

How to observe the Earth from the Space

-Introduction to the remote sensing
(SAR) and the training-

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engineering

Ishizaka, Hatoyama, Hiki, Saitama, 350-0394
Sakura-Science Oct. 25, 2019

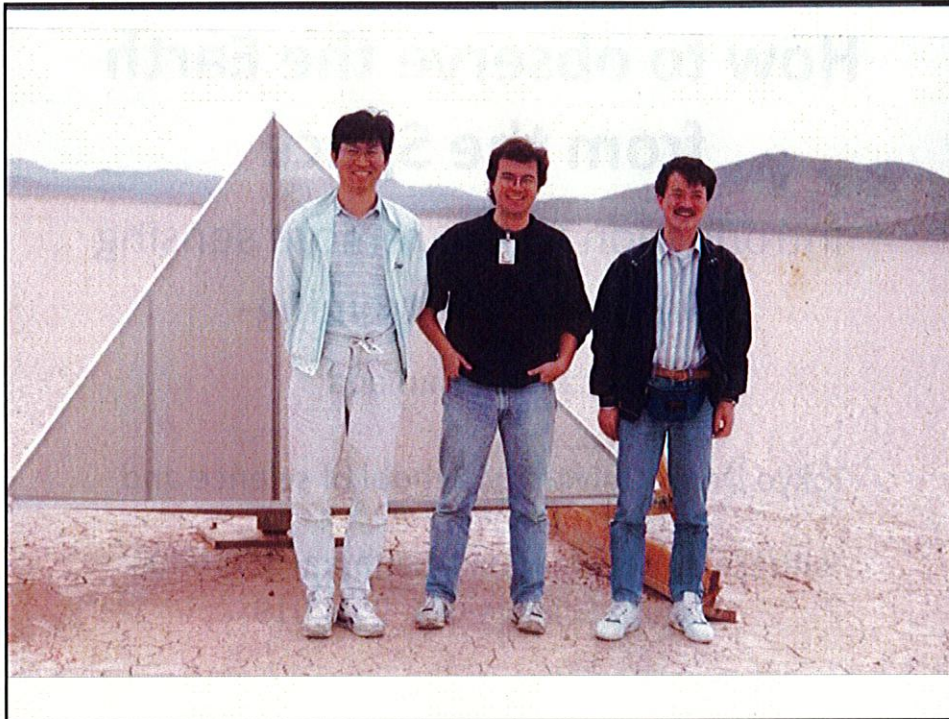
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概歴



- Born in Kagawa, March 19 1955 1955年3月19日
- Marugame High School (1970.4-1973.3)
- Kyoto University (Aerodynamics, Bachelor and Master) (1973.4-1979.3)
- PhD, The university of Tokyo, 1999.3: Precise measurement of the Normalized radar cross section of the earth surface using the spaceborne synthetic aperture radar)
- JAXA (1979.4.1-2015.3.31) (36 years)
 - Tsukuba Space center (1979.4-1985.8) (6 years 年)
 - Earth Observation Center (1985.8-1995.3) (10 years 年)
 - Jet Propulsion Laboratory (1990.1-1991.1)
 - Earth Observation Research Center (1995.4-2015.3) (20 years)
 - Roppongi (1995.4-2001.7)
 - Harumi (2001.8-2006.10)
 - Tsukuba (2006.11-2015.3)
- Professor, Tokyo Denki University, School of science and engineering, division of architectural, civil and environmental engineering (2015.4.1-)
- Major: Microwave remote sensing, SAR, Scatterometer



- **Contents**

- PART I (13:00-15:00)

1. Introduction: What is the earth?
2. What is the remote sensing? (Principles)
3. How to capture the rotating earth?
4. Satellite Operation
5. Satellite system
6. SAR system
7. ALOS-2

- PART II (15:00-17:00)

8. SAR quick training.

1. Introduction : What is the earth?

- 4,600,000,000 years from the birth.
- Ellipsoid with $R_a=6377$. and $R_b=6356$ km
- Land as the 30% of the surface and 70% as the ocean
- Four spheres for the dynamic earth surface, geosphere (solid earth), biosphere, cryosphere, hydrosphere.
- Daily Rotation angle of $360+360/365.25$
- 7,00,000,000 human beings on the earth (2011.10.31).

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Mission definition for the problem solver

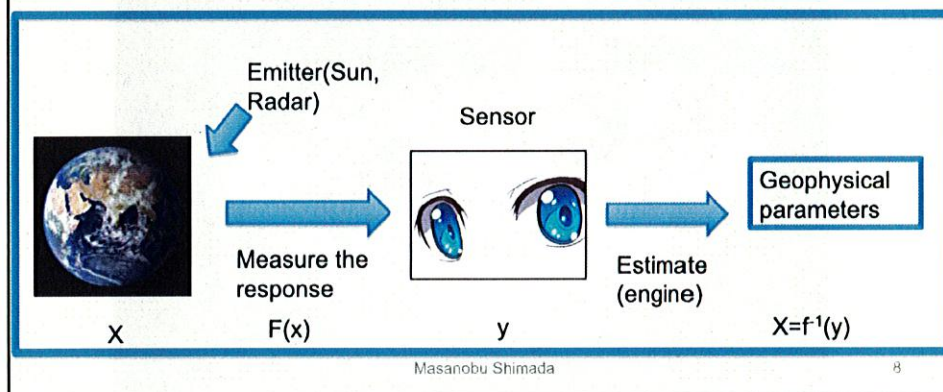
- Define the problems
- Capture the images (data) of the earth (land, ocean, and atmosphere)
- Investigate the images (data) and consolidate to interpret the images for geophysical parameter estimation

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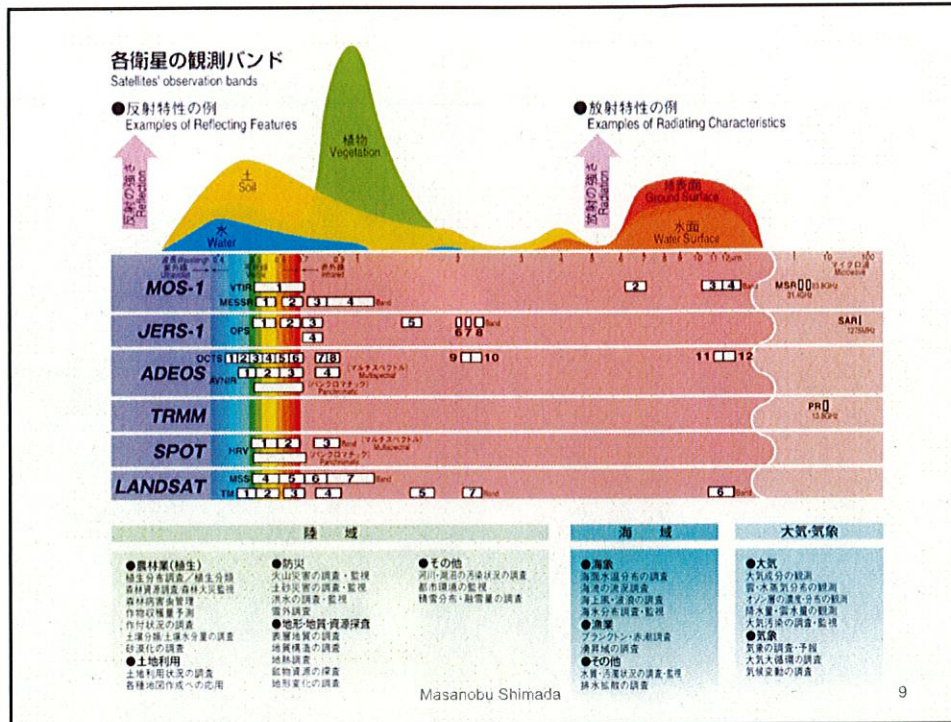
2. What is the remote sensing?

- To obtain (guess) the (geo) physical information of the target **from a distance**
- by means of the optical or microwave radiations



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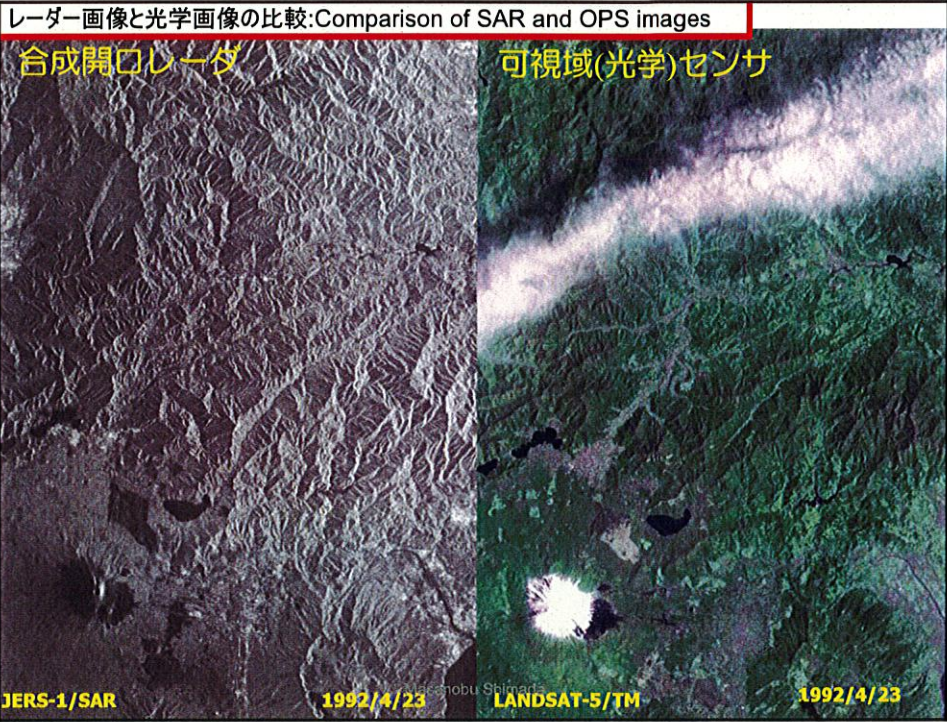


センサーと見え方: Sensor and visibility

- 光学センサー(OPS): 晴天時に地物の認識が良好。近年は非常の高分解能の人工衛星が登場。観測が晴天時日中に限定される。Target identification is well done under the fine weather condition. Recent sensor has finer resolution of under 30cm. The larger obstacle is the weather.
- 合成開口レーダー(Synthetic Aperture Radar: SAR): 全天候性で画像を取得できる。分解能は光学に劣る。All (almost) weather and sensor indispensable of the day/night. Resolution is lower than the optical sensor in general.

