PALSAR CAL VAL report to K&C

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JAXA/EORC

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- Reference：Initial CALVAL Plan, Initial CALVAL procedure

After CVST4

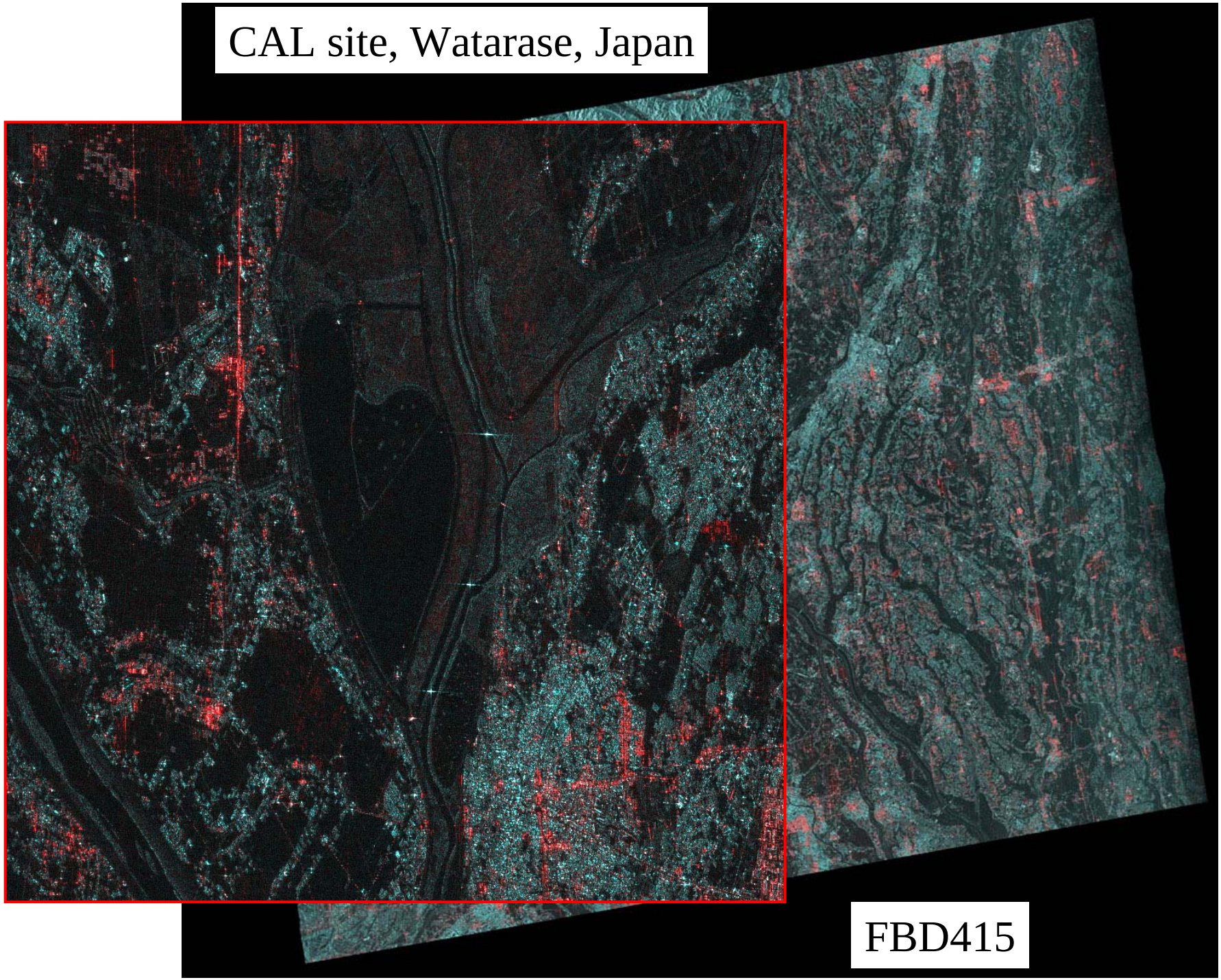
Operation for frozen orbit was conducted on Aug. 5 and 7. A 500 meter orbital tube was achieved.

Correct attenuators were uploaded to PALSAR on Oct. 5.

Firmware corrected for 1 second delay was uploaded to ALOS on Sept. 22.

Large range ambiguities appeared at 41.5 selected 34.3 as the main operation beam (Oct 2).

Software
Range time offset was retuned.


CAL site, Watarase, Japan
FBD415

1. Accuracy Goal and verification method（PALSAR）

Products	Goal	reference
Standard products –1.1 –1.5	geometry 100 m radiometry 1.5 dB（abs.） 1.0 dB（relative） 0.2 dB(amp VV/HH) 5° （phase error VV/HH）	CR, ARC's positions CR, ARC CR, ARC、Amazon CR
High level products –Ortho –DEM	geometry 50 m（horizontal） radiometry 30 m（vertical） 1.5 dB（ex. layover）	CR, ARC's positions GCP,DEM CR,ARC
Research products Surface deform mosaic soil moisture snow map biomass map sea ice	geometry 100 m radiometry 5mm 1.5 dB	Landsat image GPS Amazon image

2.Distribution schedule standard products：9 mo. After launch（Limited Uncaled data distributed in cal/Val phase）
high level products：One year after the launch
resercah procuts: One year after the launch

2 Characterization

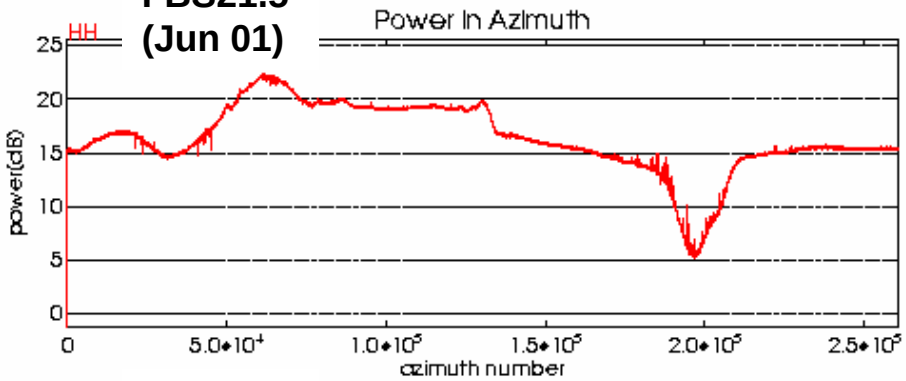
Collects the important information of the PALSAR calibration trough the statistical evaluation of the PALSAR raw data. Following is the sample info.

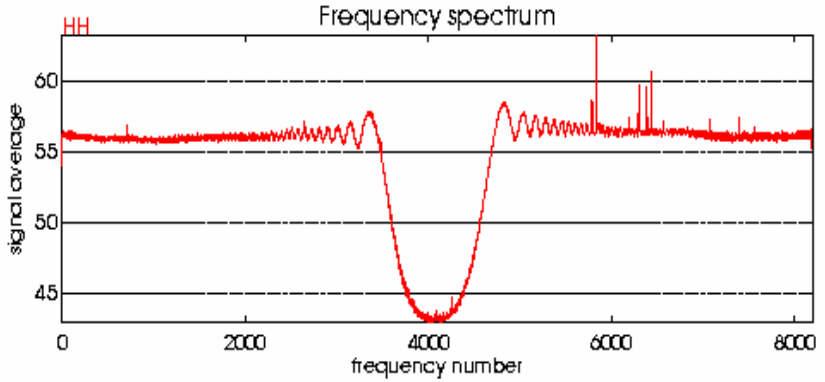
Stability
Saturation property
Interference from the radar

	FBS	FBD	PLR	WB1	WB2
I	16.049	16.188	16.254	16.245	16.041
Q	15.850	15.973	16.078	15.950	15.835
Gain diff. of I/Q	1.007	1.010	1.001	1.015	1.008
Phase diff. of I/Q(deg)	1.598	1.579	1.577	1.581	1.597
SNR (dB)	8.4235	3.3580	8.7118	7.9256	8.7332
Chirp rate (Hz/s)	-1.03158E+12	-5.15923E+11	-8.50977E+11	-5.15903E+11	-1.03159E+12
Saturation	Attenuator for basic mode is well adjusted.				
Interference	In general, it became smaller than JERS-1 (Tr power) Some times, wider band signal observed.				

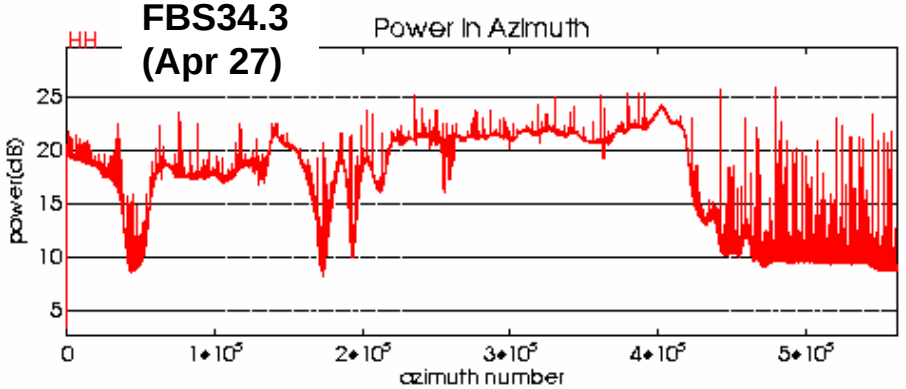
Noise depends on off-nadir angle

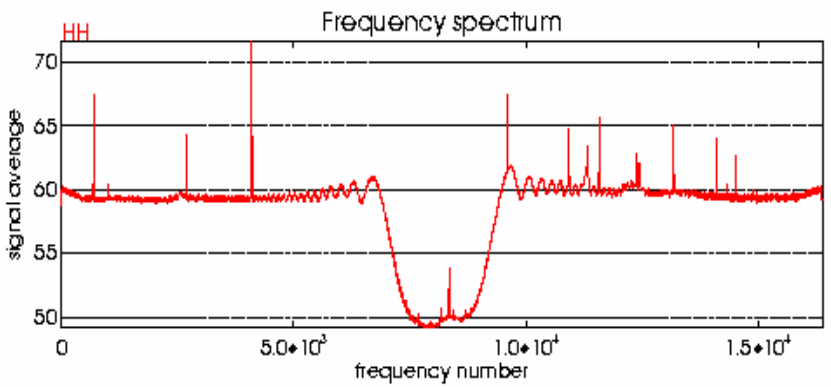
FBS21.5 (Jun 01)



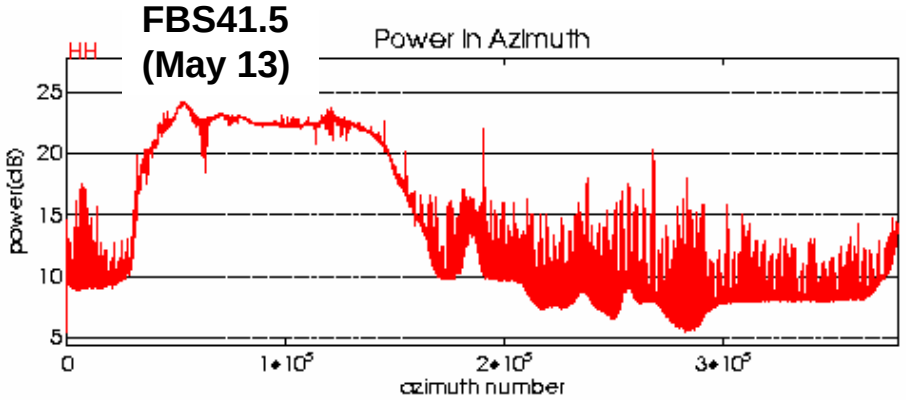


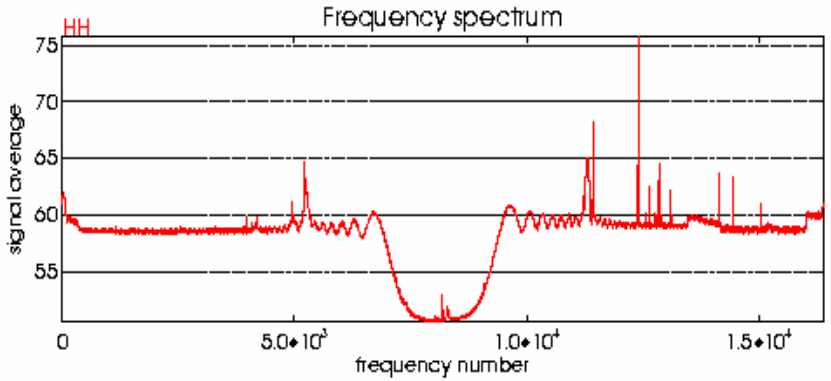
FBS34.3 (Apr 27)



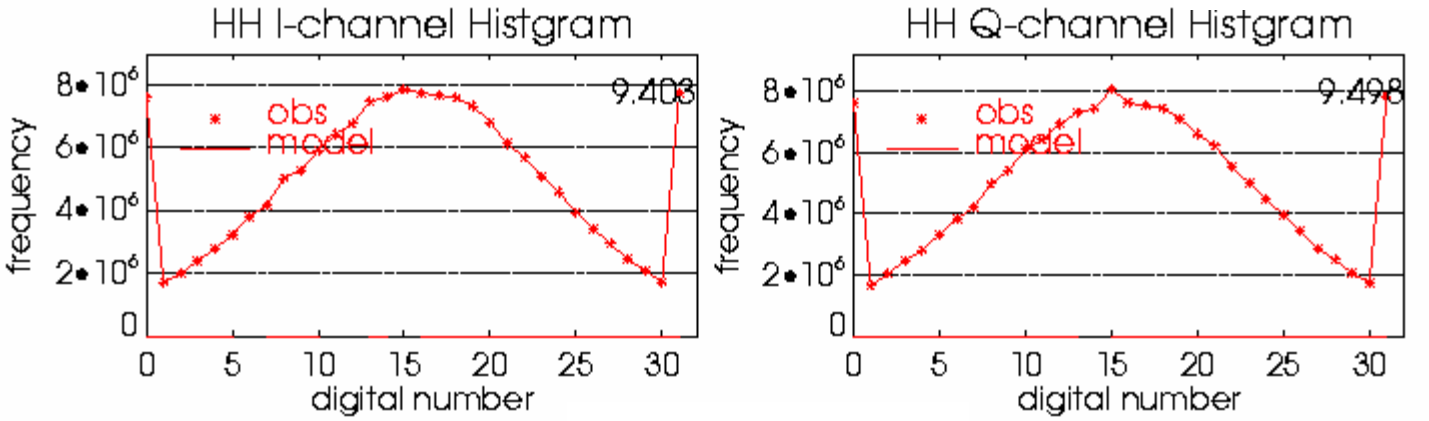


FBS41.5 (May 13)





./FBS343-0/20060321/RSP413/W0058156001-01-001/ **(Biwa Lake)**



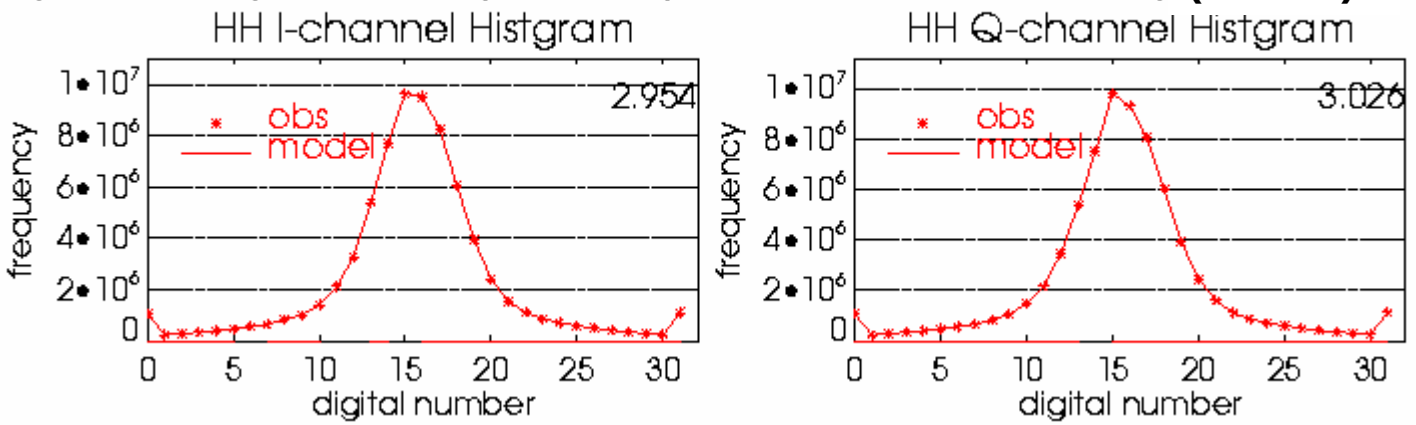
Attenuator: Auto

Before：too large Receive gain, saturation

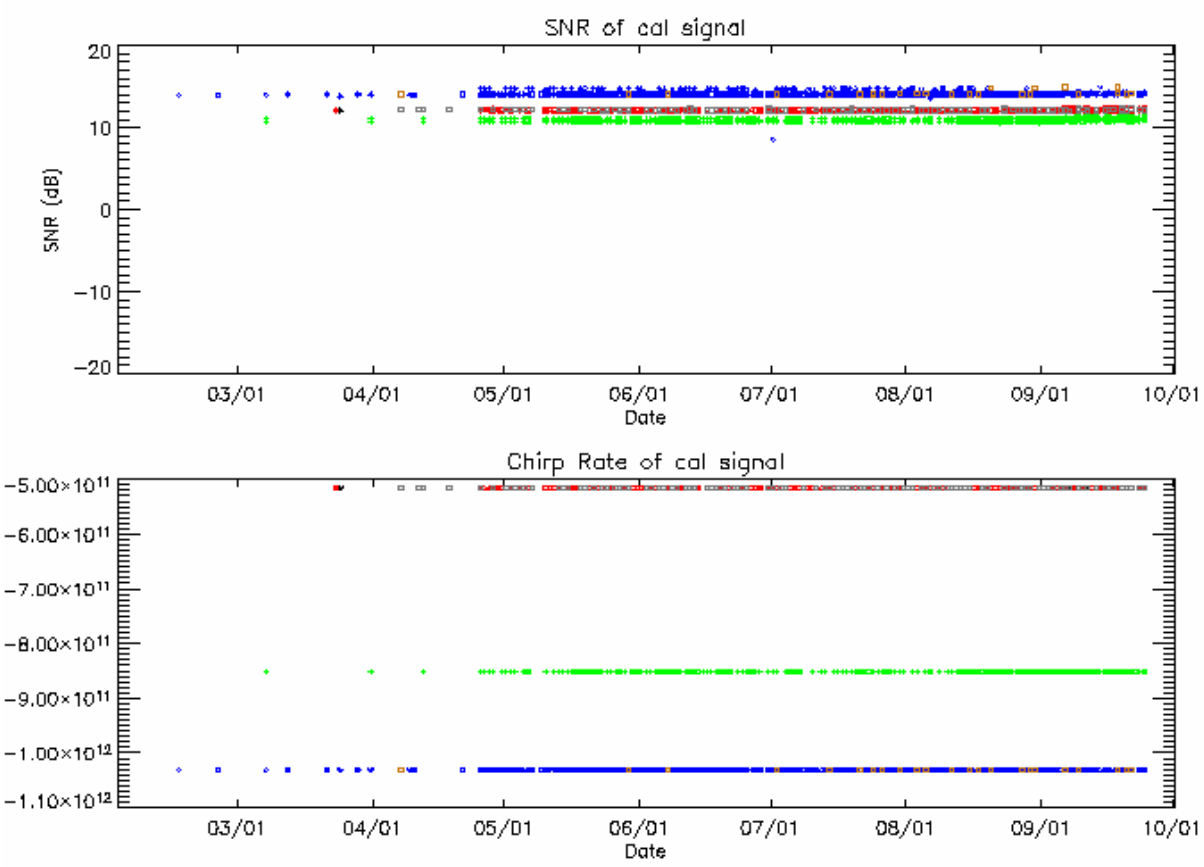
—>After ATT tuning, no more large saturation

Attenuator: 25

./FBS343-0/20060528/RSP417/W01253



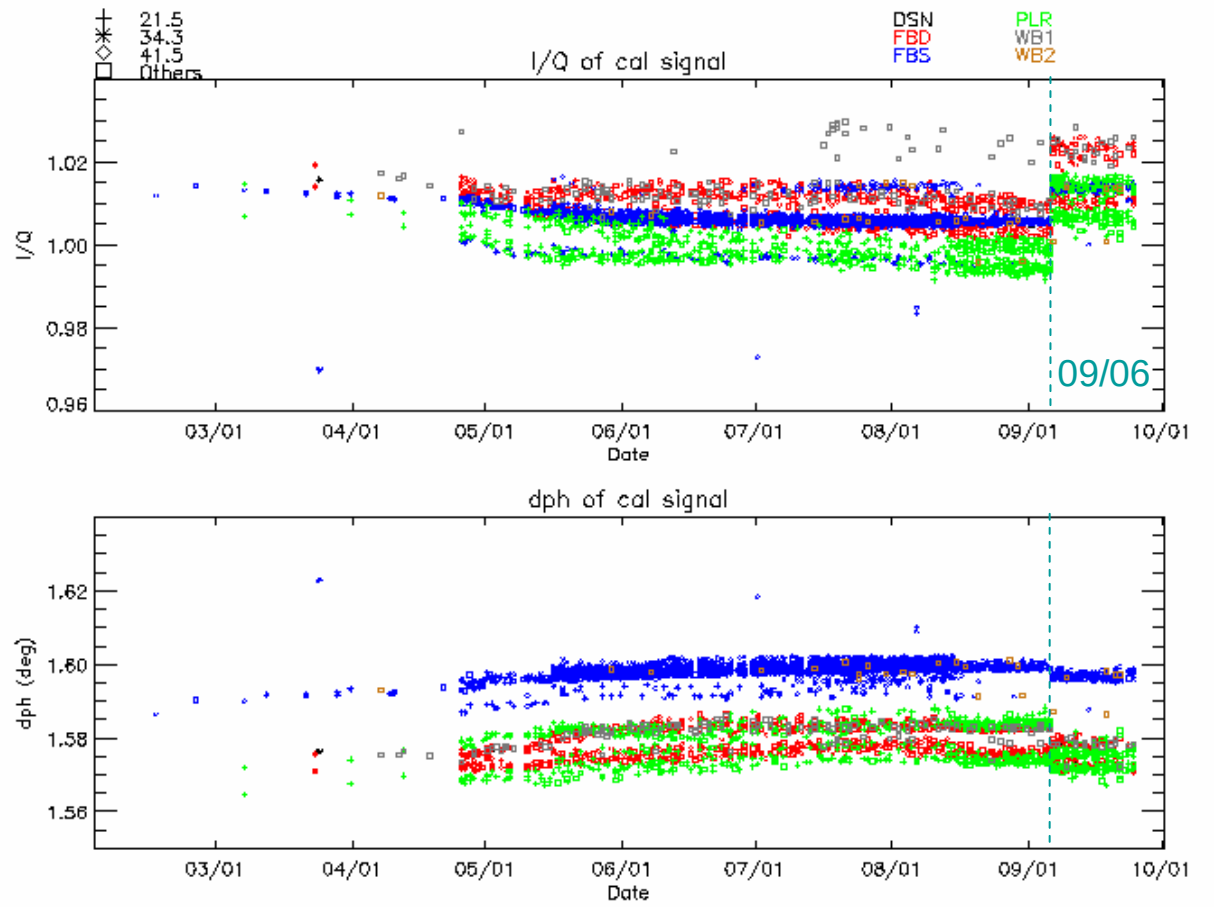
Long history of the calibration data



	SNR (dB)	Chirp rate	
	Average	Average	Std. dev.
FBS	14.056	−1.03158E+12	3.1E+07
FBD	12.142	−5.15923E+11	2.2E+07
PLR	10.892	−8.50977E+11	3.5E+07
WB1	12.126	−5.15903E+11	1.4E+07
WB2	14.200	−1.03159E+12	7.7E+07

- SNR is high and stabilized.
- Chirp rate deviates slightly, and changed a bit on Sept 6 2006. (But, this change does not impact of image quality)

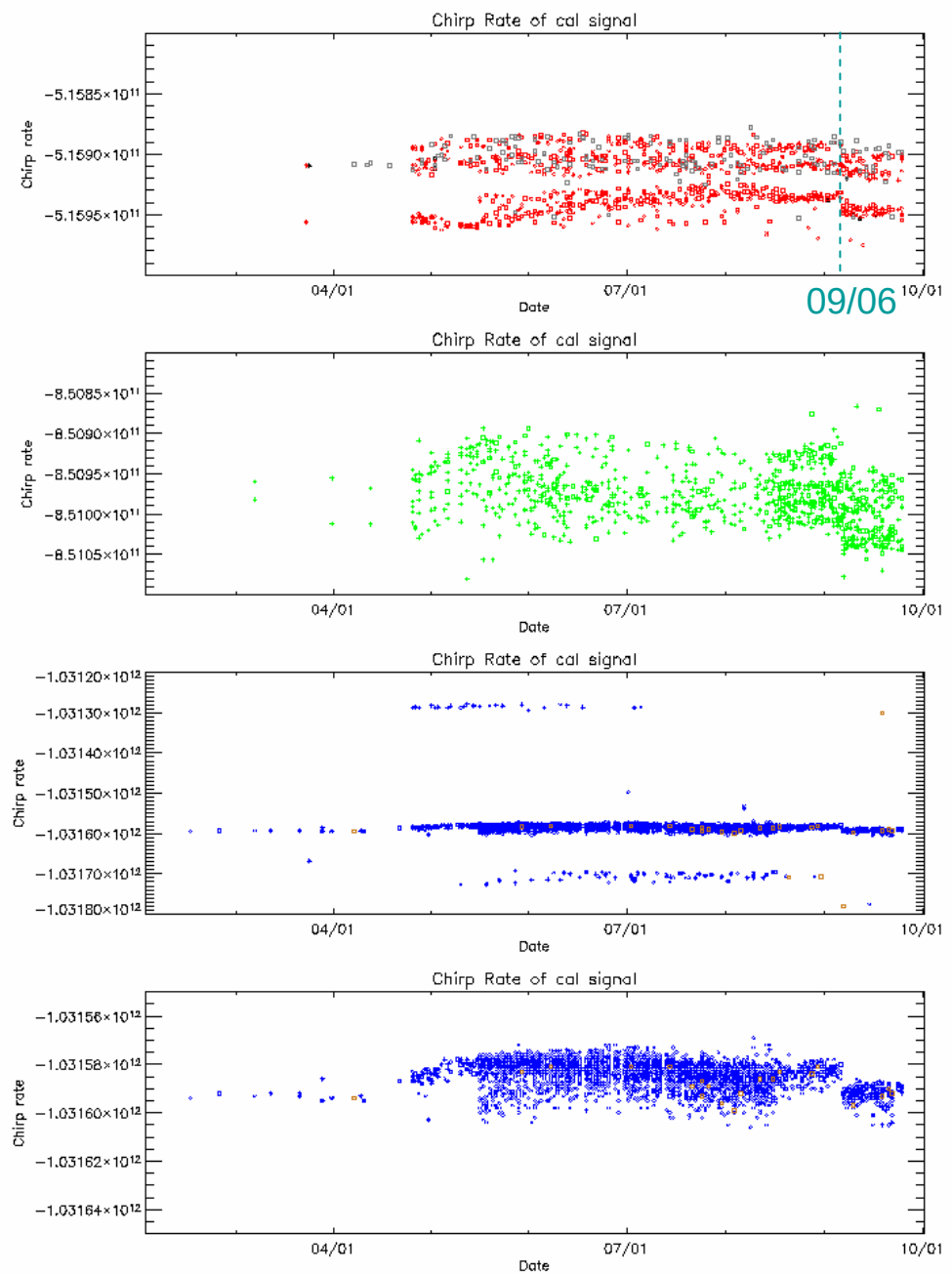
Short history of the chirp parameters(1/3)



