1st Advanced Training Text Book

Remote Sensing Technology Center of Japan

2010.June

Narrative Summary of the Project

Overall Goal

Law enforcement is enhanced ground on technical information based on satellite images on illegal deforestation

Project Purpose

Technical information based on ALOS/PALSAR images on illegal deforestation in the Brazilian Amazon is provided for law enforcement.

Outputs

1. Deforestation areas including suspicious areas are detected using ALOS/PALSAR data.
2. The information flow of satellite monitoring system throughout DPF and IBAMA is improved.
3. Human resources in DPF and IBAMA are up skilled to detect and characterize illegal deforestation

Basic Plans of project execution

To realize the project goal, following 3 basic policy is essential to successfully complete the project;

(1) Ensure technology transfer on deforestation detection by means of ALOS/PALSAR
(2) Materialize Data and Information System in DPF and IBAMA.
(3) Capacity building focused on the human resources development for the system operation, maintain and enhance.

These basic plans are well match with the PDM output description.

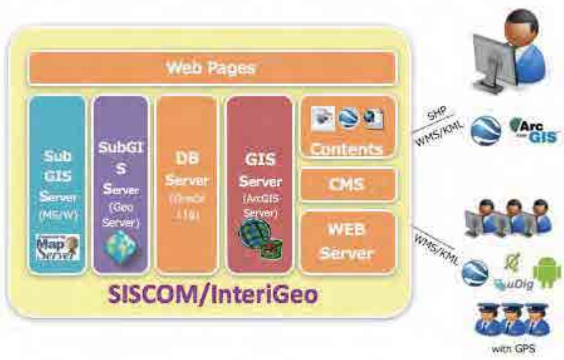
Annual Project Execution Scenario

1st Year:
Fact finding and propose solution idea and initial execution of the solution process. Implementation of system, trial operation of the system, and carry out training program.

2nd Year:
Find obstacles through initial operation and resolve by applying counter actions. Start initial operation by CP staff, skill up system operation through On the Job Training (OJT). Hazard resolution into element to dissolve them. Human skill upgrade by training and education program.

3rd Year
Watch and support independent operation of the system by CP. Skill up human resources through education program. Support the extension of training program by CP. Support future scope planning by CP.

Goal System Concept



Activity for Output 1

Illegal Deforestation Monitoring

Goal 1:

Deforestation areas including suspicious areas are detected using ALOS/PALSAR data

Activities for Output 2

System Enhancement

Goal 2:

The information flow of satellite monitoring system throughout DPF and

Activities for Output 3

Skill Up

Goal 3:
Human resources in DPF and IBAMA are up skilled to detect and characterize

Annual Activity Scenario

1st Year: Fact finding on the existing system both in DPF and IBAMA to clarify system configuration and data flow. Find operational problems for importing PALSAR data into the system and draw a solution idea and system configuration. Draft modification scope of the system, schedule and expected results of the modification. Modify the system under the permission and co work by DPF and IBAMA. Test run under the modified system. Conduct Web interface design and develop out side of the system.

2nd Year: Initial trial operation of the system for shaking down bugs and find necessary improvement. Draft improvement reflecting user's comment. Apply modification. Implement Web interface to the system.

3rd Year: Adjust Web interface and monitor operation to confirm link between DPF and IBAM works well. Support drafting plan for future upgrade to enhance or extend the system to be conducted by DPF and IBAMA.

Outline of Project Work Flow

	1st Year	2nd Year	3rd Year
Planning	Inception Report	Action plan of the year	Action plan of the year
Technology on Deforestation Detection	Establishment of data flow in SISCOM and enhanced component. Development of deforestation detection tool. Draft manual for image interpretation.	Update deforestation detection tool. Revise image interpretation Manual. Update software tools.	Update deforestation detection tool. Final issue of Image Interpretation Manual. Support on Training conducted by CP. Support future action planning
System Enhancement	Fact finding. Improvement planning and execution. Web Interface development.	Tuning of improved system. Installation of Web GIS interface.	Tuning of Web GIS interface. Support follow on upgrade planning by CP.
Skill up	Requirements survey. Conduct 1st basic training. Evaluate training. 1st training in Japan.	Conduct 2nd Basic Training. Conduct 1st Advanced Training. 2nd Training in Japan. Evaluate training.	Support Training program conducted by CP. Conduct 2nd Advanced Training. 3rd training in Japan.

Advanced GIS Course for Amazon Forest

Period/ Date	05/24	05/25	05/26	05/27	05/28	05/31	06/01	06/02
8:30-10:00	Opening ceremony	SQL	PostGIS	Google APIs	Palsar Over View, Principle Palsar Interferometry	Interferogram Generation	Simulation of SAR image for differential Interferometry	Phase Unwrap, alternative method
10:00-10:15	break	break	break	break	break	break	break	break
10:15-11:45	Introduction (10:15-10:30) Outline of GIS	Spatialite/ RDBMS	PostGIS	Google Maps API	Palsar Amplitude Image Handling	Interferogram Generation	Differential Interferometry	Conversion to Ortho DEM Geoid DEM
11:45-13:30	lunch	lunch	lunch	lunch	lunch	lunch	lunch	lunch
13:30-15:00	Data format	Spatialite with QGIS	PostGIS	Google Earth API	Palsar Raw Data Processing	Flat Earth Correction	Interpretation of Differential Interferogram	Phase Unwrap of Differential Interferogram, numerical evaluation
15:00-15:15	break	break	break	break	break	break	break	break
15:15-16:45	WebGIS/ Protocols	Spatialite/ WKTraster	PostGIS	GIS forecast	Palsar Interferometry Pair data access and	Filtering	Phase Unwrap	Closing ceremony

11

Principle of Synthetic Aperture Radar

May, 2006

Tsutomu Yamanokuchi
Remote Sensing Technology Center (RESTEC)

Table of Contents

(1) Introduction

SAR and its strong point(1)

SAR:

Abbreviation of Synthetic Aperture Radar
Sensor itself transmit a microwave on the ground and receive the reflection from ground (backscatter)

Preferable target for SAR observation

- Ice, Ocean waves
- Soil moisture, vegetation mass
- Man-made objects, e.g. buildings
- Geological structures

SAR and its strong point(2)

Strong point of SAR

- ・Can observe under all-weather condition
- ・Can work day-and-night observation
- ・Can observe polarimetric observation
- ・Have the Coherency information

Weak point of SAR

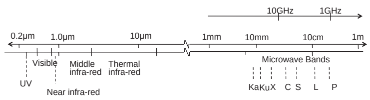
- ・Difficulty of image interpretation
  (Characteristics of microwave image)
- ・Geometric Distortion due to observation system
  (Foreshortening, Layover, Radarshadow)

Important parameters for SAR system

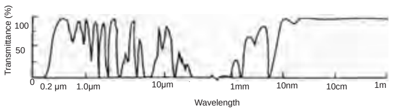
- Incidence angle
- Wavelength
- Polarization
- Spatial Resolution
- Repeat cycle

What's microwave?

Wavelength region of microwave



The electromagnetic spectrum (after NASA/JPL, 1988)

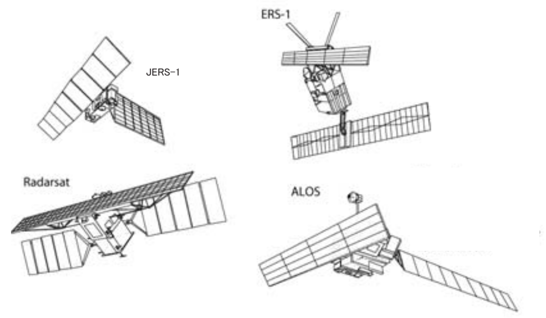


Characteristic of atmospheric spectral transmittance (after NASA/JPL, 1988)

Frequency & wavelengths for microwave bands

Band	Wavelength range[mm]	Frequency range[GHz]
Ka	7.5 - 11.0	40.0 - 26.5
K	11.0 - 16.7	26.5 - 18.0
Ku	16.7 - 24.0	18.0 - 12.5
X	24.0 - 37.5	12.5 - 8.0
C	37.5 - 75.0	8.0 - 4.0
S	75.0 - 150	4.0 - 2.0
L	150 - 300	2.0 - 1.0
P	300 - 1000	1.0 - 0.3

SAR Satellites



Optical and Microwave sensor

LANDSAT TM (23 Apr. 1992)

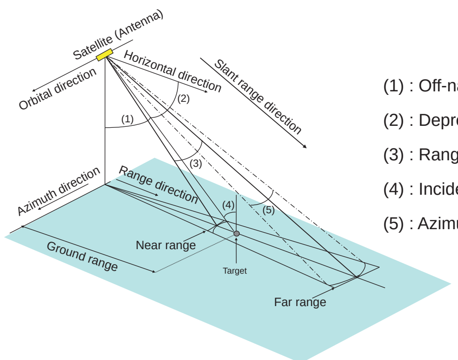
JERS-1 SAR (23 Apr. 1992)

SAR satellites

Characteristics and parameters of SAR on board satellites

	ERS-1	JERS-1	RADARSAT	ENVISAT	ALOS
Lounch	Apr. 1991	Feb. 1992	Nov. 1995	Mar. 2002	Jan. 2006
Orbital altitude	785km	568km	793 - 821km	799.8km	691.65km
Orbital inclination	98.5 deg.	97.7 deg.	98.6 deg.	98.55 deg.	98.16 deg.
Frequency	5.3GHz (C-band)	1.275GHz (L-band)	5.3GHz (C-band)	5.331GHz(C-band)	1.270GHz(L-band)
Wavelength	5.7cm	23.5cm	5.7cm	5.6cm	23.6cm
Polarization	VV	HH	HH	HH, VV, HH+VV, VV+VH, HH+HV	HH, VV, HH+HV, VV+VH, HH+VV+HV+VH
Off-nadir angle	20 deg.	35 deg.	9 - 48 deg.	13.5 - 39 deg.	10 - 51 deg.
Incidence angle	23 deg.	38.7 deg.	10 - 60 deg.	15 - 45.2 deg.	8 - 60 deg.
Swath width	100km	75km	50 - 500km	56.5 - 104.8km	20 - 350km
Azimuth resolution	30m	18m (3look)	9 - 147m	30 - 1000m	10 - 100m (2look)
Ragne resolution	30m	18m	6～147m		7 - 100m (multi-look)
Peak power	4.8kW	325W (designed as 1.3kW)	5kW	1.4kW (average)	2.3kW
Bandwidth	19MHz	15MHz	11.6/17.3/30.0	8.48-16MHz	14MHz/28MHz
Antenna size	1 x 10m	2.2 x 12m	1.5 x 15m	1.3 x 10m	3.1 x 8.9m

Observation geometry of SAR



(1) : Off-nadir angle

(2) : Depression angle

(3) : Range beam width

(4) : Incidence angle

(5) : Azimuth beam width

SAR Image Processing

Processing level

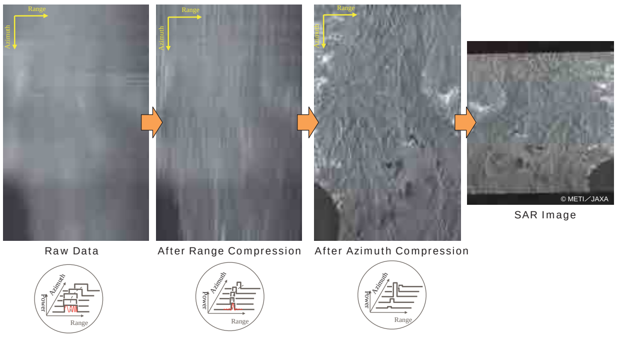
1 RAW data : Raw signal data. Before the image reconstruction of SAR image

2 SLC data : SLC means Single Look Complex. This data has phase and amplitude information in complex style

3 Image data :Each pixels are consist of real value (usually 2byte short integer). No phase information

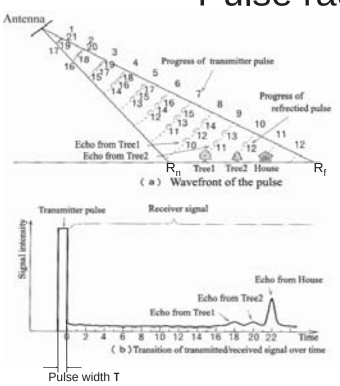
To create from data1 to 2 or 3, It is necessary to process range compression and azimuth compression

SAR image processing



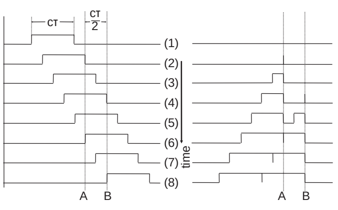
Raw Data — After Range Compression — After Azimuth Compression — SAR Image

Pulse radar



SAR illuminate the microwave to the ground and observes the "backscatter" from the ground.

Range Resolution (1) Range resolution without range compression



When the distance between two objects is less than cτ/2, these objects can not be distinguished in the image.

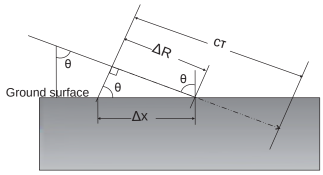
i.e. JERS-1/SAR:

The pulse width is 35 μm, therefore the range resolution Δx is as below.

$\Delta x = c\tau/2 = 3.0\times10^8 \times 35\times10^{-6}/2 = 5250\text{m}$ (in slant range)

The more narrow the pulse width is, the more higher the resolution is.

Range Resolution (2) Slant range resolution and ground range resolution



The relationship between the ground range Δx and the slant range ΔR is expressed as below with the incident angle θ .

$\Delta x = \Delta R/\sin\theta = \frac{c\tau}{2\sin\theta}$

Hence, the ground resolution Δx is lower than the slant range resolution ΔR .

Hence, the resolution is higher at the far range side than that at near range side.

i.e. JERS-1:

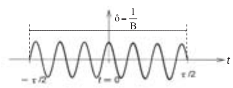
$\Delta x = c\tau/2\sin\theta = 3.0\times10^8\times35\times10^{-6}/(2.0\times\sin35^\circ) = 9153\text{m}$

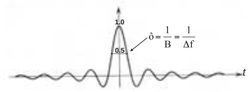
Range Resolution (3) Characteristics of pulse and resolution

S/N in SAR image : Depends on the transmission power.
Transmission power = (Pulse width) x (Injection power)
Resolution of SAR image : Depends on the band width. High resolution needs sharp pulse width, but shallow pulse width leads to the deterioration of S/N.

It is difficult to realize the pulse signal which has both sharp pulse width and high transmission power.

Increase the band width without the modulation of pulse width. ⇨ Theory of chirp compression





In the case of sine wave and rectangular wave,

Band width : $B = \frac{1}{\tau}$

Resolution (along slant range) : $\Delta R = \frac{c\tau}{2} = \frac{c}{2B}$

In the case of chirp-compressed wave,

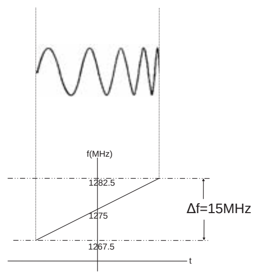
Band width : $B = \frac{1}{\tau} = \Delta f$ (After detection)

Resolution (along slant range) : $\Delta R = \frac{c\tau}{2} = \frac{c}{2B} = \frac{c}{2\Delta f}$ (After detection)

Range resolution(4) ～Chirp Modulation～

Chirp modulation:
Changing a frequency of wave in proportion to changes in time

frequency $f = f_0 + \alpha t$ (α:constant)
Output waveform $g_S(t) = \exp[2\pi i(f_0 + \alpha t)t]$



In the case of JERS-1:

f_0 =1275MHz
Δf= 15MHz
1267.5 ≦ f ≦ 1282.5

Bandwidth after phase detection:

B=Δf

In the case of JERS-1, pulse width and spatial resolution after chirp compression is following;

Pulse width $\tau_{mc} = 1/\Delta f = 6.67\times10^{-8}$(s)

Spatial resolution on slant range:
$\Delta R = C\tau_{mc}/2.0 = 10\text{m}$

Spatial resolution on ground range:
$\Delta X = \Delta R/\sin 35^\circ ≒ 17.4\text{m}$

Azimuth resolution(1) ~Azimuth resolution without azimuth compression~

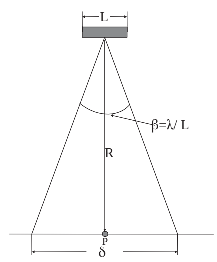
・Set spatial resolution of azimuth direction as δ and slant range length R, spatial resolution of azimuth direction is estimated following equation:

Half bandwidth $\beta = \lambda / L$ (rad)
(L:azimuth antenna width)

$\delta = \beta R = \lambda R / L$

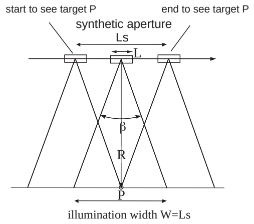
In the case of JERS-1;
λ=23cm、R=700km、L=12m,

$\delta = 0.23\times7\times10^5/12.0 = 13400\text{m}$



Spatial resolution in azimuth direction =13km→almost no use!!!(Low resolution)

Azimuth resolution(2)～Spatial resolution of azimuth direction (Aperture Synthesis)～

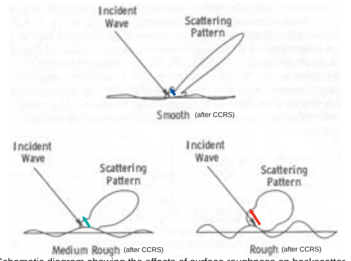


antenna beam width of real aperture
$\beta=\lambda/L$
illumination width of real aperture
$W=\beta R=R\lambda/L$
length of synthetic aperture
$L_s=W$
antenna beam width of synthetic aperture
$\beta_S=\lambda/(2L_s)$
count phase difference two times to and from satellite
spatial resolution in azimuth direction is;
$\varrho_a=\beta_S R=R\lambda/2L_s=R\lambda/(2R\lambda/L)=L/2$

∴Maximum spatial resolution in azimuth direction is limited to L/2

*Maximum spatial resolution do not depend on wavelength or distance to target

Backscatter from the Earth Surface (1)
Surface scatter (Reflection) mechanism



Schematic diagram showing the effects of surface roughness on backscatter

Rayleigh criterion

Smooth: $h > \lambda/8\cos\theta$
Rough : $h < \lambda/8\cos\theta$

h : the mean height of surface variations
λ: the radar wavelength
θ: the incidence angle

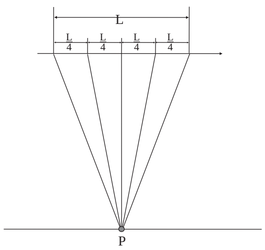
Look processing
(For reducing the effect of speckle noise)

Multi-Look processing:
Virtually separate the synthesized antenna and average the image which made by each small separated antenna
Its purpose is to reduce the effect of speckle noise.

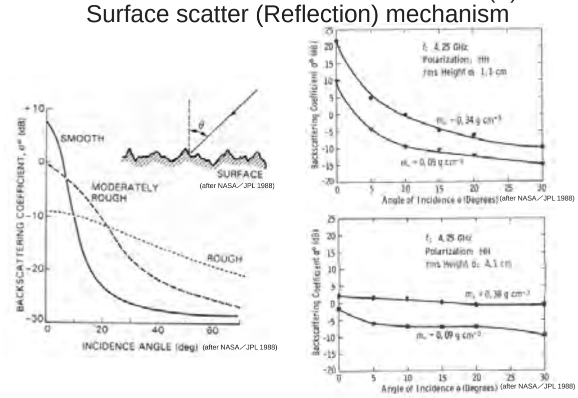
Note spatial resolution of full synthesized antenna is ϱ_A, after multi look processing is ϱ_{Am}

$\varrho_{Am}=\varrho_A \cdot L/(L/4)$
$=4\varrho_A$

spatial resolution is inversely proportional to look number



Backscatter from the Earth Surface (2)
Surface scatter (Reflection) mechanism



Comparison of the backscatter for wet and dry soil for a smooth surface (top) and a rough surface (bottom)

Spatial resolution of SAR image (Summary)

・Spatial resolution on ground range is getting higher to go to far range side.

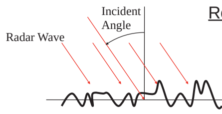
・Range compression, Azimuth compression→execute for the improvement of the spatial resolution

・The narrower the illuminating pulse width, the higher spatial resolution of image

・Maximum azimuth resolution is decided by the real antenna size and it is a half of real antenna width.

・Azimuth resolution is finally decided by the number of look number

Radar Frequency and Surface Scattering Parameter



Roughness=mean height of surface variations

Rayleigh's Criterion：h≦λ/(8cos(θ))

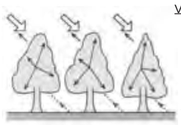
Frequency Band	P	L	S	C	X	K	Q	V	W
Frequancy(GHz)	0.3- 0.39	0.39- 1.55	1.55- 3.9	3.9- 5.75	5.75- 10.9	10.9- 36	36- 46	46- 56	56- 100
Wavelength(cm)	100- 77	77- 19	19- 7.7	7.7- 5.2	5.2- 2.8	2.8- 0.83	0.83- 0.65	0.65- 0.54	0.54- 0.1
Limit of Smoothness(cm)									
Incident Angle									
0 degree	11.063	6.000	1.669	0.806	0.500	0.227	0.093	0.074	0.040
10 degree	10.894	5.909	1.643	0.794	0.492	0.223	0.091	0.073	0.039
20 degree	10.395	5.638	1.568	0.758	0.470	0.213	0.087	0.070	0.038
30 degree	9.580	5.196	1.445	0.698	0.433	0.196	0.080	0.064	0.035
40 degree	8.474	4.596	1.278	0.618	0.383	0.174	0.071	0.057	0.031
50 degree	7.111	3.857	1.073	0.518	0.321	0.146	0.059	0.048	0.026
60 degree	5.531	3.000	0.834	0.403	0.250	0.113	0.046	0.037	0.020

Characteristics of SAR image

Scattering of microwave
-- Surface scattering and volume scattering --

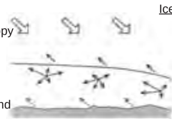
Pattern diagrams of volume scattering

Vegetation



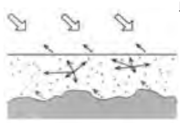
Surface scattering from canopy
Volume scattering from leaves, branches, and so on.
Surface scattering from ground

Ice in glacier



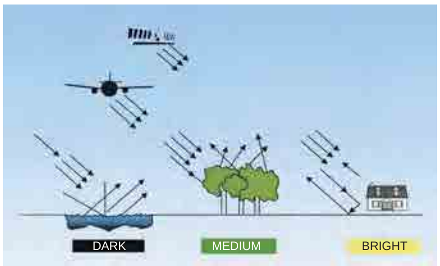
Surface scattering
Volume scattering from particles which have different permittivity
Scattering from discontinuous plane

Dried alluvium



Surface scattering
Volume scattering from particles which have different permittivity
Scattering from discontinuous plane

Image Tone



(after CCRS)

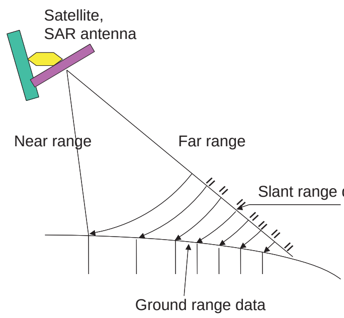
smooth surface:
Specular reflection
(DARK Tone)

Volume scattering:
(MEDIUM Tone)

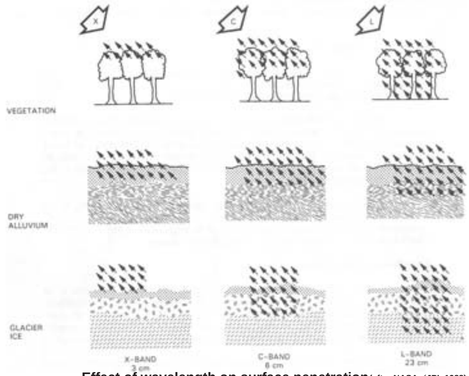
Man-made buildings:
Dihedral reflection
(BRIGHT)

Distortion of SAR image

Slant range and Ground range

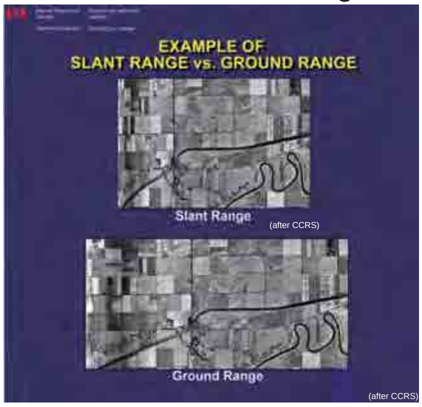


Backscatter from the Earth Surface (3)
dependency of microwave wavelength



Effect of wavelength on surface penetration(after NASA/JPL 1988)

Distortion of SAR image



(after CCRS)

(after CCRS)

Choice of Radar Frequency

Application Factor

Radar wavelength should be matched to the size of the surface features that we wish to discriminate

- -e.g. Ice discrimination, small features, use X-band
- -e.g. Geology mapping, large features, use L-band
- -e.g. Foliage penetration, better at low frequencies, use P-band

System Factor

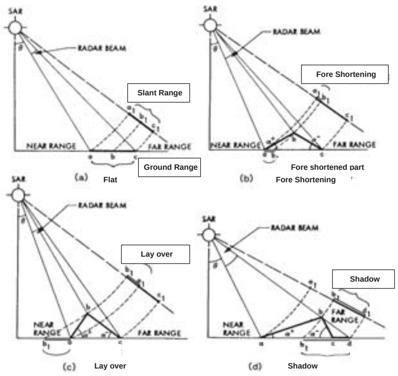
-Low frequencies

- More difficult processing
- Need larger antennas and feeds
- Simpler electronics

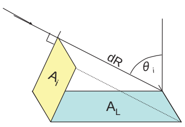
-High frequencies

- Need more power
- More difficult electronics

Geometric Distortion of SAR image



Conversion to Sigma nought (σ^0)



Backscatter coefficient(sigma nought、σ^0):
The average reflectivity of a horizontal material sample, normalized with respect to a unit area A_L on the horizontal ground plane

Validation of backscatter coefficient:
Set corner reflector which backscatter coefficient is already known and measure SAR observed intensity on the image. Then, execute the validation of SAR image.