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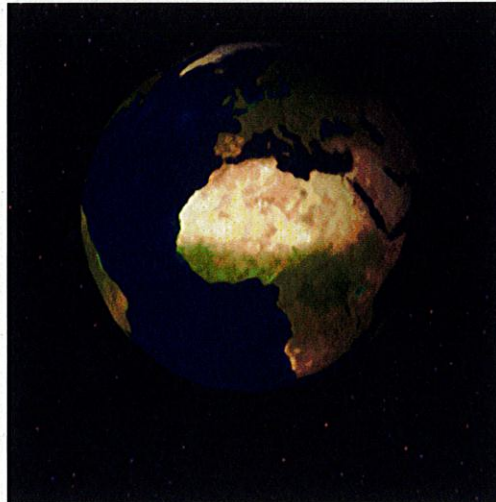
アマゾンモザイク画像(JERS-1 SAR mosaic Amazon)



•3 人工衛星による観測 (How to capture the rotating earth from the space)

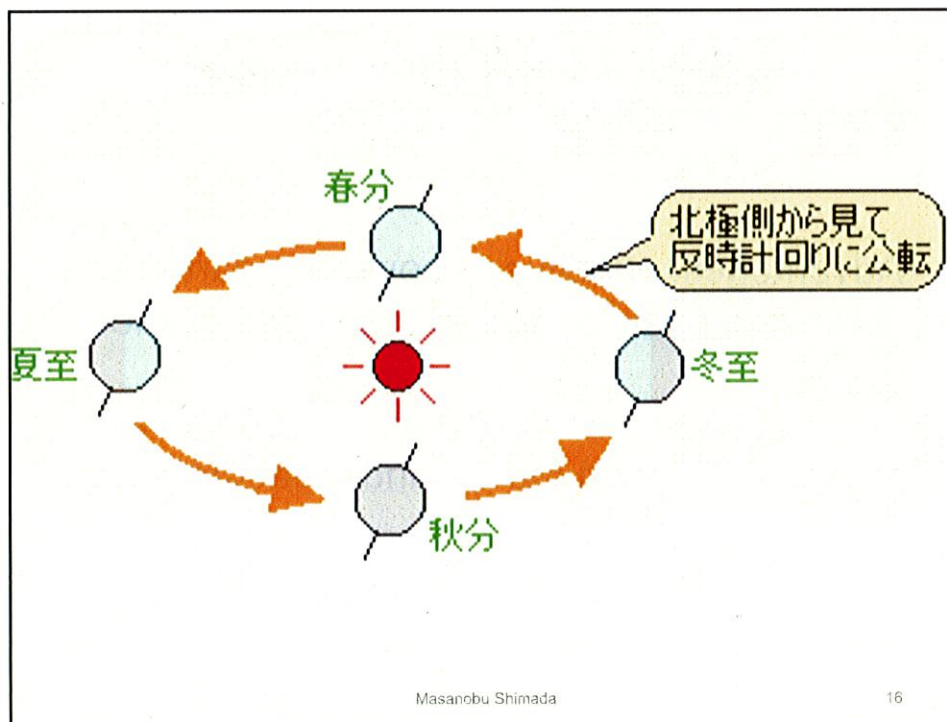
- Advantages: effective to cover the earth surfaces repeatedly within the shorter period.
- Disadvantage: resolution and sensitivity are less accurate than the ground measurements.

Capturing the rotating earth and appropriate expression the map



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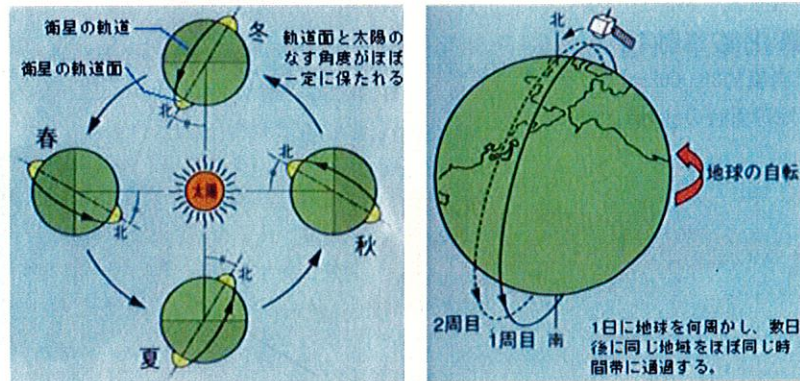


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太陽同期準回帰軌道(Sun-recurrent orbit)

低軌道(周回軌道)・高度数百km: Lower orbit Some hundreds km)



→地球をくまなく観測することに適した軌道
Adequate orbits to observe the earth surfaces

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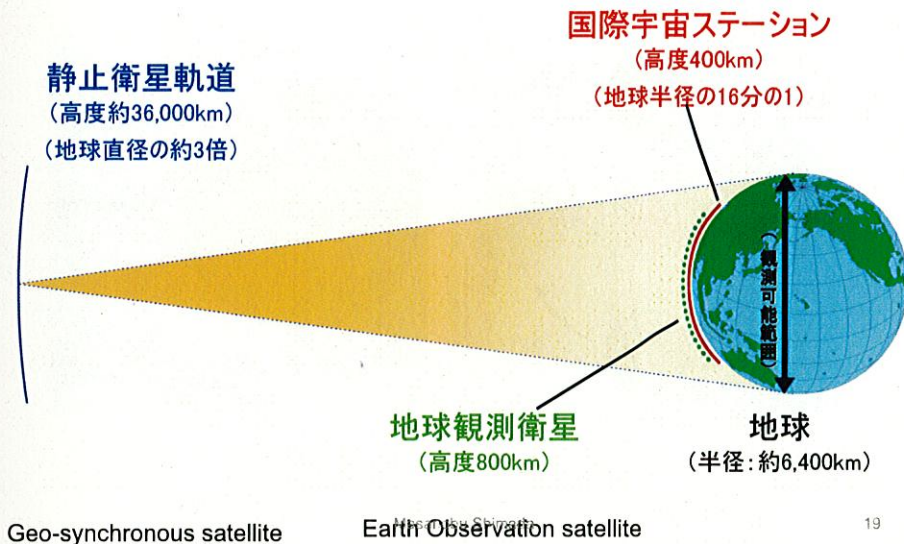
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HIIロケット:高さ50メートル、1996年8月16日

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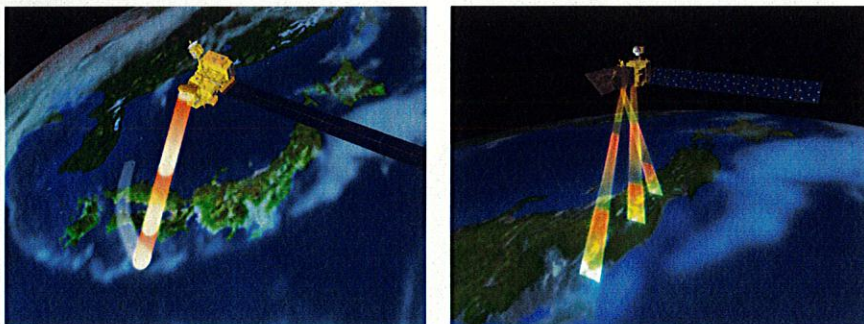
人工衛星の飛ぶ高さは？ (Height of the orbits)



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地球観測衛星(Earth Observation satellite)

地球環境の把握、監視、資源の探査、災害の監視などを目的とする人工衛星

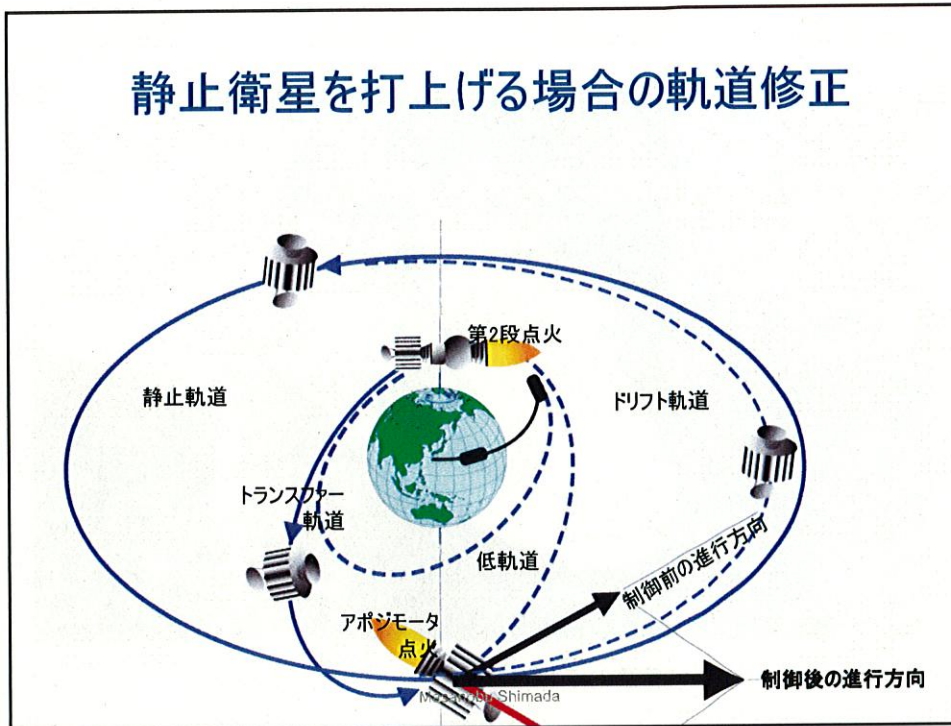


目的に応じて様々な観測センサ(カメラ)を持つ

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静止衛星を打上げる場合の軌道修正



4. Satellite Operation

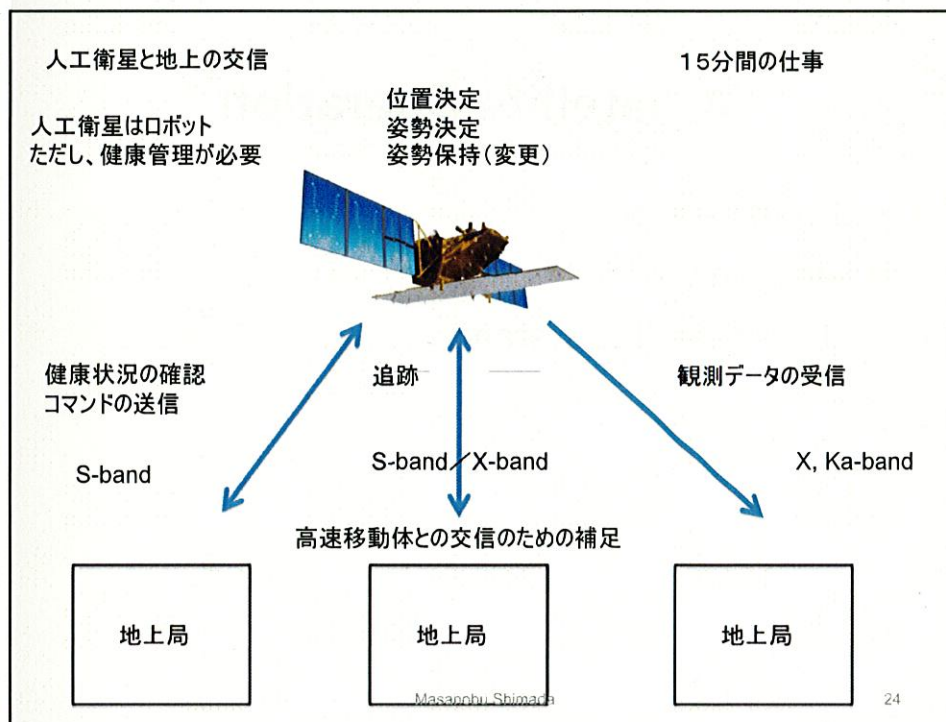
- Ground station
- Sensor data
- ALOS-2 satellite system