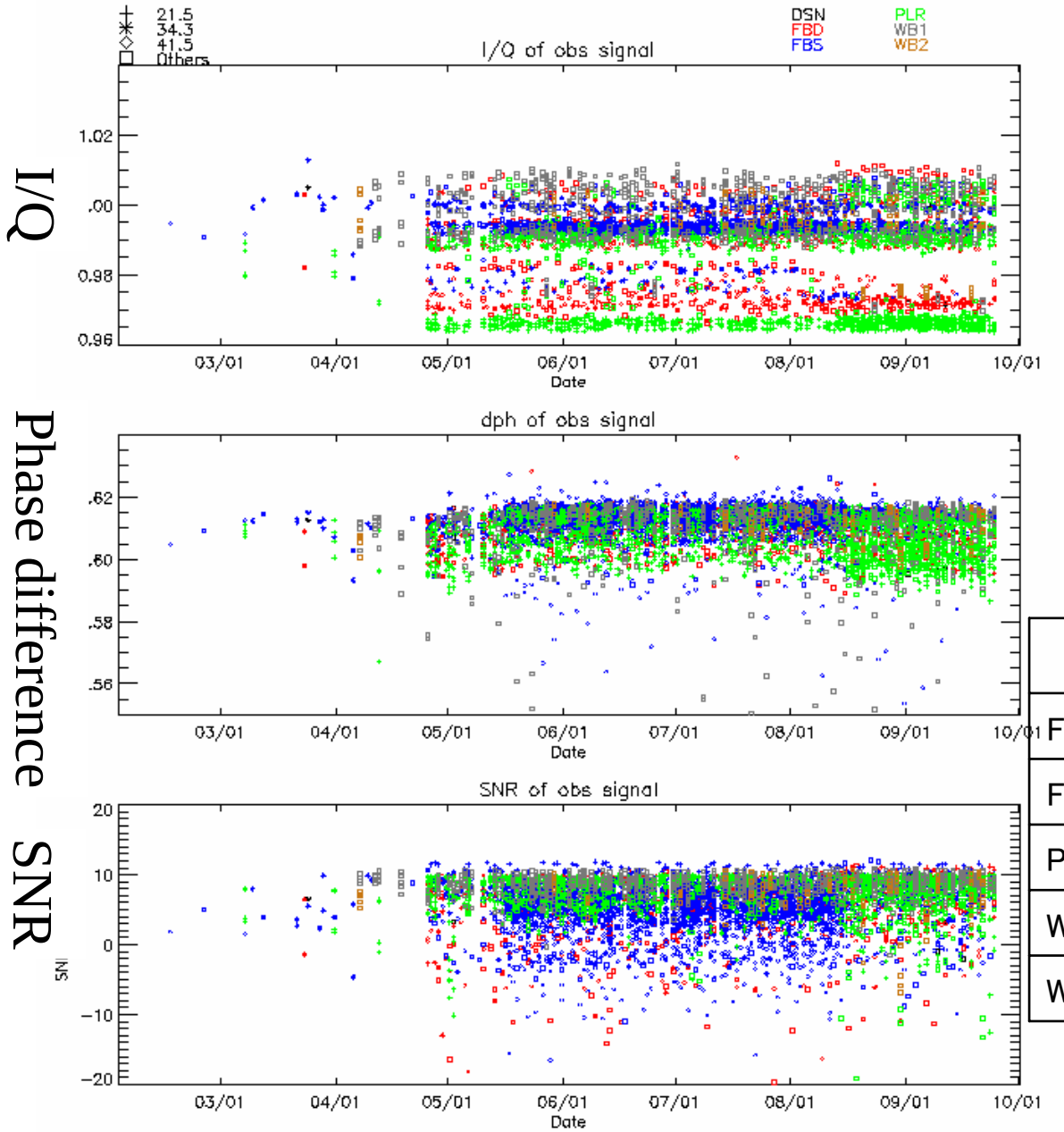
	I/Q	dph (deg)
FBS	1.007	1.598
FBD	1.010	1.579
PLR	1.001	1.577
WB1	1.015	1.581
WB2	1.008	1.597

- 09/06以降Chirpの各パラメータに変化あり
- Chirp Powerは減少

Short history of the chirp parameters(3/3)



Long history of the observation data



SNR : land

	SNR (dB)
FBS	8.4235
FBD	3.3580
PLR	8.7118
WB1	7.9256
WB2	8.7332

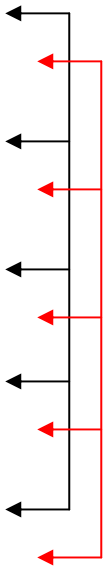
Total image

	I/Q	dph (deg)	SNR (dB)
FBS	0.9936	1.6130	5.3097
FBD	0.9847	1.6096	0.8841
PLR	0.9799	1.6067	7.2954
WB1	0.9977	1.6089	8.5953
WB2	0.9938	1.6109	6.8241

On Aug.7, larger attenuators selected for all the modes.

Saturation Rate @ MGC mode

Mode	Offn_angle	Attenuator	Saturation Rate (ave)
FBD	41.5	HH=25, HV=16 VV=15, VH=4	HH=3%, HV=4% VV=19%, VH=8%
FBS	21.5	HH=30 VV=22	HH=1.3% VV=7.5%
	34.3	HH=25 VV=Auto	HH=3% VV=10%
	41.5	HH=25 VV=15	HH=5% VV=15%
PLR	21.5	HH=30, HV=21 VH=21, VV=30	～1%
WB1	271-5	0=25, 1=24, 2=23, 3=22, 4=21	1～10%
WB2	271-5	0=25, 1=24, 2=23, 3=22, 4=21	1～10%



- Attenuators for basic mode was adjusted since April 25.
- The others need more adjustment.

3 Summary of the characterization

•Since MGC was selected as the primary mode, characterization becomes stabilized.
•Saturation rate is reduced, and image quality becomes better.
•Interference less observed, and it can be suppressed by a filter.
•Transmission power is stabilized.
•Property changed slightly on Sept/B. (It does not cause the image quality)
•Image quality of beam 34.3, shows better performance than 41.5.

•Generally, the saturation level reduced to the satisfactory level. But, high intensity target saturates the image.

4 Algorithm

Radiometric correction

- Raw data scaling

$$\mathbf{V}_{raw}^{i,j} = \frac{1}{\sqrt{G_{AGC}(T)\cdot G_{STC}(t)\cdot\left(P_t/\overline{P}_t\right)}\{1-S_a(t,T)\}}\left[\left(\mathbf{v}-\overline{\mathbf{v}}\right)\frac{\sigma_l}{\sigma_q}\right]^{i,j} E^{i,j}$$

$$E = \begin{pmatrix} \sigma_V/\sigma_H & 0 \\ 0 & 1 \end{pmatrix}$$

- Antenna Correction (Before azimuth correlation)

$$\overline{\mathbf{V}}_{rg}^{i,j} = \frac{R\sqrt{\sin\theta_{inci}}}{G_{ele}^{i,j}\left(\phi_{off},beam\right)}\mathbf{V}_{rg}^{i,j}$$

- Power

$$P_{i,j} \cong a\frac{G_{\mathbf{ele}}^{\mathbf{2}}}{R^{\mathbf{2}}\sin\theta_{inci}}\sigma_{i,j}^{0} + N_{i,j}$$

- POL mode

$$\mathbf{S}_{ij} = \mathbf{R}^{-1}\cdot\mathbf{F}^{-1}\cdot\mathbf{Z}_{ij}\cdot\mathbf{F}^{-1}\cdot\mathbf{T}^{-1}$$

i, j : transmission and reception pol.
Noise is not subtracted.

v_{raw}:raw data voltage
v_{rg} : volt after range corr.
p : power
S:caled scattering matrix
Z : uncal scattering matrix

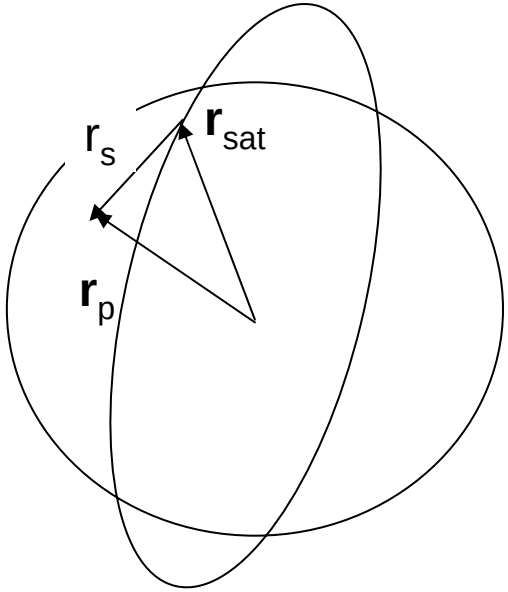
R : slant range
θ_{inci} : incidence angle
ϕ_{off} : off nadir angle
σ^0 : sigma-naught

Calibration target
G_{ele} : antenna pattern
R,T : distortion matrix
a : coefficients

Accuracy Target : Error : < 1.5 dB, location error < 100m

Geometric conversion

Doppler model depends on yaw(ψ),pitch(θ), and integer n. observation position depends on rs.



Determine attitude and Doppler model

$$\sum\left(Uw\left(f_{d,r}\right)+n\cdot f_{prf}-f_{dm,r}\left(\theta_p,\psi_y,r_s\right)\right)^2\rightarrow min.$$

位置の決定

$$r_s=\frac{c}{2}\left(\frac{i}{f_{sample}}+\frac{nn}{f_{prf}}+\Delta t\right)$$

range

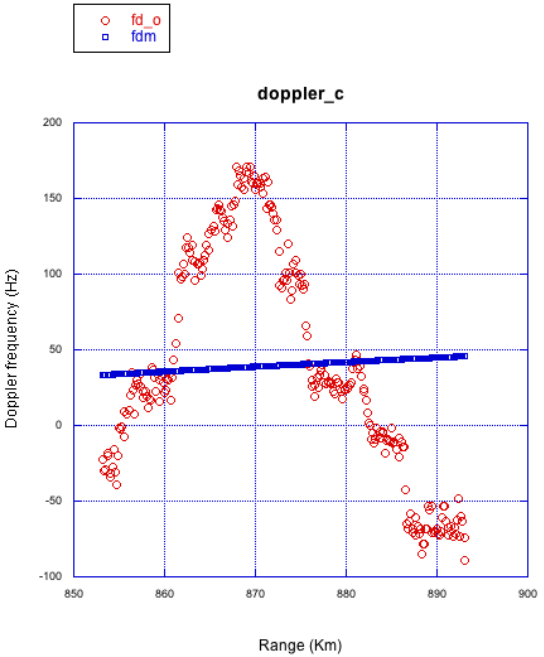
$$f_d\cong A_0+A_1\cdot r_s$$

Doppler frequency

$$f_d=\frac{2f_0}{c}\mathbf{v}_s\cdot\frac{\left(\mathbf{r}_p-\mathbf{r}_s\right)}{\left|r_p-r_s\right|}$$

$$x_p^2+y_p^2+z_p^2\frac{R_a^2}{R_b^2}=1$$

Position determine（iteration）



f_d:Doppler measurement, f_{dm}:Doppler model、E(ϕ,θ,ψ), rotation matrix , r_s: slant range, r_p:position vector(x_p,y_p,z_p), r_{sat}:satellite position, r_n:normal vector, f_{prf}:pulse repetition frequency, R_a,R_b: equatorial radius, polar radius, (GRS80)

5 Calibration and validation

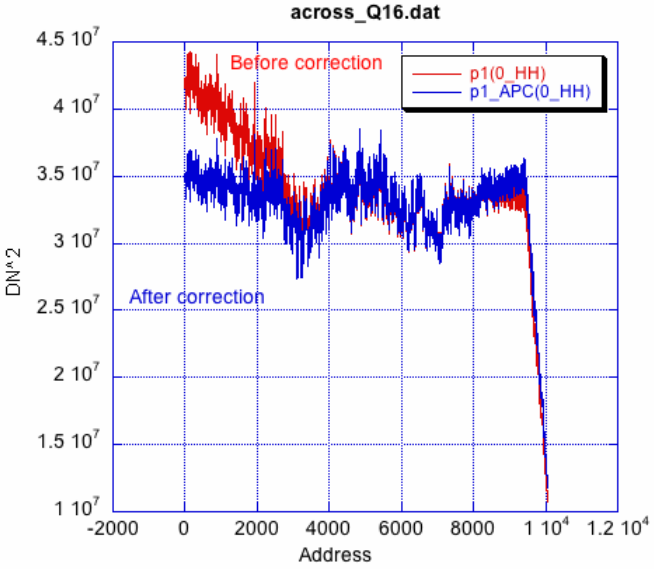
Items	Item	method
Radiometry	Antenna elevation pattern	•Amazon data analysis •modeling
	Calibration factor	•Tune suing CR、PARC •Tune gain difference among beams.
	Distortion matrices	•CR、forest area
Geometry	Range time offset	•CR、PARC
	Azimuth time offset	•CR、PARC

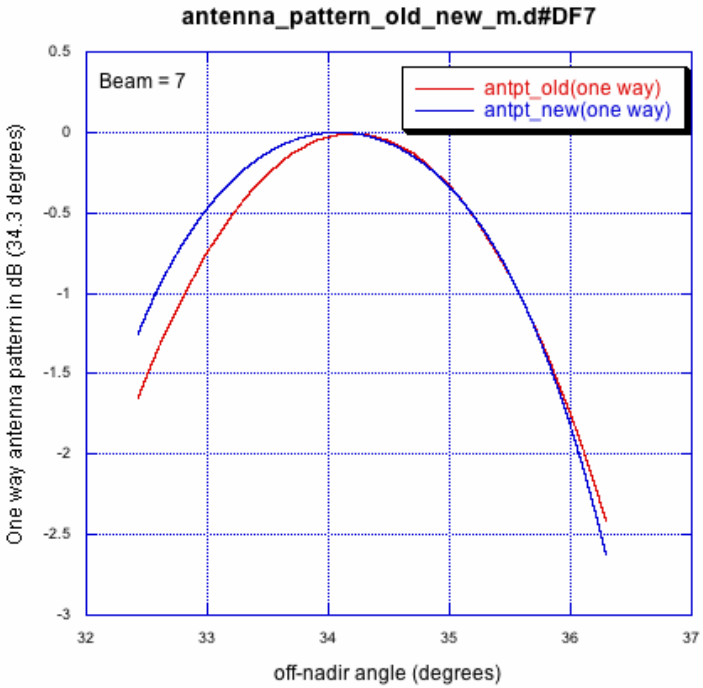
Antenna pattern estimation

$\gamma^0(\sigma^0/\cos(\theta))$= 定数

- Extract uniform area (Filtering)
- Quadratic equation
- Update antenna pattern dB

$$G(\theta) = a + b(\theta - \theta_0)^2 + c(\theta - \theta_0)^4$$



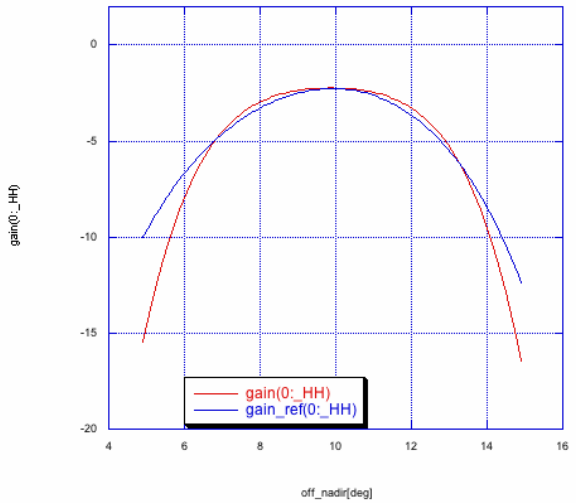


Before

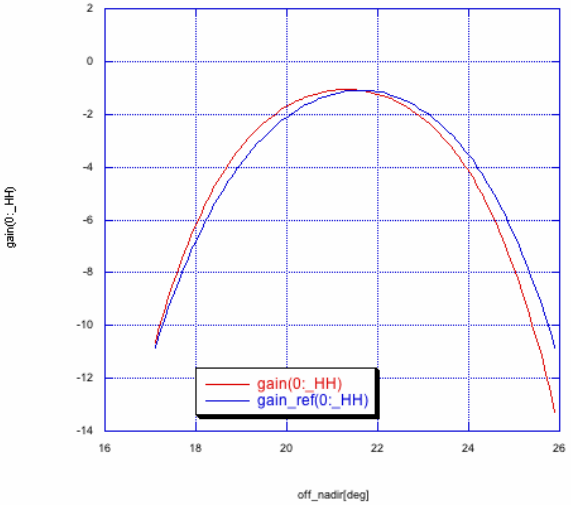
After

Antenna pattern measurement from the Amazon data

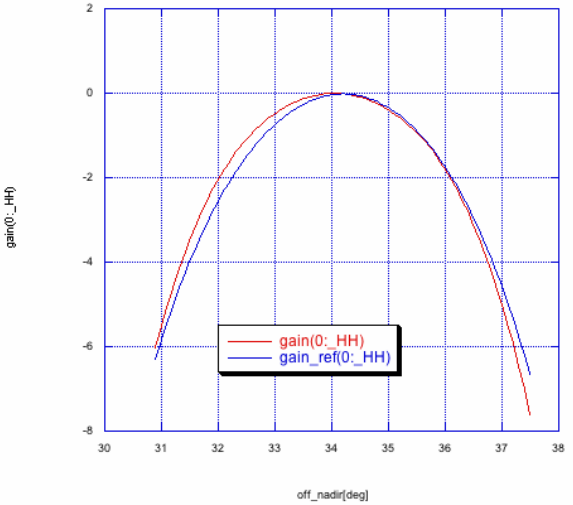
9.9



21.5

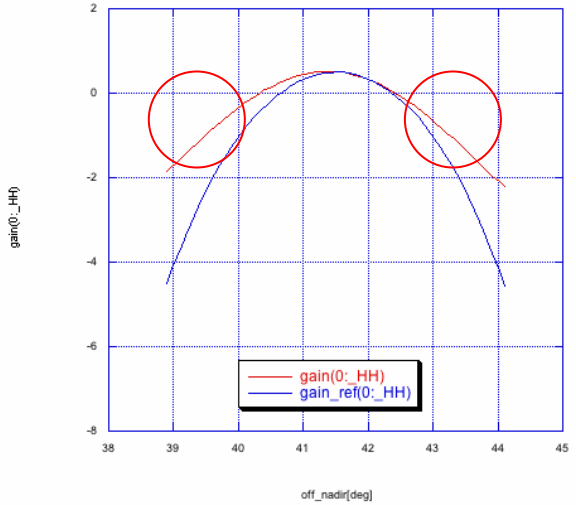


34.3

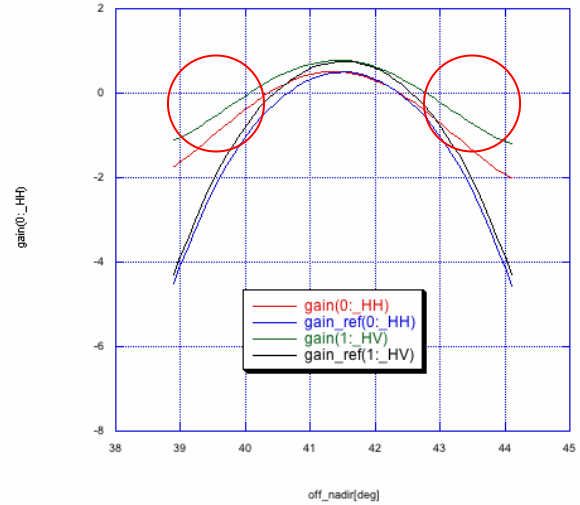


due to the range ambiguity

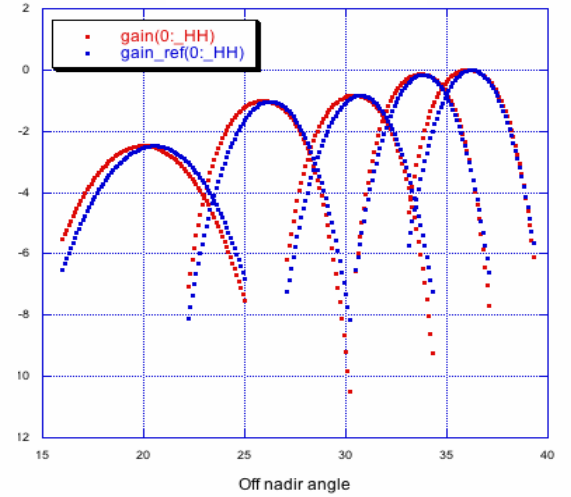
41.5



41.5D

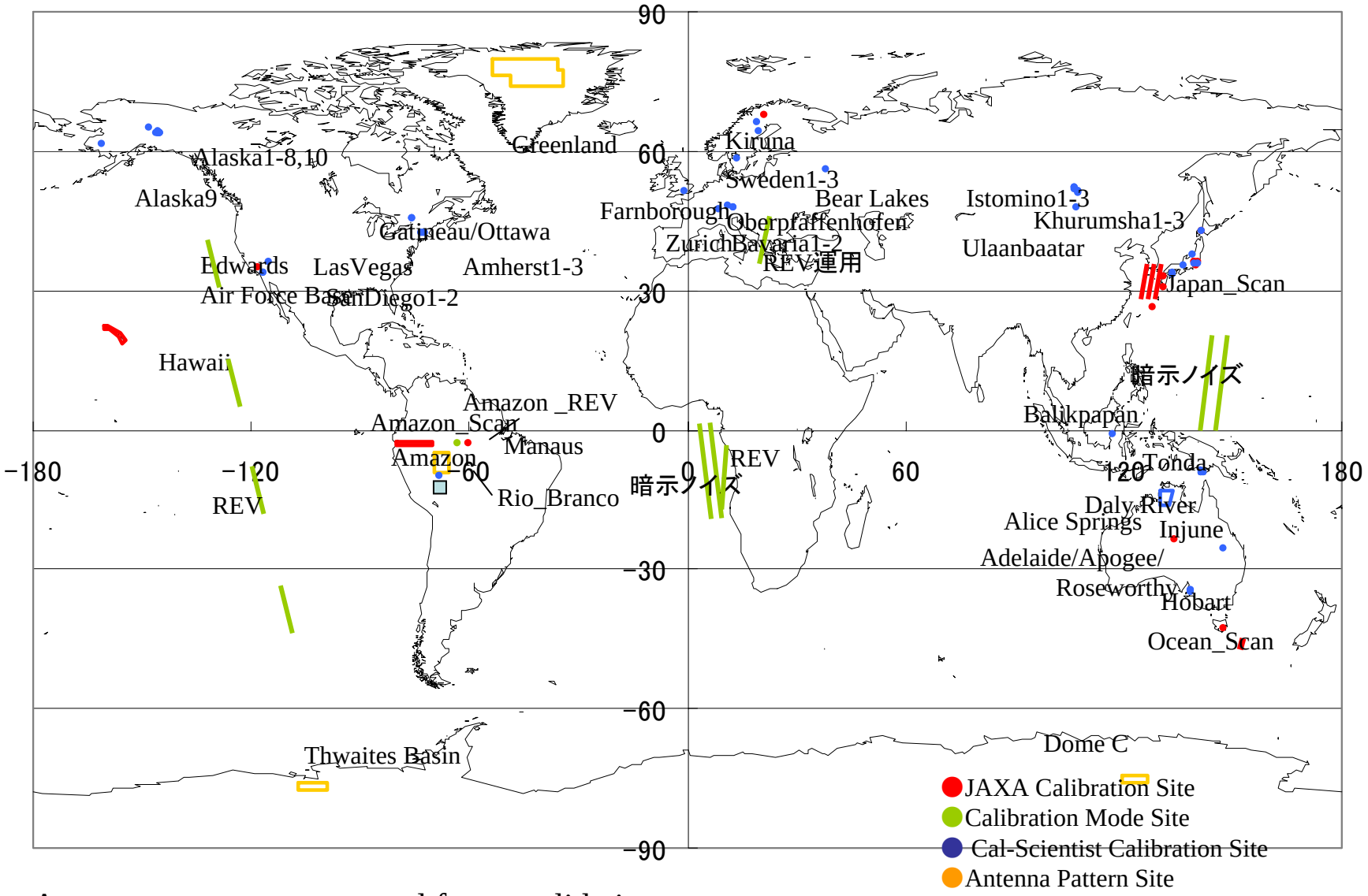


SCANSAR



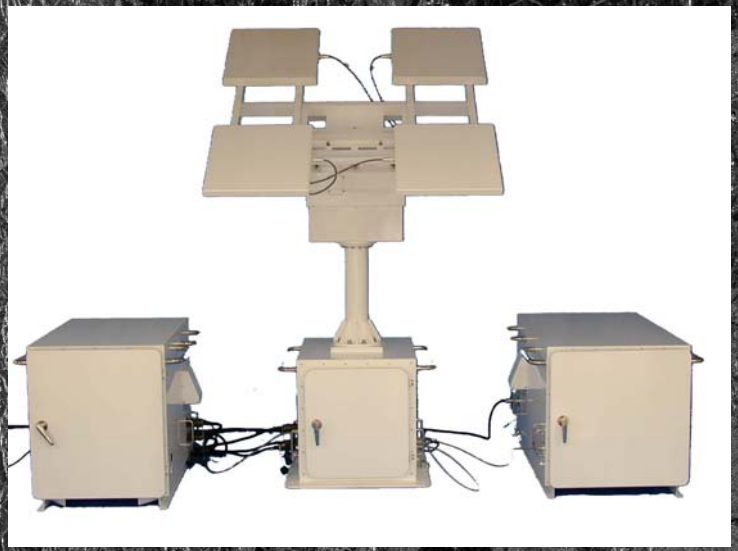
Blue: ground measurement, red: in-flight data (Amazon)

