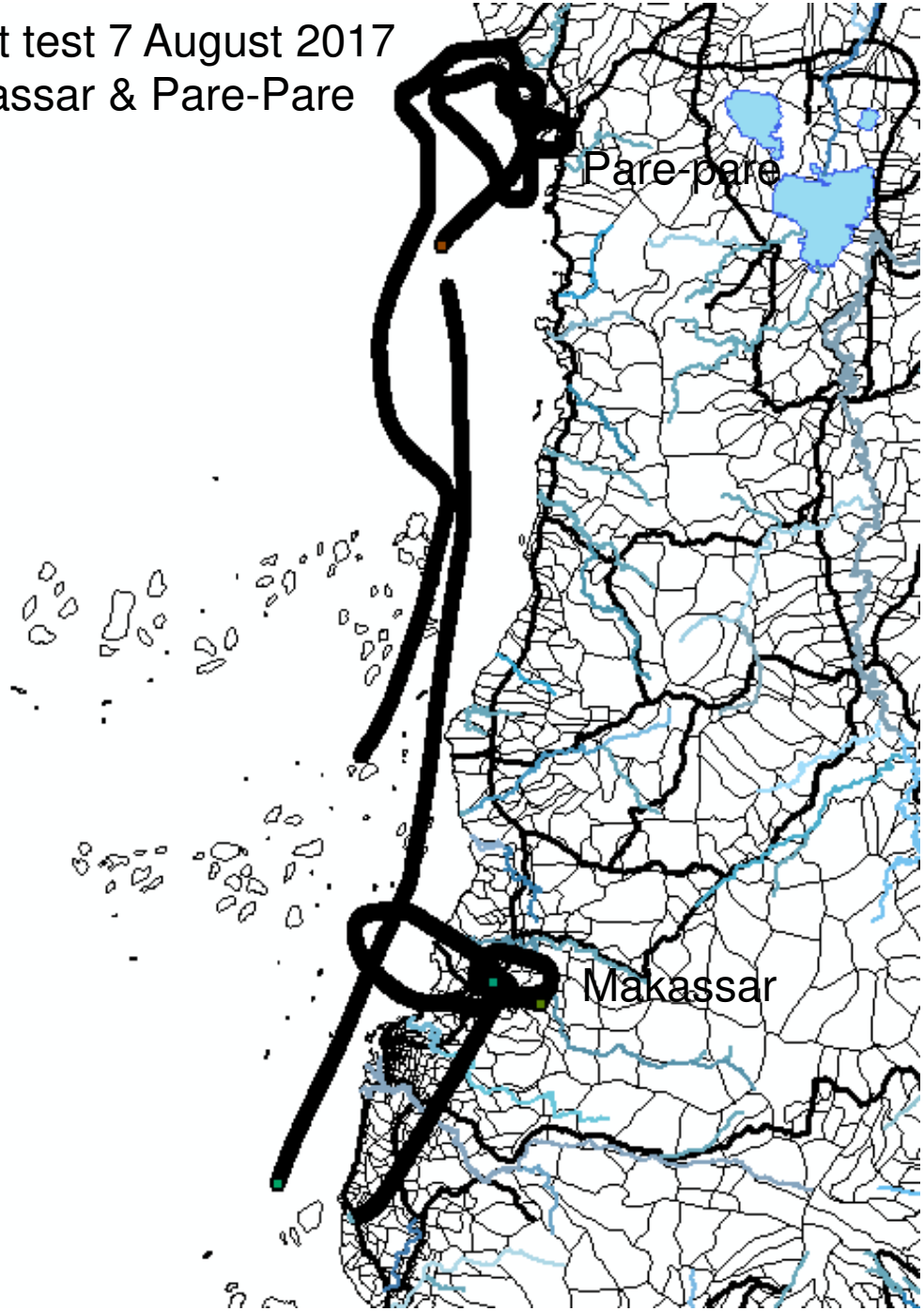
TX and Power supply

Oscilloscope

AWG

JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

Flight test 7 August 2017
Makassar & Pare-Pare



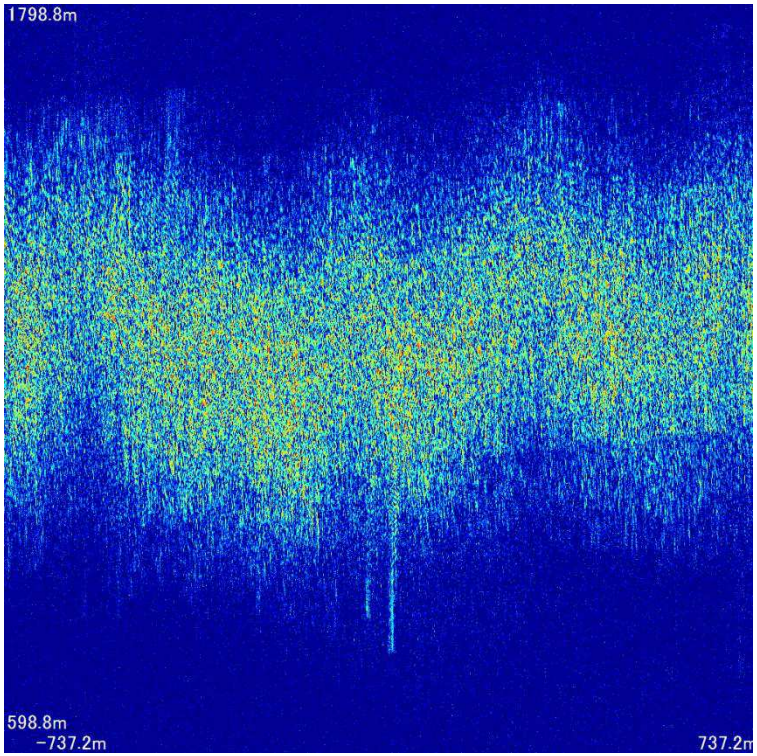
JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

Rolling observation

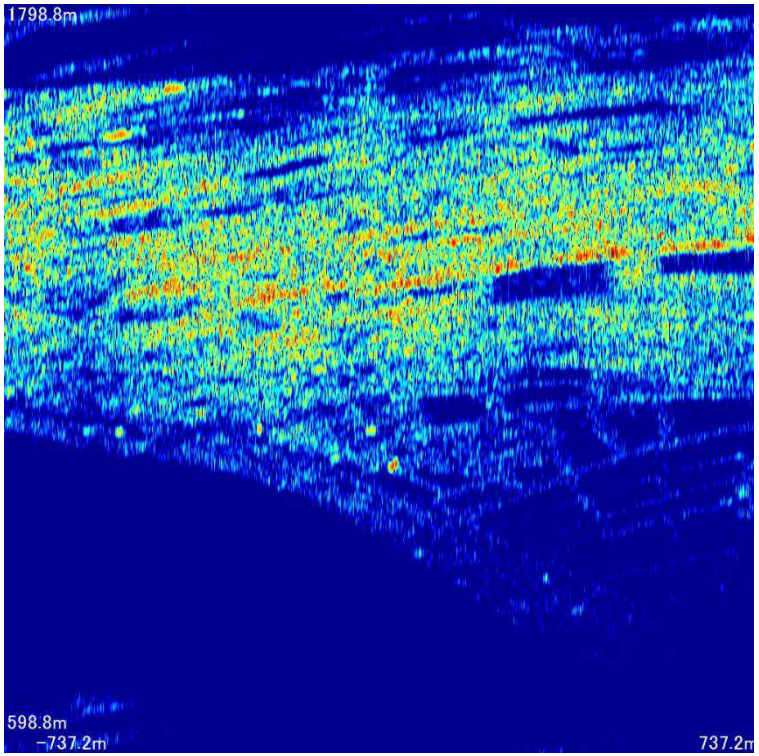
Flight test 7 August 2017
Makassar & Pare-Pare

JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

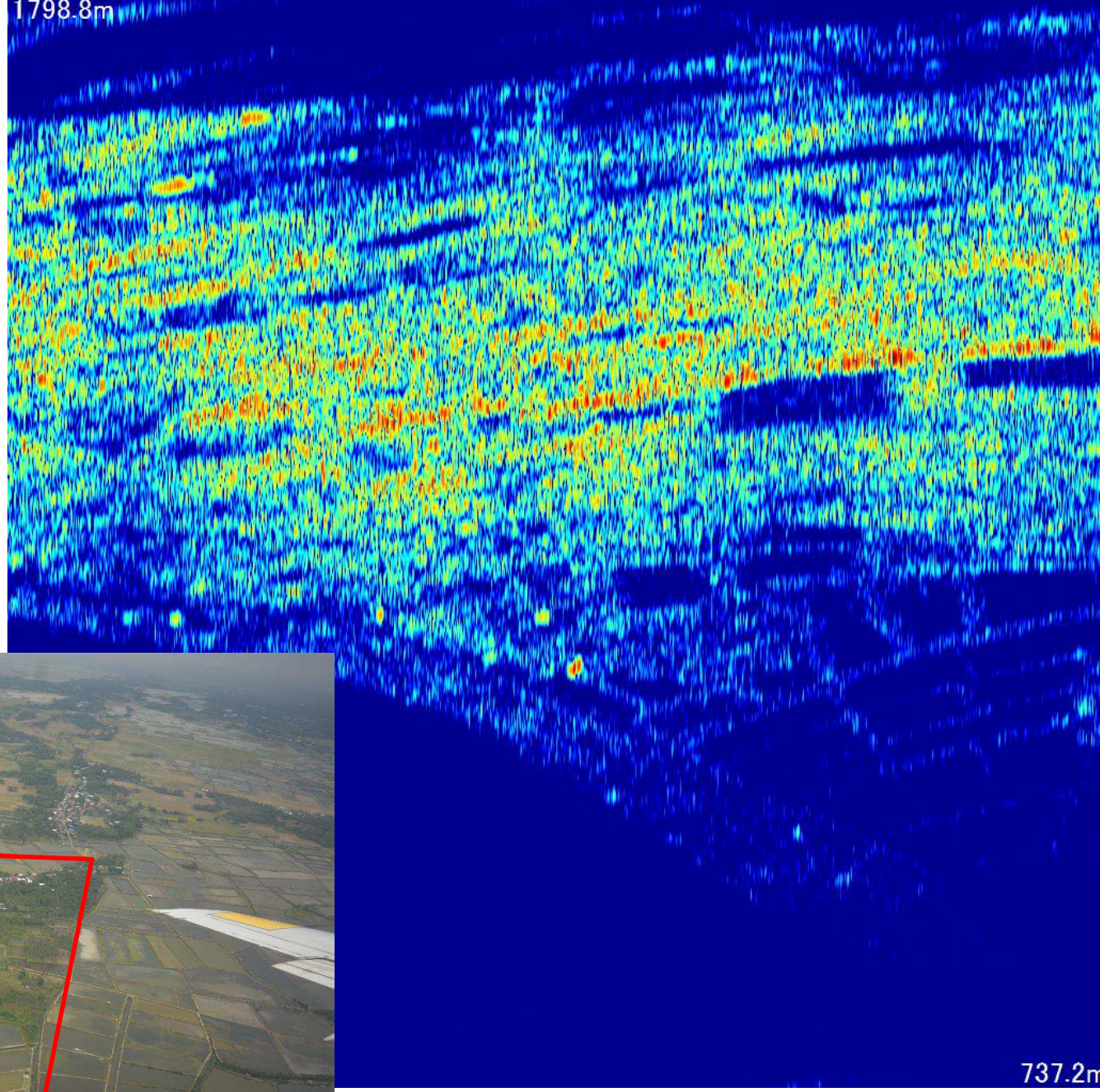
Raw Data



Processed Data



JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

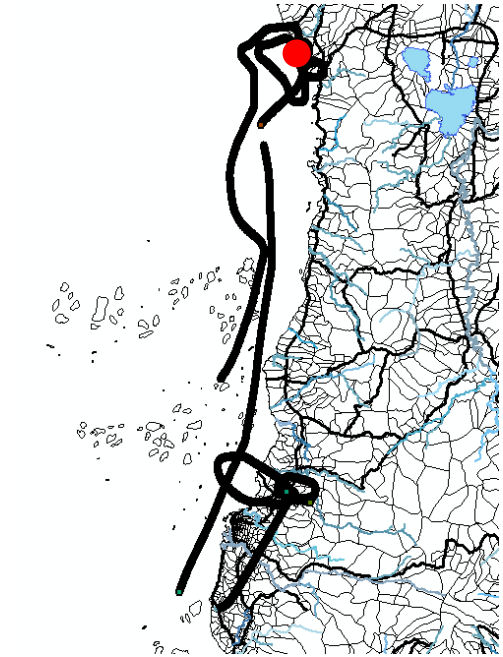


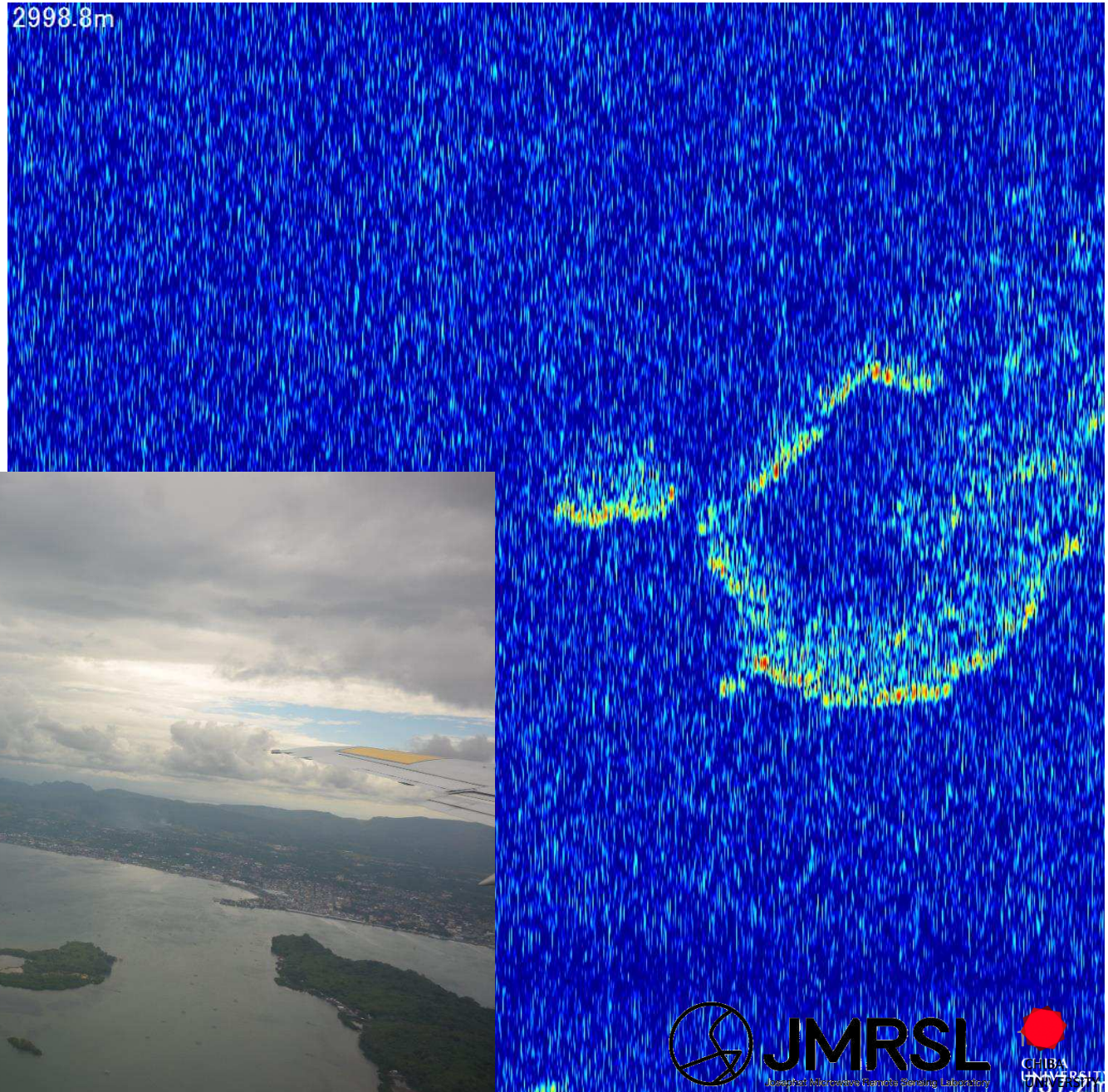
JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

