



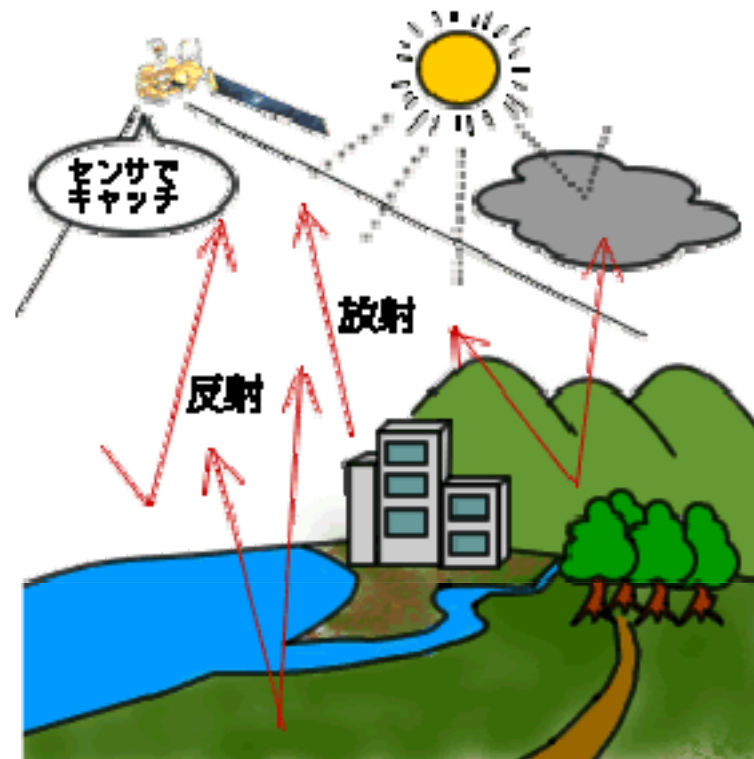
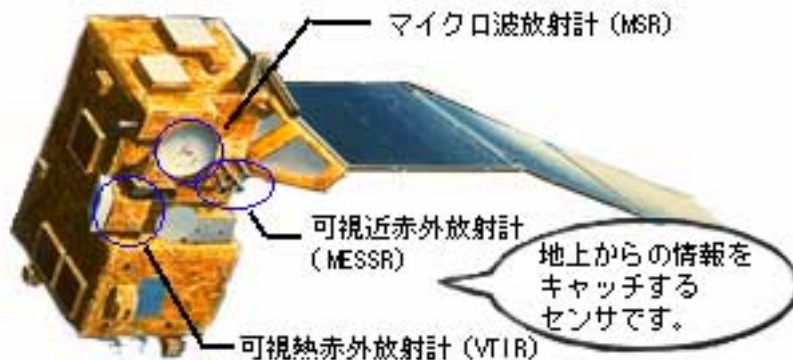
リモートセンシング技術

- 合成開口レーダ (SAR)の特長

受動センサ

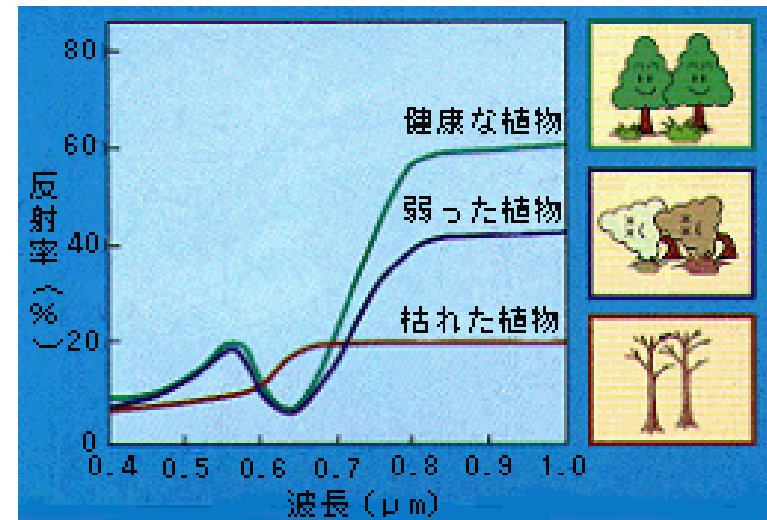
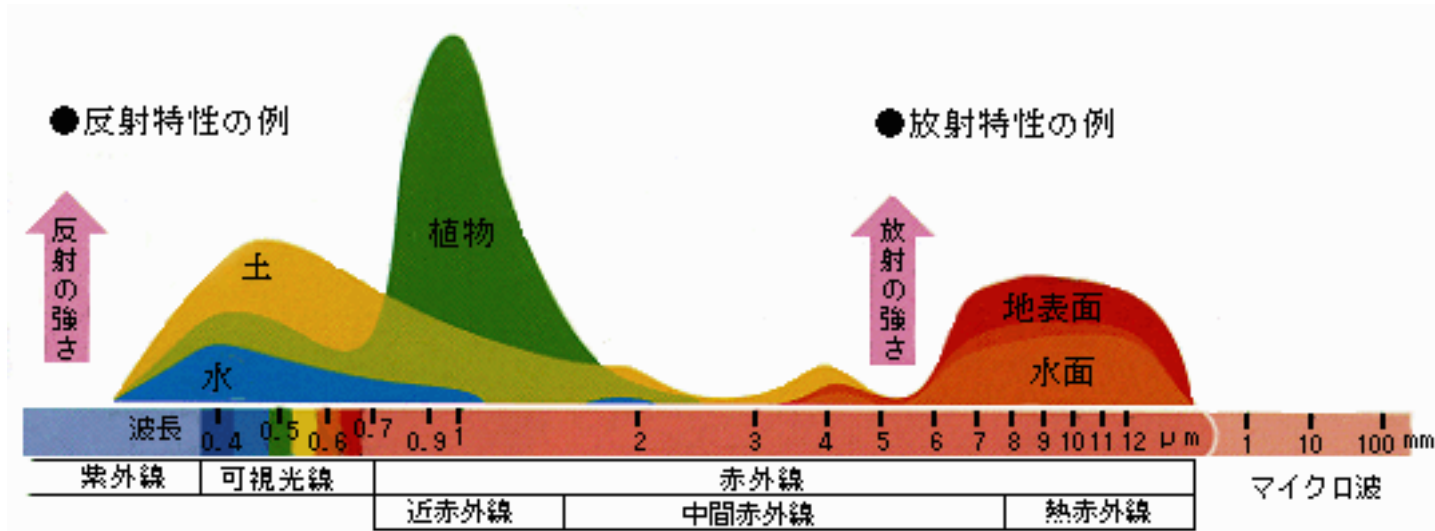
太陽光などの物体表面での反射
熱によって発生する固有の電磁波

- 赤外線
 - 可視光線
 - マイクロ波
- (これらの総称が電磁波)

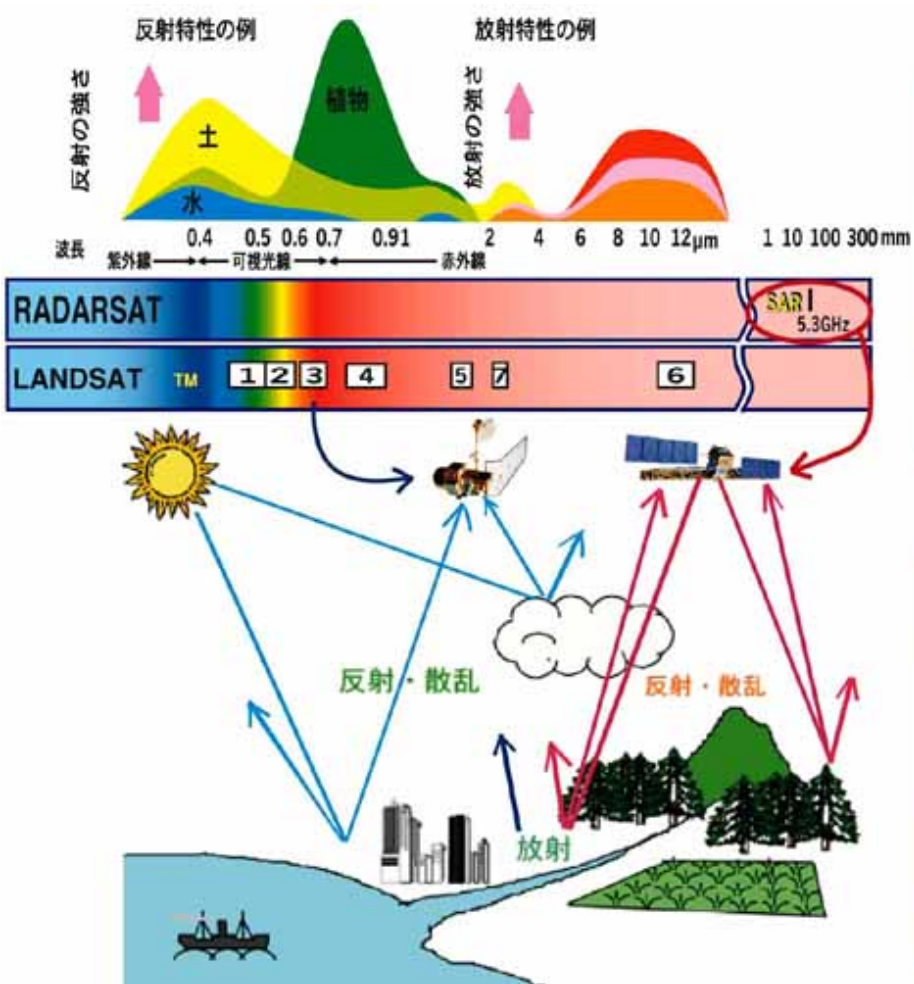


海洋観測衛星1号「もも1号」(MOS-1)

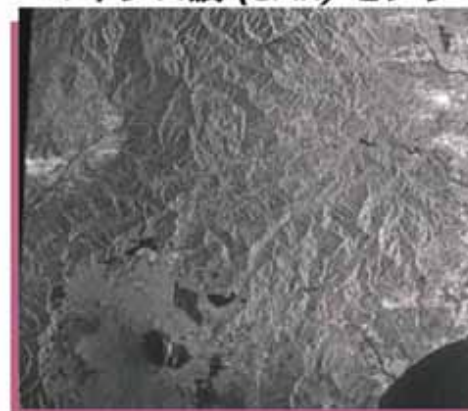
物質による電磁波の反射と放射



光学センサとマイクロ波センサ



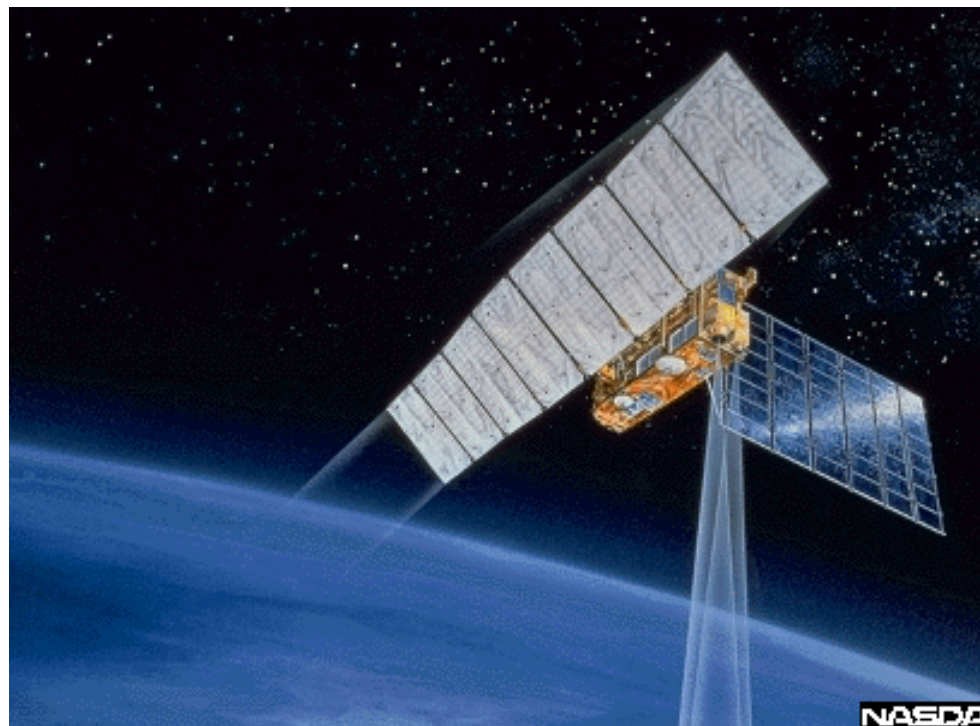
マイクロ波 (SAR) センサ



光学センサ

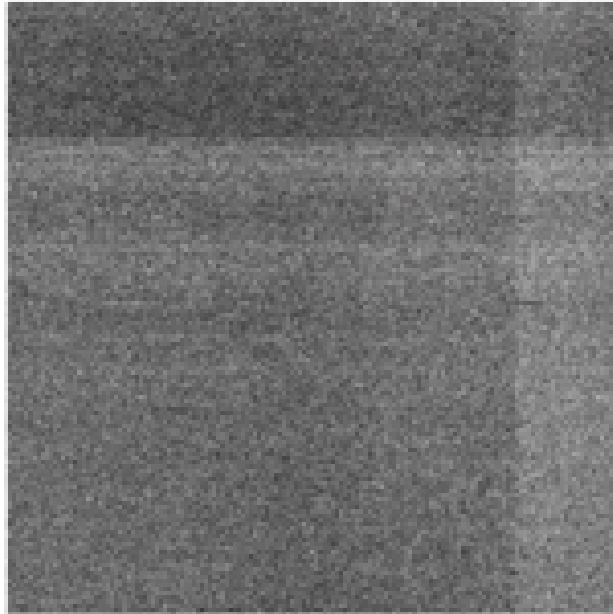


JERS-1 (ふよう)



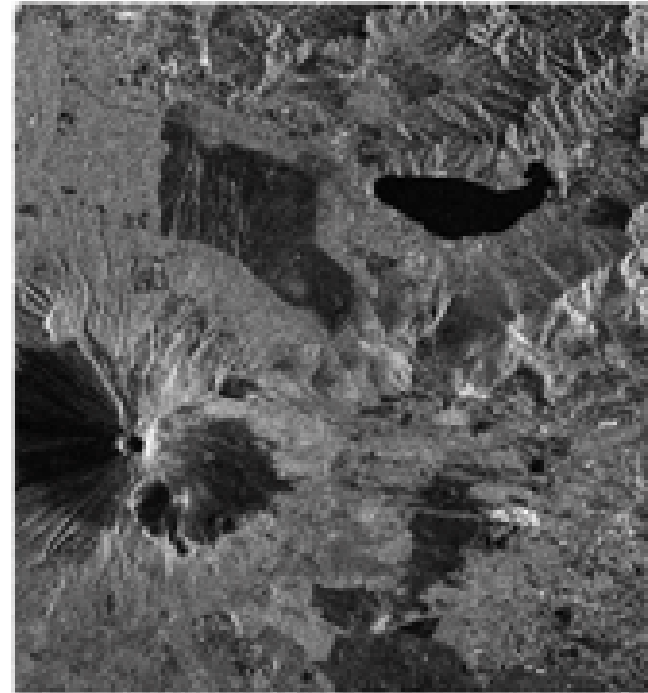
JERS-1は地球の全陸域を観測し、資源探査を主目的に国土調査、農林漁業、環境保全、防災、沿岸監視等の定常観測を行う地球観測衛星。平成4年2月11日に種子島射場よりH-Iロケットで衛星高度568km、回帰日数44日の太陽同期準回帰軌道に打ち上げ。