PALSAR calibration site

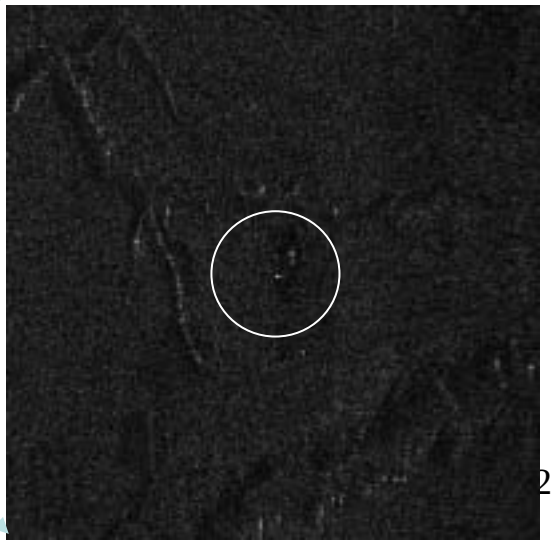


Amazon : antenna pattern, cal factor validation
CR and PARC : Cal factor, position determination

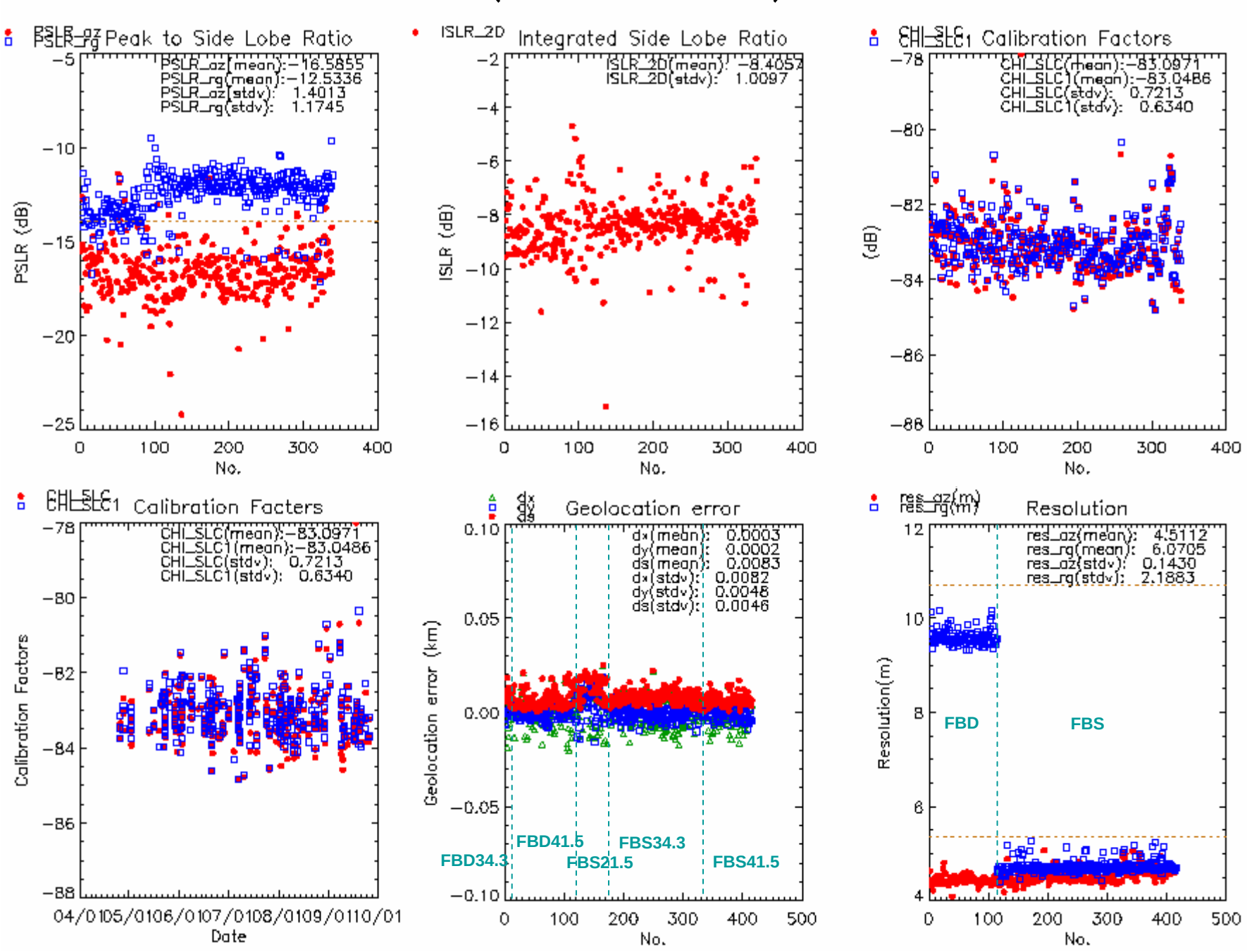
CAL instruments



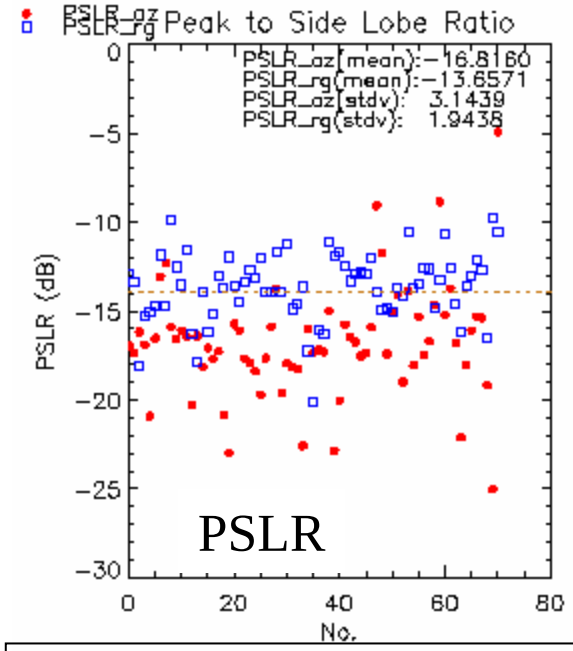
	ARC	PARC
Frequency band	1256～1284MHz	1256～1284MHz
Off nadir angle	9.9～50.8°	9.9～50.8°
RCS	15～60dBm²	15～60dBm²
RCS stability	<±0.1dB	<±0.1dB
ALOS tracking	Yes(program tracking)	Yes(program tracking)
Max. Rec. power	-44.5dBm	-44.5dBm
Max. trans. Power	22.5dBm	22.5dBm
temperature range	-10～＋50℃	-10～＋50℃
Humidity range	35～100%RH	35～100%RH

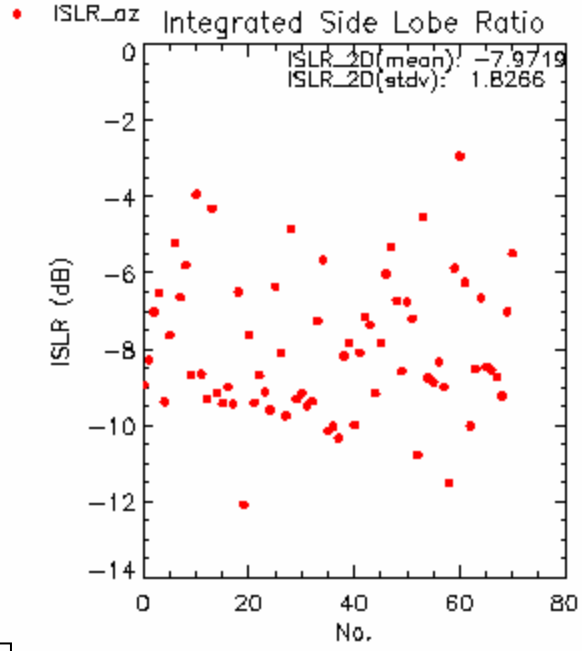


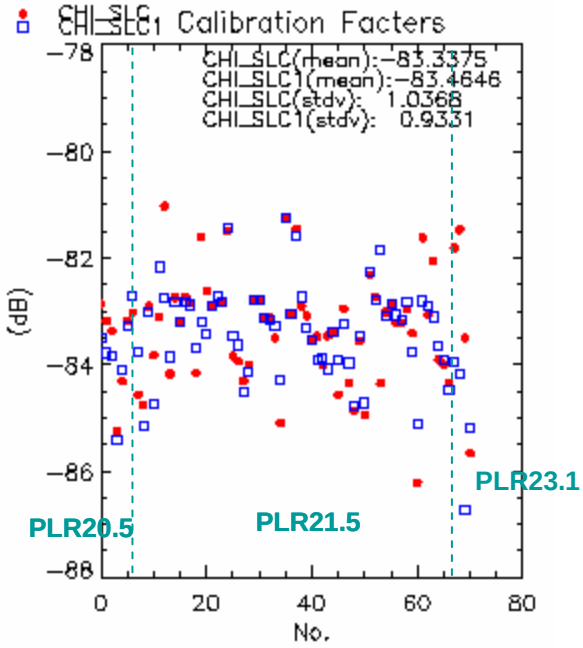
Evaluation results : FBS/FBD（CR and PARC）

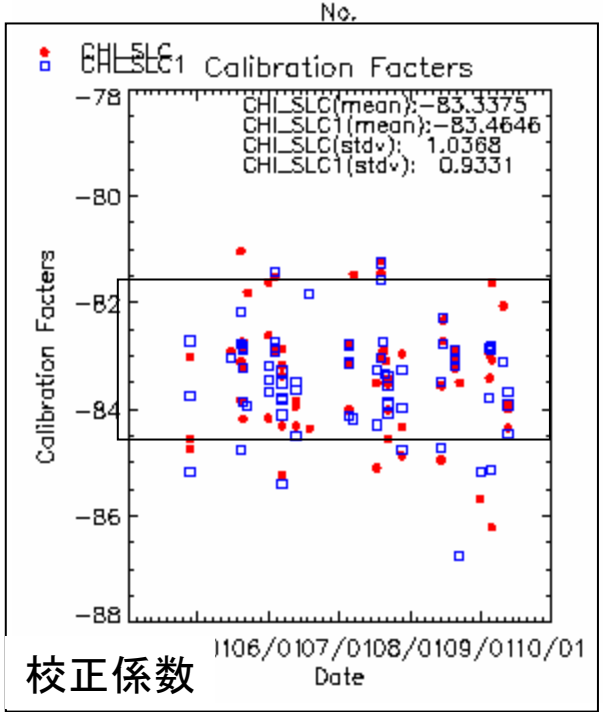


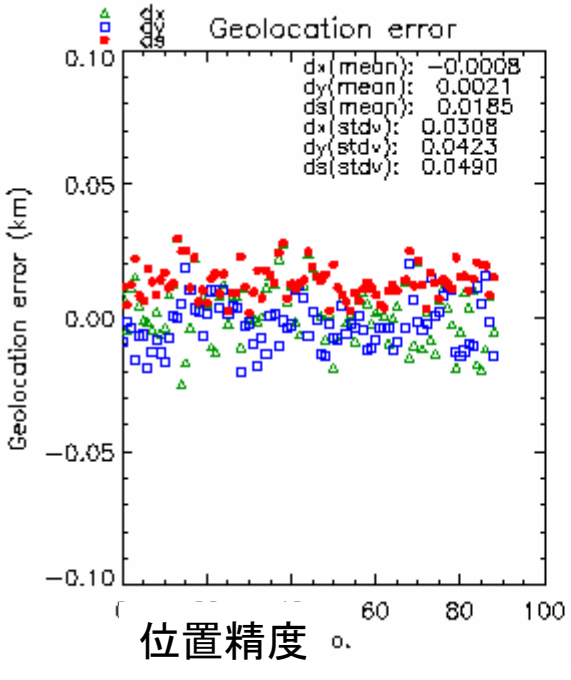
Evaluation：Polarimetry（1/2）（Use CR and PARC）

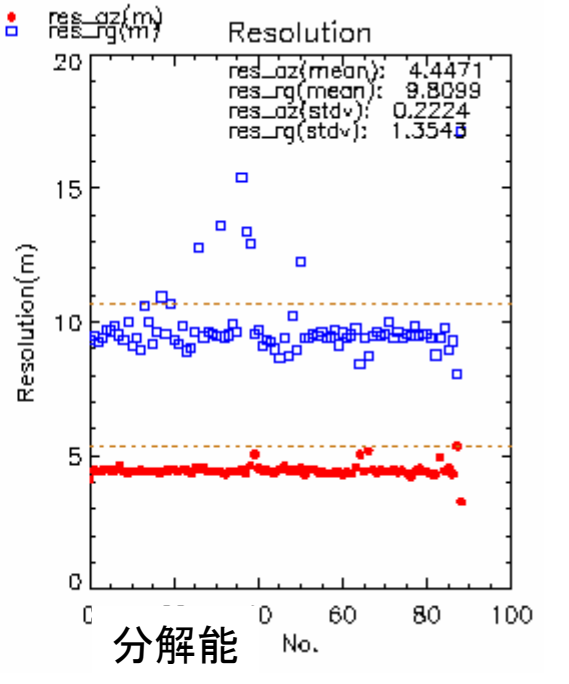




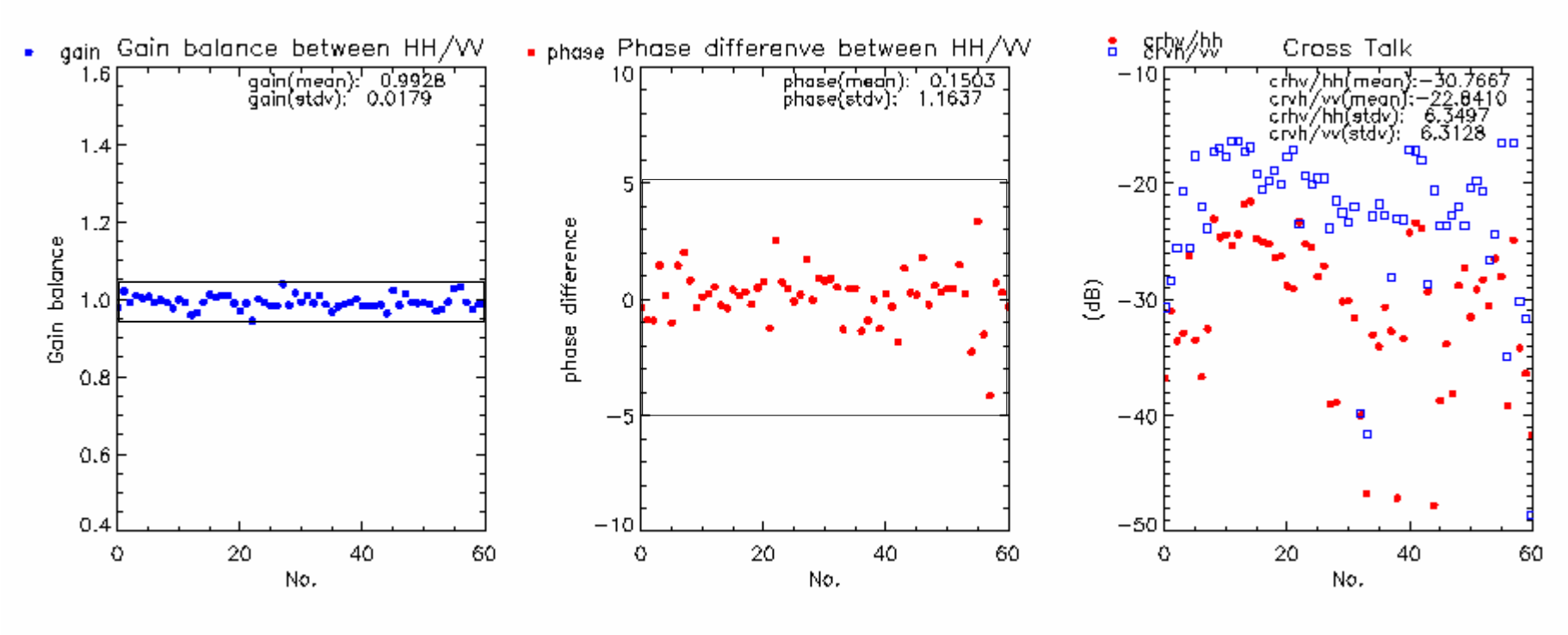








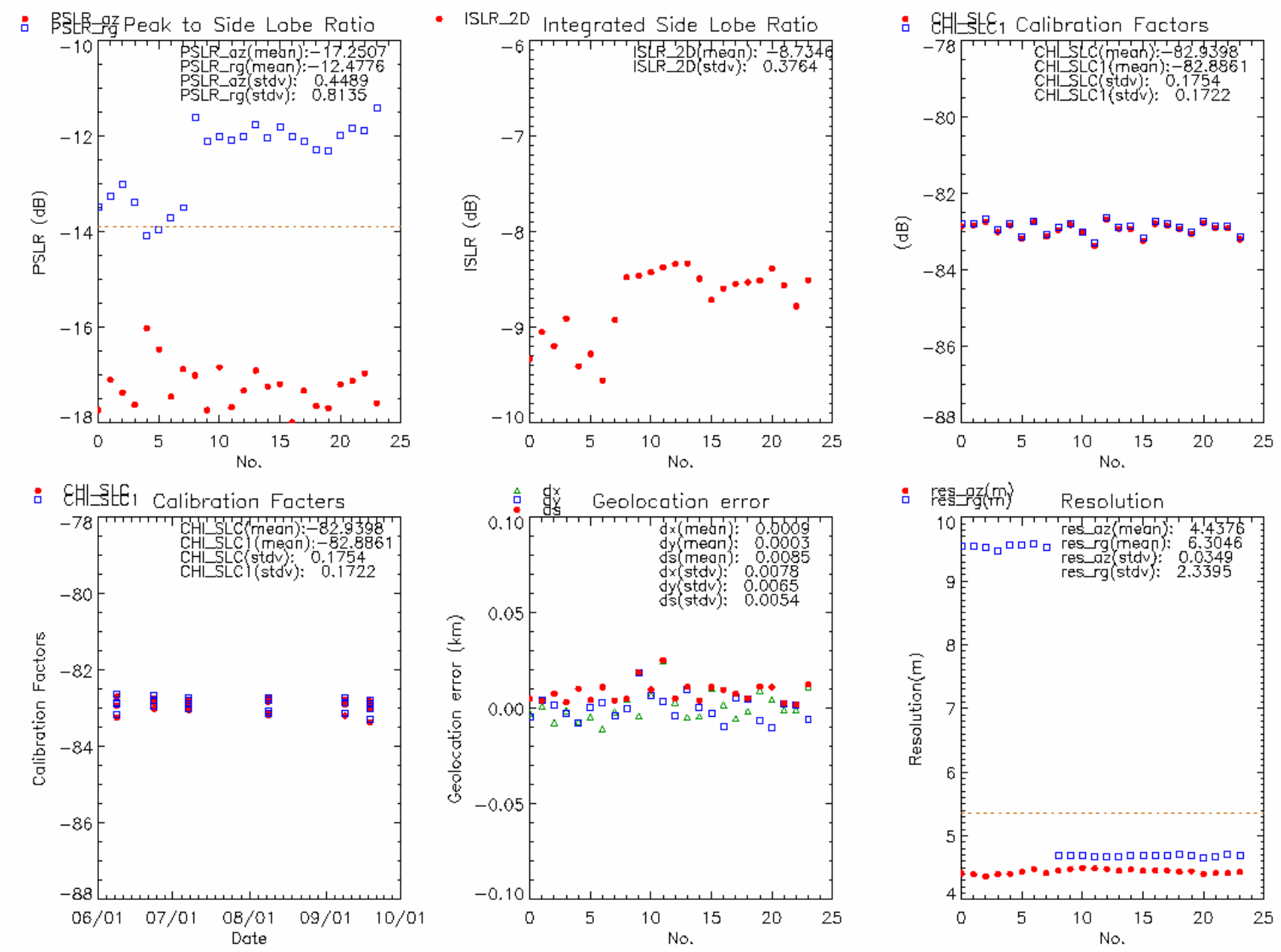
評価結果：Polarimetry（２／２）（コーナー反射鏡の使用）



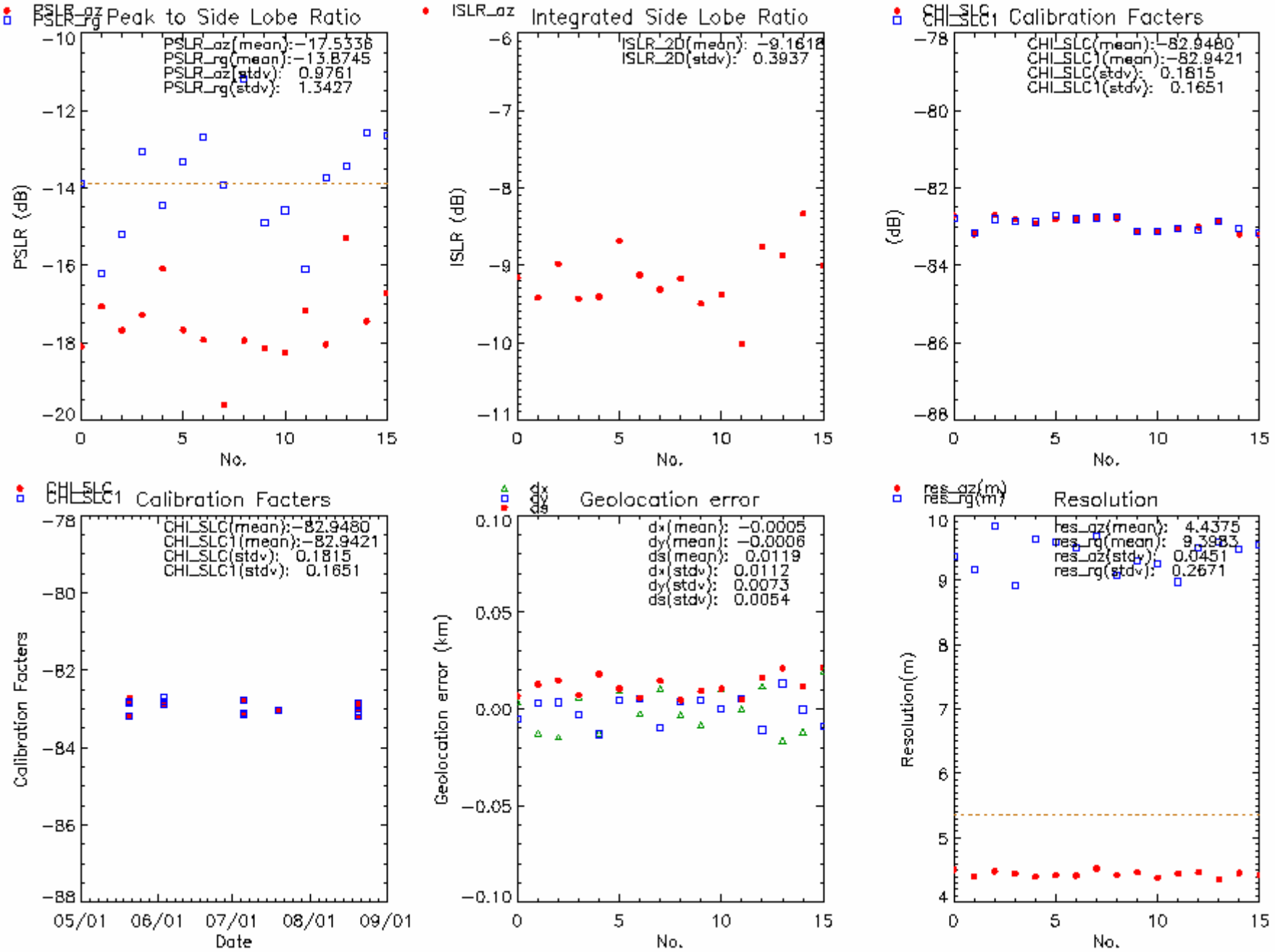
HH/VV利得変化　　HH/VV位相変化　　クロストーク

精度範囲

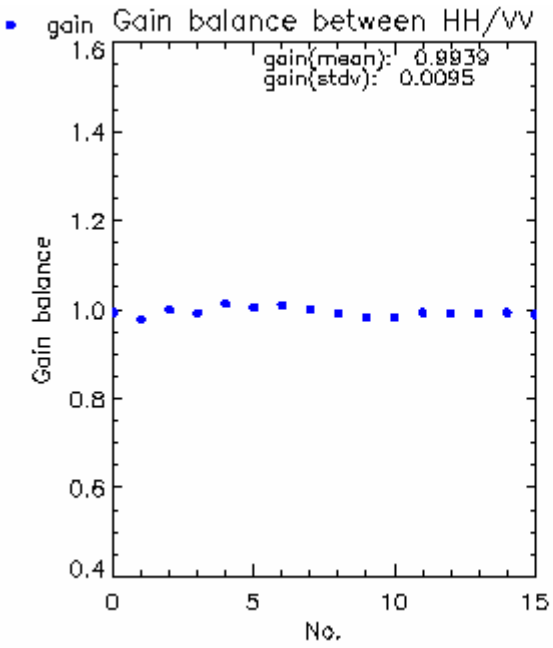
Sweden（FBD/FBS)

