

# Summary of Calibration and Research Activities of the Advanced Land Observing Satellite-2 (ALOS-2)

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## **1. *Mission Overview and Status***

## **2. *Calibration Results***

- ✓ Radiometry
- ✓ Geometry

## **3. *Research Activities Examples***

- ✓ Responses to natural disasters
- ✓ Global environment issue: Forest monitoring

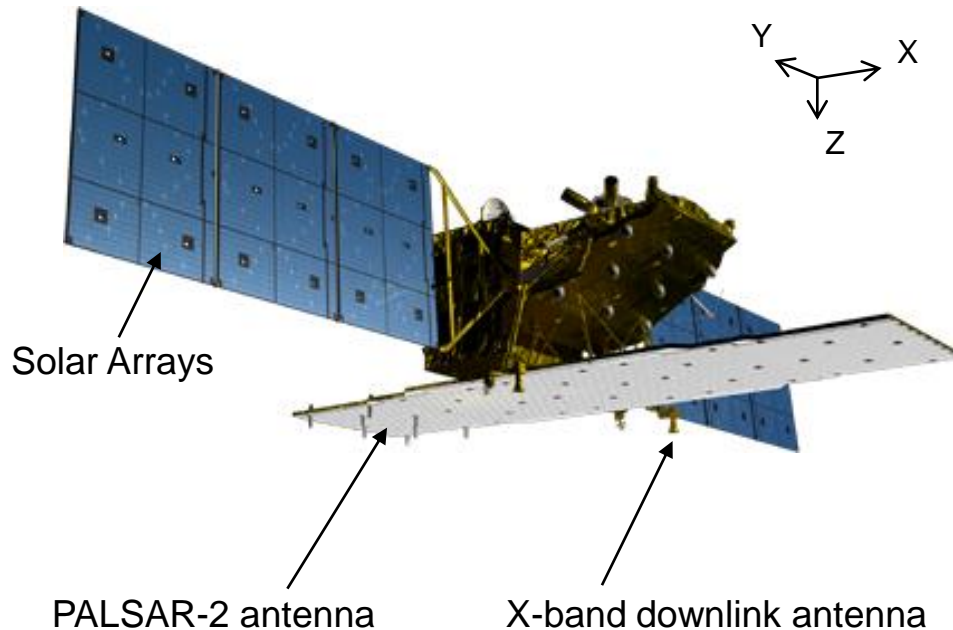
## **4. *What are Next?***

- ✓ Advanced Optical Satellite (ALOS-3)
- ✓ Advanced SAR Satellite (ALOS-4)