Cruising observation

JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

G2 20170807 11:02





C Band SAR for Aircraft

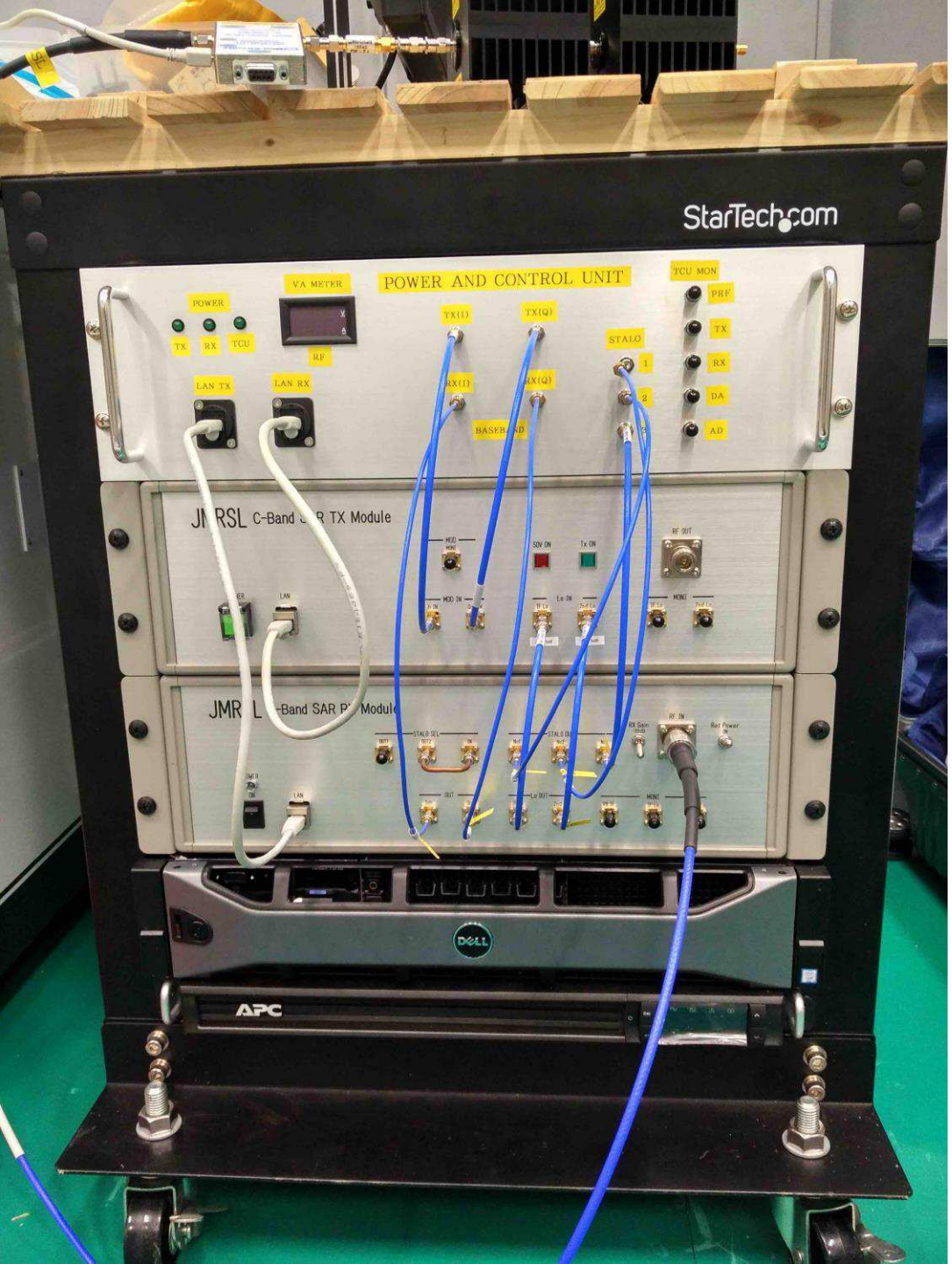
Indonesia : 2015-2016 Taiwanese NSPO : 2016 – 2017

Cessna Model 182 (Series 1997) Aircraft

C Band SAR
(Center frequency : 5.6 GHz, BW: 400 MHz) for disaster and plantation monitoring

JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

HINOTORI-C1 MISSION



Items	Spec
Center Frequency	5.6 GHz
Frequency Bandwidth	400MHz
Transmit Power	400W peak
Slant Range Resolution	1m
Azimuth Resolution	5m
Flight Altitude	～2,000m

As a brief explanation regarding the system, the system is consist of 5 modules, namely (with estimated size and weight),

1) Power and Control Unit (Dimension: 14 cm x 48 cm x 52 cm, Weight: 10 kg)

2) SAR TX Module (Dimension: 14 cm x 48 cm x 48 cm, Weight: 5 kg)

3) SAR RX Module (Dimension: 14 cm x 48 cm x 48 cm, Weight: 5 kg)

4) Server (Computer) (Dimension: 9 cm x 48 cm x 76 cm, Weight: 25 kg)

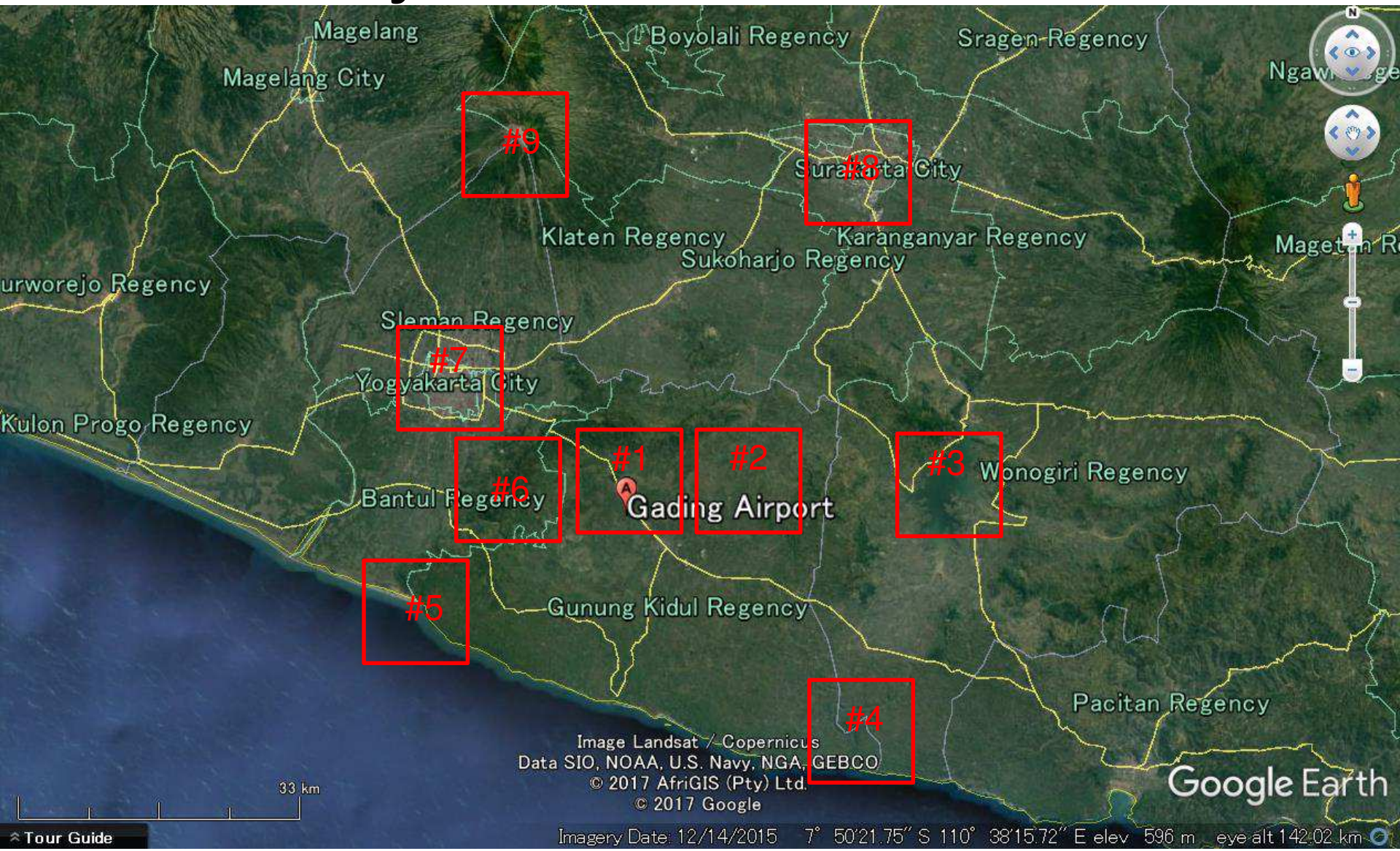
5) Uninterruptible Power Supply (Dimension: 5 cm x 48 cm x 68 cm, Weight: 25 kg)

All modules are with 19" rack mount enclosure with different height and different depth. The longest in depth module is the server.

There is a need to reserve some space in the front (around 20 cm) and at the back (around 10 cm) for the cabling.