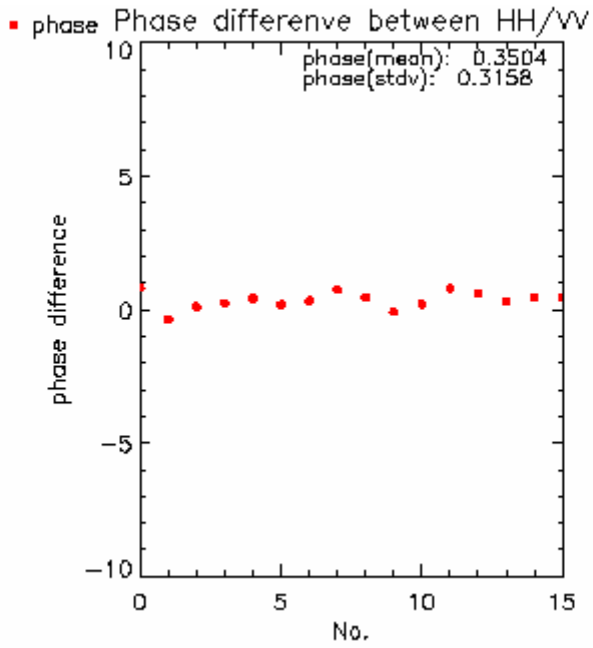


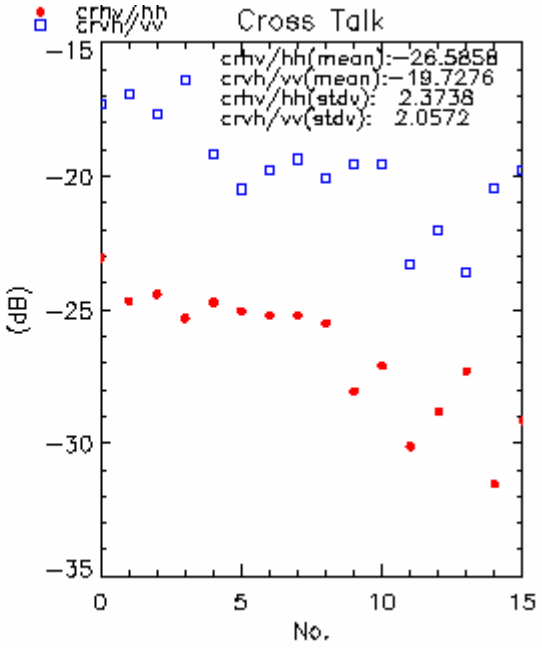
Sweden（PLR215 (1/2))11/9処理分　３点削除



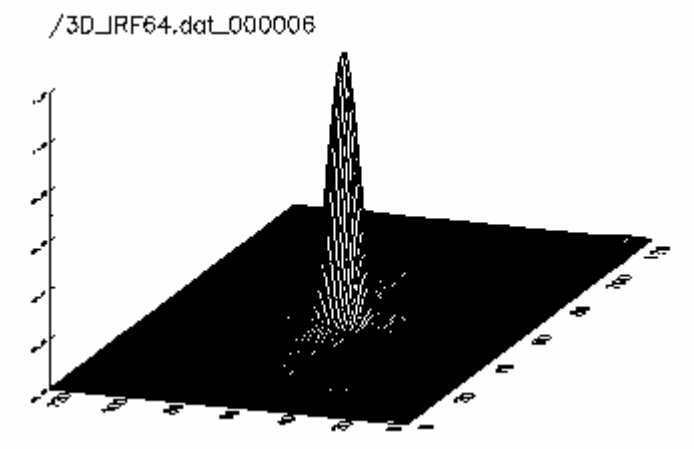
Sweden（PLR215 (2/2)) 11/9処理分　3点削除



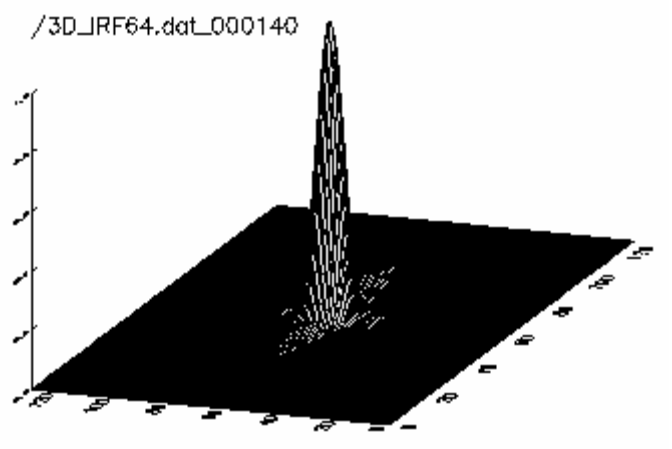




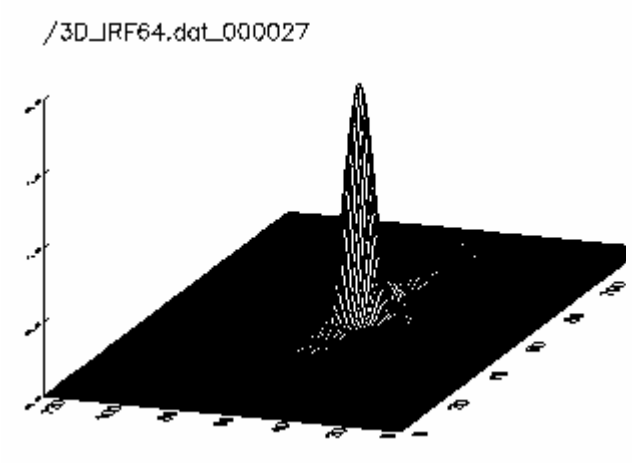
IRF of CR at different mode（FBD/FBS）



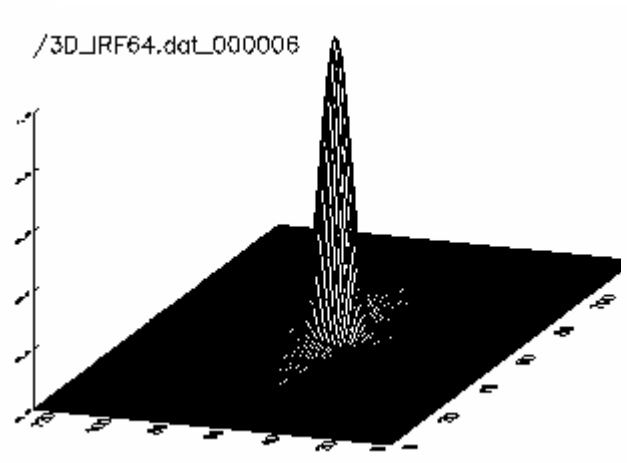
FBD34.3H
20060728/Tomakomai_J03



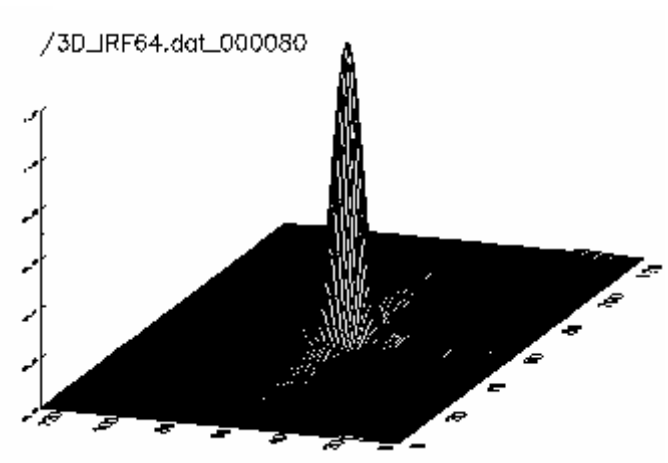
FBD41.5H
20060823/Maising



FBS21.5H
20060620/Tomakomai

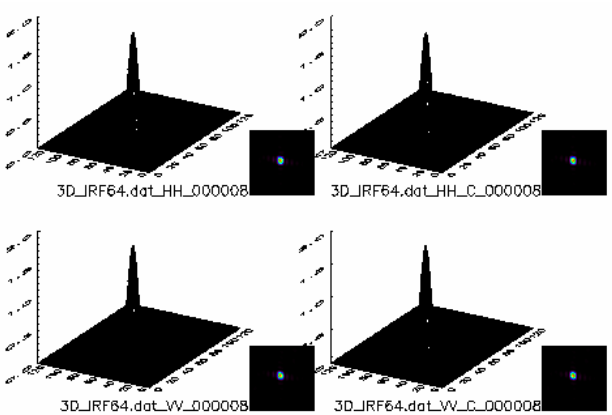


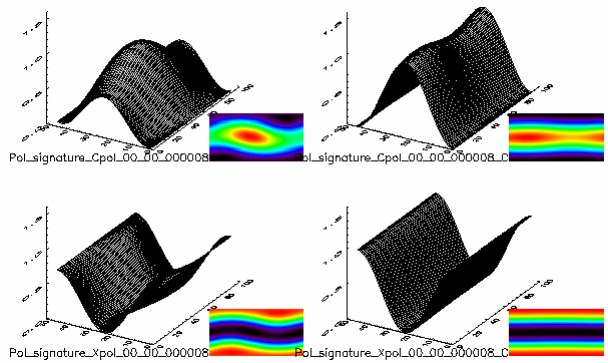
FBS34.3H
20060427/Watarase_J04



FBS41.5H
20060708/Alaska8_24

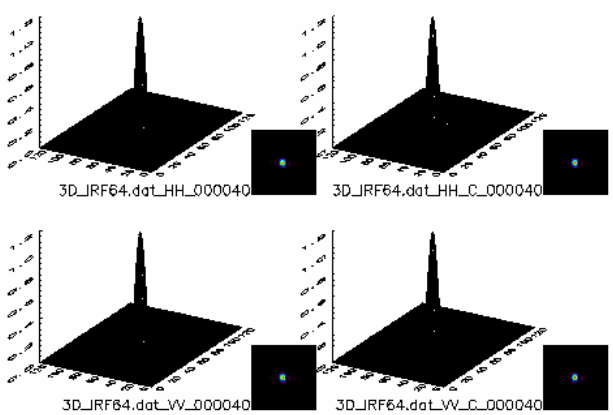
IRF of CR and Polarimetric signatures（PLR）

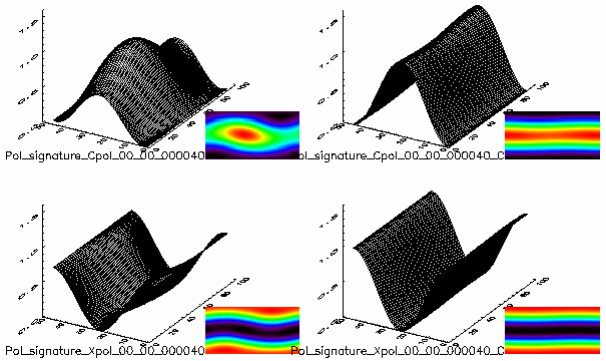




PLR21.5
20060515/Tutumi_J04

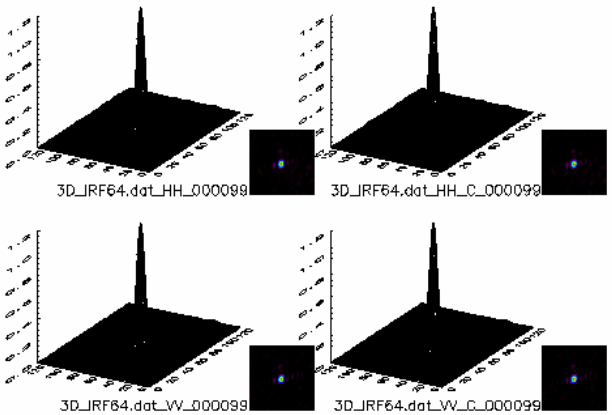
Before After

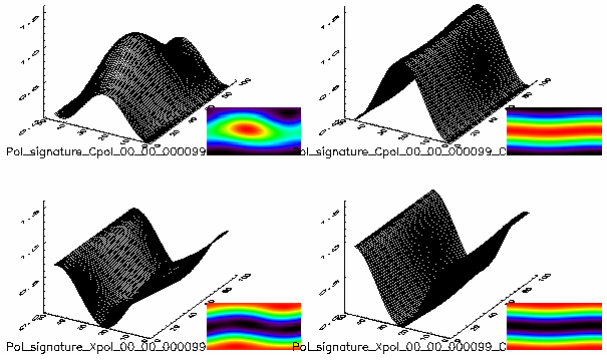




PLR21.5
20060603/Sweden1_3

Before After

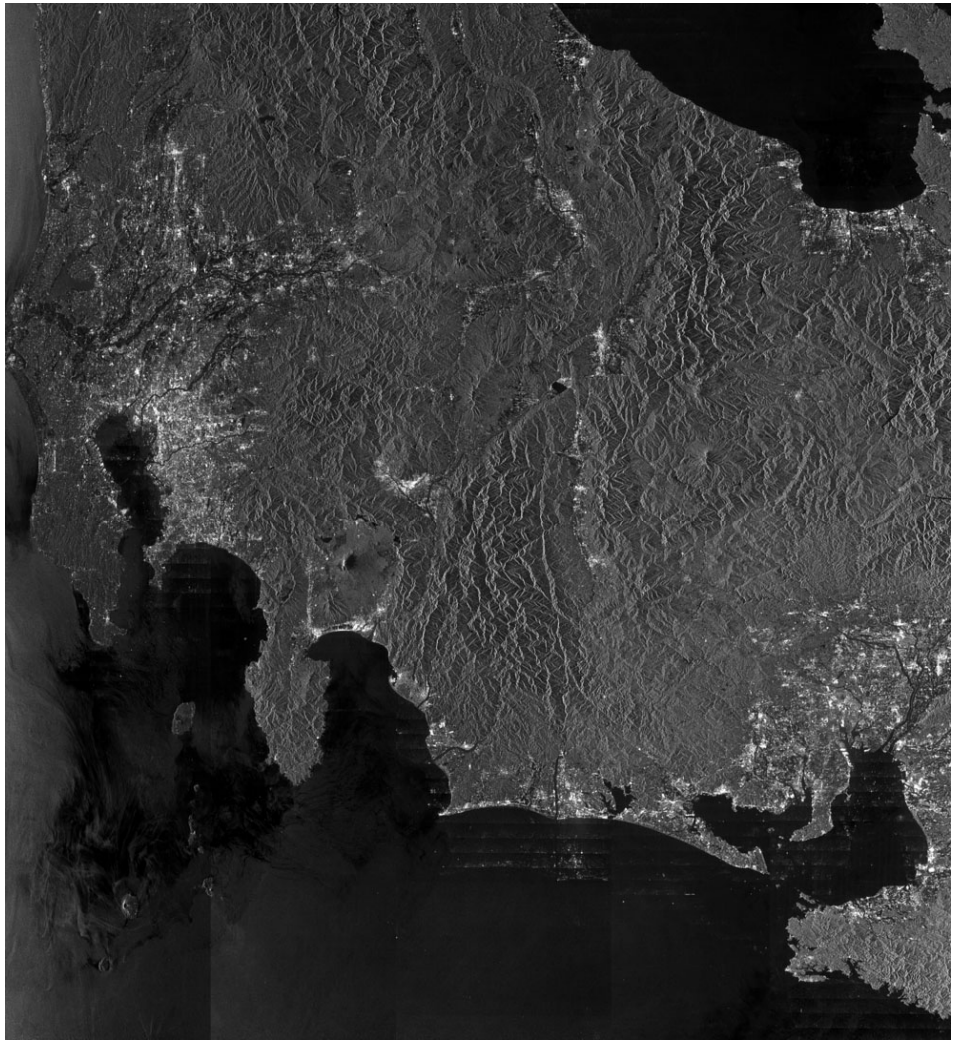


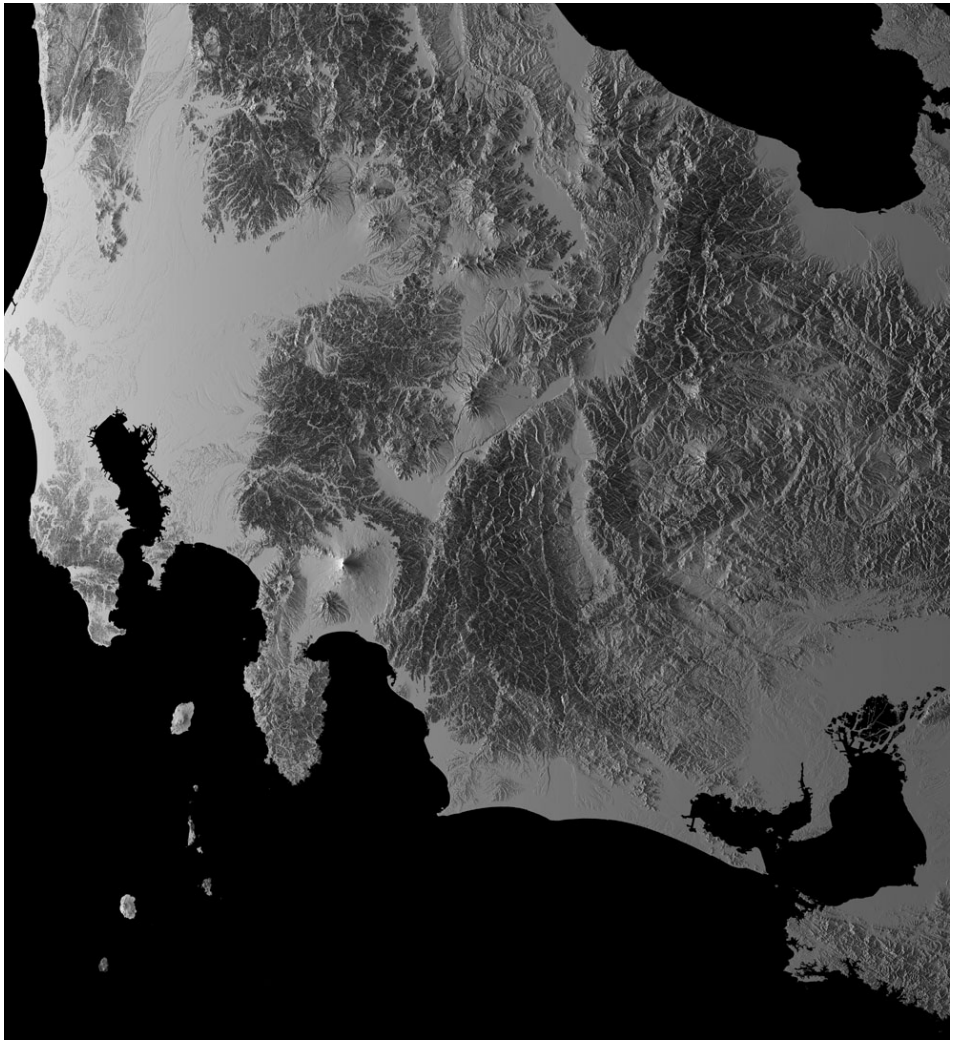


PLR21.5
20060728/Alaska1

Before After

SCANSAR Evaluation



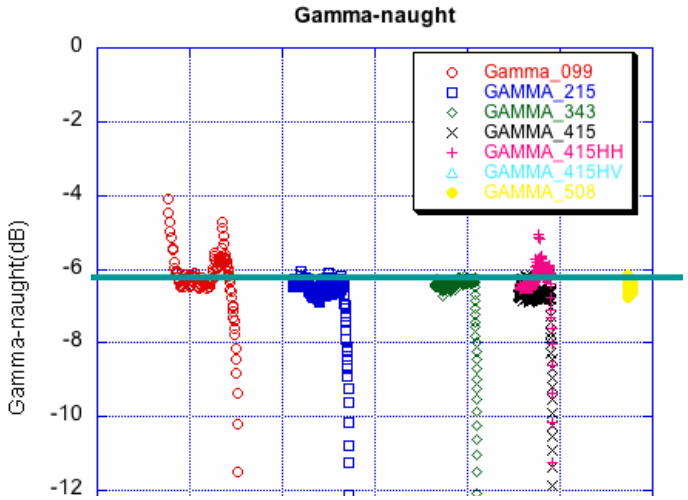


Geometry
azimuth : 20m
range :180m

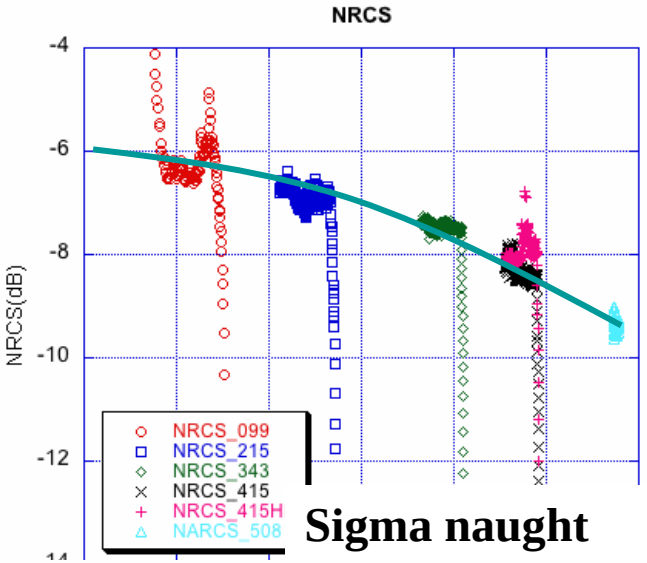
Amplitude（WB1）

Simulation（WB1）

Evaluation of calibration : Incidence angle dependency of the Amazon sigma-naught, and noise equivalent sigma zero

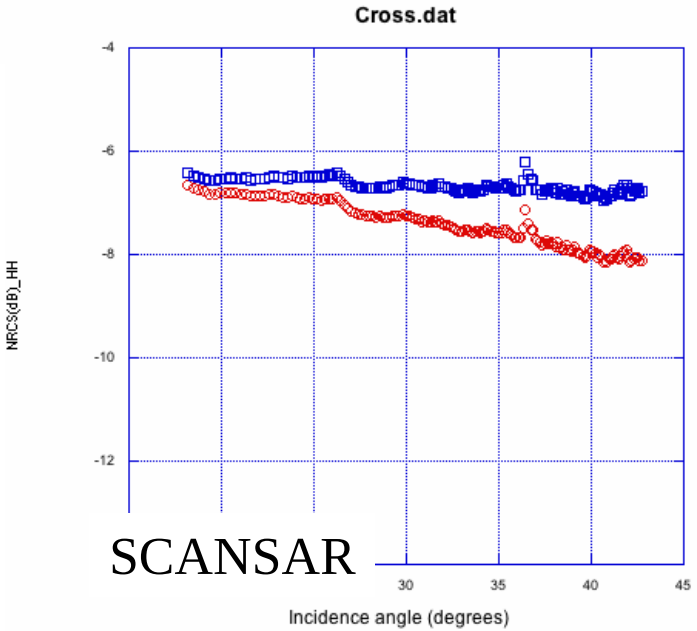


Gamma naught

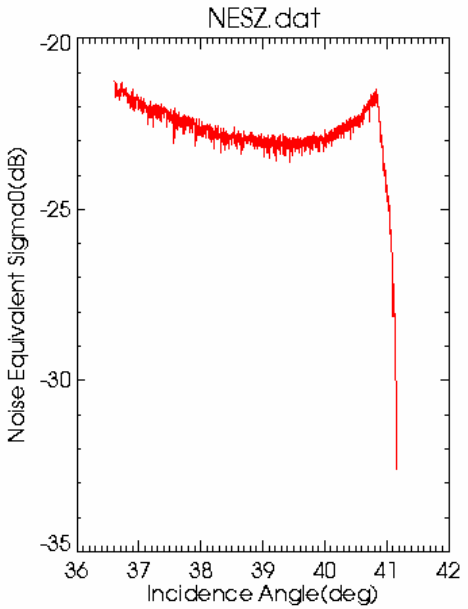


Sigma naught

antenna/Greenland/FBS343H/RSP041/20060715



SCANSAR



-23 dB

Evaluation summary of the point target

FBD/FBS（Radio：291 pt, Geo：345 pt）

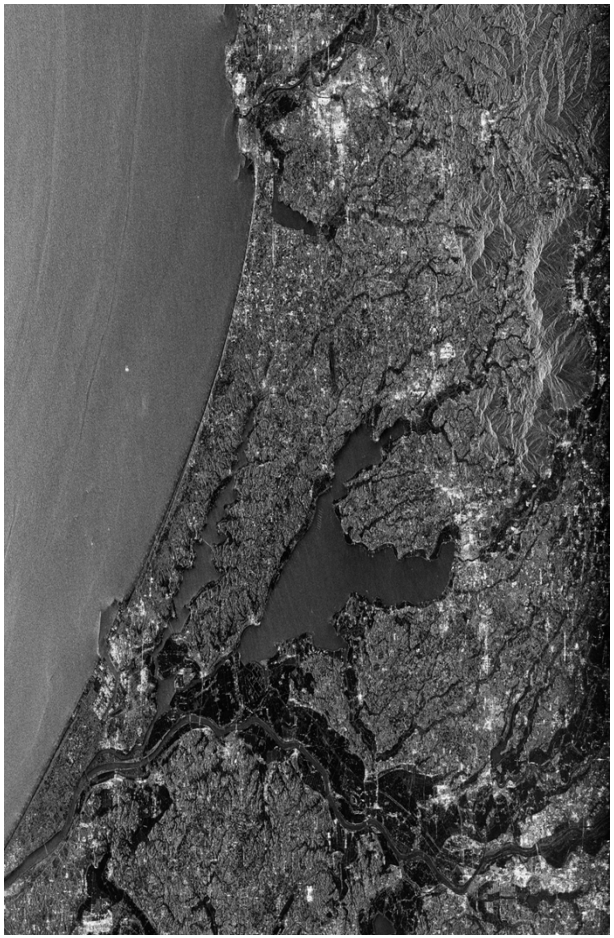
	Mean	Std. dev.	spec.
PSLR_az(dB)	-16.595	1.445	<-10dB
PSLR_rg(dB)	-12.602	1.185	<-10dB
ISLR_2D(dB)	-8.406	1.010	
CHI_SLC(dB)	-83.068	0.666	<1.5dB
CHI_SLC1	-83.015	0.635	<1.5dB
dx(Km)	0.00069	0.00802	
dy(Km)	0.00010	0.00470	
ds(Km)	0.00810	0.00459	<100m
res_az(m)	4.512	0.145	<5.0m
res_rg(m)FBD	9.592	0.153	<10.7m
res_rg(m)FBS	4.724	0.130	<5.4m
NESZ(dB)	-21~-24dB		<-21dB

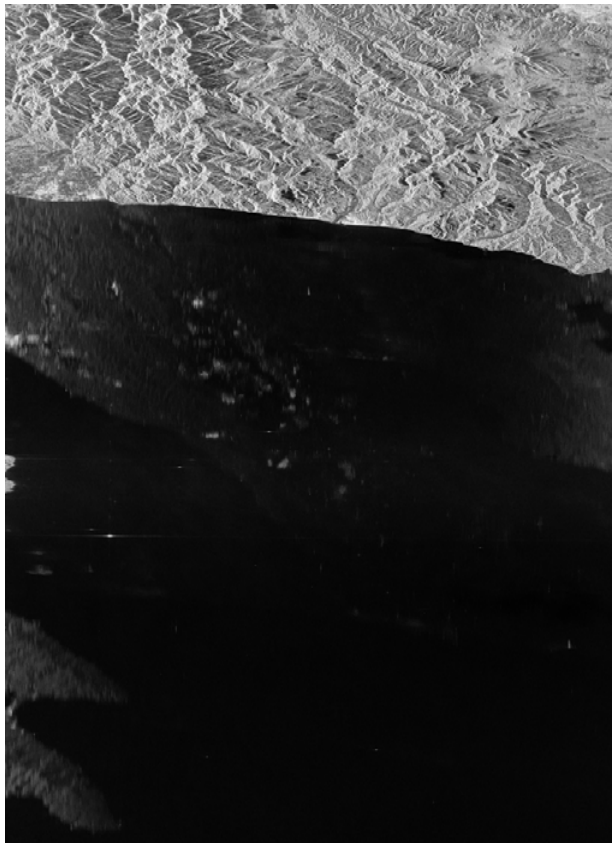
PLR（Radio：56 pt, Geo：72 pt）

	Mean	Std. dev.	spec.
PSLR_az(dB)	-17.263	2.743	<-10dB
PSLR_rg(dB)	-13.844	1.999	<-10dB
ISLR_2D(dB)	-7.972	1.827	
CHI_SLC(dB)	-83.267	0.984	<1.5dB
CHI_SLC1(dB)	-83.467	0.947	<1.5dB
dx(Km)	0.00304	0.01109	
dy(Km)	-0.00293	0.00854	
ds(Km)	0.01332	0.00624	<100m
res_az(m)	4.463	0.180	<5.0m
res_rg(m)	9.774	1.218	<10.7m
gain(VV/HH)	0.9959	0.0178	<0.2dB
phd(VV/HH)	-1.709	1.082	<5.0 deg.
crhv/hh(dB)	-26.195	3.266	<-25dB
crvh/vv(dB)	-19.565	3.399	<-25dB

Note）Calibration accuracy is measured as the difference from -83.0.

