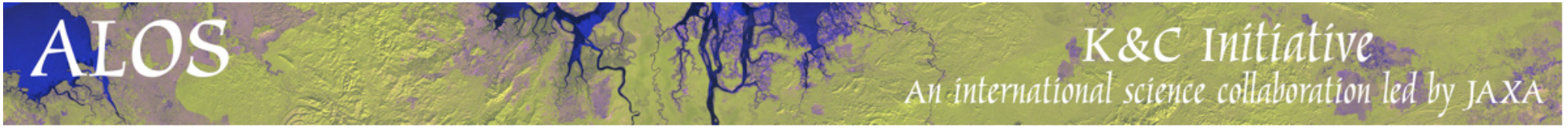


Performance of PALSAR sensor onboard ALOS: towards the retrieval of bio- and geo-physical parameters

Nicolas Longépé, Masanobu Shimada, Osamu Isoguchi, Takeo Tadono and Preesan Rakwatin

Earth Observation Research Center EORC
Japan Aerospace Exploration Agency JAXA

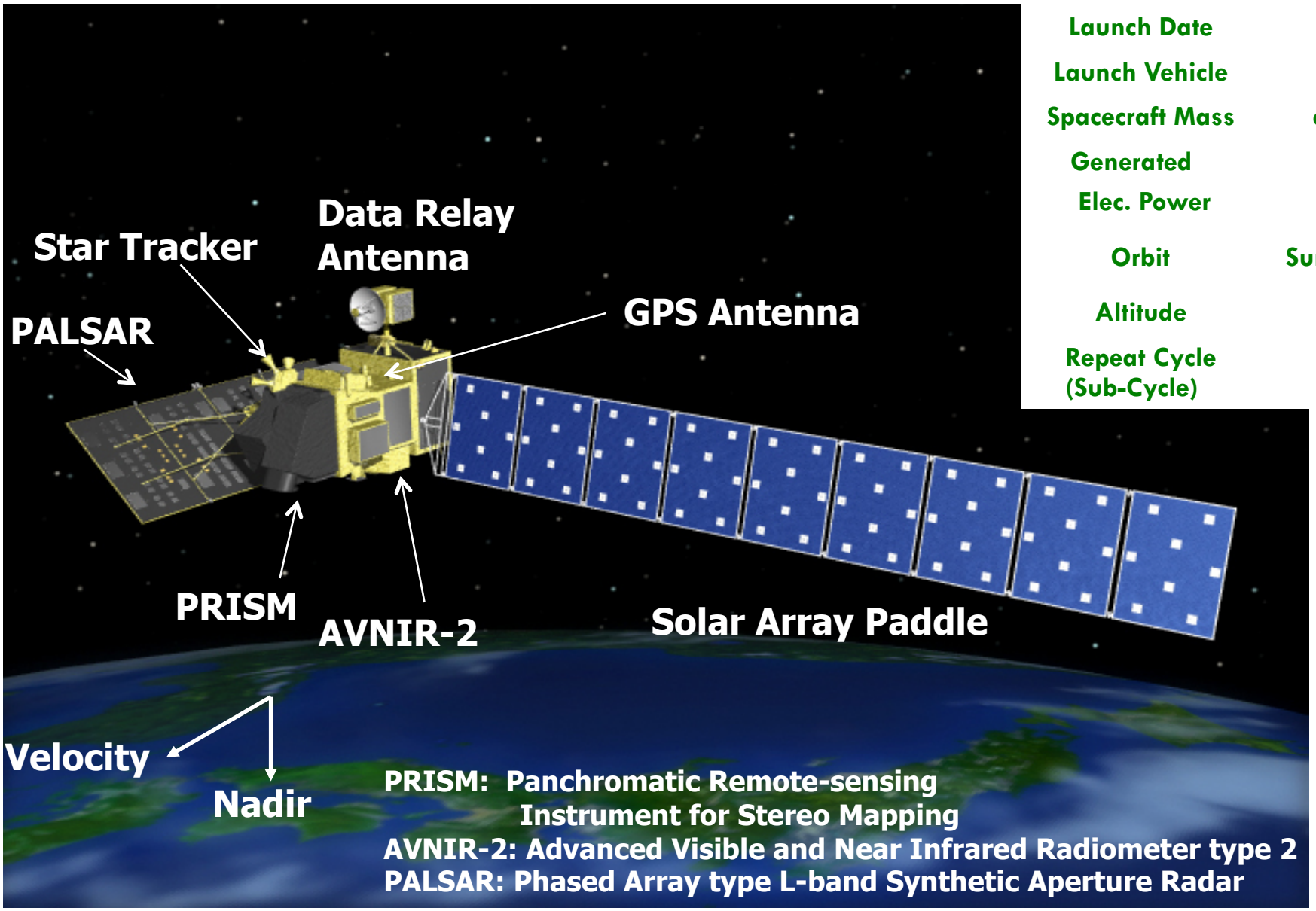
CEOS SAR Cal/Val workshop, Pasadena (CA – USA), Nov. 17, 2009

ALOS
Advanced Land Observing Satellite

ALOS

K&C Initiative

An international science collaboration led by JAXA



Launch Date	2006/1/24
Launch Vehicle	H-IIA-8
Spacecraft Mass	about 4 tons
Generated Elec. Power	about 7kW at EOL
Orbit	Sun Synchronous
Altitude	691.65km
Repeat Cycle (Sub-Cycle)	46 days (2 days)

PRISM: Panchromatic Remote-sensing Instrument for Stereo Mapping

AVNIR-2: Advanced Visible and Near Infrared Radiometer type 2

PALSAR: Phased Array type L-band Synthetic Aperture Radar

ALOS

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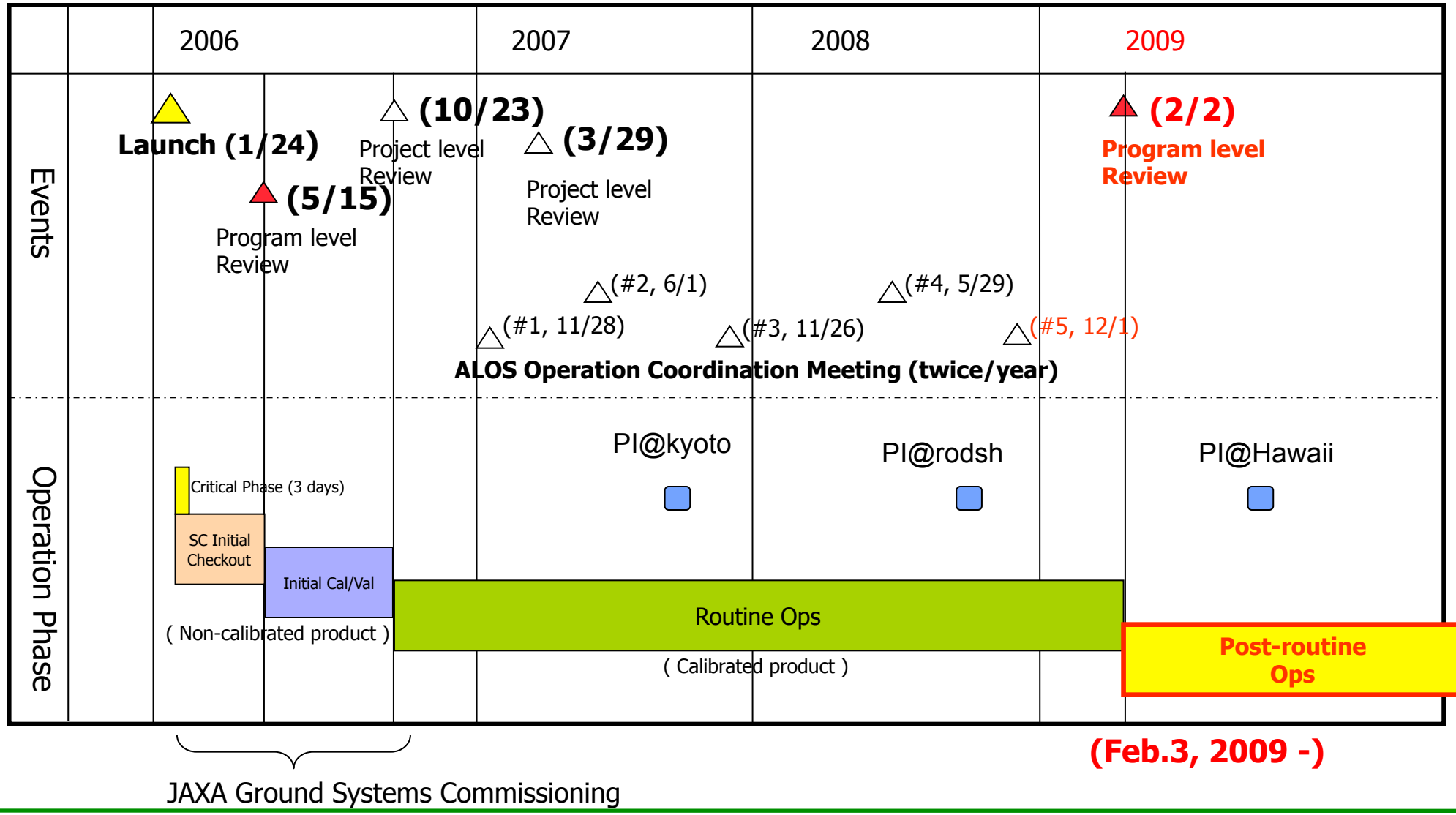
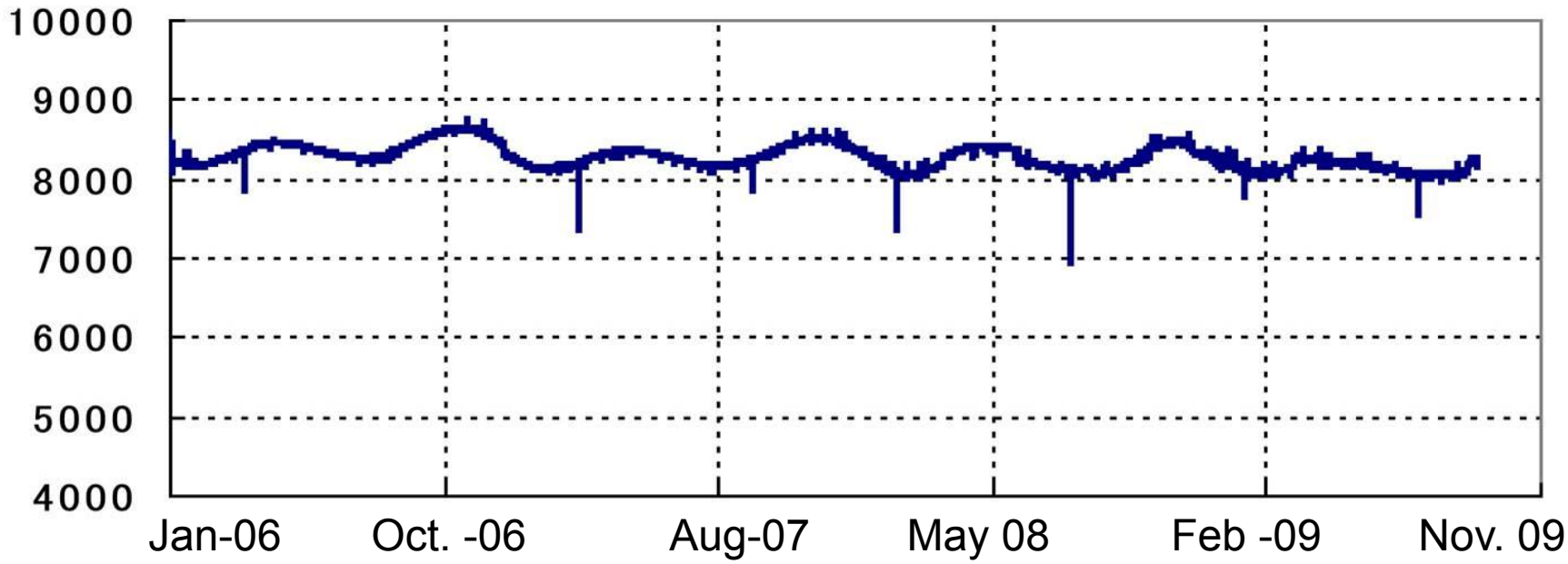
ALOS Master Schedule



- ✓**PALSAR system**
  - ✓Satellite status
  - ✓Data reception status
  - ✓Acquisition and distribution status
- ✓**Cal/Val summary**
  - ✓Transmission power stability
  - ✓Radiometric calibration
  - ✓Polarimetric-Calibration results
  - ✓Geometric-Accuracy evaluation
- ✓**Some applications**
  - ✓Regional Observation, Disaster monitoring…
  - ✓Retrieval of bio & geo-physical parameters (Forest, Ocean…)

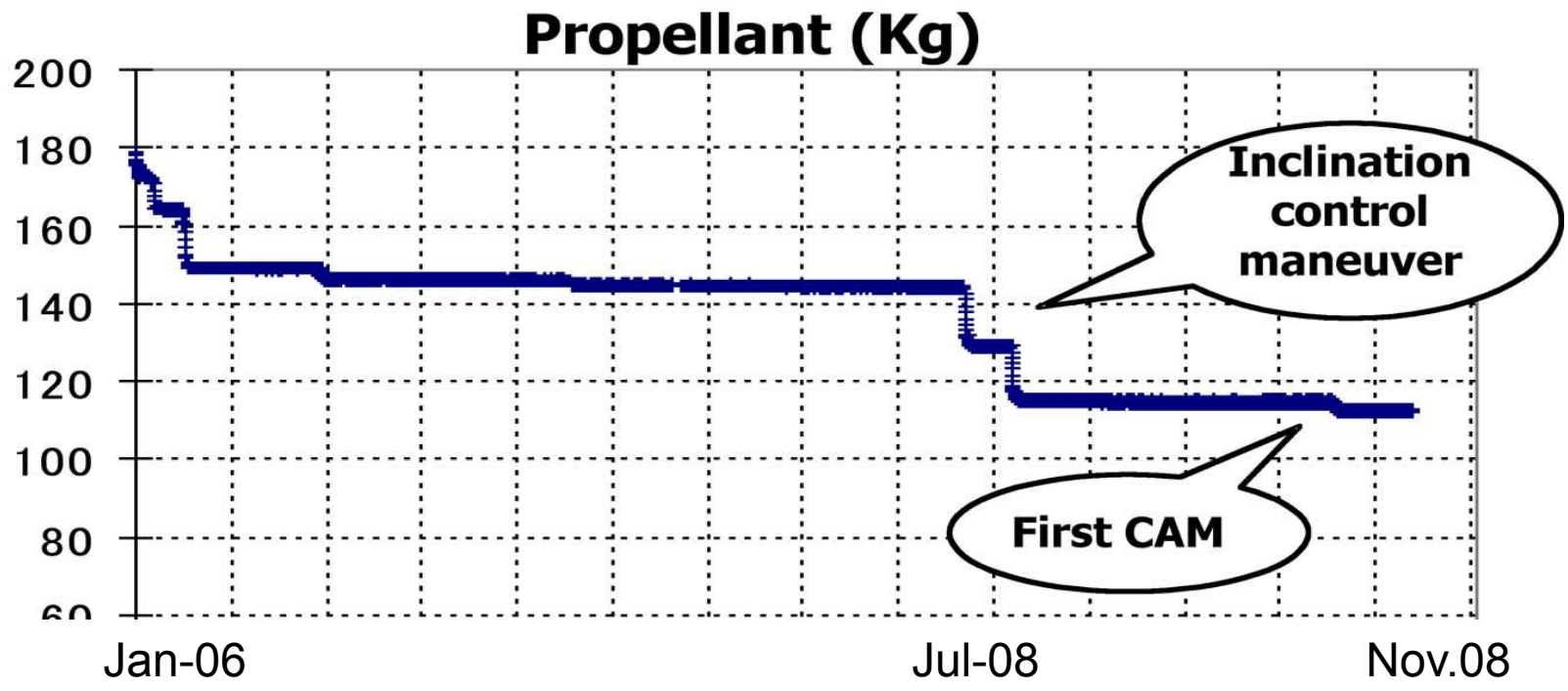
Satellite status (1)