JAXA 地球観測センターの受信アンテナ

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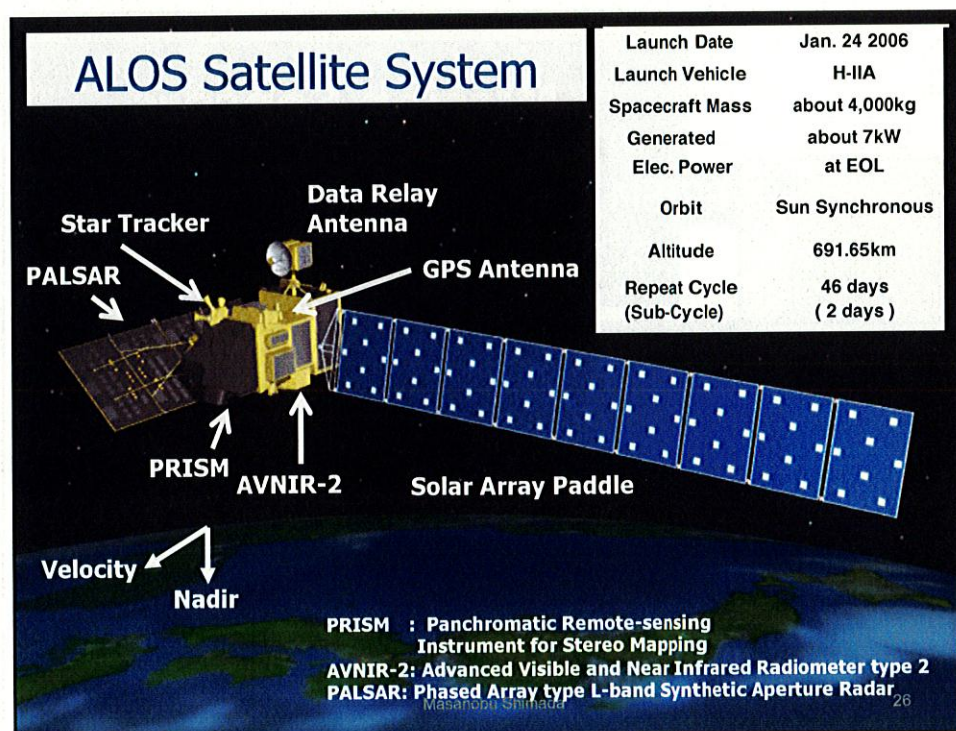
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5. Satellite Hardware (ALOS)

- 衛星構体: Satellite structure
- センサー(カメラ): Sensors
- 姿勢決定: Attitude determination
- 位置決定: Position determination
- 時刻決定: Time determination
- コンピューター: CPU

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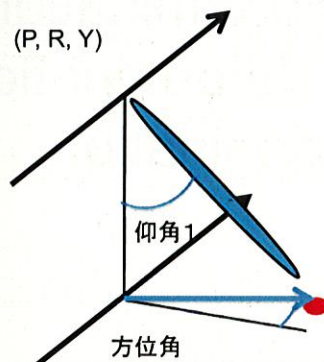
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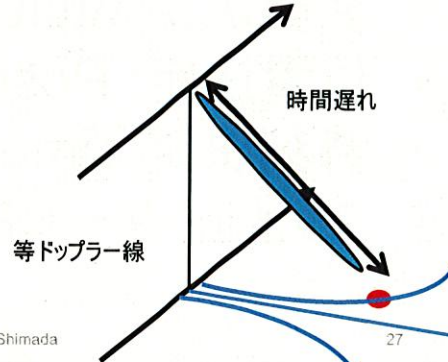
衛星から地上の位置を決定する方法 Determine the ground point from the space

方法	情報1	情報2	
カメラ	仰角	方位角	
SAR	距離(~m)	ドップラー周波数(Hz)	位置決定精度が高い

仰角-方位角法



距離-ドップラー法



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Mission Sensors



PRISM Panchromatic Remote-sensing Instruments for Stereo Mapping

- 2.5m Resolution
- Three Telescopes for Elevation Data

AVNIR-2

Advanced Visible and Near Infrared Radiometer type-2

- Multi-band Observation (4 bands)
- Wide range off-nadirs (+/-44degrees)
- 10 meter resolution



PALSAR

Phased Array type L-band Synthetic Aperture Radar

- Active Microwave Radar Sensor
- All-Weather Observation
- 9 meter resolution(azimuth)

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Precise Position and Attitude determination

Conventional Satellites

Earth Sensor - 0.03 degree · · 370m @ 700km

Star Tracker - 0.003 degree · · 37m @ 700km

ALOS

To meet the requirement of "Mapping without GCPs",

Dual frequency carrier phase tracking type GPS receiver
→ 1m Position Accuracy

High Accuracy Star tracker
→ 2.0×10^{-4} degree · · 2.5m @ 700km

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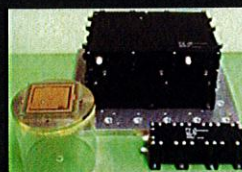
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Absolute Time Clock

Conventional Satellites

On-Board Crystal Oscillator

Relative Stability · · $10^{-5} \sim 10^{-6}$ order



ALOS' s GPS Receiver

ALOS

Internal Clock is Completely Synchronized to GPS absolute time

→ Absolute Time Accuracy is 1 μ s order

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High Stability Attitude Control

In order to minimize geometric distortion of the image...

Attitude Movement stabilized within

2.0×10^{-4} [deg] per 5 [sec]

(1 pixel distortion within 35km square scene)

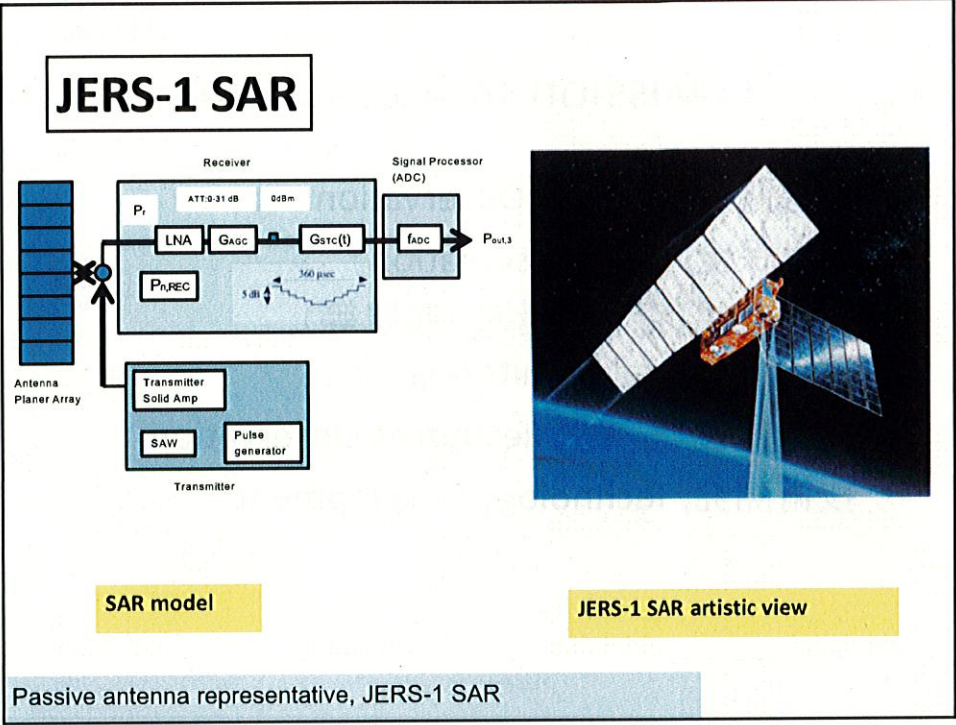


ALOS' s Star Tracker (STT)

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6. SAR system



7. Mission of the ALOS-2

- 災害観測, Disaster Observation
- 国土保全, Land Observation
- 環境監視(森林, 極域, 海域等),
Environmental Monitoring
- 資源監視(農業), Resources Observation
- 技術開発, Technology Development

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**陸域観測技術衛星2号
「だいち2号」(ALOS-2)**



2014年5月24日(土) 打上げ成功!