## **5. *Summary***

## Mission objectives:

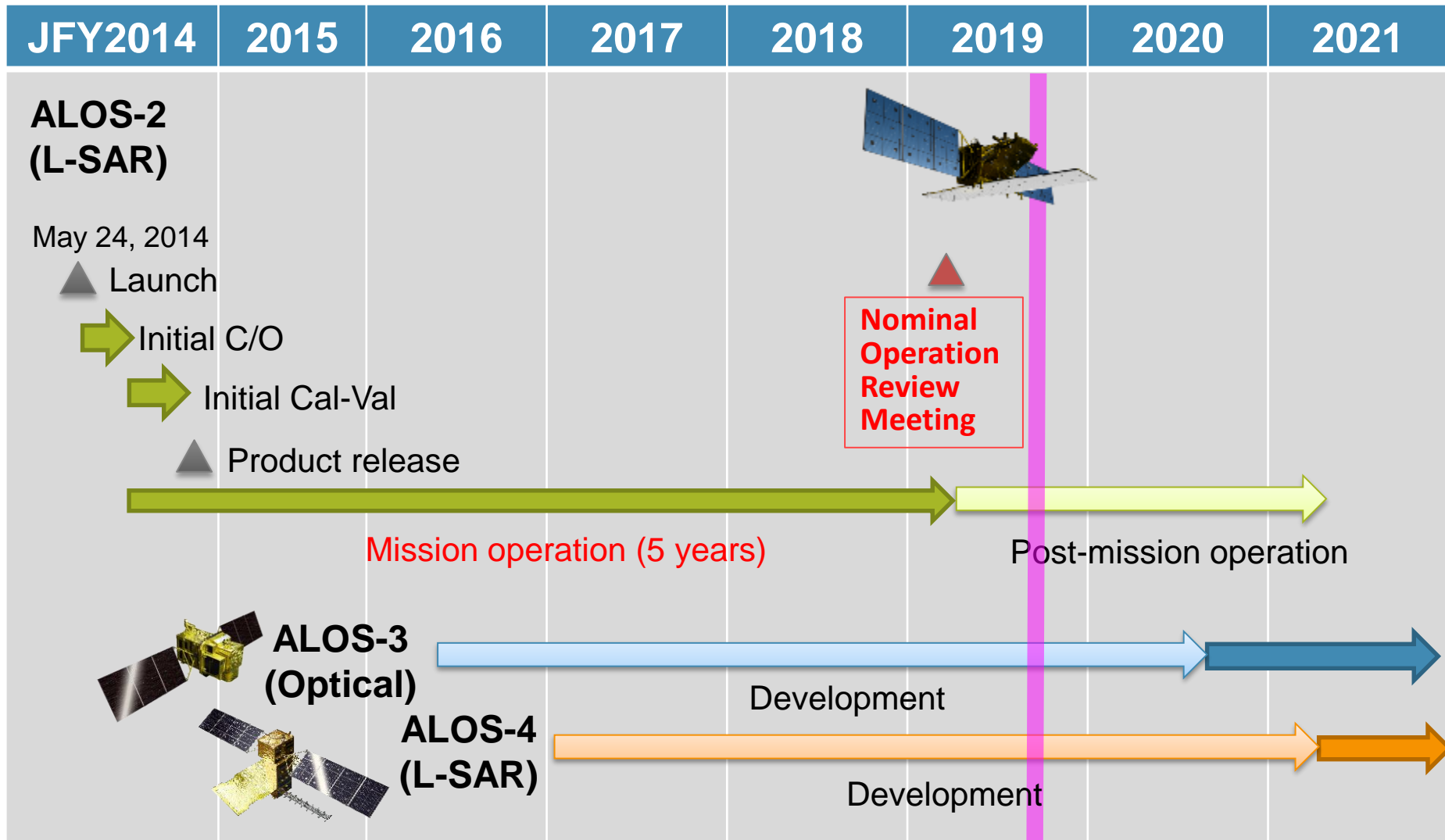
- Disaster monitoring (Earthquake, Volcano, Landslide, Flooding, ...)
- Environmental monitoring (Forest, Ice sheet, ...)
- Agriculture, natural resources, and ocean
- Technology development



Mission sensor	<b>PALSAR-2 (Phased Array type L-band Synthetic Aperture Radar 2)</b>
Launch	<b>May 24, 2014</b> H-IIA launch vehicle FY24
Mass	2.1 tons
Lifetime	<b>5 years (Target: 7 years)</b>
Orbit	Sun-synchronous, 628 km altitude, 14 days revisit, Orbit control: $\leq \pm 500$ m
Local sun time	12:00 $\pm$ 15 min (descending)  24:00 $\pm$ 15 min (ascending)
Mission data transmission	X-band: 800 Mbps (16 QAM), 200/400 Mbps (QPSK)