Microwave Remote sensing SAR



a)raw data

Raw data

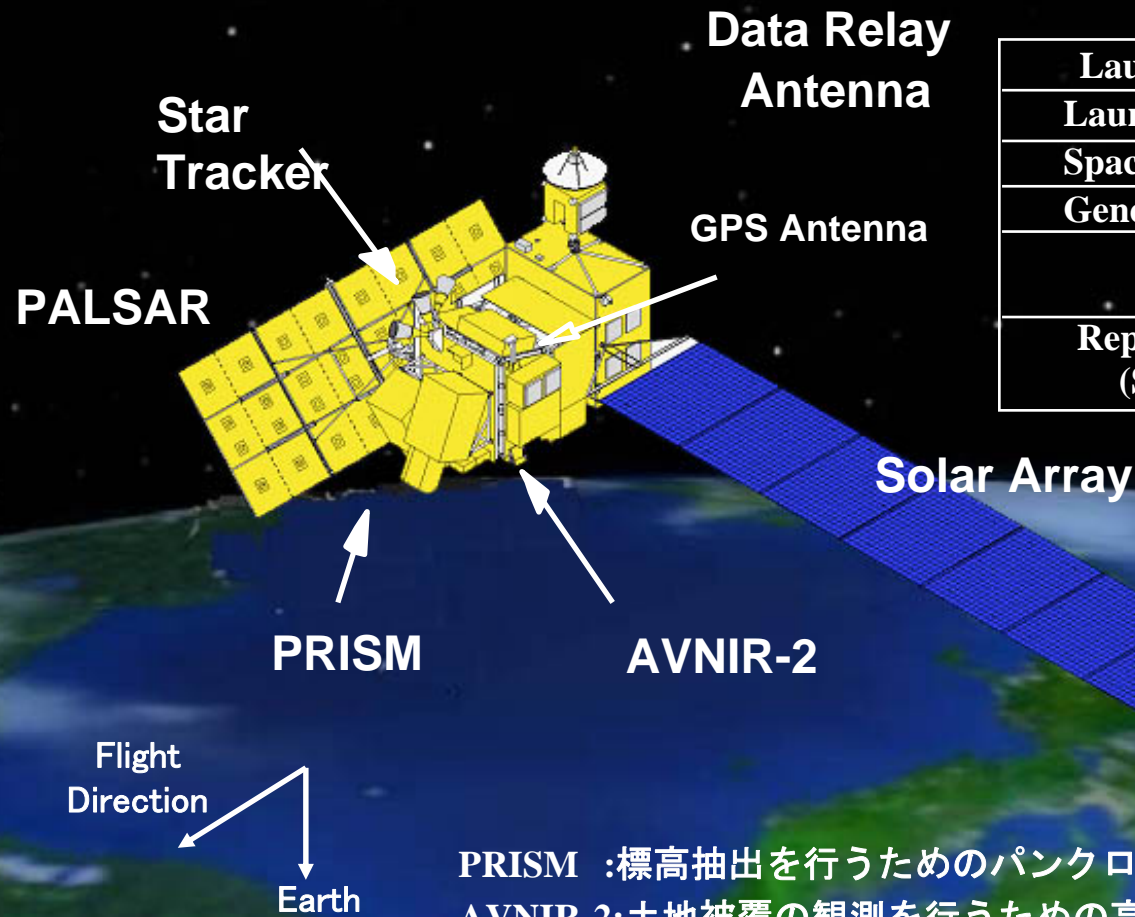


b)correlated data

SAR processed image

JERS-1, ©METI/NASDA

ALOS 2006年1月24日打ち上げ



| | |
|-----------------------------|-----------------------------|
| Launch Date | January 2006 |
| Launch Vehicle | H-IIA |
| Spacecraft Mass | 4,000kg |
| Generated Power | 7kW |
| Orbit | 691.65km Sun Synchronous |
| Repeat Cycle (Sub-Cycle) | 46 days (2 days) |

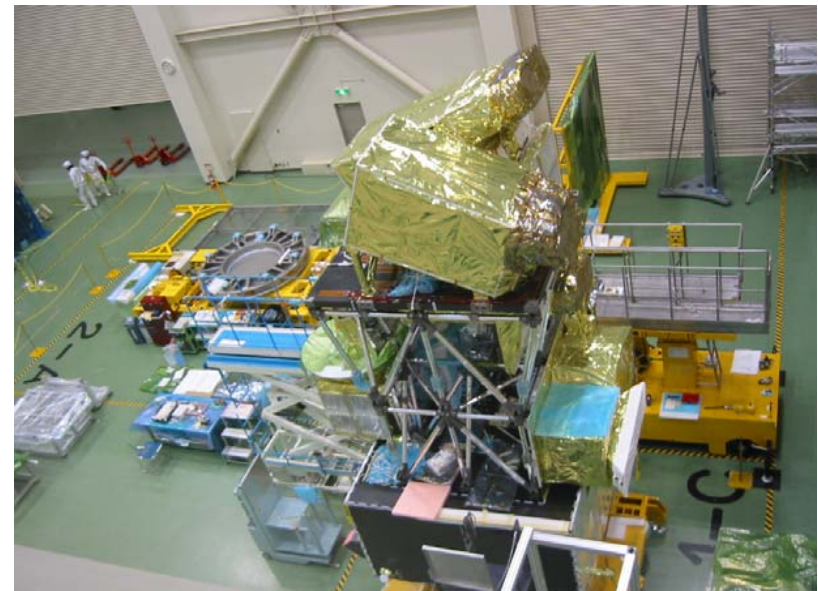
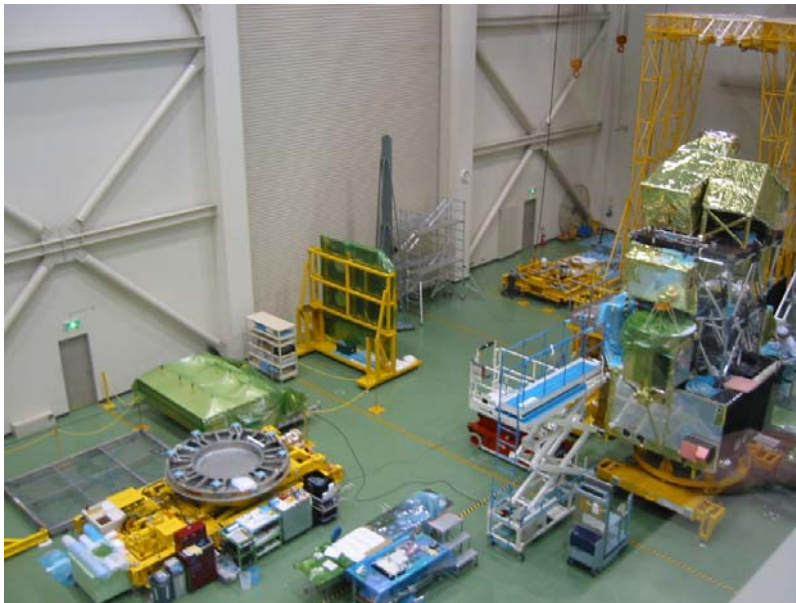
PRISM : 標高抽出を行うためのパナクロマチック立体視センサ
 AVNIR-2: 土地被覆の観測を行うための高性能可視近赤外放射計2型
 PALSAR: フェーズドレイ方式バンド合成開口レーダ

H-IIA 8th Launch

(JAXA:宇宙航空研究機構)

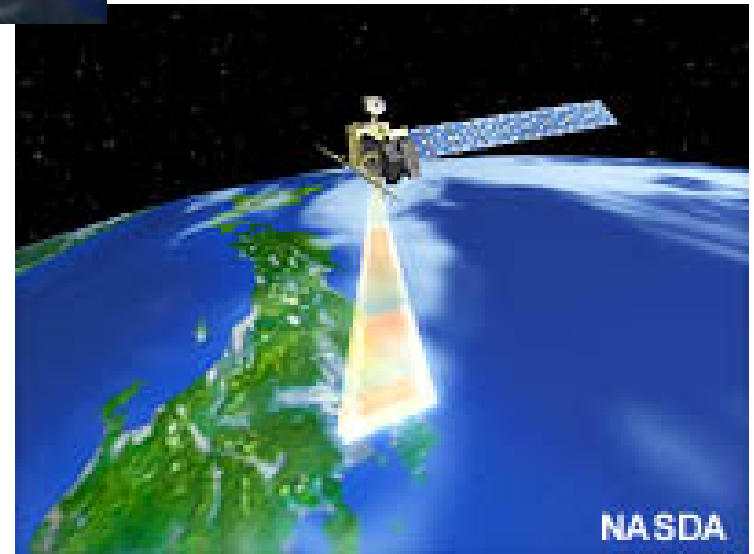
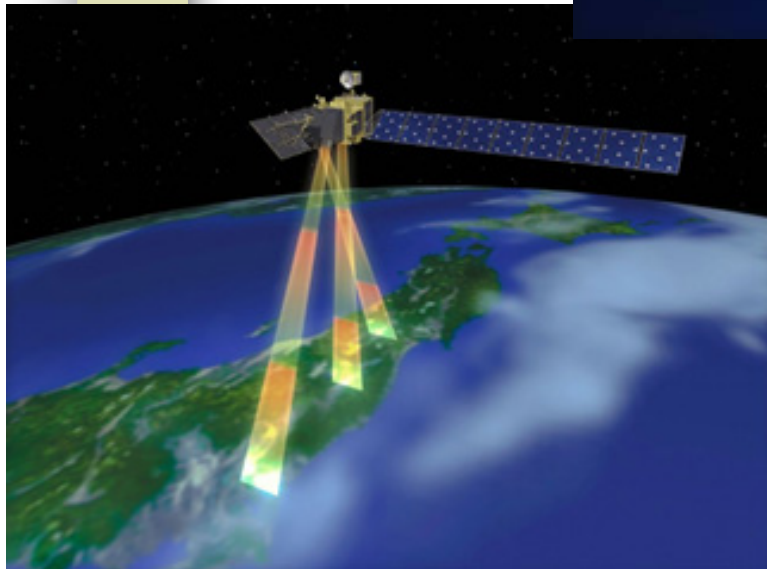
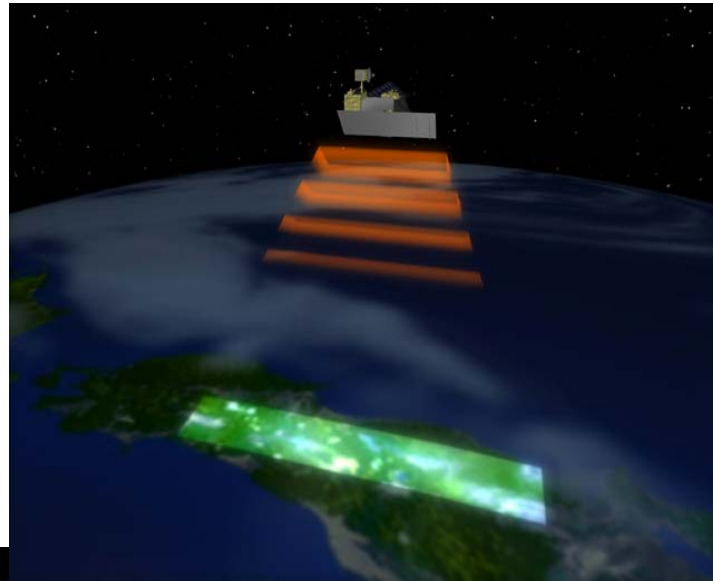


ALOS under assembly in Tsukuba Center

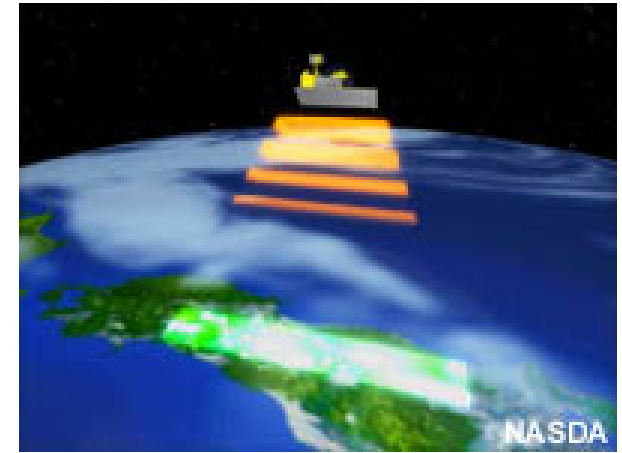


http://www.jaxa.jp/missions/projects/sat/eos/alos/index_j.html

ALOS/PALSAR-PRISM-AVNIR2



PALSAR specifications



| Observation mode | High resolution | Broad observation |
|-------------------------|------------------------|--------------------------|
| Frequency | L-band(1.27GHz) | |
| Polarization | HH,VV,HH&HV,VV&VH | HH,VV |
| Resolution | 10m | 100m |
| Swath width | 70km | 250-350km |
| Off nadir angle | 10-51 degree | |
| Noise-RCS | Ca. -23dB | |