Ambiguities





FBS21.5	FBS34.3	FBS41.5
RA=not measured	RA=not measured	RA=17 dB

Conversion to sigma-naught

$$\sigma^0{}_{sigma-sar,Q16} = 10 \cdot \log_{10}\left\langle DN^2 \right\rangle + CF_1$$

$$\sigma^0{}_{sigma-sar,slc} = 10 \cdot \log_{10}\left\langle I^2 + Q^2 \right\rangle + CF_1 - A$$

CF	mean(dB)	std (dB)
CF_1	-83.0	0.67
A	32.0	-

Parameter summary

factors	Values
Range time offset	-0.31539μs
Azimuth time offset	-2.239ms(Strip) -67ms(SCAN)
Polarimetric distortion matrices PLR215	(1.000000e+00 ,0.000000e+00) (-2.804701e-02,-2.933507e-03) (3.164040e-02 ,-1.038148e-02) (9.352351e-01 ,4.073565e-01) (1.000000e+00 0.000000e+00) (-3.699034e-02,8.453709e-04) (2.115907e-02 ,5.648345e-03) (7.249998e-01 ,5.535966e-04)

6 Calibration summary

•PALSAR was calibrated using the Amazon data and the point target data, and achieved the accuracy measure of geometry（10m<100m）、radiometry（0.7 dB <1.5dB）, both meets the specification, and polarimetry meets the specification that（CEOS SAR）（HV gain variation-0.018dB＜0.2dB、phase variation -1.7 degrees＜5 degrees）。

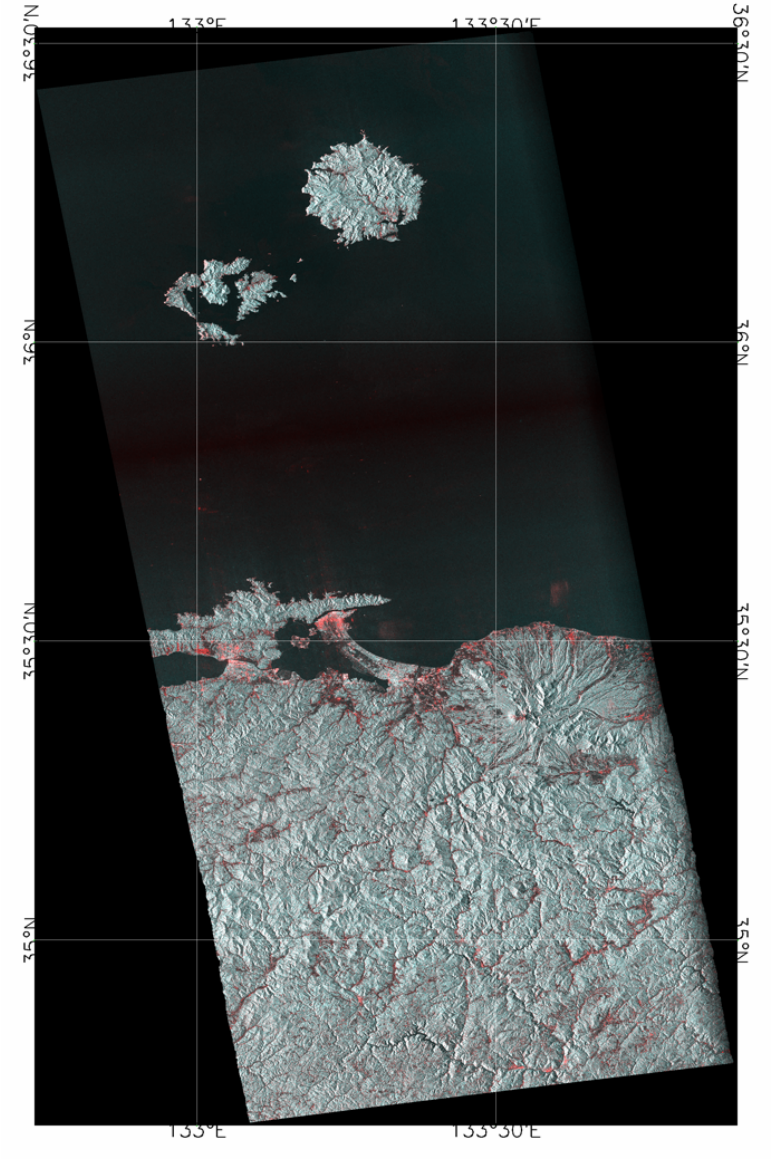
•Image quality：appears 17 dB range ambiguities at 41.5 degrees. Electric properties at 34.3 and 21.5 degrees exceed 41.5.

•Conversion method from DN to sigma-naught and position were prepared.

7 High level products

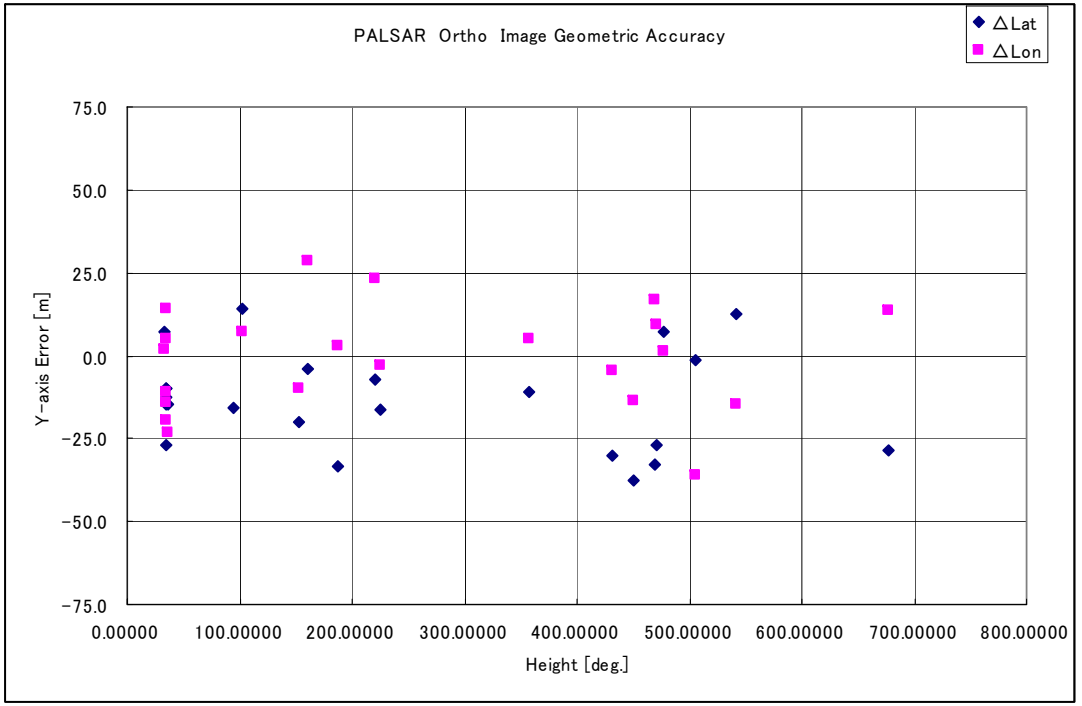
Products	status	target
Ortho rectified	Meets the accuracy req.	Jan. 2007
InSAR DEM	Meets the accuracy req.	Jan. 2007
Surface deformation	In progress	Jan. 2007
Mosaic	In progress	Jan. 2007

■PALSAR high level products ■Geometric evaluation of Ortho products



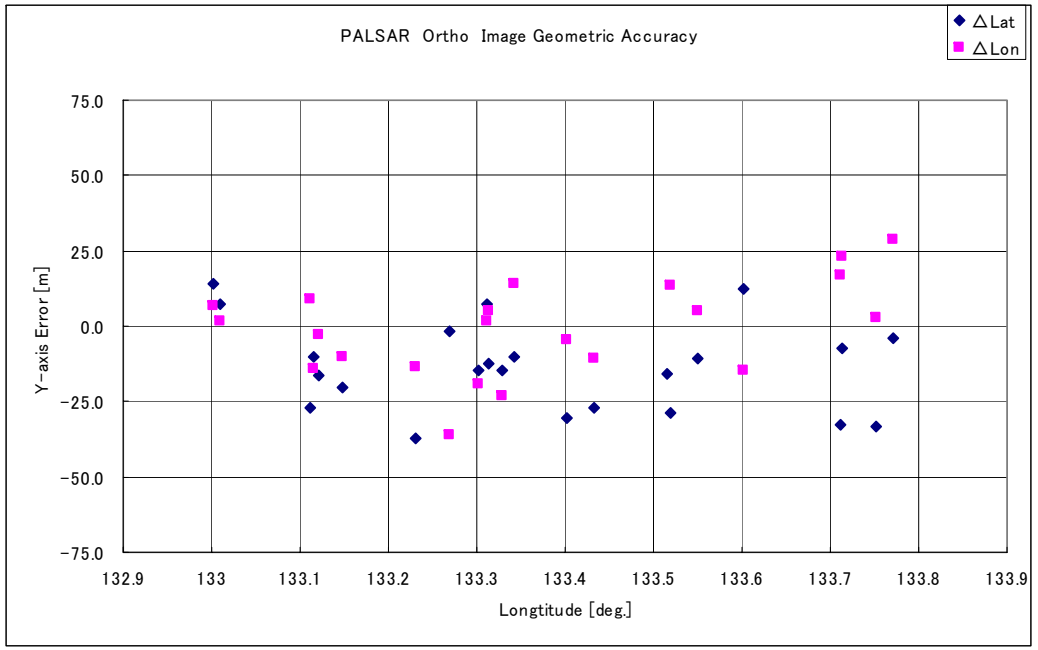
Ortho product (HH,HV,HV)

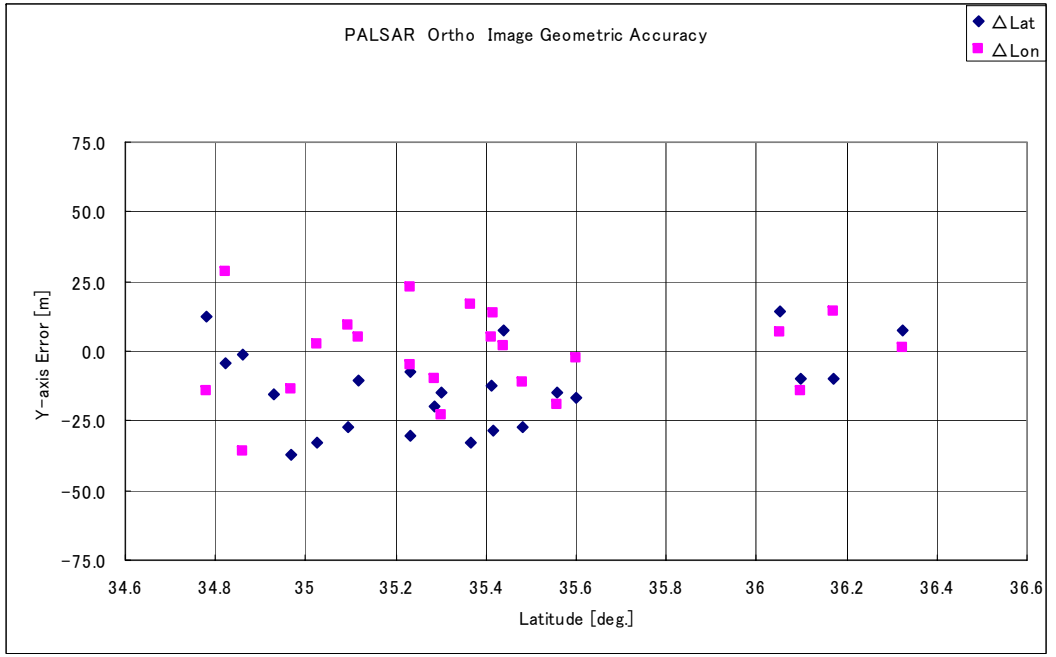
PALSAR mode :FBD41.5H
RSP : 421
Area : Mt. Daisen
OBS. Date : 2006/8/4
Image : Ortho (sar_Q16_g_HH)
Pixel Spacing : 12.5m
Map Projection : EQR
Processor : SIGMA-SAR ver20060809
DEM : Digital Map 50m Grid (Elevation)
Reference : Digital Map 25000 (Map Image)



RESULT

	Lat.	Lon.
mean	-13.6m	-0.9m
Min.	-37.4m	-36.0m
Max.	14.1m	28.7m
Std. Dev.	15.2m	15.8m

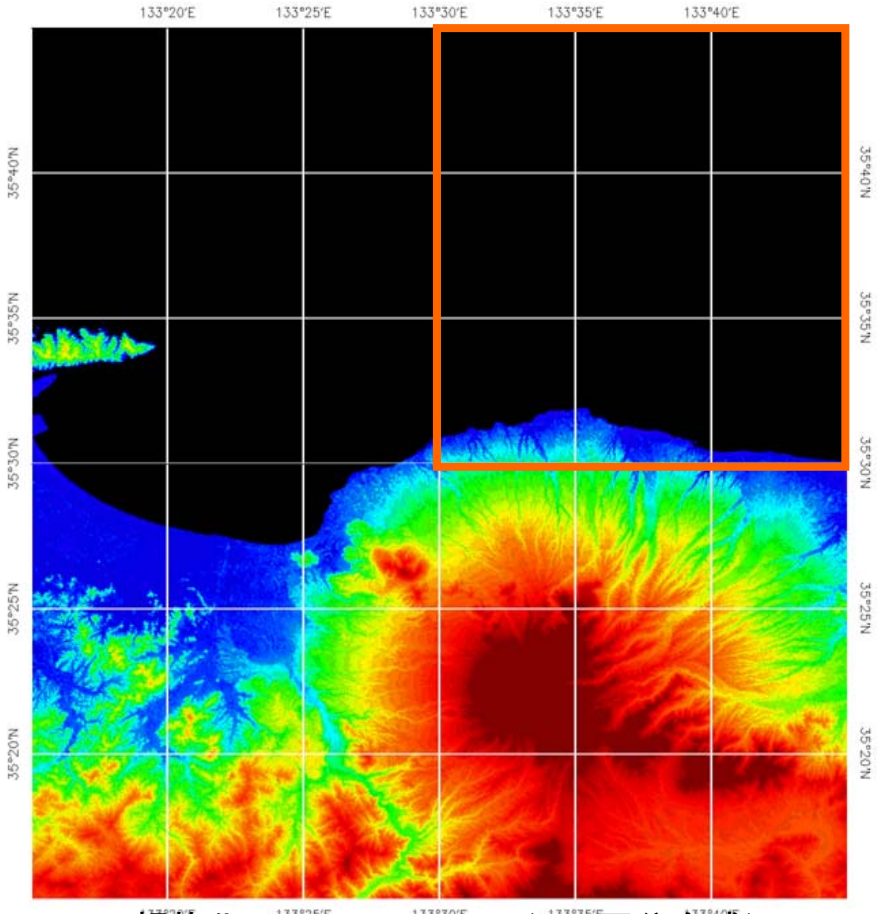




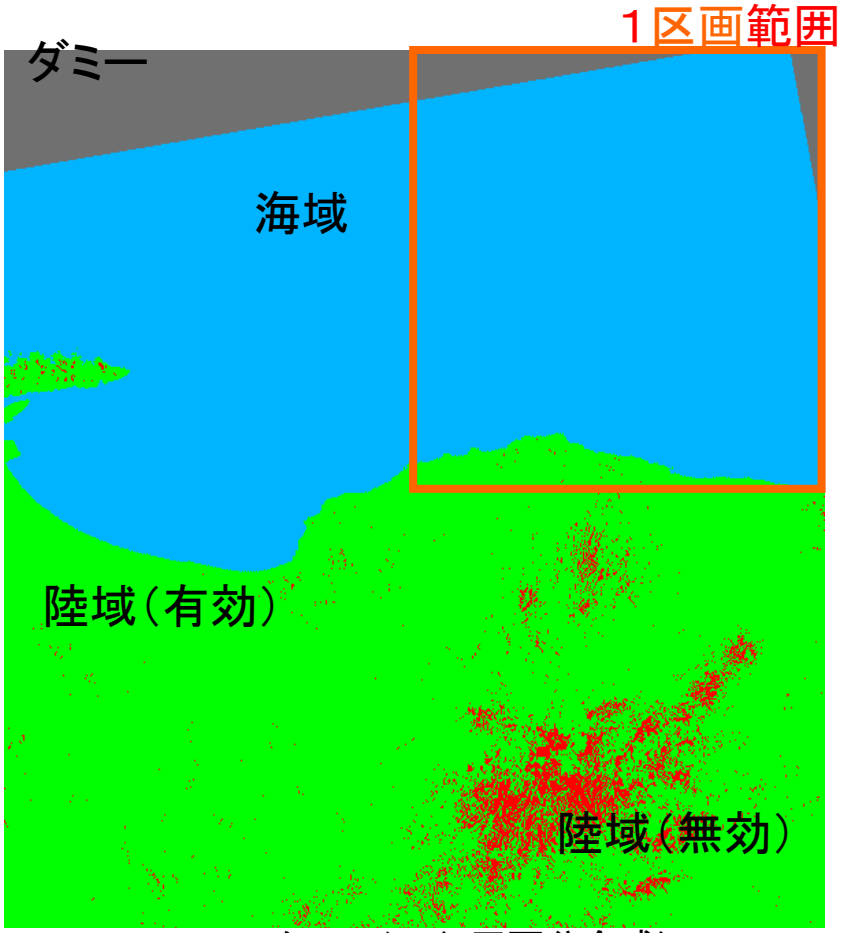
■PALSAR High level products■

InSAR DEM

PALSAR mode :FBD41.5H
RSP : 421
Area : Mt. Daisen
OBS. Date : 2006/5/4 & 2006/6/19
Baseline Distance (Bp) : −467.7〜−541.8m
Mesh size : 1.5sec.(≒50m)
Map Projection : EQR
Processor : SIGMA-SAR ver20060824
Reference : Digital Map 50m Grid (Elevation)

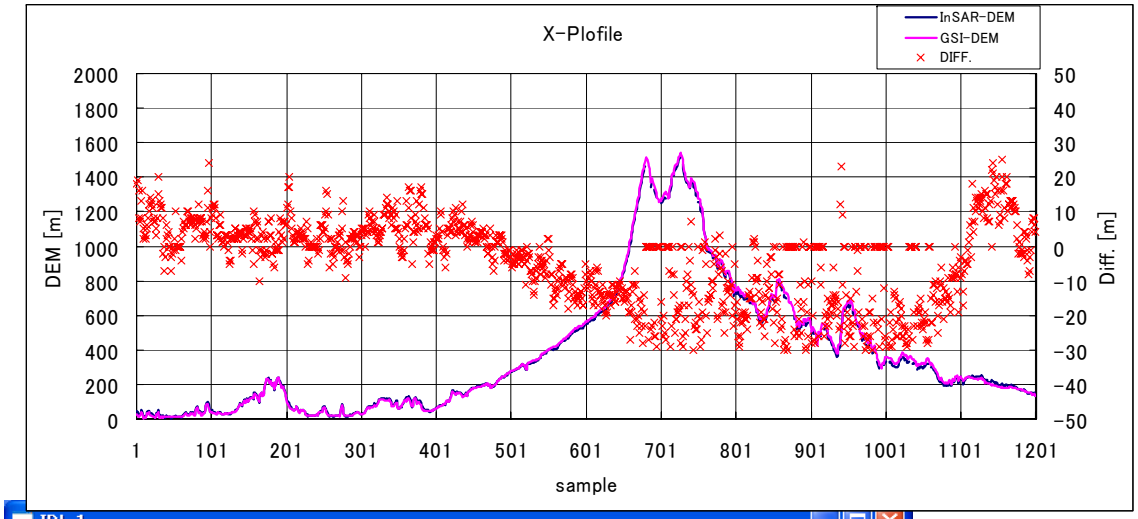


規格化DEM50mメッシュ（4区画分合成）

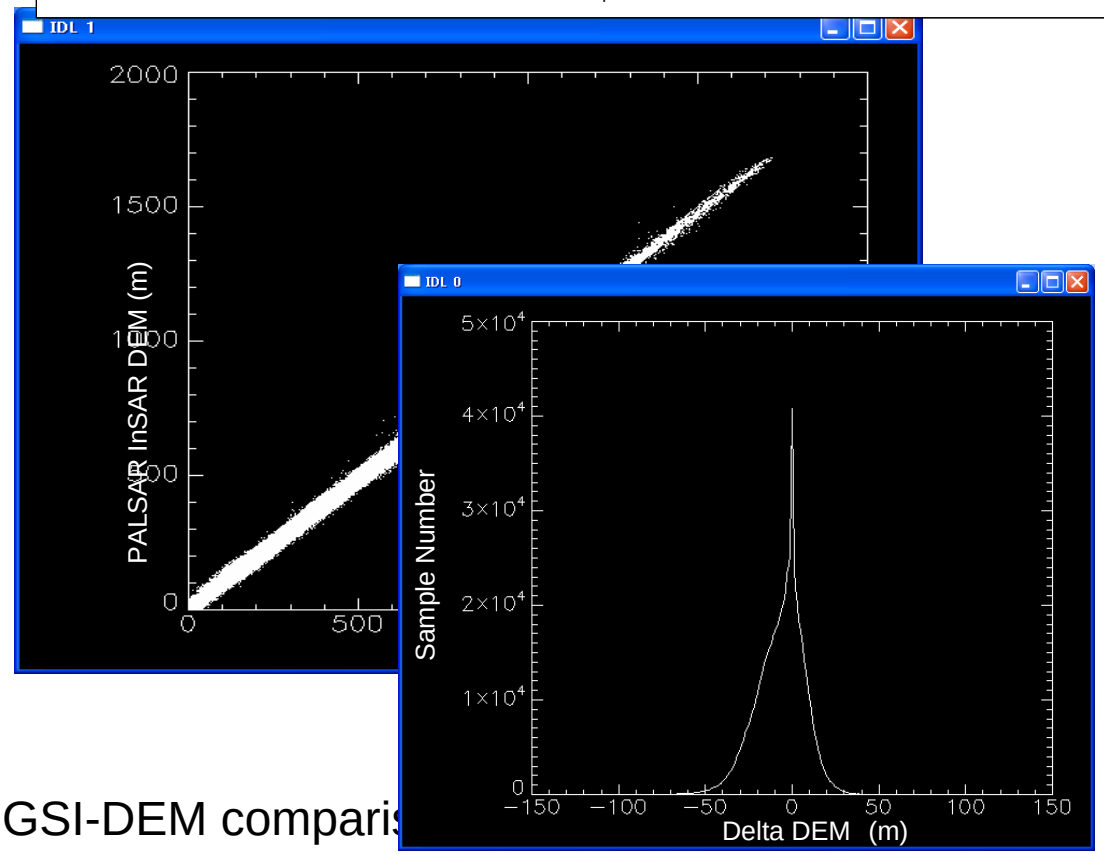


マスクファイル（4区画分合成）

RESULT



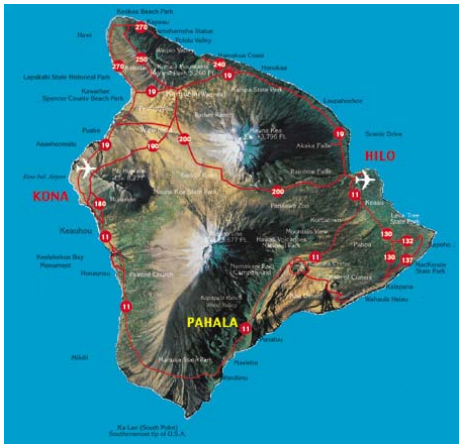
Average(m)	-4.578
Std. Dev.(m)	12.084
Max.(m)	25.0
Min.(m)	-30.0