Conversion equation to sigma nought:

In the case of JERS-1, following equation is represented by JAXA,

$$\sigma^0 = 20\log_{10}(I) + CF \text{ (dB)}$$

In the above formula, I mean the SAR image intensity and CF is a constant value and the value CF is decided by SAR operating agency.

Data products

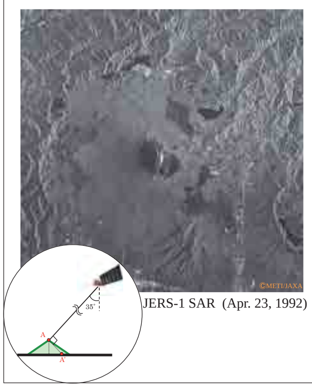
Georeferenced products:

- Relative geographic location is incorporated in the image
- not corrected to a map projection and should not be used for mapping purposes

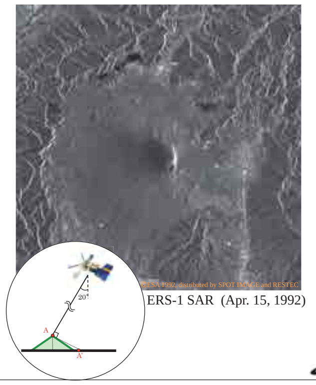
Geocoded products:

- Geometrically corrected to conform to a map projection
- Often use ground control points and DEM to increase the geocoding accuracy
- Geocoded products are usually resampled to a standard square pixel size

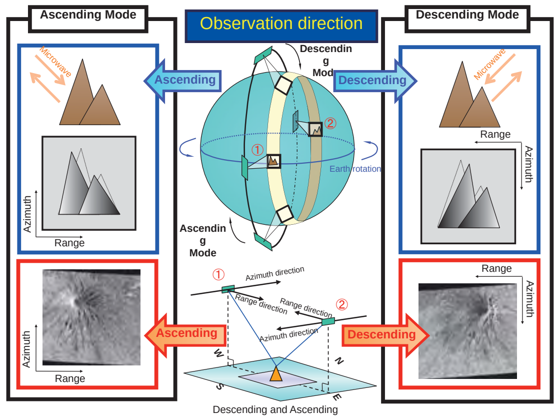
Geometric distortion of SAR image



JERS-1 SAR (Apr. 23, 1992)

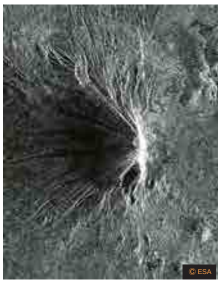

ERS-1 SAR (Apr. 15, 1992)

Effect of Look Direction



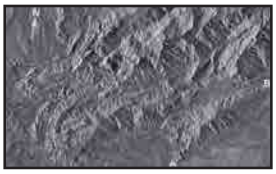
Geometric Distortion

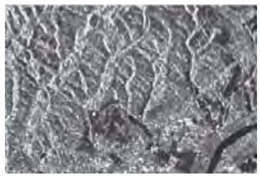
JERS-1 SAR (Incidence angle 38º)



ERS-1 SAR (Incidence angle 23º)

Effect of Look Direction


RADARST F2 Ascending


RADARST F4 Ascending

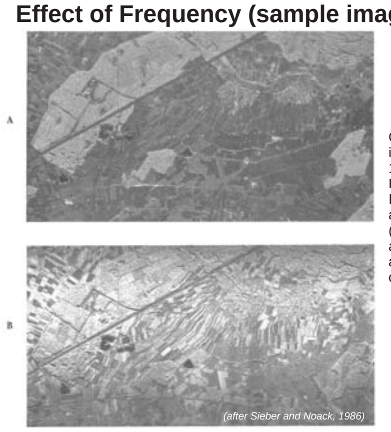

RADARST F2 Descending


RADARST F4 Descending

©CSA／MDA

Bibai, Hokkaido Pref.

Effect of Frequency (sample image)



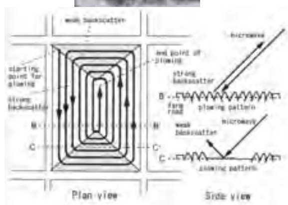
CV-580 airborne SAR image acquired July 12, 1984 over Freiburg, Germany. Image (A) was acquired in L-band (23 cm wavelength) and image (B) was acquired in X-band (3 cm wavelength).

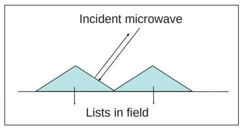
Typical image pattern can be seen in SAR image (1)

Bow tie effect

This Phenomenon is found primarily in large fields which are cultivated by machine. Main causes of this phenomenon are considered as below.

* Specular reflection (refer figure below)
* Bragg scattering (refer next section)





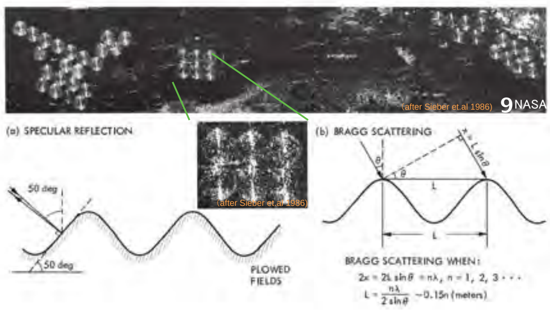
Pattern view of specular reflection

Effect of Frequency (sample image)

ERS-1 AMI Image
Wavelength：C band(5.6cm)

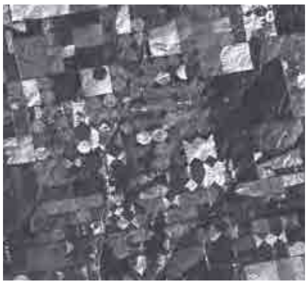
JERS-1 SAR Image
Wavelength：L band(23cm)

Typical image pattern can be seen in SAR image (2)



SIR-A image around center-pivot-type irrigated agricultural area

The effect of azimuth angle of incident microwave on ploughed fields

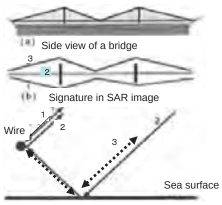


The effect of look direction on ploughed fields.
© CSA 1996 *(CCRS).*

SAR specific analysis method

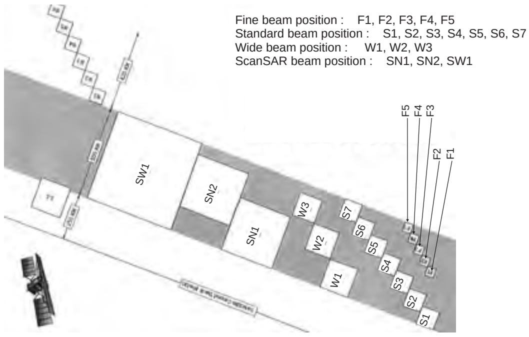
Typical image pattern can be seen in SAR image (3)

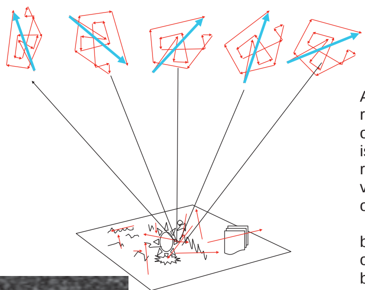
Multiple Scattering

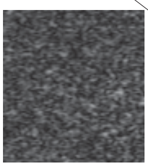


Stereo SAR Observation -Radarsat observation mode-

Fine beam position : F1, F2, F3, F4, F5
Standard beam position : S1, S2, S3, S4, S5, S6, S7
Wide beam position : W1, W2, W3
ScanSAR beam position : SN1, SN2, SW1





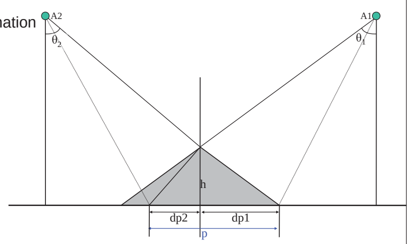


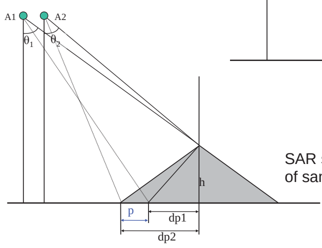
Speckle Noise

A unit cell (pixel) contains many reflecting objects. Even if each object in the cell reflects radar wave isotropically, over all summation of reflected electro-magnetic wave varies depending on the observation direction variation.
Phase similarity (coherence) will be preserved statistically if two observation points reside within a beam width of an aperture with the same size of unit cell.
To keep relative phase difference coherent among image pixels in a scene, two orbits of interferometry pair must be close enough to preserve relative phase coherency.

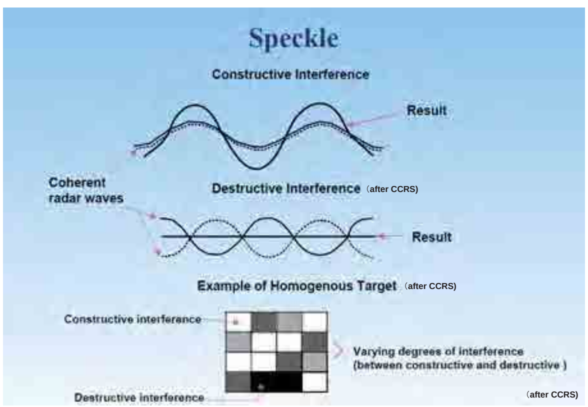
Stereo SAR (1)

SAR stereopair that have the combination of opposite illumination direction





SAR stereopair that have the combination of same illumination direction



Stereo SAR (2)

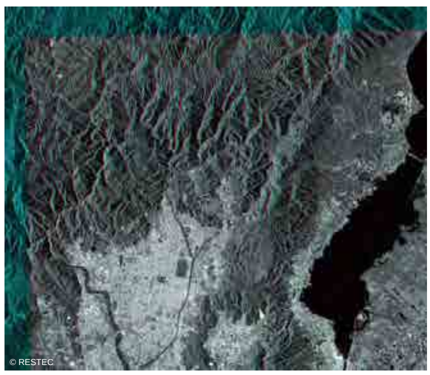
Parallax calculation

$p = |\cot\theta_1 - \cot\theta_2|*h$
same illumination direction)

$p = |\cot\theta_1 + \cot\theta_2|*h$
opposite illumination direction)

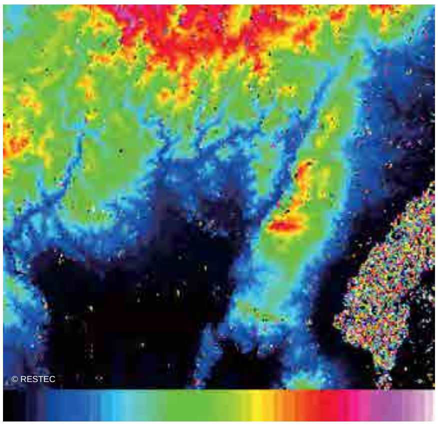
Data used

Sensor	Mode	date	inc.
RADAR SAT	F1	1997.3.17	37.6°
RADAR SAT	F5	1997.3.27	47.5°

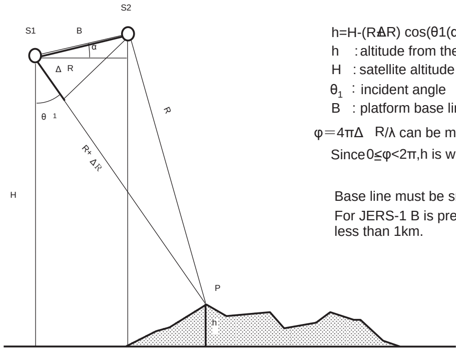


Stereo SAR (3)

DEM generated from SAR stereo



Interferometric SAR



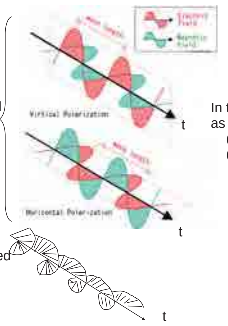
h=H-(R+ΔR) cos(θ1(α,R,ΔR,B))
h : altitude from the reference
H : satellite altitude
θ_1 : incident angle
B : platform base line

φ=4πΔ R/λ can be measured as interferogram.
Since 0≦φ<2π,h is wrapped.

Base line must be small.
For JERS-1 B is preferred to be less than 1km.

Polarimetric SAR

Linearly-polarized wave



Circular-polarized wave

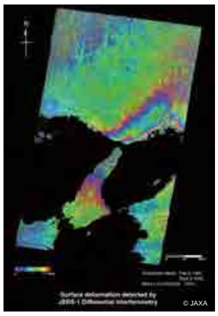
Circular polarized wave : spirally rotated polarization
Linearly polarized wave : Horizontal Polarization
Vertical Polarization

⇩

In the field of Satellite, H and V polarizations are defined as below;
(H)orizontal pol. : Parallel to satellite's orbital direction
(V)ertical pol. : Vertical to satellite's orbital direction

Case of SAR sensor :
JERS-1 : Emit H pol. and receive H pol. (HH)
ERS-1 : Emit V pol. And receive V pol. (VV)

Interferometric SAR



The great Hanshin-awaji earthquake

In the epicenter of this earthquake, earth surface displaced more than 1.2m in both vertical and horizontal direction. The displacement value estimated from this interferogram is agreed with the ground survey results.

Polarimetric SAR Pi-SAR image

X band

RGB=HH-HV-VV

L band

RGB=HH-HV-VV

References

- Canadian Center for Remote Sensing (CCRS) Tutorial Radar Remote Sensing(http://www.ccrs.nrcan.gc.ca)
- Japan Aerospace explore Agency (JAXA) ALOS site (http://www.eorc.jaxa.jp/ALOS/index.htm)
- Principles and Applications of IMAGING RADAR, Manual of Remote Sensing Third Edition,Vol.2
- NASA/JPL, Synthetic Aperture Radar, Technical Report, NASA Earth Observation System, Instrument Panel Report, Vol. IIf, 1988.
- Sieber, A., Noack, W., Results of an Airborne SAR Experiment over a SIR-B Test Site in Germany, ESA Journal, 10 No. 3, 1986.

Polarimetric SAR ～Preferable polarization (C-band)～

Application	Preferred Single Polarization	Preferred Multi-Polarization
Agriculture		
Crop Type		
・Grains (vertical)	VV or HV	HV + VV + HH
・Canola/Peas (horizontal)	HH	HV + VV + HH
Crop Monitoring	HV or VV	HV + VV + HH
Defense		
Maritime Surveillance	HH	HV + HH
・Ship (shallow incidence)	HV	HV + HH
・Ship (steep incidence)	HH	HV + HH
・Wakes	HV or HH	HV + HH
Forestry		
Clear-cut Mapping	HV	HV + HH
Biomass Estimation	HV	HV + VV + HH
Geology		
Structural Mapping	HV	HV + HH
Hydrology		
Flood Mapping	HH	HV + HH
Soil Moisture Estimation	HV	HV + VV + HH
Oceans		
Wave Spectra	HH or VV	HH + VV
Mesoscale Features	HH or VV	HH + VV
Bathymetric Mapping	VV	HH + VV
Sea Ice		
Ice Classification	HV	HV + VV + HH
Ice Edge Mapping	HV	HV + VV + HH

(C)CSA 1996

The Project for utilization of ALOS images to support the protection of the Brazilian Amazon Forest and combat against illegal deforestation.
Basic training course 2009

SAR Image Characteristics

REMOTE SENSING TECHNOLOGY CENTER OF JAPAN
TOKYO, JAPAN

1. Geometric Distortion of SAR

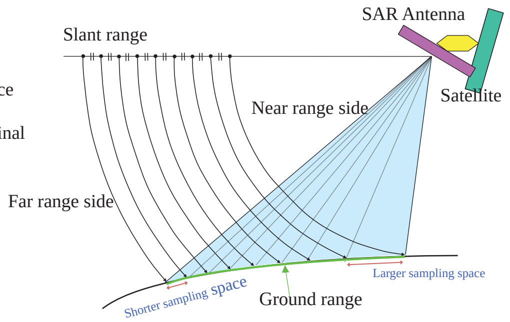
In the SAR image reconstruction process, cross track pixel sampling is originally done using range (from satellite to target distance) information. Usually equal range spaced image (referred as slant range image) is created initially. Due to the side looking geometry, equal range spacing causes unequal ground range spacing. Also, due to the image mapping process, pixel position distortion appears depending on the local land feature measured from a reference plane. This distortion happens both in slant range image and in ground range image.

Contents

1. Geometrical Characteristics of SAR

1.1 Ground range distortion by equal range sampling

・Equal slant range space causes unequal ground range sampling in original image.



・In PALSAR image products, georeferenced and geocoded data is resampled to equal ground sampling space.
•SLC data is usually slant range image to keep original phase information.

1. **Geometrical Characteristics of SAR**

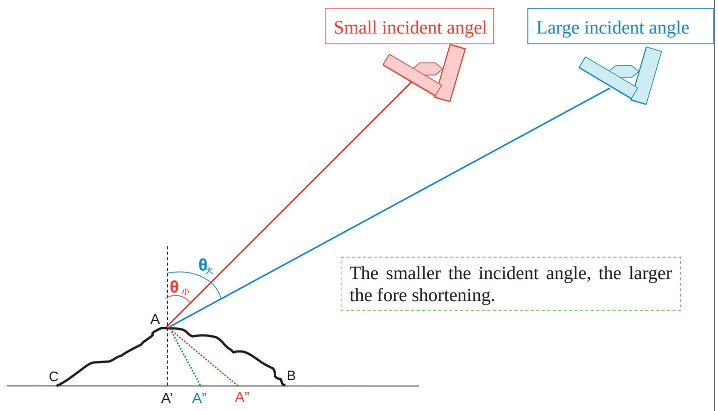
1.1 Difference between Slant range image and Ground range image

Slant range image

Ground range image

1. **Geometrical Characteristics of SAR**

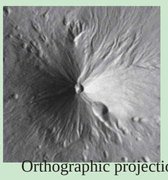
1.2 Fore Shortening



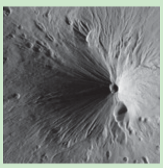
1. **Geometrical Characteristics of SAR**

1.2 Image Distortion due to local land feature and satellite geometry

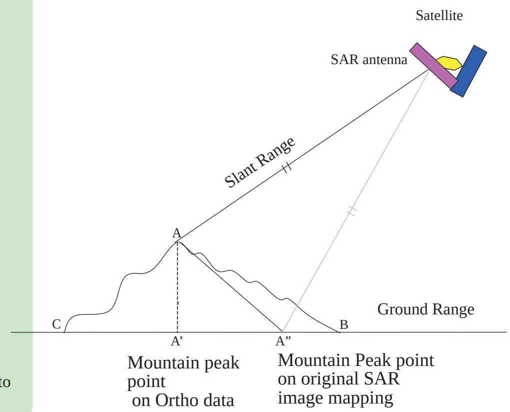
Simulated SAR image



Orthographic projection



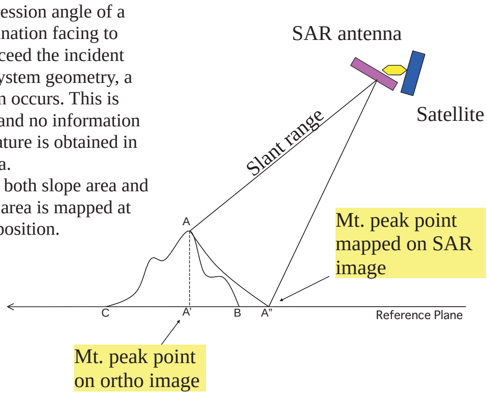
Slant range image (re-sampled to equal ground range space)



1. **Geometrical Characteristics of SAR**

1.3 Lay Over

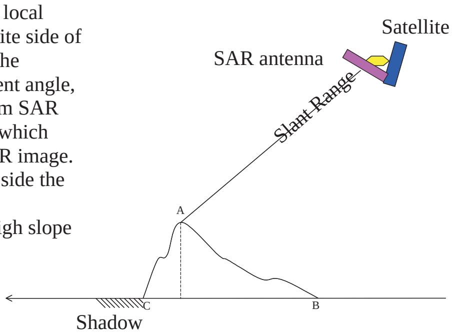
In case the depression angle of a local slope inclination facing to SAR system exceed the incident angle of SAR system geometry, a severe distortion occurs. This is called lay over and no information on the target feature is obtained in the lay over area.
In lay over area both slope area and moderate slope area is mapped at the same pixel position.



1. Geometrical Characteristics of SAR

1.4 Radar Shadow

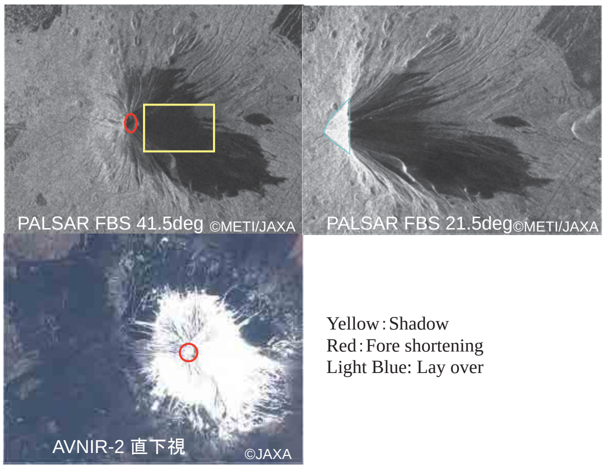
If the inclination of a local slope facing to opposite side of SAR system exceed the complement of incident angle, the slope is hided from SAR system illumination, which causes shadow in SAR image. Shadow continues in side the blanket area of the illumination by the high slope object.



terça-feira, 13 de outubro de 2009

1. Geometrical Characteristics of SAR

Examples



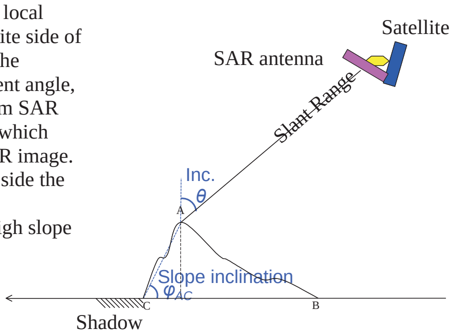
Yellow : Shadow
Red : Fore shortening
Light Blue: Lay over

terça-feira, 13 de outubro de 2009

1. Geometrical Characteristics of SAR

1.4 Radar Shadow

If the inclination of a local slope facing to opposite side of SAR system exceed the complement of incident angle, the slope is hided from SAR system illumination, which causes shadow in SAR image. Shadow continues in side the blanket area of the illumination by the high slope object.



Shadow occures when $\theta + \varphi_{AC} > 90°$.

terça-feira, 13 de outubro de 2009

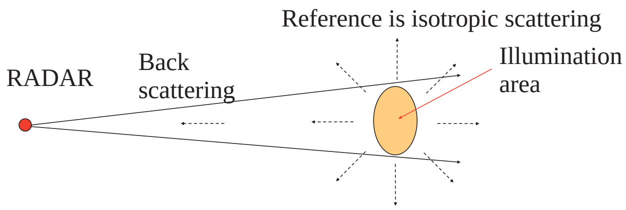
2. Radiometric Characteristics of SAR

2.1 SAR system Element to affect intensity
- a wavelength
- b incident angle
- c polarization
- d illumination orientation
- e speckle noise

2.2 Target Element to affect intensity
- a electromagnetic parameter (dielectric/magnetic constants)
- b surface texture
- c surface pattern
  - Mirror, Dihedral, Trihedral, Bragg scattering

terça-feira, 13 de outubro de 2009

Digital Number of SAR image



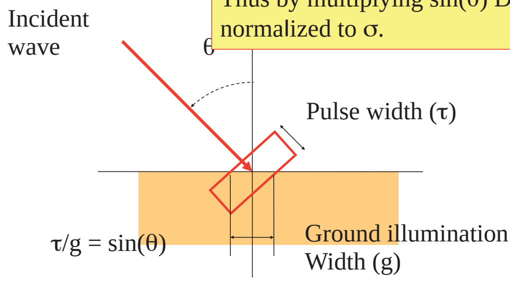
DN is a digitized back scattering signal strength
normalized by Radar illumination strength.

terça-feira, 13 de outubro de 2009

Value of σ in RADAR image

$\sigma = DN \sin(\theta)$

σ is normalized back scattering signal strength per ground sampling unit space which is proportional to 1/sin(θ).
Thus by multiplying sin(θ) DN is normalized to σ.



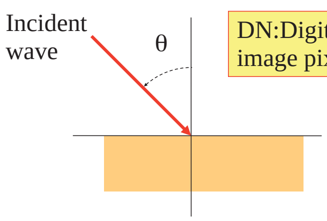
terça-feira, 13 de outubro de 2009

Concept of σ

Radar back scattering cross section(RCS)= return energy within a beam width and range bin. (Wikipedia)

$\sigma = DN \sin(\theta)$ (normalized by pulse illuminated area)
$\gamma = \sigma/\cos(\theta)$ (normalized value to perpendicular incident energy)

DN:Digital Number of an image pixel brightness.