- ✓ **Paddle & Electric Power System: good**
  - ✓**Average power generation: about 8 kW . [Spec. ＞ 7 kW]**
  - ✓**Power consumption: about 5kWmax.**
  - ✓**Battery characteristic (C/D ratio, DOD, charge voltage): stable**



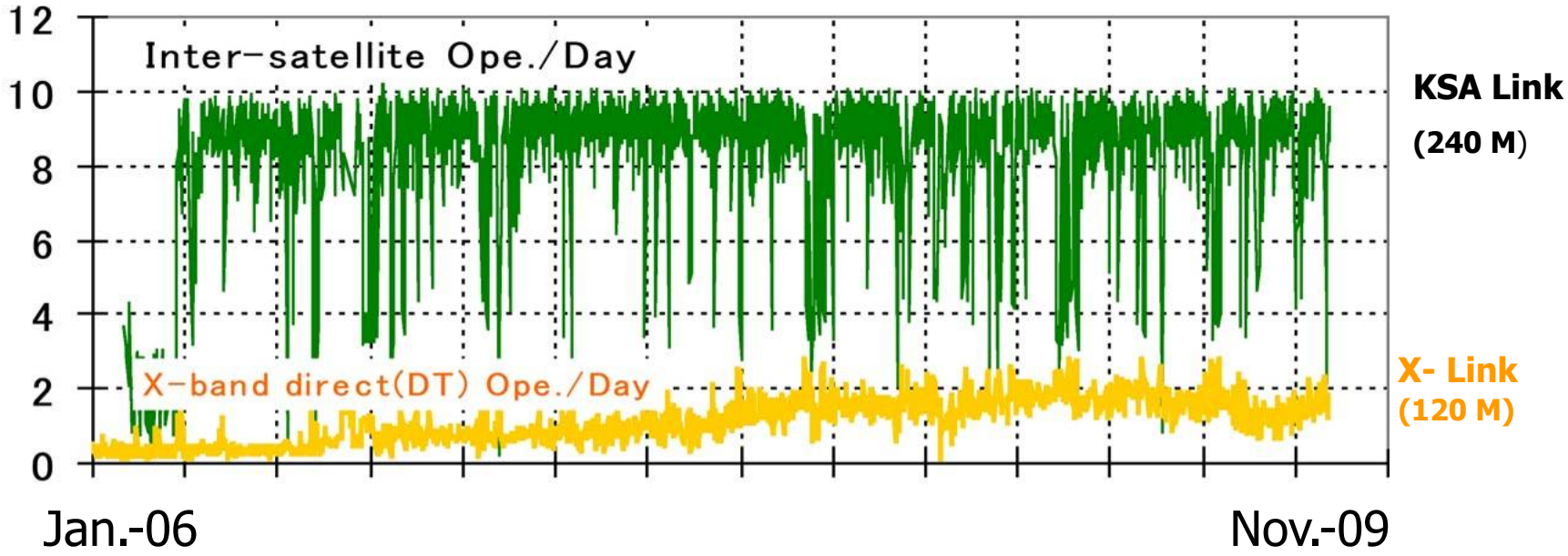
Satellite status (2)

- ✓ **Attitude and Orbit subsystem: good**
  - ✓ **All functions & mode transitions operate well.**
  - ✓ **About 67kg of propellant has been consumed.**
  - ✓ **This quantity can achieve long-term mission more than five year**



Satellite status (3)

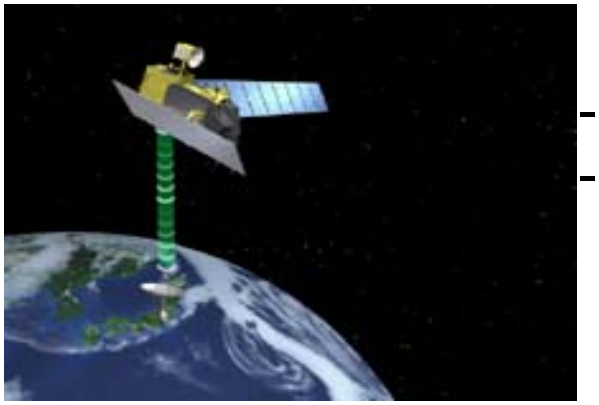
- ✓ **Mission Data Handling (MDHS): good**
  The daily duty times of X-band direct (DT) & inter-satellite KSA transmissions (DRTS).



- ✓ **Thermal Control System: good**
  All components' temperatures within acceptable ranges

Data reception status (1)

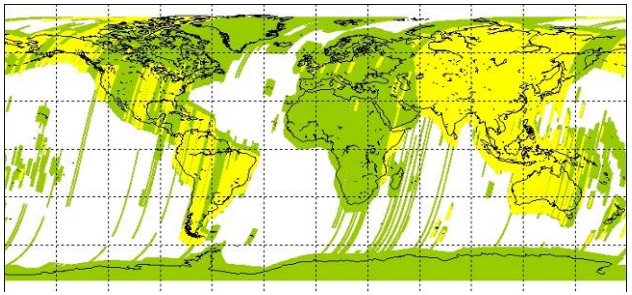
Via Data Relay Satellite (JAXA DRTS)
KSA link (240Mbps)
- Primary link
routine ops.
- topics: ALOS data downlink via TDRSS/NASA under development
- Operation will start in April, 2010(TBD)

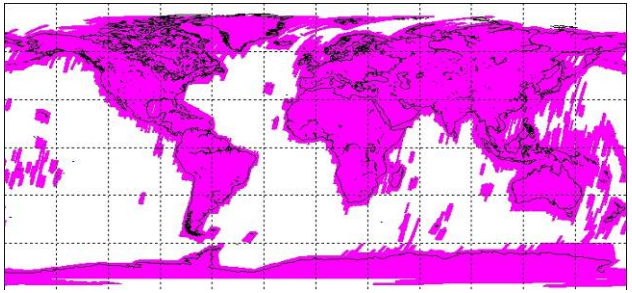


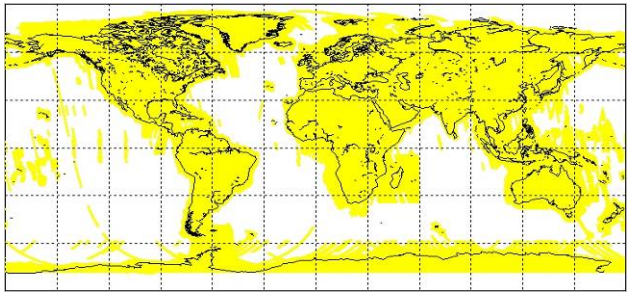
- **Direct Transmission**
X-band link (120Mbps)
- Secondary link
- For near real-time use, not only in Japan but also in overseas countries (by ALOS Data Nodes)
ASF, Cordoba, Miami, Tromsoe, Matera, Maspalomas, Alice Springs, Hobert, Bangkok

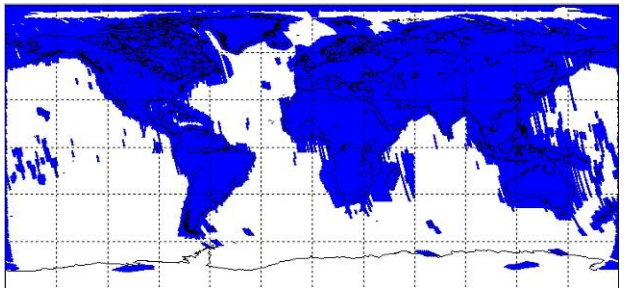
Acquisition and distribution status (1)
(May 16, 2006 – Sep. 30, 2009)

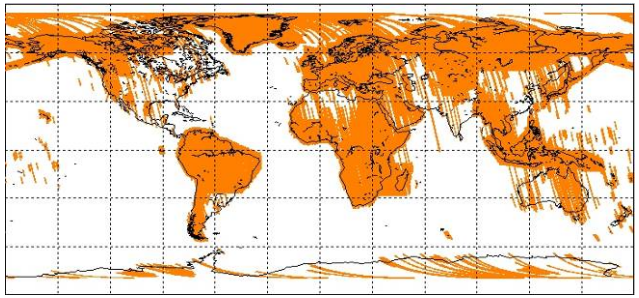
PRISM: 1,850,000 scenes
AVNIR-2: 840,000 scenes
PALSAR: 1,380,000 scenes

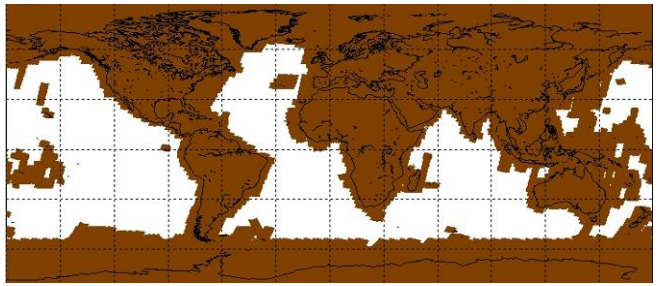

PRISM


AVNIR-2


PALSAR(FBS)


PALSAR(FBD)


PALSAR(PLR)


PALSAR(WB1/WB2)

Acquisition and distribution status (3)
Emergency observation (As of Sep.30, 2009)

2006 A total of 32 times for the year
2007 A total of 45 times for the year
2008 A total of 127 times for the year
2009 A total of 18 times preceding the last ADN meeting

2009 Recent activities (after the last ADN meeting)

- 2/20 Floods in Australia (PALSAR)
- 2/24 , 3/2 Floods in Namibia (PALSAR)
- 2/28 Volcano in Chile (AVNIR-2)
- 2/28 , 3/8 Wildfire in Oceania (PALSAR , AVNIR-2)
- 3/3 , 8 Wildfire in Australia (PALSAR)
- 3/10 Volcanic eruption in Sakurajima (PALSAR)
- 3/12 , 14 Oil spills in Australia (PALSAR)
- 3/13 Floods in Indiana (PALSAR)
- 3/23 Volcano in Tonga (AVNIR-2)
- 3/29 Floods in North Dakota (PALSAR)
- 4/1 Floods in Indonesia (PALSAR , AVNIR-2)
- 4/7 , 9 , 10 , 19 , 22 Earthquake in Italy (PALSAR , AVNIR-2 , PRISM)
- 4/9 Volcano in Vanuatu (AVNIR-2)
- 4/10 , 14 Volcanic eruption in Sakurajima (PALSAR , AVNIR-2)
- 4/11 Volcano in Chile (PRISM , AVNIR-2)
- 5/23 , 24 Floods in Afghanistan (PALSAR)
- 5/27 , 31 Floods in Bangladesh (PALSAR , AVNIR-2)
- 6/17 , 18 , 19 , 27 Volcano in Chisima (PALSAR , AVNIR-2)
- 7/7 Floods in Vietnam (PALSAR)
- 7/8 , 9 floods in Wakayama (PALSAR,AVNIR-2)
- 7/10 , 11 Earthquake in China (PALSAR,AVNIR-2)
- 7/15 , 23 Earthquake in New Zealand (PALSAR,AVNIR-2)
- 7/15 Floods in Benin (PALSAR)
- 7/23 - 26 Floods in Yamaguchi (PALSAR , AVNIR-2) ; 6 times of observations conducted
- 7/26 , 28 Wildfire in French (AVNIR-2)
- 7/27 Floods in Fukuoka (PALSAR,AVNIR-2)
- 7/28 Landslide in Fukuoka (AVNIR-2)
- 7/28 Floods in Wakayama (PALSAR)
- 7/30 Floods in Yamaguchi (PALSAR , AVNIR-2)
- 8/11 Typhoon in Hyogo , Okayama , Tokushima (AVNIR-2)
- 8/11 – 22 Earthquake in Suruga bay (PALSAR,AVNIR-2) ; 7 times of observations conducted
- 8/11 , 19 Typhoon in Philippines (PALSR , PRISM)
- 8/13 , 23 , 25 Typhoon in Taiwan (PALSAR , AVNIR-2)
- 8/28 Floods in Nepal (PALSAR)
- 8/25 Wildfire in Greece (AVNIR-2)
- 8/28 , 9/11 , 14 , 19 Driftwoods in Senkaku Islands (AVNIR-2 , PRISM) ; 6 times of observations conducted
- 8/31 , 9/1 Typhoon in Tokyo (PALSAR , AVNIR-2)
- 9/1 Wildfire in Argentina (AVNIR-2)
- 9/3 Wildfire in Portugal (AVNIR-2)
- 9/3 , 4 , 13 Earthquake in Indonesia (PALSAR , AVNIR-2 , PRISM)
- 9/4 Floods in Senegal (AVNIR-2 , PRISM)
- 9/4 Floods in Burkina Faso (PALSAR)
- 9/14 Floods in Turkey (PALSAR)
- 9/14 - 17 Wildfire in Italy (PALSAR , AVNIR-2 , PRISM) ; 5 times of observations conducted
- 9/25 Earthquake in Bhutan (AVNIR-2)
- 9/25 Floods in Georgia (PALSAR)
- 9/26 , 29 Floods in Philippines (PALSAR , AVNIR-2)
- 9/30 Tsunami in Samoa (AVNIR-2)
- 9/30 Typhoon in Vietnam (PALSAR)

