Status of ALOS-2 PALSAR-2 calibration/validation and ALOS-4 development

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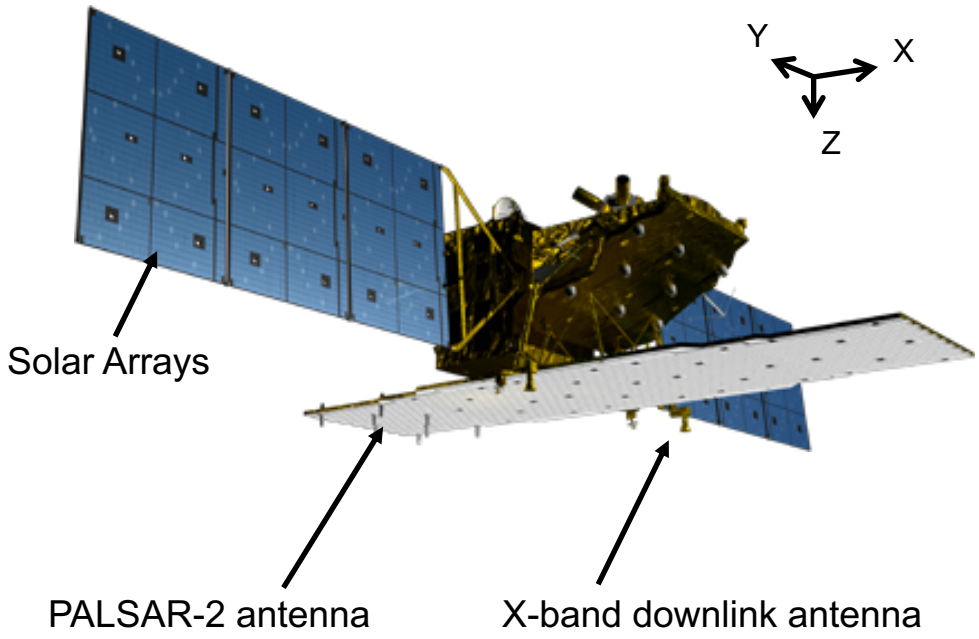
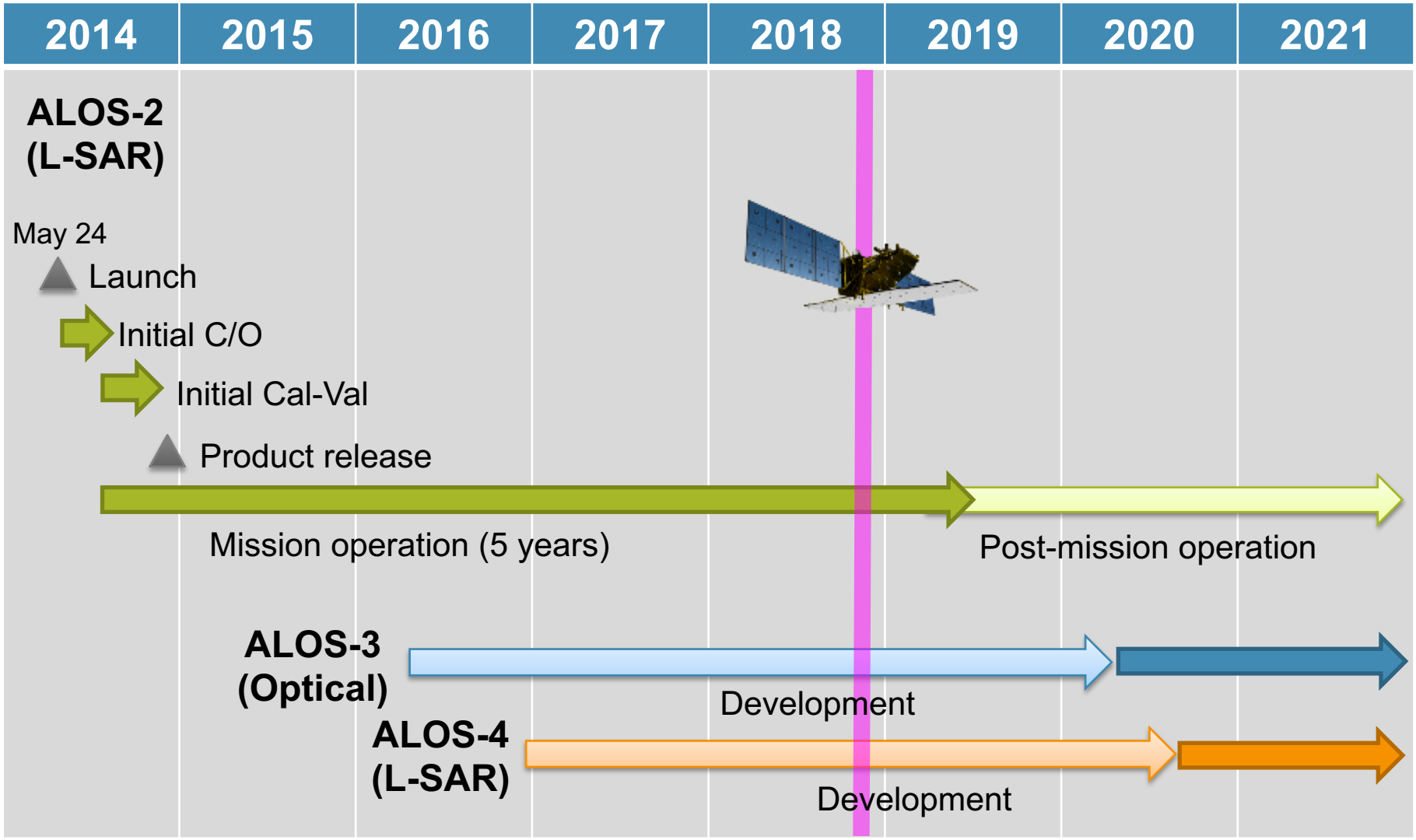
Advanced Land Observing Satellite-2 (ALOS-2)