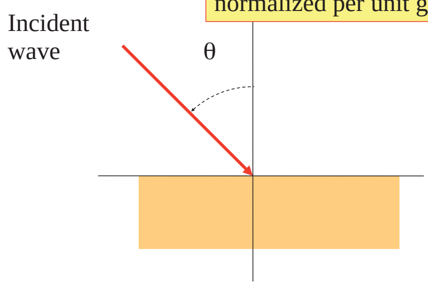


terça-feira, 13 de outubro de 2009

Concept of γ

- $\gamma = \sigma/\cos(\theta)$

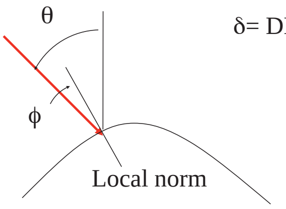
Illumination intensity of radar pulse per unit ground length is proportional to cos(θ).
By dividing σ with cos(θ), σ is normalized per unit ground length.



terça-feira, 13 de outubro de 2009

Slope Correction

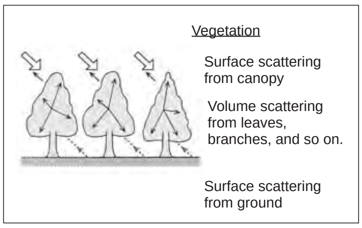
- In the derivation of s, sin(q) is multiplied to DN. In standard processing q is counted as angle or incident wave direction (opposite direction) and normal vector on flat earth surface.
- If incident angle relative to slope of local feature is taken

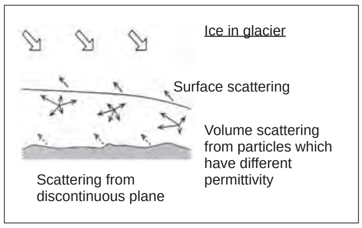


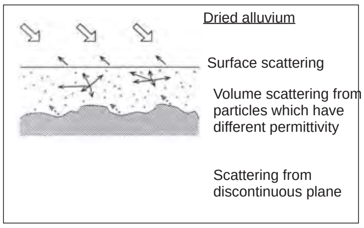
δ= DN* sin(ϕ)

2. **Radiometric Characteristics of SAR**

2.1 Effect of wavelength







2. **Radiometric Characteristics of SAR**

2.1 System parameter effect of wavelength

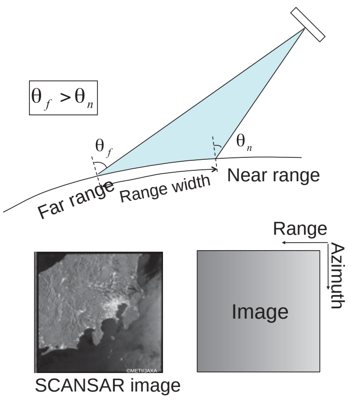
PiSAR X band HH

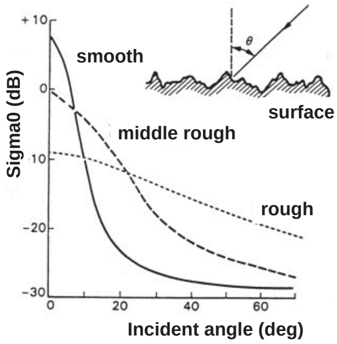
PiSAR L band HH

Saku, Nagano, Japan 2004.8.4

2. **Radiometric Characteristics of SAR**

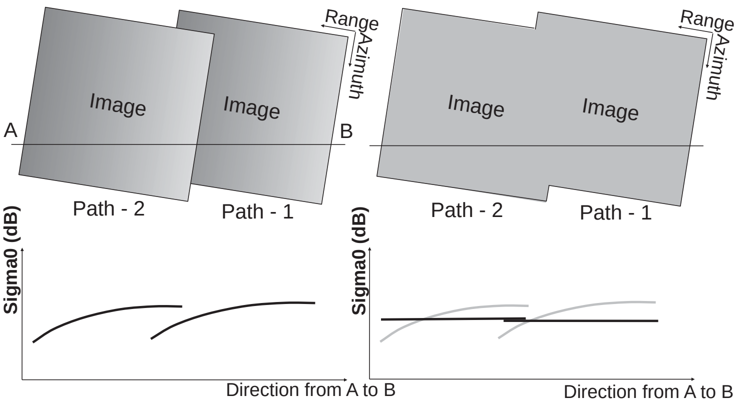
－2.1 Effect of Incident angle





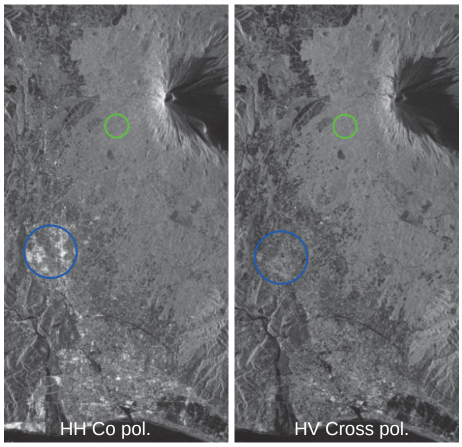
2. **Radiometric Characteristics of SAR**

2.1 Image discontinuity due to the effect of incident angle



2. **Radiometric Characteristics of SAR**

2.1 Effect of polarization



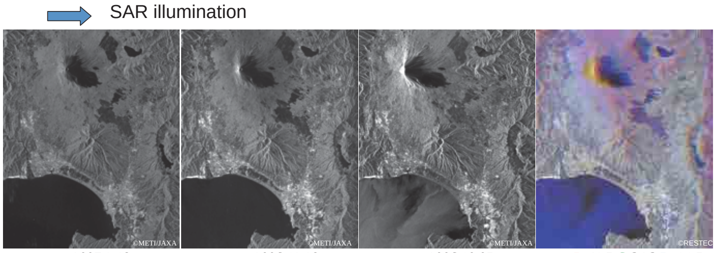
ALOS / PALSAR FBD 2008.7.3 (C)METI/JAXA

Dual polarization reception in PALSAR (copol. And cross pol.) provides additional surface information from the SAR image pair. Urban area usually causes weak reflection in cross pol. While it causes bright reflection(blue circle). On the contrary, forested area the difference between co pol. And cross pol. Is small（green circle）

2. **Radiometric Characteristics of SAR**

2.1 Example of incident angle difference

SAR illumination



2007.2.18 41.5deg	2006.12.29 34.3deg	2006.10.05 21.5deg	R:41.5 G:34.3 B: 21.5

Check ! Difference in fore slope

Difference in local slope effect

Difference of Sea surface

2. **Radiometric Characteristics of SAR**

2.1 Effect of polarization

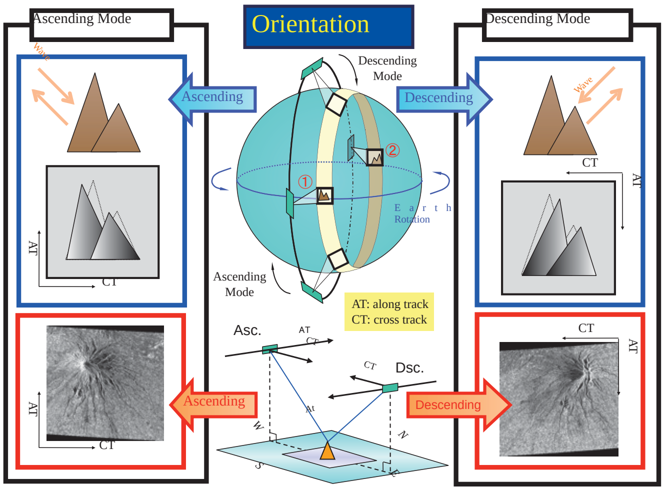
Pi SAR X band

RGB=HH-HV-VV

Airborne PiSAR Xband Image (2004.8.4)
Grow stage indication of vegetable field appears in the color difference of the agriculture fileds.

2. **Radiometric Characteristics of SAR**

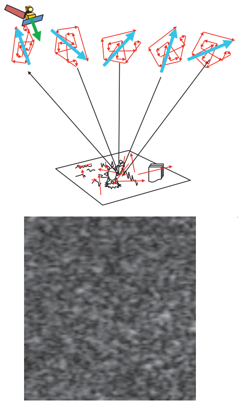
2.1 Effect of illumination orientation (Ascending and Descending)



terça-feira, 13 de outubro de 2009

2. **Radiometric Characteristics of SAR**

2.1 Speckle Noise



A unit cell (pixel) contains many reflecting objects in the cell. Even if each object in the cell reflects radar wave isotropically, over all summation of reflected electro-magnetic wave varies depending on the observation direction due to the variation of relative phase.

Radar reflectance is a measure to evaluate power reflection ratio to incident power.

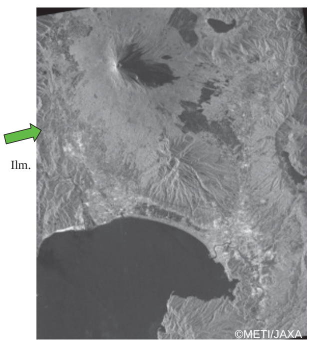
But in the SAR image processing, amplitude summation from individual object with various reflectance is calculated as pixel value. Thus statistic expectation of the vector summation (complex pixel value) is zero (summation of random complex number) while the statistic expectation of the variance is the Radar reflectance.

Difference of the two value appears as speckle noise which is multiplicative nature. Thus the noise looks significant compared with the thermal noise in optical images.

terça-feira, 13 de outubro de 2009

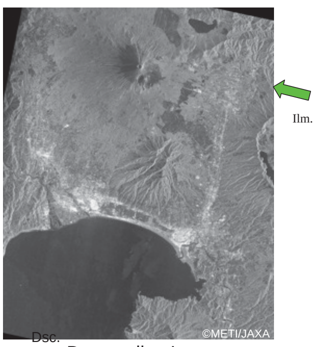
2. **Radiometric Characteristics of SAR**

2.1 Example of Ascending observation and Descending observation



Ascending Image

north



Descending Image

terça-feira, 13 de outubro de 2009

2. **Radiometric Characteristics of SAR**
2.1 Speckle noise reduction

- From the basic SAR process nature, speckle noise reduction can be done in various ways.
- Using a statistic theory, one effective way is to obtain many samples showing a pixel and non coherently averaging the data to evaluate Radar reflectance.
- This is called multi look processing.
- By sacrificing resolution, several independent pixel value can be obtained from an original image, which can be averaged to reduce speckle noise.

terça-feira, 13 de outubro de 2009

Radiometric Characteristics of SAR

2.2 Target depend elements

Following 3 element affect intensity level of SAR image.

(a) Surface roughness
(b) Dielectric constants
(c) Surface pattern and texture

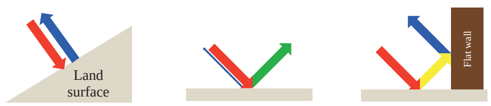
Discrimination of surface roughness and dielectric constants

Use of dual polarization or polarimetry may provide solution.

Shape and pattern/texture：

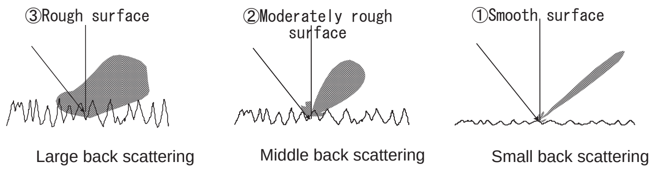
depending on the target shape, location pattern and texture causes various kind scattering as: Bragg, specular, volume, multiple bounce scattering.

Specular reflection　　Single bounce　　Dual bounce



Radiometric Characteristics of SAR

2.2 Surface roughness: Typical sample



Radiometric Characteristics of SAR

2.2 Surface roughness

Rayleigh's condition

$$h \le \frac{\lambda}{(8\cos(\theta))}$$:smooth limit

（h: rms of height variation, λ: wavelength, θ: incident angle）

In the case of ALOS/PALSARやJERS-1, θ=38°、λ=0.23m then;

Smooth limit is $h \leqq 3.65$㎝

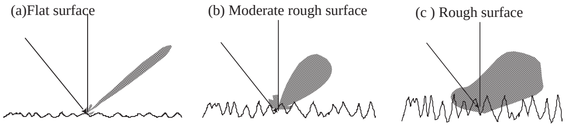


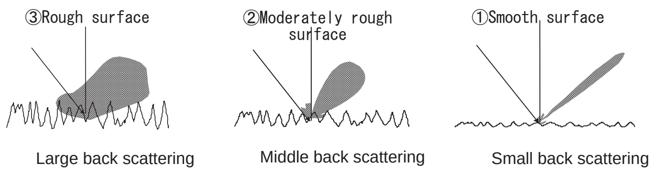
Image of scattering directivity relative to surface condition.

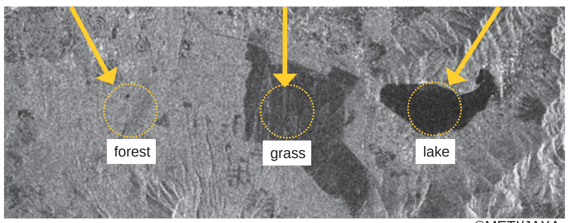
Spatial distribution of surface roughness must also be counted. If the spatial frequency is less than wavelength, rough surface looks like a some smooth dielectric body sheath.

29

Radiometric Characteristics of SAR

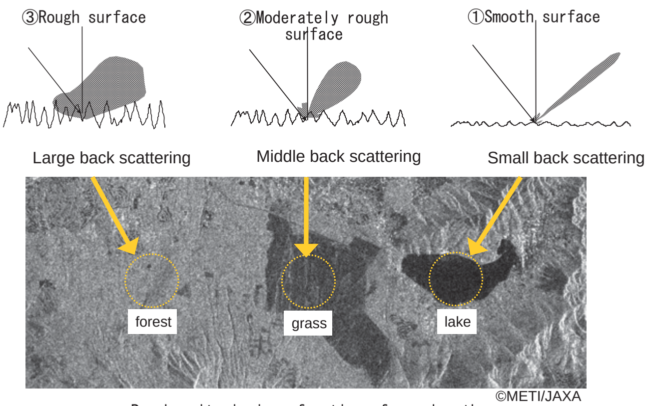
2.2 Surface roughness: Typical sample





Radiometric Characteristics of SAR

2.2 Surface roughness: Typical sample



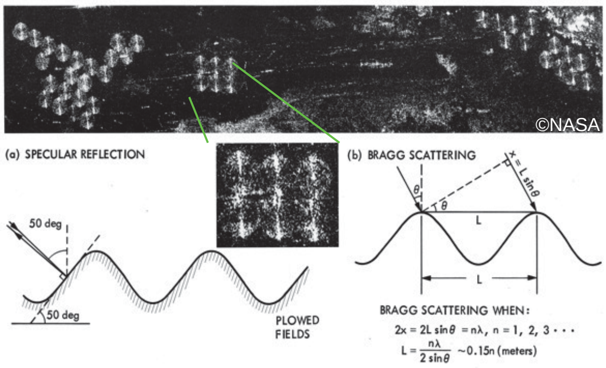
Rough criteria is a function of wavelength

terça-feira, 13 de outubro de 2009

2. Radiometric characteristics of SAR

2.2 Pattern

Specular reflection, Bragg scattering



リビアのセンターピボット式灌漑農業地帯のSIR-A画像

32

terça-feira, 13 de outubro de 2009

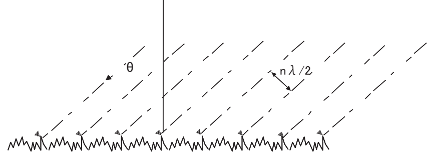
Radiometric Characteristics of SAR

2.2 Surface roughness

・Bragg scattering

repeated pattern of local random surface causes a strong reflection to specific directions.This phenomena are called Bragg scattering and used in various analysis in physics. In the radar remote sensing this is often used to analyze sea surface observations.

In land observation, agriculture field often causes Bragg scattering to show some directive periodic structure effect.



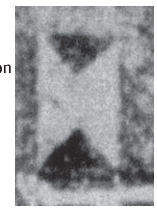
31

terça-feira, 13 de outubro de 2009

2. Radiometric characteristics of SAR

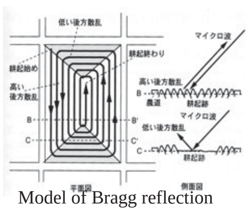
2.2 Pattern and shape

Illumination

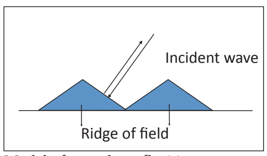


・Bowtie effect

Plowing in a large scale farm caused by,
・specular reflection of ridges in the filed
or
・Bragg reflection by the regular ridge pattern



Model of Bragg reflection



Model of specular reflection

33

terça-feira, 13 de outubro de 2009

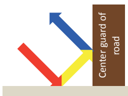
2. Radiometeric characteristics of SAR

2.2 Shape and location

・Cardinal Effect

Strong back scattering in urban area from buildings inside. Reflection from building face to wave incidence causes strongest back scattering.
Dihedral an trihedral reflection and multiple reflection by its combination is the main reason of the reflection.
Parallel structure to wave incidence direction is almost dark in the image.

L band :Purple
X band :Green



34

terça-feira, 13 de outubro de 2009

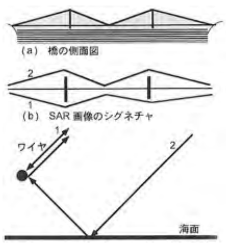
3. Calibration of Reflectance

terça-feira, 13 de outubro de 2009

2. Radiometeric characteristics of SAR

2.2 Shape / location

・Multiple reflection by a bridge and water surface

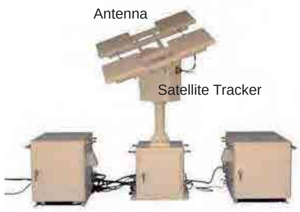


35

terça-feira, 13 de outubro de 2009

3.1 Conversion to back scattering coefficient

•Back scattering coefficient Sigma naught (s^0)): Ratio of return signal power over incident power.
•In a SAR system, theoretical beam width after image processing and its illumination power density distribution is necessary to evaluate the value.
•Calibration using known reflectance object appears in the image is easier than theoretical dedication.
•Passive or active corner reflector is used as reference reflection source.

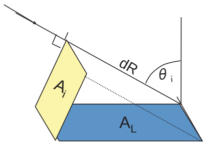


Active Radar Calibrator (ARC)

terça-feira, 13 de outubro de 2009

3.1 Conversion to back scattering coefficient

Calculation of back scattering:
Set a corner reflector with known back scattering coefficient to be appears in the processed SAR image and use the value in the image as reference back scattering.



ALOS/PALSAR (L1.5)

$\sigma^0 = 10\log_{10} < I^2 > + CF$ (dB)

- I: Digital number of a pixel in SAR image
- CF: calibration constant derived from processed corner reflector pixel value in SAR image.
- CF is written in the leader file of PALSAR image products.
- If the signal processing parameter or equation is modified the CF may be changed.

4. SAR data analysis technology

4.1 SAR interferometry

・SAR Interferometry

Using precision return phase preservation nature of SAR signal processing, interferometer is realize from a pair of images.

- Phase detection
  - Interferometry
    - Along Track Interferometry: measurement of sea surface current
    - Cross Track Interferometry
      - Interferometry(InSAR): Digital elevation model
      - Differential Interferometry(DInSAR): Earth surface change detection
  - Coherence Analysis: Extract signature on surface texture or surface change

4. SAR Image Analysis Technology

4.1 Interferometry

4.2 Polarimetry

4.3 StereoSAR

4. SAR data analysis technology

4.1 SAR Interferometry

Geometry of SAR interferometry

Assume δ as slant range difference between observation A1 and A2 and phase difference φ following equations stand as;

Assuming $\kappa = \frac{\pi}{2} - \theta$

$\delta_1 = B\cos(\kappa + \alpha)$

$= B\cos(\frac{\pi}{2} - \theta + \alpha)$

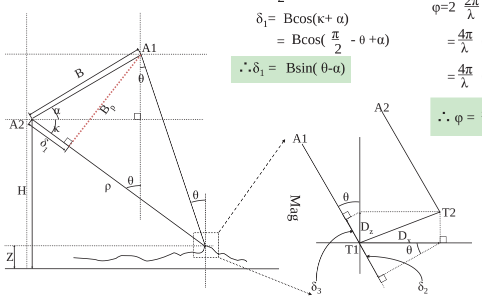
$\therefore \delta_1 = B\sin(\theta - \alpha)$

$\varphi = 2\frac{2\pi}{\lambda}\delta$ (Twice for turn around)

$= \frac{4\pi}{\lambda}(\delta_1 + \delta_2 + \delta_3)$

$= \frac{4\pi}{\lambda}(B\sin(\theta - \alpha) + D_x\sin\theta - D_z\cos\theta)$

$\therefore \varphi = \frac{4\pi}{\lambda}(B\sin(\theta - \alpha) + D_x\sin\theta - D_z\cos\theta)$**



$\therefore \delta_2 = D_x\sin\theta$

$\therefore \delta_3 = -D_z\cos\theta$

4. SAR data analysis technology

4.1 SAR Interferometry

Reduction of basic equation

Phase component

In the image of previous page, an equation to show relations among Z,ρ, and θ as;

$$Z = H - \rho\cos\theta$$

Calculate total differentia of f using equation in

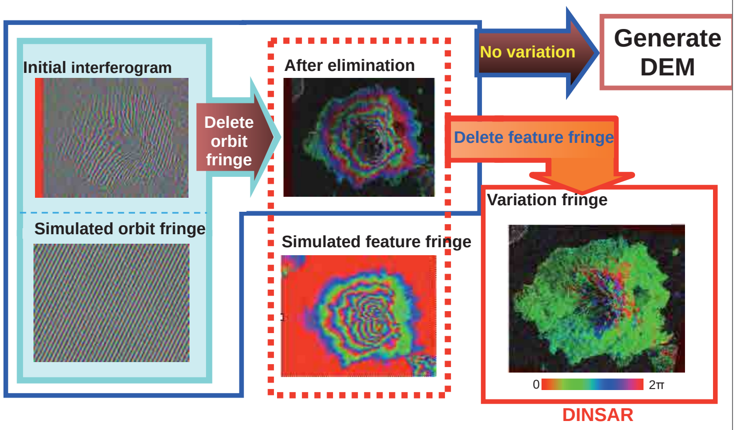
$$d\phi = \underset{(a)}{\frac{\partial\phi}{\partial\rho}d\rho} + \underset{(b)}{\frac{\partial\phi}{\partial z}dz} + \underset{(c)}{\frac{\partial\phi}{\partial Dx}dDx} + \underset{(d)}{\frac{\partial\phi}{\partial Dz}dDz}$$

where (a) : Orbit fringe
(b) : Land feature fringe
(c) ,(d) : Variance fringe

Since (a) doesn't contain land feature information, it is eliminated in post processing. Other items are used in various way.

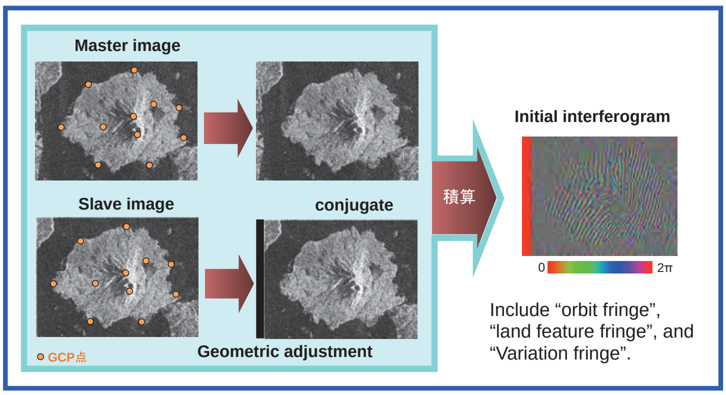
4. SAR data analysis technology

4.1 SAR Interferometry process flow



4. SAR data analysis technology

4.1 SAR Interferometry process flow



4. SAR data analysis technology

4.1 SAR Interferometry

2. Land feature fringe
$$\frac{\partial\phi}{\partial z} = \frac{4\pi B\cos(\theta-\alpha)}{\lambda\rho\sin\theta} = \frac{4\pi Bp}{\lambda\rho\sin\theta} = \frac{1}{\cos\theta}\frac{\partial\phi}{\partial\rho}$$

Above equation indicates countablity of digital elevation mode. In the case of JERS-1, assumin Bp of 500m 1 cycle fringe is equivalent to 100m elevation. By assumin no variation between 2 observattion, height difference is proportional to phase difference as,

$$\frac{\partial\phi}{\partial z} = \frac{4\pi Bp}{\lambda\rho\sin\theta}$$

3. Variation fringe

$$\frac{\partial\phi}{\partial Dx} = \frac{4\pi}{\lambda}\sin\theta$$

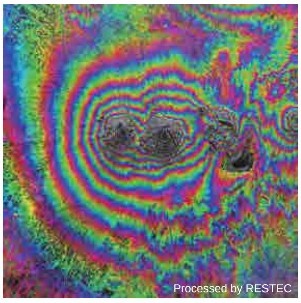
$$\frac{\partial\phi}{\partial Dz} = -\frac{4\pi}{\lambda}\cos\theta$$

Dx:horizontal variation
Dz:vertical variation

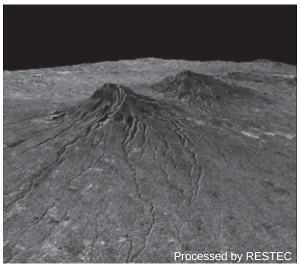
By removing feature fringe, variation happens in between two observation can be detected. It is very sensitive to change even a half wavelength displacement can be detected.

4. SAR data analysis technology

4.1 SAR Interferometry: Digital elevation model



PALSAR Interferogram



InSAR DEMPALSAR 3D using InSAR DEM

4. SAR data analysis technology

4.1 SAR Interferometry

coherence : a measure for phase stability in a pair of Single Look Complex image(SLC).
(Coherence)   The value is calculated as covariance of two conjugate pixel values.

$$\rho_c = \frac{\left|E\left(c_1 c_2^*\right)\right|}{\left[E\left(c_1 c_1^*\right)E\left(c_2 c_2^*\right)\right]^{1/2}}$$

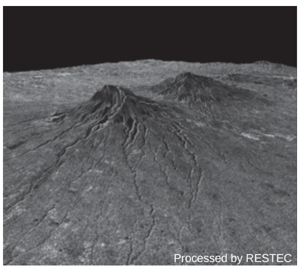
c_1 c_2 is conjugate 2 pixel values in the two SAR images

*means conjugate of a complex number、E() is an expectation of the component.