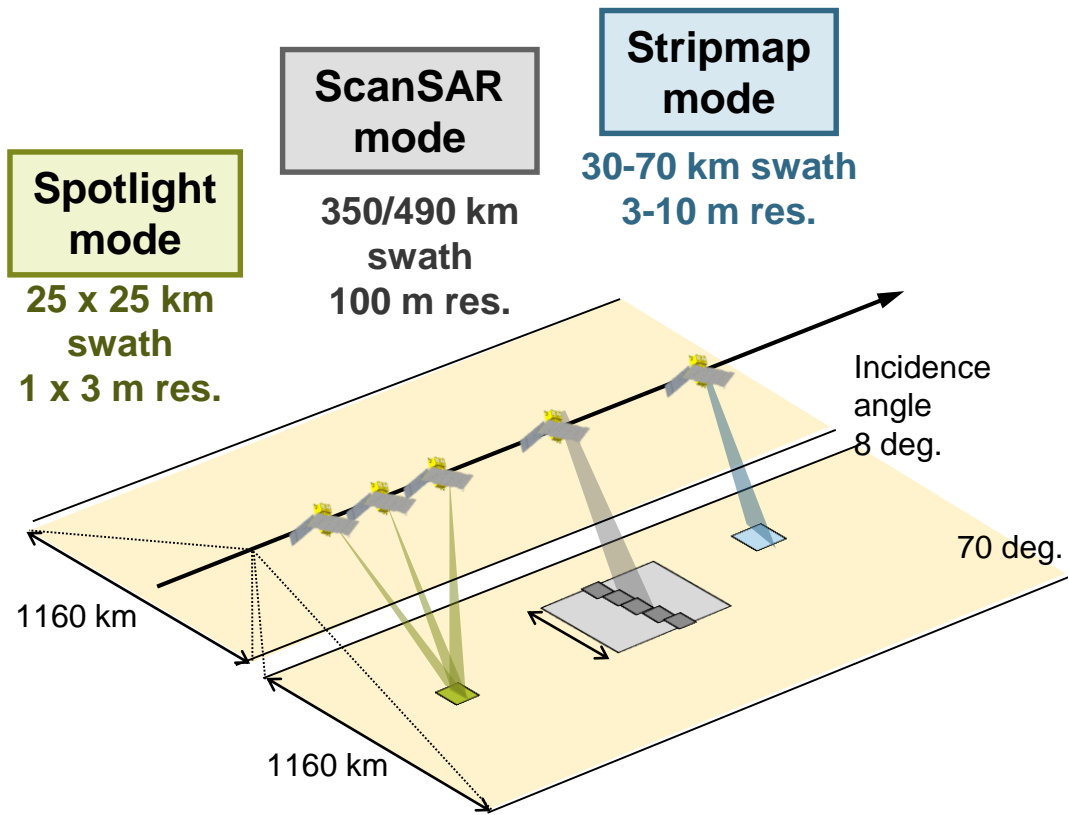
The compact infrared camera (CIRC) and SPAISE2 for detecting ships are carried as a technology demonstration payload.

# ALOS-2 Mission Operation

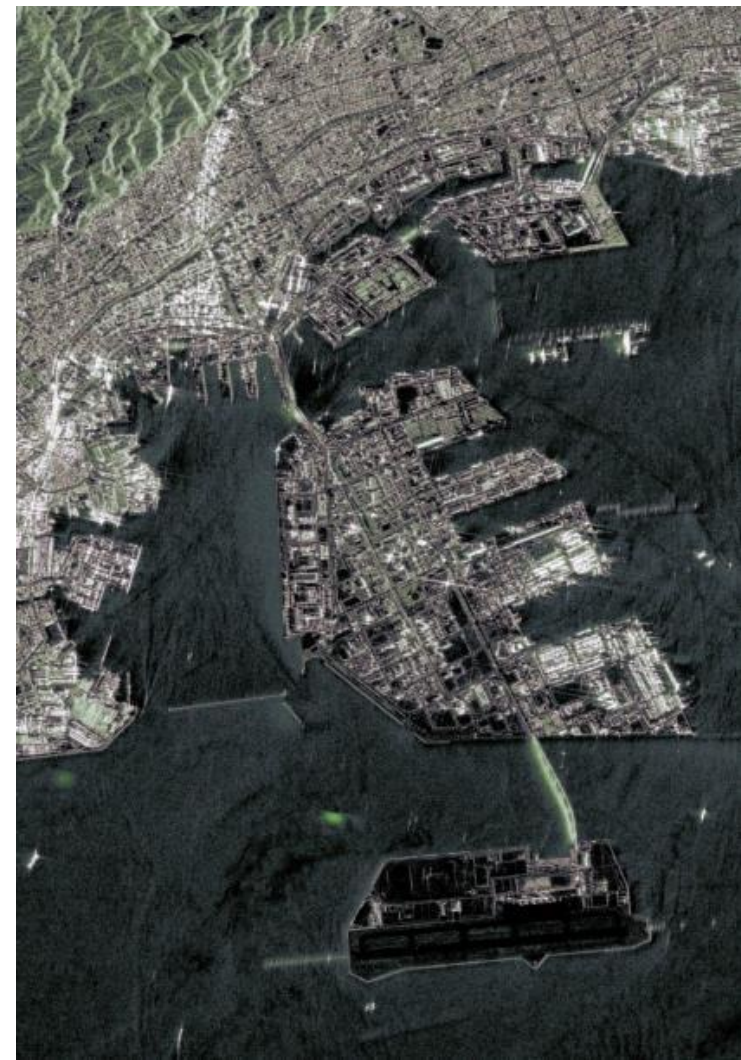


- ALOS-2 and PALSAR-2 instrument status nominal
- Completing 5 years in orbit. ALOS-2 entering “post-operational” phase from May 2019
- Reduction of duty cycle from 50% to 30%
- Impact on Basic Observation Scenario (BOS)
  - 10 m dual-pol Fine Beam mode
    - Observations reduced to single global coverage per year at top priority
    - Additional observations planned at low priority → focus on [Super Sites](#)
  - 50 m ScanSAR
    - No change.
    - Every 42-day repeat maintained