Mission sensor	• **PALSAR-2 (L-band SAR)** • **SPAISE2 (AIS)**
Launch	May 24, 2014 H-IIA launch vehicle
Lifetime	5 years (target: 7 years)
Orbit	Sun-synchronous, 628 km altitude, 14 days revisit, Orbit control: ≦ +/- 500 m
Local sun time	12:00±15 min (descending) 24:00±15 min (ascending)
Mission data transmission	X-band: 800 Mbps (16 QAM), 200/400 Mbps (QPSK)

ALOS-2 operation phase



PALSAR-2 cal/val status

- On-board internal calibration has been performed every 3 months.
- Product quality of major observation modes has been evaluated regularly using SAR data over calibration sites.
- Standard product processing software was updated on Jun-5-2018 (radiometric calibration) and on Nov-20-2018 (correction of range offset).

Validation results of standard products (as of 2018-Aug-07)

Items	Results	
Geometry (RMSE)	[Stripmap and Spotlight] **5.34 m (L1.1) / 6.73 m (L2.1)** [ScanSAR] **60.77 m (L1.1) / 29.93 m (L2.1)**	
Radiometry	RCS accuracy (1σ)	**0.48 dB (corner reflectors)** **0.41 dB (Amazonian forests)**
Polarimetry	VV-HH amplitude ratio	**1.000 (σ=0.012)**
	VV-HH phase difference	**0.137 deg (σ=0.962)**
	Cross talk	**[HV/HH] -41.90 dB (σ=5.264)** **[VH/VV] -41.56 dB (σ=4.953)**

Radiometric calibration

- Digital number of PALSAR-2 product can be converted to sigma-zero value by using the following equation.
- The Calibration Factor (CF) in the equation is evaluated by measuring CRs.

For L1.1 (SLC)

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

For L1.5 and 2.1 (Amplitude)

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

I, Q (SLC), DN (amplitude): digital number

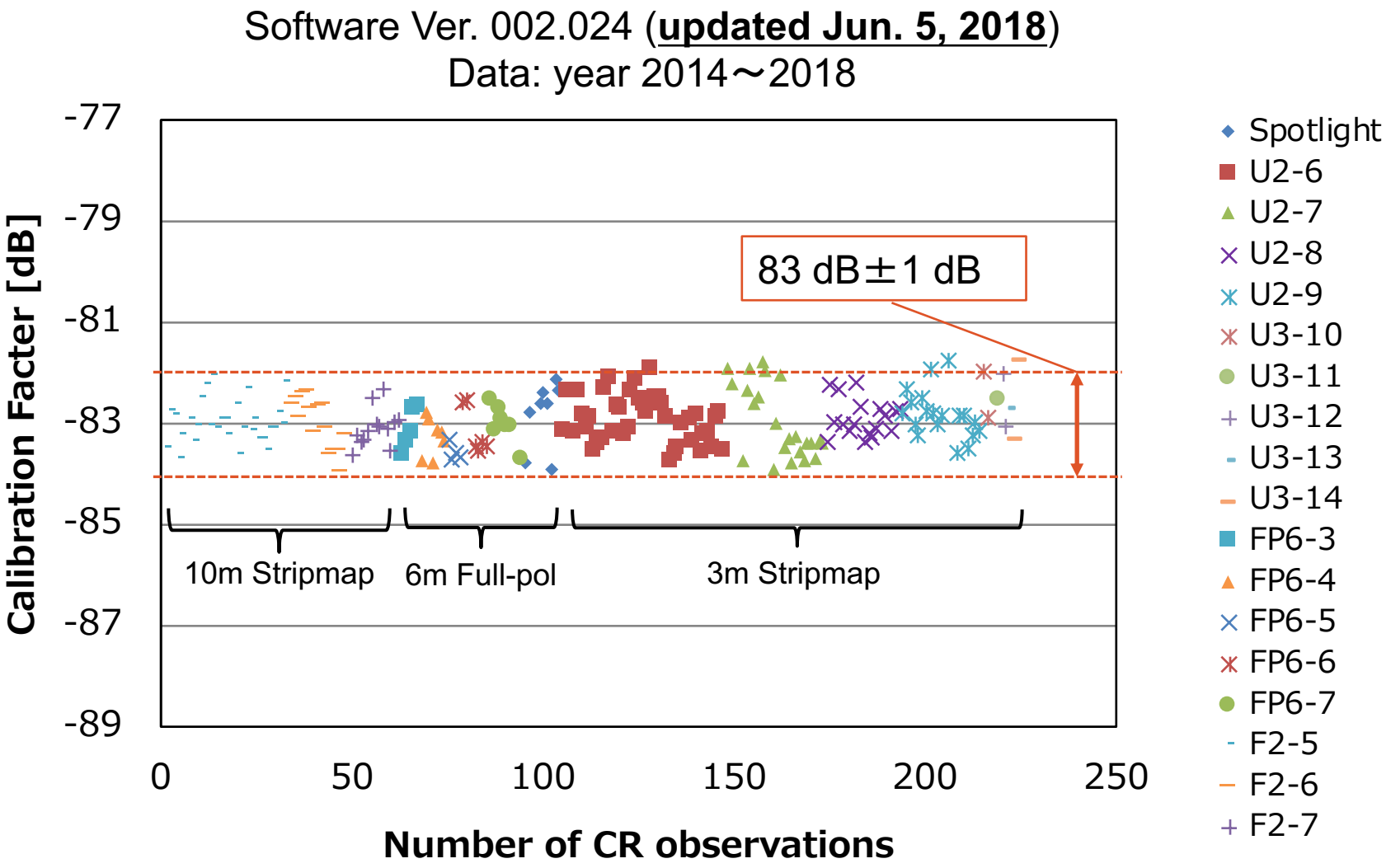
CF = -83 dB

A = 32 dB

Radiometric calibration factor (CF) [Jun. 2018 update]