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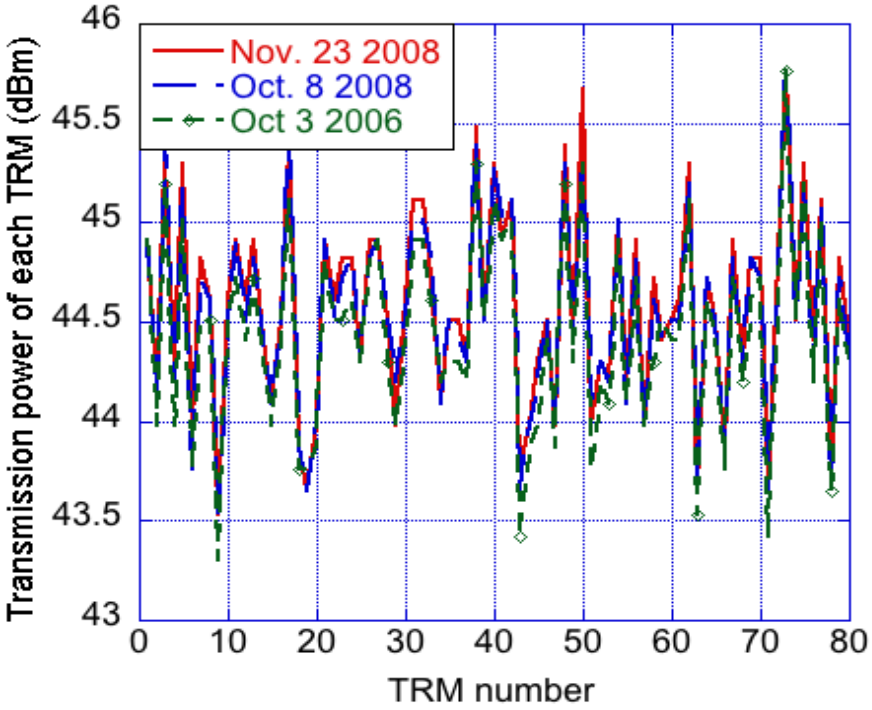
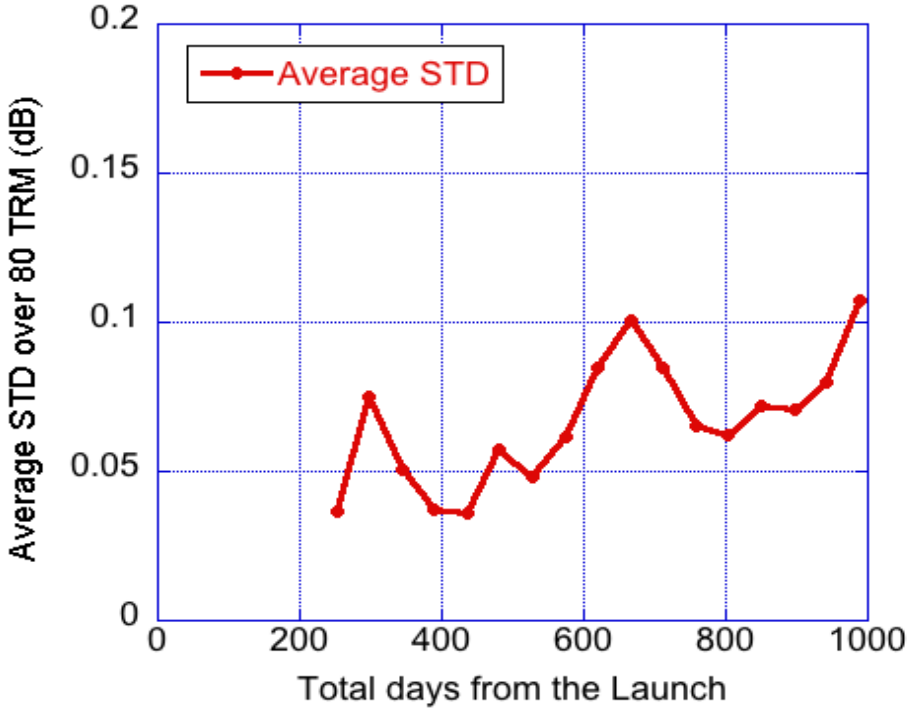
  - ✓Polarimetric-Calibration results
  - ✓Geometric-Accuracy evaluation
- ✓**Some applications**
  - ✓Regional Observation, Disaster monitoring…
  - ✓Retrieval of bio & geo-physical parameters (Forest, Ocean…)

M. Shimada, et al. , “PALSAR Radiometric and Geometric Calibration, “ Trans. GRS, VOL. 47, NO. 12, Dec. 2009

Transmission power monitoring



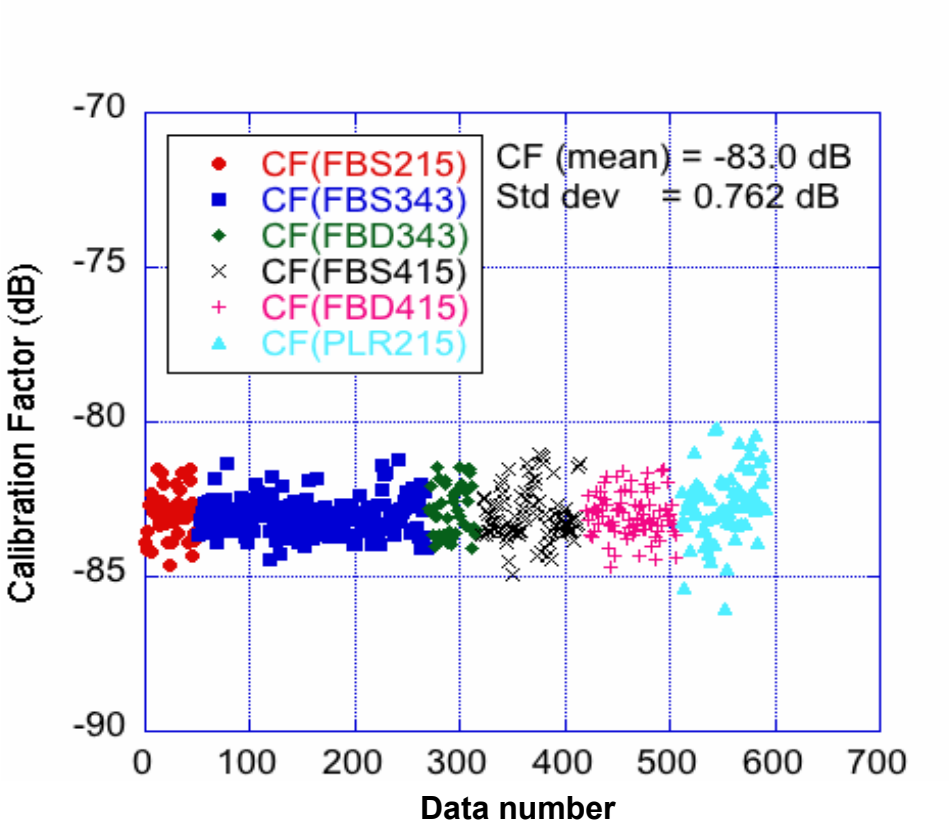
Variation of the transmission power over 80 TRM



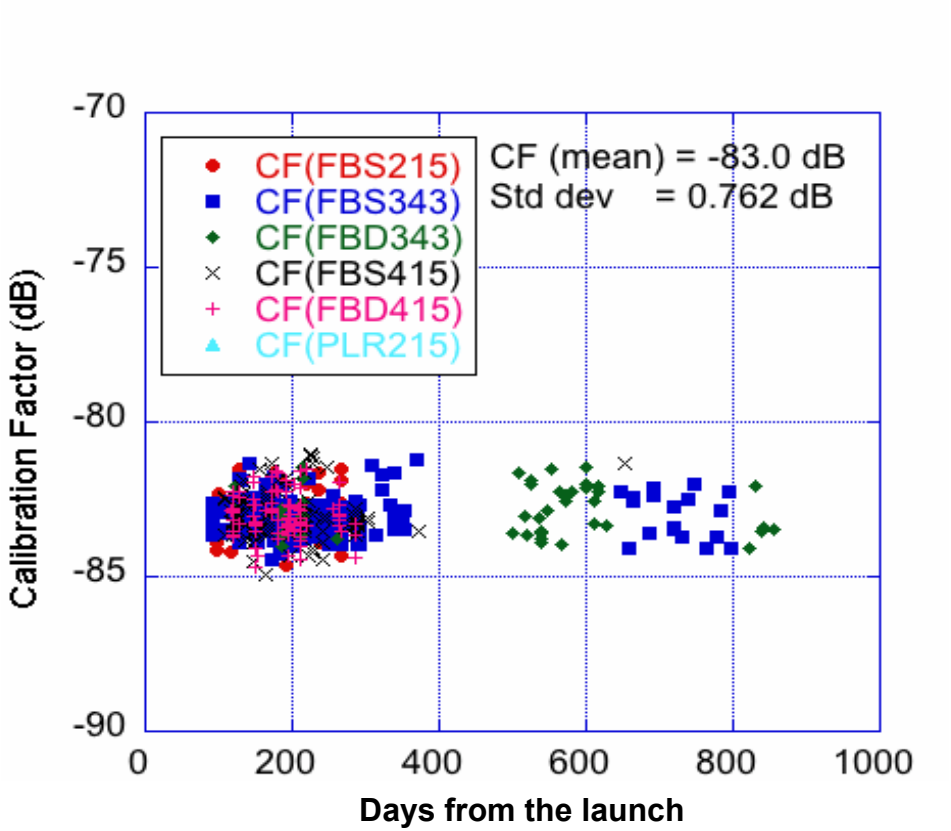
Standard deviation over 80 TRM

Radiometric Calibration using the CRs

Mode and time dependency over last three years



Distribution of the CFs for all the modes



Long-term variation of the CFs

PolCal table in the SAR processor (SIGMA-SAR)

estimated by Queagan method to CRs deployed in Rio Branco

Item	Values(real, imaginary)	Notation
Transmission distortion matrix	(1.000000e+00 ,0.000000e+00) (2.427029e-03, 1.293019e-02) (-1.147240e-02, -6.228230e-03) (9.572169e-01, 3.829563e-01)	 δ_1 δ_2 f_1
Reception distortion matrix	(1.000000e+00 0.000000e+00) (-6.263392e-03, 7.082863e-03) (-6.297074e-03, 8.026685e-03) (7.217117e-01, -2.367683e-02)	 δ_3 δ_4 f_2

Current data

f_1=1.030979981 /21.80501612(degrees)

f_2=0.722099971 /−1.878998903

δ_1=-25.538(3.09) /79.36933594)

δ_2=-25.385(0.077) /−151.5032329

δ_3=-25.077(3.107) /131.4864021

δ_4=-25.897(2.416) /−1.878998903

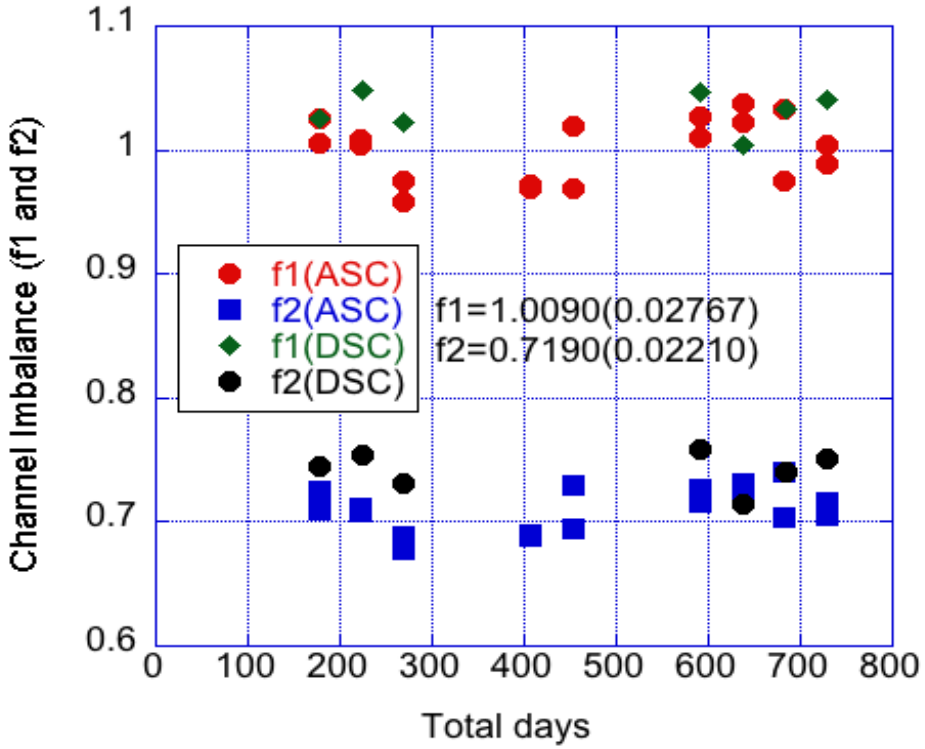
CAL of FBD

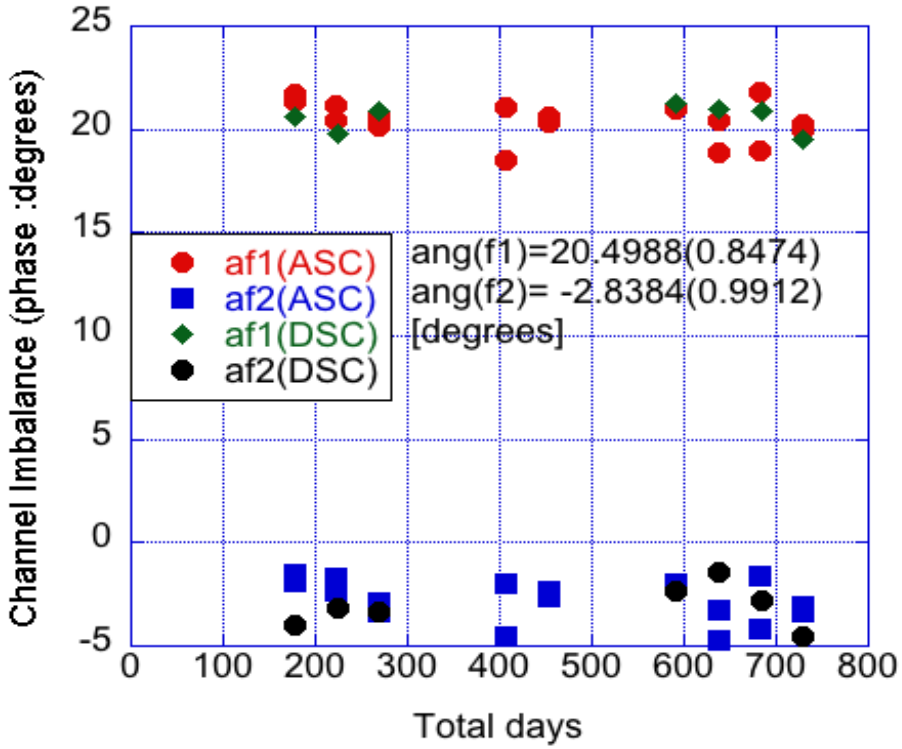
$$\begin{pmatrix} Z_{hh} & Z_{hv} / f_1 \\ Z_{vh} / f_2 & Z_{vv} / f_1 / f_2 \end{pmatrix}$$

Phase term is only 2 degrees.