# PALSAR-2 Observation Mode



- Quick response (latency < 1 day) for disaster monitoring
  - Wide observable range (incidence angle 8-70 deg.)
  - Right / left pointing



Spotlight mode  
Kobe, Japan



# PALSAR-2 Calibration Summary

- On-board internal calibration is performed every 3 months.
  - Product quality of major observation modes is evaluating regularly using SAR data over calibration sites.
  - The standard product processing software was updated on June 2018 (radiometric calibration) and on Nov. 2018 (correction of range offset).
- > PALSAR-2 keeps in good conditions and performances.

## Calibration summary as of **September 2019**.

Items	Results	
Geometry (RMSE)	[Stripmap and Spotlight] [ScanSAR]	6.29 m (L1.1) / 6.73 m (L2.1) 60.77 m (L1.1) / 29.33 m (L2.1)
Radiometry	RCS accuracy (1 $\sigma$ )	0.55 dB (Corner Reflectors) 0.41 dB (Amazonian forests)
Polarimetry [SM 6m]	VV-HH amplitude ratio	1.002 ( $\sigma=0.012$ )
	VV-HH phase difference	-0.148 deg ( $\sigma=1.446$ )
	Cross talk	[HV/HH] -43.27 dB ( $\sigma=6.83$ ) [VH/VV] -42.94 dB ( $\sigma=4.70$ )