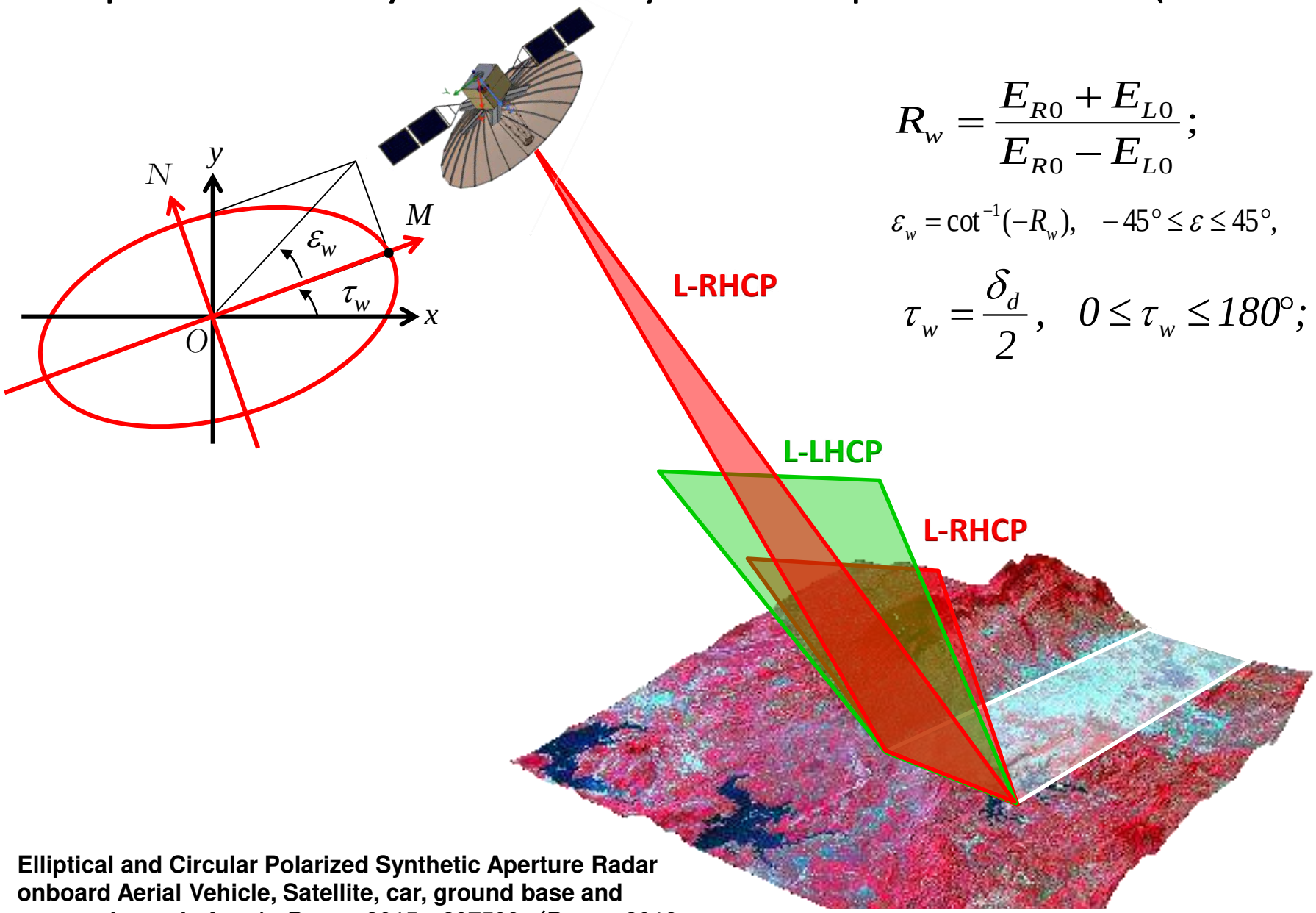
JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

Natural Object Observation



JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

Concept of Circularly Polarized Synthetic Aperture Radar (CP-SAR)



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

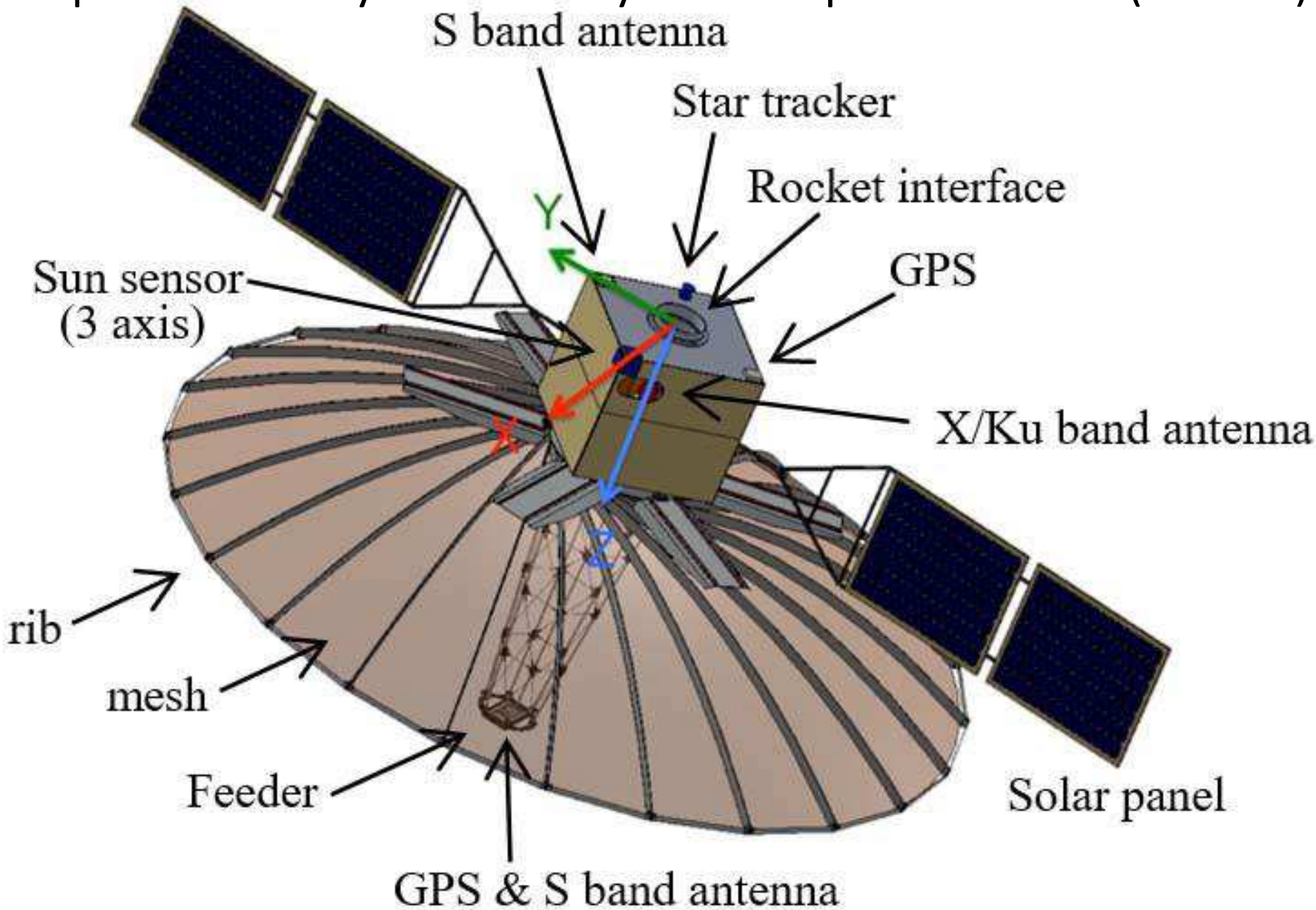
$$\varepsilon_w = \cot^{-1}(-R_w), \quad -45° \le \varepsilon \le 45°,$$

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

Elliptical and Circular Polarized Synthetic Aperture Radar onboard Aerial Vehicle, Satellite, car, ground base and stratosphere platform), Patent 2015－207590（Patent 2016－80710、16 May 2016）No. 2014-214905, 21 October 2014

JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

Concept of Circularly Polarized Synthetic Aperture Radar (CP-SAR)



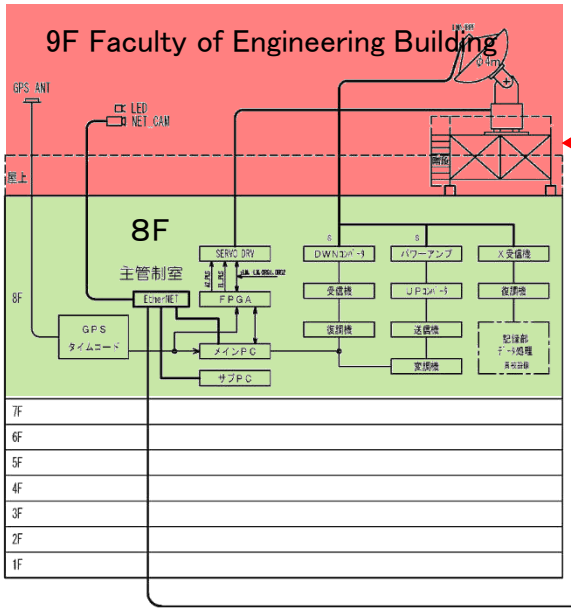
Elliptical and Circular Polarized Synthetic Aperture Radar onboard Aerial Vehicle, Satellite, car, ground base and stratosphere platform), Patent 2015－207590 （Patent 2016－80710, 16 May 2016）No. 2014-214905, 21 October 2014