Lバンド合成開口レーダ(PALSAR-2)

- 広い観測可能範囲(2,320km)
- 左右観測機能
- 高分解能(1-3m)
- 昼夜・天候に影響されず観測
- 世界唯一のL-バンドSAR
- Lバンドの強み=高い干渉性
- 緊急時は12時間以内に観測

ALOS-2の主要な利用分野: Main Application

**変化抽出
Change detection**

(1) 災害(地震・火山・地滑り等による地殻・地形の変化): Disaster Observation

(2) 環境監視(森林+海氷): Environmental Observation

(3) 海洋監視(船舶+波浪): Ocean Observation

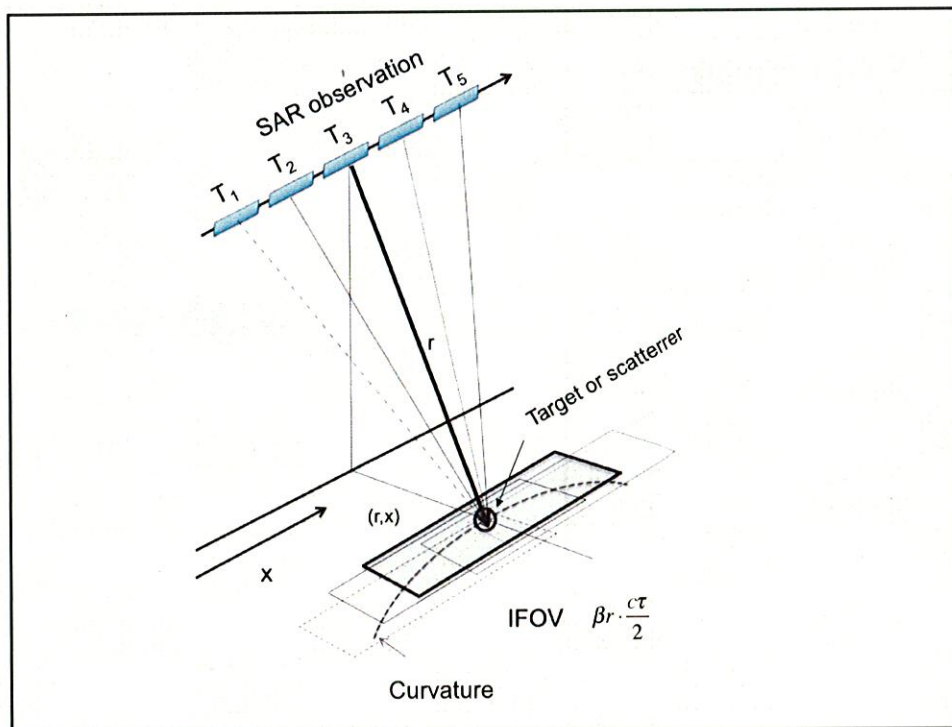
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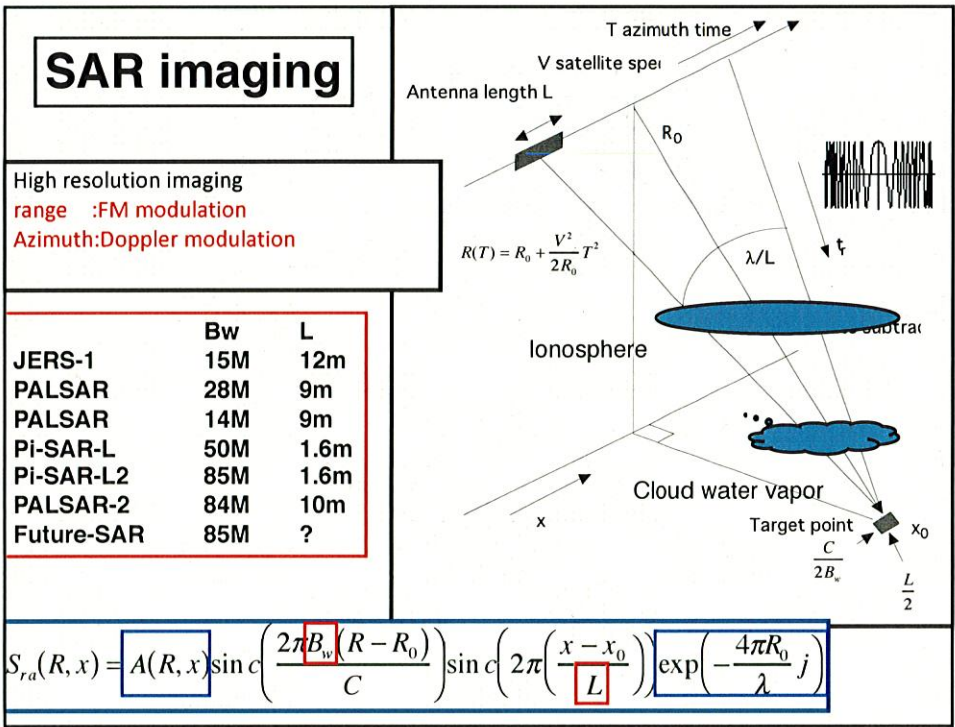
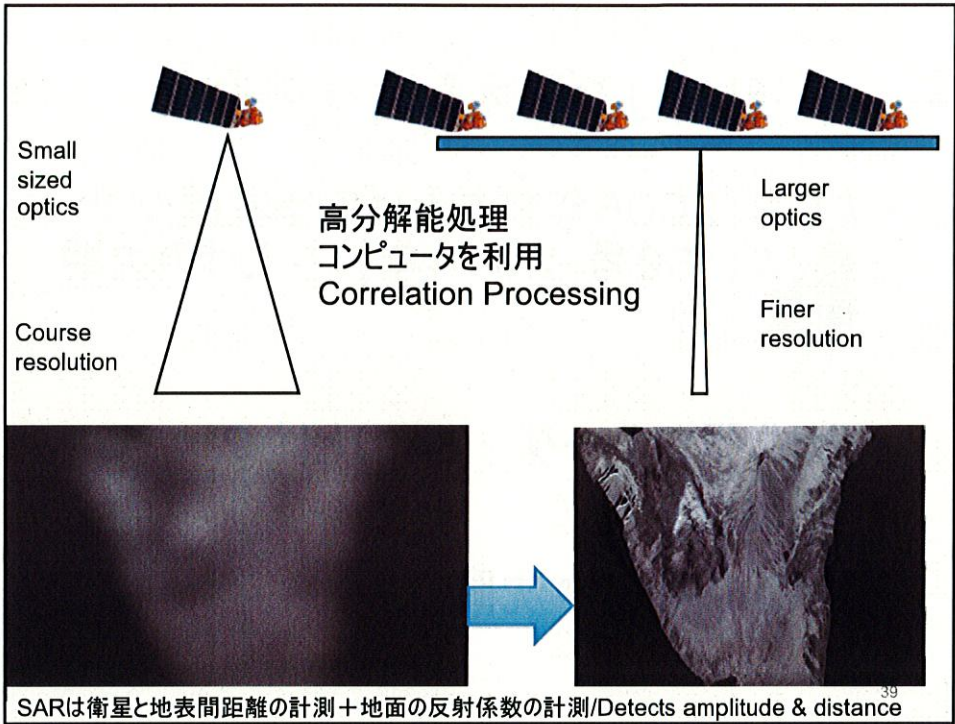
「だいち」で見える地球の変化

- だいち: 2006年打ち上げの陸域観測衛星、だいち2号: 2014年打ち上げの次期衛星
- 合成開口レーダー(SAR)とは？
- 森林の増減
- 地面の隆起や沈降

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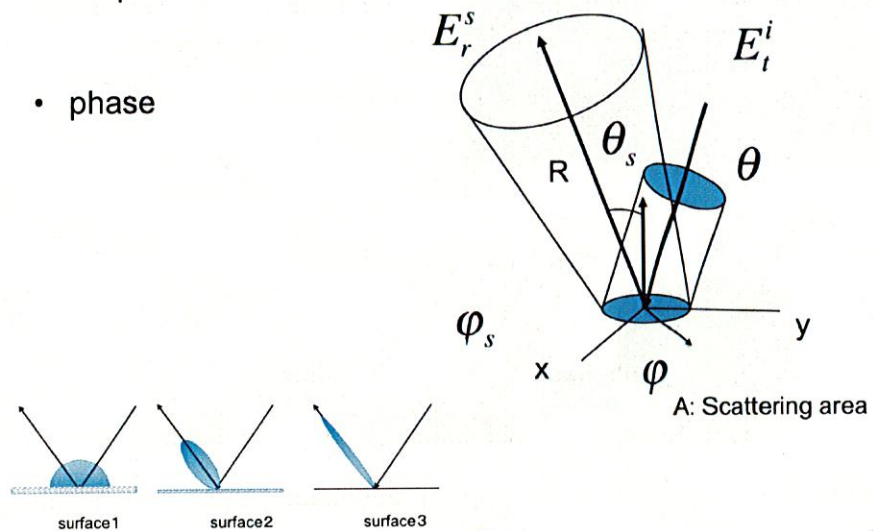
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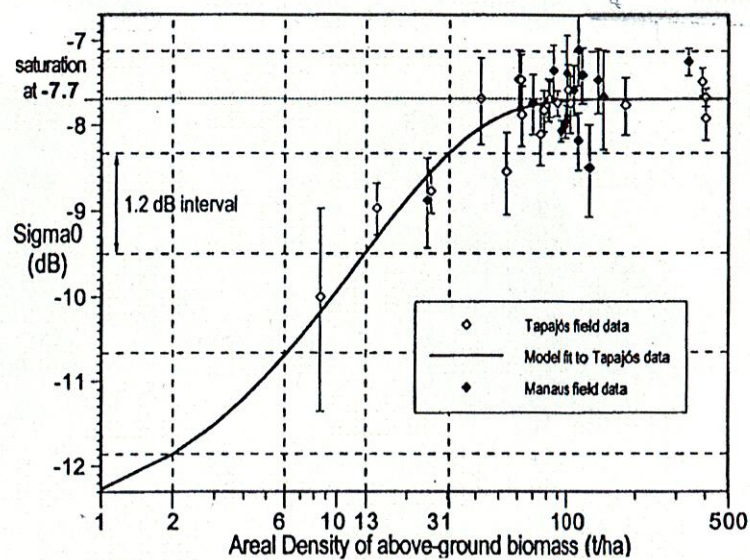
SAR measurements