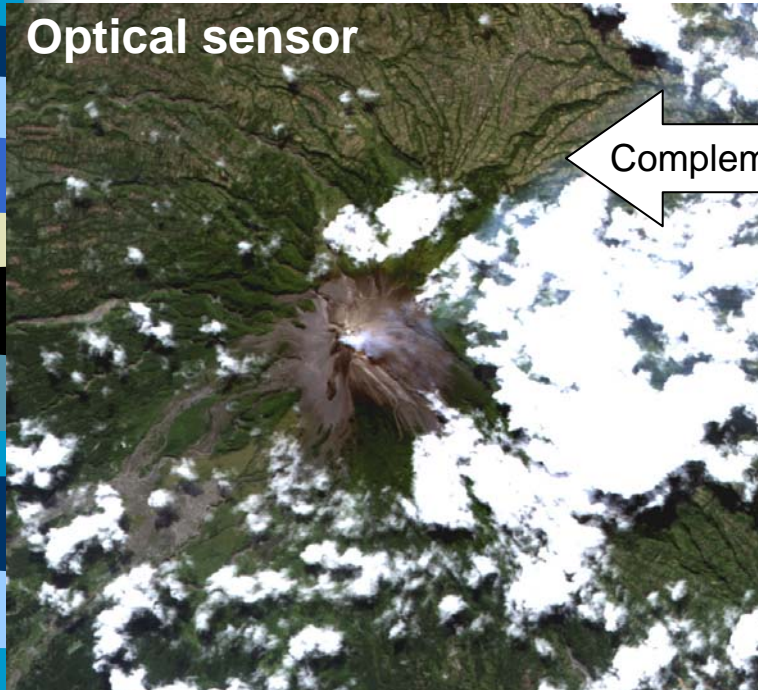
Optics vs. SAR

Advantages of RS by EOS

- Extensive Coverage and Contemporaneousness
- Periodicity
- Workability

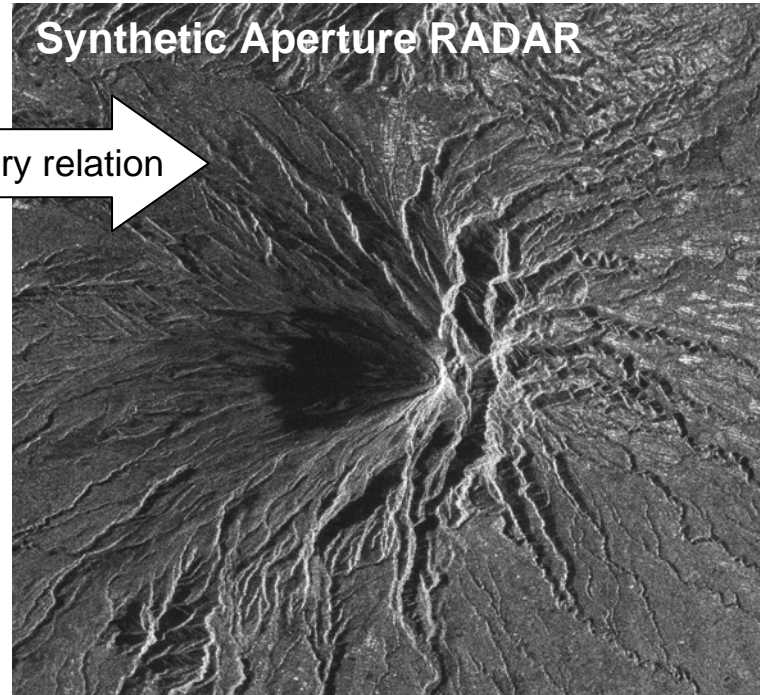
Mt. Merapi, Indonesia, April 29th, 2006

Optical sensor



ALOS/AVNIR-2 (可視近赤外放射計2型)

Synthetic Aperture RADAR



ALOS/PALSAR

©METI, JAXA EORC

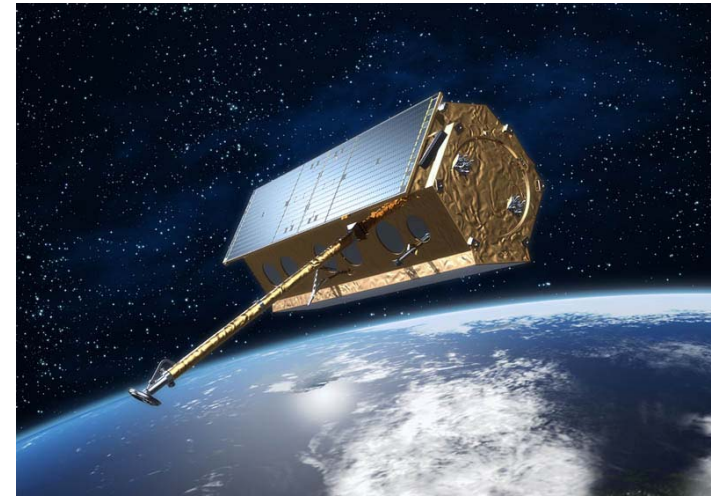


Flight Direction
↓

SAR Remote Sensing by Satellite

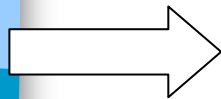


ALOS/PALSAR, Japan, January 24, 2006, L-band
(Nicknamed as "Daichi".)



TerraSAR-X, Germany, June, 2007, X-band

-Each sensor can operate
Quad polarizations observation.
(HH, HV, VH, VV)



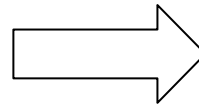
Polarimetric SAR
(POLSAR)



RADARSAT-2, Canada, March, 2007, C-band

Pi-SAR

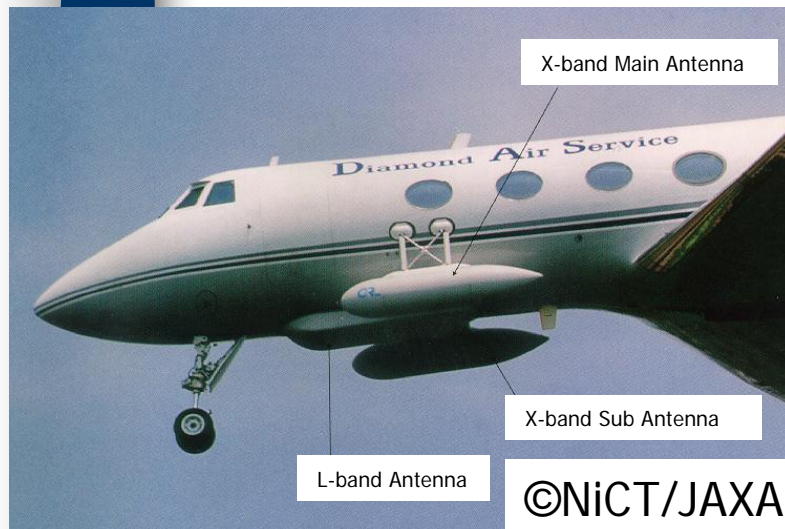
地球環境計測技術の研究開発の一環



NICTとJAXAが共同で開発 (1996年)

Pi-SAR: 航空機搭載型高分解能マルチパラメータ SAR

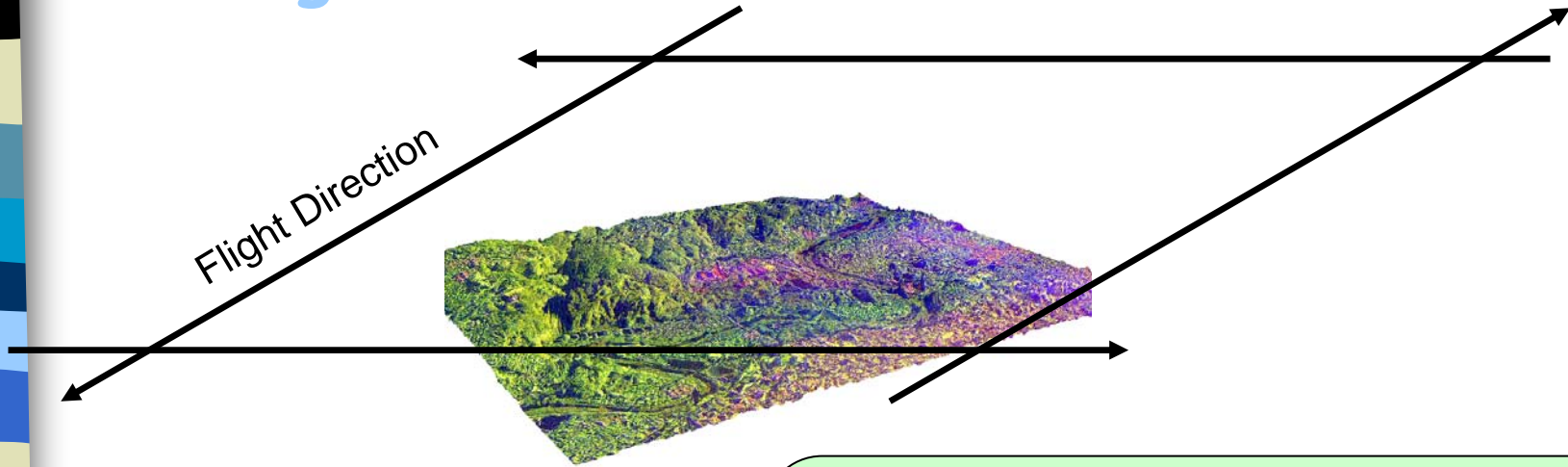
Pi-SAR 性能諸元



| | X-band | L-band |
|------------------|--|-------------------------------------|
| Frequency | 9.55GHz | 1.27GHz |
| Wave length | 3.14cm | 23.6cm |
| Resolution | 1.5m | 3m |
| Observation mode | Polarimetry (HH/HV/VH/VV) Interferometry | Polarimetry (HH/HV/VH/VV) |

データ観測: 2001年8月30日、2002年6月12日、11月6日、2003年5月9日、8月21日、
2004年2月10日、2005年2月12日

Background & Motivation

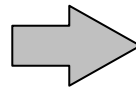


Conventional Techniques

Interferometry

Tomography

Stereography

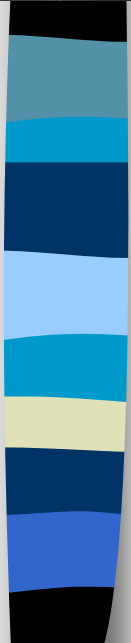


Topographic Mapping



Precise 3D Imaging, for example
Buildings, Small Objects

- Square Flight Path Dataset
- Polarimetric Information
- SAR Stereo-rectification

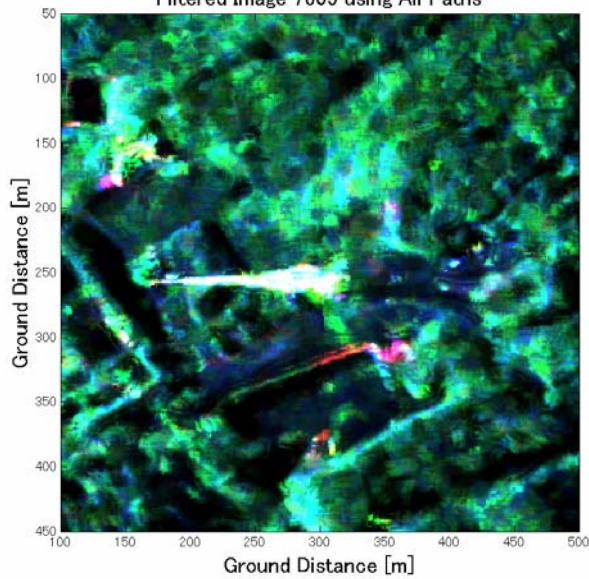


Speckle filtered Images

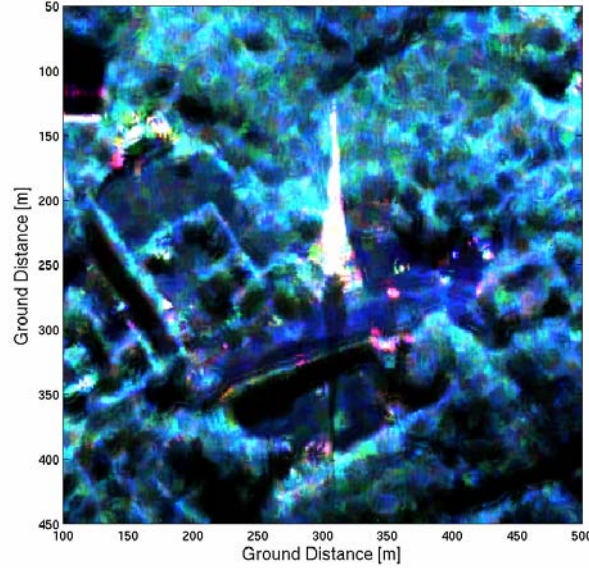
(J.S.Lee et al., 1999)