4. SAR data analysis technology

4.1 SAR Interferometry: Digital elevation model

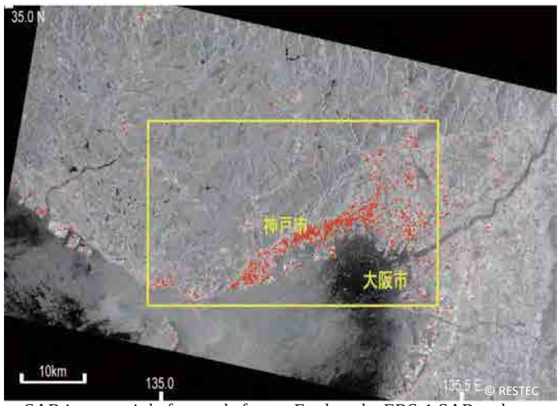
Unwrapped Phase Image



InSAR DEMPALSAR 3D using InSAR DEM

4. SAR data analysis technology

4.1 SAR Interferometry : Damage analysis

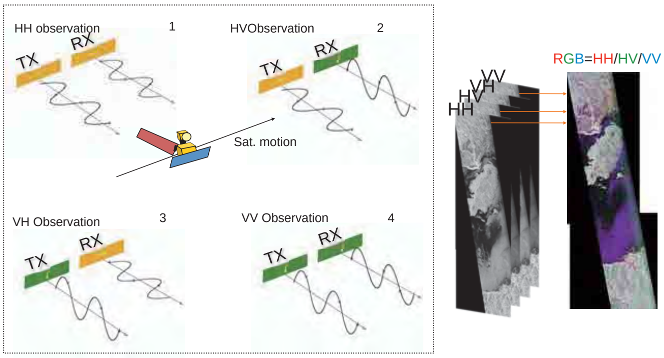


SAR image pair before and after an Earthquake ERS-1 SAR, coherence was calculated to detect damage by the earthquake.

4. SAR data analysis technology

4.1 SAR Polarimetry

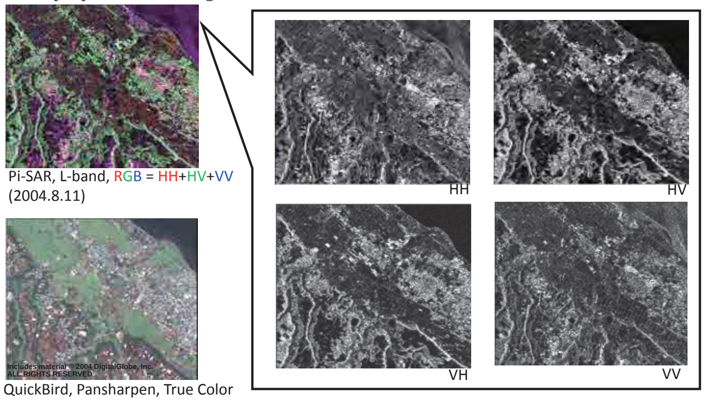
- 4 independent data are acquired from the SAR system.
- Pixel value is stored as complex number to preserve phase delay between TX and RX, which make a scattering matrix.



4. SAR data analysis technology

4.1 SAR Polarimetry

Example polarimetric images

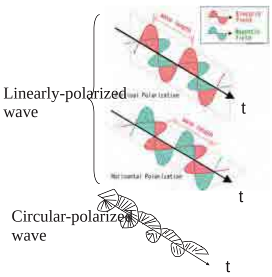


Pi-SAR, L-band, RGB = HH+HV+VV (2004.8.11)

QuickBird, Pansharpen, True Color (2004.8.18)

4. SAR data analysis technology

4.1 SAR Polarimetry



Circular polarized wave : spirally rotated polarization
Linearly polarized wave : Horizontal Polarization
Vertical Polarization

⇩

In the field of Satellite, H and V polarizations are defined as below;
(H)orizontal pol. : Parallel to satellite's orbital direction
(V)ertical pol. : Vertical to satellite's orbital direction

Case of SAR sensor :
JERS-1 : Emit H pol. and receive H pol. (HH)
ERS-1 : Emit V pol. And receive V pol. (VV)

If we obtain 4 component as phase preserved image data, this is a unique component to express RADAR reflectance. Any transmission and reception mode can be numerically realized from the 4 component. In free space operation only the 3 component is independent upon the reciprocity theorem in electromagnetic theory.

4. SAR data analysis technology

4.1 SAR Polarimetry

Scattering Matrix

In a polarimetric SAR image each pixel consists of a scattering matrix of 2 by 2 complex numbers.

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

In the linear stable system $S_{HV} = S_{VH}$ by the reciprocity theorem of Electromagnetism.

The advantage of the matrix is its flexibility that the matrix can be converted in various basis like circular polarization, ellipsoidal polarization, etc.

Circular polarization base

$$[S(RL)] = \begin{bmatrix} S_{RR} & S_{RL} \\ S_{LR} & S_{LL} \end{bmatrix}$$

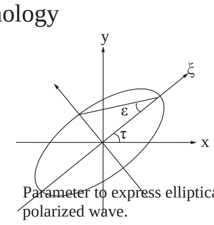
$$S_{RR} = (S_{HH} - S_{VV} - 2jS_{HV})/2$$
$$S_{LL} = (S_{VV} - S_{HH} - 2jS_{HV})/2$$
$$S_{RL} = S_{LR} = -j(S_{HH} + S_{VV})/2$$

4. SAR data analysis technology

4.1 SAR Polarimetry

Polarization signature

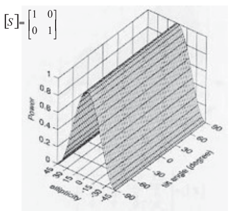
This is an expression of response between Trans mission and reception by taking incident wave source with ellipsoidal expression by Tilt angle and ellipticity angle and reception by the same wave source.
The response often shows characteristic pattern depending on the target structure.



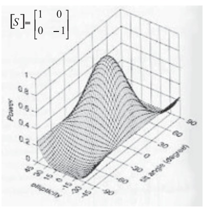
Parameter to express elliptically polarized wave.

τ : Tilt angle (-90≦τ≦90)
ε : Ellipticity angle (-45≦ε≦45)

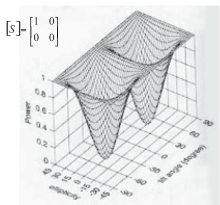
Polarization signature



Flat plane



2面コーナーリフレクタ



水平ワイヤ

4. SAR data analysis technology

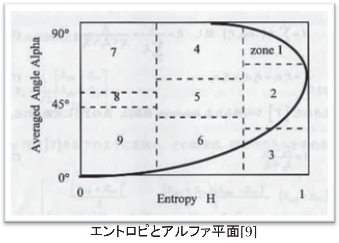
4.1 SAR Polarimetry

Entropy alpha plane

From eigenvalue l of Coherency matrix and Angle α of Eigen vactor, entropy H andαis defilend.

Entropy H (0～1) index for randomness of scattering.
H=0 : surface scattering only
H=1 : 3 kind of scattering is mixed (total randomens)

Angle α (0°～90°) index for polarization dependency
0° : plate,、 45° : wire, 90° : Corner reflector



エントロピとアルファ平面[9]

Using entropy and alpha scattering index is divided into several region, which segment the target category.

Left 9 zone is commonly used to define region on H-A plane.

4. SAR data analysis technology

4.1 SAR Polarimetry

Instead of scattering matrix, several pre processed matrix is often used. All the matrix is derived from scattering matrix component.

Covariance Matrix

$$\langle C\rangle = \begin{bmatrix} \langle S_{HH}S_{HH}^*\rangle & \sqrt{2}\langle S_{HH}S_{HV}^*\rangle & \langle S_{HH}S_{VV}^*\rangle \\ \sqrt{2}\langle S_{HV}S_{HH}^*\rangle & 2\langle S_{HV}S_{HV}^*\rangle & \sqrt{2}\langle S_{HV}S_{VV}^*\rangle \\ \langle S_{VV}S_{HH}^*\rangle & \sqrt{2}\langle S_{VV}S_{HV}^*\rangle & \langle S_{VV}S_{VV}^*\rangle \end{bmatrix}$$

Correlation coefficient

$$Cor(XY, AB) = \frac{\langle S_{xy}S_{ab}^*\rangle}{\sqrt{\langle S_{xy}S_{xy}^*\rangle\langle S_{ab}S_{ab}^*\rangle}}$$

XY, AB means polarization combination of transmission and reception.
In linearly pol. :HH, HV, VH, VV、
In circular:RR, RL, LR, LL.

Covariancevector、Coherency vector

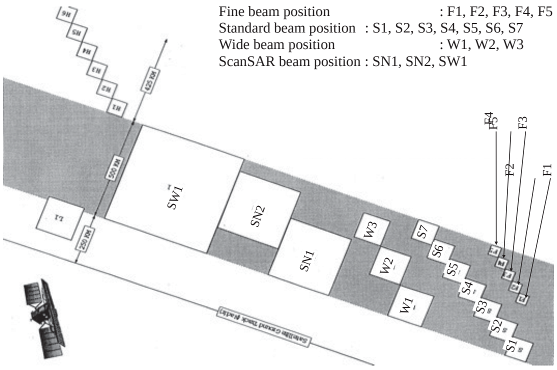
$$\kappa_p = \frac{1}{\sqrt{2}}\begin{bmatrix} S_{HH}+S_{VV} \\ S_{HH}-S_{VV} \\ 2S_{HV} \end{bmatrix}$$

$$[T] = \kappa_p\kappa_p^{*T} = \begin{bmatrix} \frac{|S_{HH}+S_{VV}|^2}{2} & \frac{(S_{HH}+S_{VV})(S_{HH}-S_{VV})^*}{2} & (S_{HH}+S_{VV})S_{HV}^* \\ \frac{(S_{HH}-S_{VV})(S_{HH}+S_{VV})^*}{2} & \frac{|S_{HH}-S_{VV}|^2}{2} & (S_{HH}-S_{VV})S_{HV}^* \\ S_{HV}(S_{HH}+S_{VV})^* & S_{HV}(S_{HH}-S_{VV})^* & 2|S_{HV}|^2 \end{bmatrix}$$

4. SAR data analysis technology

4.1 SAR Stereo

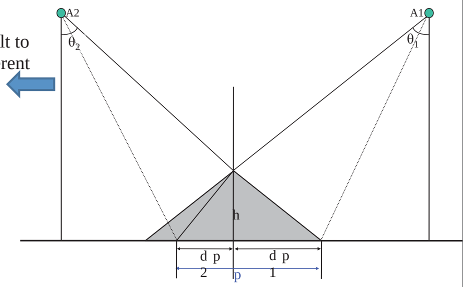
Fine beam position : F1, F2, F3, F4, F5
Standard beam position : S1, S2, S3, S4, S5, S6, S7
Wide beam position : W1, W2, W3
ScanSAR beam position : SN1, SN2, SW1

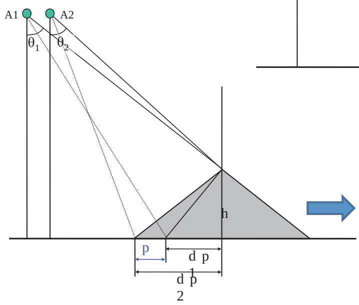


4. SAR data analysis technology

4.1 SAR Stereo

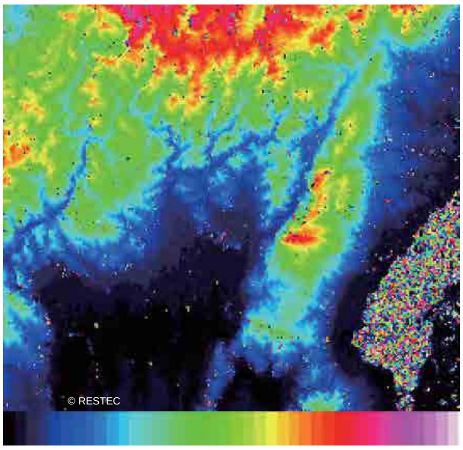
Opposite side illuminaton is difficult to find matching point due to the different impression of image.





Same sid illumination with different incident angel. It is almost sole stereo pair.

DEM from SAR stereo



4. SAR data analysis technology

4.3 SAR Stereo: Aanaglyph

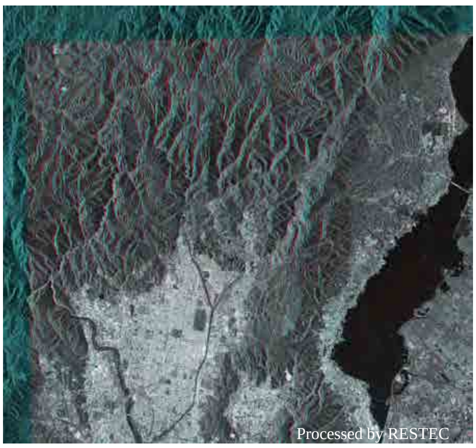
Parallax equation of same side stereo pair of SAR image.

$p=|\cot\theta_1 - \cot\theta_2|*h$
(same illumination direction)

$p=|\cot\theta_1 + \cot\theta_2|*h$
(opposite illumination direction)

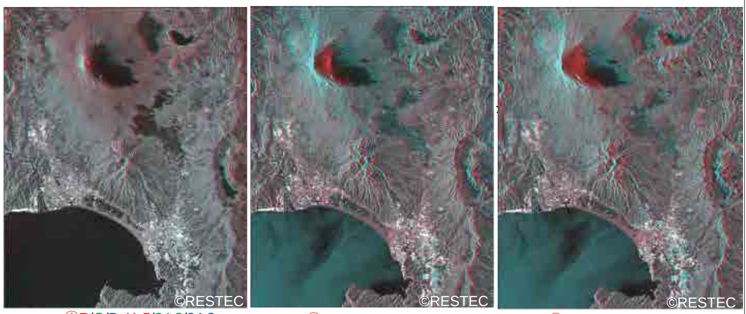
Image parameter

SAR	Mode	Date	Inc.
RADAR	F1	1997.3.17	37.6°
RADAR	F5	1997.3.27	47.5°



4. SAR data analysis technology

4.3 SAR Stereo: Aanaglyph



①R/G/B:41.5/34.3/34.3 ②R/G/B:34.3/21.5/21.5 ③R/G/B:41.5/21.5/21.5

RESTEC

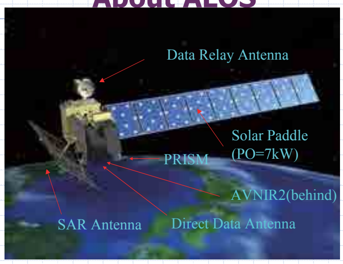
Overview of ALOS System

Remote Sensing Technology Center of Japan

1

RESTEC

About ALOS



2

RESTEC

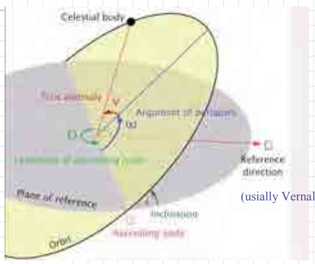
Satellite

- ◆Weight 4 metric tons
- ◆Designed Life:3~5 years (Launch 2006.1.21)
- ◆Orbit Sunsync:H=691.65km, Inc=98.16deg,
  Recursion=46days, sub cycle=2days
- ◆Total turn/recursion=671
- ◆Sensors:
  - PRISM :Optical
  - AVNIR2:Optical
  - PALSAR:Radar

3

RESTEC

Satellite Orbit Parameter Definition



(usially Vernal Equinox)

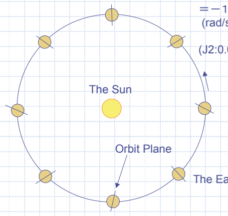
4

RESTEC

Satellite Orbit in the Solar System

Rotation Speed of orbit plane
$=-1.5 J_2 R_e^2 \mu / R_o^7 \cos(\theta i)$
(rad/sec)

(J_2:0.00108263, μ=398600.9)



Earth Rotation around the Sun

5

RESTEC

Orbit Day Full Path(46days)

15path/day
105path/week
451path/month
Separation=58km

RESTEC

Orbit Night Full Path (46days)

7

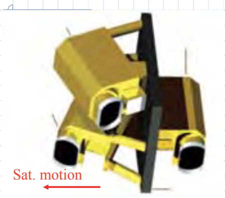
RESTEC

Observation Scenario

- ◆ ALOS completes 671 orbits during a 46-day satellite cycle
- ◆ 8 satellite cycles per year(368 days, 46days each)
- ◆ Cycle 1-2: Commissioning phase done
- ◆ Cycle 3-6: Calibration/Validation phase done
- ◆Cycle 7+: Operational acquisitions according to the Observation Strategy（Current）

8

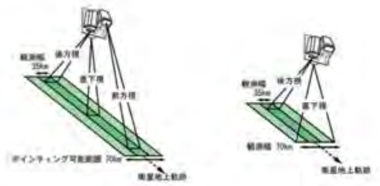
Sensor 1: PRISM



- •Panchromatic Camera
- •Wavelength:0.52~0.77μm
- •Stereo:3 channel (nadir, forward,backward)
- •Resolution:2.5m
- •Swath: nadir=70km
  stereo=35km
- •Sampling:8bit

9

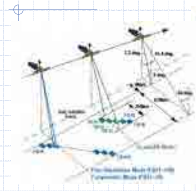
Sensor 1: PRISM Stereo



10

TGA－RE－162

Sensor 3: PALSAR



PALSAR Characteristic

Mode	Fine		ScanSAR	Polarimetric (Experimental mode)*1
Center Frequency	1270 MHz (L-band)			
Chirp Bandwidth	28MHz	14MHz	14MHz, 28MHz	14MHz
Polarization	HH or VV	HH+HV or VV+VH	HH or VV	HH+HV+VH+VV
Incident angle	8 to 60deg	8 to 60deg	18 to 43deg	8 to 30deg
Range Resolution	7 to 44m	14 to 88m	100m (multi look)	24 to 89m
Observation Swath	40 to 70km	40 to 70km	250 to 350km	20 to 65km
Bit Length	5 bits	5 bits	5 bits	3 or 5 bits
Data rate	240Mbps	240Mbps	120Mbps, 240Mbps	240Mbps
NE sigma zero *2	< -23dB (Swath Width 70km) < -25dB (Swath Width 60km)		< -28dB	< -29dB
S/A *2,*3	> 16dB (Swath Width 70km) > 21dB (Swath Width 60km)		> 21dB	> 19dB
Radiometric accuracy	scene: 1dB / orbit: 1.5 dB			

13

JAXA's Observation Strategy

- ◆Set default mode in each sensor and use them as a standard observation mode except
  emergency observation
- ◆Change mode interval is set as recursion days
- ◆Systematic coverage of satellite path.

14

TGA－RE－162

Geometric Accuracy of PRISM 1B2

1) Absolute Accuracy

The evaluations were carried out about 1,390 GCPs (64 image scenes) for each radiometer.

	Pixel direction (cross track)	Line direction (along track)	Distance
Nadir view (RMS)	6.5 m	7.3 m	9.8 m
Forward view (RMS)	8.0 m	14.7 m	16.7 m
Backward view (RMS)	7.4 m	16.6 m	18.1 m

* Evaluation method: Compared with the GPS measured geolocation of GCPs after projected onto the GRS 80 in correcting the height.

2) Relative Accuracy

	Pixel direction (cross track)	Line direction (along track)	Distance
Std. dev. in a scene(1σ)	1.9 m	2.3 m	3.0 m

11 11

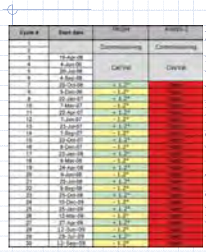
Sensor 2: AVNIR2

4 Band multi spectral imager
Wavelength: B1=0.42~0.5μm
B2=0.52~0.60μm
B3=0.61~0.69μm
B4=0.76~0.89μm
Resolution: 10m
Swath:70km
Cross Track Pointing:
-44deg.~+44deg.
Sampling :8bit/band

12

TGA－RE－162

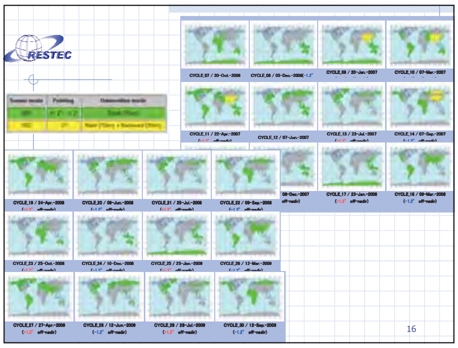
Prism Observation Scenario



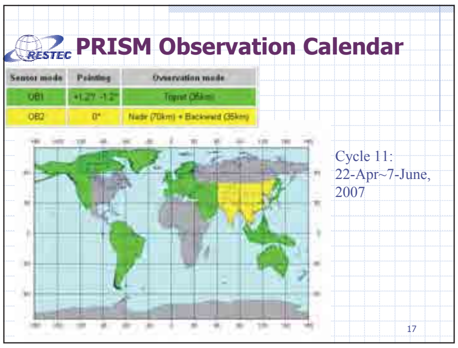
PRISM Strategy Characteristics

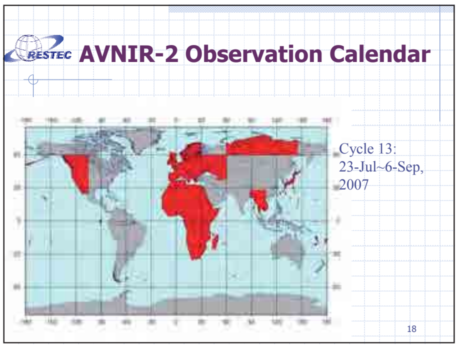
The default mode for PRISM is the triplet mode, which allows simultaneous along-track stereo observations with the three telescopes. As the swath width in triplet mode however is reduced to 35 km, PRISM requires two 46-days cycles to cover a given region without gaps, during which the instrument is alternately tilted 1.2° across-track to the right and left. This pointing is done by picking up part of full swath CCD detectors. So, no physical pointing of camera is applied on the apparent sensor pointing.

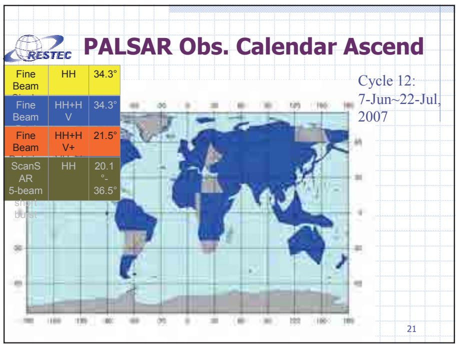
15

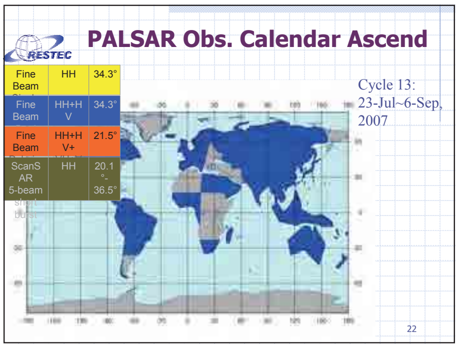


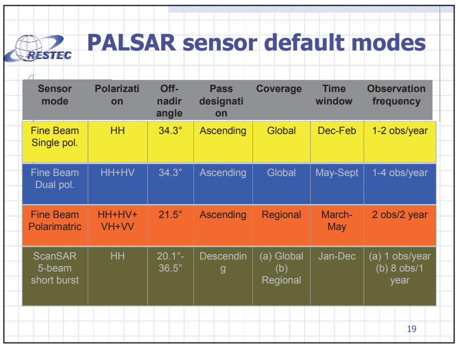
16







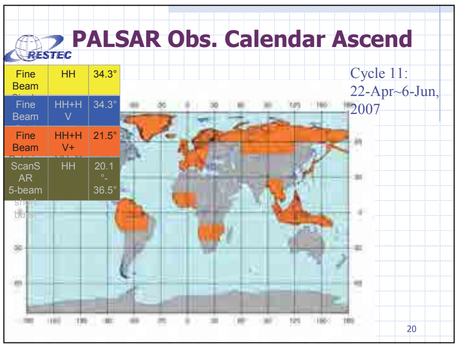


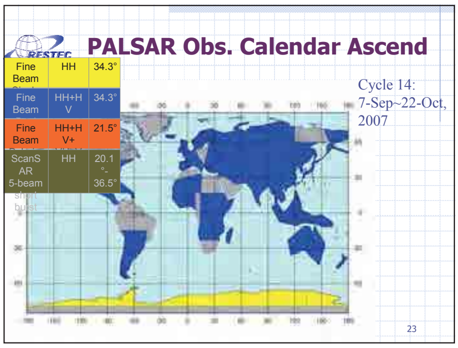

RESTEC

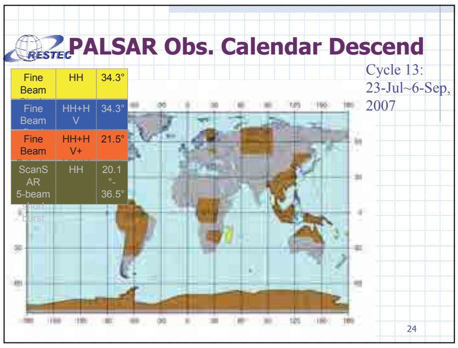
PALSAR sensor default modes

Sensor mode	Polarization	Off-nadir angle	Pass designation	Coverage	Time window	Observation frequency
Fine Beam Single pol.	HH	34.3°	Ascending	Global	Dec-Feb	1-2 obs/year
Fine Beam Dual pol.	HH+HV	34.3°	Ascending	Global	May-Sept	1-4 obs/year
Fine Beam Polarimatric	HH+HV+VH+VV	21.5°	Ascending	Regional	March-May	2 obs/2 year
ScanSAR 5-beam short burst	HH	20.1°-36.5°	Descending	(a) Global (b) Regional	Jan-Dec	(a) 1 obs/year (b) 8 obs/1 year

19



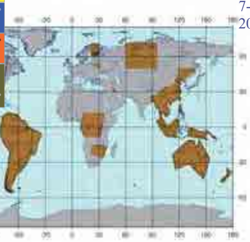




PALSAR Obs. Calendar Descend

Fine Beam	HH	34.3°
Fine Beam	HH+HV	34.3°
Fine Beam	HH+HV+	21.5°
ScanSAR 5-beam	HH	20.1 ~ 36.5°

Cycle 14: 7-Sep~22-Oct, 2007



25

AVNIR2 Observation Scenario

- Use nadir pointing as default mode

AVNIR-2 Observation Strategy Characteristics

The default mode for the AVNIR-2 scenario observations is the nadir view mode, as indicated in the table of next page.