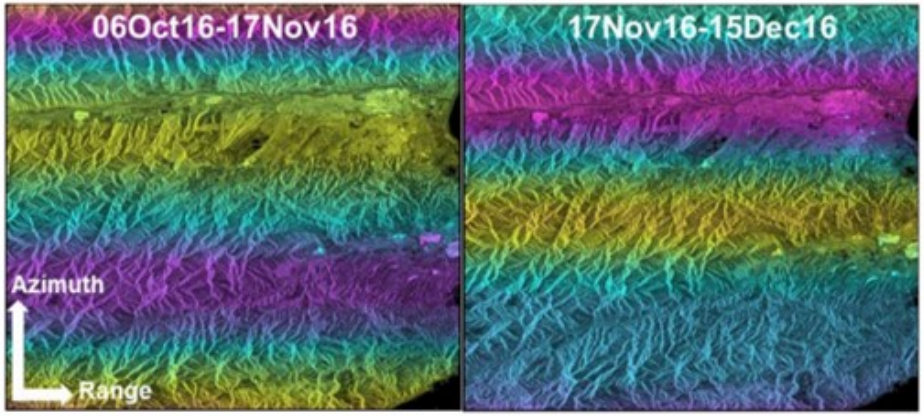
Product ordering time for AUIG-2			**Sep. 11, 2014 ~ Sep. 28, 2016**	**Sep. 28, 2016 ~ Mar. 28, 2017**	**Mar. 28, 2017 ~ Jun. 5, 2018**	**Jun. 5, 2018 ~**
Version of the processing software			**000.001 ~ 002.021**	**002.022**	**002.023**	**002.024**
CF [dB]	Spotlight	all	-81.1		-83.0	-83.0
	Stripmap [3 m]	U2-6	-81.6			
		U2-7	-81.2			
		U2-8	-81.6			
		U2-9	-81.7			
	Stripmap [6 m]	FP6-3	-81.0		-84.0	
		FP6-4	-81.7		-83.0	
		FP6-5	-82.8			
		FP6-6	-82.5			
		FP6-7	-80.8		-84.0	
	Stripmap [10 m]	F2-5	-82.4		-83.0	
		F2-6	-82.4			
		F2-7	-81.9			
	ScanSAR [14 MHz]	W2	-79.0	-83.0		
	ScanSAR [28 MHz]	W2	-82.0	-86.0		
	The other modes		-83.0			

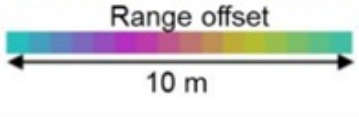
Radiometric accuracy



Range offset error [Nov. 2018 corrected]

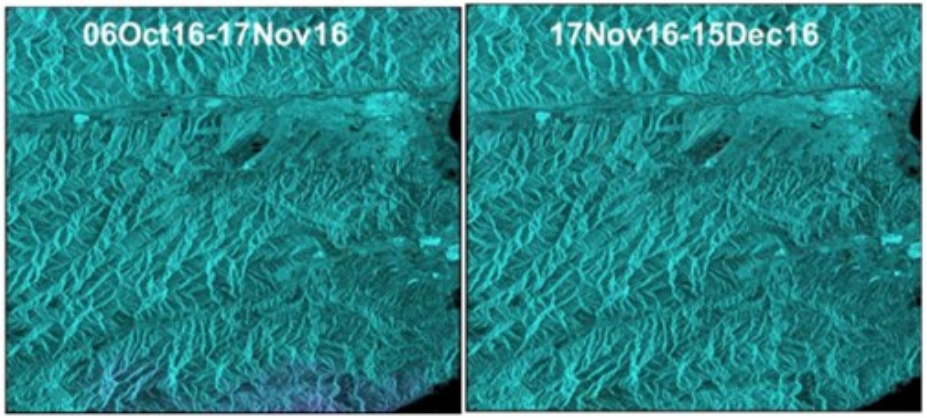
- Range offset anomaly sometimes occurred in Stripmap 10-m, ScanSAR 350km (14/28MHz), and ScanSAR 490km observation modes
- On Nov. 20, 2018, JAXA updated the software for PALSAR-2 standard products to fix the range offset error.