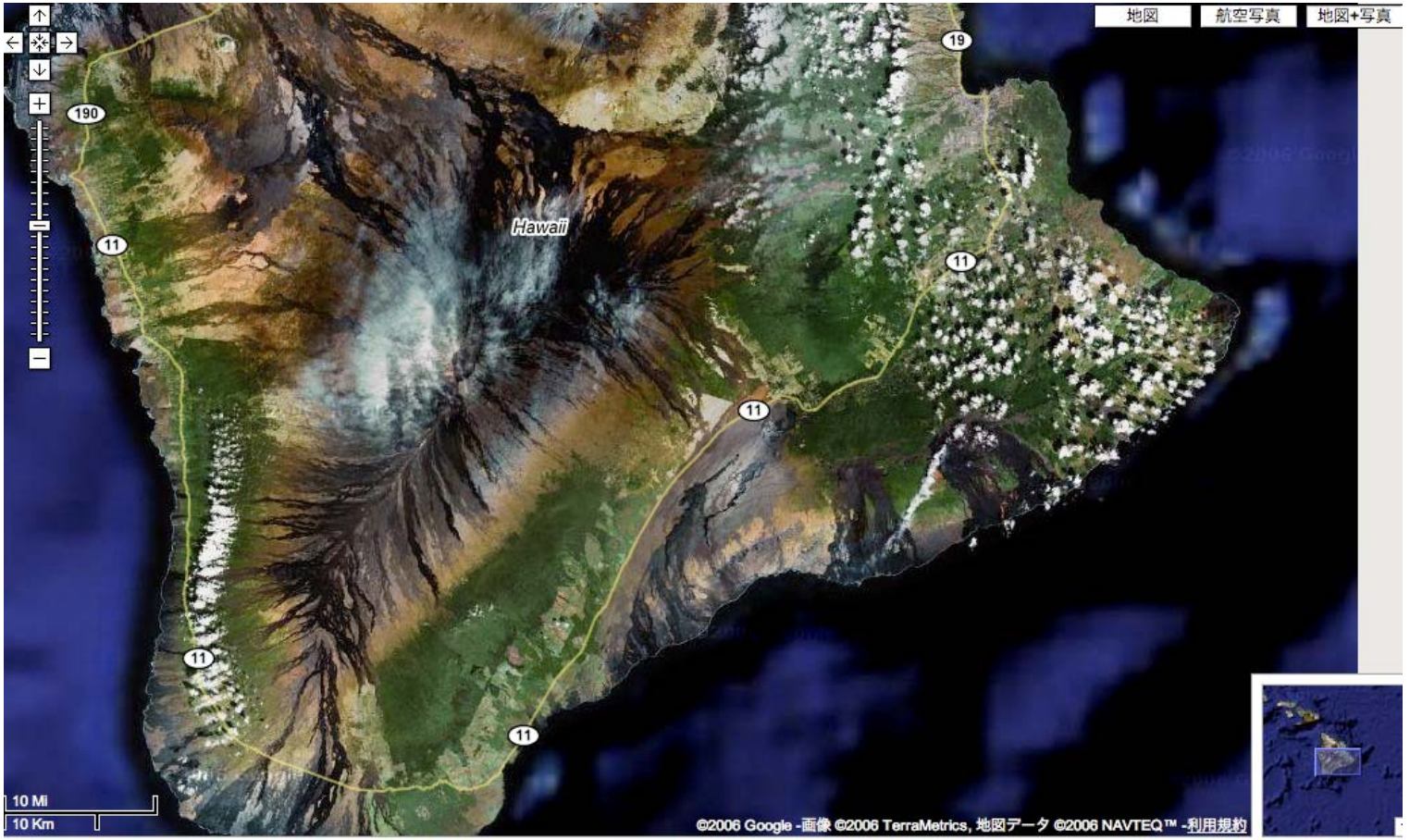


Valid_rate(DN=0)[%]	47.082
Dummy_rate(DN=1)[%]	6.454
Non-DEM_rate(DN=2)[%]	2.801
Sea_rate(DN=3)[%]	43.663
True-Valid_rate[%]	94.385
Average[m]	-4.742
Std.Dev.[m]	11.384
Maximum[m]	30.0
Minimum[m]	-30.0

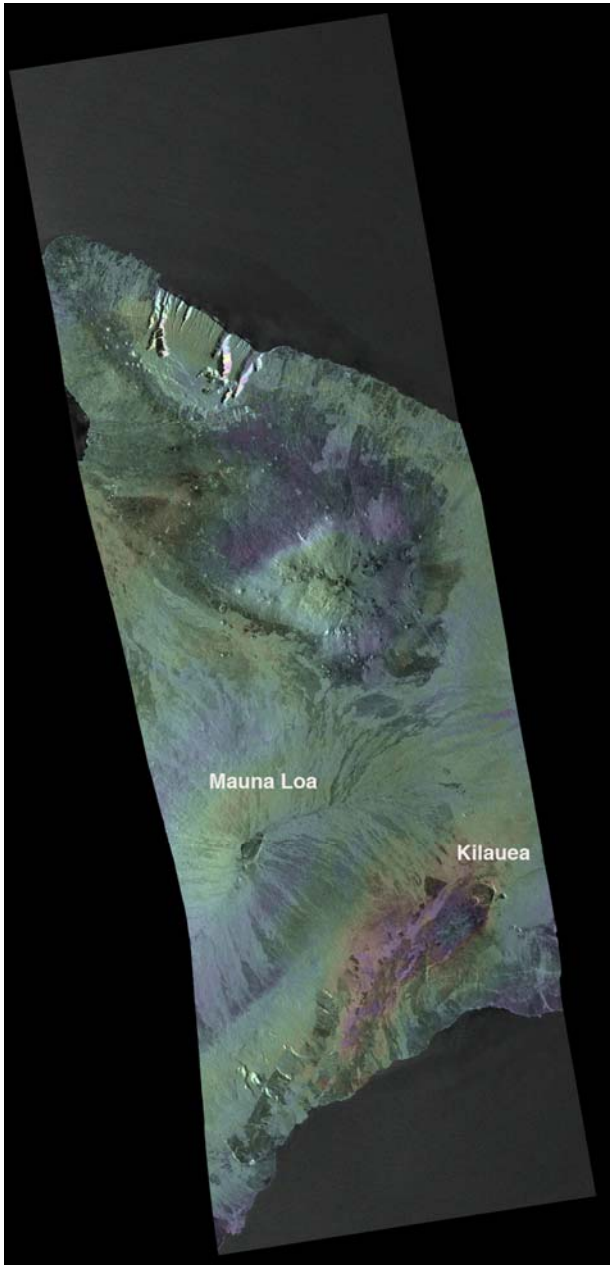
GSI-DEM comparis

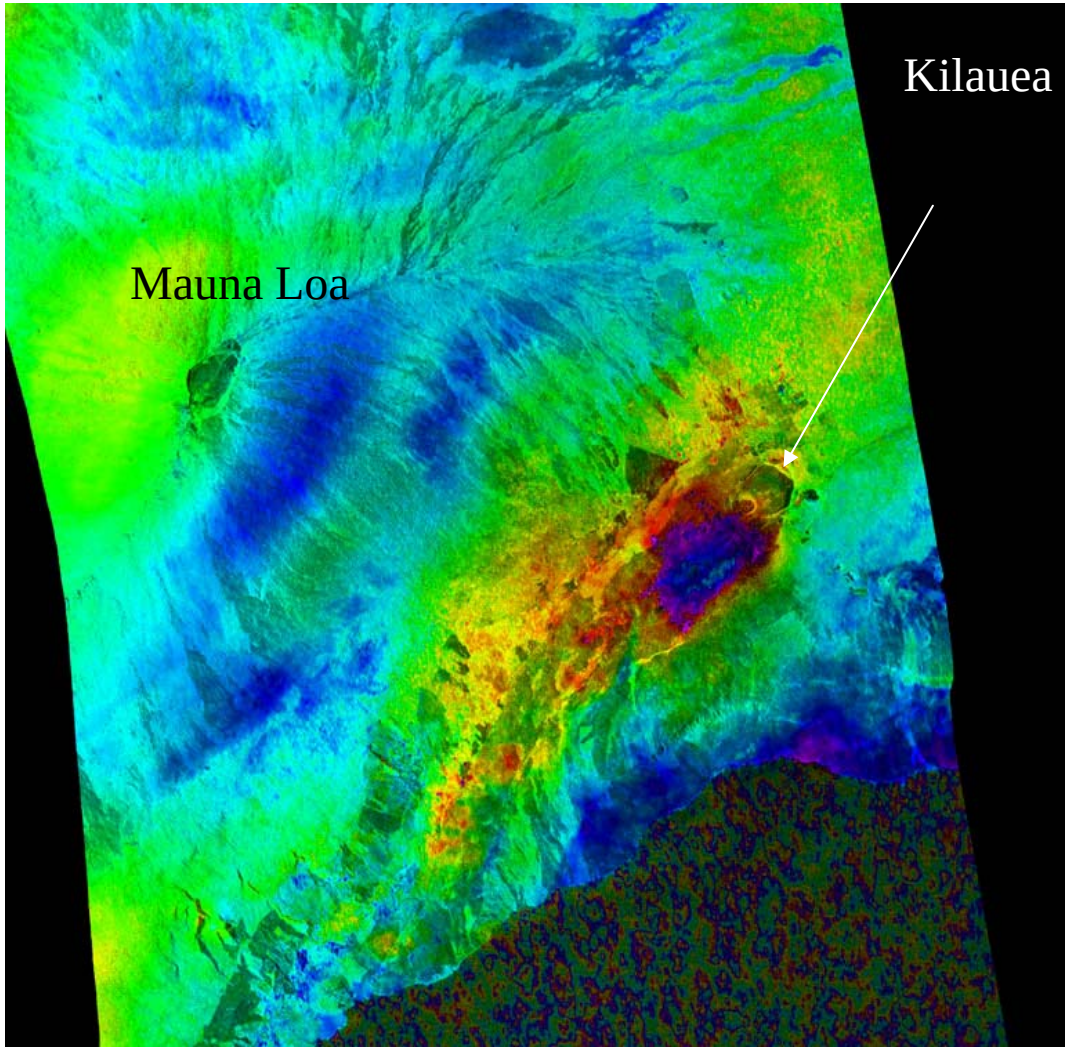
Surface deformation
Hawaii
Acquisition : Aug. 2 2006-May 2 2006
Baseline : 70m
Mode : FBS343H



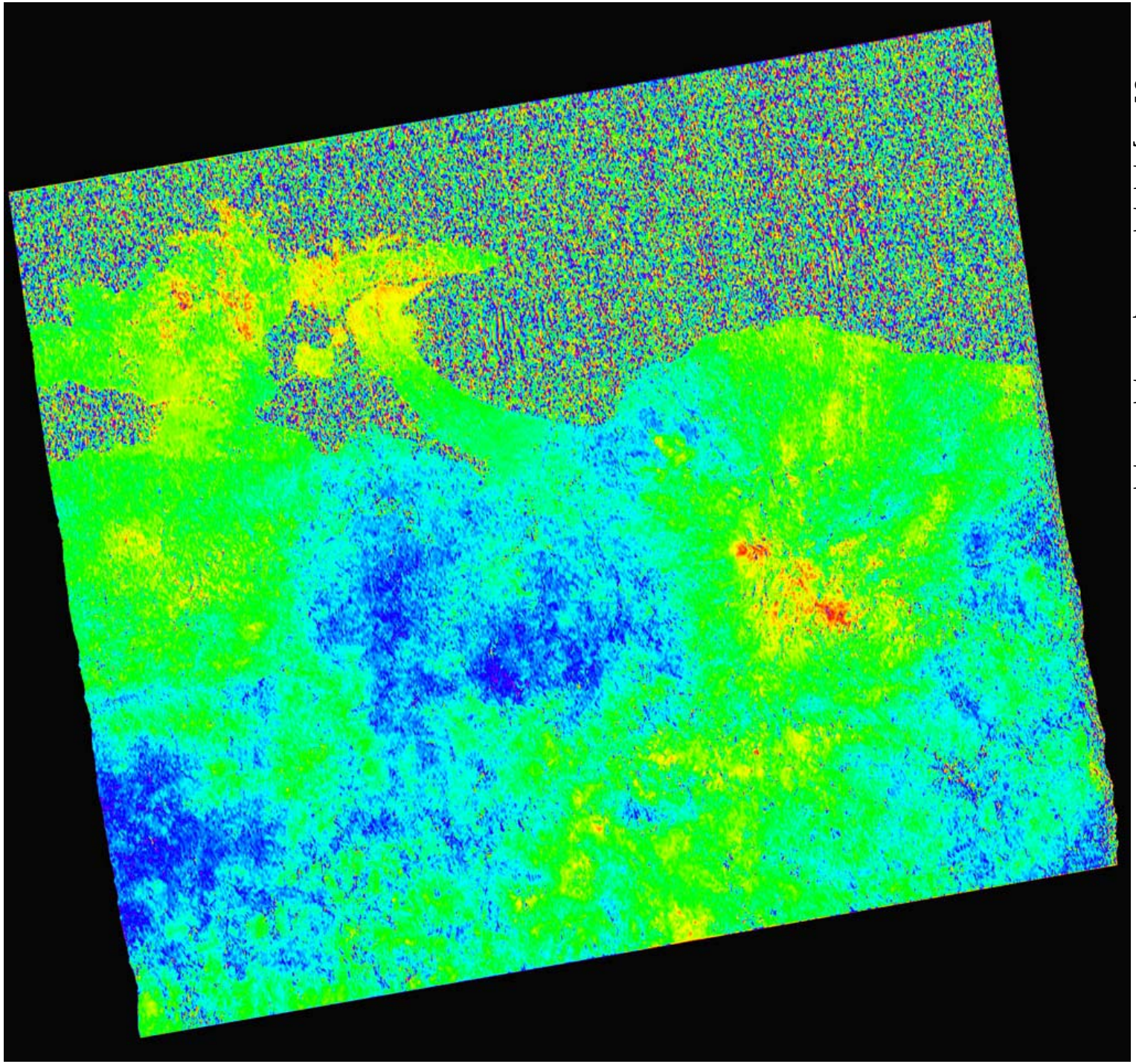


Volcanic activity of Hawaii monitored by PALSAR





South of the Kilauea was uplifted by 6 cm.