QPS JMRSL Josaphat Microwave Remote Sensing Laboratory CHIBA UNIVERSITY

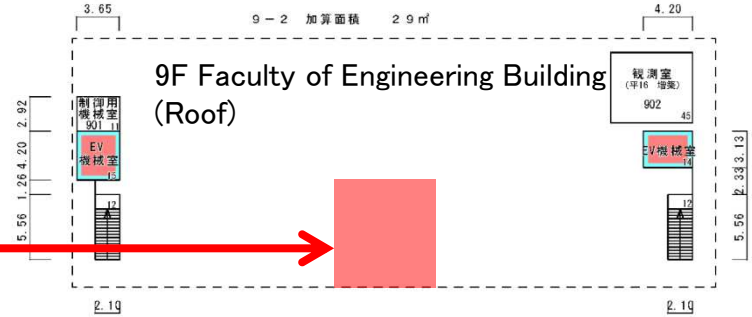
Measurement System of SAR for Microsatellite

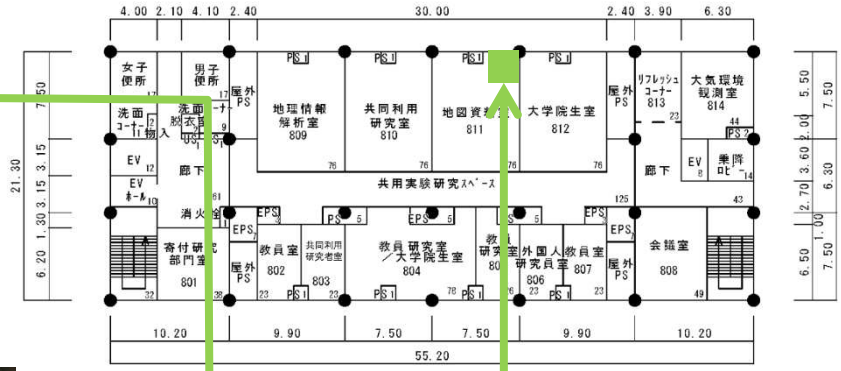
Satellite Ground Station of JMRSL

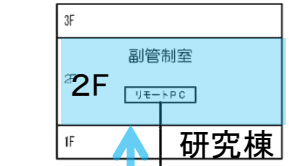
S Band : Command TX & Telemetry RX
X Band : Mission Data RX

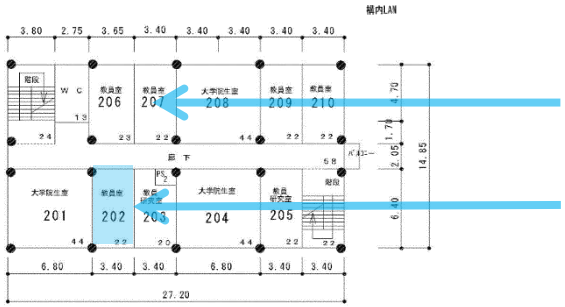


Antenna & Controller









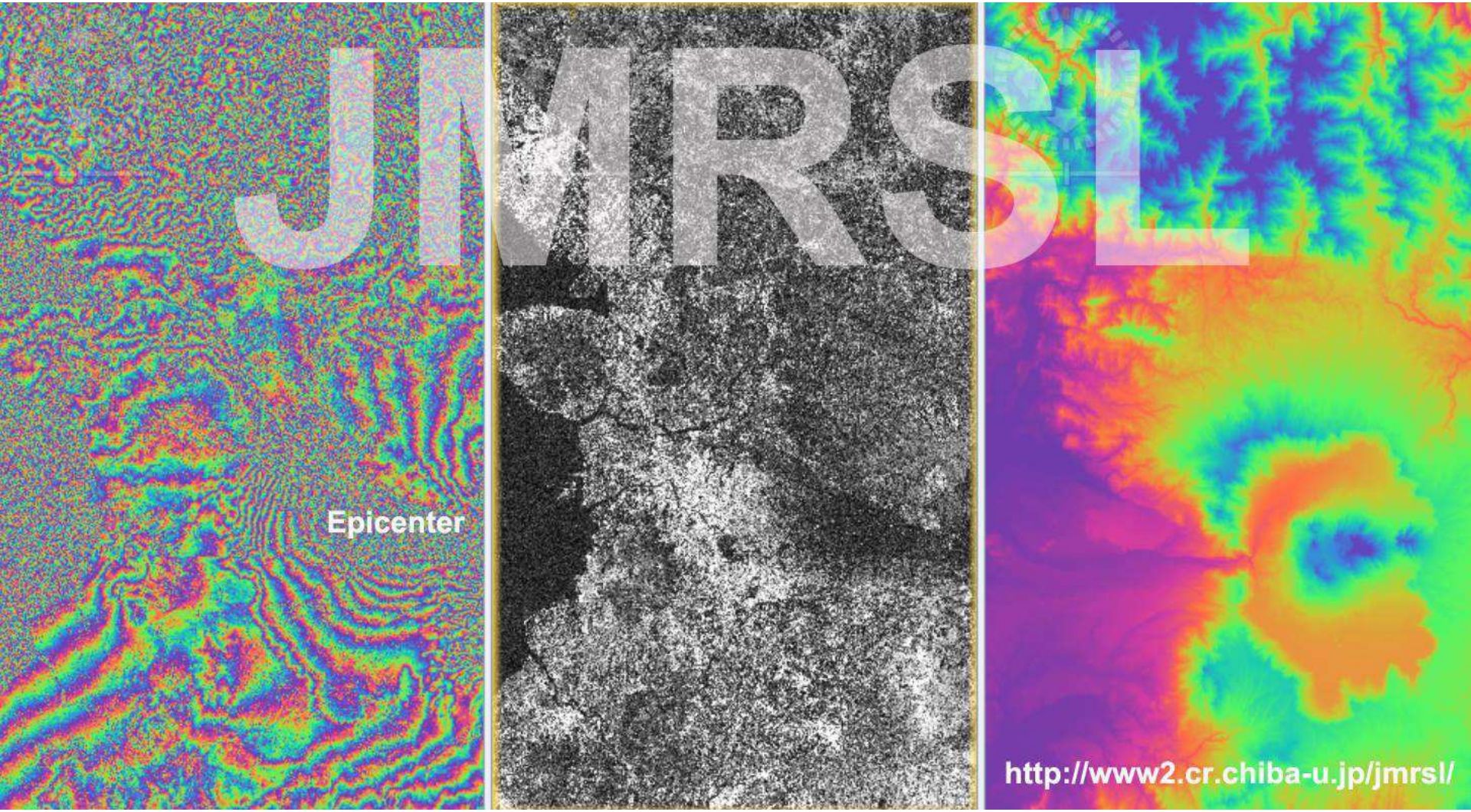
2F Center For Environmental Remote Sensing Building (Josaphat Laboratory)

Sub Ground Control Room

Main Ground Control Room

JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

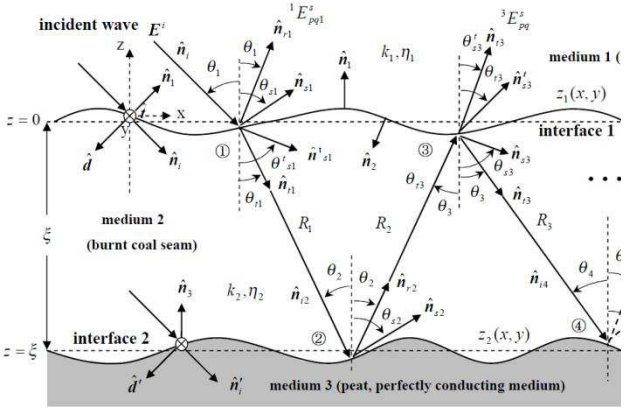
Synthetic Aperture Radar (SAR)

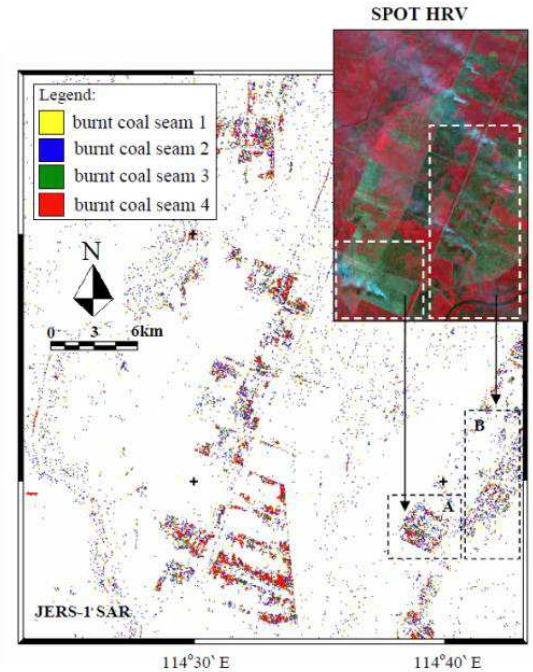


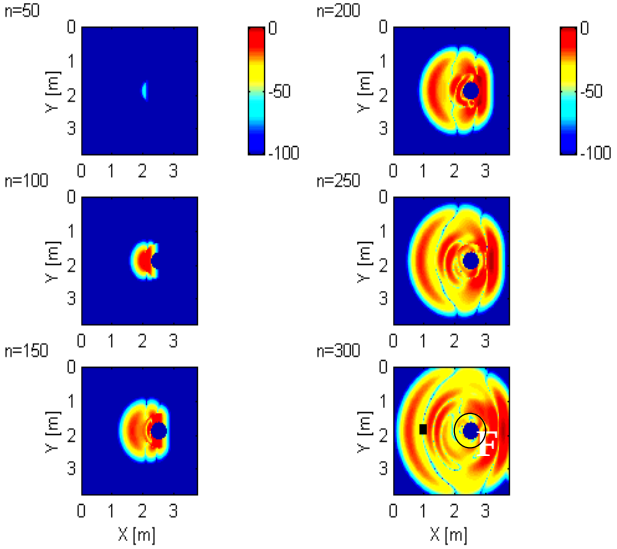
JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