For any given region, AVNIR-2 is typically scheduled for "one acquisition during two consecutive cycles", meaning that if an acquisition is successfully programmed the first of the two cycles in question, it will not be included in the plan during the second (regardless of cloud cover). One full global AVNIR-2 coverage is planned per year as a part of the observation strategy.

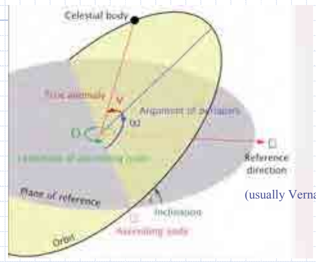
As the AVNIR-2 instrument however operates with only half the data rate of that of PRISM and PALSAR, there is comparably favorable opportunities for users to make additional requests for AVNIR-2.

26

Using Orbitron

29

Orbit Parameter

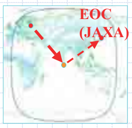


(usually Vernal Equinox)

30

Observation and Acquisition

- Due to a high data rate of onboard sensors, not all data mode can put on ALOS direct down link.
- All data can be transferred via data relay satellite link to ground station at JAXA.



Observation in Real Time & Recorder Playback for whole satellite coverage

A limited mode data can be transferred to regional ground station directly.

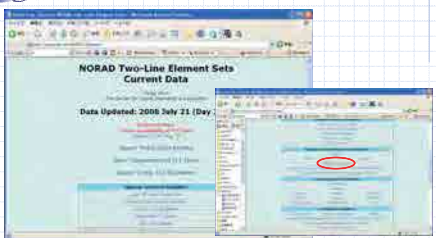
27

Check of Satellite Orbit

Down Load "Orbitron"
http://www.stoff.pl/

28

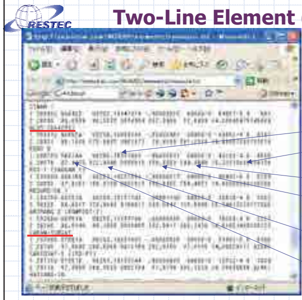
Get NORAD Two-Line Element data



http://celestrack.com/NORAD/elements/

31

Two-Line Element (TLE)

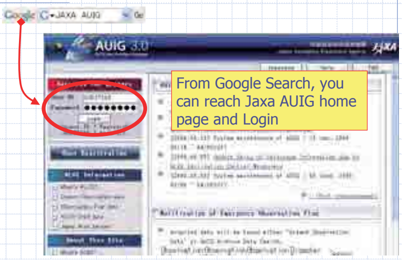


Display Satellite Orbit using Orbitron

- Epoch(year_day)
- Trun/day
- True Anomaly(degree)
- Argument of Periapsis
- Longitude of Ascending node
- inclination

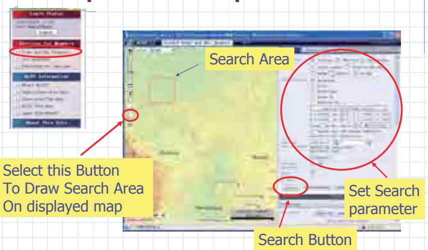
32

Method to Access ALOS Data



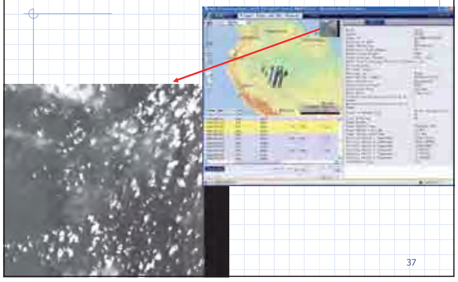
33

From “Order and Obs. Request” to Open Search Map



34

Case of Prism



37

End of ALOS Overview

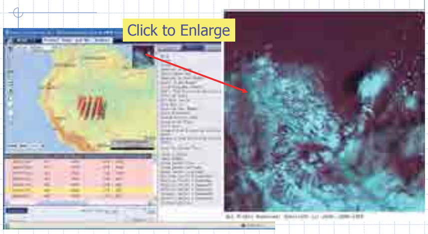
Thank you for your attention !

38

Search Result (case of Palsar)

35

Case of AVNIR2



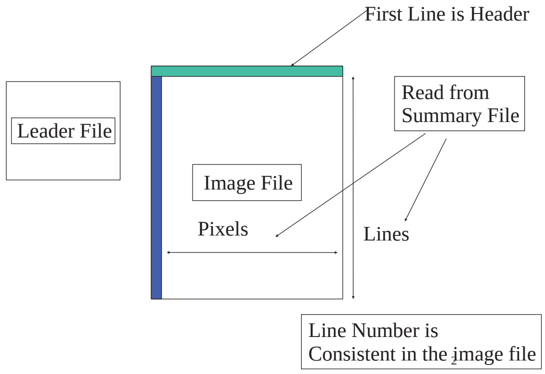
36

Remote-sensing 2009

Access and Open ALOS Images

REMOTE SENSING TECHNOLOGY CENTER OF JAPAN
TOKYO, JAPAN

PRISM/AVNIR2



Getting Parameter

1. Read Summary text to find line number
2. Find file size from windows property
3. Calculate apparent pixel number

Pixels=File_size/(line+1)

Header=Pixels(number shown above)

3

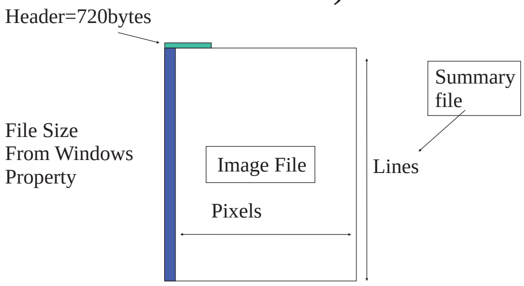
Naming of Image Files

- Image starts with “IMG-”
- PRISM: IMG-ALPSM*********1B2-UN
- AVNIR2 IMG-B1-ALAV”****1B2R

**** is orbit turn number from launch (5digit)+process code

4

PALSAR Image File Structure (Lev. 1.5)



5

Find PALSAR Parameter(Lev 1.5)

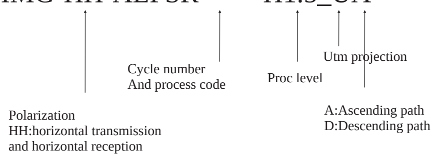
Pixel=(FileSize-720)/（Line x 2)

Byte Order:UNIX format (High byte first order) byte swap is required in the Intel systems.

6

Naming of PALSAR(Lev 1.5)

- IMG-HH-ALPSR****-H1.5_UA

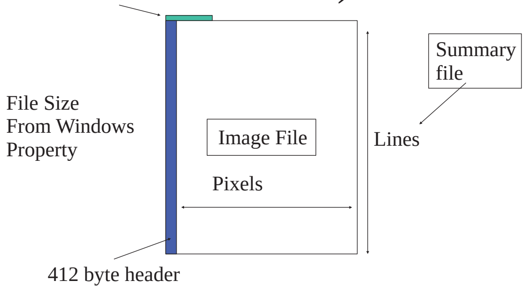


VV:vertical trans. /vertical rec.

HV: horizontal trans./vertical rec.

7

PALSAR Image File Structure （Lev. 1.1)



8

Find PALSAR Parameter(Lev 1.1)

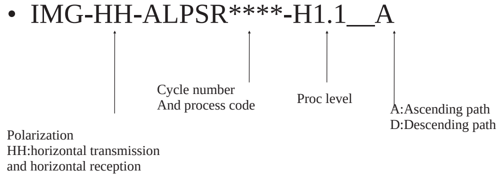
Pixel=((FileSize-720)/Lines-412)/8

Byte Order:UNIX format (High byte first order) byte swap is required in the Intel systems.

9

Naming of PALSAR(Lev 1.1)

- IMG-HH-ALPSR****-H1.1__A



VV:vertical trans. /vertical rec.

HV: horizontal trans./vertical rec.

10

Process Code

- Every ALOS scene has unique number as;

  IMG-HH-ALPSRP207217030-H1.5_UA (PALSAR)
  IMG-03-ALAV2A185263730-O1B2R_U (AVNIR2)
  IMG-ALPSMW185263735-O1B2R_UW (PRISM)
- 9 digit (under lined) shows satellite orbit cycle number and position on orbit plane

11

First 5 digit

- First 5 digit of process code shows orbit cycle number after launch.
- Knowing 671 cycles in 46 days, launch date of January 21, 2006, and cycle time of 98.71833 minutes, you can calculate date of data acquisition.
- Cycle time can be calculated from 46*24*60/671.

Hours of 1 cycle

12

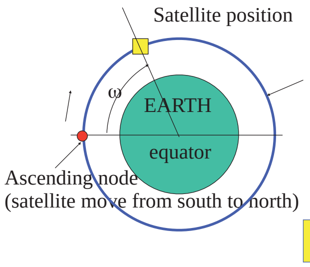
First 5 digit

- By the relations,

  if 1 data of first 5 digit of "ABCDE" covers a targeted area, "ABCDE+671*N" may covers the same area 'assuming same last 4 digit and same observation mode for PALSAR and AVNIR2). N is arbitral integer number.

13

Second 4 digit



Second 4 digit is w*20

14

Second 4 digit

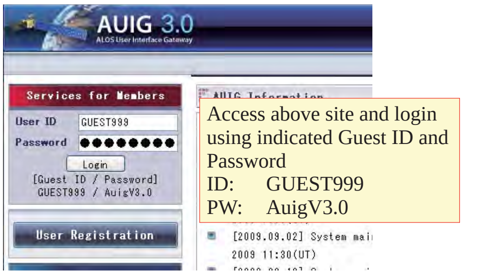
ω to latitude conversion
Using trigonometric function,

Sin(latitude)=Sin(w)*Sin(orbitinc)
You can calculate latitude of satellite position.

15

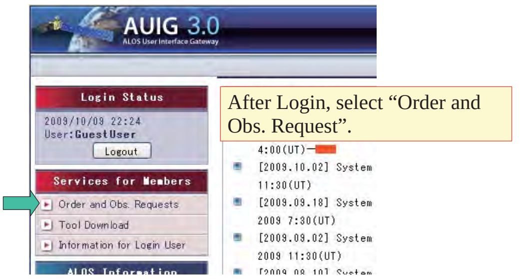
Access to AUIG

https://auig.eoc.jaxa.jp/auigs/top/TOP1000LoginLang.do



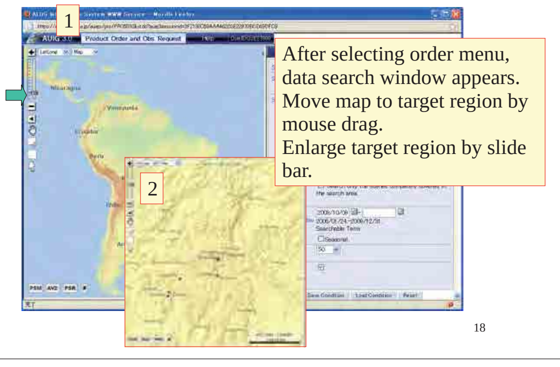
16

Login and Order



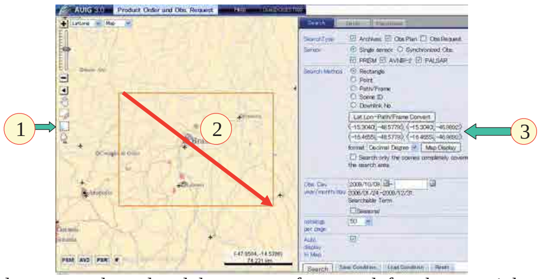
17

Data search window



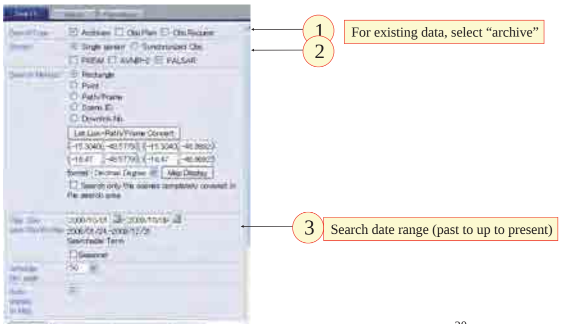
18

Set search rectangle

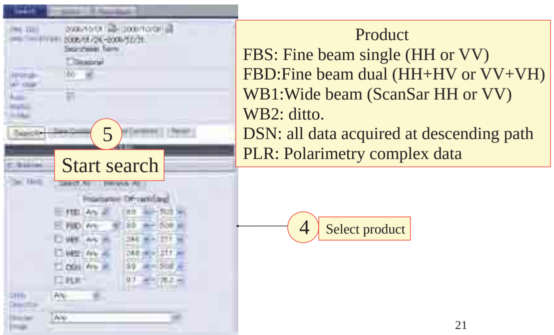


Select rectangle tool and drag mouse from top left to bottom right.
4 corner geo information appears on right hand dialog.
Alternately, you can directly specify the value in the right dialog

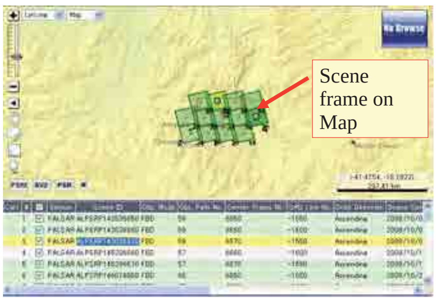
Select search conditions (1 PALSAR)



Select search conditions (1 PALSAR)

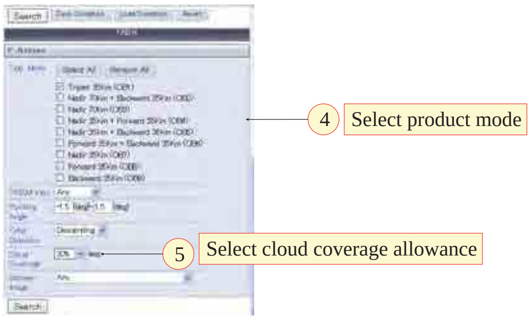


Search result



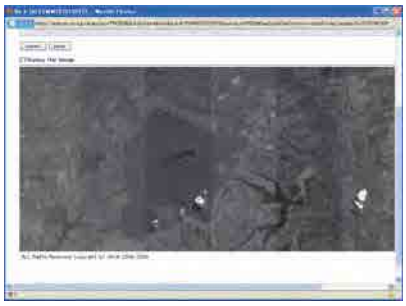
In PALSAR image search, no browse data exist because there is no need of check because of cloud free.

Case of PRISM

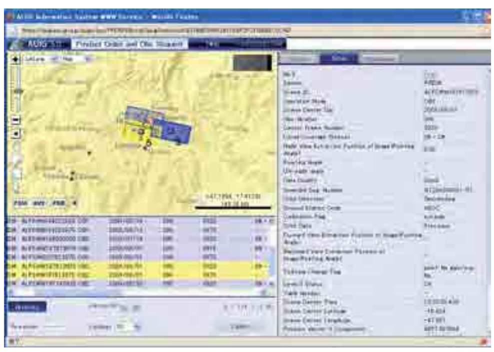


Search result

Enlarged thumb nail image



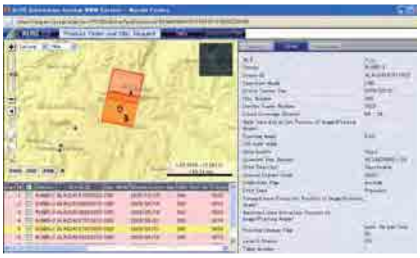
Search result



Enlarged thumb nail image

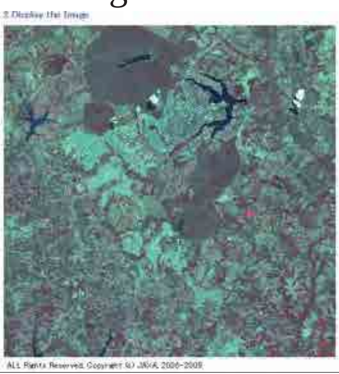
27

Case of AVNIR2



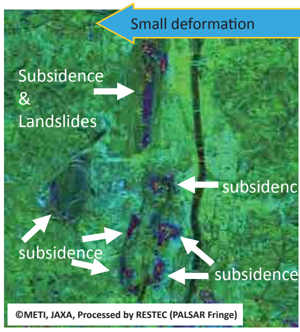
28

Enlarged thumb nail image



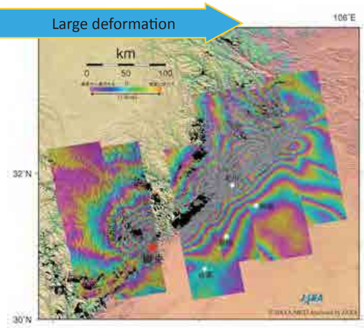
29

Example of Differential interferogram



$-\pi$ $+\pi$ 1 cycle = 11.8cm

Subsidence due to coal mining at Fushun, China, in three month
Approximately 12 cm subsidence detected from a pair of PALSAR data by DInSAR analysis.

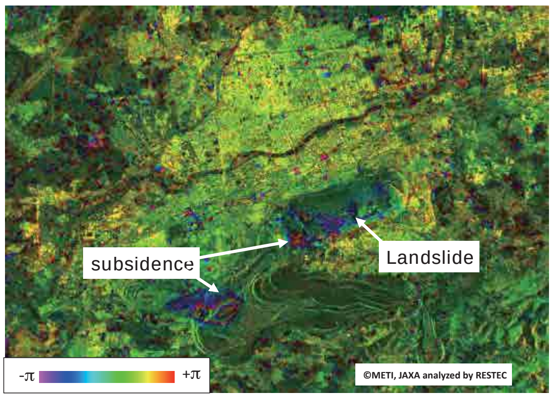


Crustal deformation due to Earthquake at Sichuan, China, 2008
Mosaic image of differential SAR interferogram of 6 observation path overlaid on the map of SRTM-DEM.

1

segunda-feira, 31 de maio de 2010

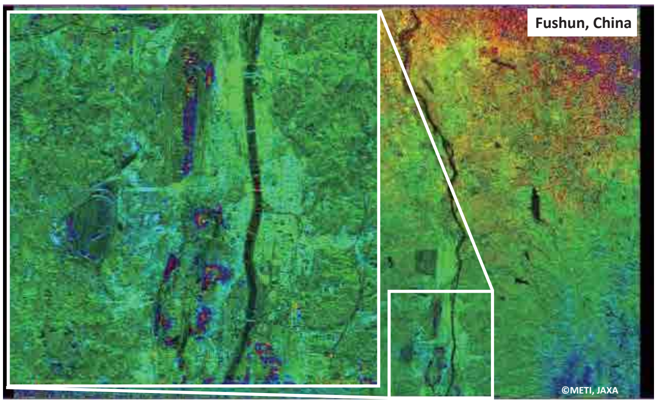
Application for Subsidence Monitoring (1/2)



Subsidence and landslide were able to be detected by ALOS/PALSAR differential interferometry (DinSAR).

segunda-feira, 31 de maio de 2010

Application for Subsidence Monitoring (2/2)

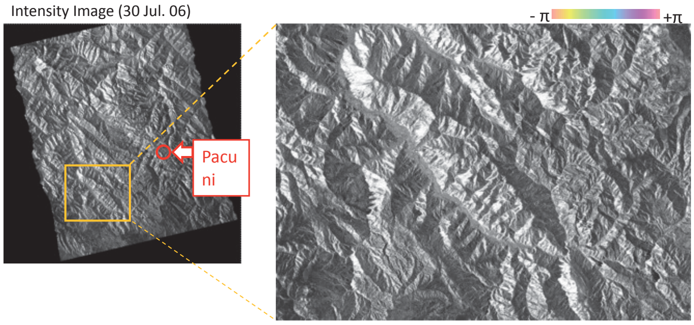


-π [colour scale] +π 1 cycle = 11.8cm

Application for Landslide Monitoring (3/3)

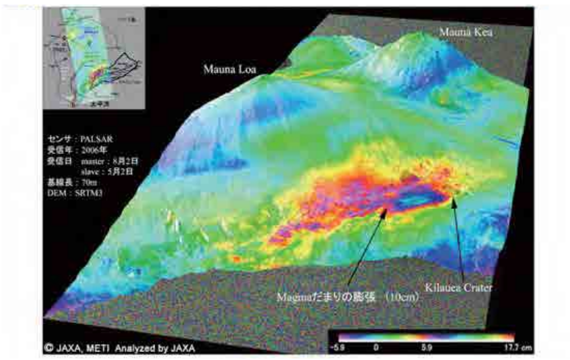
Landslide detection in mountainous area

Intensity Image (30 Jul. 06)



Landslide fields (local movement points) are appeared different color with the surroundings in the Interferogram of DInSAR.

Application for Volcanic Monitoring (3/3)



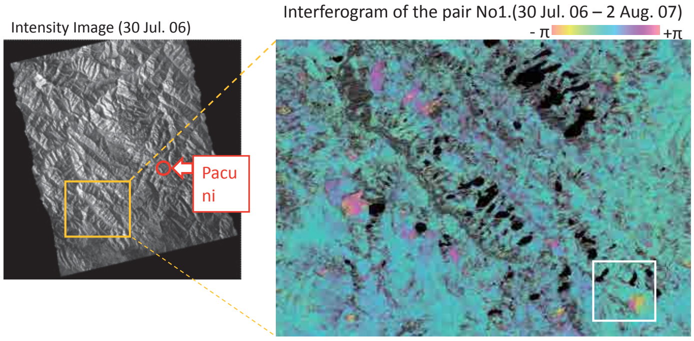
Uplift detection around the Kilauea Crater, Hawaii by ALOS/PALSAR interferometry.

Application for Landslide Monitoring (3/3)

Landslide detection in mountainous area

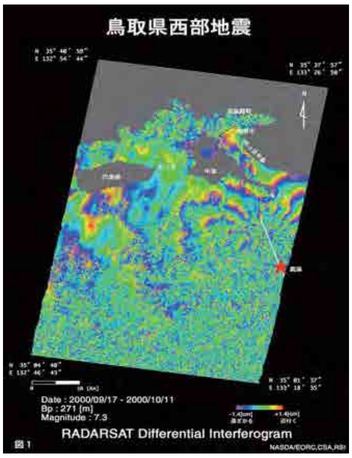
Interferogram of the pair No1.(30 Jul. 06 – 2 Aug. 07)

Intensity Image (30 Jul. 06)



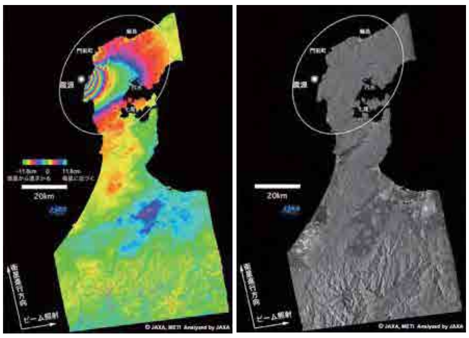
Landslide fields (local movement points) are appeared different color with the surroundings in the Interferogram of DInSAR.

Application for Earthquake Monitoring (1/2)



SAR interferometry by RADARSAT showing deformation around Tottori, Japan by the earthquake occurred in Oct. 2000. The red star indicate the hypocenter

Application for Earthquake Monitoring (2/2)



SAR interferometry by ALOS/PALSAR showing deformation around Noto Peninsula, Japan by the earthquake occurred in 2007.

August 6, 2009

User's Manual of ALOS PALSAR Fringe

Version 3.0(Soft version 4.0.1)

M. Ono

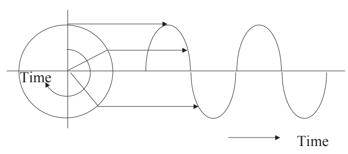
Remote Sensing Technology Center of Japan

Contents

(intentionally Blank)

1. Radar System

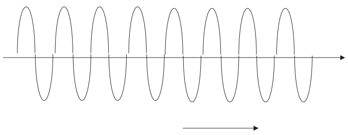
1.1 Wave and Phase



SAR uses Electro Magnetic wave

Phase (in Space by Stop Time)

Delay ⟷ Progress



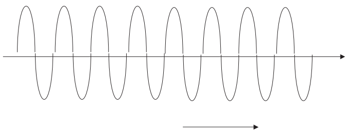
Stop Time

Distance to wave propagation

5

Phase in Time at a Point in Space

Delay ⟷ Progress

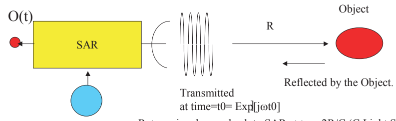


Elapsed Time

6

1.2 Detection of Phase Delay

"t" is time



Stable Oscillator
Signal=exp[jωt]

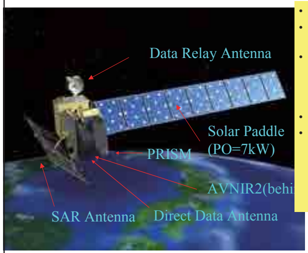
(Phase progress by time)

Return signal come back to SAR at t_{delay}=2R/C (C:Light Speed)
Stable Oscillator signal at returned time is exp[jω(2R/C)]
In the SAR receiver returned signal is divided by the stable oscillator signal
As
O(t)=Ar exp[jwt0- jw((2R/C)+t0)]
=Ar exp[-jw(2R/C)]=Ar exp[-4π/λR]

Phase delay is preserved in the signal by the receiver function.