- Amplitude
- phase



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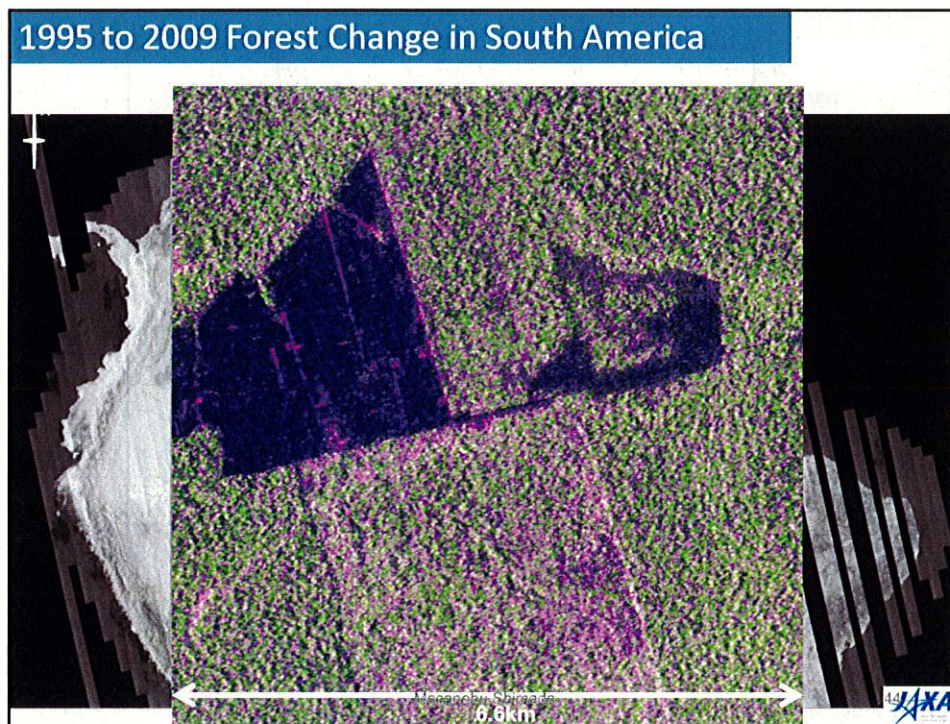
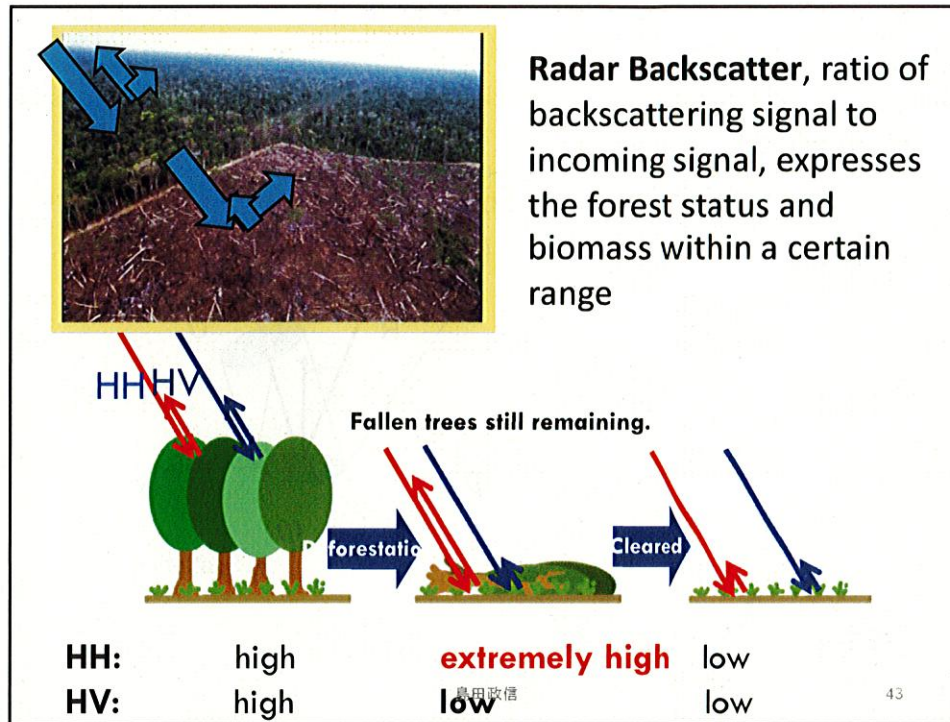
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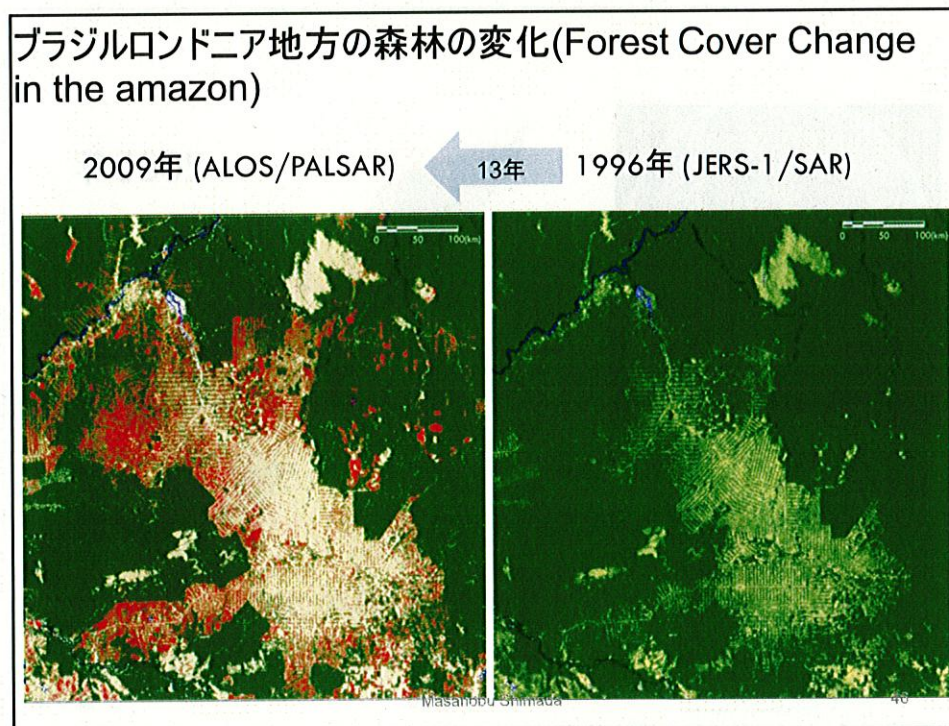


Quantised biomass density retrieval scheme

σ^0 in L-HH. (after J. R. Baker [97]).

A. Luckman et al., "Tropical Forest Biomass Density Estimation Using JERS-1 SAR: Seasonal Variation, Confidence Limits, and Application to Large Mapping Remote Sensing For 1998"

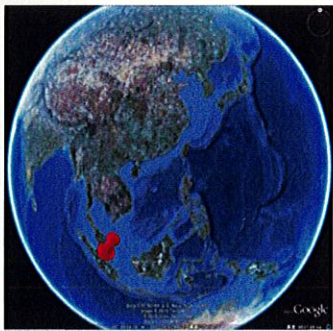
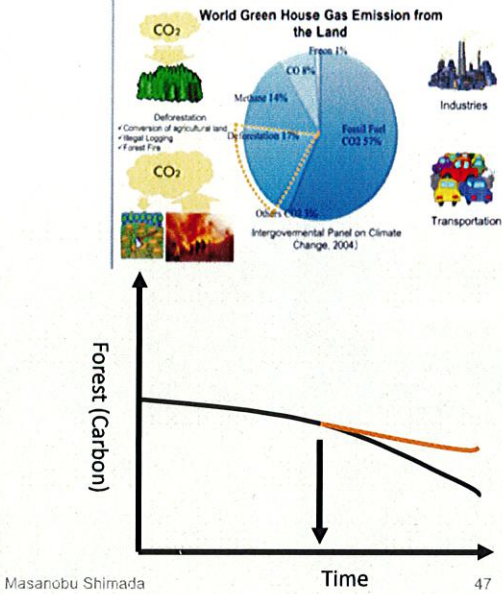
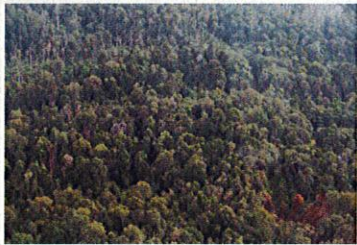




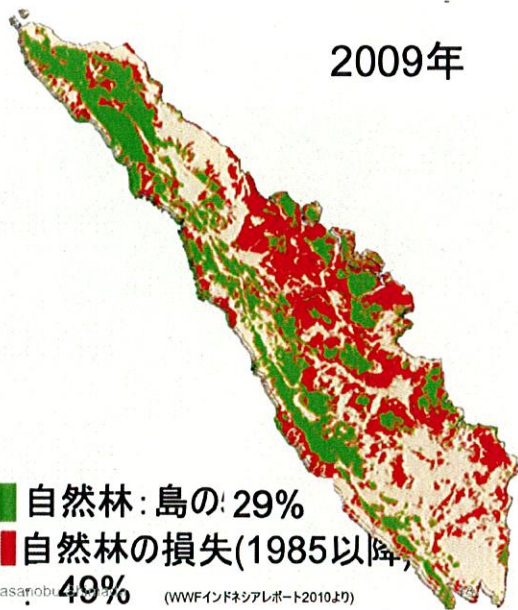
REDD+: 森林減少に伴うCO2の増加を減らしましょう！ :Reduce the CO2 emission~

- 森林・非森林の変化
- Cとその変化の推定

•-> Carbon Credit



24年間(1985-2009)の損失面積:約125,000 km²



森林観測の課題 (Issue on the forest observation)

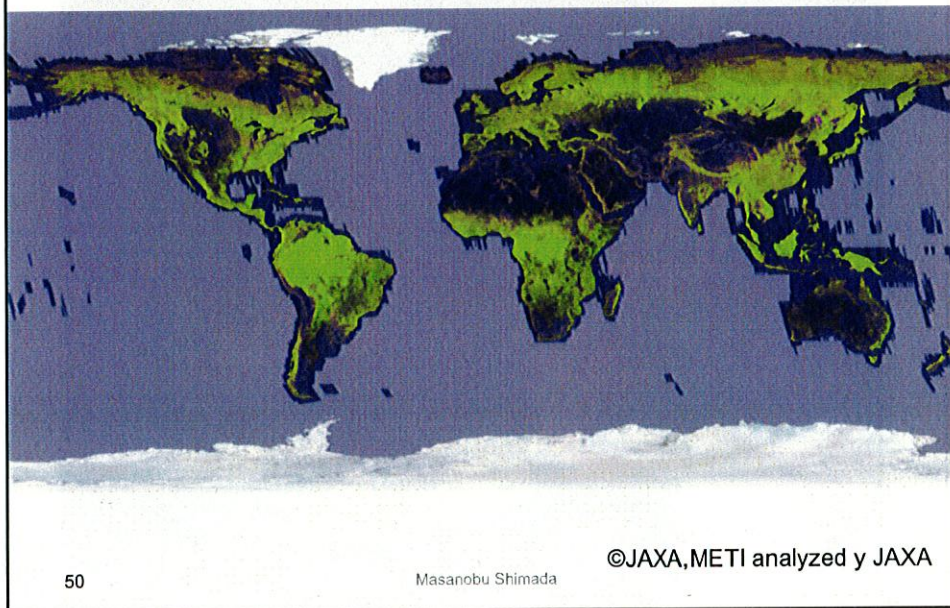
森林の何が分かりたいのか? : Observation Target
FAOは森林の分類や森林の変化(面積)
森林バイオマス