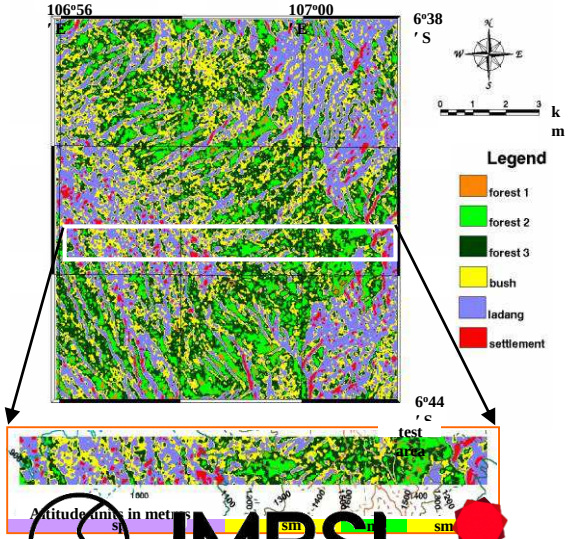
Previous Research Results : FY 1999 - 2002
Electromagnetic Modelling of SAR Scattering for Burnt Coal Seam Monitoring

Josaphat Tetuko Sri Sumantyo et al.
Pages : 187pp. Publisher : ITB Press ISBN : 979-3507-28-4





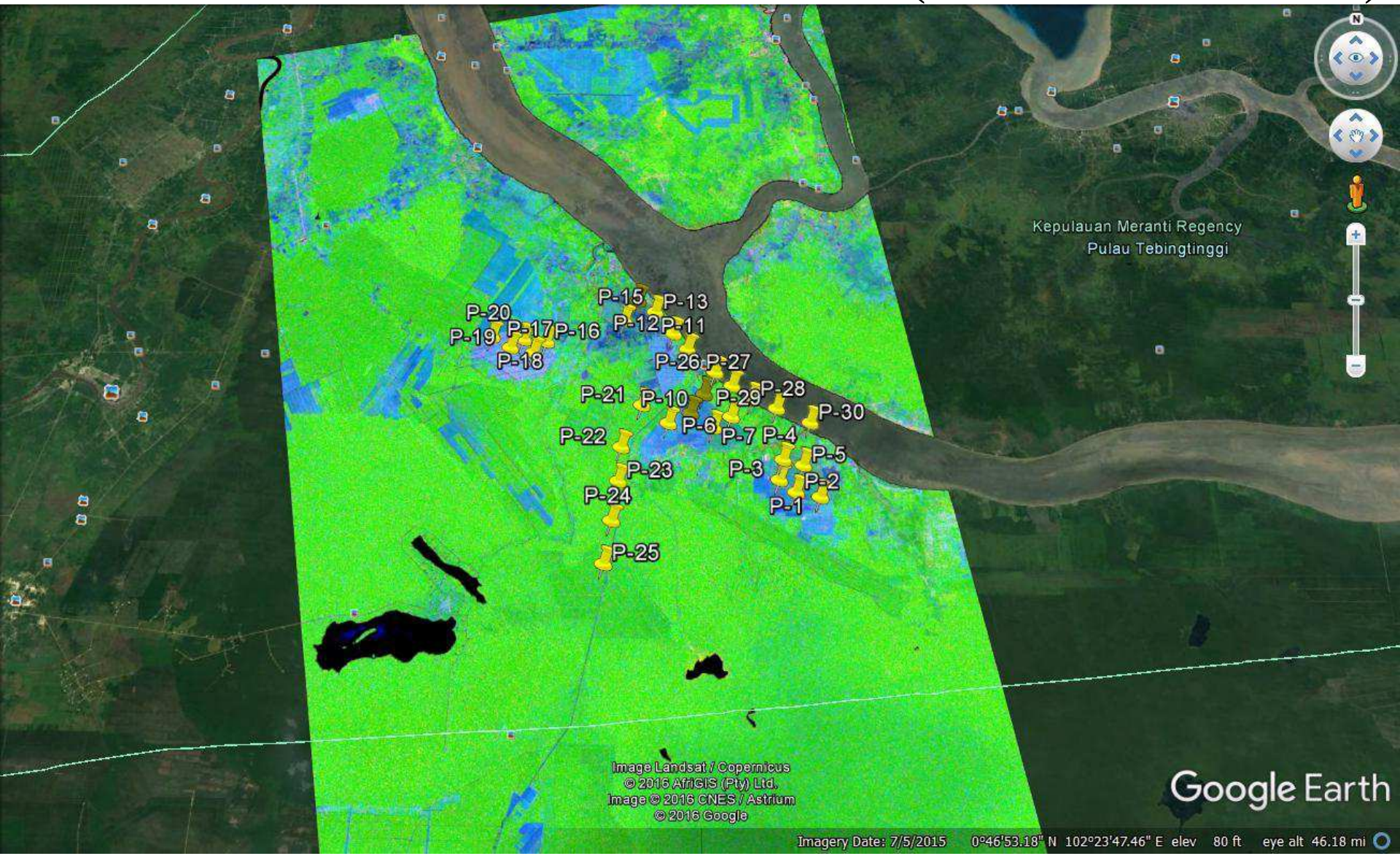




- Josaphat Tetuko Sri Sumantyo, R. Tateishi, N. Takeuchi, "Estimation of burnt coal seam thickness in central Borneo using a JERS-1 SAR image," **International Journal of Remote Sensing**, Vol. 24, No. 4, pp. 879 - 884, February 2003 (London: Taylor and Francis)
- Josaphat Tetuko Sri Sumantyo, R. Tateishi, N. Takeuchi, "A physical method to analyse scattered waves from burnt coal seam and its application to estimate thickness of fire scars in central Borneo using JERS-1 SAR data," **International Journal of Remote Sensing**, Vol. 24, No. 15, pp. 3119 - 3136, August 2003 (London: Taylor and Francis)
- Josaphat Tetuko Sri Sumantyo, and R. Tateishi, "A technique to analyse scattered waves from rough burnt coal seam and its application to estimate thickness of fire scars in central Borneo using L-Band SAR data," **Journal of Japan Society of Photogrammetry and Remote Sensing**, Vol. 43, No. 6, pp. 48-61, January 2005 (Tokyo: JSPRS)