9

1.3 About ALOS Satellite



- Weight 4 metric tons
- Designed Life:3~5 years (Launch 2006.1.21)
- Orbit Sunsync:H=691.65km, Inc=98.16deg, Recursion=46days, sub cycle=2days
- Total turn/recursion=671
- Sensors:
  - PALSAR:Radar
  - PRISM :Optical
  - AVNIR2:Optical

10

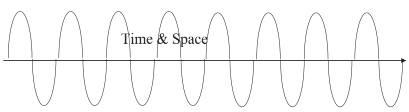
Phase at a Space Position and Time

f(t, R)=A(t) exp[j(ωt-4πR/λ)]

Where t:elapsed time
ω:angular frequency (=2πf)
R: distance along wave propagation
λ:wavelength

7

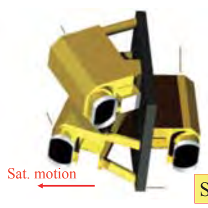
Nature of Phase Function



- if we set time and position in space, we can calculate phase.
- But if we define phase we can not decide time and position.
- Inverse of phase function is ambiguous.

8

ALOS Sensor PRISM



- Panchromatic Camera
- Wavelength:0.52~0.77μm
- Stereo:3 channel (nadir, forward,backward)
- Resolution:2.5m
- Swath: nadir=70km stereo=35km
- Sampling:8bit

Stereo (Triplet) capability

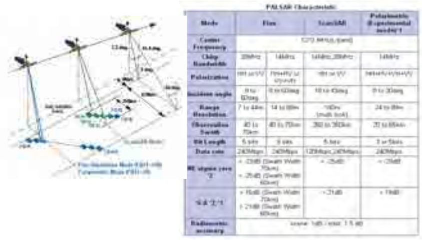
11

ALOS Sensor AVNIR2

4 Band multi spectral imager
Wavelength: B1=0.42~0.5μm
B2=0.52~0.60μm
B3=0.61~0.69μm
B4=0.76~0.89μm
Resolution: 10m
Swath:70km
Cross Track Pointing:
-44deg.~+44deg.
Sampling :8bit/band

12

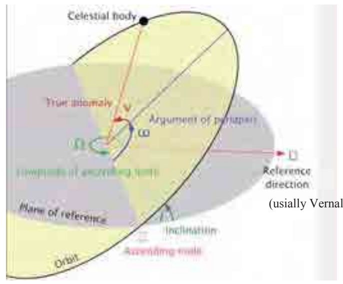
ALOS Sensor PALSAR



1.4 Satellite Orbit

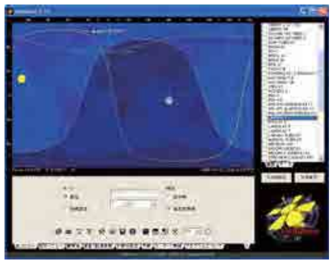
14

Orbit Parameter



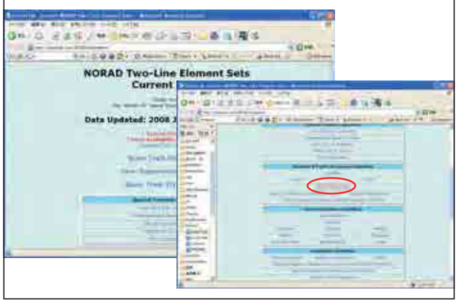
17

Using Orbitron

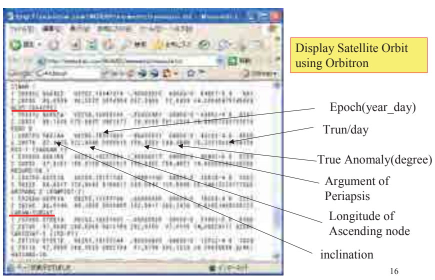


18

Get NORAD Two-Line Element data set

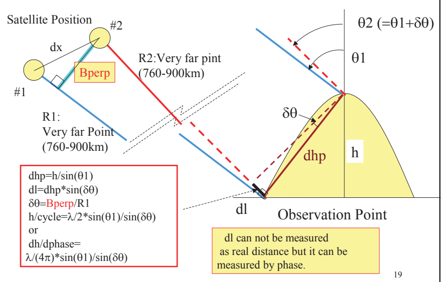


TLE



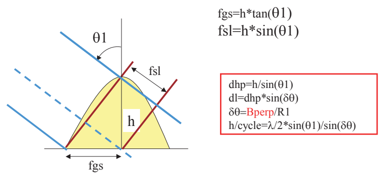
16

1.5 Interferogram



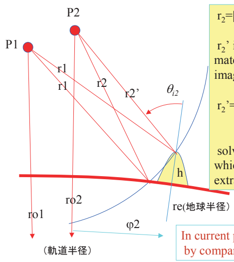
19

Foreshortening correction



20

1.6 Fringe to Height Interpretation



$r_2=[(ro_2-re)^2+2ro_2*re*(1.-\cos(\varphi_2))]^{1/2}$

r_2' is calculated from conjugate point matching between master and slave images with an accuracy of sub pixel.

$r_2'=[(ro_2-(re+h))^2 +2ro_2*(re+h)*(1.-\cos(\varphi_2))]^{1/2}$

solving the equation, h can be evaluated, which can be used for DEM calibration extracted from fringe.

In current program, height evaluation is done by comparing with SRTM DEM.

21

Evaluation of H

$r_2'^2=(ro_2-(re+h))^2+2ro_2*(re+h)*(1.0-\cos(\varphi_2))$

Coefficients

h^2:1.0
h :-2re-2 $ro_2\cos(\varphi_2)$
const: $ro_2^2+re^2-2ro_2\, re*\cos(\varphi_2)- r_2'^2 =rs_0^2- r_2'^2$

thus
$h=re+ ro_2\cos(\varphi_2) -[(re+ ro_2\cos(\varphi_2))^2-const)]^{1/2}$

22

Interferogram Calculation

- O1(P)=Ar exp[-j4πR1/λ]; out put form #1 configuration
- O2(P)=Ar exp[-j4π(R1-dl)/λ]; output from #2 configuration

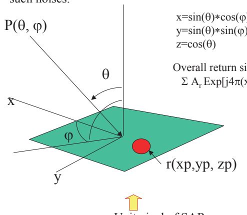
D(P)=O2(P)/O1(P)
=exp[j4π(dl)/λ]=R+jX ;phase detection (element of inteferogram)

$\phi=\tan^{-1}(X/R)$; Fringe value

23

1.7 Reflectance in a Pixel of SAR

As a inherent problem of SAR system, there is speckle noise to disturb accurate phase calculation. The image below shows the mechanism to cause such noises.



x=sin(θ)*cos(φ)
y=sin(θ)*sin(φ)
z=cos(θ)

Overall return signal of a pixel=
$\Sigma A_r \mathrm{Exp}[j4\pi(xp*x+yp*y+zp*z)/\lambda]$

In a unint pixel, there are many objects which reflect radar wave with various strength and phase.

Unit pixel of SAR processed image.

24

Phase and Amplitude Stability
(Dependency to Observer Point)

Example shown below was simulated sugnal for a 10m size pixel with 10 sub section (see previous page. "φ" is assumed to be zero).
This table shows an example of ampritude and phase variation depending on the observation incident angle.

Incident angle (degree)	Sin(θ)	cos(θ)	Amp	Phase(degree)
30	0.5	0.866025	1.09556	−26.96440517
30.05	0.501	0.865589	0.924711	4.235031869
30.1	0.502	0.865151	0.862187	1.119699379
30.15	0.502	0.864713	0.796748	−1.994057568
30.2	0.503	0.864275	0.730097	−5.106236602
30.25	0.504	0.863836	18.01189	−8.216835352
30.3	0.505	0.863396	0.59033	−11.32585145
30.35	0.505	0.862955	0.518221	−14.43328253
30.4	0.506	0.862514	0.444981	−17.53912622

Amp and phase changes significantly by a slight incident angle change.

In a distance of satellite from a ground observed point, observation angle difference for 1 km apart points is around 0.07 degrees.
To make a satellite SAR image, more than 10km separated raw data is accumulated along a satellite path which suffers this signal modification and finally appears as speckled image.

Phase stability is important to obtain noise free interferogram

25

Source of Phase Error and method to reduce the effect in SAR interferometry

- Cell reflectance variation for observation angle change
- Receiver Noise
- Along track phase instability

Avoid by Averaging after Inteferogram calc.

- Conjugate point evaluation error

Accurate orbit calculation

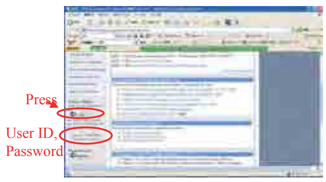
- Time dependency of the objects
- Environmental dependency of the observation (freeze temperature or not, wet or dry)

Avoid by Scene Selection

26

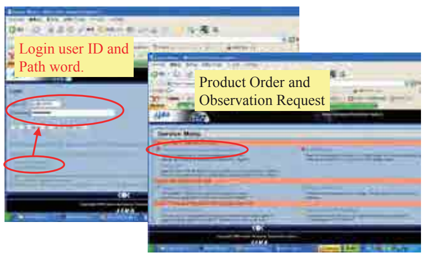
2. SAR Interferometry Process
2.1 How to Check Pair Data

Orbit distance between a pair observation is a key parameter in interferometry process.
To check orbit distance of Palsar data, open Auig at "https://auig.eoc.jaxa.jp/"



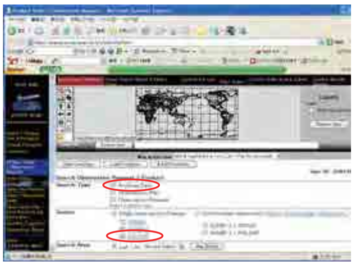
27

Auig



28

Auig (initial search window)



29

Enlarge Target Area

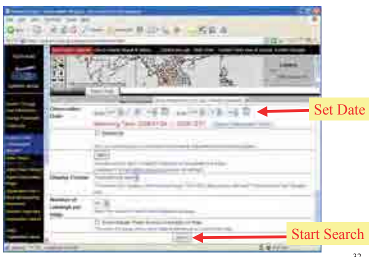
30

15

Set Search Region

31

Set Search Date Duration and Start Search



32

16

Running Search

33

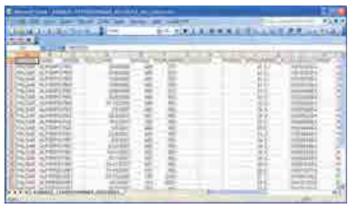
Results Come up and Save to File

Search result output is "CSV" List table.

34

17

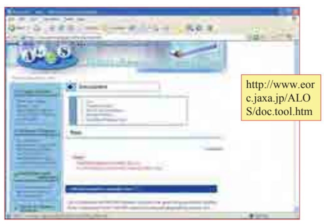
Saved Result as a CSV file



35

2.2 Orbit Distance Analysis

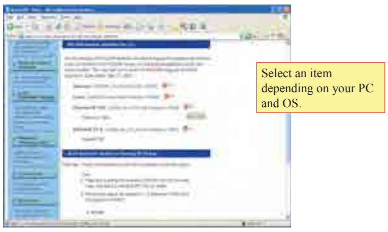
Down Load an Orbit Distance Analysis Tool



36

18

Select Target File



37

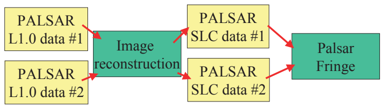
Save Data

38

3. SAR Image Generation PalsarProcessor

For detailed manual, refer" PALSAR_ProcessorV2.2".

- Palsar Porcessor is a tool to convert Palsar level 1.0 data into a single look complex data (SLC).
- The process is SAR image reconstruction and after SLC generation for a pair SAR data interfrogram will be generated by the next program "PalsarFringe".



41

3.1 Image Reconstruction

- SAR image is almost same with hologram
- Image reconstruction either in Single Look Complex (SLC) form or amplitude form is necessary.
- To process SAR interfrometry, original SAR signal must be processed to Single Look Complex (SLC) data.
- This process exactly trace SAR signal compression in complex number space.
- Amplitude conversion from SLC is usual SAR intensity image. In the usual intensity image, phase information (complex number is discarded.
- SAR image reconstruction is almost linear operation which means reversible operation.
- From raw data to single look complex (SLC) process is exactly a linear operation where a Fast Fourier Transform(FFT) is preferred to accelerate the processing speed drastically.

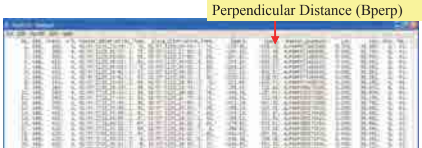
42

Move Search Result(page 35) to the Inventory Folder then Apply Calc_Bp.bat.

39

Calculated Results (Bperp is the key parameter)

Perpendicular Distance (Bperp)

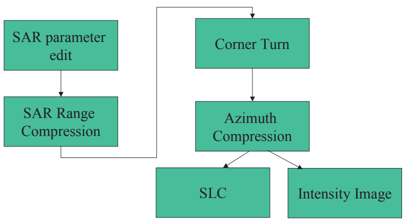


Refer Bperp in p. 8 of this document.
In general for PALSAR case, Bperp is preferable to be less than 500m and both observation is preferable to be in dry season and no drastic temperature difference combination*.
*note: drastic temperature difference combination means one observation is conducted at higher than water freeze temperature while other is conducted at lower than water freeze temperature.

40

Image Reconstruction process flow

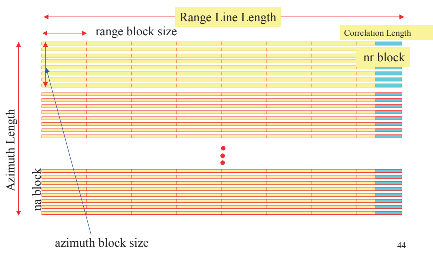
SAR image reconstruction is a linear correlation process using reference function generated from sensor parameter and orbit/attitude information. Since data size is huge, some treatment of a data file is necessary.



43

Data Structure of SAR Processing

- Range Compression



44

SAR image Reconstruction

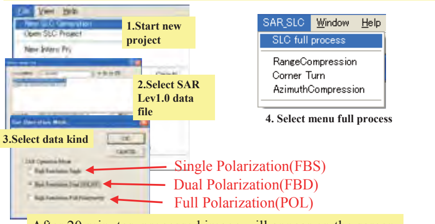
- This is the process described in the previous page.
- A new program “PALSAR Processor” is prepared to conduct the whole process.

45

PALSAR Processor Operation

Follow the process below, basic process flow is shown in page 16.

Range Compression (from SAR parameter edit to range Compression)



After 20 minutes, processed image will appear on the screen.

An Result of Palsar Processor

La Paz Air port

49

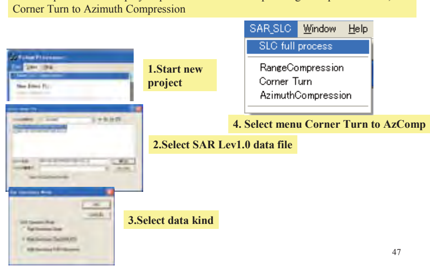
Display Pair Image

- In dual polarization mode, we have 2 image data (HH, HV).
- The data can be displayed and switched from check menu.

50

PALSAR Processor Operation

You can process data step by step manner. The first step is range compression then, Corner Turn to Azimuth Compression



47

In Case Error Happens when running SAR Processor

•In case error happens in the “SLC full process”, start program again but this time from open project.
•Start corner turn and wait until “corner turn complete” message appear.
•Start Azimuth compression.

48

4. SAR Interferogram Generation
4.1 Fringe Program

After processing two images a pair of Single Look Complex data(SLC) is ready. Now you can start the program “PalsarFringe.exe”

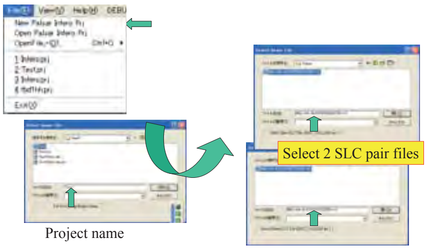
51

4.2 New Functions of Version 3.0

- Version 3 of PalsarFringe is enhanced for Differential interferometry operation.
- For the purpose, SAR image simulation function is implemented. This function uses SRTM DEM which covers most of low and middle latitude area.
- All the process is interactively conducted.

52

4.3 Create New Project and Select Associate Files



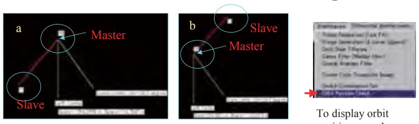
Project name

4.4 Index Image after Opening files

•When you create interferogram, always 2 images(SLC) are selected as specified by initial parameter selection.
•After the initial selection or after select open project, an index images are created and displayed.
•Default display is the first SLC image you have specified.
•By pressing “v” key, you can switch image 1(Master SLC) to 2 (Slave SLC) and vice versa.

54

Selection of Master/ Slave images



a)Master image by observation 1, Slave image by observation 2.

b) Master image by observation 2, slave image by observation 1.

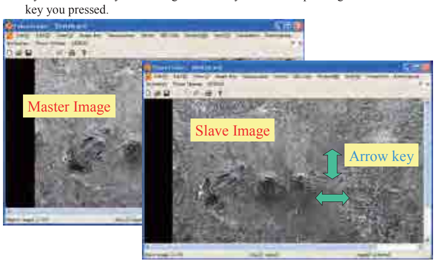
To display orbit position, use above menu.

In order to make fringe phase increase coincide with height increase, slave orbit position must be right of master orbit position in above images. So, b) is OK but in a), phase increase in fringe corresponds to height decrease. If orbit combination looks like a), change scene selection order so that orbit position becomes like b).

55

4.5 Switch Master and Slave images

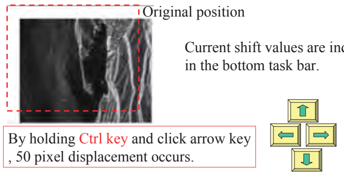
In image display, you can switch master and slave images by pressing “v”key. By click arrow key slave image moves any direction depending on the arrow key you pressed.



4.6 Moving Slave Image

Slave image can move in the display frame while master image is fixed in the frame. This function is used to make conjugate point in two images be close. To move slave image, click arrow key to any direction.
By a click, image is one pixel displaced to arrow direction.

Original position



Current shift values are indicated in the bottom task bar.

By holding Ctrl key and click arrow key , 50 pixel displacement occurs.

57

Revised Key Stroke

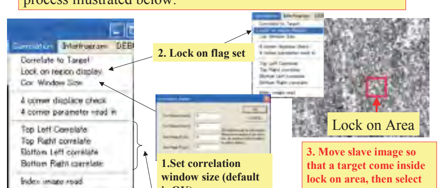
- In the current version new switch function is added.
- “v” key :Switch master and slave images.
- “f” key :Switch master image to fringe.
- “s” key :master image to simulated image
- Shift + “s” key: Fringe to simulated fringe

Last 2 function will work after switching to differential mode.

58

4.7 Lock on any Slave image pixel to Master image pixel by correlation

To correlate master image pixel on slave image. Follow the process illustrated below.

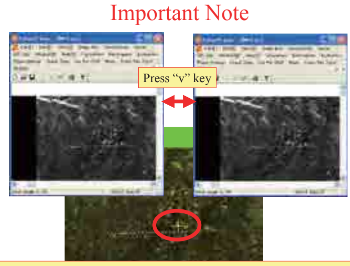


3. Move slave image so that a target come inside lock on area, then select menu Correlation to Target

5. Apply correlate to Target at near 4 corner of master image and select menu according to the set position.

59

Important Note

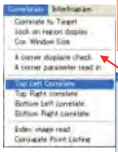


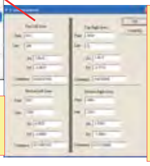
After adjustment by Menu “Correlation, you must check stability of the conjugate point (no motion) by pressing “v” key.

60

4.8 Establish 4 corner Correlation

Firstly, select lock on points at near four corners (Top Left, Top Right, Bottom Left and Bottom Right).
Then lock on at each point by selecting menu item (Top Left Correlate, …… Bottom Right Correlate).





After 4 corner correlation was set, select menu 4 corner displace check. Then a dialog appears as shown below. Check the similarity of Dx and Dy in the dialog, then press "OK". If the number is to much different with each others, cancel. Set correlation again.

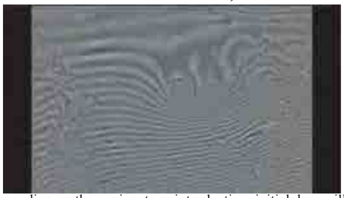
Horizontal pair is recommended to be within 1 pixel

Slave Image Lock on for an arbitral pixel

- After 4 corner point is set, pixel of slave image at any position in the image will be located to fit with corresponding master pixel.
- By holding "m" key and click mouse at any point in the image. Then slave image at clicked point will move to lock on to corresponding master pixel.

62

Initial Fringe(without flat earth correction)

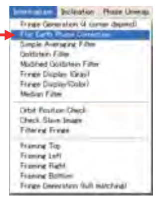


Depending on the conjugate point selection, initial dem will have different patterns.
This will be corrected by applying "Flat Earth Correction" in the interferogram menu.

After fringe generation slave image is replaced by fringe.

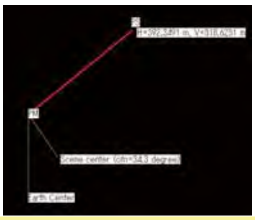
Flat Earth Correction

- Due to the fringe inclination, even a seashore or lake shore looks not flat.
- But using the natural object, we can correct water shoreline inclination.
- Put 3 point along a water land boundary to make a triangle which must be a horizontal plane.
- In the ALOS system orbit information is so accurate that we can correct flat erath relying on the information.
- By the menu selection as shown in the right menu, the image inclination will be corrected using orbit information.
- Exact equation of flat earth correction is shown in the next page.



In the current version "Flat Earth Correction" is done associated with "Fringe generation". You don't need to awared of this process.

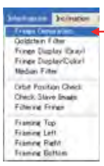
Relative orbit position display



Relative orbit position is displayed at the top left corner of window
From the coordinates, height sensitivity
(altitude change per fringe cycle = a rank) will be calculated

4.9 Fringe Generation

- After establishment of 4 corner lock on, fringe generation is an simple process.
- Select menu "Fringe generation".



In the new version 2.8.4 or later, Fringe Generation and Flat Earth correction is performed succeddingly when you select Fringe generation.

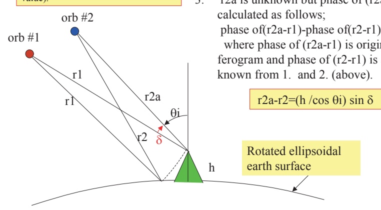
64

Equation of Flat Earth Correction

Note: phase is the fraction part of a value divided by wavelength.
In SAR fringe, this becomes as ;
phase=(r2a-r2)/λ-[(r2a-r2)/λ],
where l is wavelength and [] is Floor and ceiling function (integer part of value).

1. r1 is calculated from slant range line number and orbit parameter.
2. r2 is calculated conjugate point address (line number) and orbit parameter.
3. r2a is unknown but phase of (r2a-r2) is calculated as follows;
phase of(r2a-r1)-phase of(r2-r1),
where phase of (r2a-r1) is original inter ferogram and phase of (r2-r1) is already known from 1. and 2. (above).

r2a-r2=(h /cos θi) sin δ



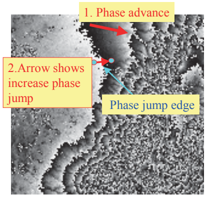
67

After Flat Earth Correction

This fringe coincide with dem.

68

4.10 Understanding Fringe



•Fringe is a gray scaled expression of interferogram.

•Fringe is divided into many sub areas surrounded by phase jump edge as sub area border.

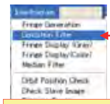
•In a sub area, phase advances in accordance with brightness increase(see 1, in the left image).

•On the contrary, increase phase jump occurs at the bright to dark change at the border(see 2 in the left image).

69

4.11 Filter , Goldstein Filter

- Goldstein filter is a popular tool to reduce fringe noise.
- To apply the filter select menu "Goldstein filter". Then put weighting factor (0-1). Weighting 0 means no filtering and 1 is highest filtering. Usually 0.2-0.7 is adequate value. Usually it is recommended to use appeared default value.



In most cases, apply "Goldstein Filter" once. No other filter is necessary.

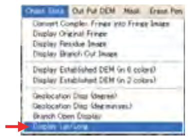
70

4.13 Note on OpenProject

- After conducting new project menu items, you can close the program and restart program with Open Project to go back to the last process before you close the program.
- If you move files to other directory of original point or you import the data (project files and/or SLC files), you must first start with new project menu again and select existing project to overwrite it.
- Then close the project and open the project again.
- All the process parameter is kept as before and move on to next step without conducting interferogram generation again.

73

Display GeoLocation



When you select left menu item, mouse clicked point geolocation (latitude nd longitude) is displaied in the bottom task bar.

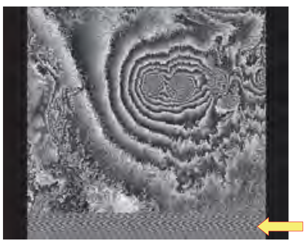
74

4.12 Sigma Filter

- Sigma filter is a kind of Median filter but dedicated to preserve phase continuity.
- The filter works any point either before Goldstein filtering, after it.
- Multiple operation is also possible.

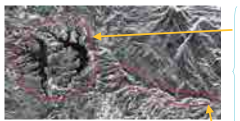
71

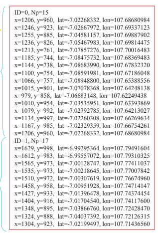
Results of filtering (Goldstein)



72

Save Polygon parameter as Geolocation data



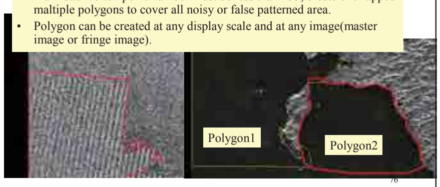


When you select menu "display lat/lon" as shown in previous page and create polygons and save, text file with the polygon file will be saved as text. The text file name is the same with your specified polygon file but the attribute of "txt".

75

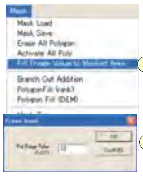
4.14 Masking Sea or Lake Area

- Some times, sea or lake area shows noisy or periodic false pattern in fringe image.
- The area must be cut out for phase unwrapping.
- To clear the area first make polygons to enclose the area. Since individual vertex point number must be less than 255, create overlapped maltiple polygons to cover all noisy or false patterned area.
- Polygon can be created at any display scale and at any image(master image or fringe image).