レーダでできること: What radar can do
PALSARによる分類と時間変化の追跡
Tracking the forest cover change in time

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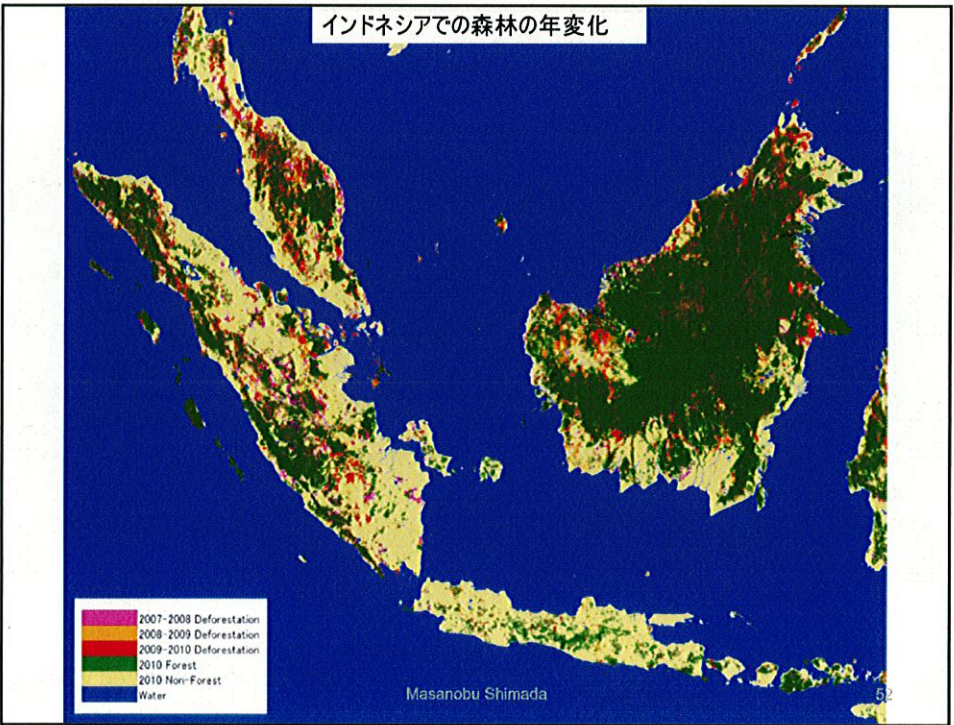
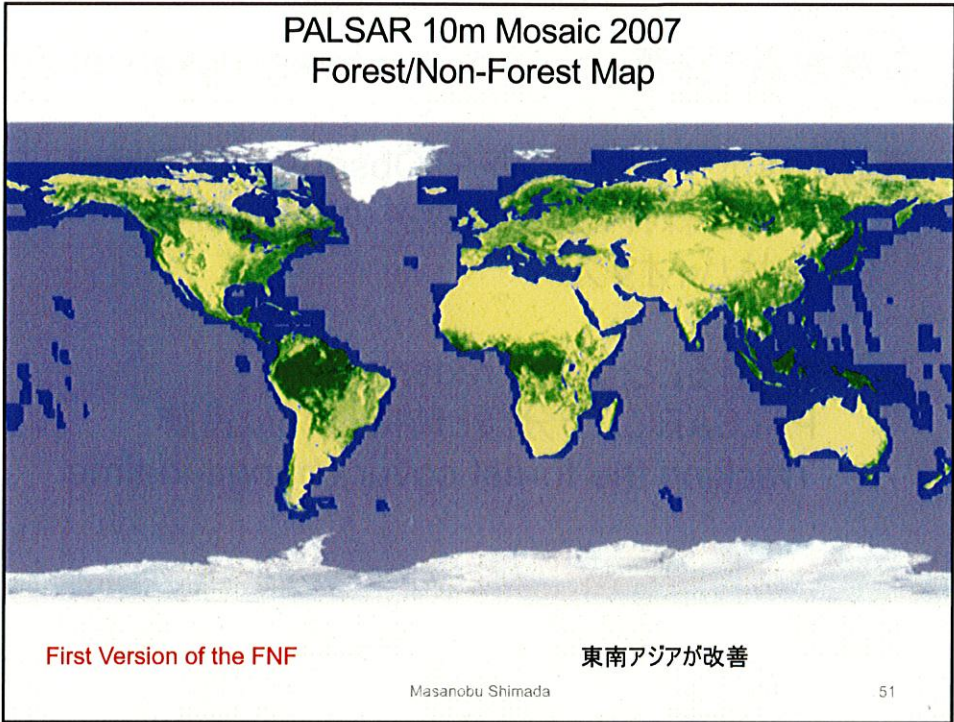
全世界10m分解能モザイク-2009:Global 10m Mosaic



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©JAXA, METI analyzed y JAXA



違法伐採の監視 IBAMA(1/2)

PALSARを用いた違法伐採監視は、2007年

Annual deforestation at Brazil

Deforestation area :

19000km²(1996~2005)

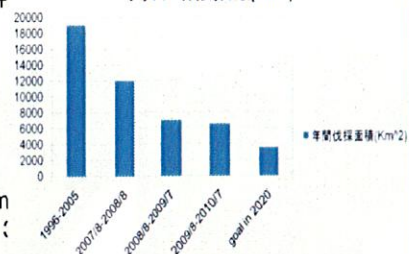
12000km²(2007/8~2008/7)

7000km²(2008/8~2009/7)

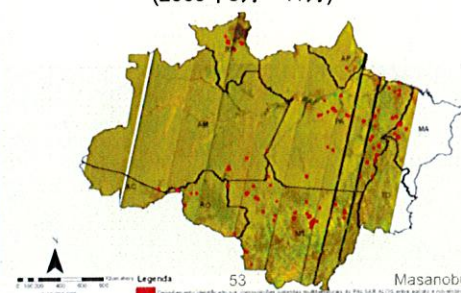
4000km²(2020 goal)

Environment Minister "Minc" said that the m
effective. Total deforestation of south america :
Global deforestation: 70000km²/year

ブラジル年間伐採面積(Km²)

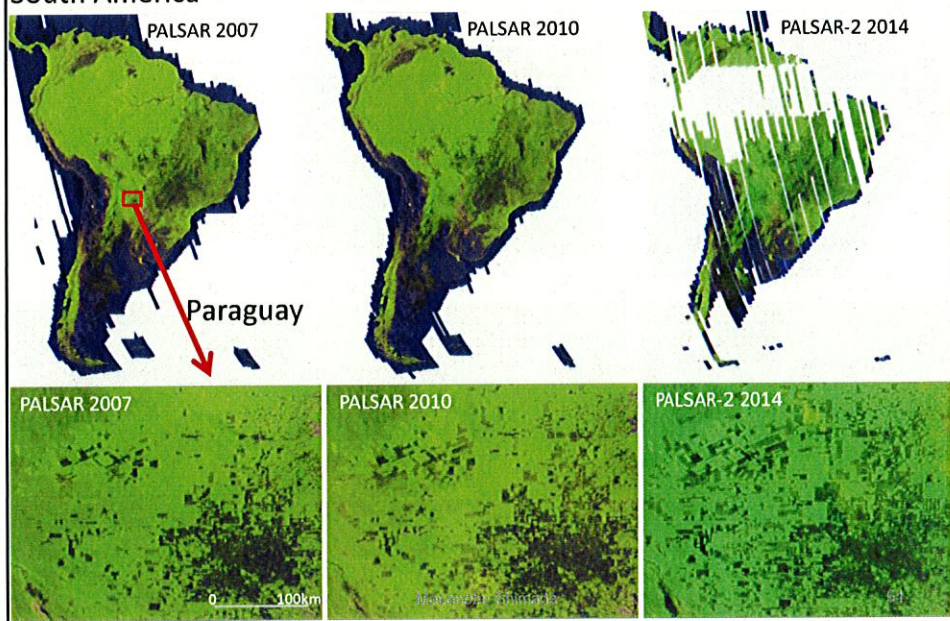


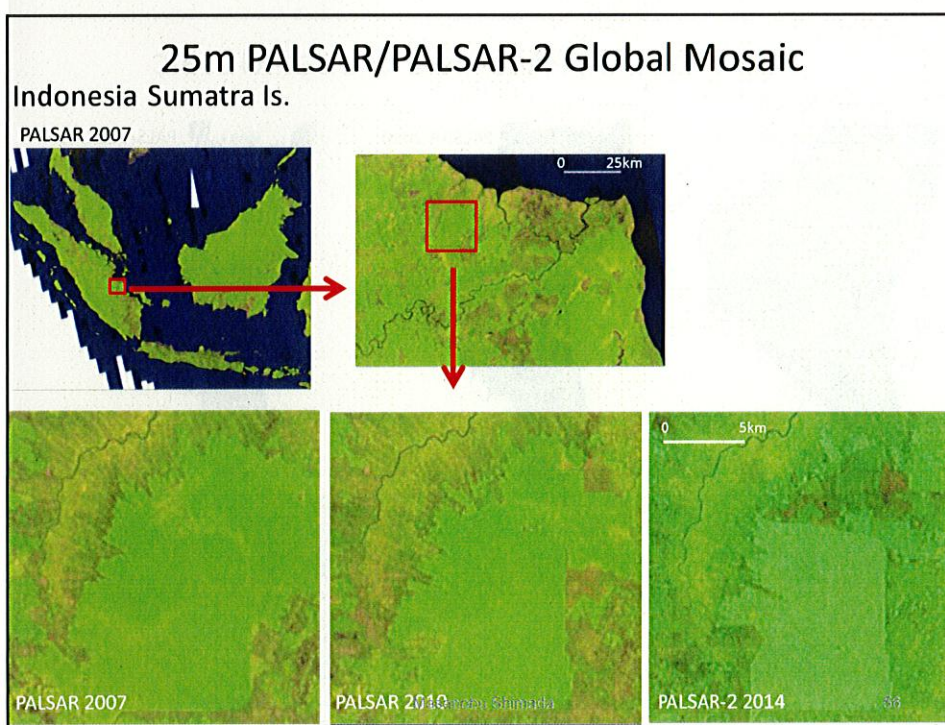
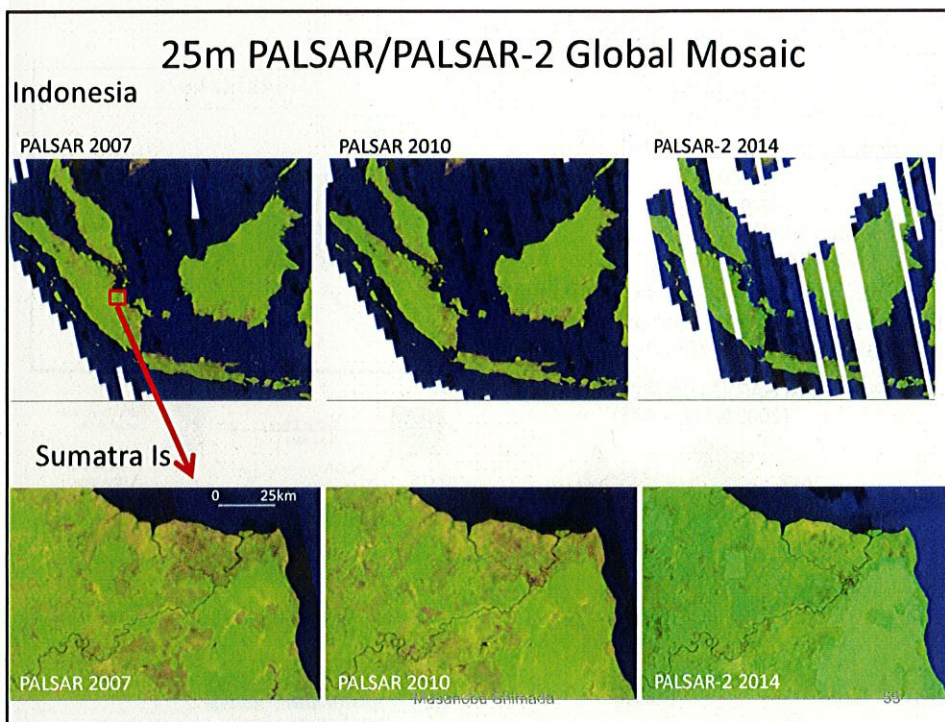
「だいち」(PALSAR)により確認された違法伐採
(2009年8月~11月)