Peatland Ground Survey and Spaceborne SAR Monitoring

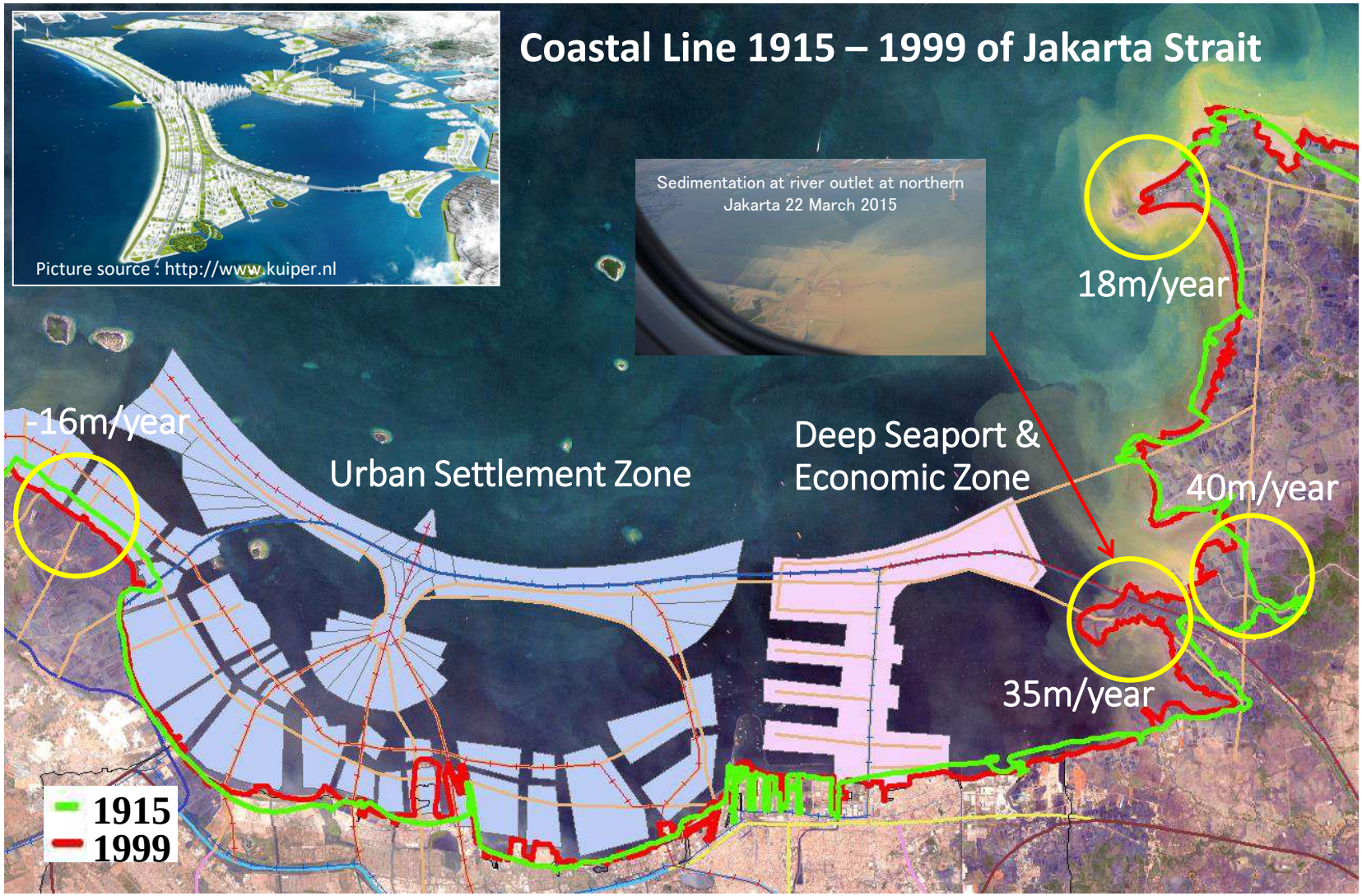
(ALOS-2 25 March 2017)



JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

Soil Roughness and DGPS Measurement 21-28 March 2017

Applications : Monitoring of Sedimentation at Jakarta Coastal line



JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

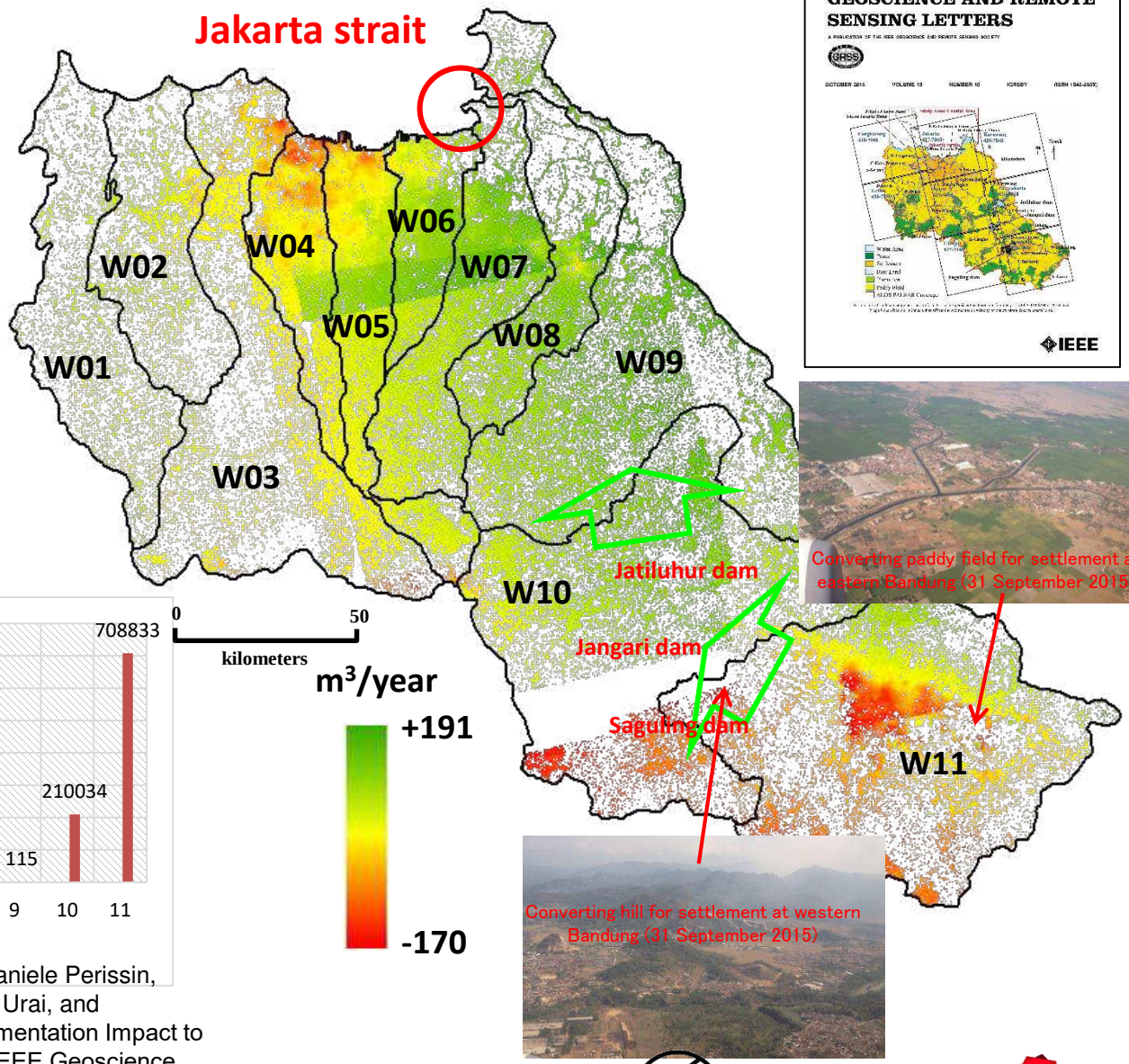
Applications : Monitoring of Sedimentation at Jakarta Coastal line

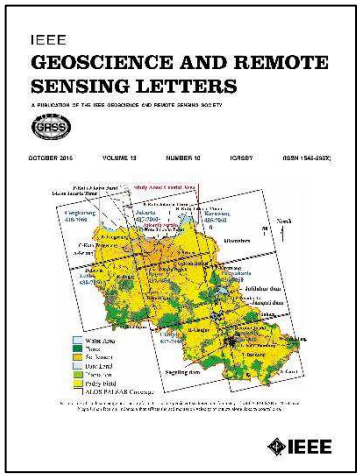
Analysis Result : Volume Loss (m^3/year)

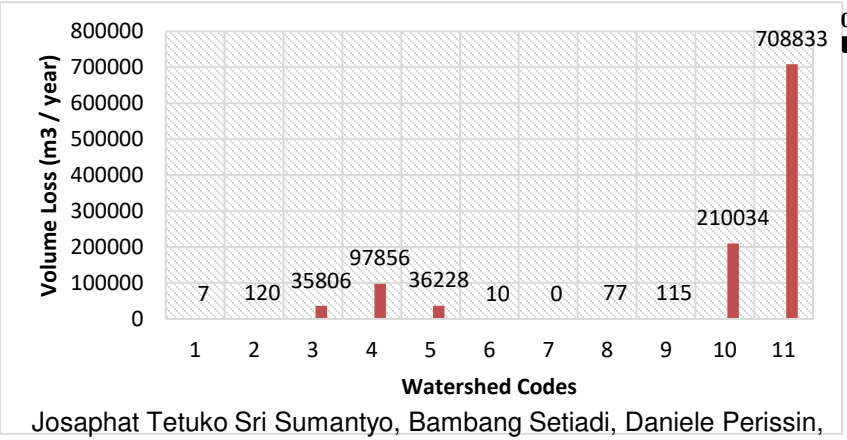
Volume loss in each watershed using ALOS PALSAR images

Volume loss in watersheds of W03, W04, W05, W10, and W11

Volume loss of sedimentation material does not occurred in W07-W09, therefore the land deformation in these watersheds does not influence to Jakarta Giant Sea Wall.