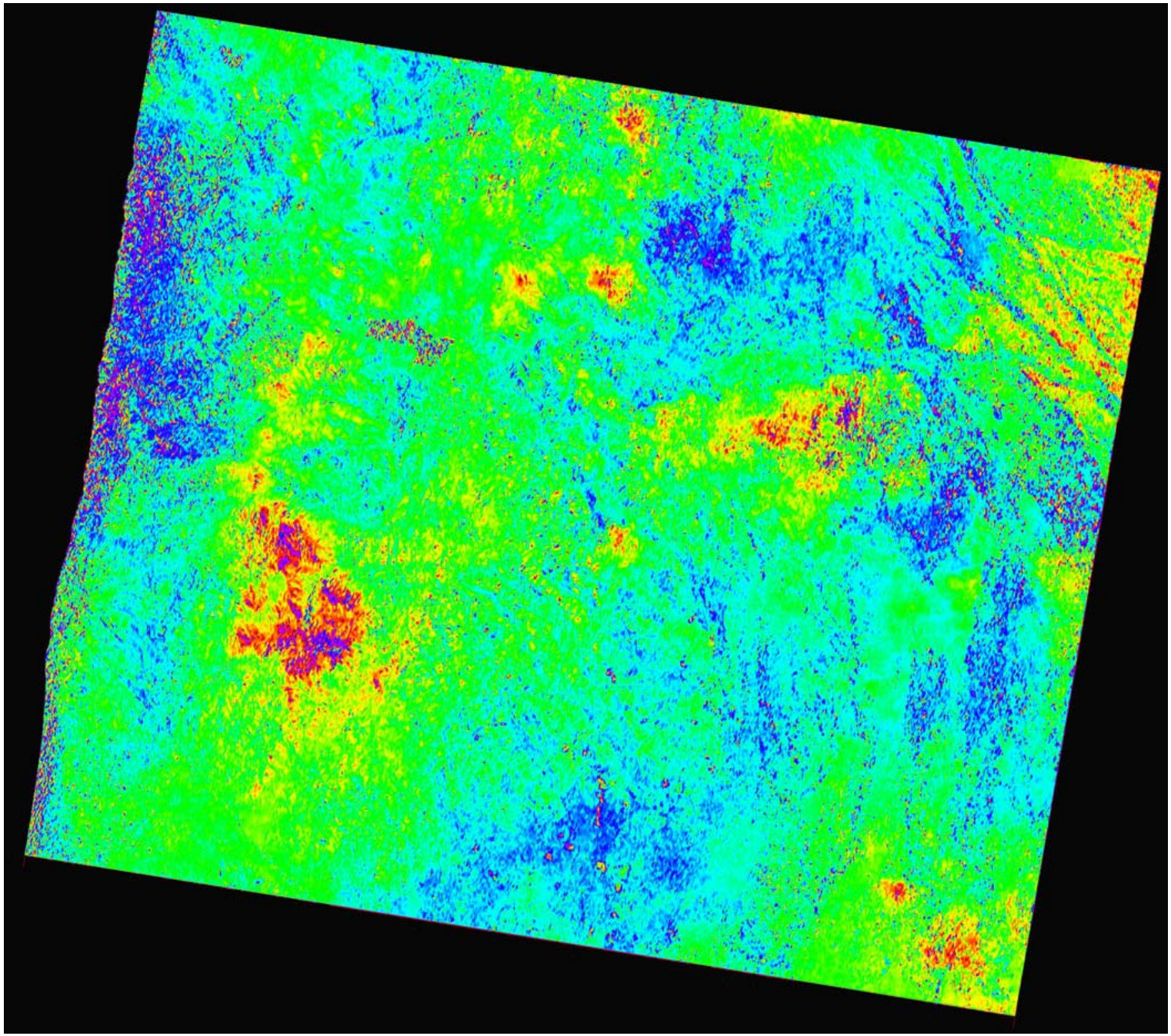


Shimane,
Japan
FBD415
Bp~500m

Amplitude

Height

Deformation



Nikko
Chuzenji

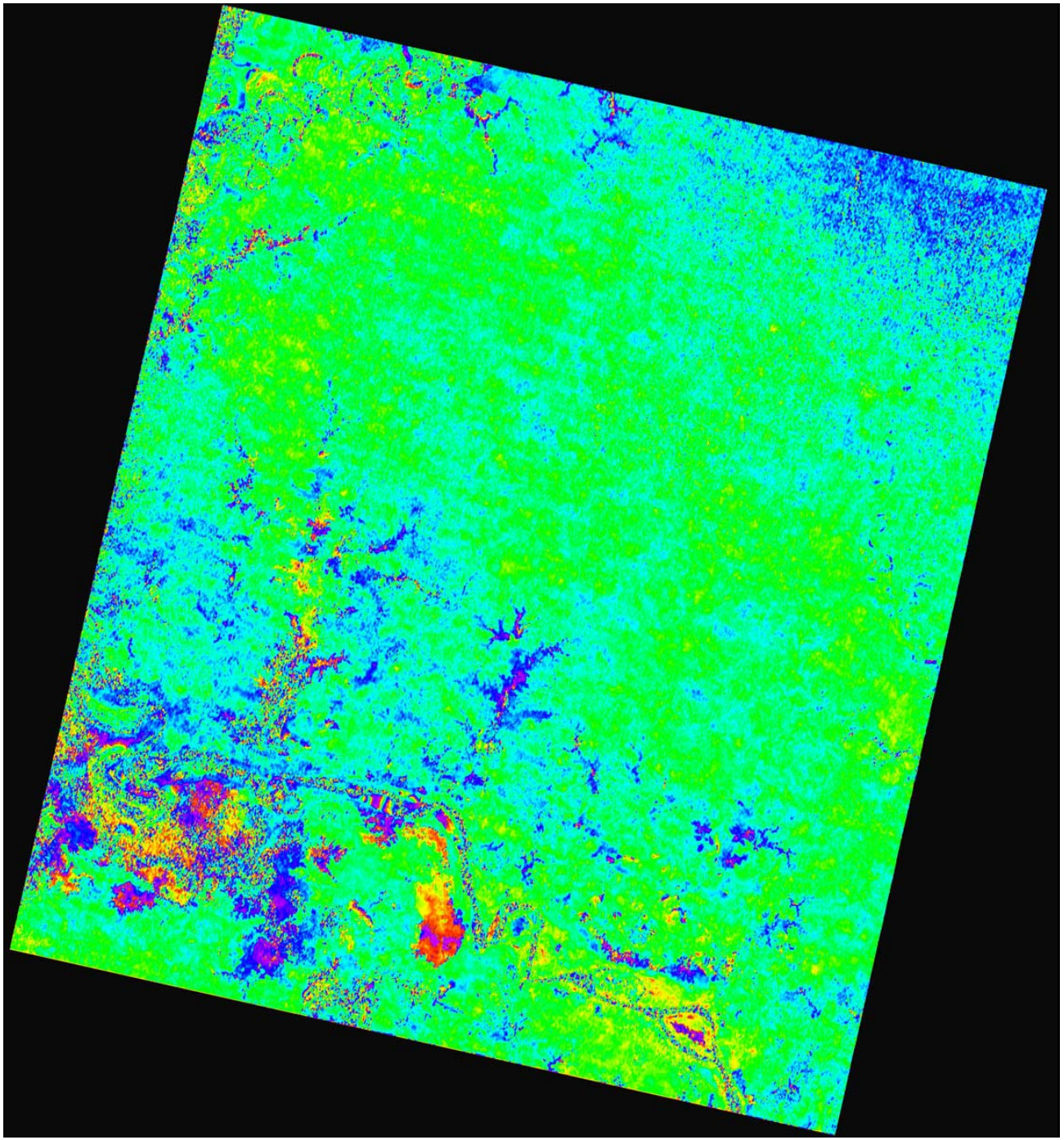
FBS415H
Bp~500m

Amplitude

Coherence

Height

Deformation



New guinea

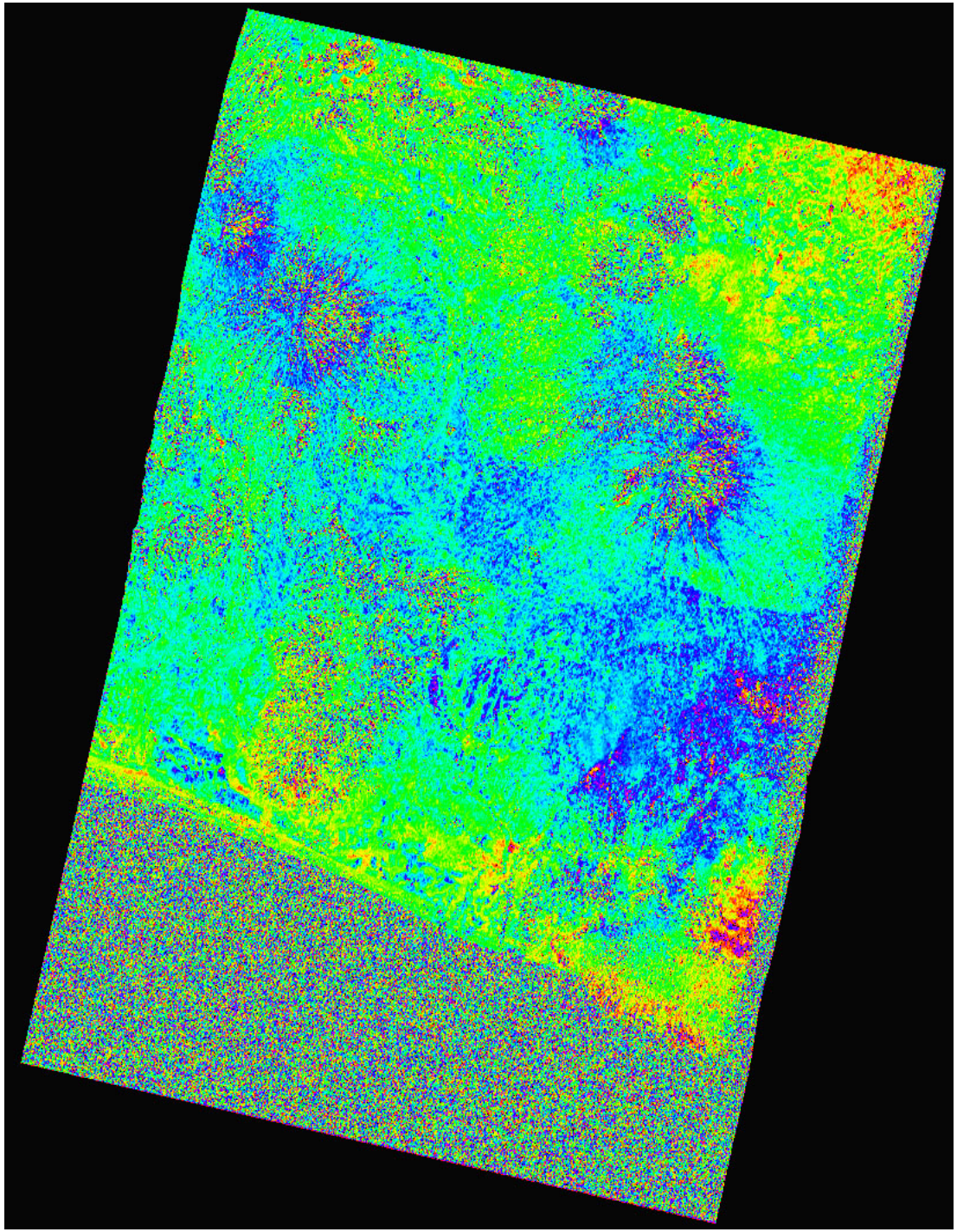
9/23∽8/8
FBS343
Bp~500m

Amplitude

Coherence

Height

Deformation



Merapi

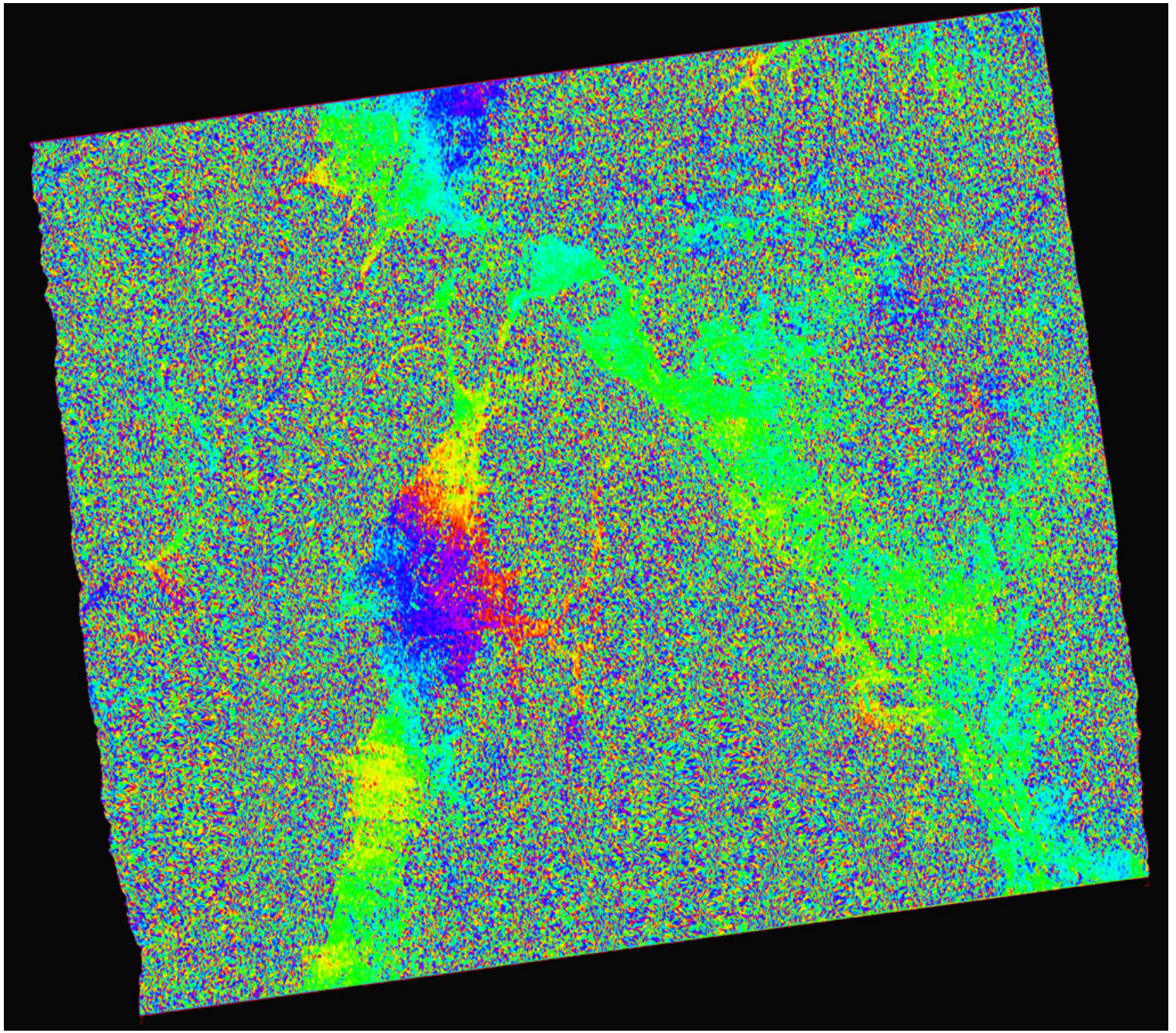
Bp~1.7Km

Amplitude

Coherence

Height

Deformation



Tenryu-river
FBS343
Bp~2.7Km

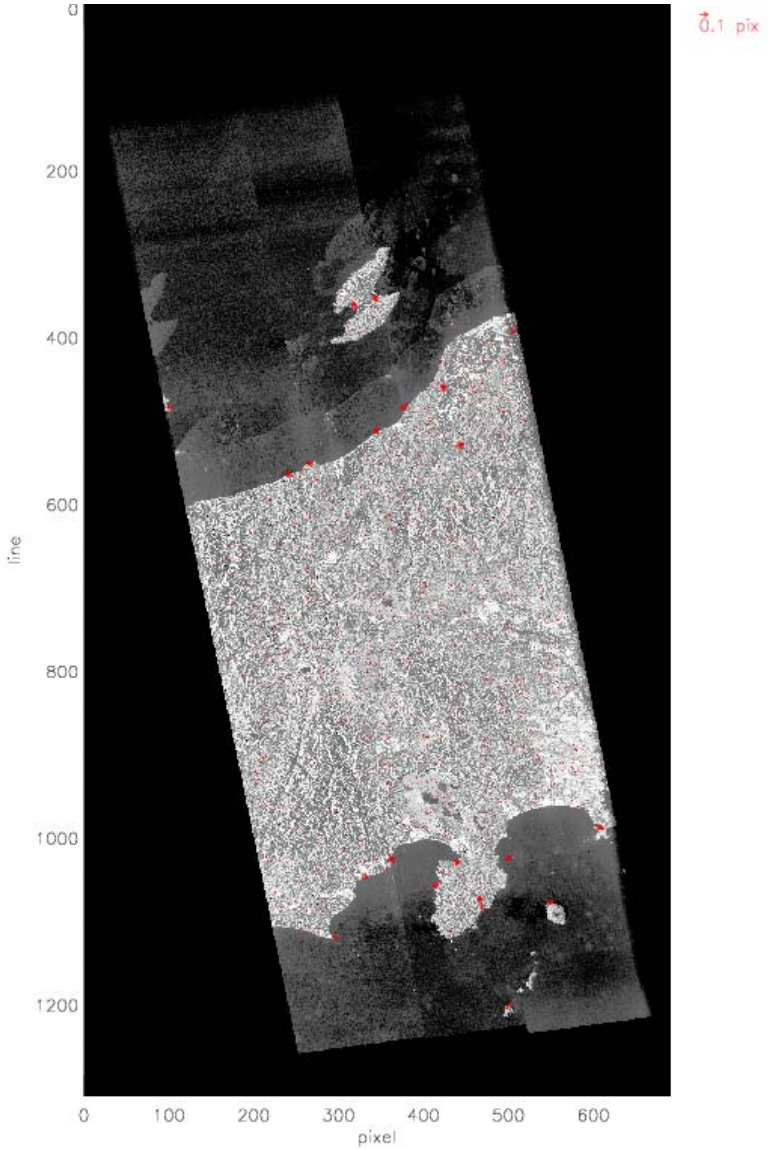
Amplitude

Coherence

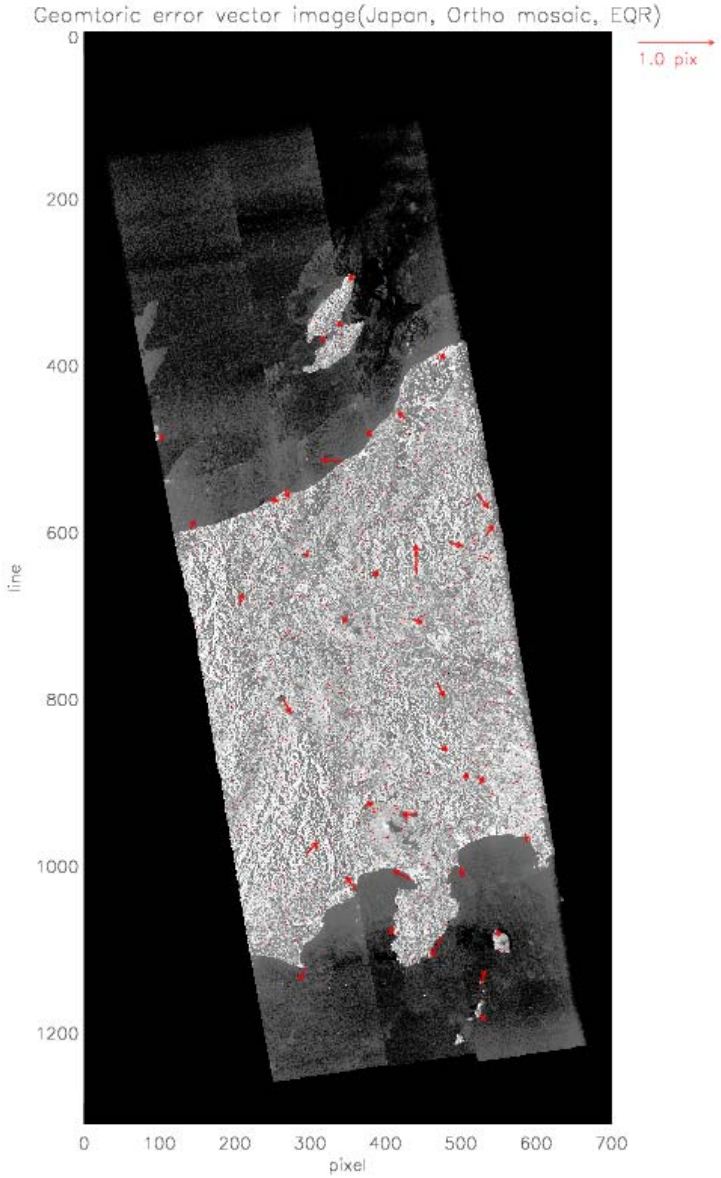
Height

Deformation

Mosaic of the PALSAR 41.5 data

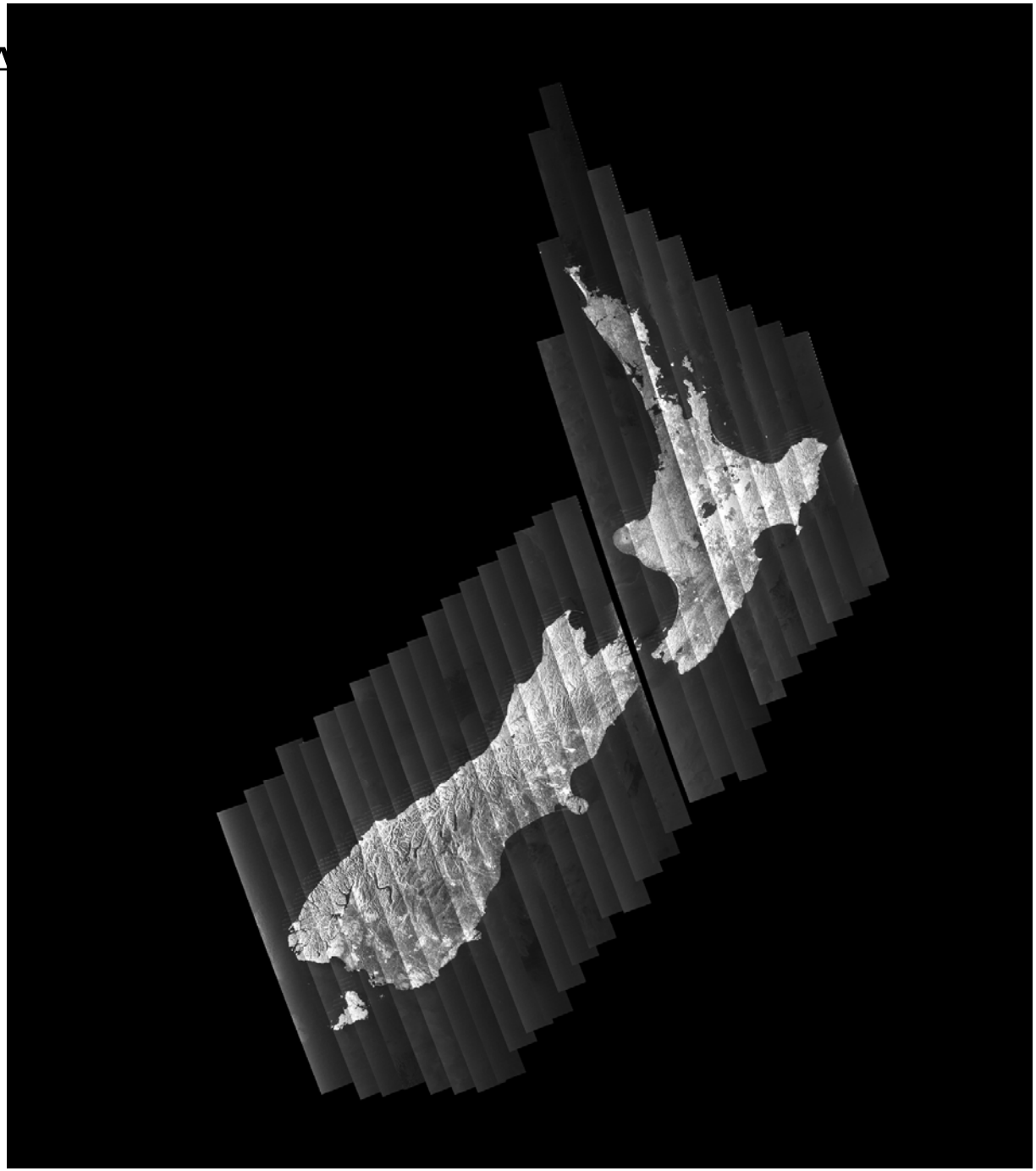


50m mosaic



Ortho 50m mosaic

SA



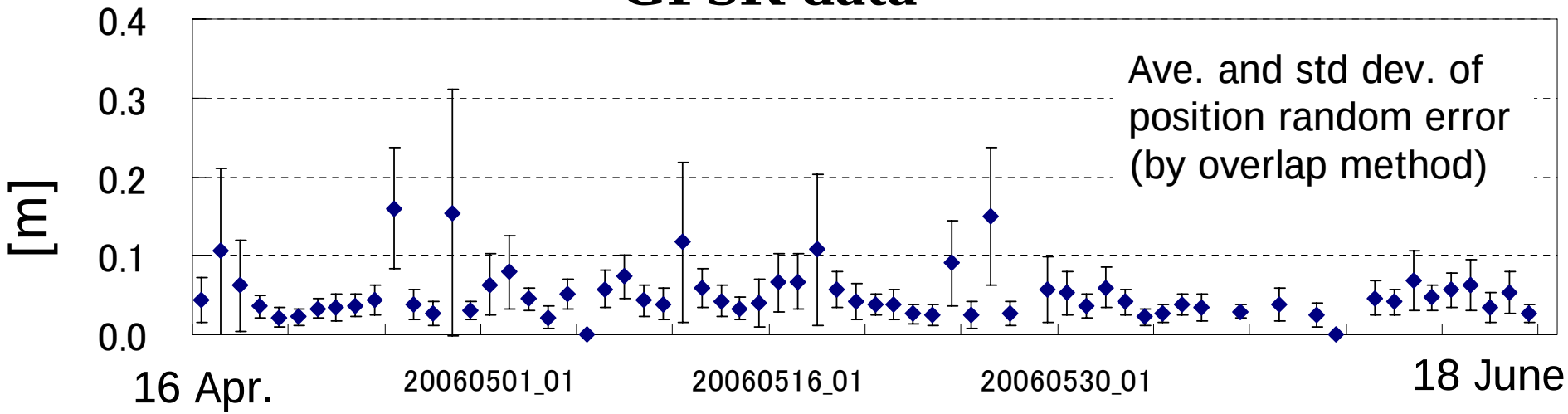
Evaluation items	Goal accuracy	mesasurements
Radiometry ●Attenuator chracteristics（STC/AGC） ●Antenna pattern（azimuth・range） ●Noise level ●Fundamental chrcatreistics saturation SNR I-Q orthogonality I-Q gain ballance Tranmission chirp chracteristics Doppler measurements Statbility of the trammission power Isolation of cross polarization ●absolute calibration ●sigma-naught ●polarimetric calibration ●simultaneous datatake with PiSAR ●resolution ●Chirp signal time change	 0.1dB/step ＜ 0.1dB以下（azimuth、range） ＜ NEσ^0 -21 dB（@34.3） ＜5% ＞5 dB（生データ） 90+-5° ＜0.2dB TBD Hz/sec以下 ＜50Hz ＜0.6 dB（1 revolution） ＞25 dB ＜1.5 dB <1.5 dB HH/VV<0.2 dB, phase of HH/VV＜5deg. 8／19，10／4 10m<2look ーーー	 NA <1dB -22~-23 dB@ north pole Meets left at MGCMGC 8dB(FBS),PLR(8dB)、FBDは3dB 90+1.6 degrees 0.03dB --- Same to the left 0.03dB（separating 7 mins.） 26 dB (HV-HH) 0．7dB 0．7dB HH/VV:ー0．018 dB以下，位相角:-1.7度 In evaluation Meets the left ーーーーー
geometry ●geometric accuracy	 200 m以下	 10m（13m）:mean (std. Dev.)
Image quality ●radiometry PSLR（range、azimuth） ISLR SA（range、azimuth） Effective number of looks interference ●geometry resolution（IRF3dB dwon width） Geometruc evaluation	 <ー10 dB <ー5dB ＞ 20dB ＞ 20dB ーーー ーーー <5m（azimuth）、<10m（range） <200m	 ー16dB（Rg）、ー12dB（Az） ー8dB 17dB(RA), non measurable(Az):41．5 Non-measurable（RA、AZ）:34．3 Weaker than JERS-1 <10m Mets the left 8m（5m）:mean and std. Dev.

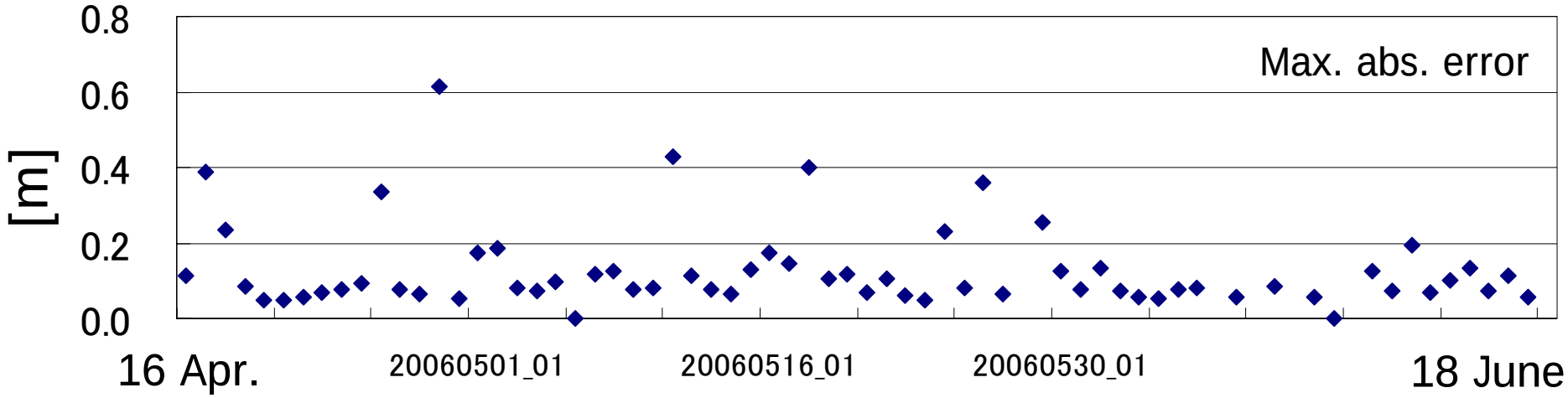
Summary（2）

High level products generation: Ortho images and InSAR DEM were successfully generated, meeting the goal accuracy. Continue to evaluate the products for more robust product generation.

Research Products generation: confirmed that the generation of the surface deformation capability using the PALSAR. Generated the SAR mosaic experimentally.

Precision position determination using onboard GPSR data

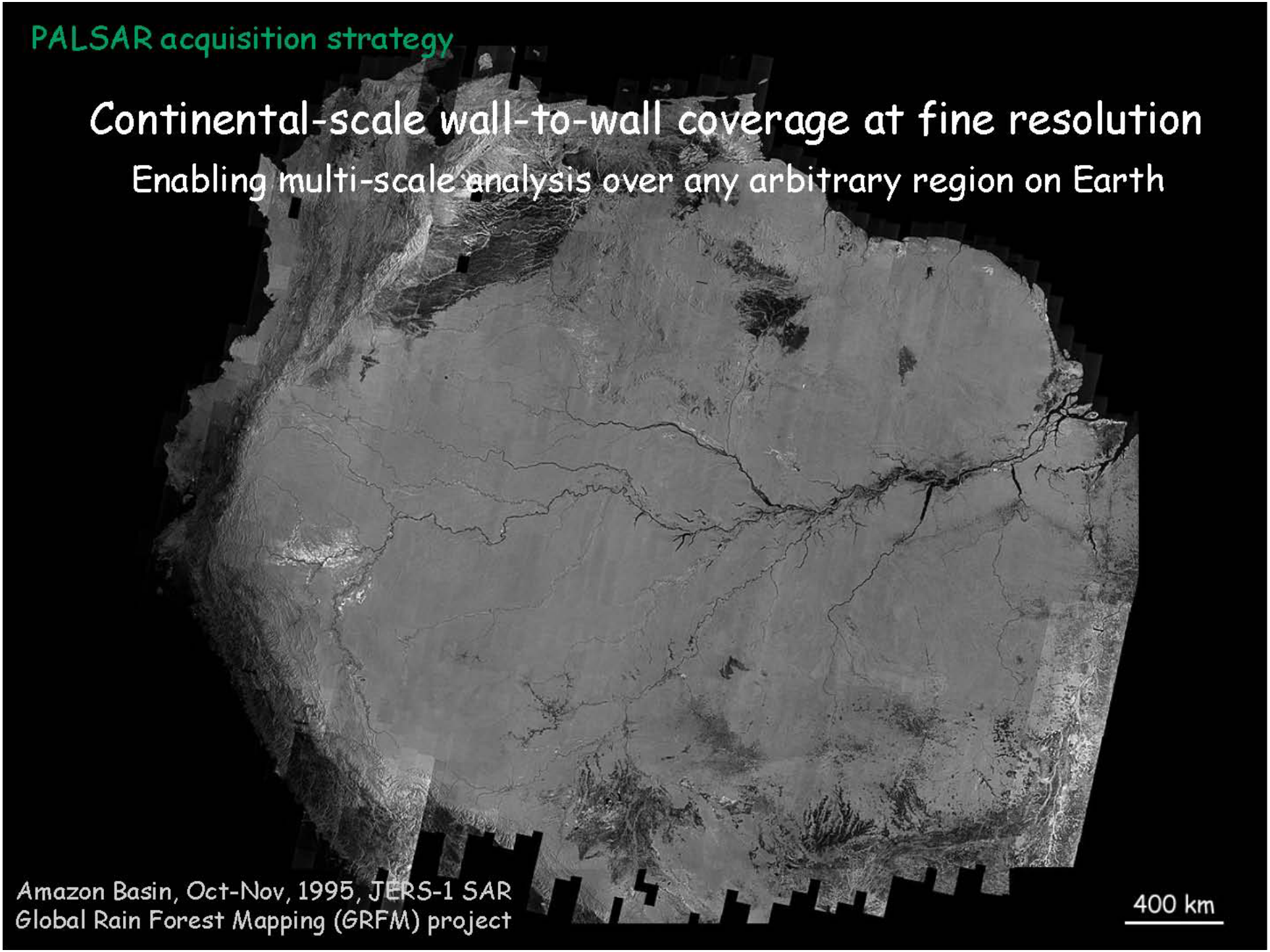




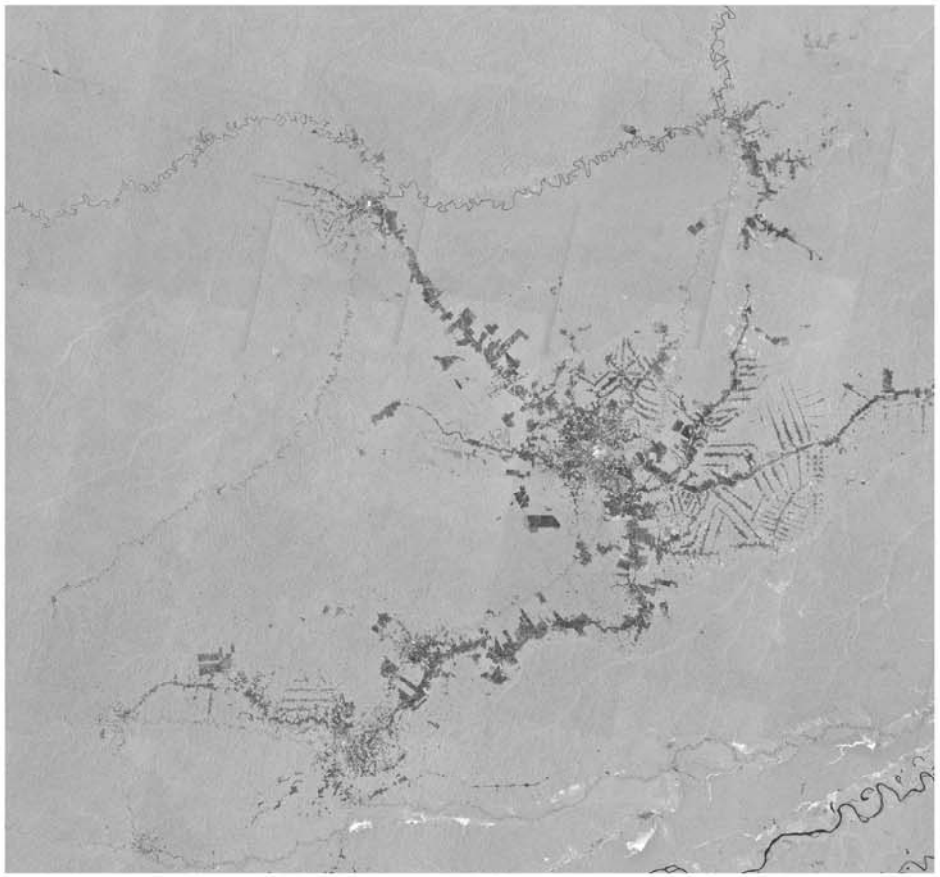
PALSAR acquisition strategy

Continental-scale wall-to-wall coverage at fine resolution

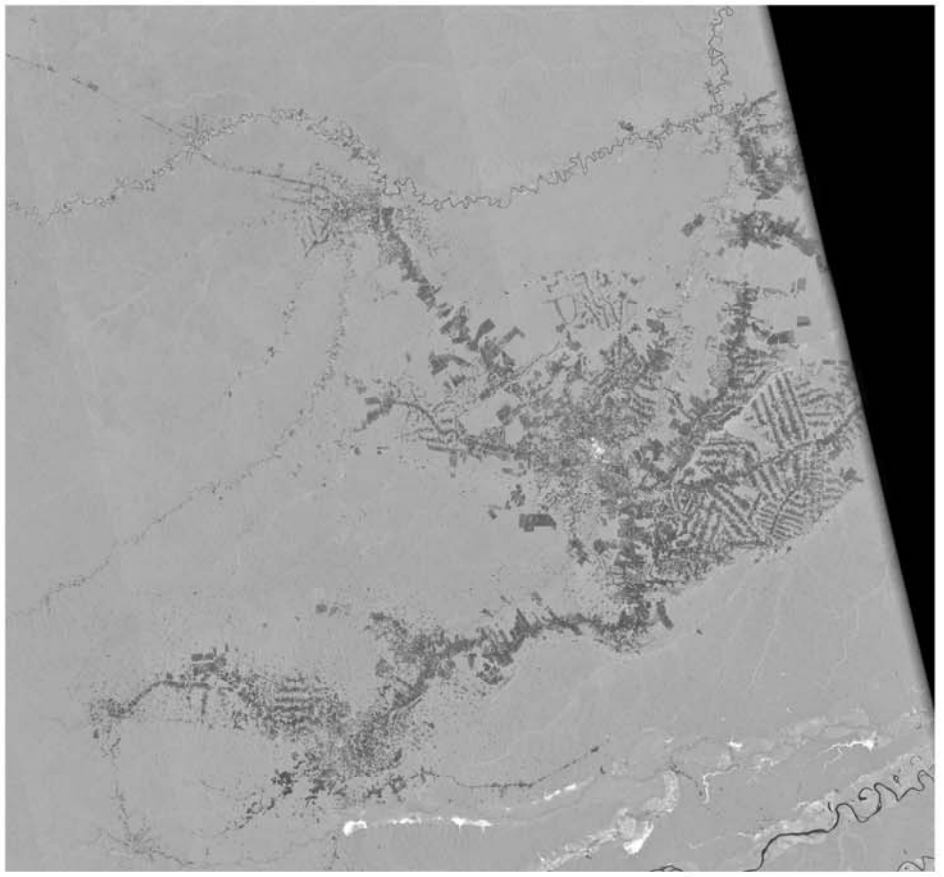
Enabling multi-scale analysis over any arbitrary region on Earth



Amazon mosaic(Rondonia area)