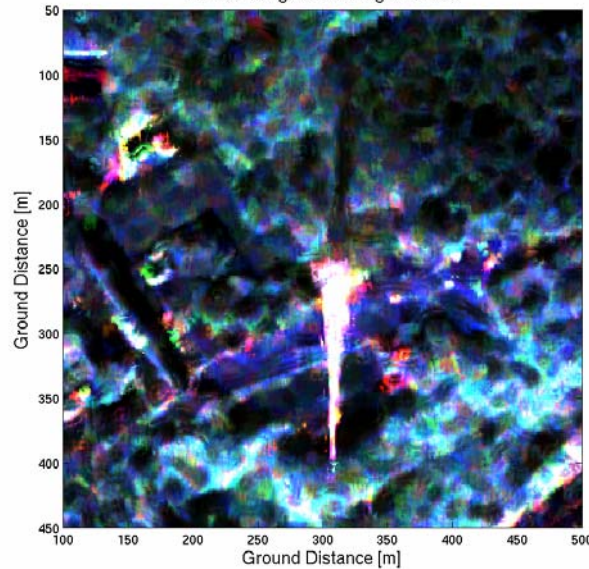
Filtered Image 7605 using All Paths



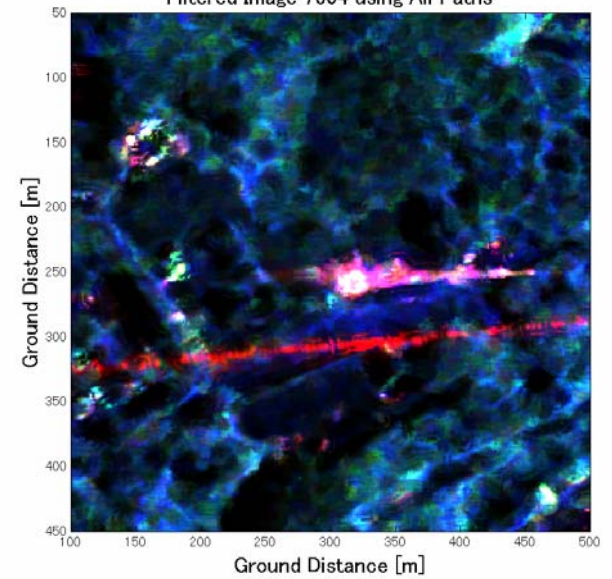
Filtered Image 7602 using All Paths



Filtered Image 7603 using All Paths



Filtered Image 7604 using All Paths



400m x 400m

HH-VV: Red

HV: Green

HH+VV: Blue

Reconstructed Images

Directional Mask

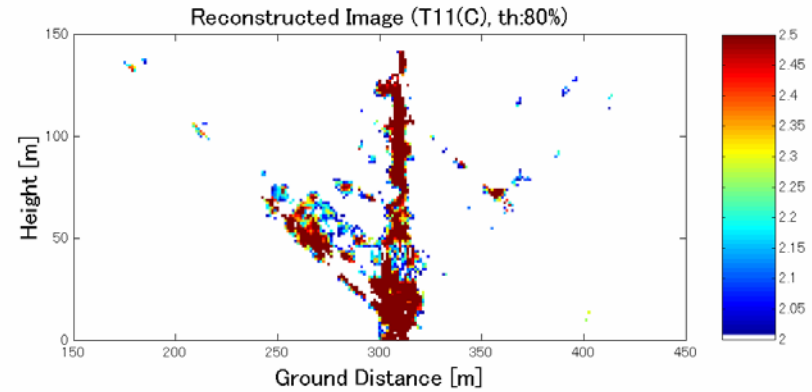
If $CV > \text{Threshold Value}$

$$Tt_{i,i}(x, y, z) = 0$$

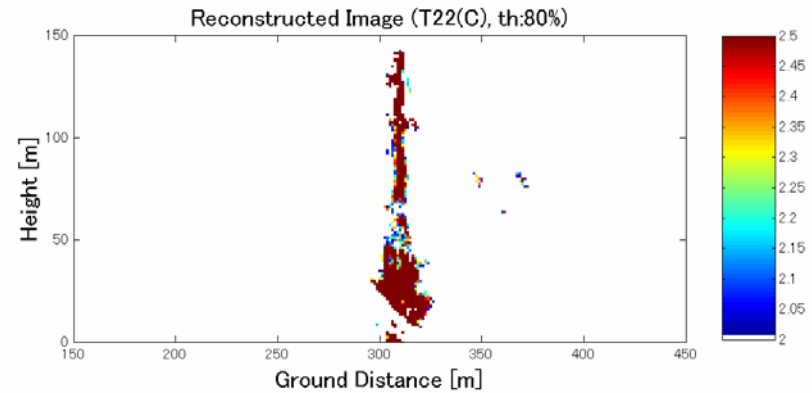
where

Threshold Value = 80%

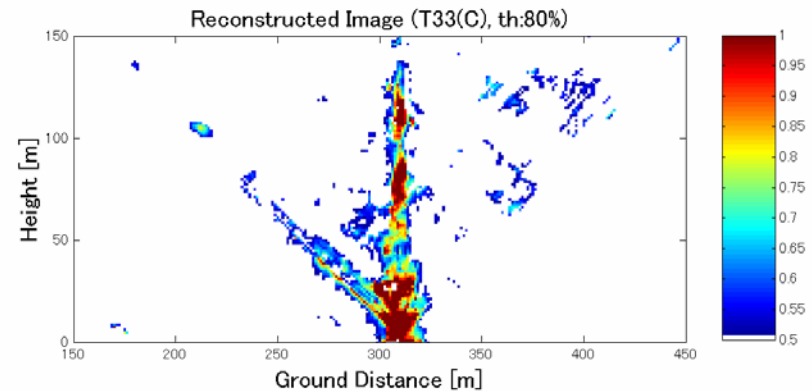
Tt_{11}

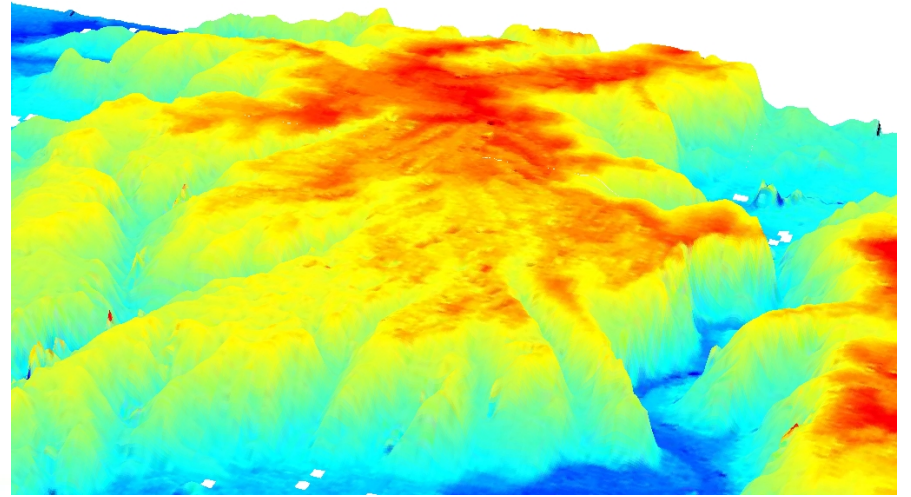


Tt_{22}



Tt_{33}





Pi-SARによる仙台DEM

目で見えない物の計測

➤物理量計測

➤地下水

➤鉱物

➤経時変化

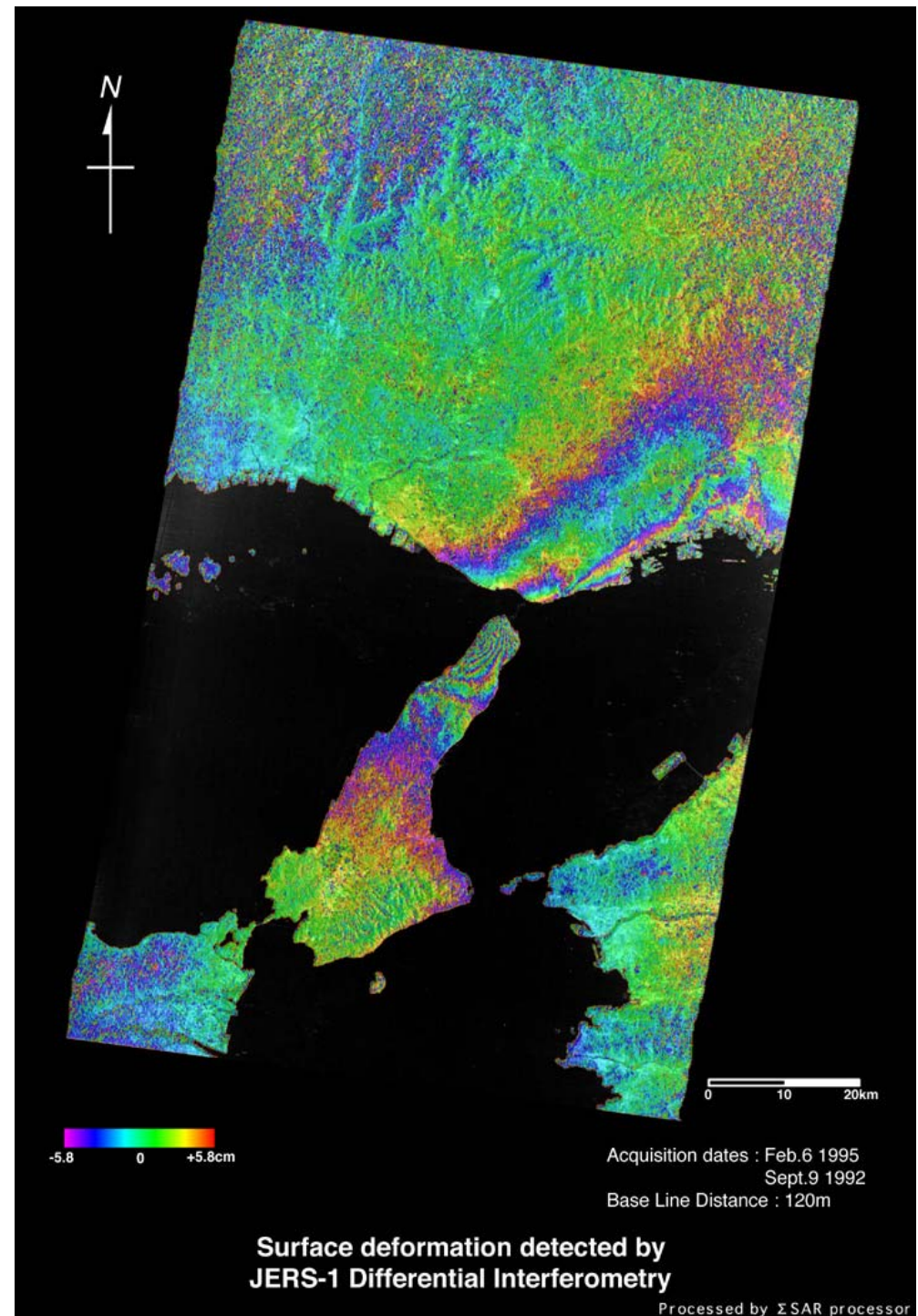
➤定量計測

➤バイオマス計測

➤降水量

➤農作物の作高予測

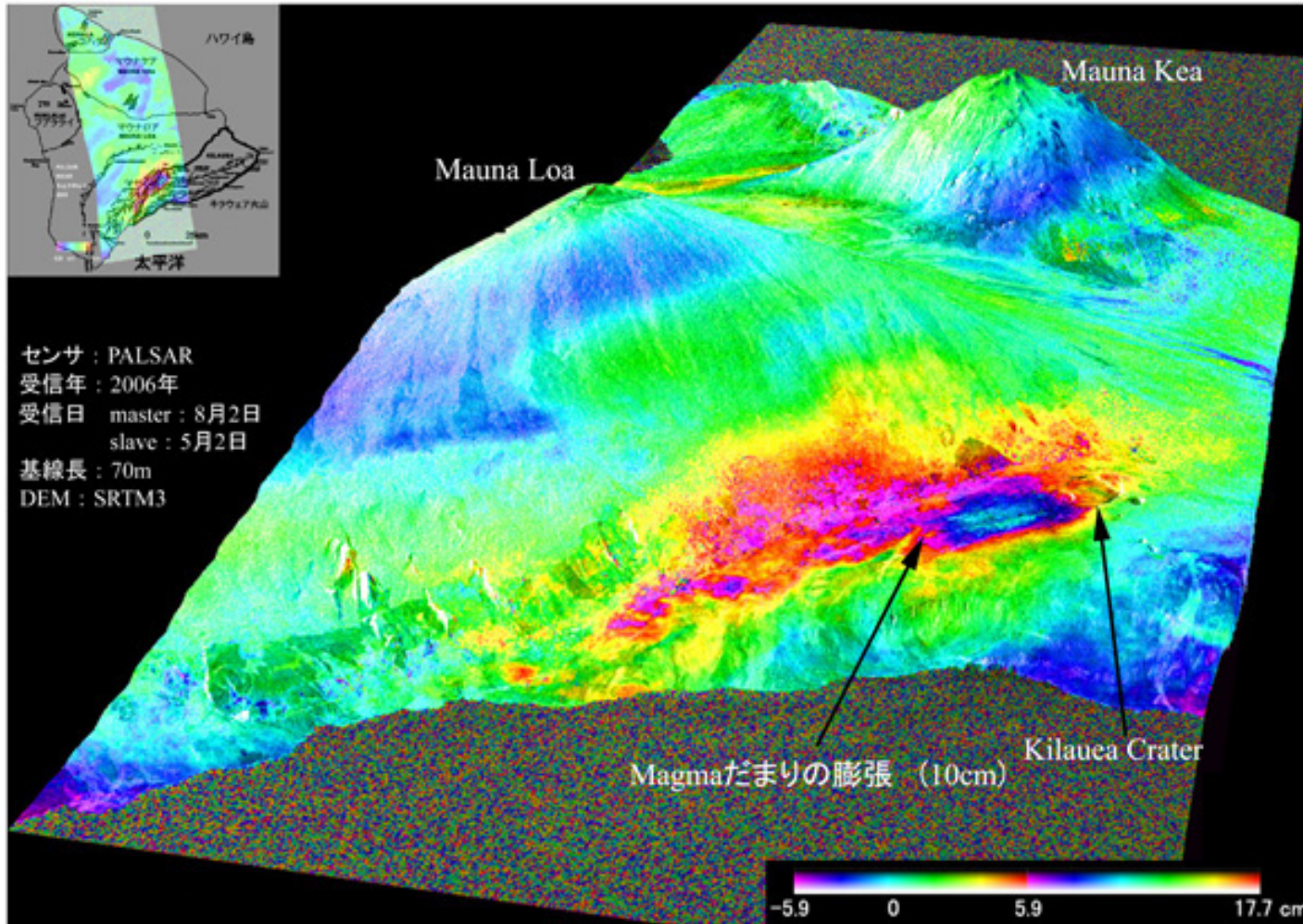
➤立体地図



干渉SARによる地殻変位の計測

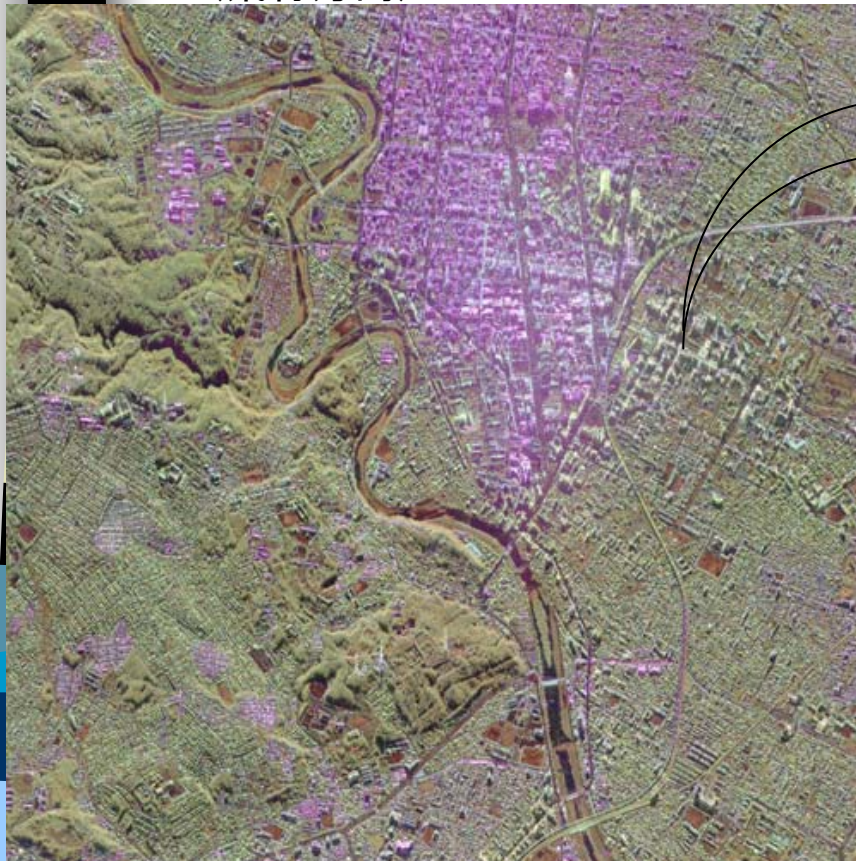


PALSARによるハワイ島・キラウエア火山火口部の隆起検出



Pi-SAR POLSAR Image

azimuth(飛行方向) ←



Range(照射方向) ↓

Sinclair Matrix, Scattering Matrix, 散乱行列

$$[S] = \begin{bmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{bmatrix}$$

POLSAR dataとは散乱行列からなるデータであり、POLSAR画像データはピクセルごとに1つの散乱行列が対応する二次元データ。

[S]は次式のように定義。

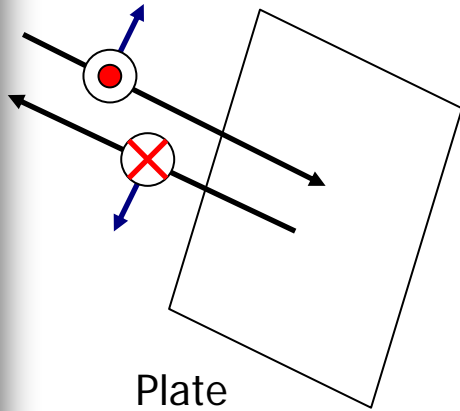
$$\begin{bmatrix} E_H^s \\ E_V^s \end{bmatrix} = [S] \begin{bmatrix} E_H^t \\ E_V^t \end{bmatrix} = \begin{bmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{bmatrix} \begin{bmatrix} E_H^t \\ E_V^t \end{bmatrix}$$

通常、レーダ観測では直線の水平偏波Hと垂直偏波Vが使われ、 E^t は送信電界、 E^s は受信電界を表す。例えば、 S_{HV} とは垂直偏波Vで送信、水平偏波Hで受信するチャンネルの偏波情報を表す。