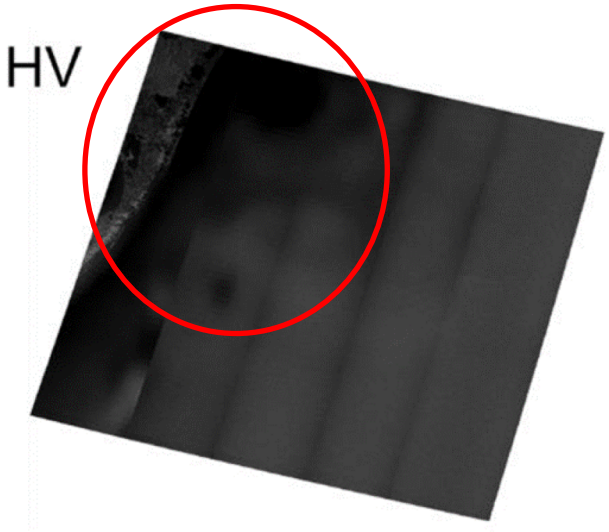
-6 ~ +8 meters error

After update



Other issues

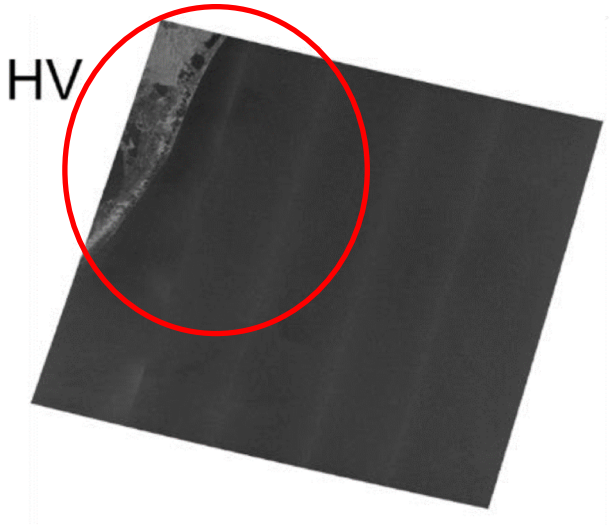
- It was found that the ScanSAR HV-polarization images sometimes became dark and blurred over ocean and coastal regions.
- The cause of this issue was that the onboard ATT (attenuator) setting for ScanSAR cross-polarization was higher.
- On April 11, 2018, the ATT setting for ScanSAR cross-polarization was changed to 20 dB.



ALOS2117174250_160724

ATT 25dB, 2016/7/24

Before ATT setting change



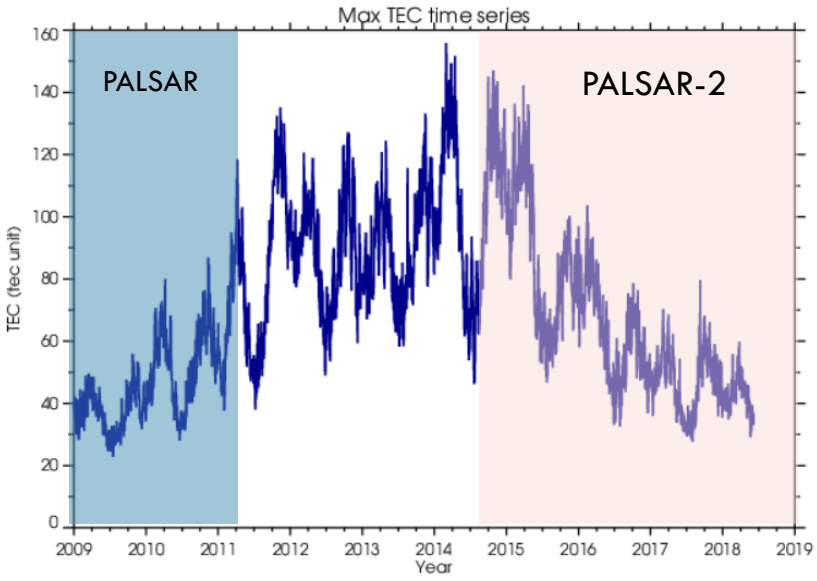
ALOS2191694250_171210

ATT 20dB, 2017/12/10

After ATT setting change

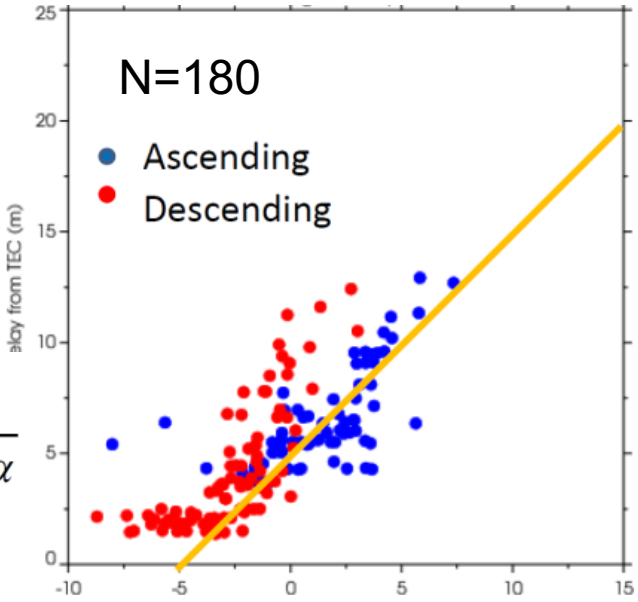
Ionosphere effect on geometric accuracy

Time series in global average TEC



Range difference estimated by TEC (m)

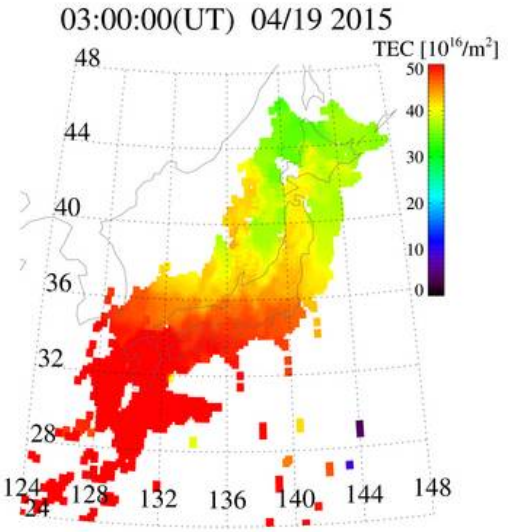
$$\Delta s = K \frac{TEC}{f^2 \cos\alpha}$$



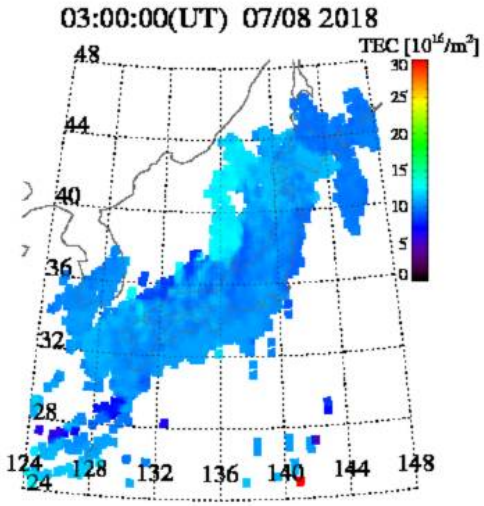
Geometric error in slant range (m)