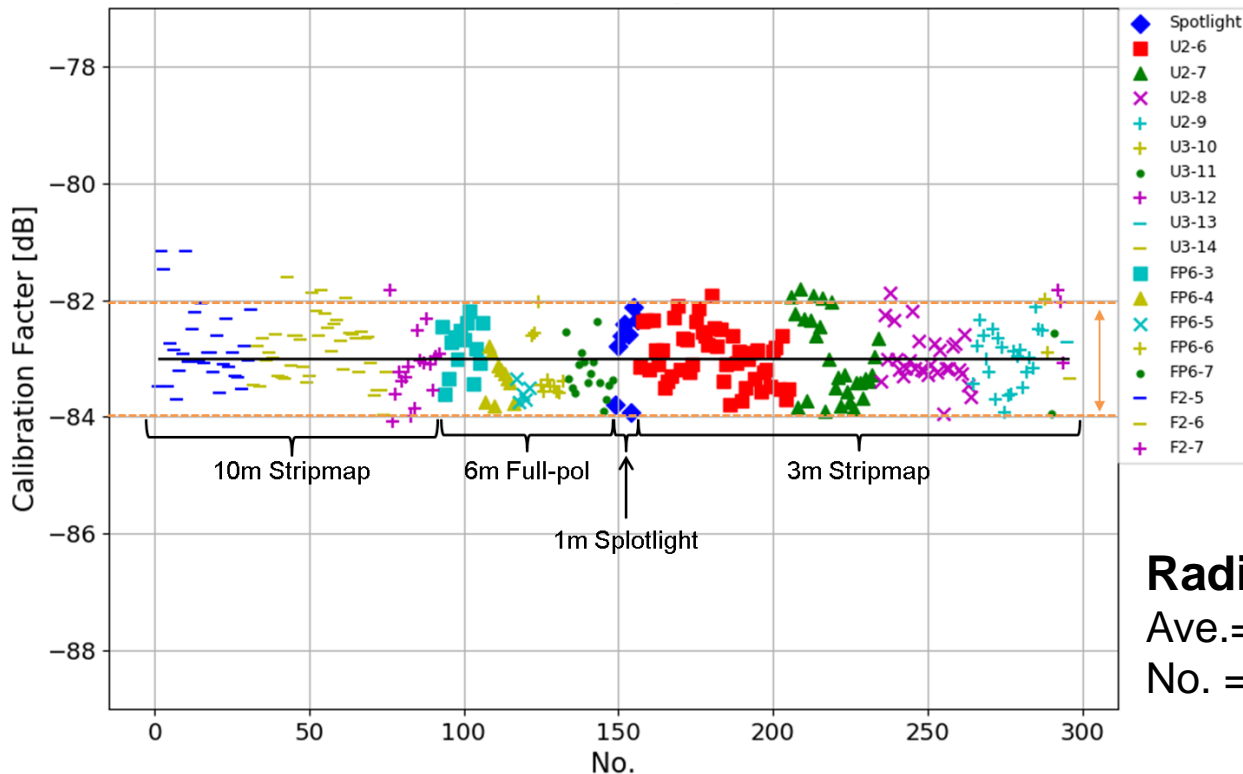
# PALSAR-2 Radiometric Calibration

- 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.

$$\sigma^0 = 10\log_{10}\langle DN^2 \rangle - \boxed{CF} + A \quad (\text{for L1.1}) \quad \text{DN: digital number}$$

$$CF = \underline{-83 \text{ dB}}$$

$$\sigma^0 = 10\log_{10}\langle DN^2 \rangle - \boxed{CF} \quad (\text{for L1.5 and L2.1}) \quad A = 32 \text{ dB}$$



**Radiometric accuracy evaluation.**

Ave. = -82.97 dB, 1-sigma = 0.55 dB

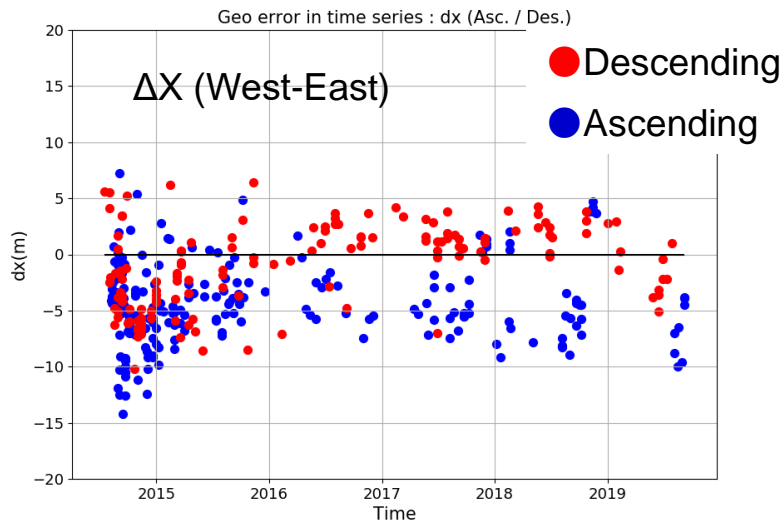
No. = 296 CRs



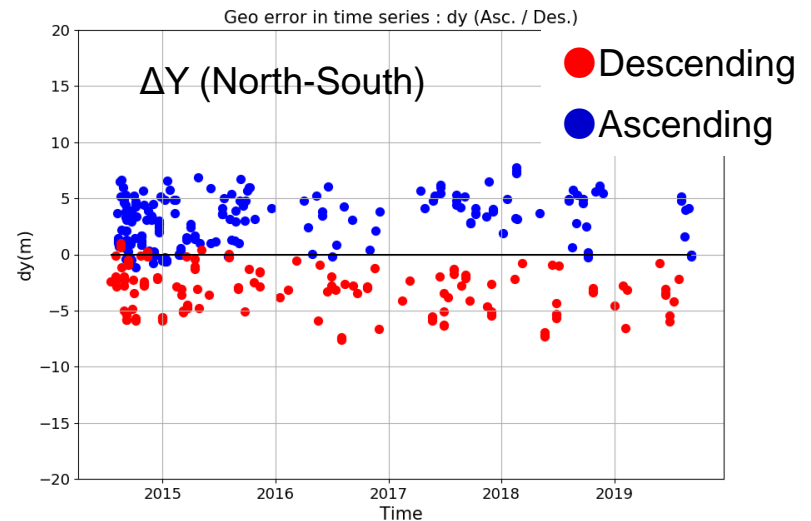
# PALSAR-2 Geometric Calibration

Differences between point target responses in SAR images and in-situ GPS measurements