Stability Evaluation of the distortion matrix

Using the Amazon CRs deployed by ASF, IBGE, and JAXA

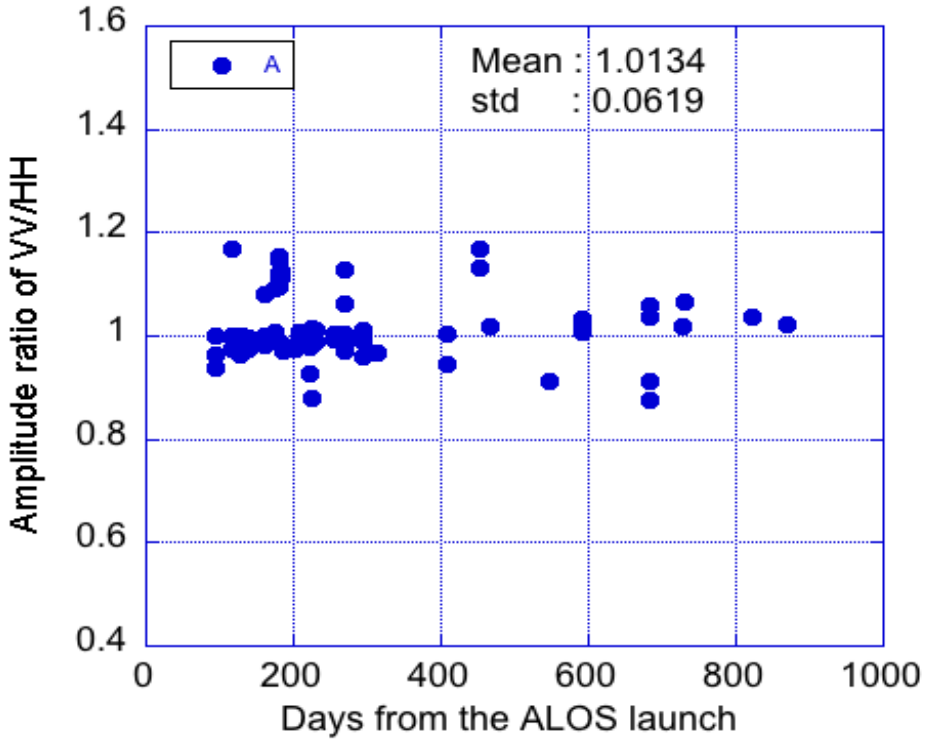




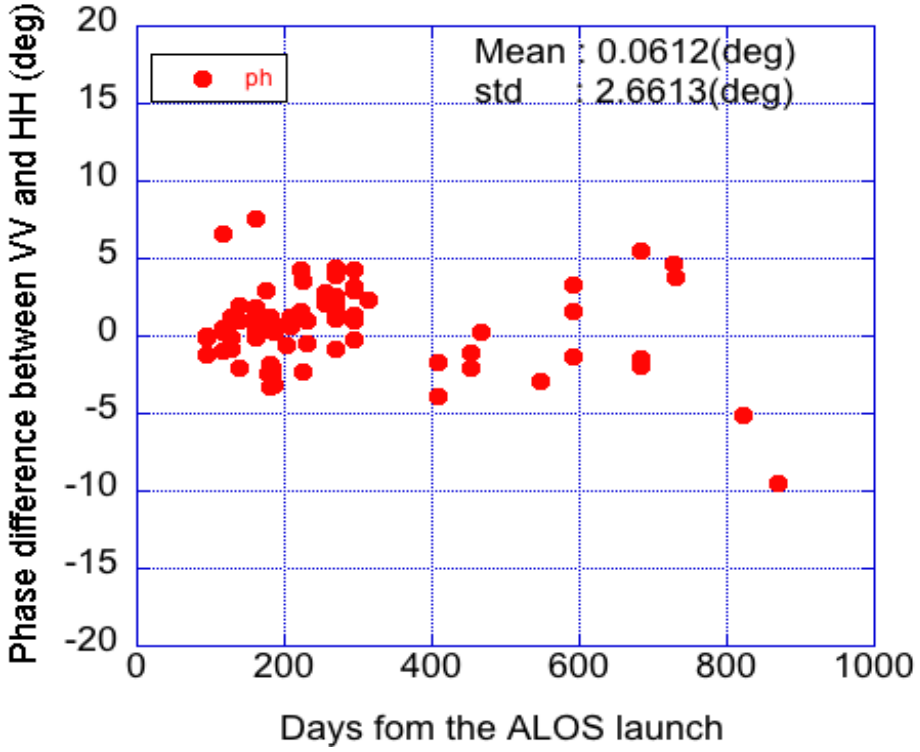
- ✓ **No variation of the distortion matrix on time confirmed**
- ✓ **Distortion matrix was not updated from the operation start**

Polarimetry Calibration Accuracy

Using the CRs at Rio Branco, Brazil



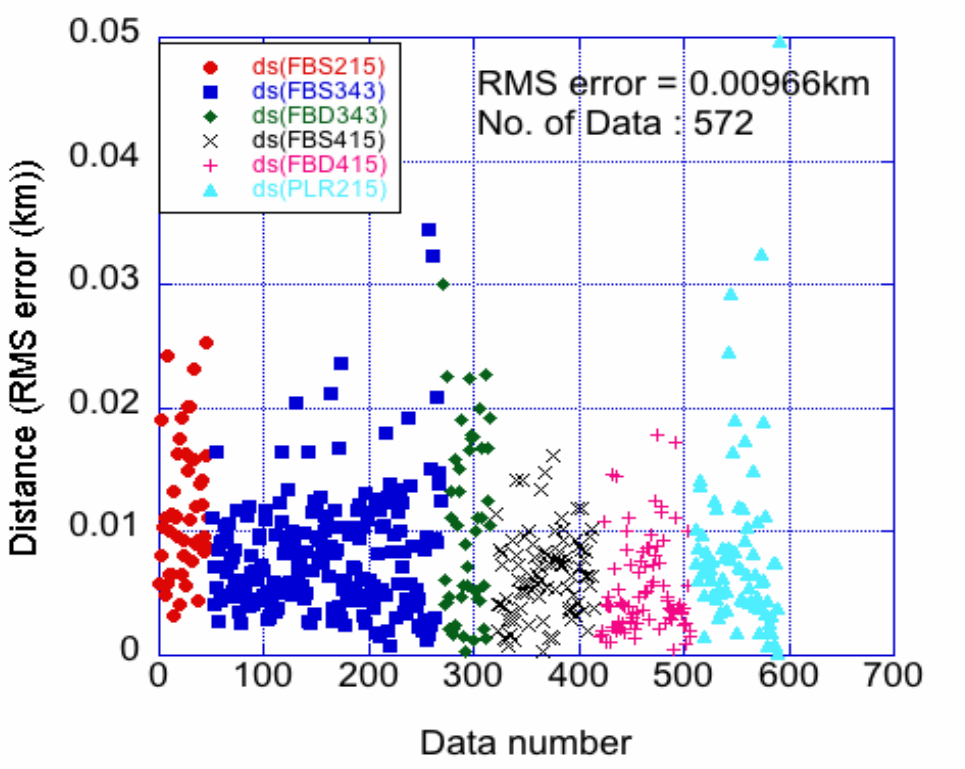
Amplitude (VV/HH)

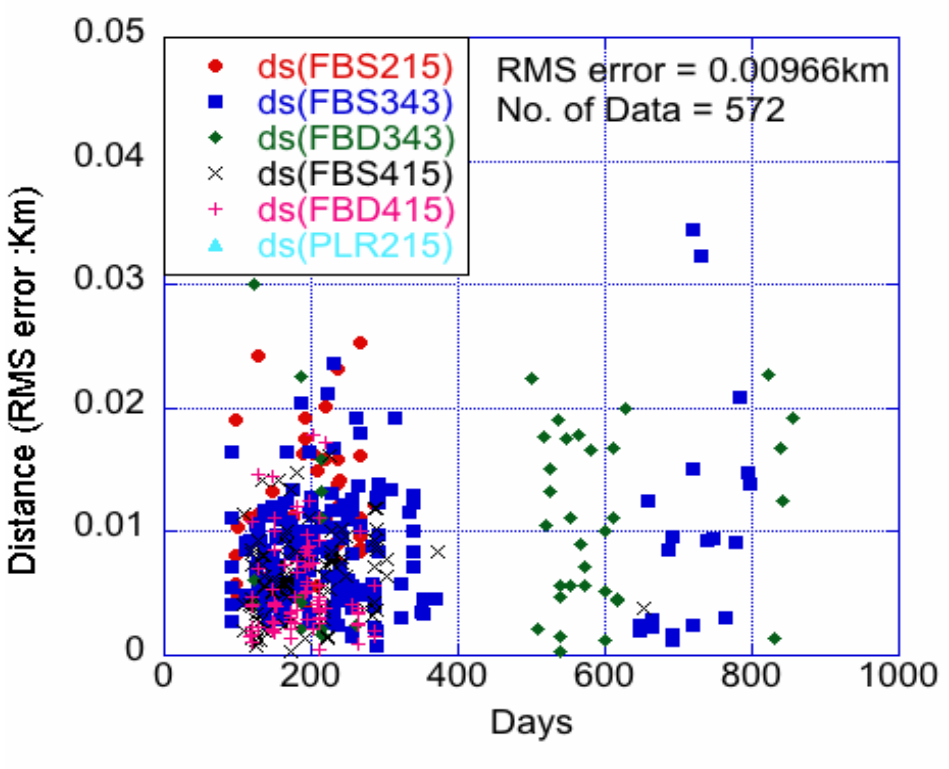


Phase of (VV/HH)

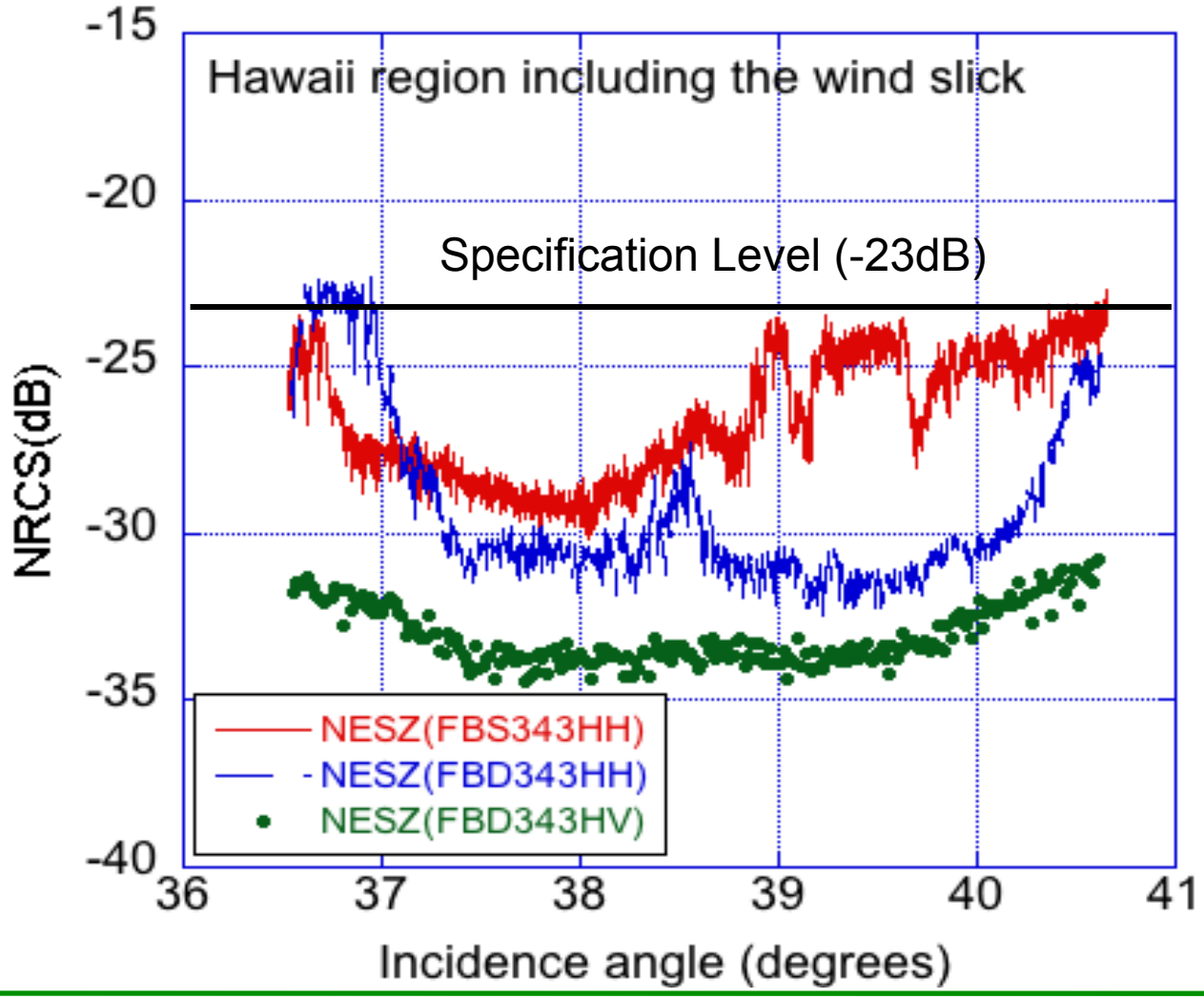
Geometric calibration using the CRs

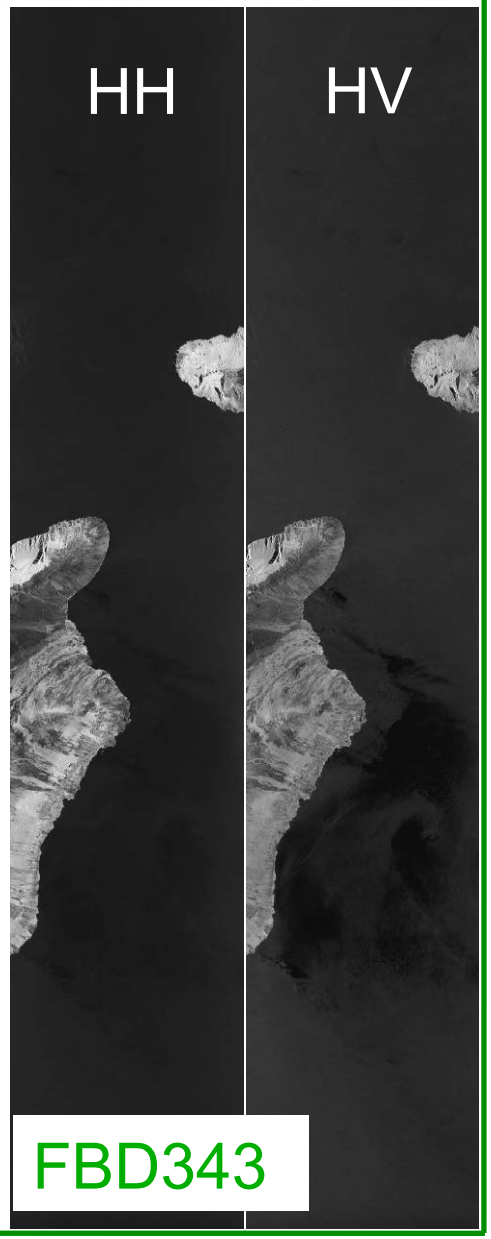
Mode and time dependency over last three years





Noise Equivalent Sigma-Zero (NESZ)