Geometric accuracy

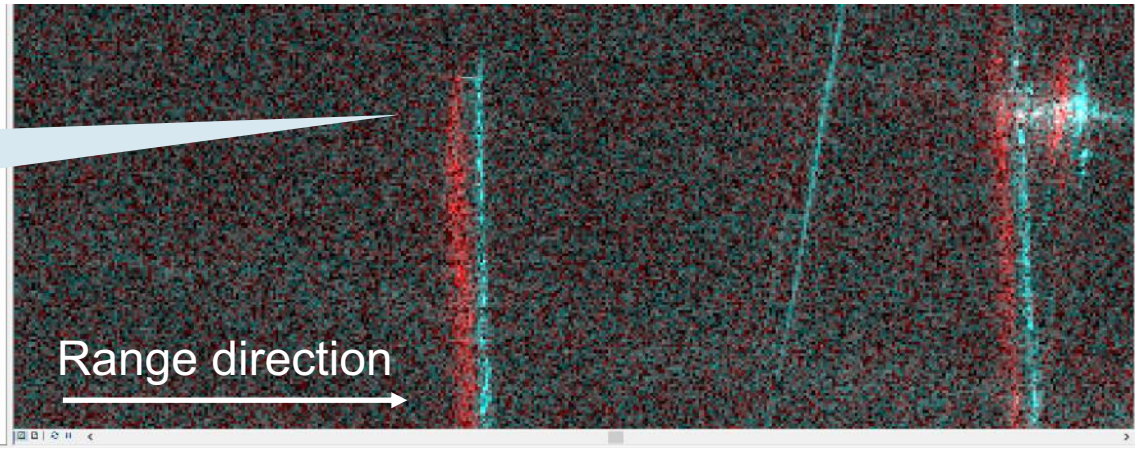
2015/04/19 UT3:00
50 TECU → g_range shift -25 m



2018/07/08 UT3:00
10 TECU → g_range shift -5 m

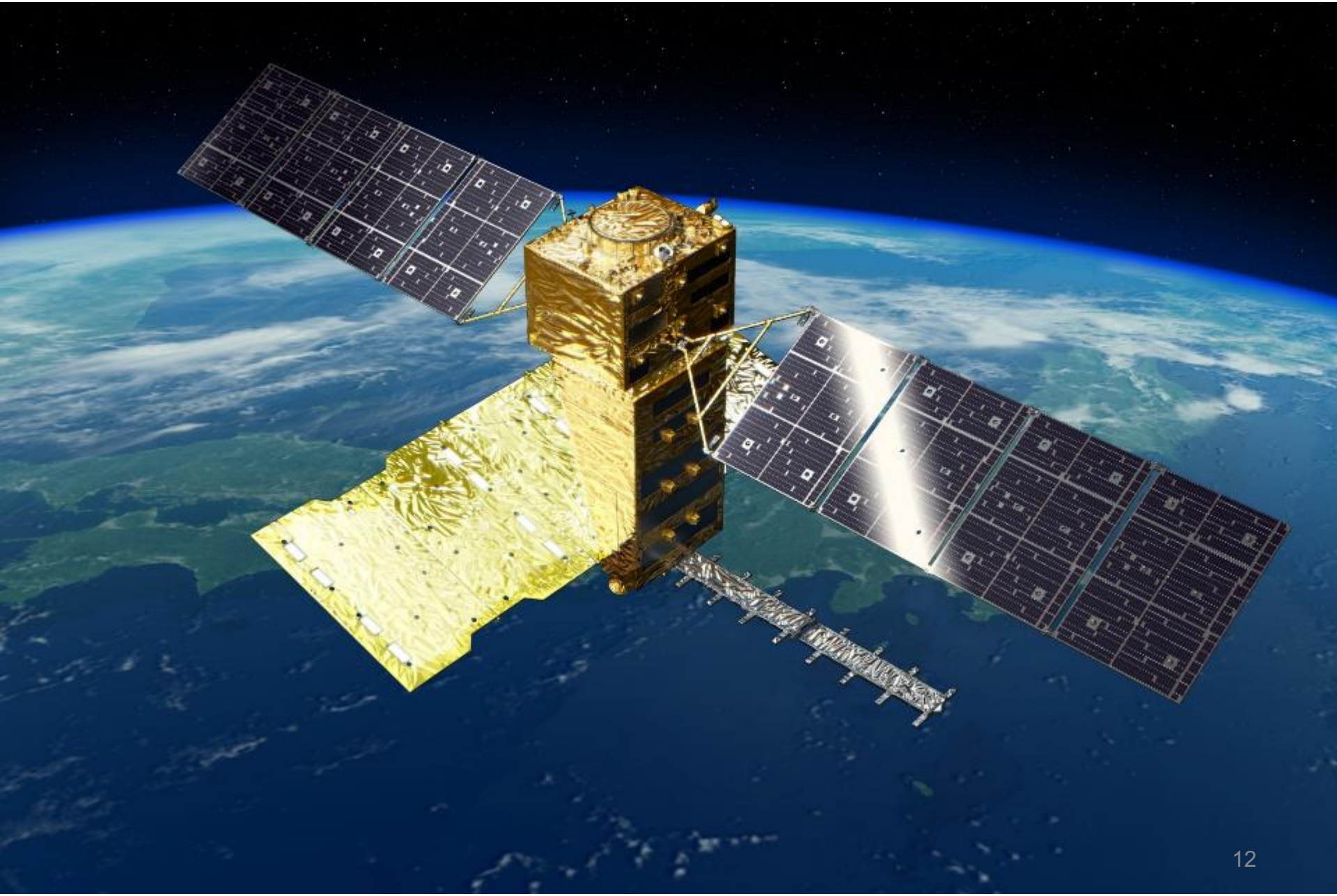


R: 2015/04/19, G&B: 2018/07/08



difference
~ 20 m

ALOS-4 (Advanced Land Observing Satellite-4)