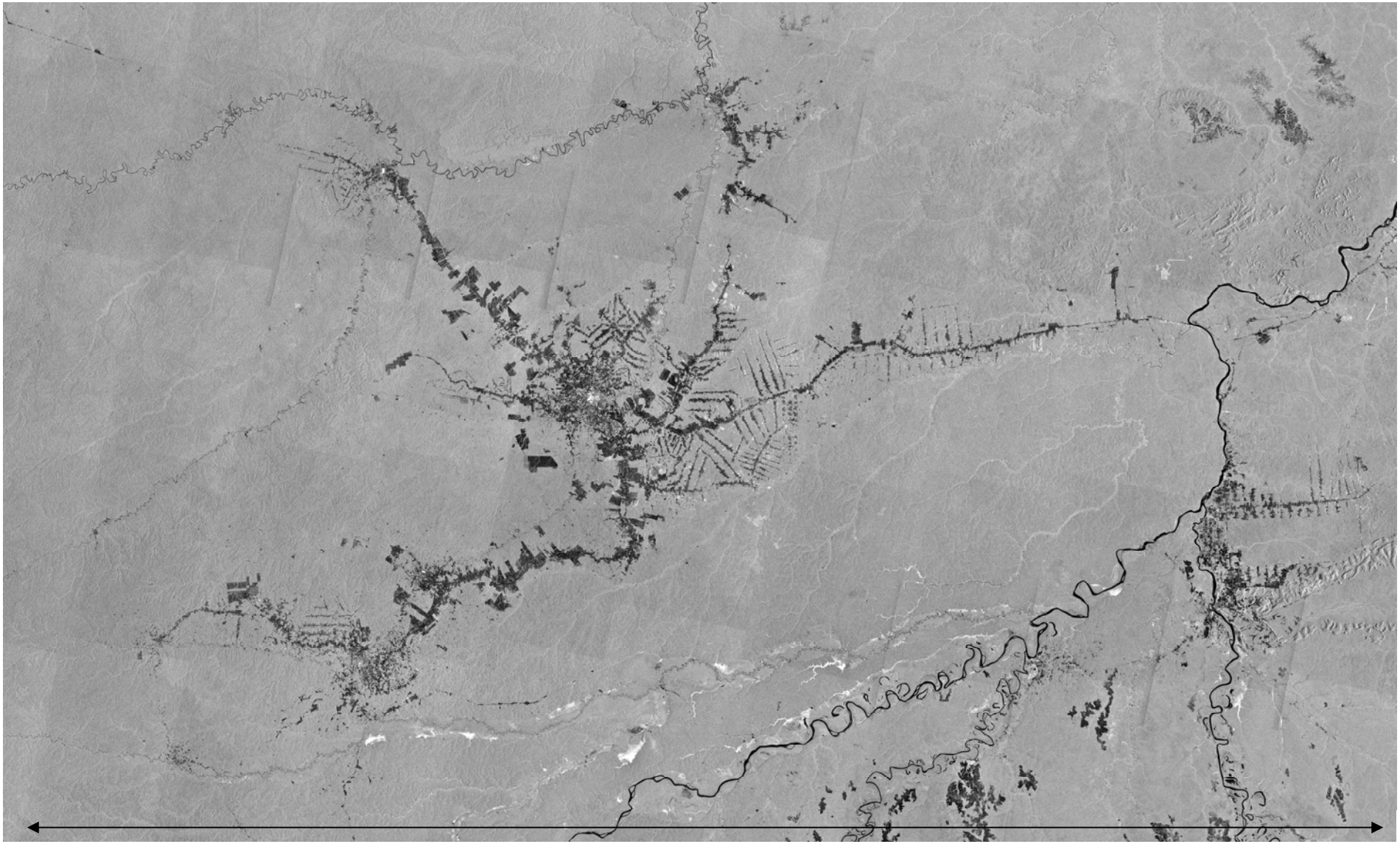
JERS (Sep/Dec, 1995, pixel spacing=100m)



PALSAR (2006, pixel spacing=50m)

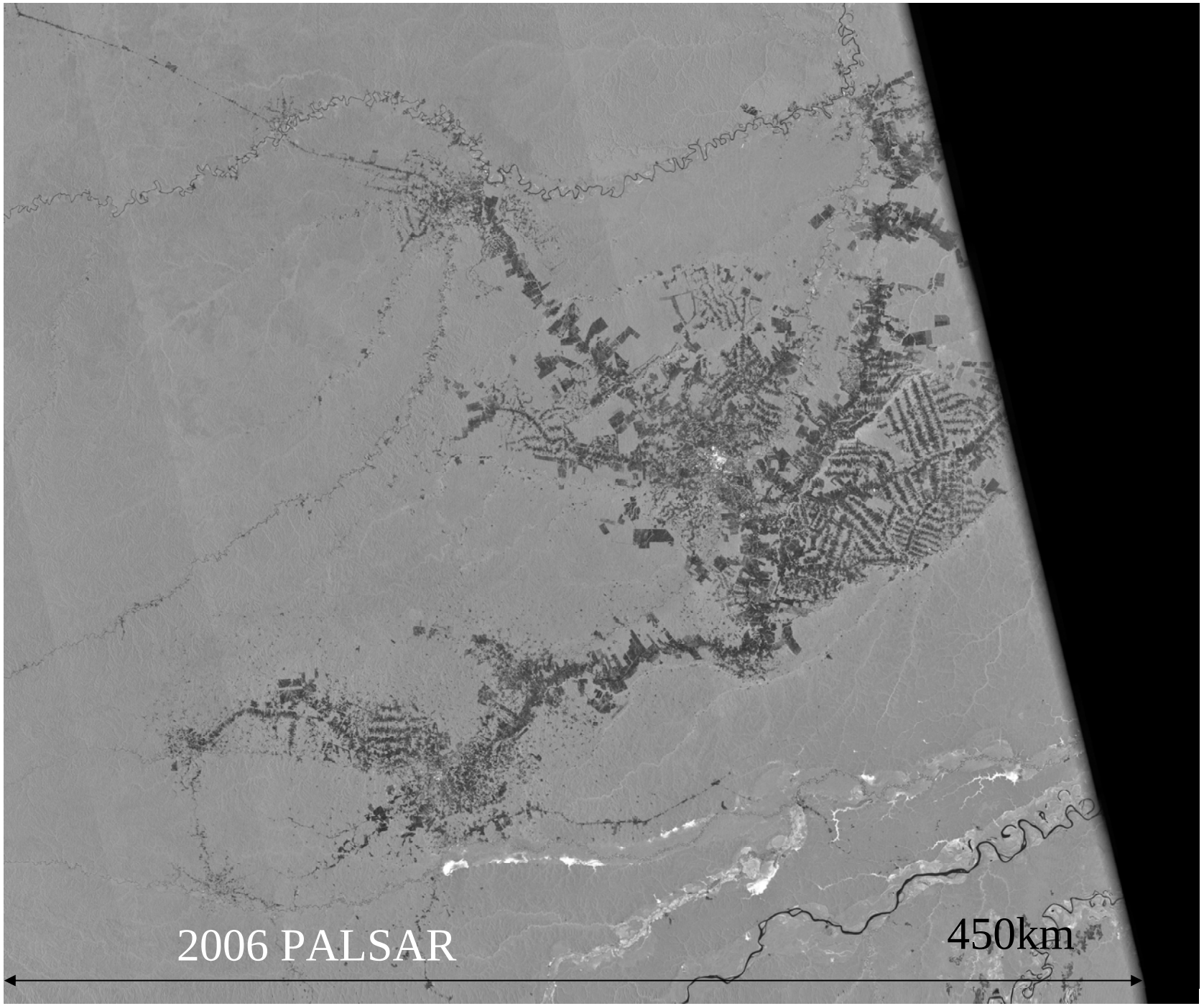
Mode : FBS41.5[deg]
Polarization : HH
Map projection : Mercator

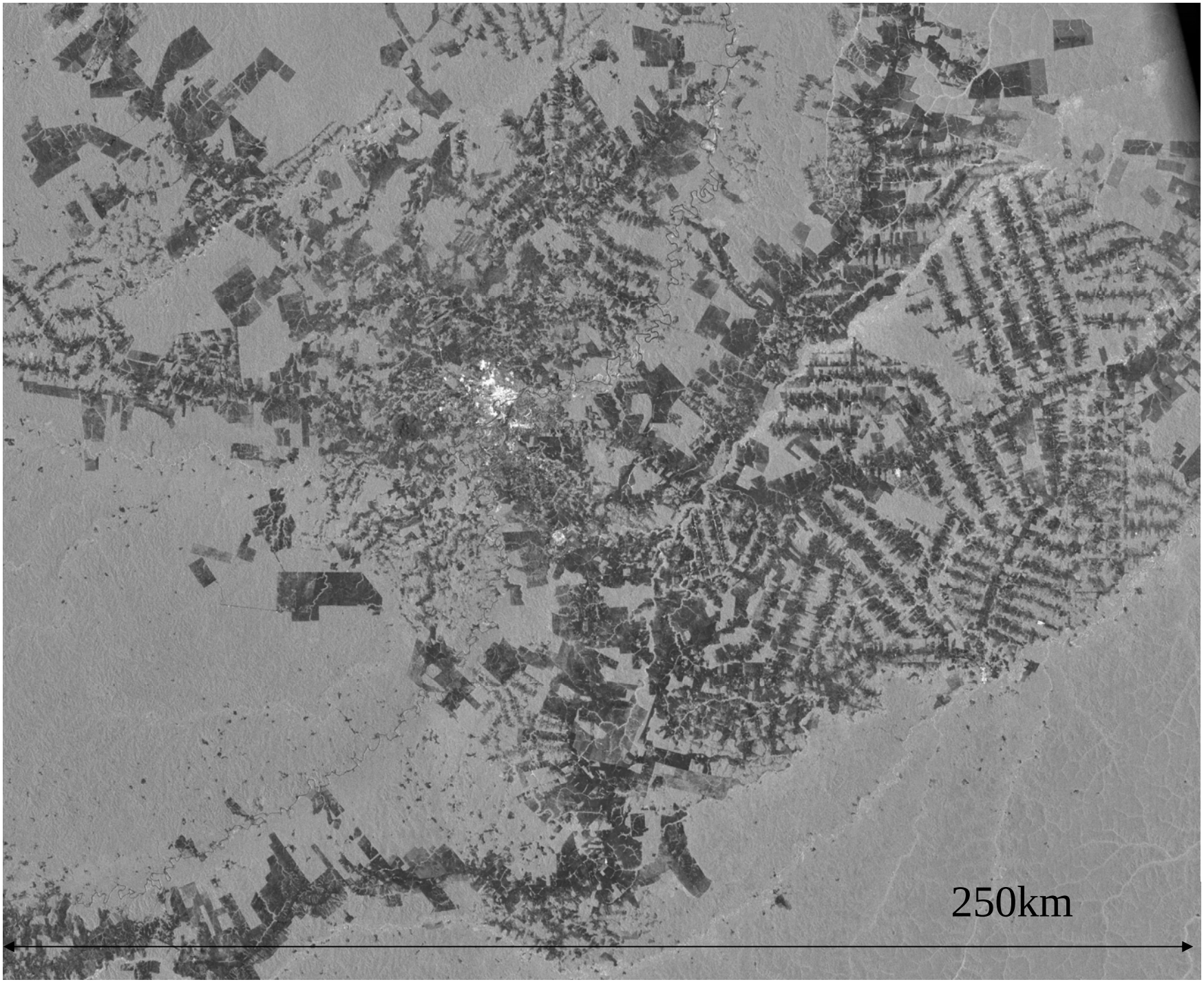
JAXA
Japan Aerospace Exploration Agency

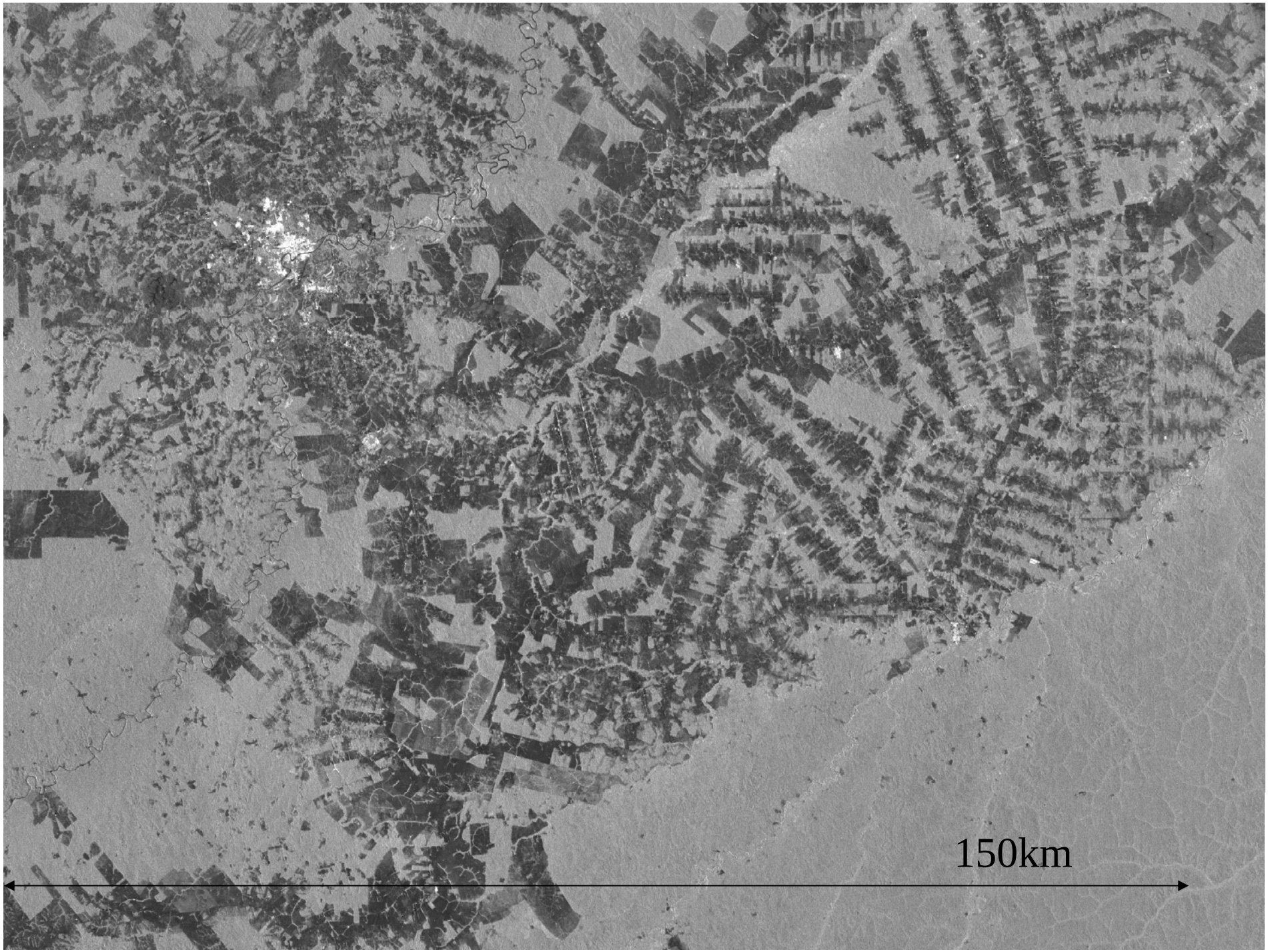


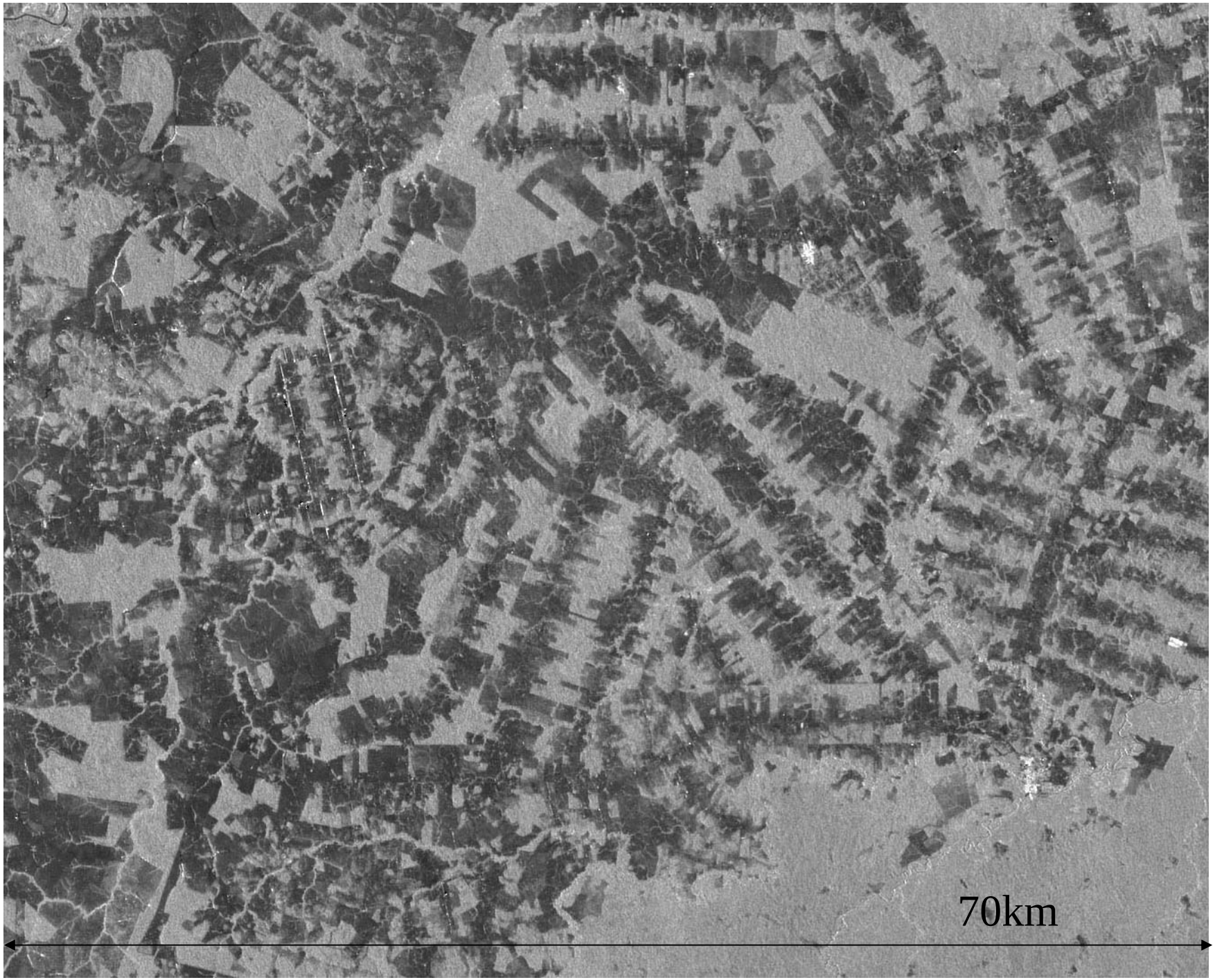
700km

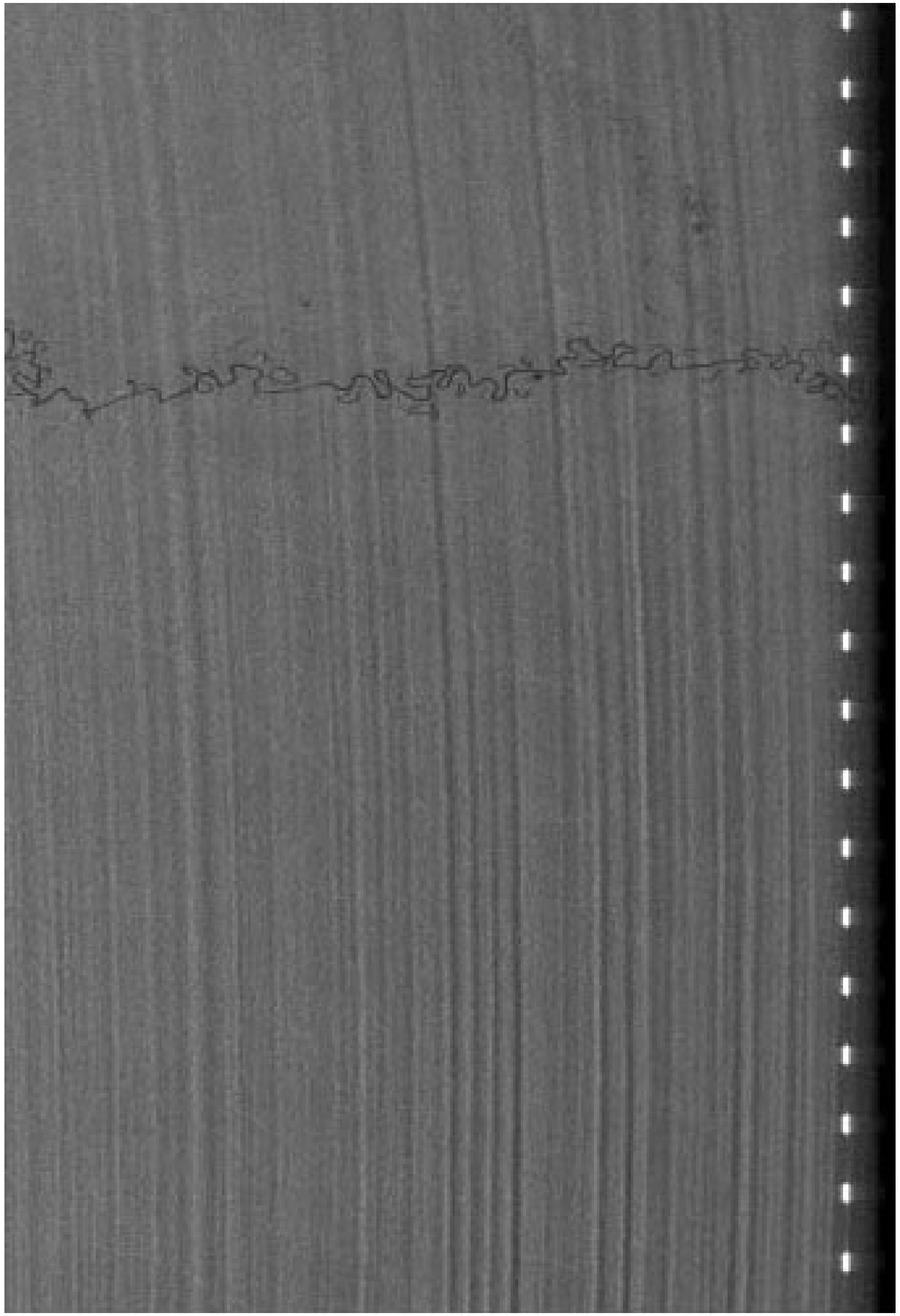
1995年　JERS-1 SAR


2006 PALSAR
450km

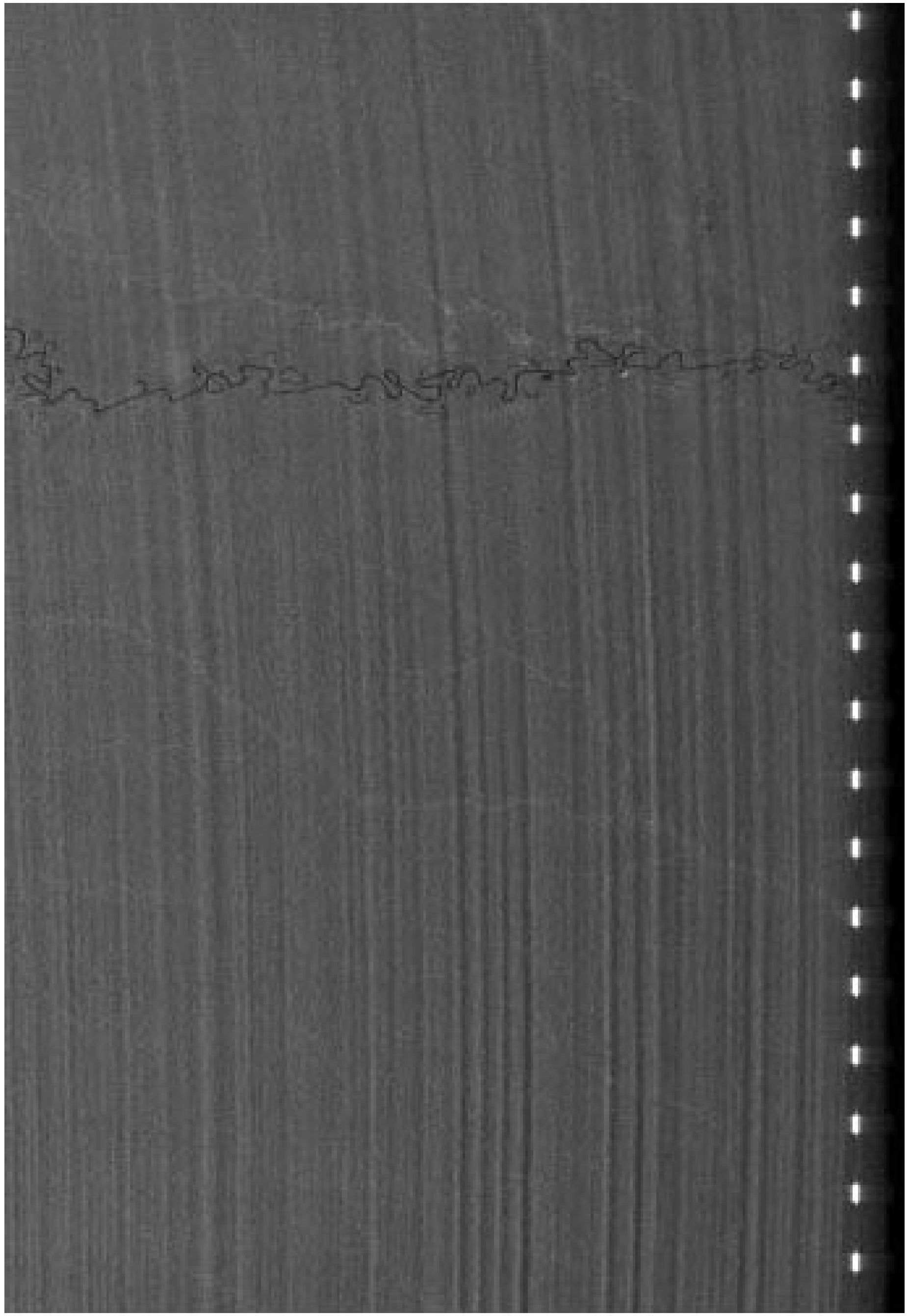

250km


150km


70km



HV



HH