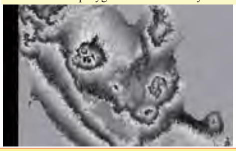


76

Masking polygon with a Fringe value



•After creating polygon(s), select menu and put a fill fringe value.
•After a while polygon will be filled by the value



In this example which shows an island, shore line is not a same gray value due to mostly plane inclination of fringe.
To correct the inclination, it is easier to apply differential interferogram and inclination correction (see Chapter 6.6).

77

5. Phase Unwrap

(Unweighted Least Mean Square Method Mark D. Pritts's method)

Currently several unwrap method is under development in this program. Wait for next version for complete the process.
Phase unwrap function is now moved to separate program "PALSAR_PhaseUnwrapV1.1.4.exe".
Use the program for phase unwrap.

78

Unwrapped phase (16bit)

81

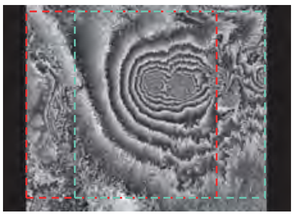
5.3 Out Put DEM

- Convert to DEM value
- Fore shortening correction(not implemented yet)
- Geotif output
- Rotated to Georeference coordinate system (north up but a range line is horizontal).
- Original image is also cut and rotated and GeoTiff out.

dhp=h/sin(θ1)
dl=dhp*sin(δθ)
δθ=Bperp/R1
h/cycle=λ/2*sin(θ1)/sin(δθ)
(See page 18)

82

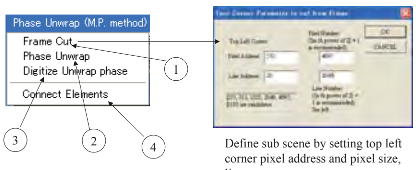
5.1 Divide to Sub scenes



In the current version, process unit is limitted to a specific sizes. To cover full valid area, diveide source image into 2-4 sub images.

79

5.2 Unwrap Flow



Define sub scene by setting top left corner pixel address and pixel size, linseze.

Both pixel and line can be 4097 and this is most recommendable value for FBD data set.

80

6. Differential Interferometry

- Differential interferometry is a good tool to monitor precise displacement or changes happened in between the two observations for inteferogram genaration.
- It can be used to monitor small land deformation in an earthquake, industrial or city area land subsidence due to overwelling in the area, monitoring large scale land slide, or monitoring volcanic activities.
- To achieve differential interferometry, we need a reference Digital elevation model and currently Shuttle Radar Topgraphic Mission (SRTM) provides us a good quality DEM.
- In the current program the DEM is used. Most of the area except USA are covred by 3 arcsec spacing DEM which is almost enough to be used as the reference DEM.

83

6.1 Import SRTM Dem and Geoid Data

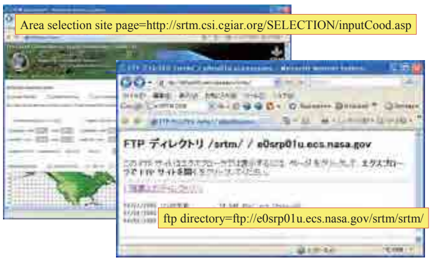
- Currently SRTM dem can be down loaded from various site supporting SRTM project.
- The dem is edted to 1 degree segment and modified to geoid dem using EGM96 geoid.
- For current use, rotated ellipsoidal dem is necessary. So, geoid data is also necessary to convert SRTM dem int rotated ellipsoidal dem.

http://cddis.nasa.gov/926/egm96/egm96.html

Geoid data=WW15MGH.DAC

84

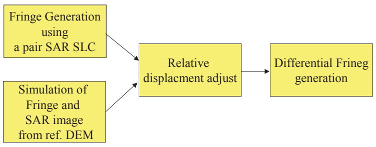
SRTM site



85

6.2 Process of Differential Interferometry

Process of differential interferometry is shown in the process image.

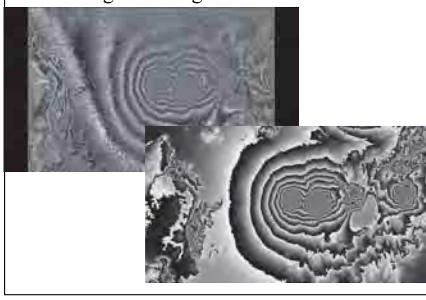


86

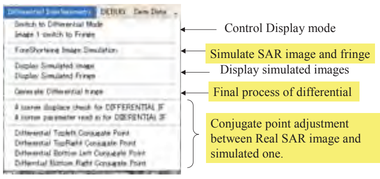
Original Image and Simulated Image

89

Original Fringe and Simulated one



6.3 Differential Interferometry Menu Items



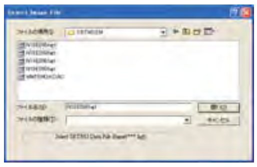
87

6.4 SAR Image Simulation

When you select simulation menu item, a dialog apperas to show necessary SRTM dem and Geoid files. Take note the file name and cancel dialog at the moment. Prepare the data in a folder and repeat the process again but this time selct OK in the dilalog to go next step.

88

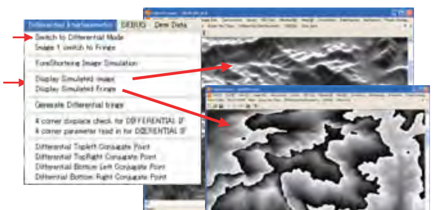
SAR Image Simulation(2/2)



Go to SRTM DEM and Geoid file folder, then open indicated image.
Simulation process starts and after several minutes simlation will be complete.

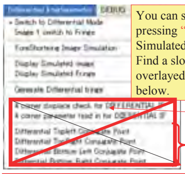
91

Display simlated image



Check "Switch to Differential Mode" and select menu "Display…" image will be displayed.

6.5 Match Image Position



You can switch original image and simulated image by pressing "v" key.
Simulated image can move by pressing arrow key.
Find a slope feature and adjust the position to exactly overlayed to orginal image. Then follow the process below.

This functions are not necessary any more. In the new version V3.5.2 or later, the menu item is deleted.

Using SRTM dem and PALSAR orbit parameter, relative distortion of simulated image from original image is negligible. You can use the same displacement value at 4 corners. So after adjusting a displace of simulated image by arrow key, apply "Generate Differential Fringe".

Default position to match is horizontally 300 pix and vertically 0.

93

Key Assignment in Differential mode

Key	Function
s	Switch Master image and simulated image
f	Switch Master image and interferogram
k	Fringe square parameter in vertical cycle increase
SHIFT + k	Fringe vertical cycle decrease
L	Fringe horizontal cycle increase
SHIFT + L	Fringe horizontal cycle decrease
h	Fringe square parameter in vertical cycle increase
SHIFT + h	Fringe vertical cycle decrease
j	Fringe horizontal cycle increase
SHIFT + j	Fringe horizontal cycle decrease

94

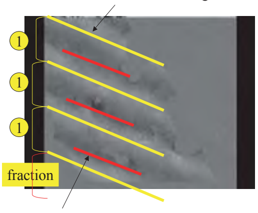
Differential Image Display

In the initial differential fringe, often stripe of bright band appears. This is due to a remaining error of relative orbit position between master image orbit parameter and slave image orbit parameter.

97

6.7 Inclinaton Correction(1/3)

Middle of a bright band

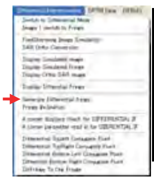


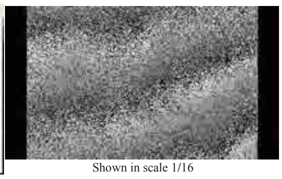
Boudary of adjacent band

In this differential fringe case, 3 brightness band plus a fraction part is recognized in vertical direction.
Since the bright band is inclined, horizontal inclination also exist.

98

6.6 Calculate Differntial Fringe





Shown in scale 1/16

Select "Generate Differential frine", the process will be executed. When the process complete, differential interferogram will be appeared on the display.
You can display the differential interferogram from menu.

95

Differential Image Display

1 cycle brightness change

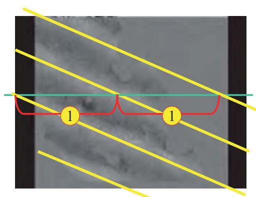
Shown in scale 1/16

2 cycle brigthtness change

In the current case differential calculation was conducted on SRTM DEM so the difference shows deviation from SRTM dem.
Looking at the fringe, you recognize 2 cycle almost linear brightness change in the vertical direction and 1 cycle in horizontal direction.

96

Inclinaton Correction(2/3)



Also, 2 brightness band plus a fraction part is recognized in horizontal direction.

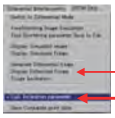
99

Correction of inclination using GUI

Usually initial differential fringe looks like what is shown left. In a large area average scene must be almost flat. The initial view has apparent inclinations which must be corrected.
In the current program this inclination is corrected by flat plane inclination model.
Interactive operation of this process is shown in the next pages.

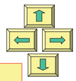
100

Dif. Fringe Inclination Process



Activate visual inclination function by selecting left menu item.

Press arrow key to modify differential fringe.
"Ctrl key + arrow key" is fine adjustment.



Quadratic parameter is able to modify by holding "shift key" and apply above control

101

Flatten differential fringe

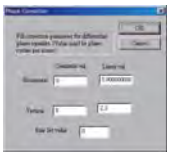
Interactively modified.

By pressing arrow key, fringe inclination is corrected as shown left.

Initial

102

Apply the interactive correction parameter



After adjusting parameter, select menu "Fringe Inclination" to show above dialog.
The parameter is already picked up in accordance with the interactive modification.
Click OK to start inclination correction.

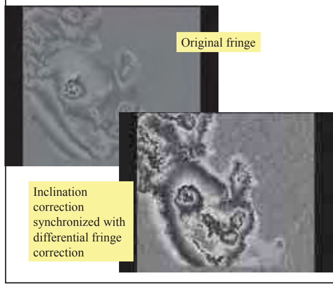
103

Inclination Correction(3/3)

Resultant inclination correction appears as shown above. In inclination correction process, original interferogram is corrected simultaneously and result become the fringe shown in the next page.

104

Inclination correction on original Fringe



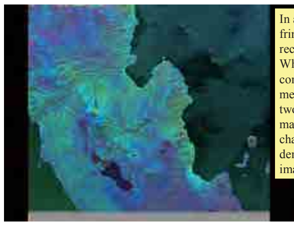
Original fringe

Inclination correction synchronized with differential fringe correction

Inclination correction on differential interferogram is synchronized with the original interferogram correction. When you apply inclination correction on dif. Fringe, original interferogram inclination is corrected accordingly.

105

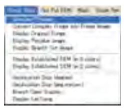
Color Composite of Dif. Fringe



In a corrected differential fringe no bright band is recognized.
When you generate a color composite, different color means some changes between two observation date of master and slave image plus a change between reference dem generation and master image generation.

106

GeoTiff output of color composite

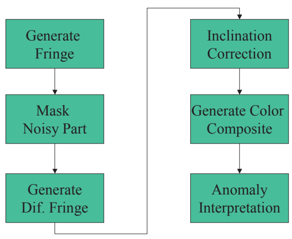


After creating color composite image either differential or original and display interferogram (original or differential), this image can be converted to geotiff file by selecting menu shown left.
In this process unnecessary blank area can be cut out from frame dialog(left bottom).
Output filename is specified by your input in standard file out dialog.
Following 3 geotif files with the last characters of "G.tif" will be created.
1) Color composite (differential or original).
2) SAR image of the same area.
3) SAR fringe (or differential fringe) of the same area.

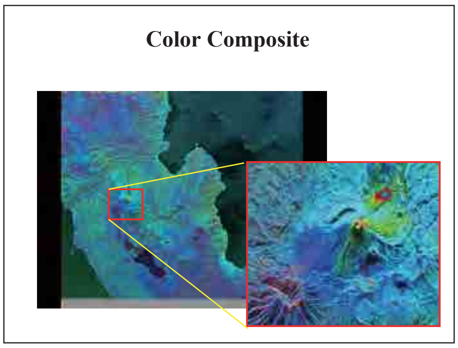
107

6.8 Change Detection by Differential Interferometry

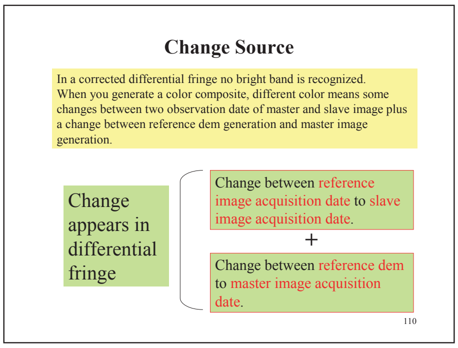
Process Flow:



108

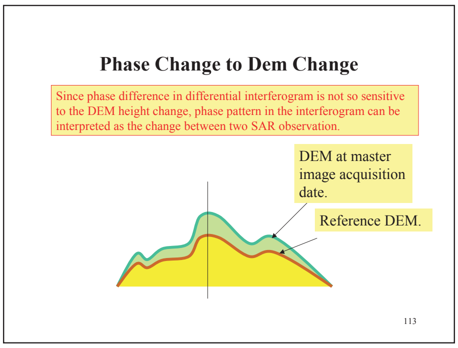


Color Composite

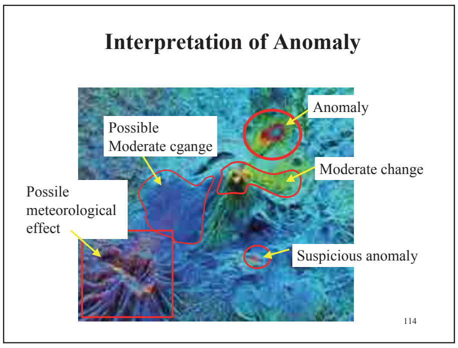


Change Source
In a corrected differential fringe no bright band is recognized.
When you generate a color composite, different color means some changes between two observation date of master and slave image plus a change between reference dem generation and master image generation.
Change appears in differential fringe
Change between reference image acquisition date to slave image acquisition date.
+
Change between reference dem to master image acquisition date.
110

55

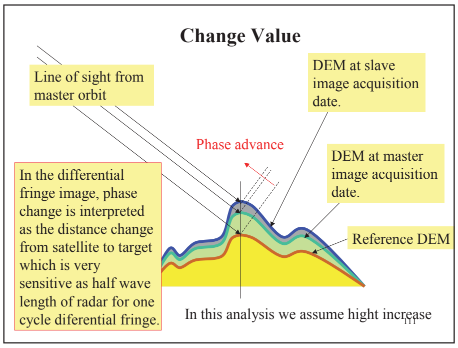


Phase Change to Dem Change
Since phase difference in differential interferogram is not so sensitive to the DEM height change, phase pattern in the interferogram can be interpreted as the change between two SAR observation.
DEM at master image acquisition date.
Reference DEM.
113

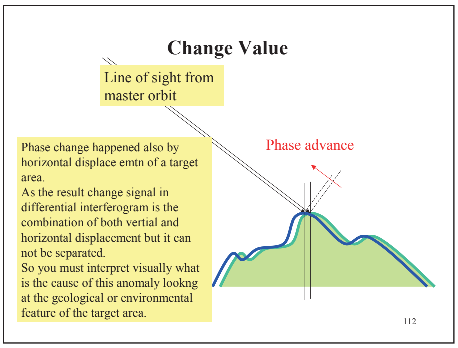


Interpretation of Anomaly
Anomaly
Possible Moderate cgange
Moderate change
Possile meteorological effect
Suspicious anomaly
114

57

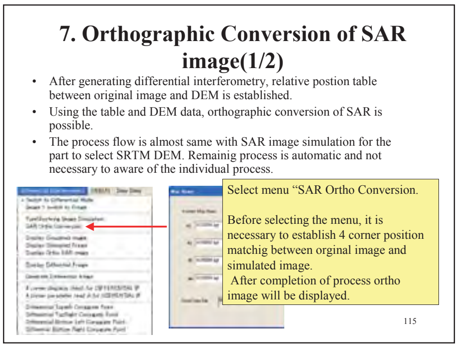


Change Value
Line of sight from master orbit
DEM at slave image acquisition date.
Phase advance
DEM at master image acquisition date.
In the differential fringe image, phase change is interpreted as the distance change from satellite to target which is very sensitive as half wave length of radar for one cycle diferential fringe.
Reference DEM
In this analysis we assume hight increase
111

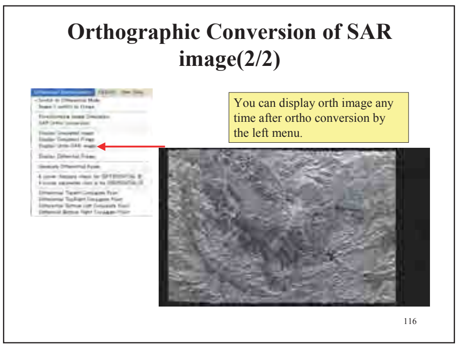


Change Value
Line of sight from master orbit
Phase change happened also by horizontal displace emtn of a target area.
As the result change signal in differential interferogram is the combination of both vertial and horizontal displacement but it can not be separated.
So you must interpret visually what is the cause of this anomaly lookng at the geological or environmental feature of the target area.
Phase advance
112

56



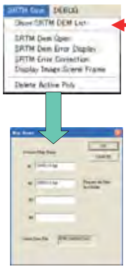
7. Orthographic Conversion of SAR image(1/2)
After generating differential interferometry, relative postion table between original image and DEM is established.
Using the table and DEM data, orthographic conversion of SAR is possible.
The process flow is almost same with SAR image simulation for the part to select SRTM DEM. Remainig process is automatic and not necessary to aware of the individual process.
Select menu "SAR Ortho Conversion.
Before selecting the menu, it is necessary to establish 4 corner position matching between orginal image and simulated image.
After completion of process ortho image will be displayed.
115



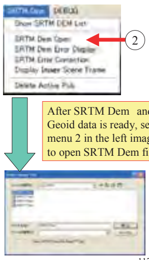
Orthographic Conversion of SAR image(2/2)
You can display orth image any time after ortho conversion by the left menu.
116

58

8. SRTM data Handling
8.1 Open SRTM Dem Files



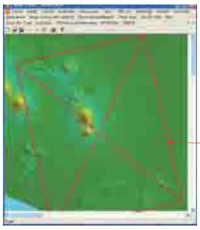
① Select the menu, then a dialog appears to show SRTM dem file name(s) which covres opend SAR image scene. Just click OK to close the dialog.



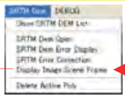
② After SRTM Dem and Geoid data is ready, select menu 2 in the left image to open SRTM Dem file.

117

Display Shadowed SRTM Dem



When you select a Dem in file dialog SRTM dem will be displayed as shown left.
SRTM Dem is Color Coded by altitude and shadowed by slope illumination.

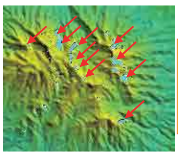


When you select above menu item, SAR image frame of current scene will be displayed.
Selet same menu to erase the frame.

118

8.2 Error Correction of SRTM Dem (1/4)

SRTM Dem some times has defect pixels where Dem value is set to be zero intentionally. For fore shortening correction or differential interferogram generation, these defect point must be repaired in advance.
In this program, interpolation using surrounding valid pixel value is applied.
Defect points are displayed as light blue which is the same color of sealevel but you can recognize defect points as a light blue speckle in high relief area.



Light Blue speckle in the left image (indicated by red arrow) is defect points of SRTM Dem.
Shadow or steep fore slope int Space shuttle radar operation causes such unprocessed pixels.

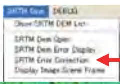
119

Error Correction(2/4)

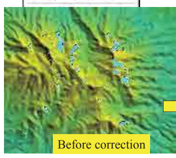
(1)Hold "t" key and click mouse to surround error area by a plygon (yellow line).
(2)Press "r" key to register polygon.
(3)Hold "c" key and click mouse inside the polygon to activate it(Blue polygon).
(4) Hold SHIFT+c key to inactivate.

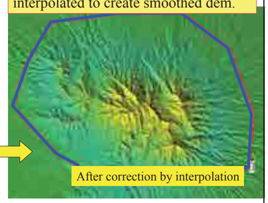
120

Error Correction(3/4)



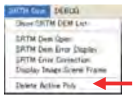
(5)Select menu in the left image, then Error inside active polygon will be interpolated to create smoothed dem.





121

Error Correction(4/4)



To delete polygon, selet left menu. Activated polygon will be erased and remained polygon is renumbered.

122

Ver 1.2 June 2010

PALSAR Phase Unwrap Tool

M. Ono
Remote Sensing Technology Center of Japan

Process conditions

This tool is dedicated to unwrap phase of SAR interferometry for DEM extraction.
Program is designed to work on the results of "PALSARFringeV3" program.

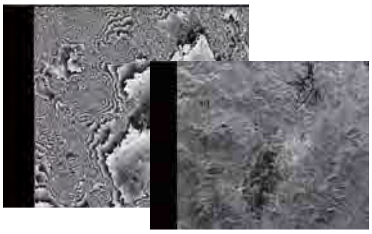
Process environment:
OS: Windows XP (Vista is not recommended but works with minor GUI incompatibilities.)
Memory: more than 1 GB
HD space: more than 10GB free space
Clock Speed 2GHz or better (works on 1GHz but slow)

Start Program

Open Project

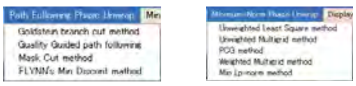
To start process, open inferoproject which was created by "PALSAR_Fringe" program.
In the new system, projectname is "***inf.prj" instead of "***.prj".

Switch Image



By pressing "v" key image and inter ferogram can be switched.

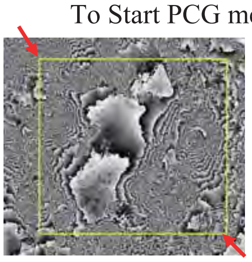
Phase Unwrap Menu Items



There are various method of phase unwrapping, original algorithms are borrowed from an excellent literature (1).
Currently not all process of unwrap menu items work.
PCG method and Min Lp-norm method is recommended tentatively.

(1) Dennis C. Ghiglia and Mark D. Pritt, "Two-Dimensional Phase Unwraping Theory, Algorithms, and Software", John Wiley & Sons Inc., 1998.

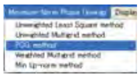
To Start PCG method



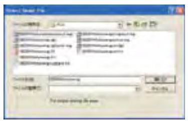
Click mouse at topleft and bottom right of the valid fringe area by holding "c" key.
Target area of unwrap is marked by yellow line square.

Holding "c" key and click mouse again, frame will disappear.

PCG dialog



Select menu "PCG method



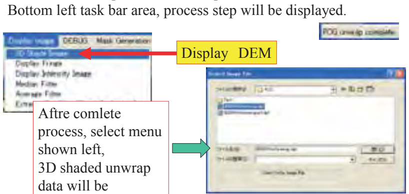
Output file dialog appears.
Create a folder to store unwrapped data with associated several files. In this example, PCG folder is created.
For output file name, you can specify a unique name.

PCG Parameter

In the PCG method, processing frame size is limitted number, select button to set frame.
Left and Top is a mouse clicked point address.
Only red arrow indicated point may be modified.

PCG process check

After selecting "OK" in the previous dialog, unwrap process start and after a while process will complete.
Bottom left task bar area, process step will be displayed.



Aftre comlete process, select menu shown left, 3D shaded unwrap data will be displayed.

Select created **.dgt file.

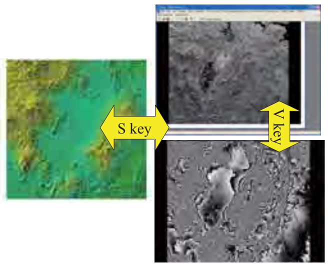
3D shadowed dem

Unwrapped shadow dem is displayed by the selection menu in previous page.
By pressing "s" key, you can switch to original image either intensity image or fringe.

Ortho Image

When you generate ortho dem, original image is converted to ortho and output as geotiff as shown left.

Switch 3D dem and original Image



By pressing "s" key, you can switch to original image either intensity image or fringe. Press "s" key again go to 3D dem image

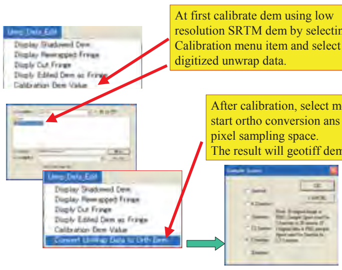
Process Unit

- The size of frame to unwrap fringe have some limit depending on the process you have chosen.
- In PCG method, 2049x2049 is a recommended size but smaller is faster to process. The size of 4097x4097 will work on phase unwrap process but due to large memory consumption, it can not be converted to ortho dem and ortho image (due to out of memory in window system).
- In Min Lp-norm method smaller size like 1024 by 1024 is recommended to achieve a good result.
- Multi element connection is necessary but currently not supported yet.

Convert to Orthographic Dem

At first calibrate dem using low resolution SRTM dem by selecting Calibration menu item and select target digitized unwrap data.

After calibration, select menu to start ortho conversion ans select pixel sampling space.
The result will geotiff dem file.

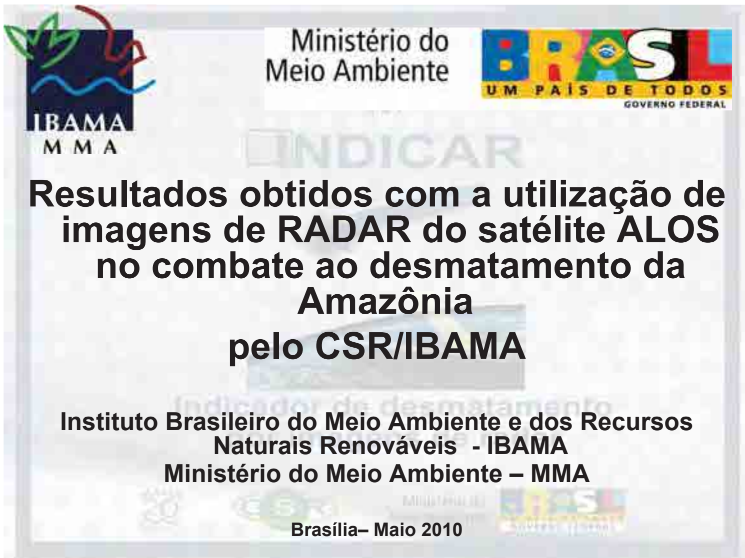


Ortho Dem

Minus dem value

Output from previous page process is Geotiff dem and Geotiff image.
Dem value is calibrated using SRTM ans wihte pattern shown left is minus dem value which may be caused due to unwrap error.