25m PALSAR/PALSAR-2 Global Mosaic

South America

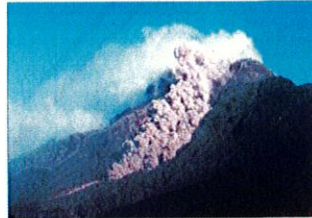




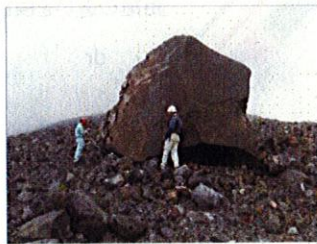
Surface deformation(Volcano, Earthquake, Subsidence)



三宅島の降灰（平成12年7月16日）



雲仙岳の火砕流（平成6年6月24日）



浅間山の噴石（平成17年8月4日）



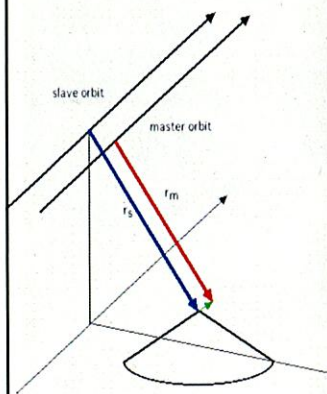
地表面の細かな変化をキャッチ

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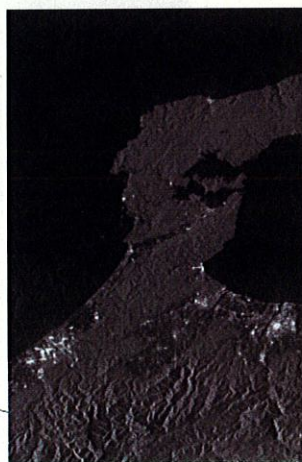
SAR干渉 (SAR Interferometry)

近くを飛行する2台のSARの得た画像の差分(位相差)を計算し、地面の上下動(沈降, 隆起)や地面の高さを測る技術。

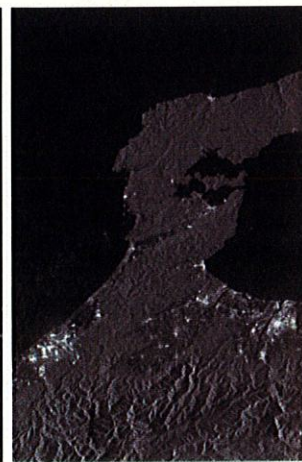
Two SAR images flying in close distance detect the surface deformation and DTM.



座標

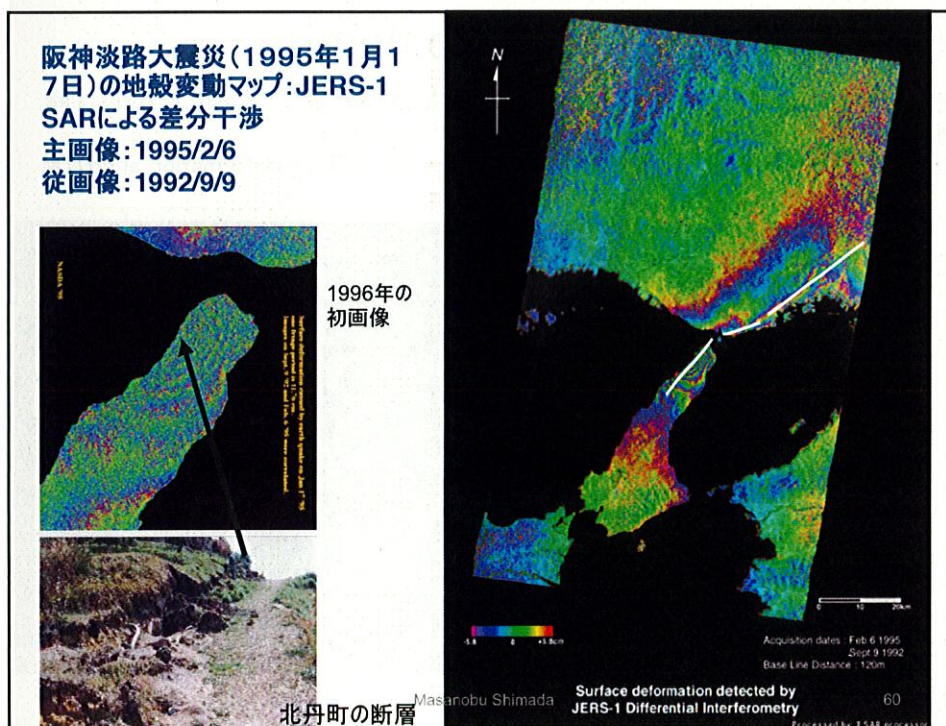
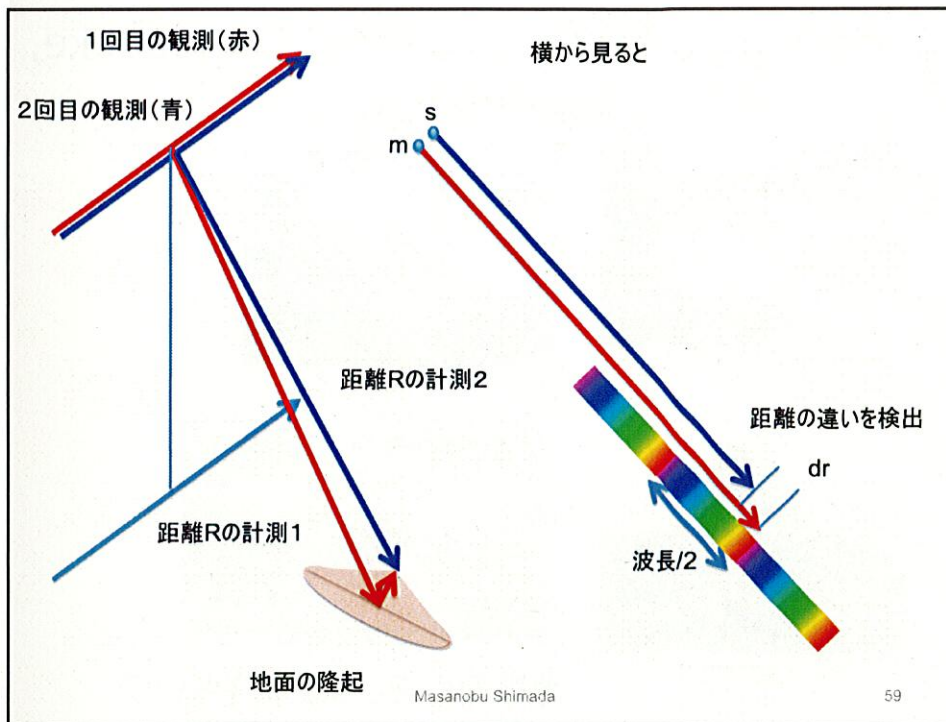