Mode	$\Delta X$ (west-east) [m]			$\Delta Y$ (north-south) [m]			n
	mean (bias)	SD	RMS	mean (bias)	SD	RMS	
Spotlight	-5.423	4.278	7.140	2.540	2.439	3.622	10
Stripmap 3 m (U2-6~9, U3-10~14)	-0.818	3.642	3.733	-1.139	3.979	4.140	165
Stripmap 6 m (FP6-3~7)	-4.741	3.723	6.046	3.193	2.151	3.863	103
Stripmap 10 m (F2-5~7)	-5.169	2.563	5.802	-0.055	2.637	2.637	72

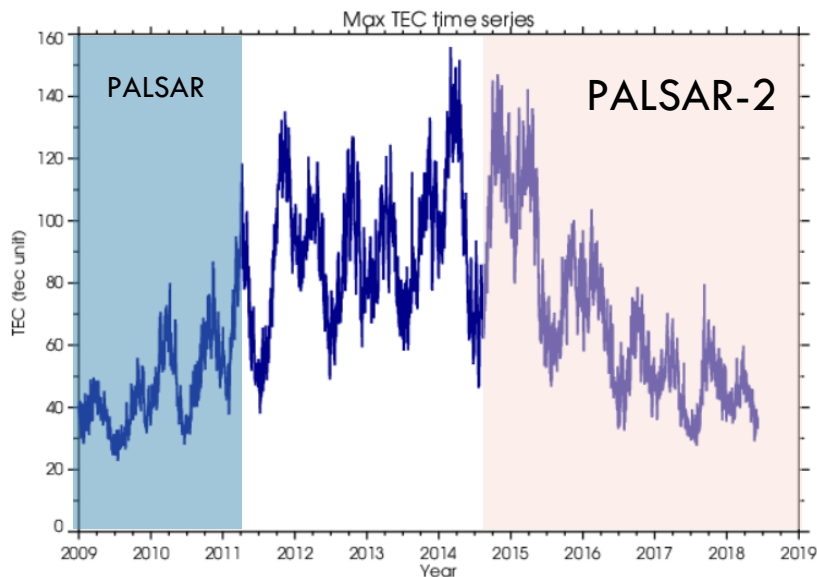


(a) Geometric error in EW direction.



(b) Geometric error in NS direction.

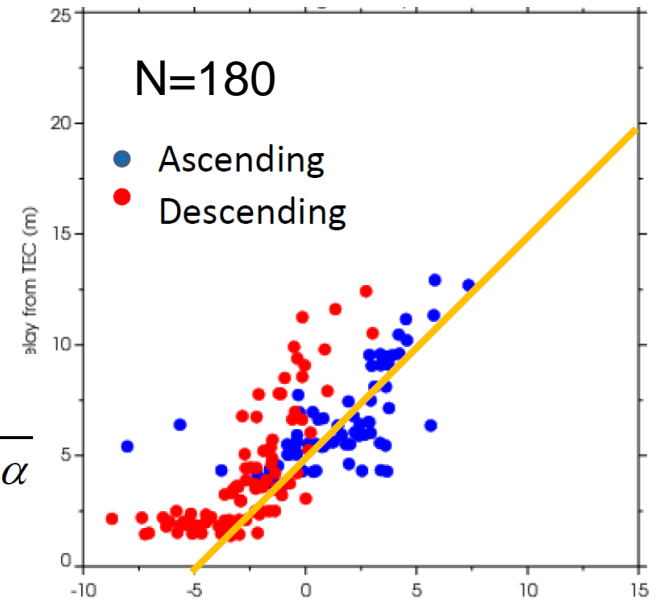
**Time trend of geometric accuracy (SM 3, 6, 10 m and Spotlight 1 m).**



Time series in global average TEC.

Range  
difference  
estimated  
by TEC (m)

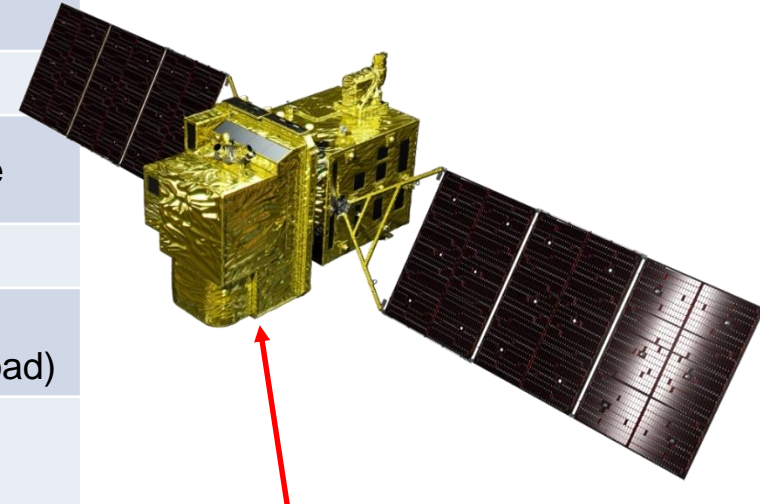
$$\Delta s = K \frac{TEC}{f^2 \cos \alpha}$$



Geometric error in slant range (m).