Sendai City, 4000pixels*4000pixels,
5000m*5000m, X-band, HH, HV, VV

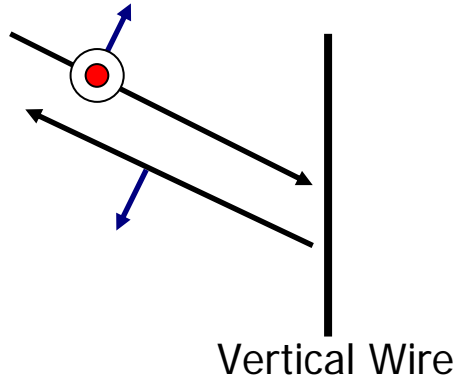
行列と二次統計量

ターゲットと観測される[S]



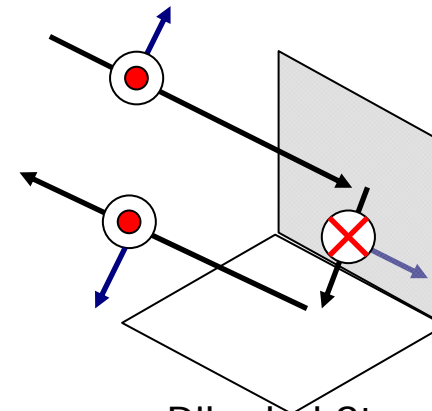
Plate

$$[S]_{Plate} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$



Vertical Wire

$$[S]_{Vertical\ wire} = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}$$



Dihedral Structure

$$[S]_{Dihedral} = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$$

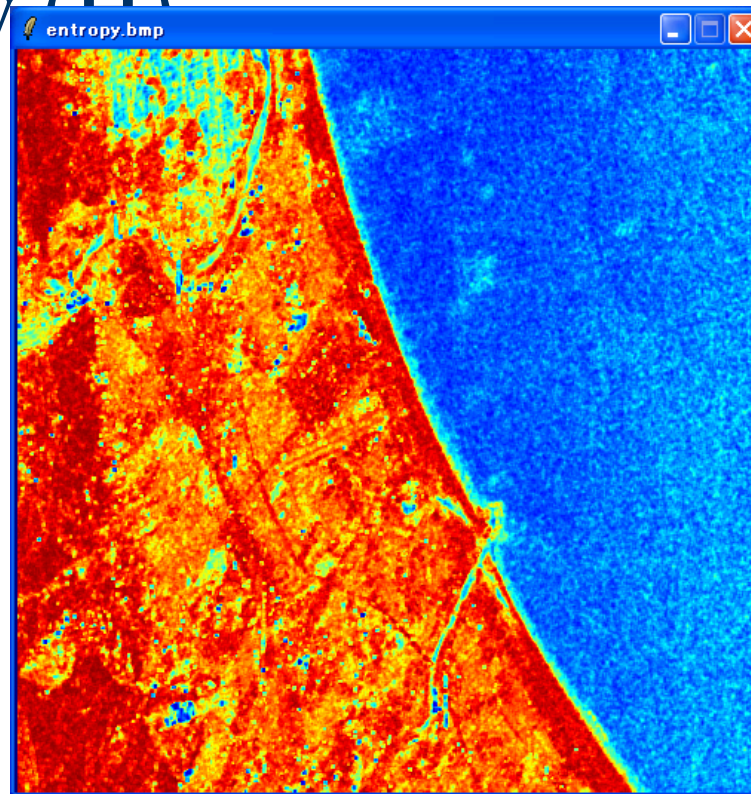
二次統計量を要素とするCoherency行列[T]

ターゲットの分類や散乱メカニズムの解析には偏波情報の集合平均が必要.

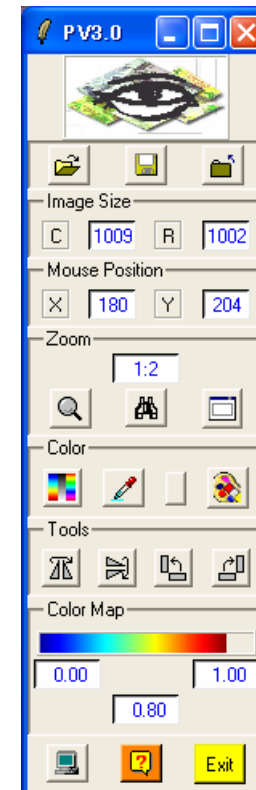
$$\langle [T] \rangle = \frac{1}{n} \sum k_P k_P^* = \frac{1}{2} \begin{bmatrix} \langle |S_{HH} + S_{VV}|^2 \rangle & \langle (S_{HH} + S_{VV})(S_{HH} - S_{VV})^* \rangle & \langle 2S_{HV}^*(S_{HH} + S_{VV}) \rangle \\ \langle (S_{HH} - S_{VV})(S_{HH} + S_{VV})^* \rangle & \langle |S_{HH} - S_{VV}|^2 \rangle & \langle 2S_{HV}^*(S_{HH} - S_{VV}) \rangle \\ \langle 2S_{HV}(S_{HH} + S_{VV})^* \rangle & \langle 2S_{HV}(S_{HH} - S_{VV})^* \rangle & \langle 4|S_{HV}|^2 \rangle \end{bmatrix}$$

[T]行列はエルミート正定値行列であり、固有値解析により様々なパラメータを定義できる.
Entropy, Alpha等.

Entropy (II)



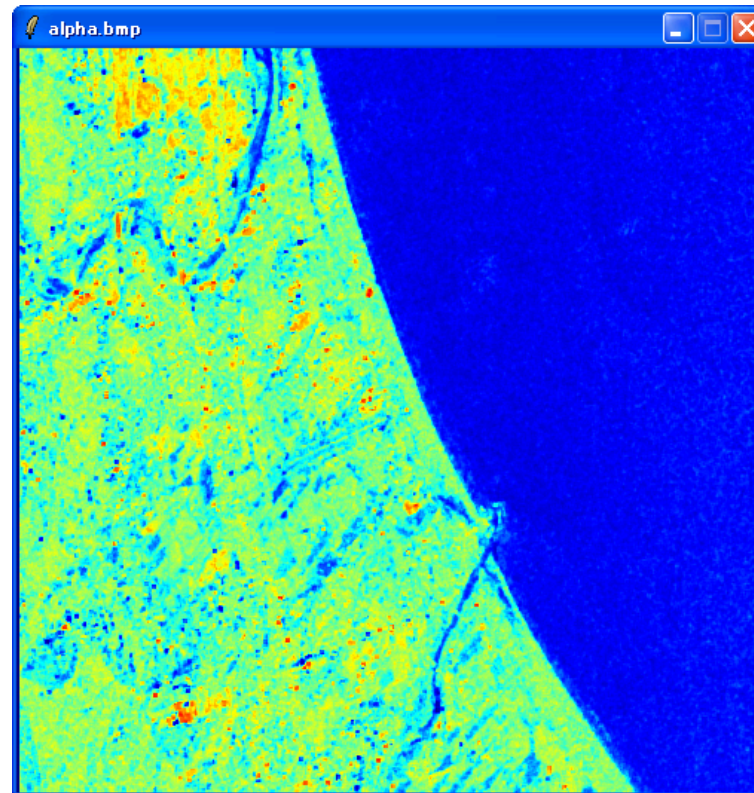
Entropy bmp Image



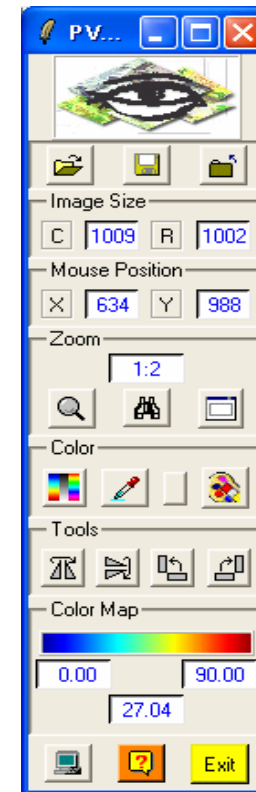
PV 3.0 widget

- Entropyは0から1までの範囲をとり、散乱の乱雑さを表す。H=0で1つの散乱メカニズムが発生することを表しており、H=1で3つの散乱メカニズムが同程度で発生することを表す。
- 海面上の散乱は低い乱雑さを表す。人口構造物のある領域では中間程度の乱雑さ、様々な散乱メカニズムが発生する森林植生域では高い乱雑さを示す。

Alpha



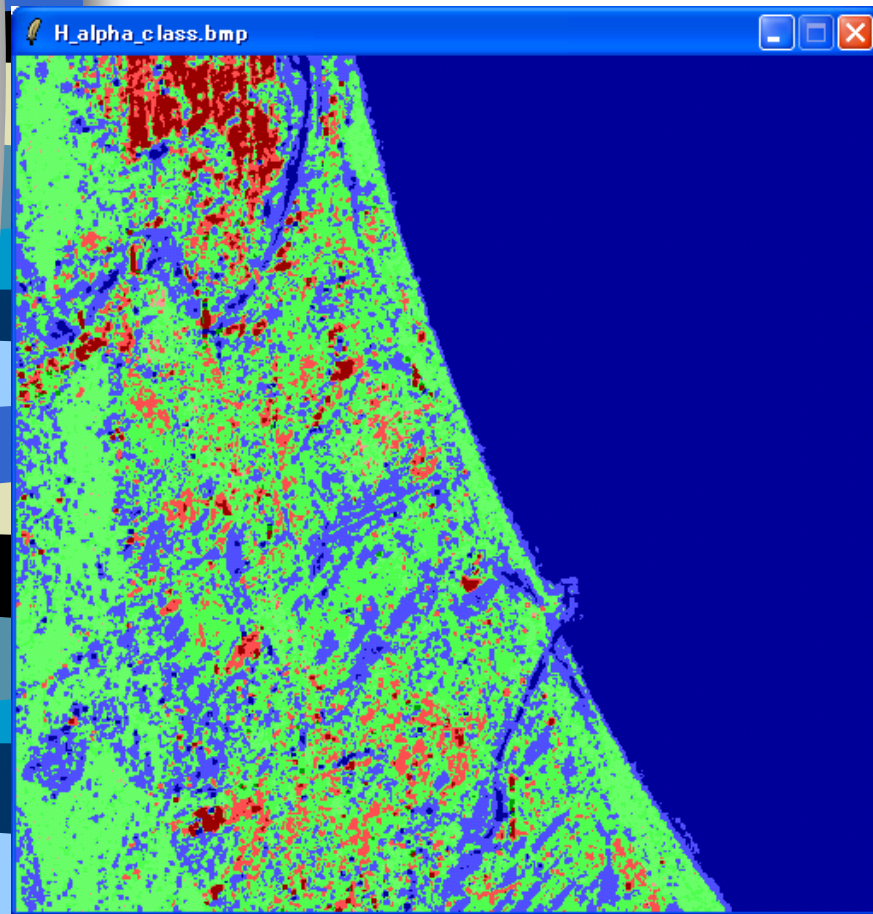
Alpha bmp Image



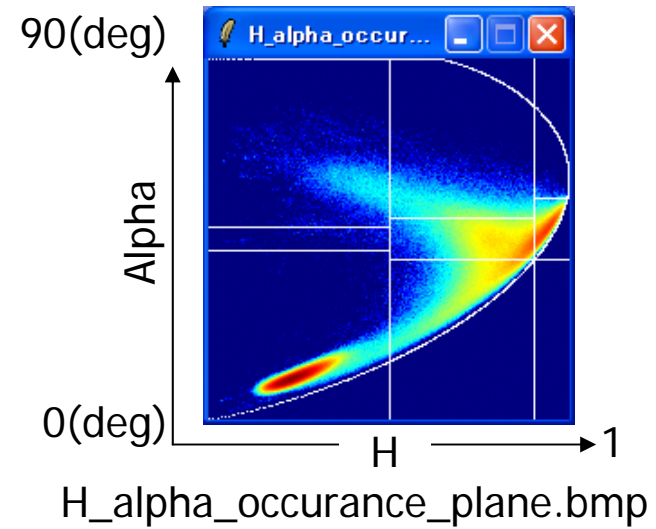
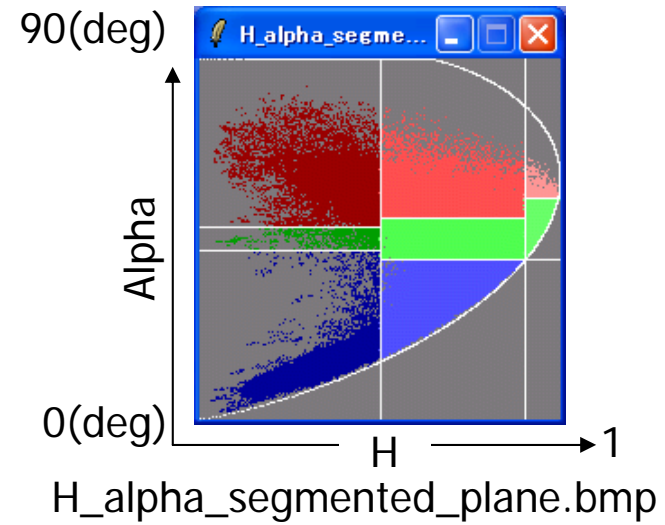
PV 3.0 widget

- Alphaは0から90(deg)までの範囲をとり、散乱のメカニズムを表す. 0(deg)でプレート(奇数回反射)、45(deg)でワイヤ(線状散乱体)、90(deg)でコーナーリフレクタ(偶数回反射)を表す.
- 海面は0(deg)を示し、プレート(奇数回反射)のような散乱メカニズムを、人工構造物の多い市街地では90(deg)付近を示し、コーナーリフレクタ(偶数回反射)のような散乱メカニズムを表す.