Josaphat Tetuko Sri Sumantyo, Bambang Setiadi, Daniele Perissin, Masanobu Shimada, Pierre-Phillipe Mathieu, Minoru Urai, and Hasanuddin Zainal Abidin, "Analysis of Coastal Sedimentation Impact to Jakarta Giant Sea Wall using PSI ALOS PALSAR," IEEE Geoscience and Remote Sensing Letters (GRSL), Vol. 13, Issue 10, pp. 1472 – 1476, 1 October 2016 (DOI (identifier) : 10.1109/LGRS.2016.2592940)

JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

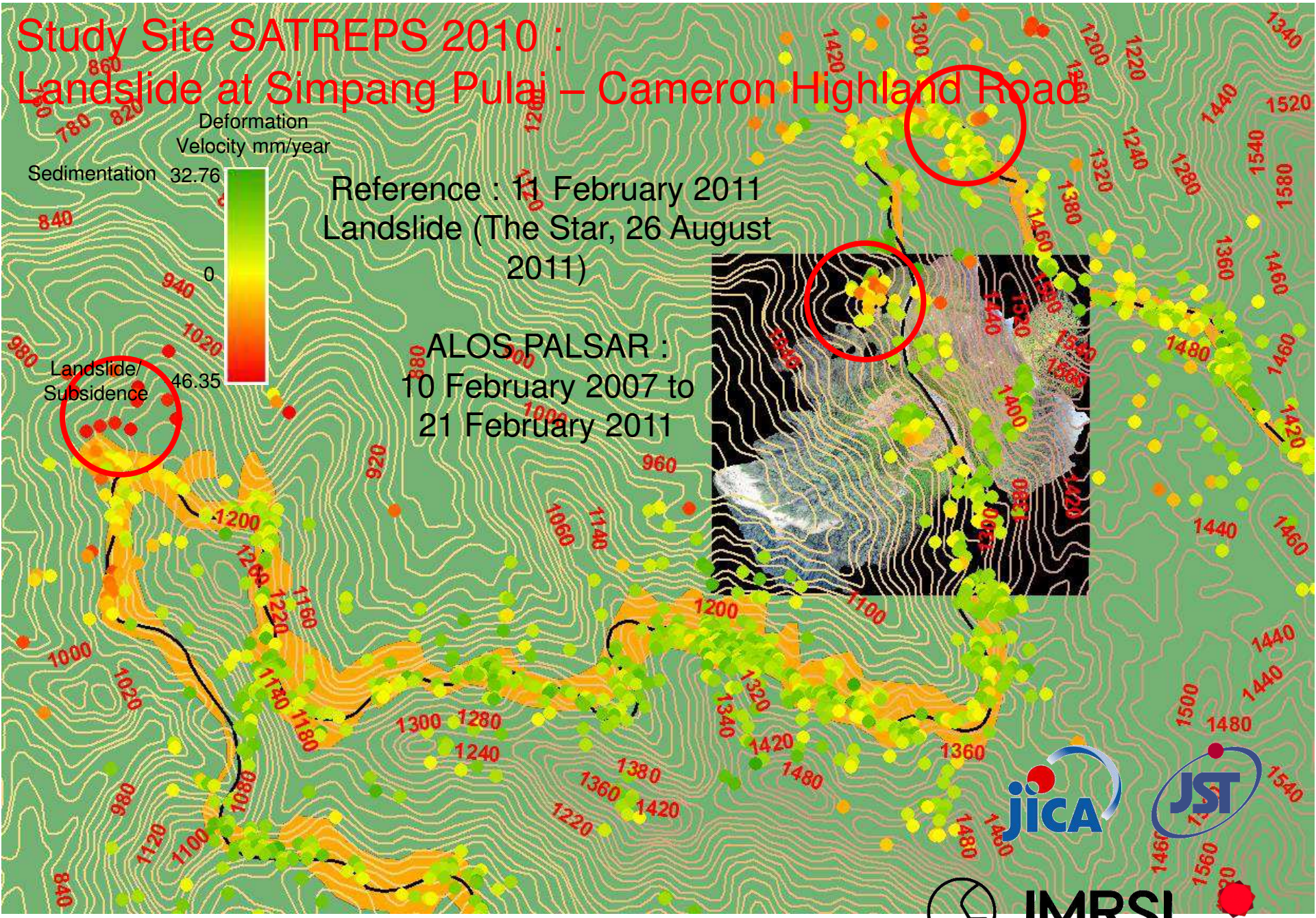
Application : Monitoring of Landslide at Malay Peninsula

JICA JST - SATREPS Project FY2010 - FY2015

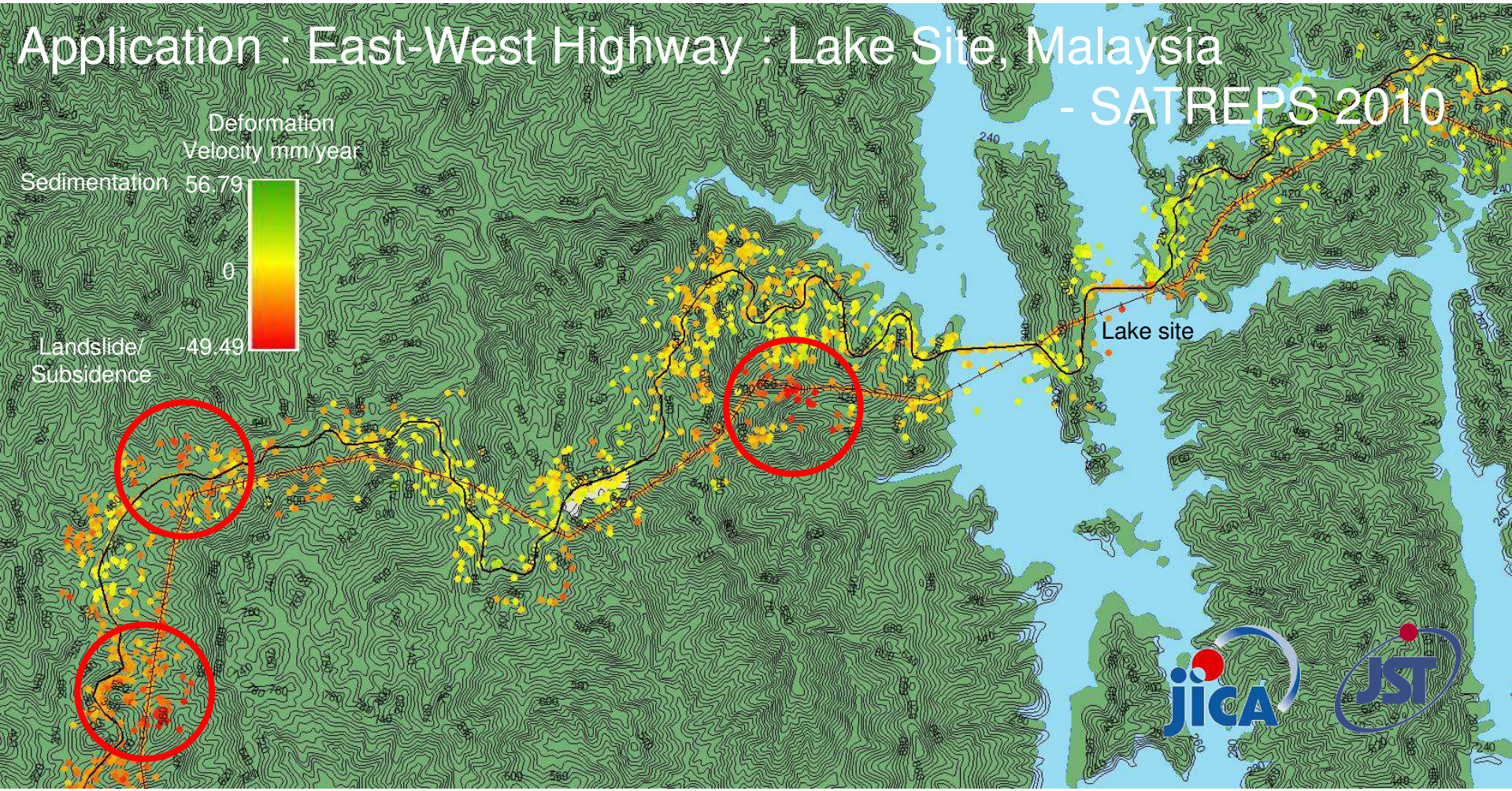
Cameroon Highland ground campaign with Malaysian Government JGR, Universiti Sains Malaysia, and JICA on 20 September 2014

JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

Study Site SATREPS 2010 : Landslide at Simpang Pulai – Cameron Highland Road



Application : East-West Highway : Lake Site, Malaysia - SATREPS 2010



Scale : 1:50,000

JMRSL
Josaphat Microwave Remote Sensing Laboratory
CHIBA UNIVERSITY

Thank you very much for your attention !

Josaphat Laboratory Satellite Ground station

Contact Person :

Prof. Josaphat Tetuko Sri Sumantyo, Ph.D

Josaphat Microwave Remote Sensing Laboratory (JMRSL)

Center for Environmental Remote Sensing, Chiba University

1-33, Yayoi-cho, Inage-ku, Chiba-shi 263-8522 Japan

Telp. +81(0)43-290-3840 Fax +81(0)43-290-3857

Email jtetukoss@faculty.chiba-u.jp

Website http://www2.cr.chiba-u.jp/jmrsl/

Fujikawa Airfield, 29 August 2013 UTC 06:09:54.521

JMRSL Josaphat Microwave Remote Sensing Laboratory

CHIBA UNIVERSITY