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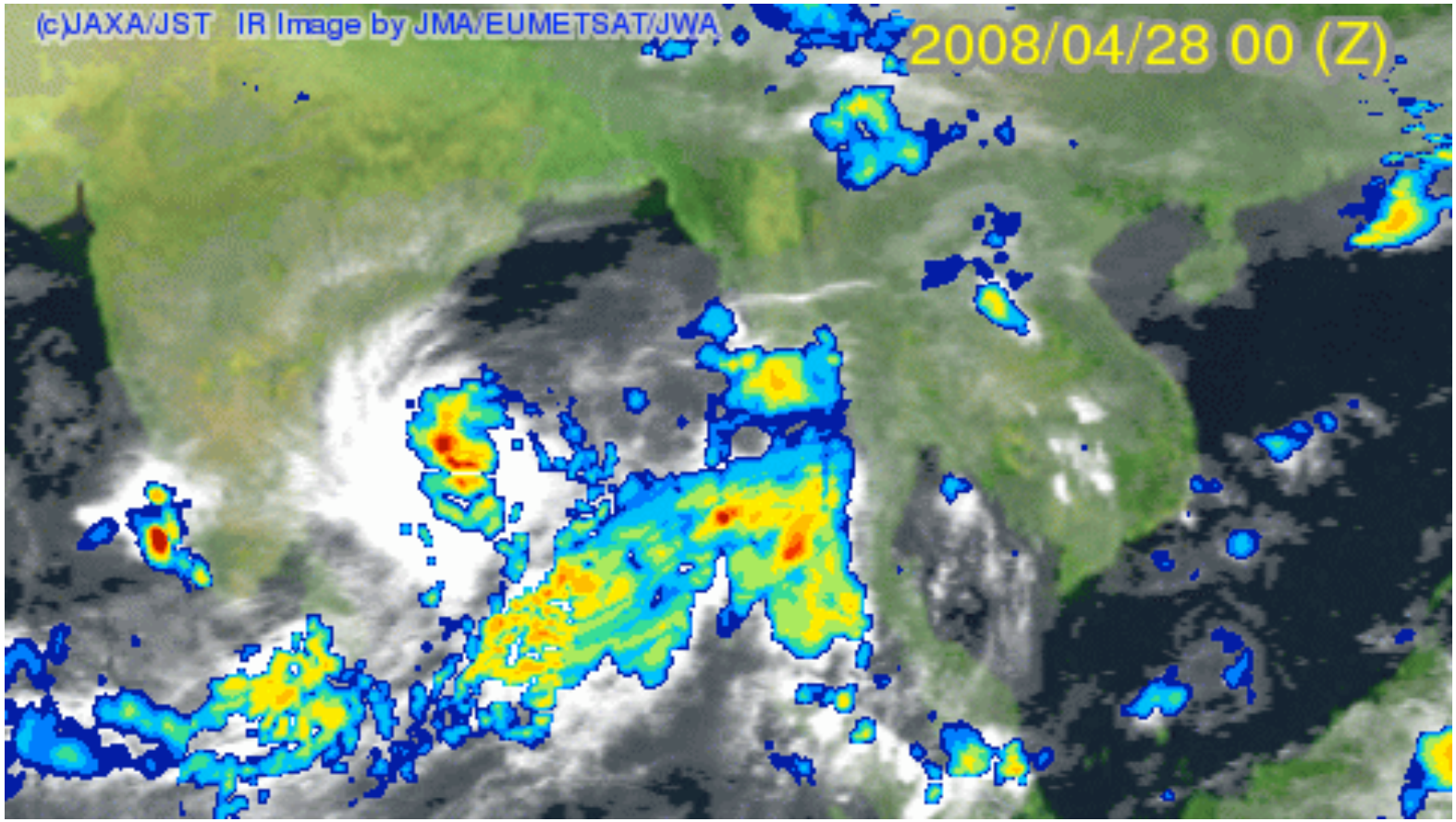
Myanmar heavy flooding
Cyclone Nargis in May 2008



ALOS

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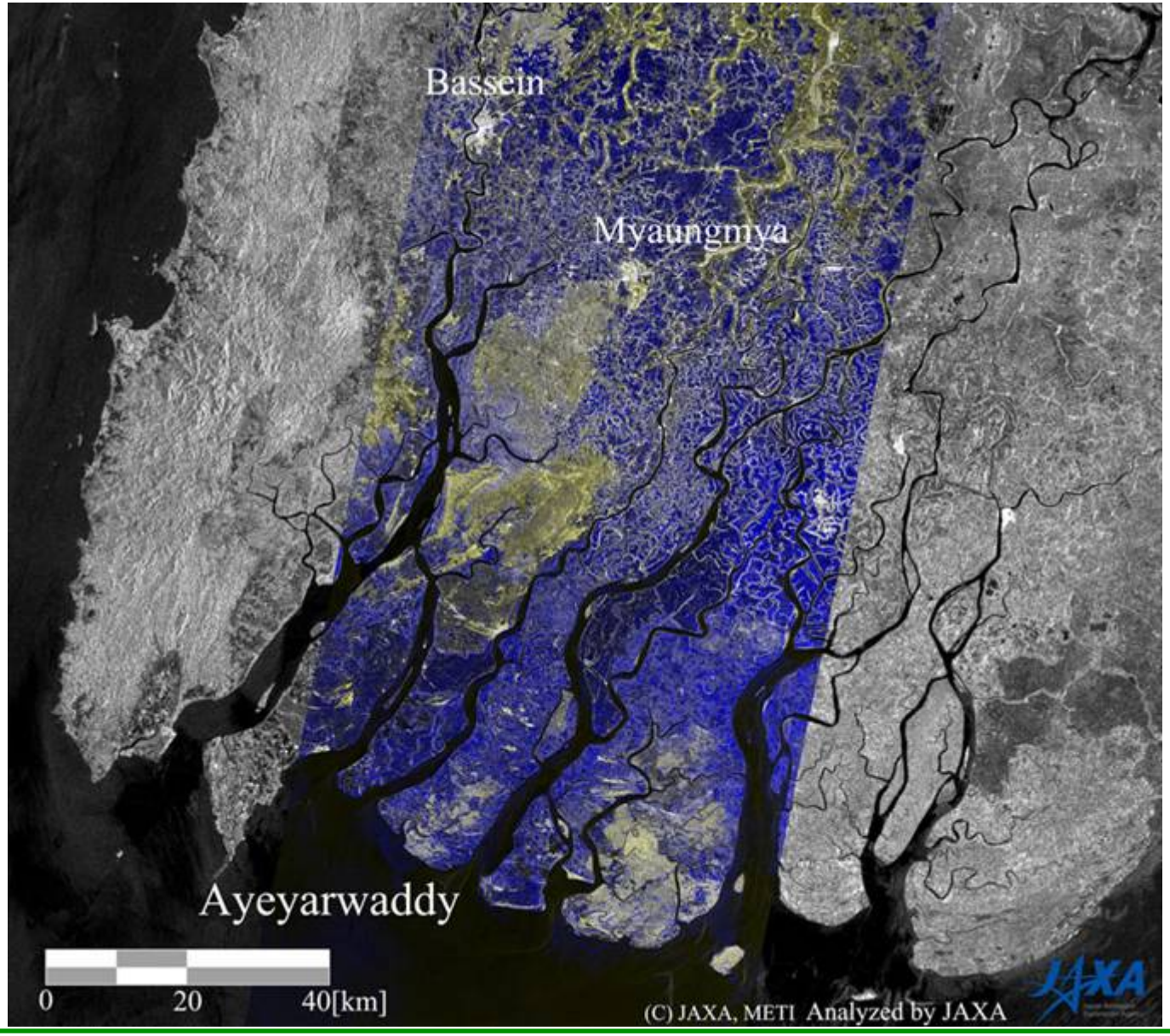
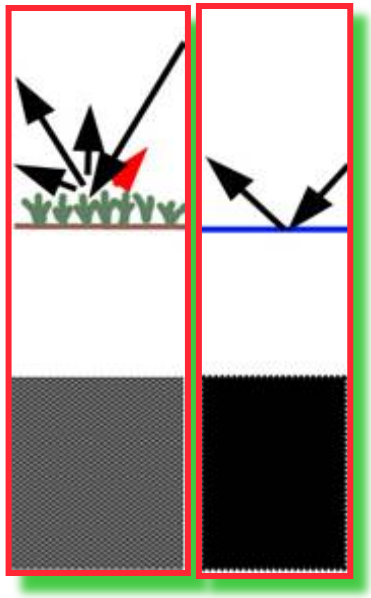
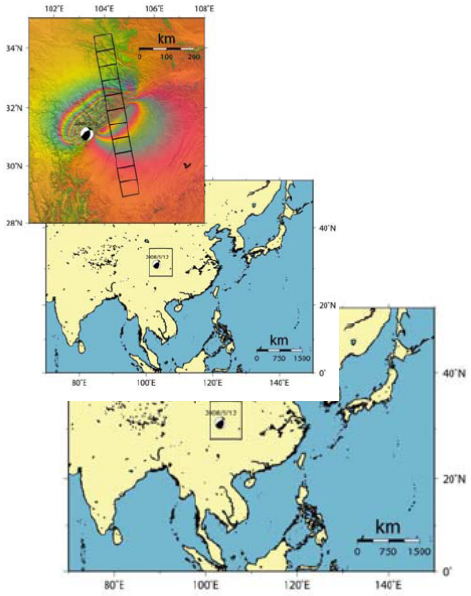