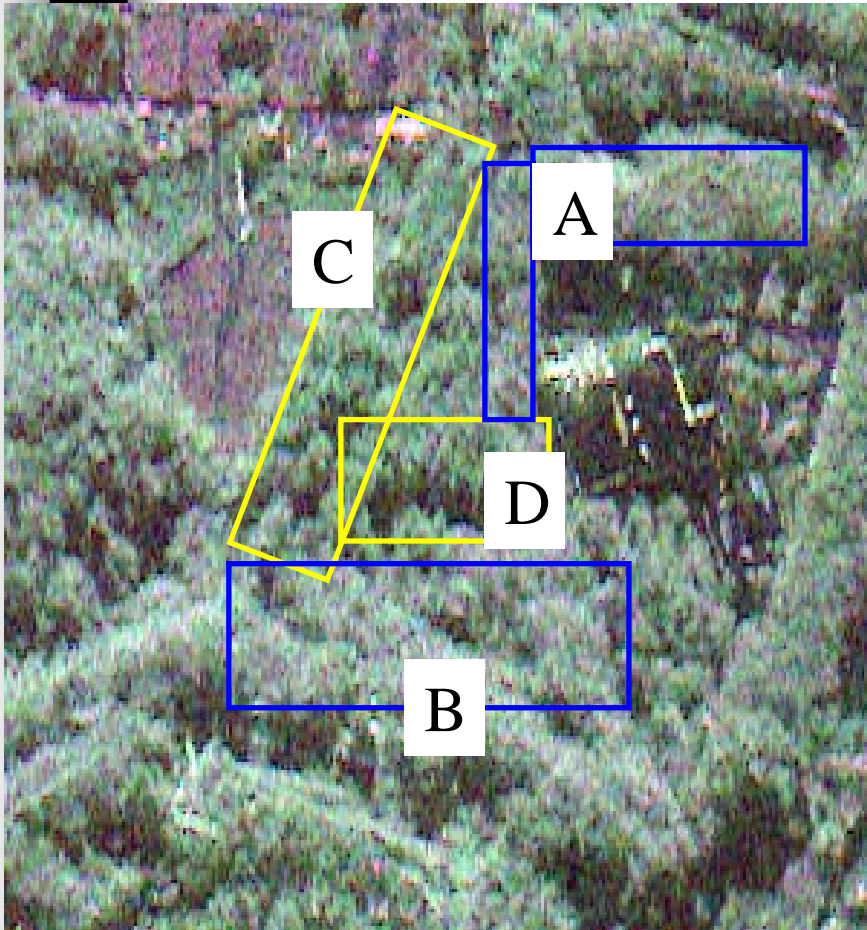
H-Alpha 分類図



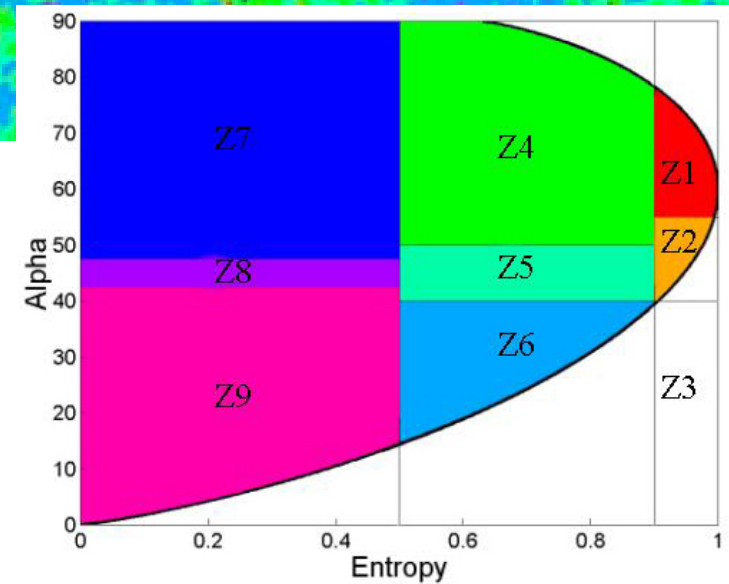
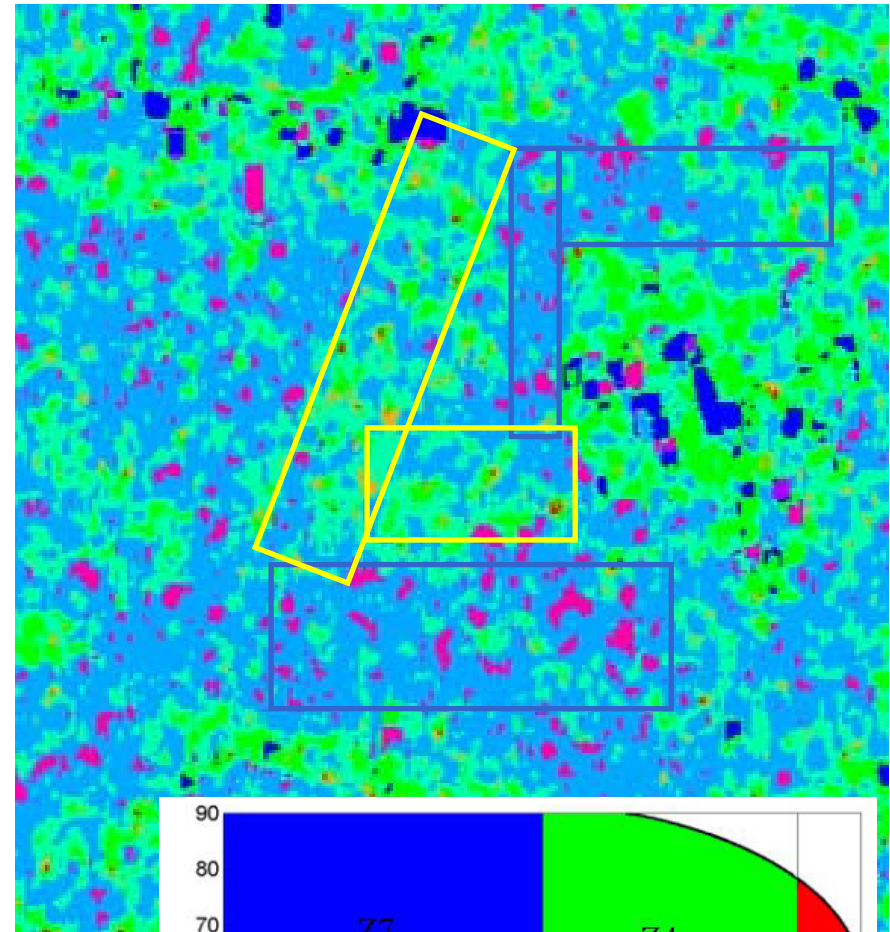
H_alpha_class.bmp



Pi-SAR classification of forest trees



X-band, 30/08/2001 375m*400m



Overview of Site



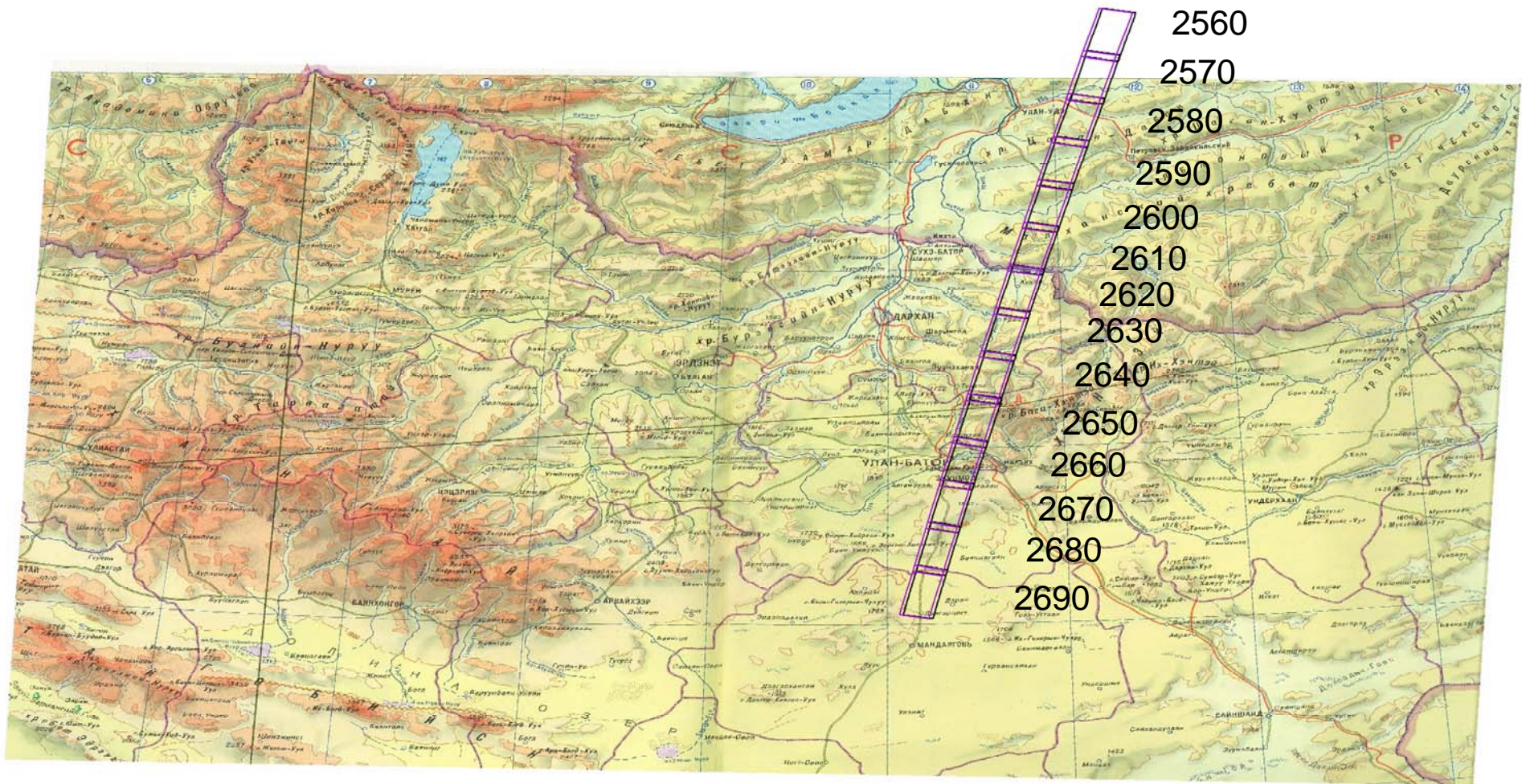
Overview of Site



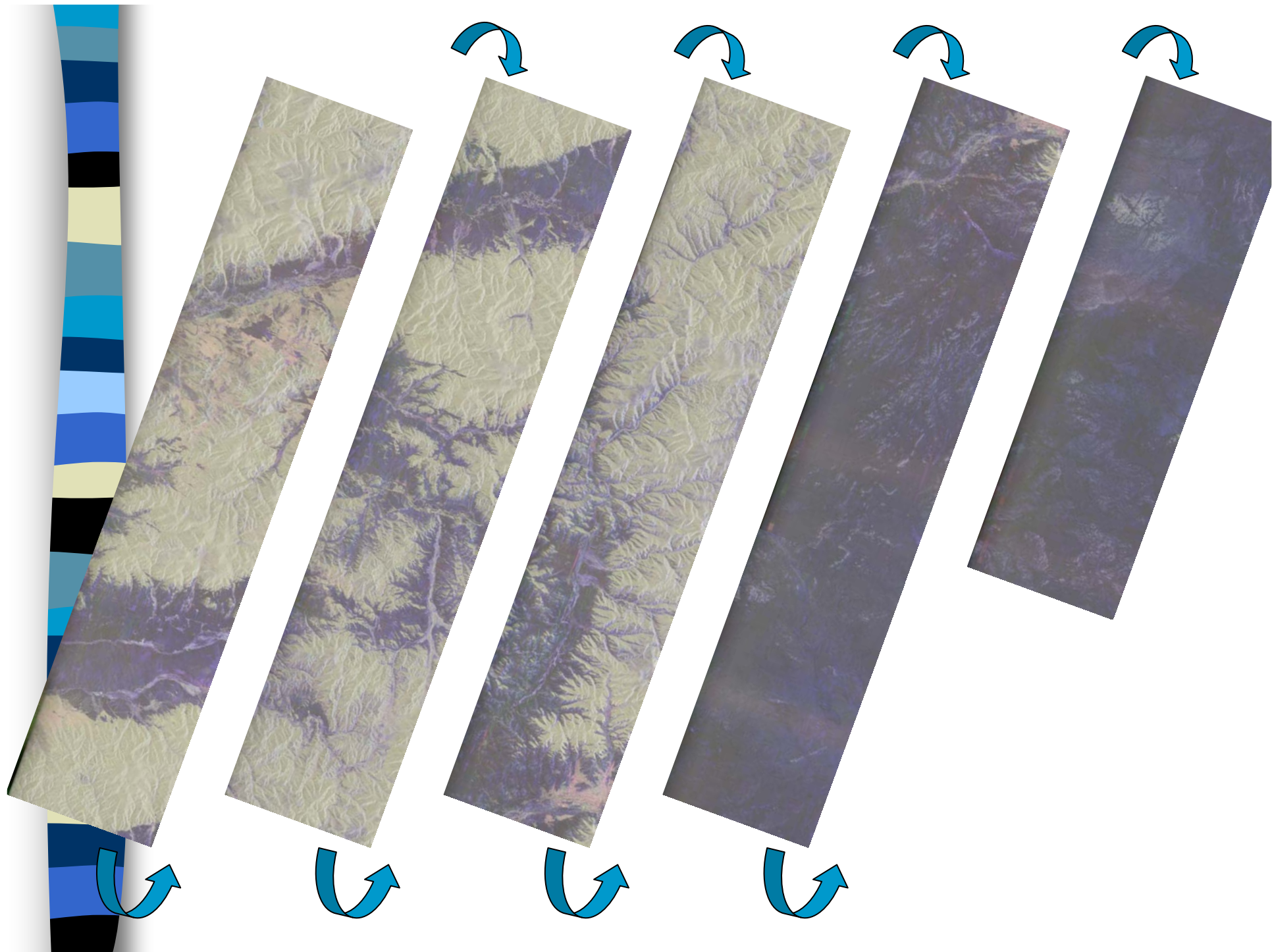
反射鏡の設置



Scene area on Map

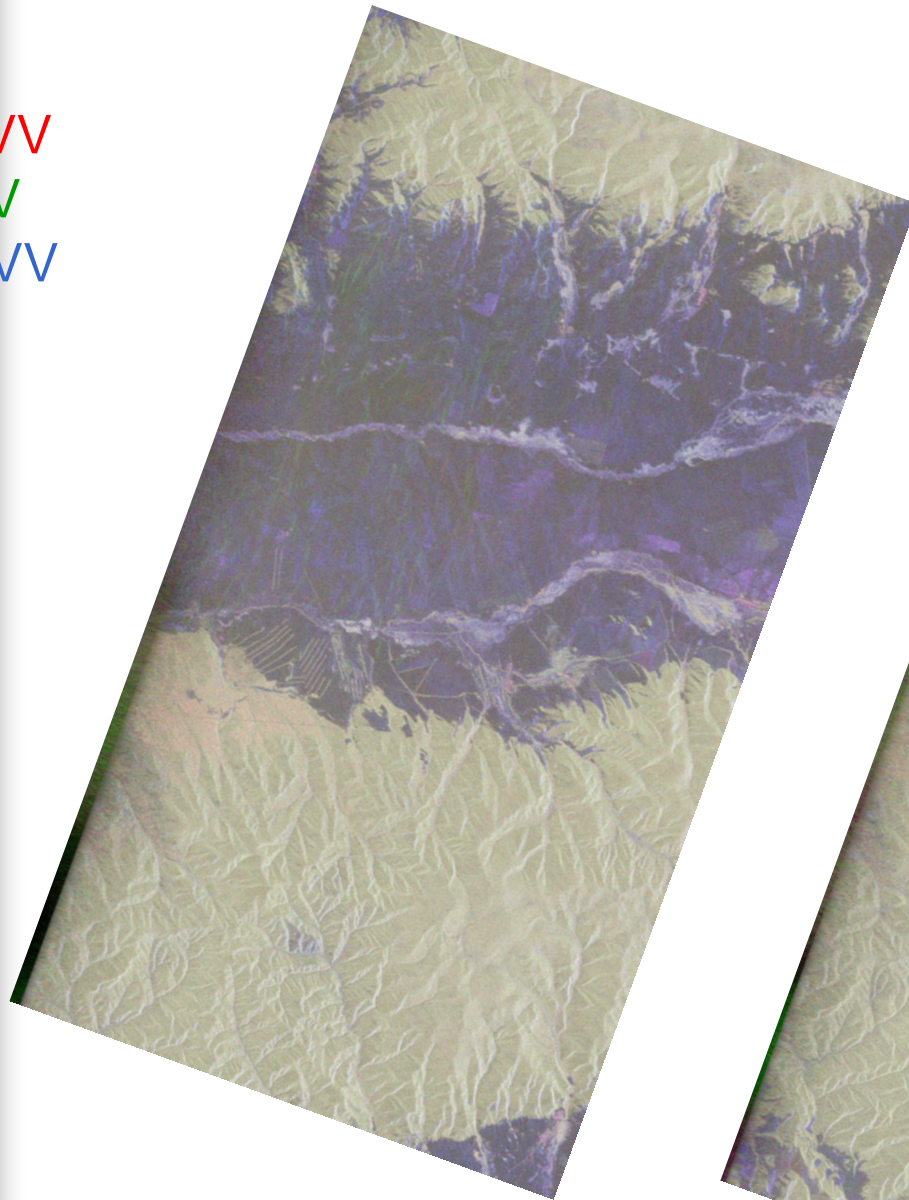


14 scenes in the north-south direction.
1 scene is about 36km*66km.