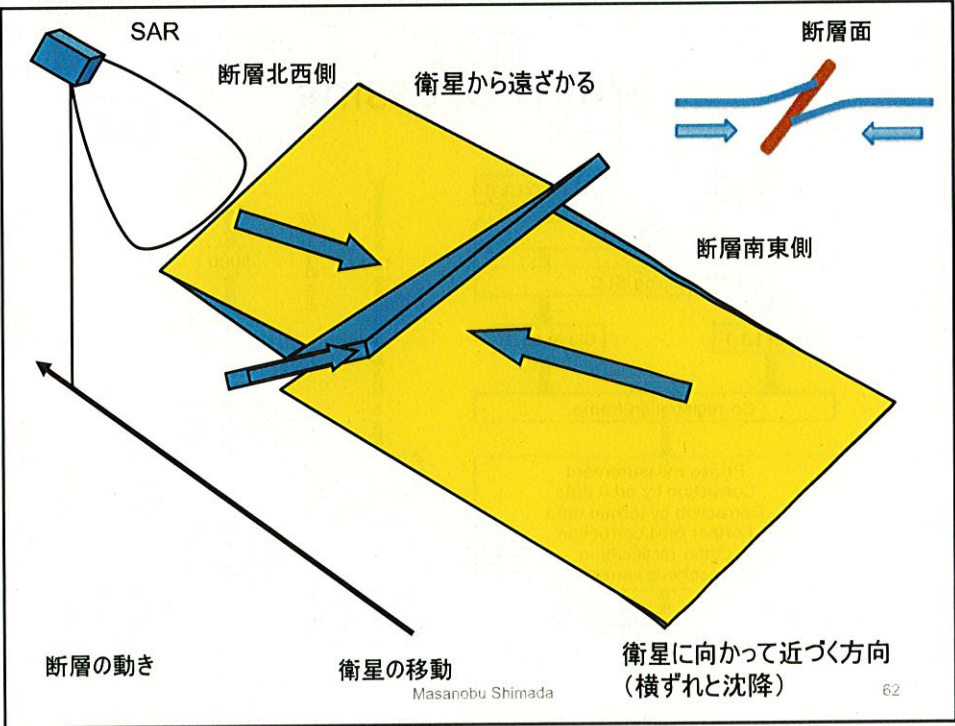
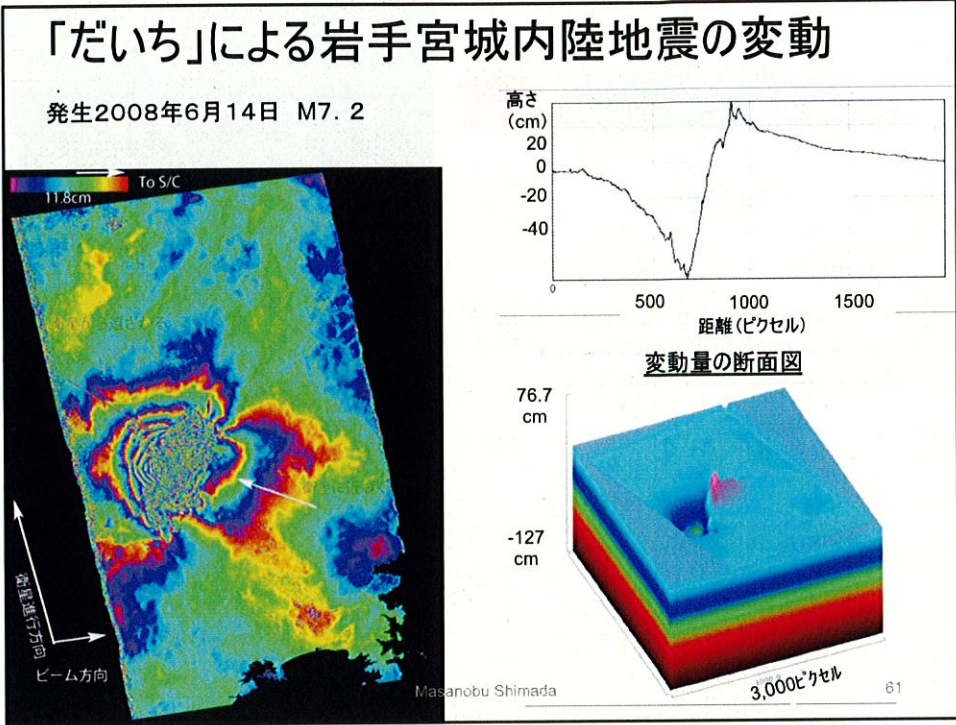
master(4/10/2007)hada

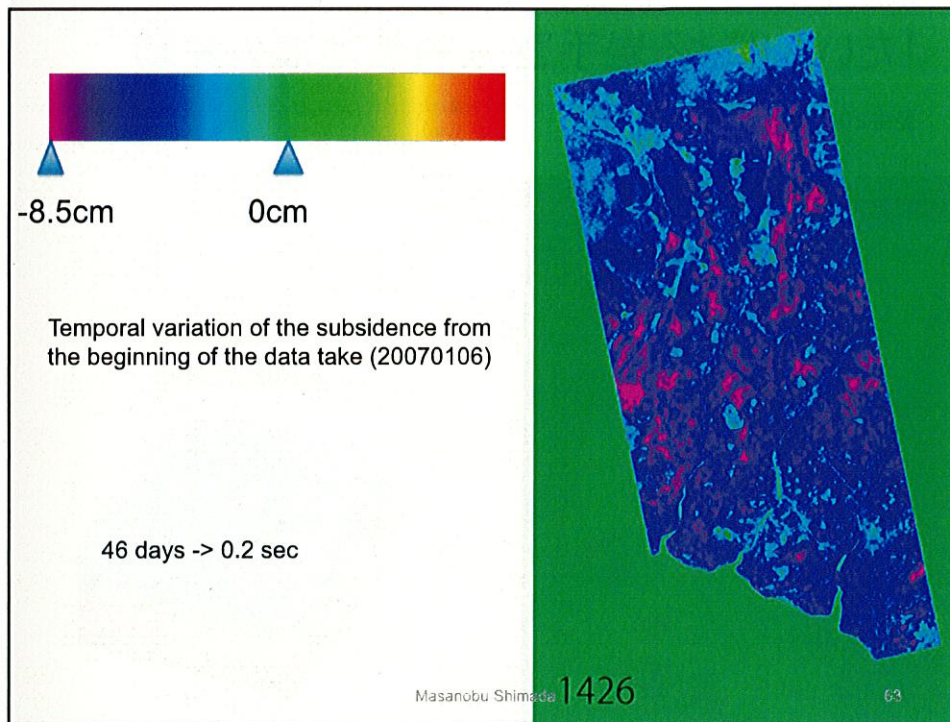


slave(2/23/2007)

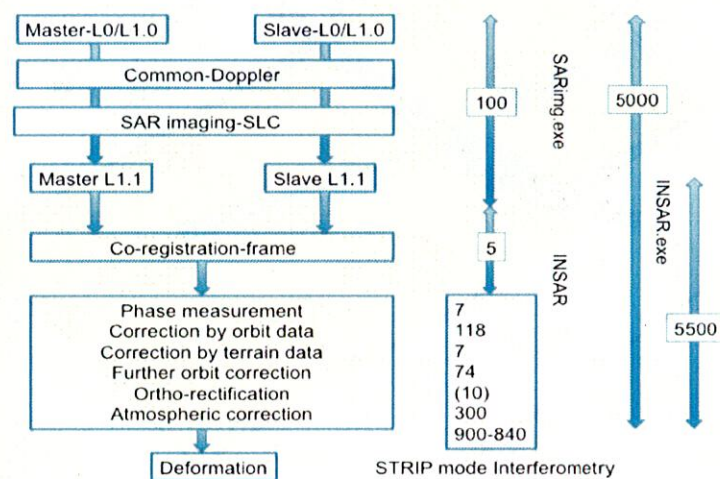
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SAR processing



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SAR processing using the cloud system



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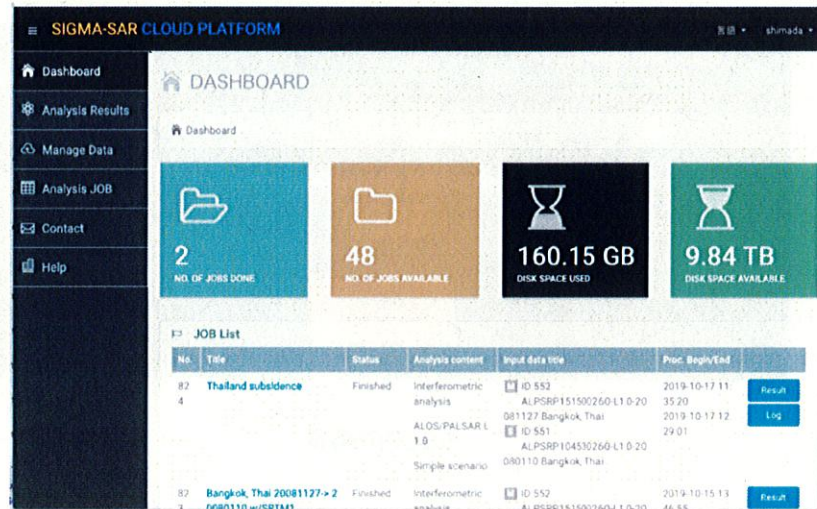
SAR processing using the cloud system



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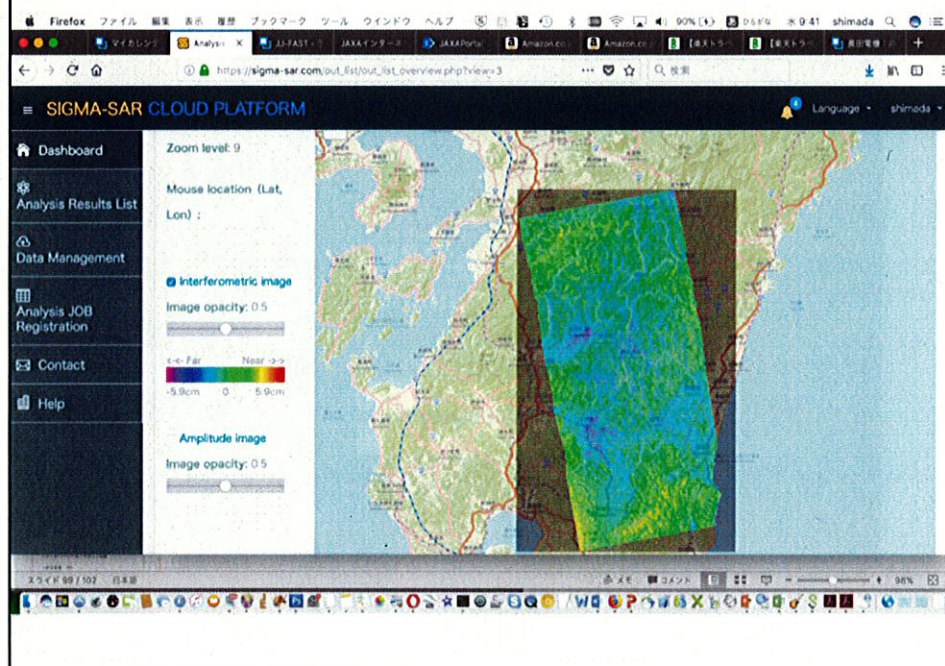
SAR processing using the cloud system



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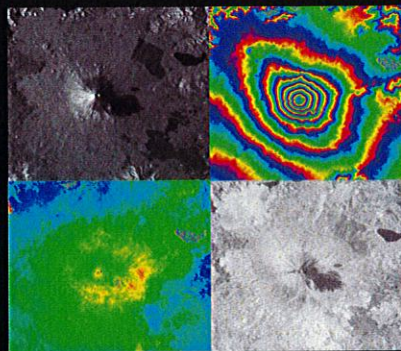
SAR processing using the cloud system



2018, Oct. mid

On sale

Taylor and Francis P



**IMAGING FROM SPACEBORNE
AND AIRBORNE SARs,
CALIBRATION,
AND APPLICATIONS**

Masanobu Shimada



CRC Press
Taylor & Francis Group