Mission objectives of ALOS-4

Continuation and enhancement of the ALOS-2 missions and new applications

1. Land deformation and subsidence monitoring

- Detecting anomalies at an earlier stage by increasing observation frequency

2. Disaster monitoring

- Keeping observation capability at night and at bad-weather conditions
- Wide-area coverage for large earthquakes and multiple events

3. Other continuous missions and new applications

- Environmental monitoring: time-series change of forests, wetlands, ice sheets, etc.
- Ocean: ship detection, sea ice drift monitoring, etc.
- Agriculture and natural resources
- Inspection of increasing aging infrastructures (dams, airports, etc.) using time-series interferometry

User needs to system requirements

Main user needs

Land deformation and subsidence

- High observation frequency and spatial resolution
- Basemap observation over Japan

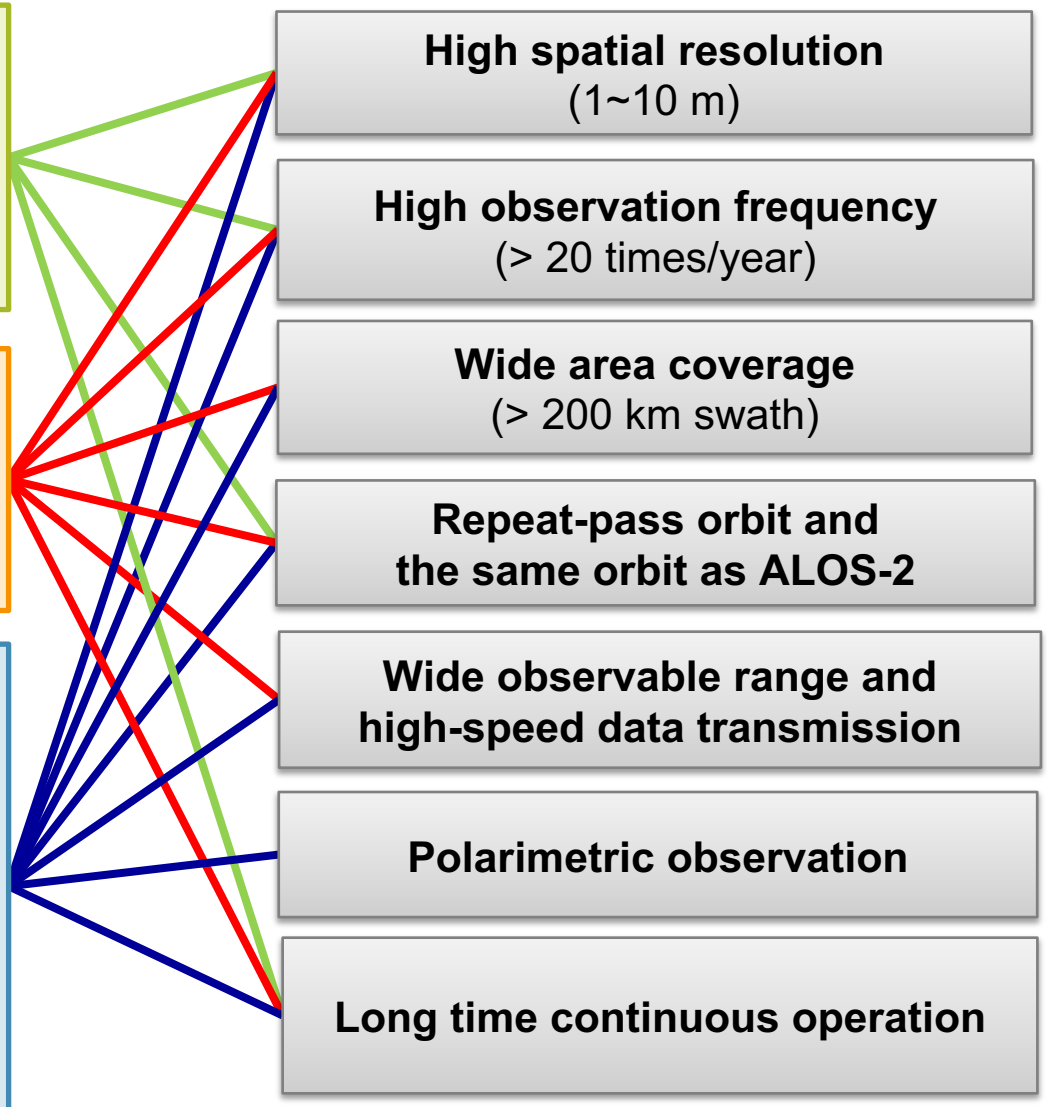
Disaster monitoring

- Observation at night time and bad weather condition
- Quick initial response

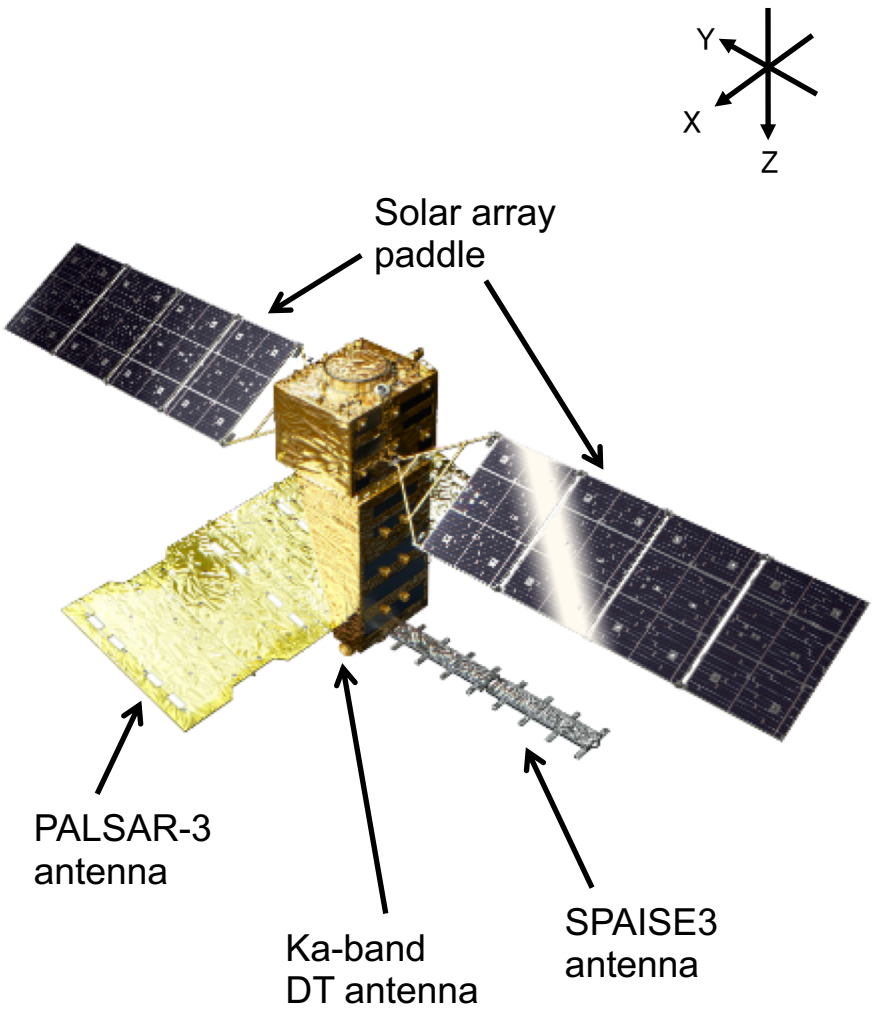
Continuation from ALOS-2 and new applications

- Infrastructure (dams, etc.)
- Forest and wetland