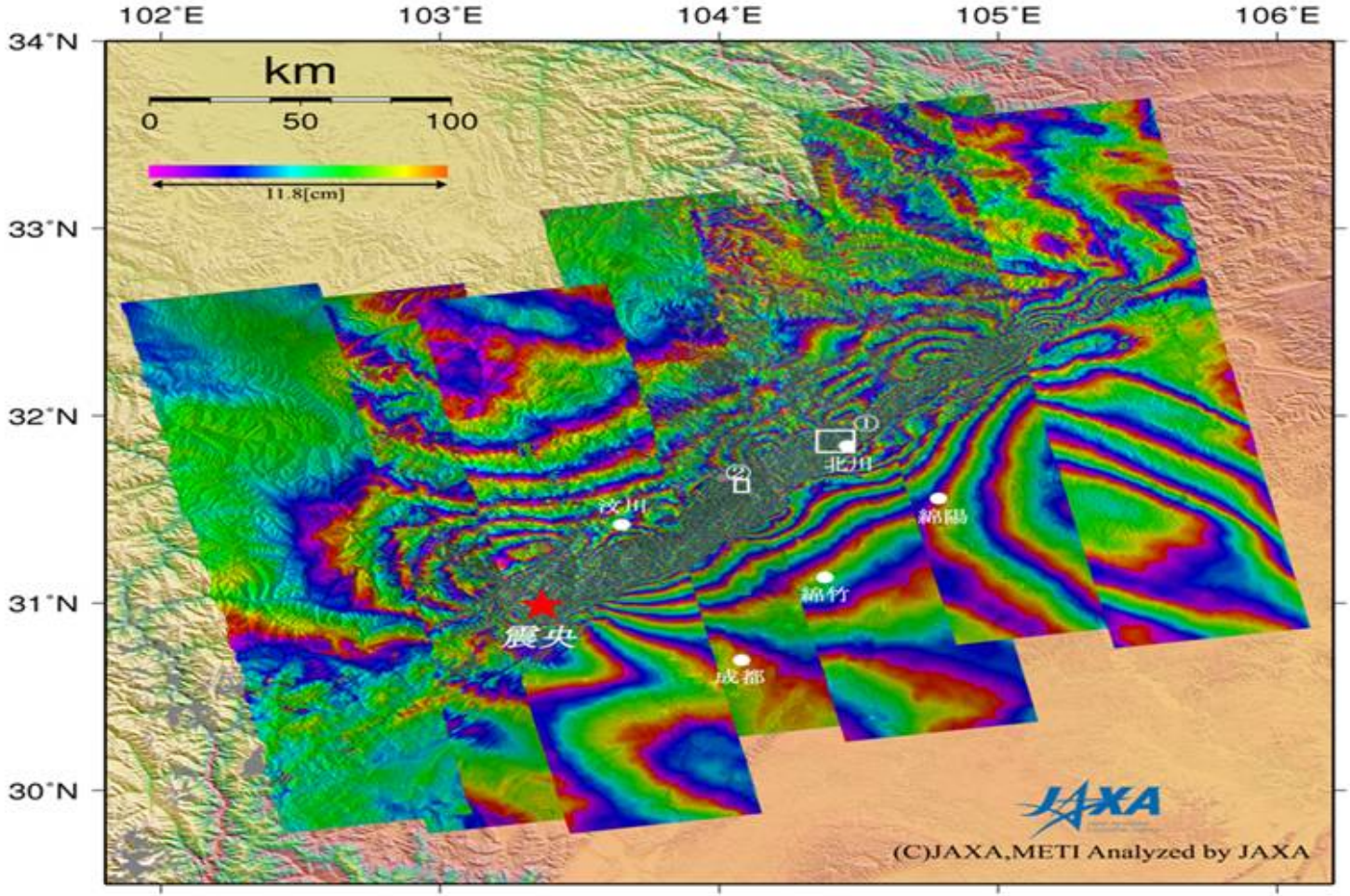


Crustal deformation by PALSAR DInSAR techniques

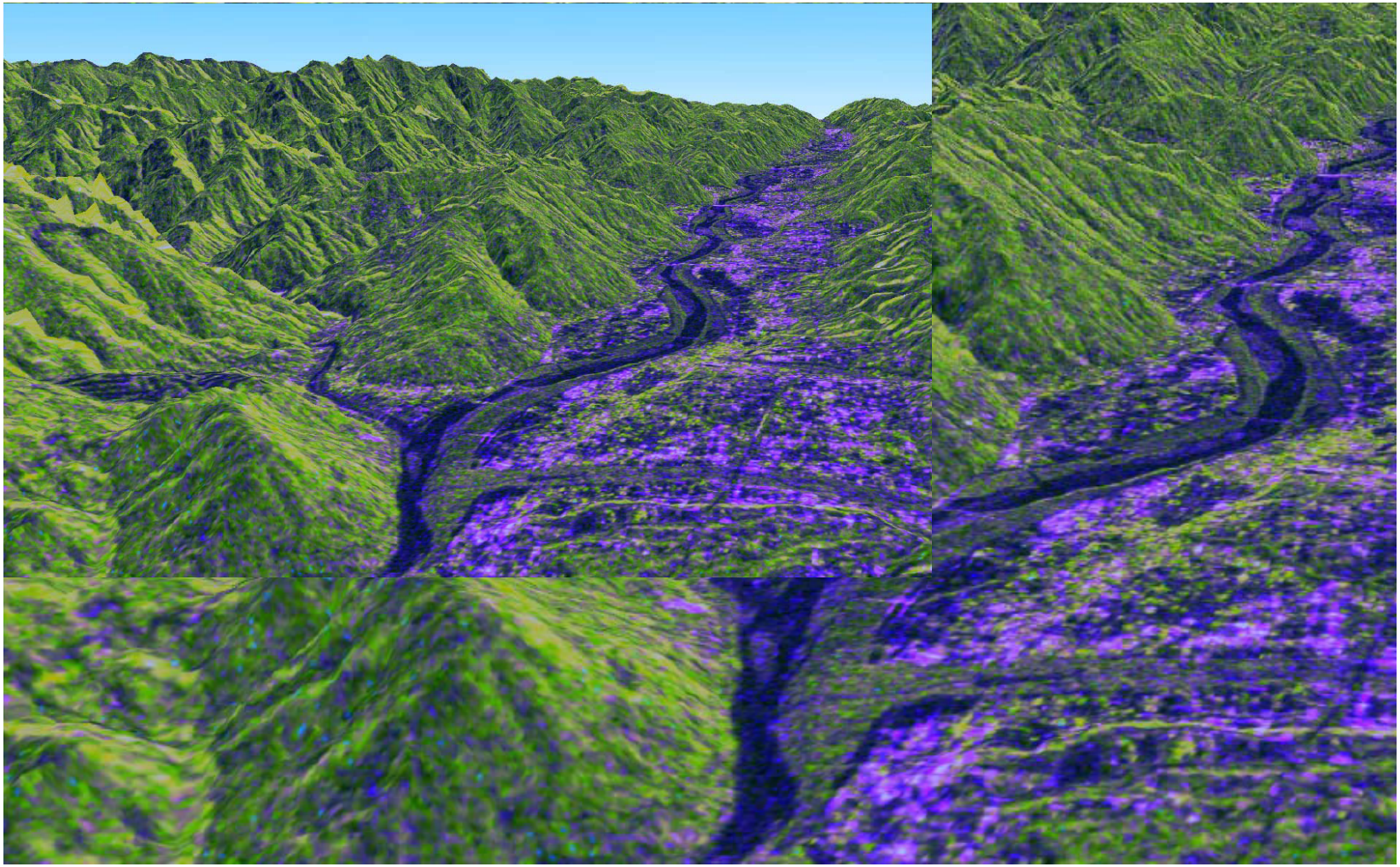
M8.0 earthquake

May 12, 2008 in Sichuan province



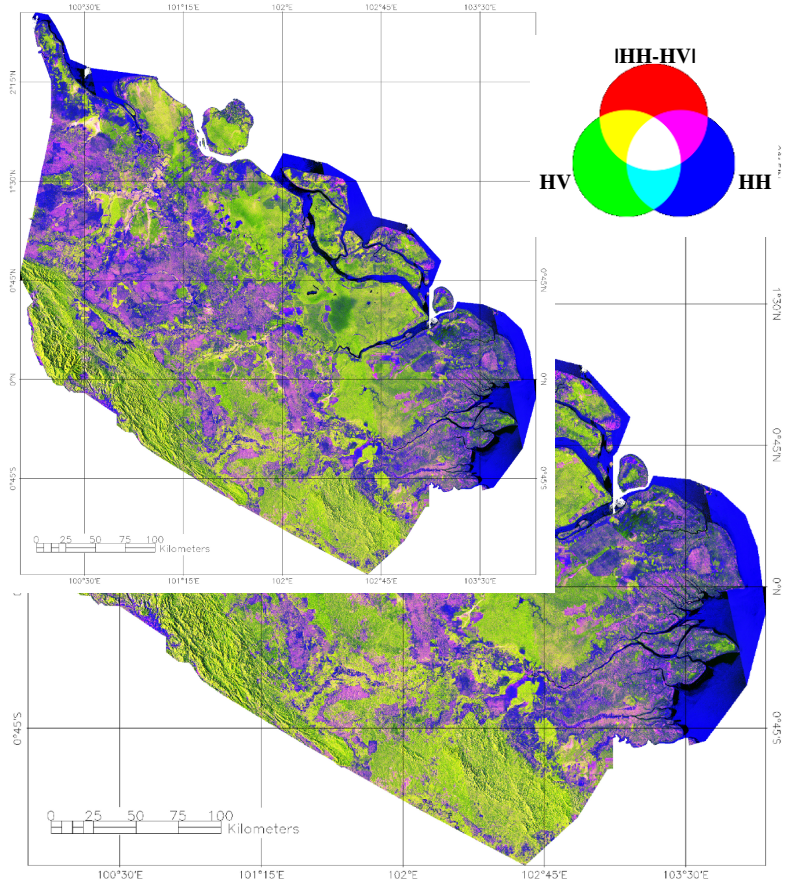


3D view of a FBD PALSAR image using PALSAR INSAR DEM
Yoshino river and the surrounded area, Shikoku, Japan.



Development of Semi-Automated Systems for detection of forest and land cover change based on PALSAR mosaic data

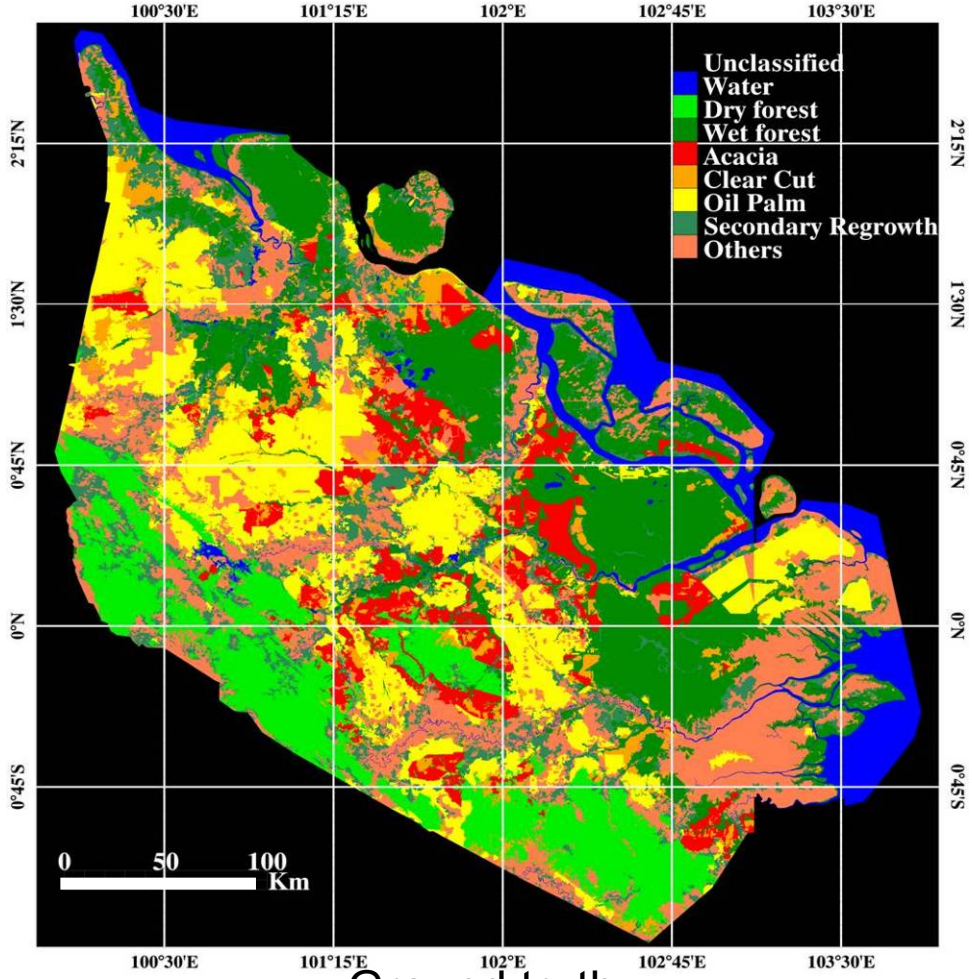
➪ **Possible applications for carbon stock estimates**



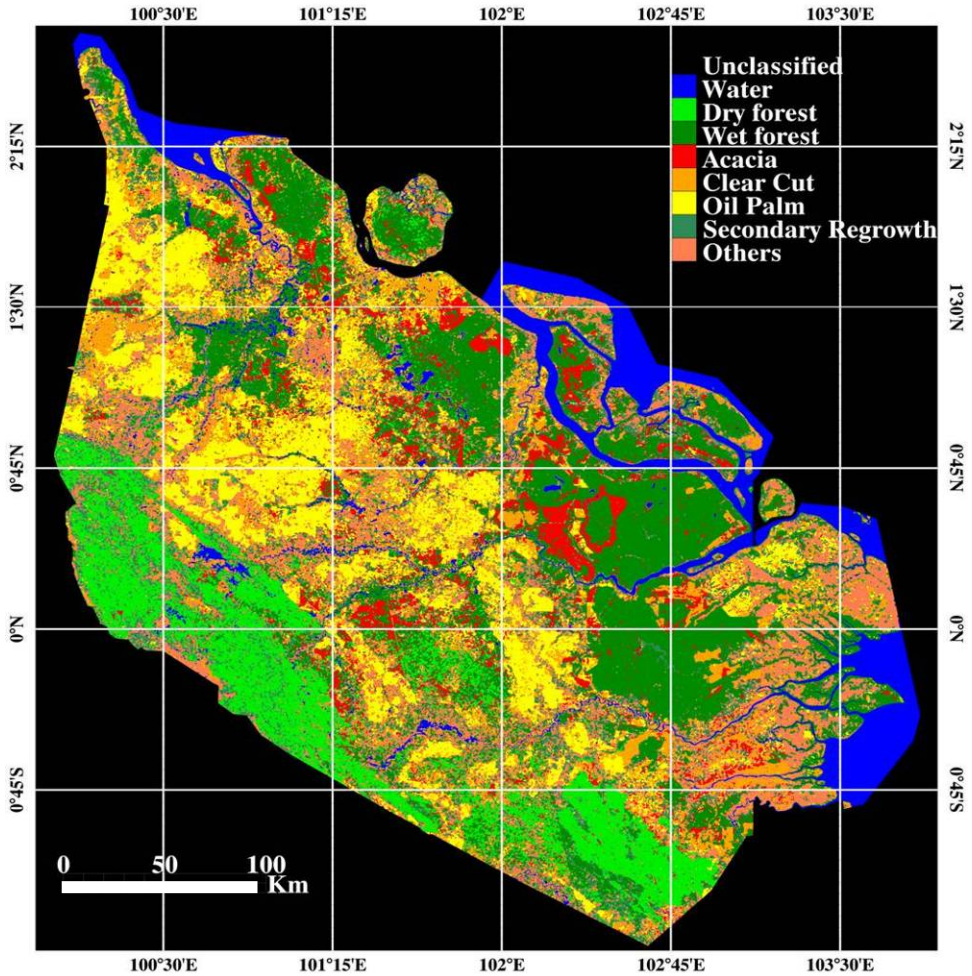
50m orthorectified PALSAR mosaic in 2007

➪ Land cover classification at 50m resolution over Riau province (111 186,5 km²)

- **Based on the Support Vector Machine and an optimized set of textural parameters**

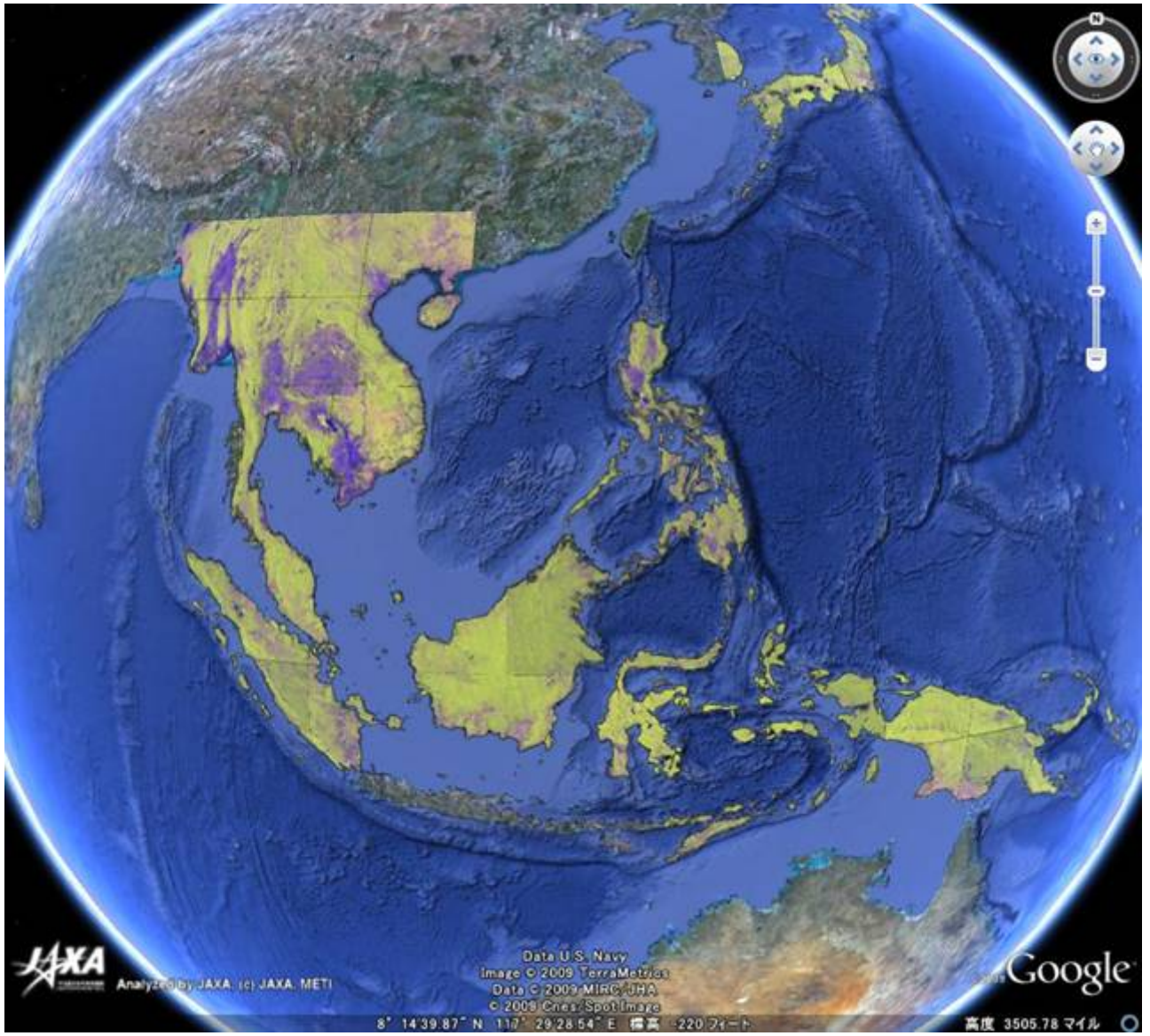


Ground truth



PALSAR estimation

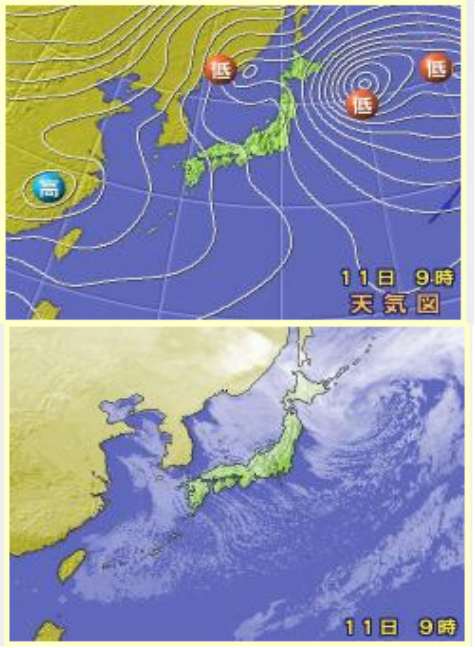
N. Longépé et al.: Assessment of ALOS PALSAR 50m Orthorectified Mosaic Data for Regional Land Cover Classification by using Support Vector Machines", *IEEE Trans. Geosci. Remote Sensing, to be submitted, 2009*.