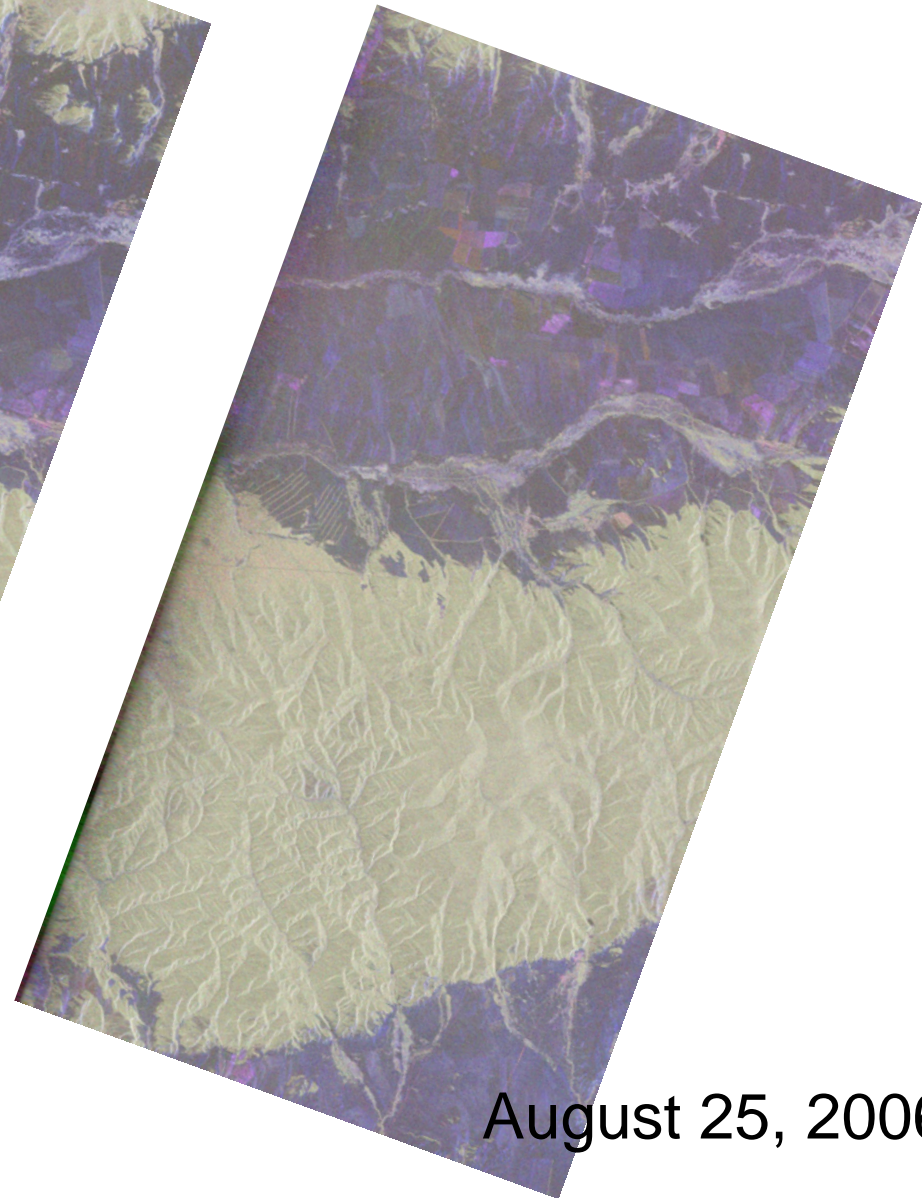


Scene ID: 2580

HH-VV
2HV
HH+VV

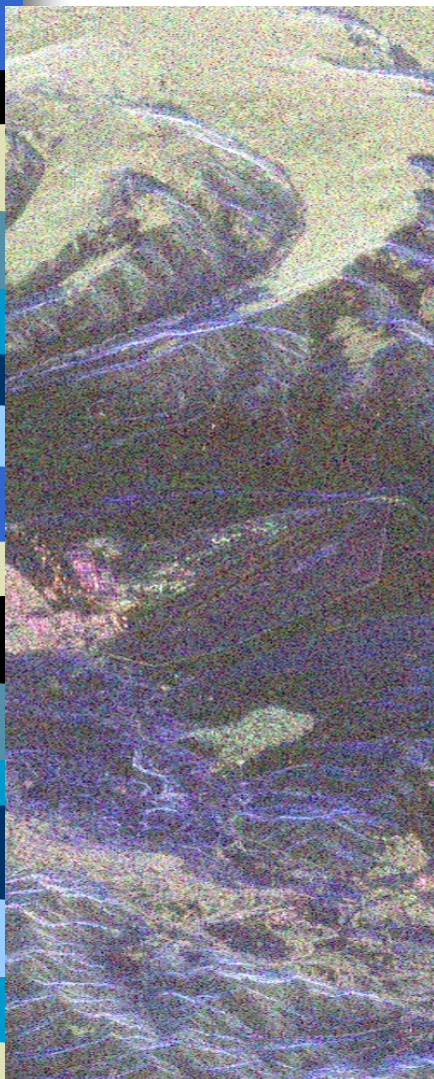


May 25, 2006

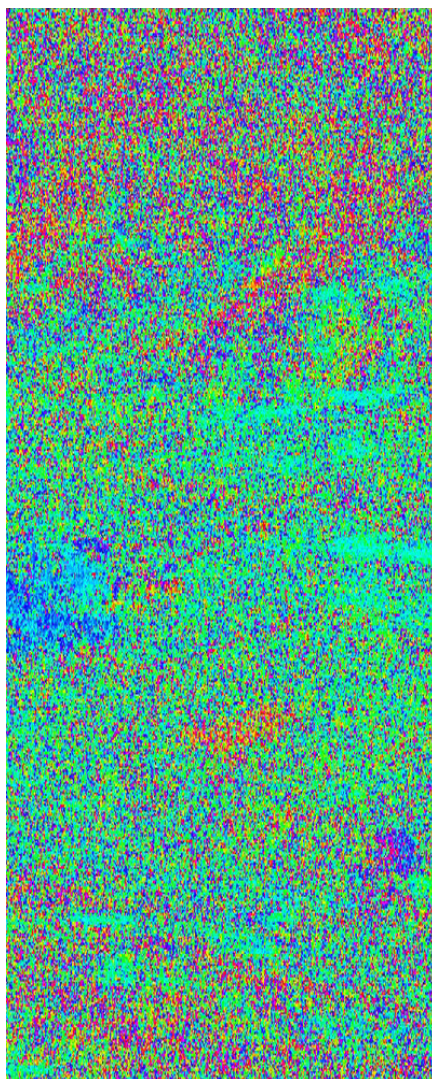


August 25, 2006

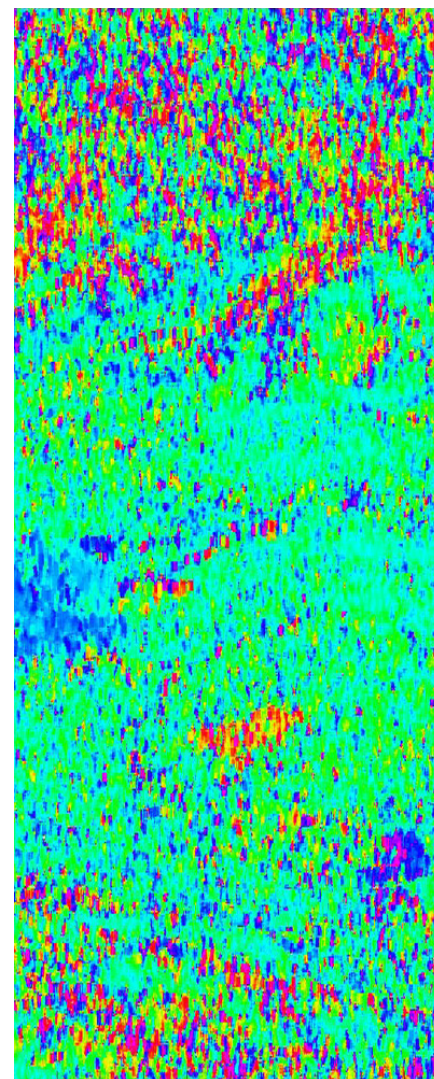
Terrain effect (Orientation angle shift)



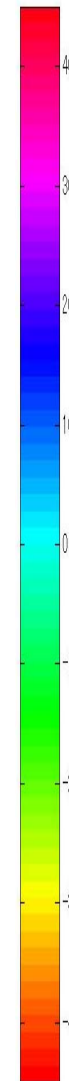
HH-VV, 2HV, HH+VV



3×3 pixels

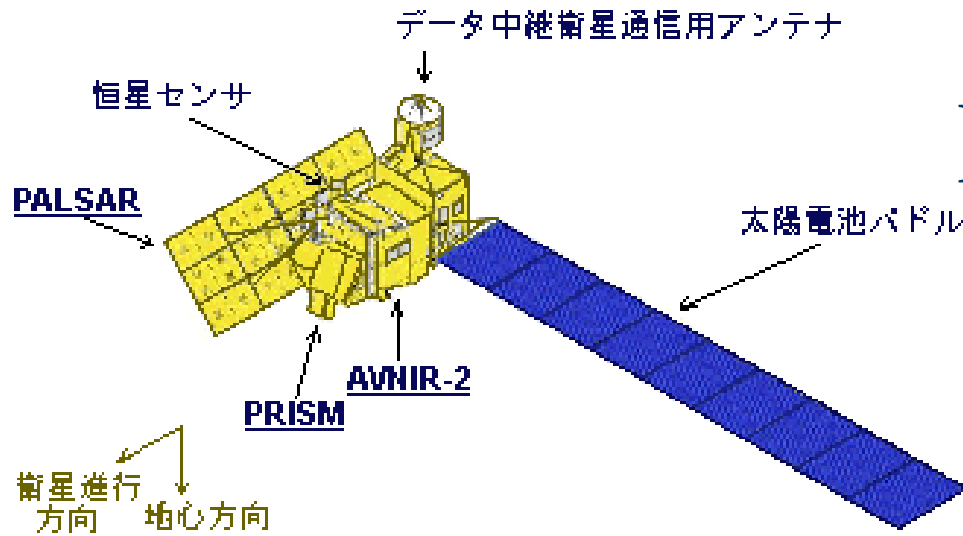


9×9 pixels

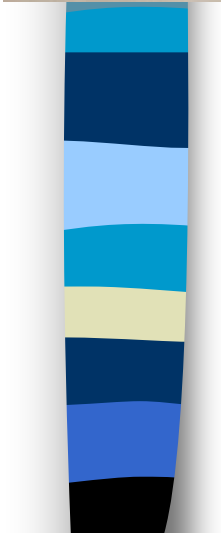
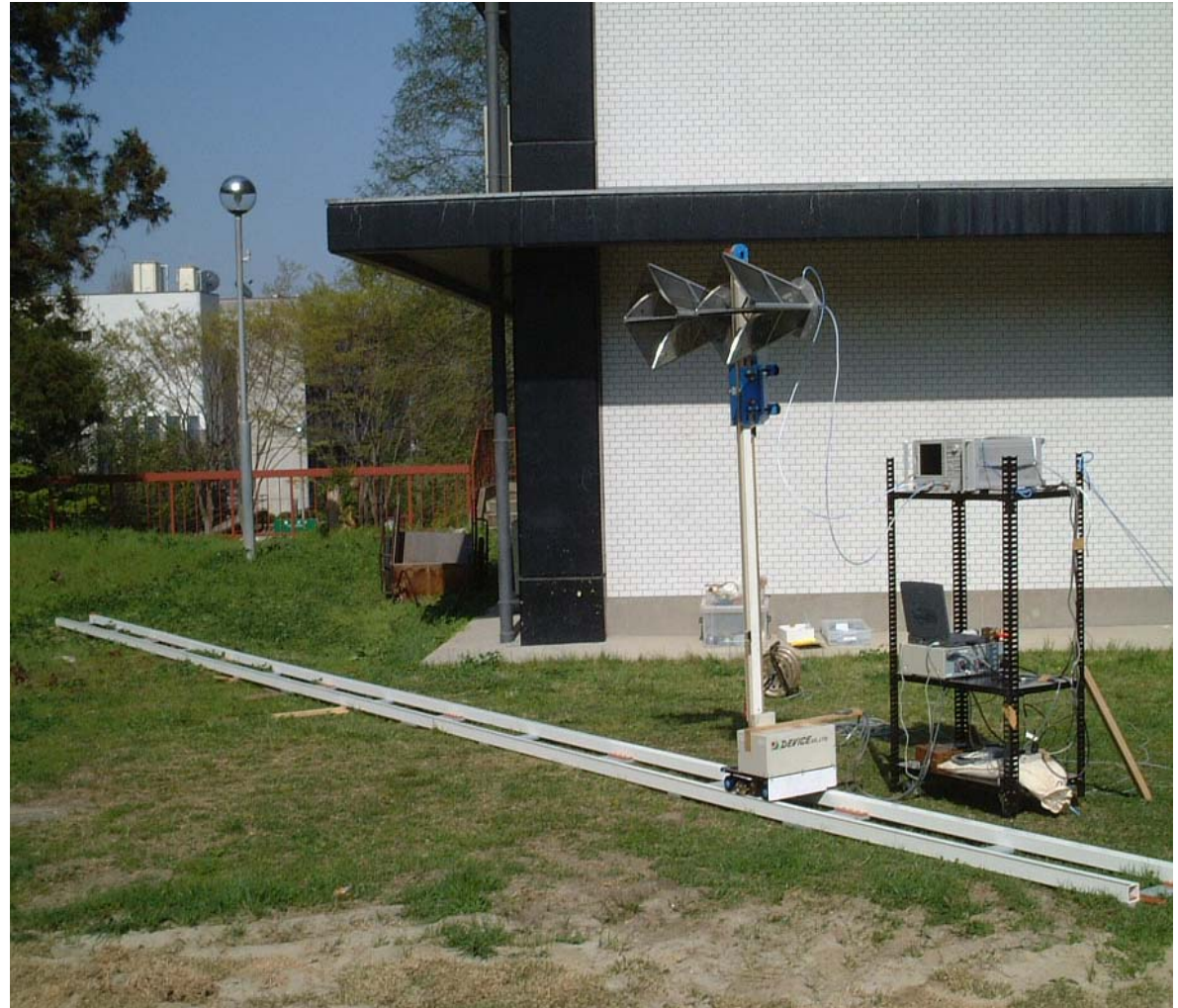