Important note: Due to processing accuracy and speed limit, output DEM is mapped as UTM projection where central longitude is set as the center longitude of the target scene although zone id shows the standard zone numbering. This problem will be solved in the next version.



IBAMA & INPE Cooperação

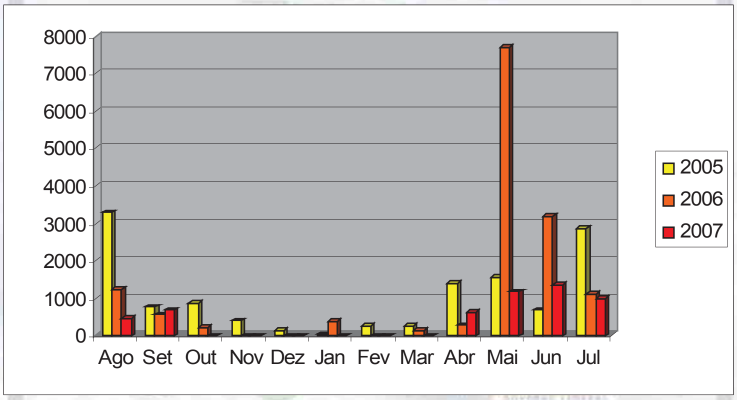
Sistema PRODES
Sistema de medição de desmatamento (intervalo anual)

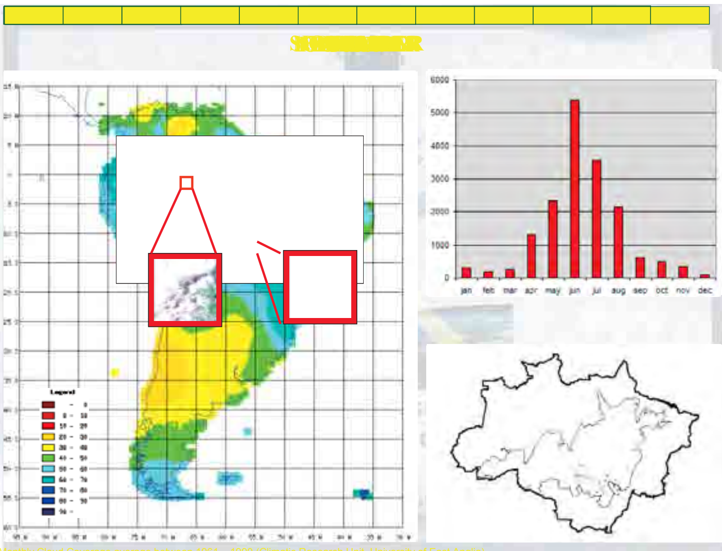
Sistema DETER
Sistema de detecção em tempo real (15 dias)

Sistema DETEX
Sistema de detecção de corte seletivo (Escala Regional)

Sistema Degrad
Detecção de Degradação progressiva (intervalo anual)

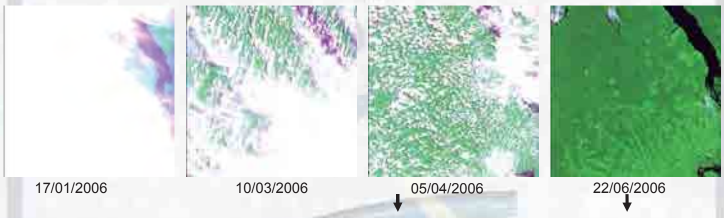
Area Total Detectada pelo Sistema DETER





Podemos detectar o desmatamento com RADAR?

CBERS 2 – 165-103



LANDSAT 19/08/2005 RADAR R99B 07/04/2006 CBERS 2 22/06/2006

Detecção de desmatamento com ALOS PALSAR

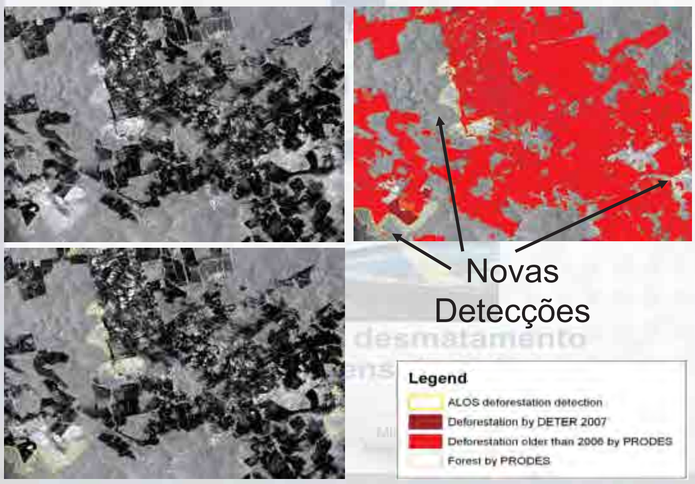
Detecção de novos desmatamentos em áreas cobertas por núvens_

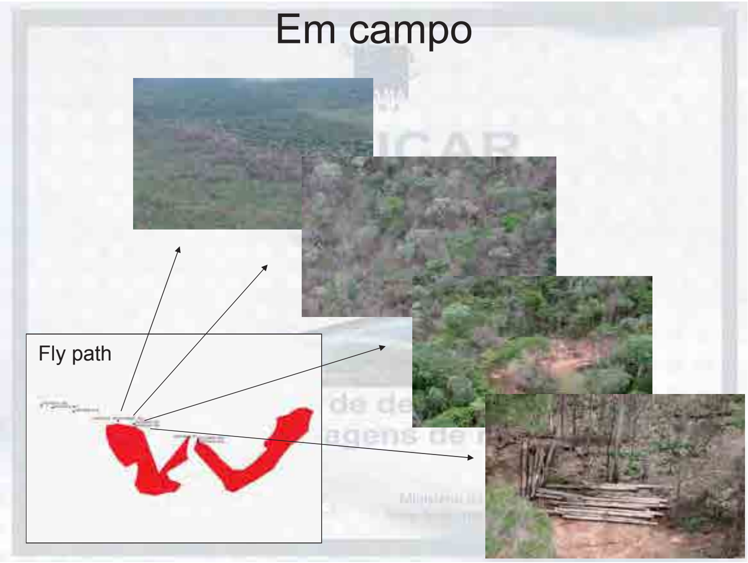
Alvos

Type	Area	Min	Max	Ampl	Mean	Std
DETER Recently (1)	2279	-12,330	4,204	16,534	-4,992	1,893
Forest by PRODES (2)	132020769	-15,520	0,178	15,699	-7,254	1,818
Deforest by PRODES (3)	162780000	-20,374	0,899	21,273	-11,020	2,505

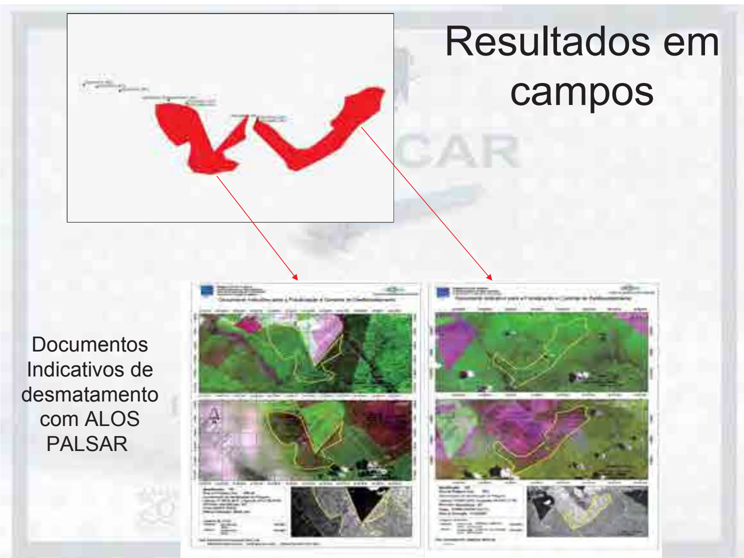
(1) (2) (3)

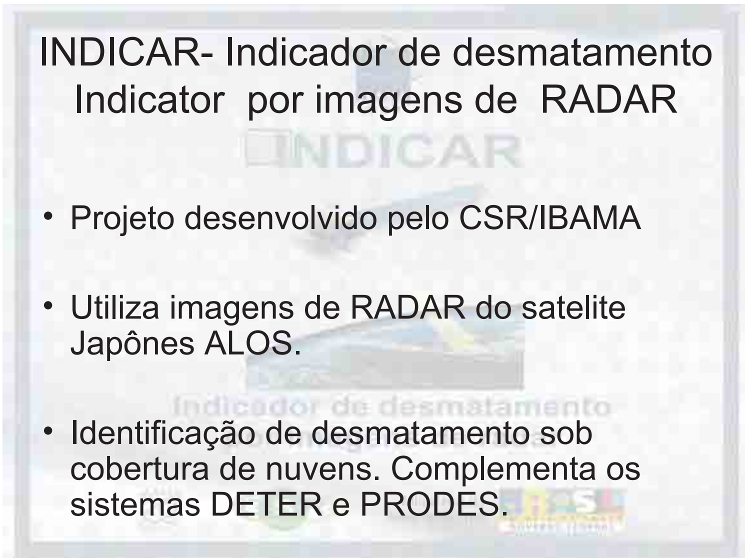
Máscara PRODES




Em campo
Fly path

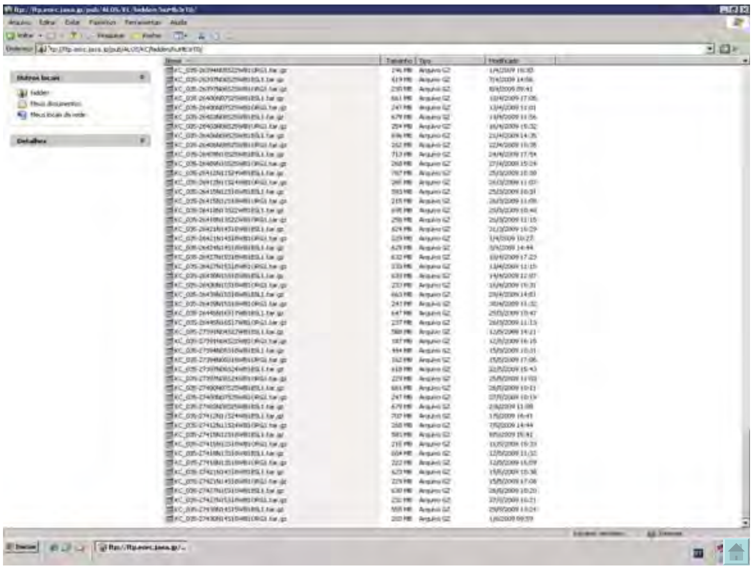

IBAMA
MMA
INDICAR
Indicador de desmatamento
por imagens de radar
IBAMA 20
CSR
Ministério do
Meio Ambiente
BRASIL
UM PAÍS DE TODOS
GOVERNO FEDERAL

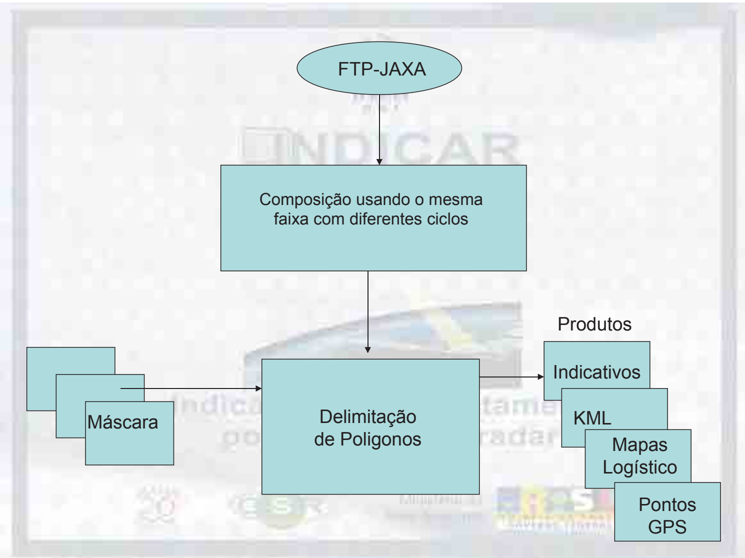

Resultados em
campos
Documentos
Indicativos de
desmatamento
com ALOS
PALSAR

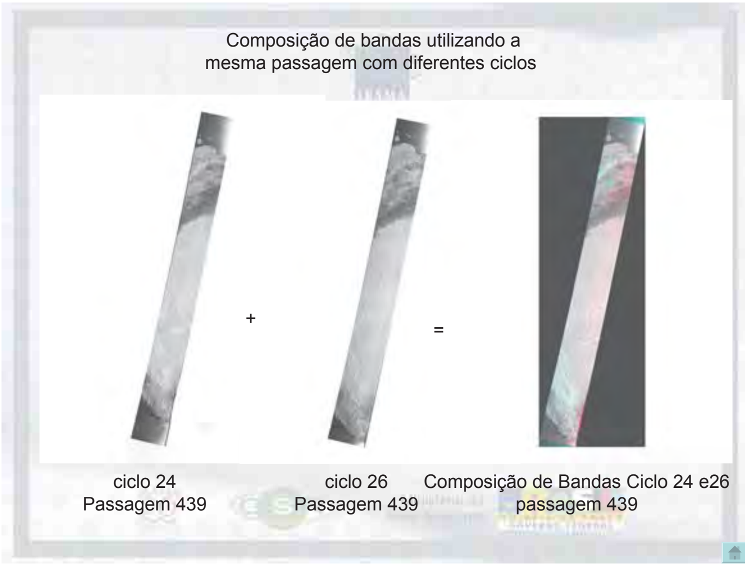

INDICAR- Indicador de desmatamento
Indicator por imagens de RADAR
• Projeto desenvolvido pelo CSR/IBAMA
• Utiliza imagens de RADAR do satelite
Japônes ALOS.
• Identificação de desmatamento sob
cobertura de nuvens. Complementa os
sistemas DETER e PRODES.

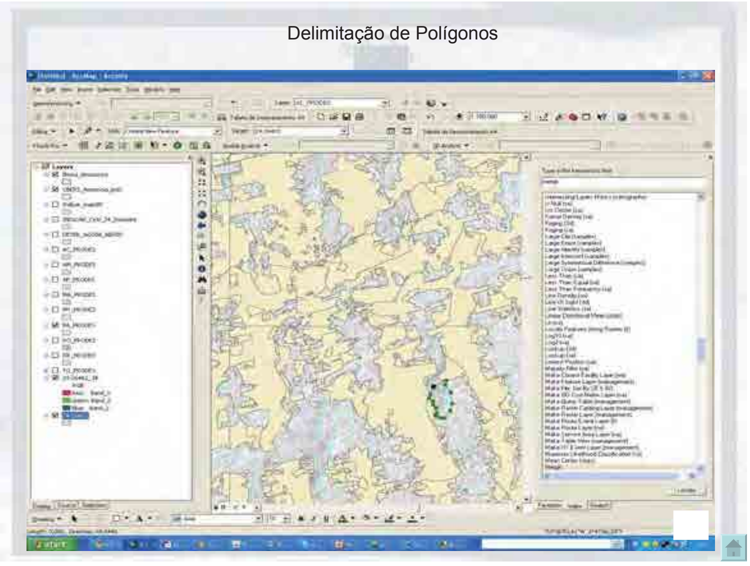
INDICAR Metodologia

- Utiliza imagens ScanSAR com 100 metros de resolução.
- Composições Multitemporais com imagens de RADAR.
- Máscara com PRODES e DETER
- Delimitação de Polígonos e validação com imagens opticas (e alguns saídas a campo).

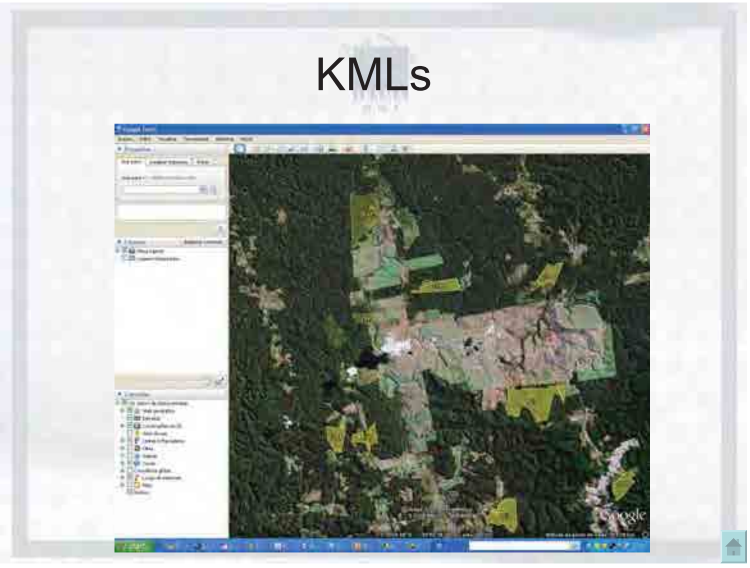


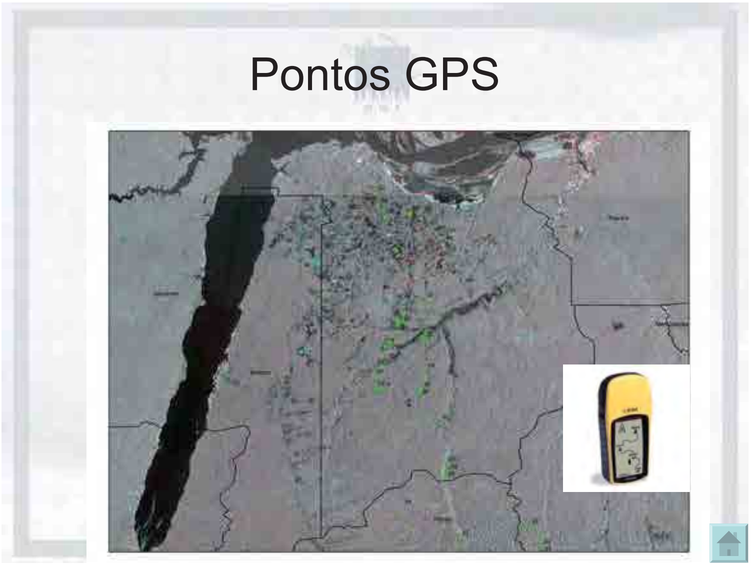





Delimitação de Polígonos


Mapas Logísticos

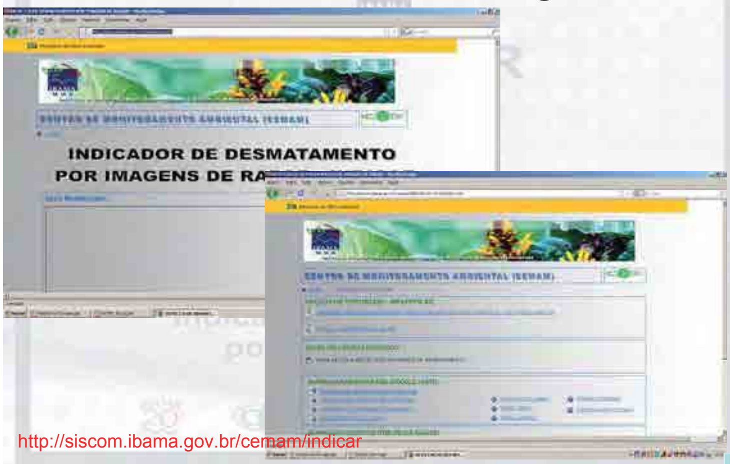

KMLs


Pontos GPS

Máscaras

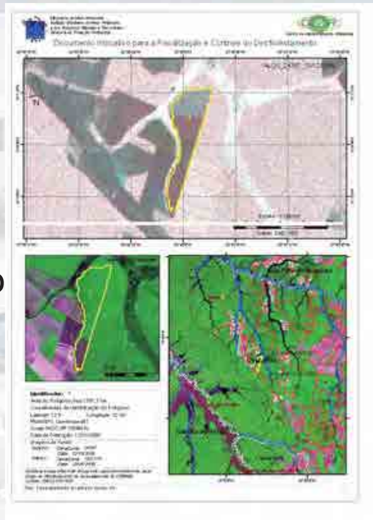
- PRODES 1997 até Agosto de 2009;
- DETER August 2009 até março de 2010
- INDICAR ciclos anteriores

INDICAR Web Page

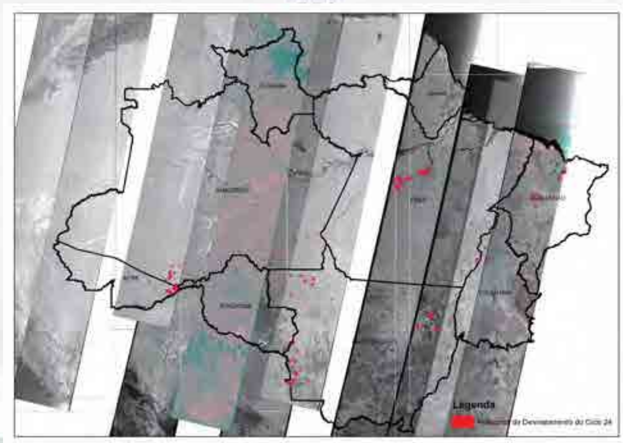


http://siscom.ibama.gov.br/cemam/indicar

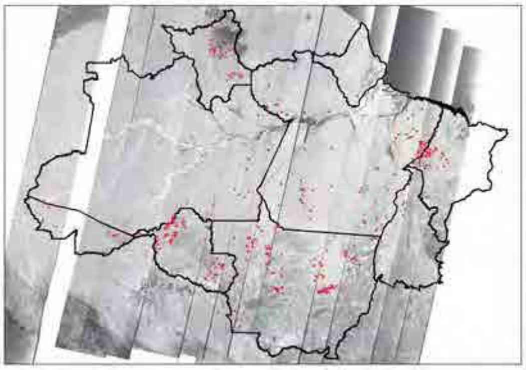
Documento Indicativo de desmatamento pelo INDICAR



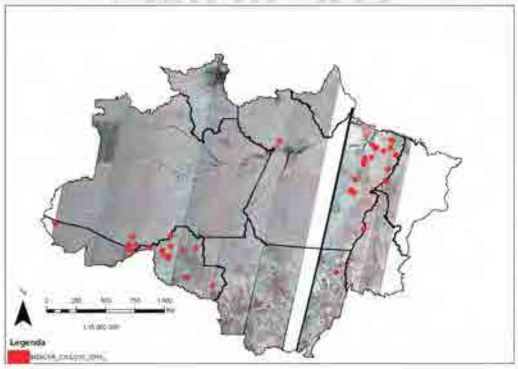
Resultados INDICAR Dezembro de 2008 (Ciclo 24)



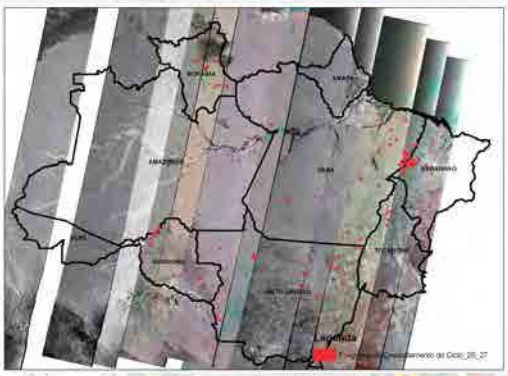
Resultados INDICAR
maio de 2009 (Ciclos 26 e 27)



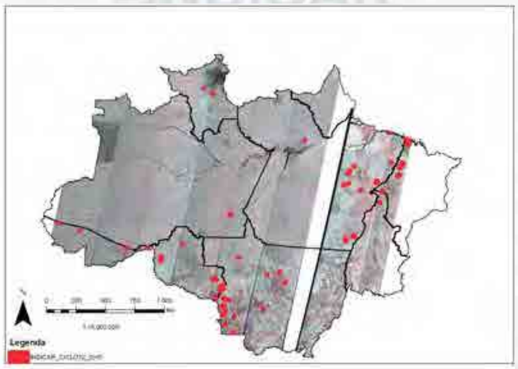
Resultados INDICAR
Dezembro 2009 (Ciclos 29-31)



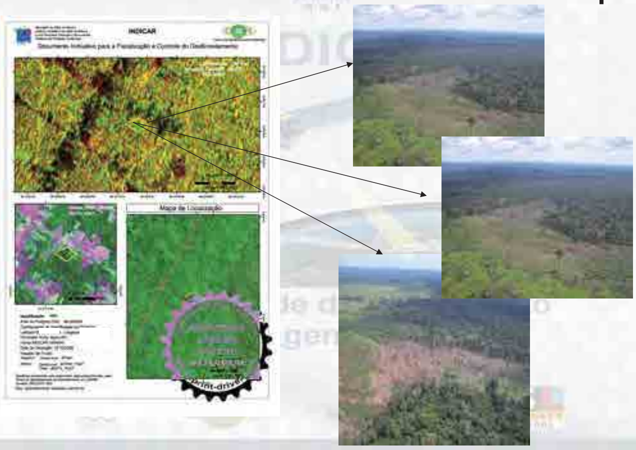
Resultados INDICAR
Novembro 2009 (Ciclos 28-30)



Resultados INDICAR Janeiro
2010 (Ciclos 30-32)



INDICAR Resultados em campo



STAFF

- Humberto Mesquita Jr.
- Marlon Crislei Silva
- Daniel Freitas
- Felipe Luis Matos
- Rodrigo Souza
- Werner Gonçalves

INDICAR Resultados em campo

Muito Obrigado

csr@csr.ibama.gov.br