www.eorc.jaxa.jp/ALOS/kc_mosaic/kc_mosaic.htm

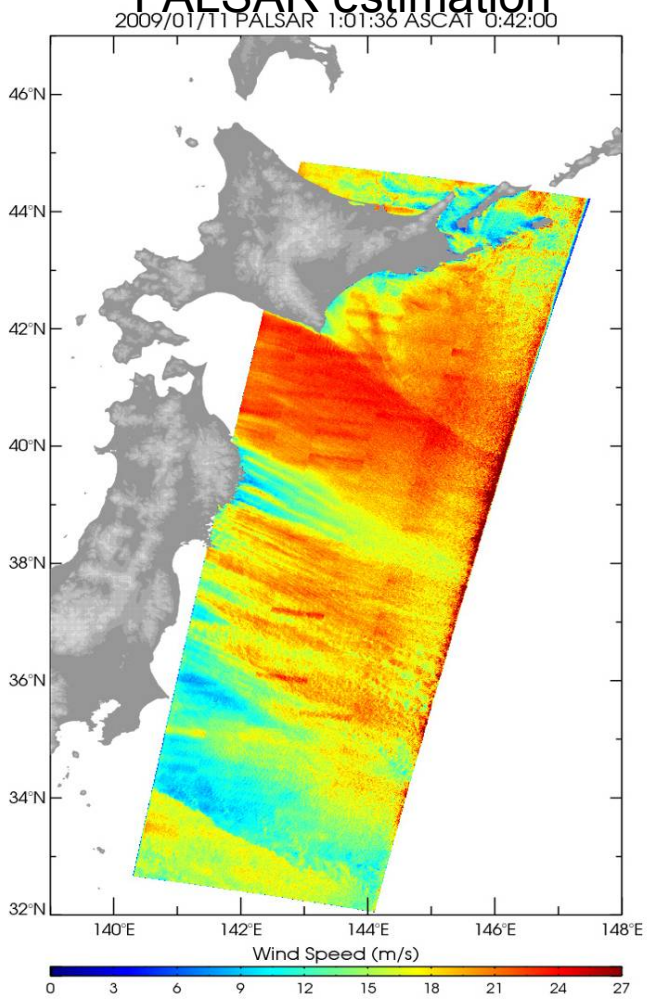
Wind speed retrieval by an L-band ocean geophysical model function derived from PALSAR

2009/1/11

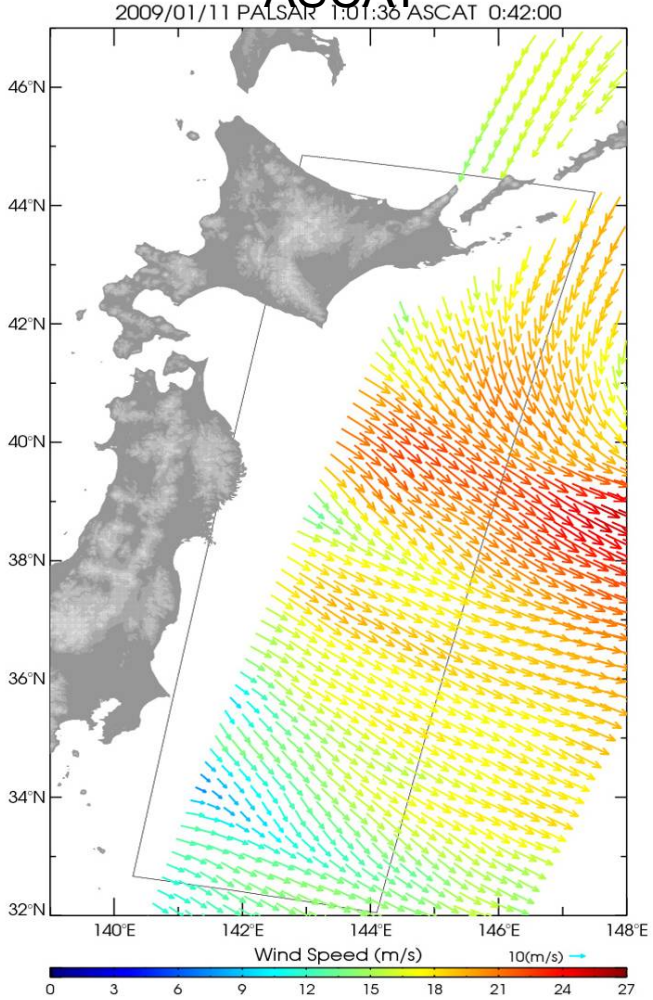


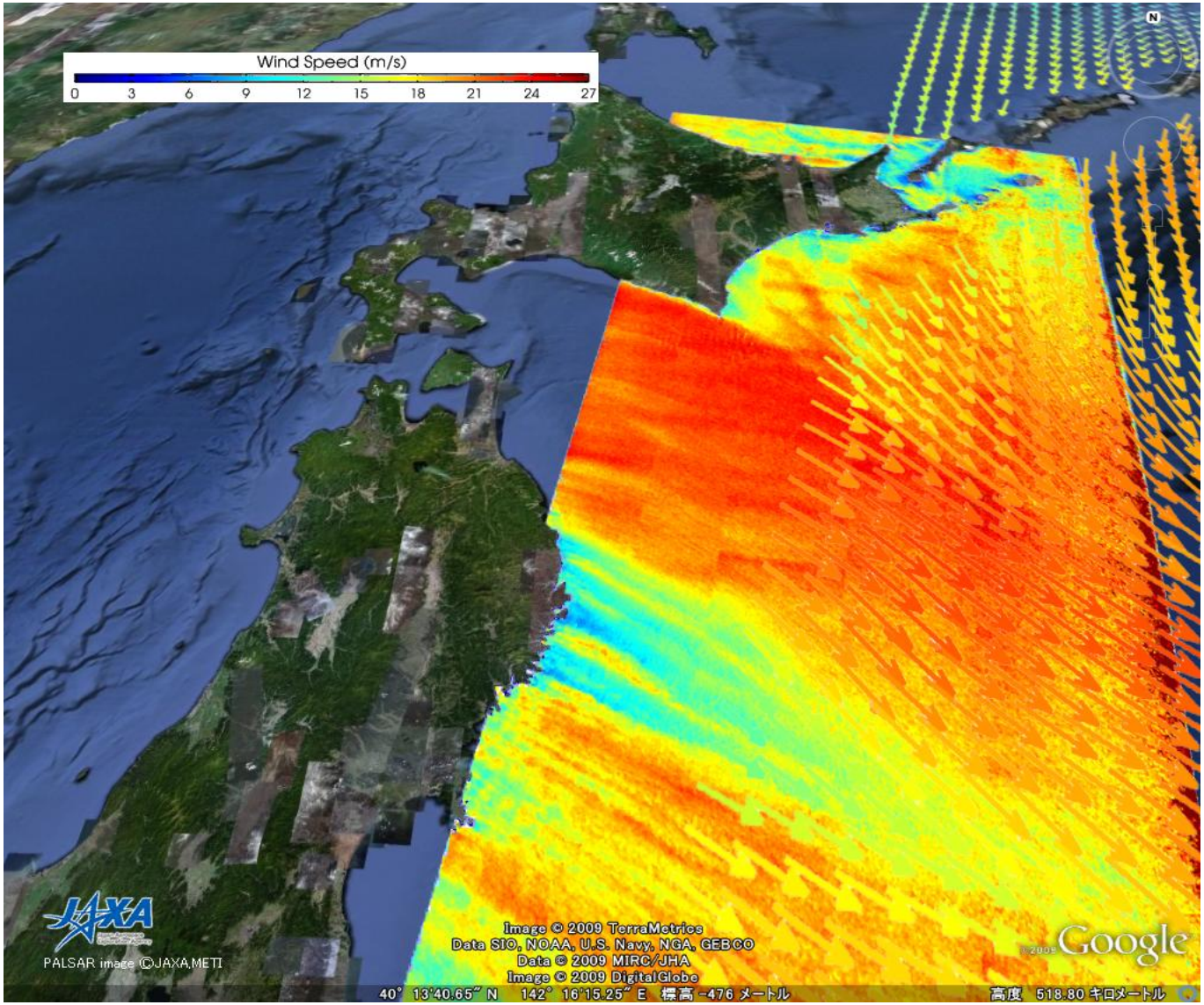
http://www.weathermap.co.jp/kishojin/diary/200902/index.php

PALSAR estimation



ASCAT





Isoguchi, O., and M. Shimada: An L-band ocean geophysical model function derived from PALSAR", *IEEE Trans. Geosci. Remote Sensing2009*.

Summary

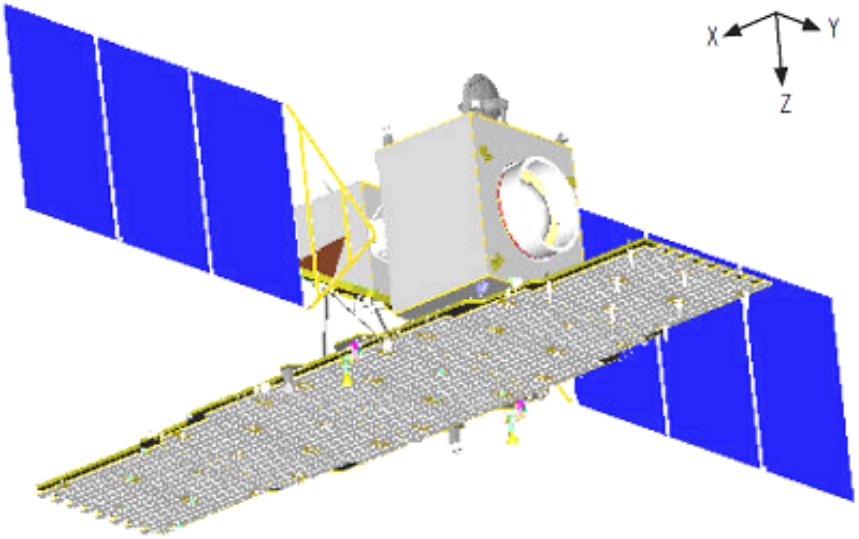
- PALSAR passed almost four years on orbit with successful operations and is still in good conditions.
- PALSAR is a powerful tool for global Earth observation, notably for disaster monitoring (crustal deformation, floods…) and resources management (forest, crop…)
- ALOS-2 with a L-band SAR onboard is planed to be launch in 2013/14

ALOS

K&C Initiative

An international science collaboration led by JAXA

ALOS-2



orbit	type	sunsynchronous
	height	~630km
	LST	12:00(local noon) descending
Recurrence time		**14 days**
Designed life		**Five years**
Launch	time	**Winter, JFY2012**
	Launcher	H-2A
satellite	mass	2 ton type
	paddle	2 paddles
Mission data		Direct transmission and Ka band DRTS
SAR frequency		**L-band (1.2 GHz)**
Main observation modes	High resol.	1～3m、swath25km
	Basic obs.	3m、swath:50km
	Wide obs.	100m、swath:350km
Main target areas		**Deformation**, volcano, change detection, resource finding.
		Forest, Sea ice, river, rice field monitoring

Features of ALOS-2

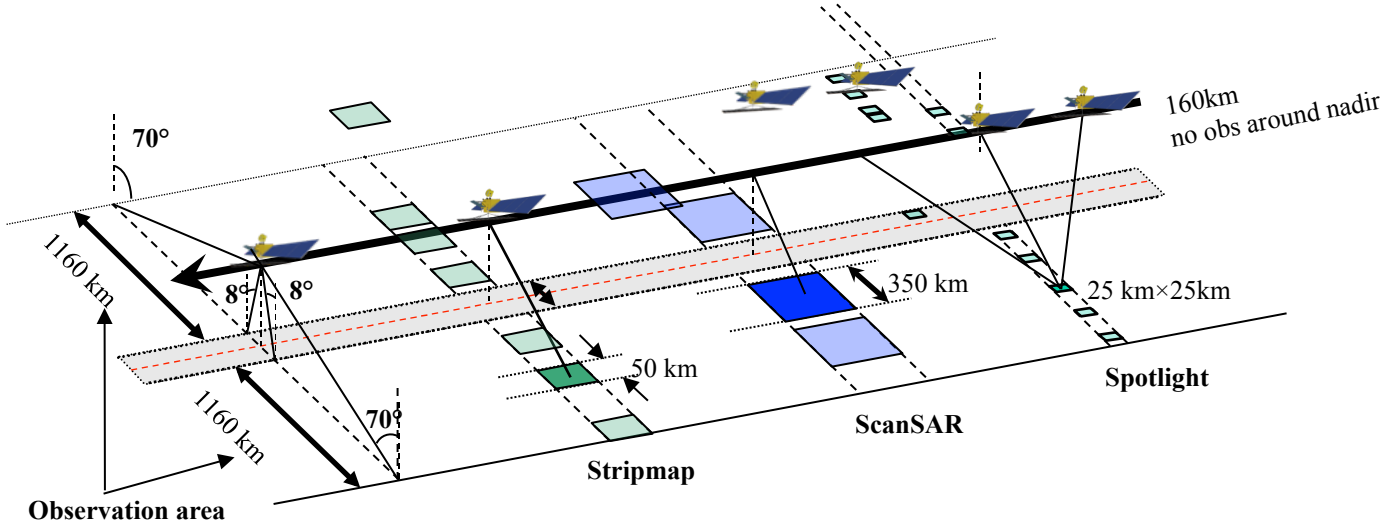
- High resolution SAR based observation system
- Similar Observation duties of ~30% to ALOS/PALSAR.
- Improving the observation response (once per day)
  - ✓ Both side capability
  - ✓ Enlarged incidence angle of 8~70 degrees.
- Frequent orbit inclination maintenance for successive interferometry
  - ✓ All the orbits will be within 500m tube of the reference orbit
- High band data transmission
  - ✓ Direct transmission：840Mbps（6 times of ALOS）
  - ✓ Communication with DRTS：278Mbps（similar to ALOS）

ALOS-2 SAR observation modes

parameter \ mode		Spotlight	Stripmap (High Resolution)	Stripmap (High Sensitivity)	Stripmap (Conventional)	ScanSAR
Frequency		1257.5MHz				
Incident angle		8 to 70 degree				
Bandwidth		84MHz	84MHz	42MHz	28MHz	14MHz
Res.	Rg	3m	3m	6m	10m	100m
	Az	1m	3m	6m	10m	100m
Swath		25km(Rg)*25km(Az)	50km	50km	70km	350km
Polarimetry		single	single,dual	single,dual,CP,FP	single,dual,CP,FP	**single,dual**
NESZ		-26dB	-24dB	-28dB	-26dB	-26dB
S/A	Rg	25dB	25dB	23dB	25dB	25dB
	Az	20dB	25dB	20dB	20dB	20dB

Performance @ incident angle 37deg

CP: Compact Polarimetry, FP: Full Polarimetry (HH+HV+VV+VH)



Thank you for your attention

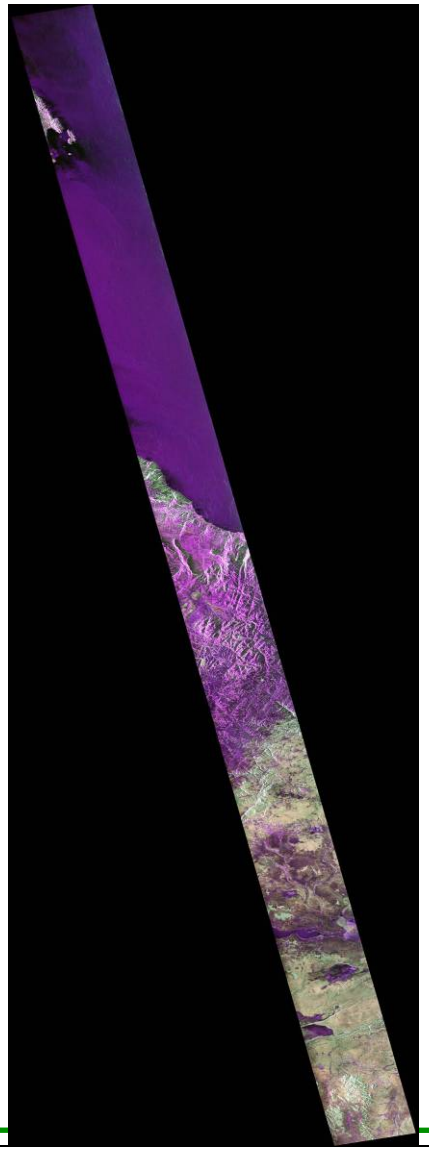
Any questions ?