Polarization Orientation Angle

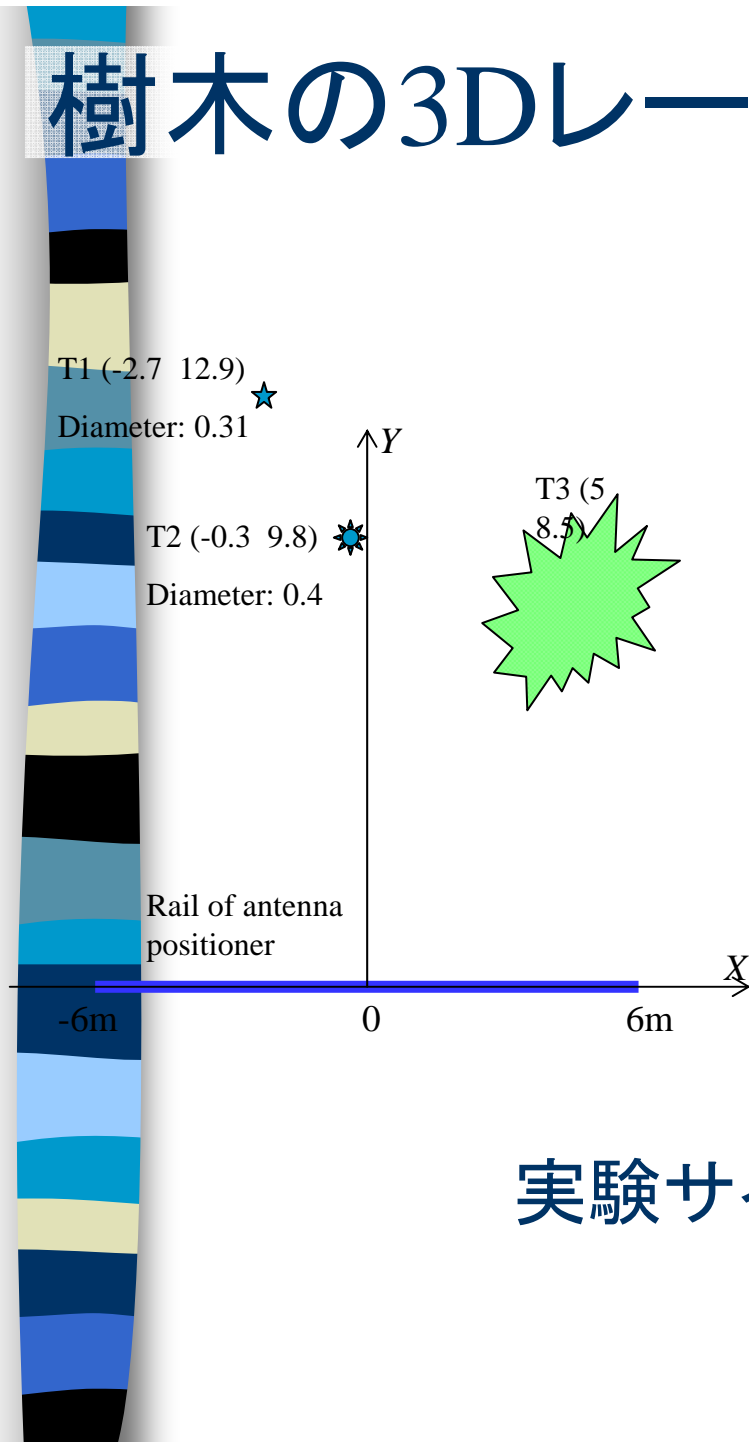
Pi-SAR+ALOS



地上設置型SAR(GB-SAR)



樹木の3Dレーダ測定

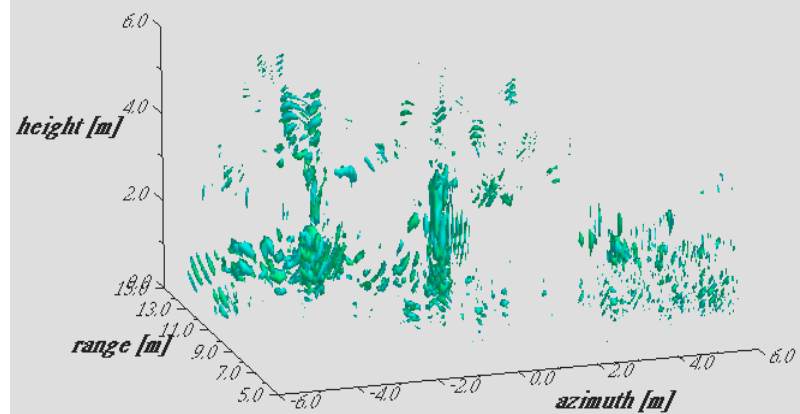


実験サイト（東北大学川内北キャンパス）

春

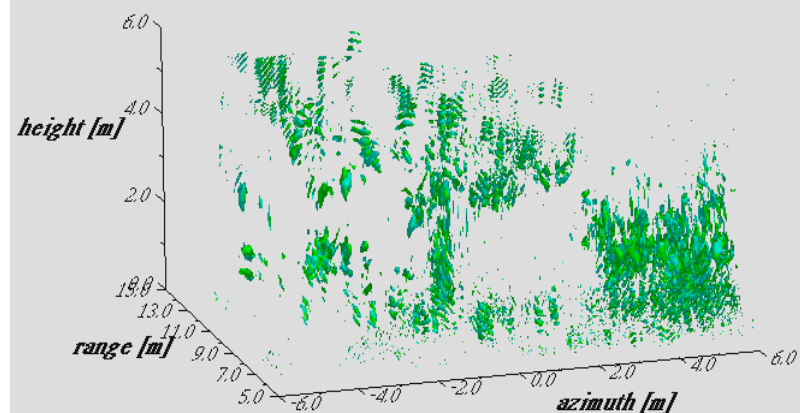
HH of exp#1

on April 19, 2002



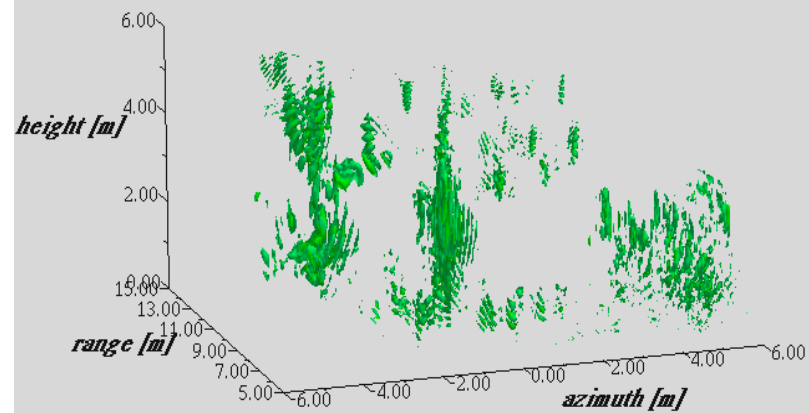
VH of exp#1

on April 19, 2002



VV of exp#1

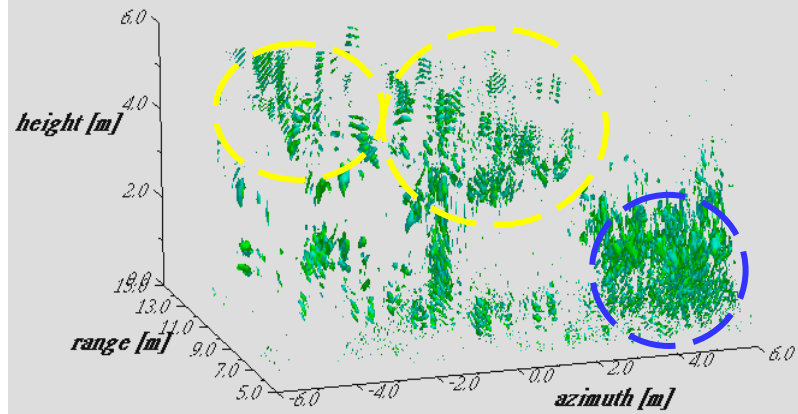
on April 19, 2002



VH of exp#1

on April 19, 2002

春

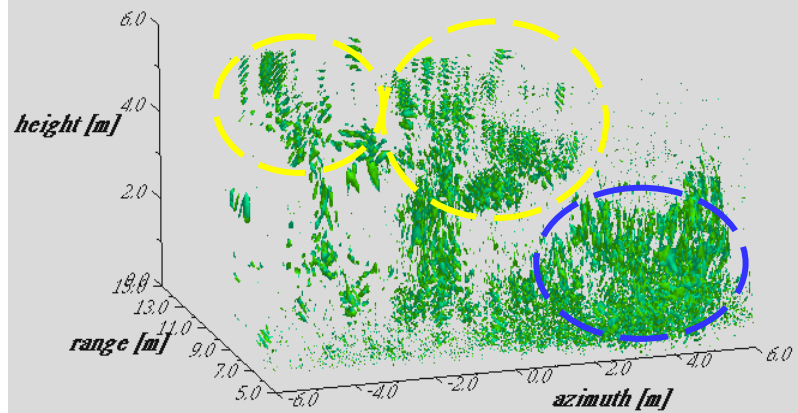


季節変化(HV)

VH of exp#2

on May 28, 2002

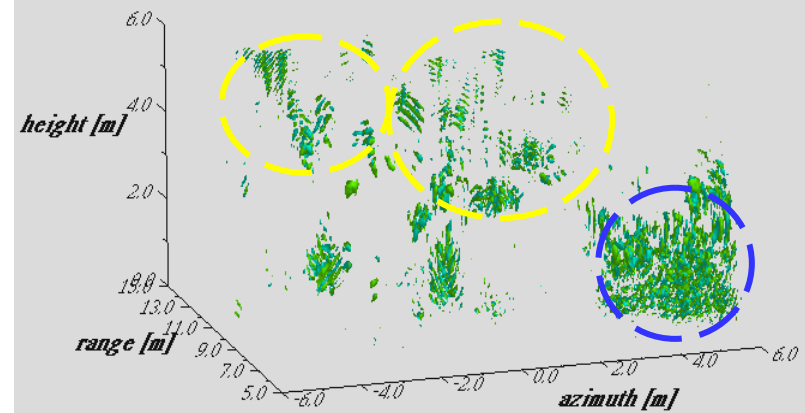
夏



VH of exp#3

on Nov. 11, 2002

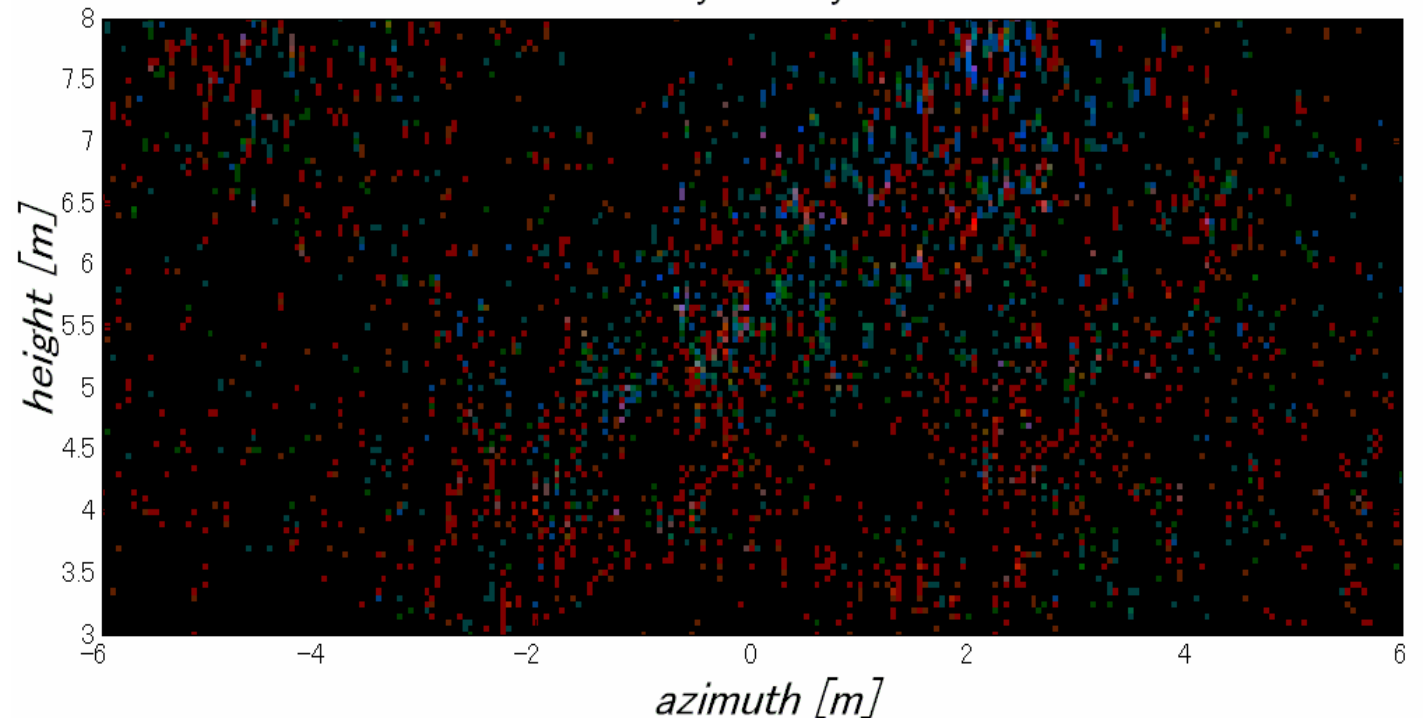
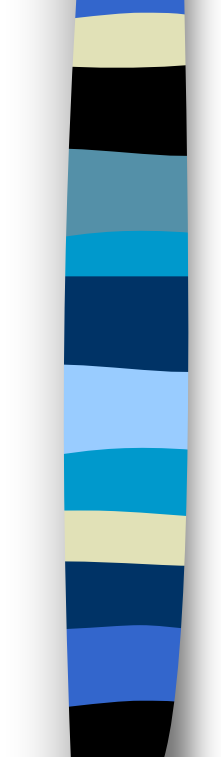
秋





桜 1.5 GHz

Color Overlay of Cherry at 1.5 GHz red: HH green: VH blue: VV





桜4.5 GHz

Color Overlay of Cherry at 4.5 GHz red: HH green: VH blue: VV