- Ship detection
- Agriculture
- Sea ice and ice sheet
- Natural resources

System requirements



ALOS-4 System characteristics



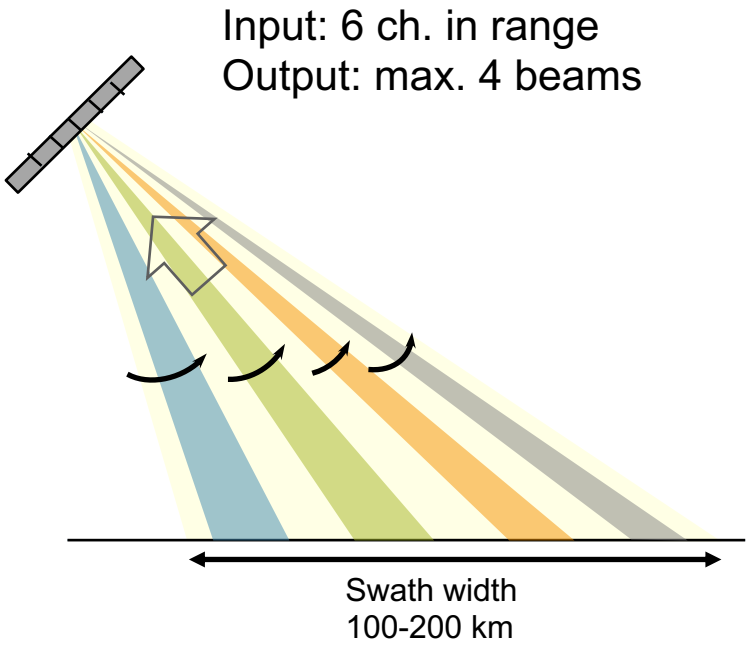
Launch	**JFY 2020** **H3 launch vehicle**
Orbit	**Same orbit as ALOS-2** Sun-synchronous sub-recurrent orbit Altitude: 628 km Inclination angle: 97.9 degree Local sun time at descending: 12:00 ± 15 min. Revisit time: 14 day (15-3/14 rev/day)
Lifetime	**7 years**
Satellite Mass	approx. 3 tons
Downlink	3.6 Gbps/1.8 Gbps (**Ka-band**)
Mission Instruments	- **PALSAR-3** (Phased Array type L-band Synthetic Aperture Radar-3) - **SPAISE3** (SPace based AIS Experiment 3)
Prime contractor	Mitsubishi Electric Corporation

Characteristics of PALSAR-3

- **Expanding swath width** without decreasing the resolution and image quality of PALSAR-2 by using the digital beam forming (DBF).
- To guarantee the continuity of ALOS-2 applications, PALSAR-3 would **inherit the major function and performance (NESZ, S/A, etc.) of PALSAR-2**

	ALOS-4	ALOS-2
Stripmap (res. 3/6/10 m)	**100-200 km**	30-70 km
ScanSAR (res. 25m*)	**700 km**	350-490 km
Spotlight (res. 1 x 3 m)	**35km × 35km**	25km × 25km