Polarimetry Bit-Shift issue

Bit shift occurs at POL21.5 and 23.1 sometimes since April 2007.
23.1 degrees: 5% of data
21.5 degrees: 0.5% of data

Most of the data (99.7%) are recovered
Non-recovered scenes: 550 / 195,500

Corrected



Uncorrected

PALSAR calibration summary (after Shimada et al., 2009)

Items	Measured values		No. of Data	Spec.
geometric accuracy	9.7m(RMS): STRIP mode		572	100m
	70m(RMS): SCANSAR			
radiometric accuracy	0.219 dB(1 sigma) from Amazon forest			1.5 dB
	0.64 dB (1 sigma) from CRs		572	1.5 dB
	0.17 dB (1sigma: Sweden CRs)		16	1.5 dB
	-34 dB (Noise equivalent Sigma-zero for HV)			-23 dB
	-32 dB (as a minimum of FBD-HH)			
	-29 dB (as a minimum of FBS-HH)			
Polarimetric calibration	VV/HH ratio	1.013 (0.062)*	81	0.2 dB
	VV/HH phase diff	0.612deg(2.66)*		5 deg.
	Crosstalk	-31.7 (4.3)		-30 dB
resolution	azimuth	4.49 m (0.1) *	572	4.5m
	range (14MHz)	9.6m(0.1m) *		10.7m
	range (28MHz)	4.7m(0.1m)*		5.4m
Side lobe	PSLR in azimuth	-16dB	572	-10dB
	PSLR in range	-12.5 dB		-10dB
	ISLR	-8.6 dB		-8dB
Ambiguity	Azimuth	not appeared		16dB
	Range	23 dB		16 dB
Transmission power	Sum of 80 TRM	2220W		2000W

M. Shimada, et al. , “PALSAR Radiometric and Geometric Calibration, “ Trans. GRS, VOL. 47, NO. 12, Dec. 2009, in press.

Update of the Calibration Factor (CF)

Recalibration on Jan. 2009

$$\sigma^0 = 10 \cdot \log_{10} \langle DN^2 \rangle + CF \ [dB]$$

Table 4 History of CF (dB)

Date	Before Jan 6, 2009	After Jan 7 2009
FBS099HH	-83.16	-83.0
FBS215HH	-83.55	-83.0
FBS343HH	-83.4	-83.0
FBD343HH	-83.2	-83.0
FBD343HV	-80.2	-83.0
FBS415HH	-83.65	-83.0
FBD415HH	-83.19	-83.0
FBD415HV	-80.19	-83.0
FBS508HH	-83.30	-83.0
PLR215	-83.40	-83.0

Before Calibration
Mode dependent variation

After Calibration
Constant values

Question: How about the phase update for FBD (HV) ?

Table 2 Representative gamma-naught measured for the Amazon forest

Off-nadir angle	Mode	1-Gamma-naught (dB)	2-Gamma-naught (dB)
9.9	FBS-HH	-6.255 (0.228)	-6.389(0.219)
21.5	FBS-HH	-5.960 (0.112)	-6.510(0.242)
34.3	FBS-HH	-6.550 (0.142)	-6.550(0.141)
34.3	FBD-HH	-6.318 (0.228)	-6.517(0.222)
41.5	FBS-HH	-6.082 (0.107)	-6.502(0.107)
41.5	FBD-HH	-5.764 (0.317)	-6.504(0.317)
50.8	FBS-HH	-6.202 (0.400)	-6.502(0.400)
Average-strip		-6.201 (0.326)	-6.515(0.219)
18-42	SCAN-HH	-6.65 (0.4)	

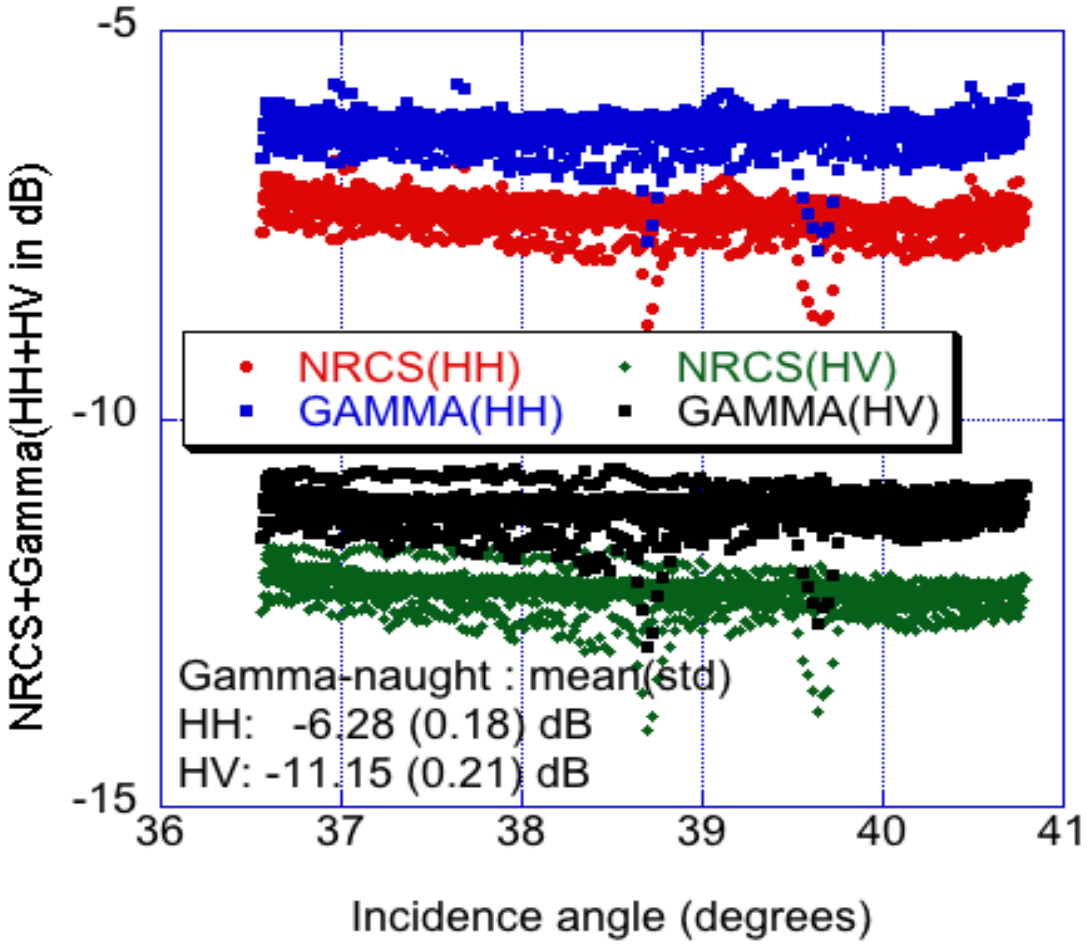
Calibration : CR base : Amazon forest

Jan.2009

Table 3 Gain offset table referred to 34.3 FBSHH (dB)

Beam (off nadir angles, degrees	FBS	FBD	PLR
9.9	-0.4025	-0.4025	-
21.5	-0.427	-0.427	0.223
34.3	-0.200	0.200	-
41.5	-2.050	-1.690	-
50.8	-2.600	-2.600	-

Update of the FBD HV Range antenna pattern and validation using the Amazon data



Data reception status (2)

X-band Ground Stations

JAXA Hatoyama EOC (Japan) in operation
Hiroshima HIT (Japan) in operation tentatively
Kumamoto TSIC (Japan) in operation tentatively

ADEN Kiruna (Sweden) operation ended in Apr.15, 2007
Tromsoe (Norway) in operation since Apr.16, 2007
Maspalomas (Spain) in operation since Jun.25, 2007
Matera (Italy) in operation since May 7, 2007

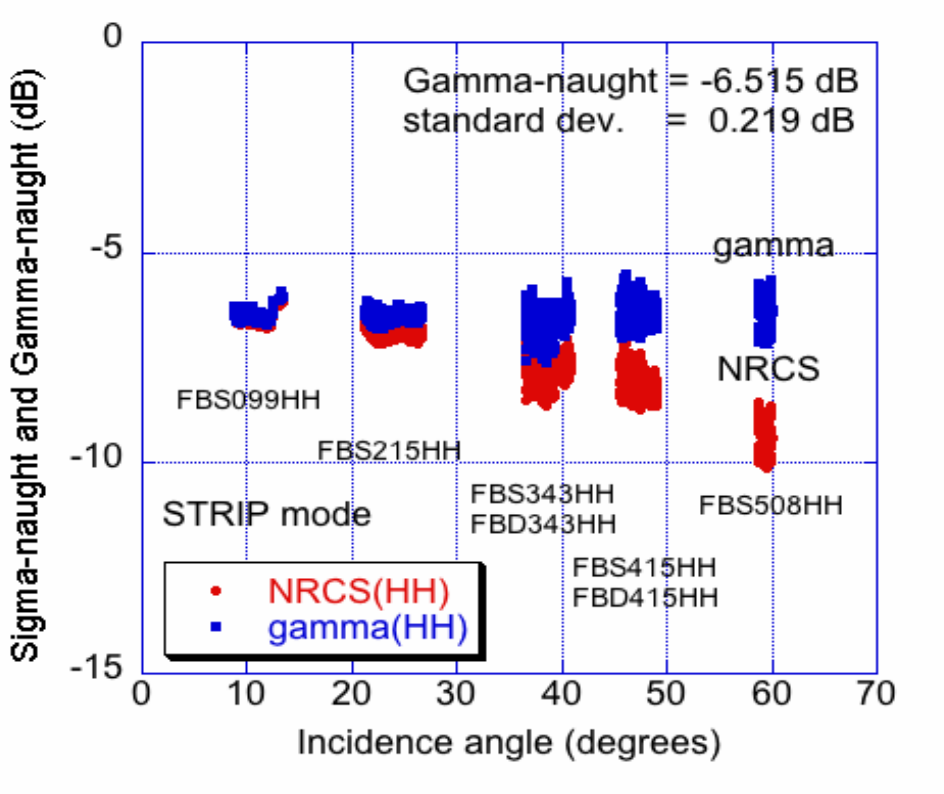
AADN Fairbanks ASF (USA) in operation since May 19, 2008
Cordoba (Argentina) in operation since May 19, 2008
Miami (USA) in operation since April 14, 2009

OADN Alice Springs (Australia) in operation
Hobart (Australia) in operation

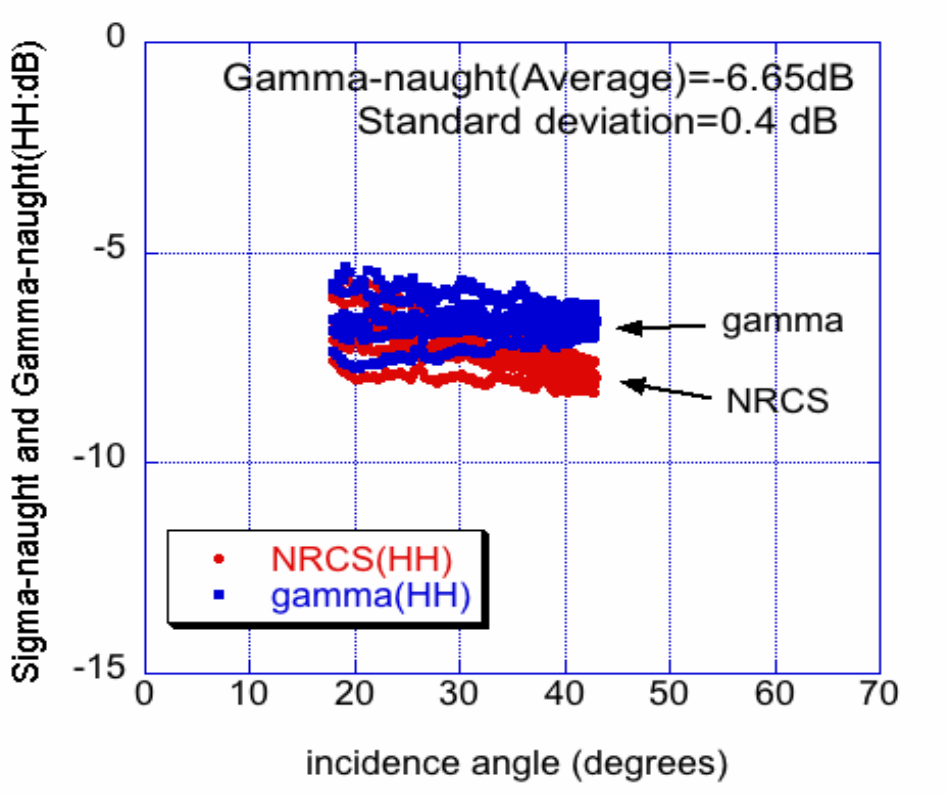
TASN Lat Krabang (Thailand) in operation since May 19, 2008

Incidence angle dependence of the gamma naught

Evaluation conducted using the Amazon data



Strip modes



ScanSAR data

Acquisition and distribution status (2)

- **Archived Level 0 data acquired by JAXA**
  3,440 DTF-2 (200GB/casette) as of September 30, 2009
  PRISM > 1,845,595 scenes * (nadir)
  AVNIR-2 > 840,848 scenes
  PALSAR > 1,375,893 scenes

- **Deliver Level 0 data to ALOS Data Nodes**
  Number of DTF-2 (standing/on-demand) as of September 30, 2009
  ADEN 887 / 276
  AADN 890 / 397
  OADN 570 / 101
  TASN 469 / 1

- **AUIG 3.0 (new GUI) is available since Apr.,2008.->**
  https://auig.eoc.jaxa.jp/