*single look



System improvement from ALOS/ALOS-2

	ALOS 2006-2011	ALOS-2 2014-	**ALOS-4 2020-**
Antenna size	3 m × 9 m	3 m × 10 m	**3.6 m** × 10 m
Number of T/R module	80 (Si)	180 (GaN)	**232 (GaN)**
Transmit power	2,000 W	6,120 W	**7,888 W**
Receive beam	Single beam	Dual beam (azimuth)	**DBF (range)** + Dual beam (azimuth)
Ionospheric correction	N/A	N/A	**Split-band mode (28 + 10 MHz)**
Pointing	Right	Right and Left	Right and Left
Orbit control	< +/- 2.5 km (at equator)	< +/- 500 m (all latitude)	< +/- 500 m (all latitude) **Laser reflector for absolute calibration**
Data recorder	90 GB	128 GB	**1 TB**
Data transmission	120 / 240 Mbps	800 Mbps	**3.6 / 1.8 Gbps**

Summary

- PALSAR-2 calibration and validation are conducted regularly. ALOS-2 keeps good performance over 4 years.
- After the nominal mission operation phase (5 years) completed, post-mission operation will start from Mid 2019
- JAXA has started the development of ALOS-4 as a follow-on L-band SAR satellite of ALOS-2. The ALOS-4 project is now in phase C (Final design phase).

Jul 28 - Aug 2, 2019
Yokohama, Japan

Paper Submission Deadline:
Jan 8, 2019

PALSAR-2 observation modes

JAXA's routine Cal/Val mainly evaluated the major observation modes and beams used in the basic observation scenario.

- ✓ Stripmap 3-m single-pol (UBS), beam U2-6～9
- ✓ Stripmap 6-m quad-pol (HBQ), beam FP6-3～7
- ✓ Stripmap 10-m dual-pol (FBD), beam F2-5～7
- ✓ ScanSAR 350-km swath dual-pol (WBD/WWD), beam W2

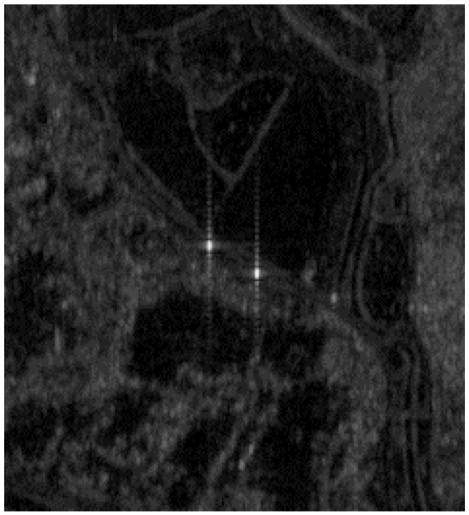
Mode		Spotlight	Stripmap			ScanSAR		
			Ultra fine	High sensitive	Fine	nominal		wide
Bandwidth		84 MHz	84 MHz	42 MHz	28 MHz	14 MHz	28 MHz	14 MHz
Resolution		Rg × Az: 3 × 1 m	3 m	6 m	10 m	100 m (multilook)		60 m (multilook)
Swath		Rg × Az: 25 × 25 km	50 km	50 km	70 km	350 km (5-scan)		490 km (7-scan)
Polarization		SP	SP/DP	SP/DP/QP/CP		SP/DP		
NESZ		-24dB	-24dB	-28dB	-26dB	-26dB	-23dB	-23dB
S/A	Rg	25dB	25dB	23dB	25dB	25dB		20dB
	Az	20dB	25dB	20dB	23dB	20dB		20dB

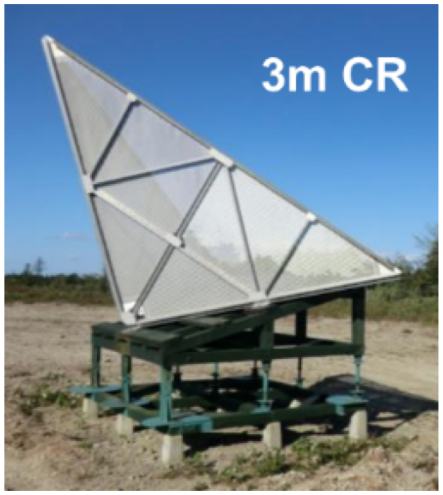
SP: HH or HV or VV, DP: HH+HV or VV+VH, QP : HH+HV+VH+VV
CP : Compact pol (experimental mode)

ALOS-2 Cal/Val sites (Japan)

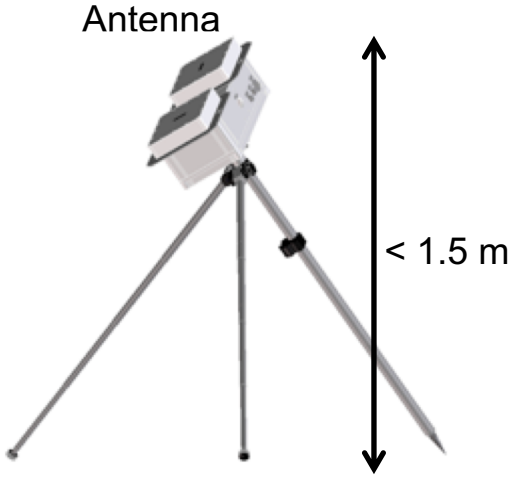
- **Tomakomai, Hokkaido**
  … 4 permanent CRs
  2 dihedral CRs and 2 trihedral CRs

- **Kanto region (around Tokyo)**
  … Temporally deployed CRs/ARCs/GCs
  20-30 times/year





CR (Corner Reflector)



ARC (Active Radar Calibrator) /
GC (Geometric Calibrator)

Signal receiver

ALOS-2 Cal/Val sites (World)

- **CR sites**
  - ✓ Amazon/Rio Branco (JAXA)
  - ✓ Alaska (ASF)
  - ✓ ALOS-2 Cal/Val Team member's sites
- **Antenna pattern calibration**
  - ✓ Amazon forest area ... Flat and homogeneous target