Ionosphere effects on geometric accuracy.

Items		Specifications
Orbit	Type	Sun-synchronous sub-recurrent
	Altitude	669 km at the equator
	Local Sun Time	10:30 am +/- 15 minutes at the descending node
	Revisit	35 days (Sub-cycle 3 days)
Instruments		<ul style="list-style-type: none"> <li>- Wide-swath and high-resolution optical imager</li> <li>- Dual-frequencies Infrared sensor (hosted payload)</li> </ul>
Ground Sampling Distance (GSD)		<ul style="list-style-type: none"> <li>- Panchromatic band (Pa): 0.8 m</li> <li>- Multispectral band (Mu): 3.2 m (6 bands)</li> </ul>
Quantization		11 bit / pixel
Swath width		70 km at nadir
Mission data rate		Approx. 4 Gbps (after onboard data compression: 1/4 (Pa) and 1/3 (Mu))
Mission data downlink		<ul style="list-style-type: none"> <li>- Direct Transmission: Ka and X-band</li> <li>- <i>via.</i> the Optical Data Relay Satellite</li> </ul>
Mass		Approx. 3 tons at launch
Size		5 m × 16 m × 3.5 m on orbit
Duty		10 mins / recurrent
Design life time		Over 7 years



Wide-swath and high-resolution optical imager

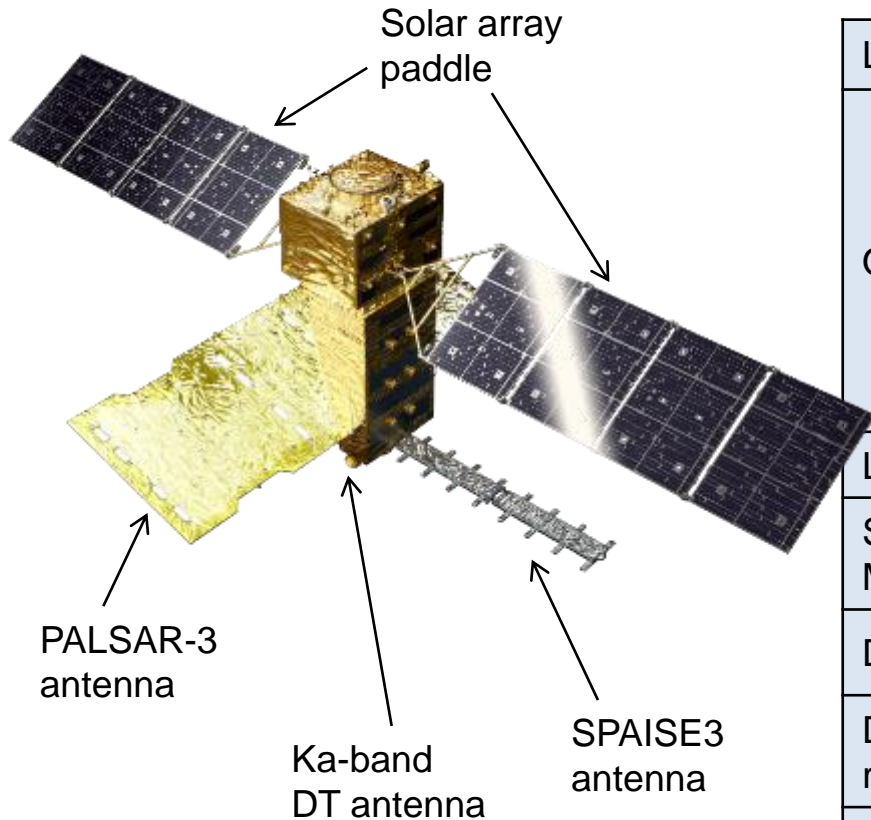
In-orbit configuration

14:00-, Thu, 21 Nov, 2019  
 "Calibration of Future Missions"



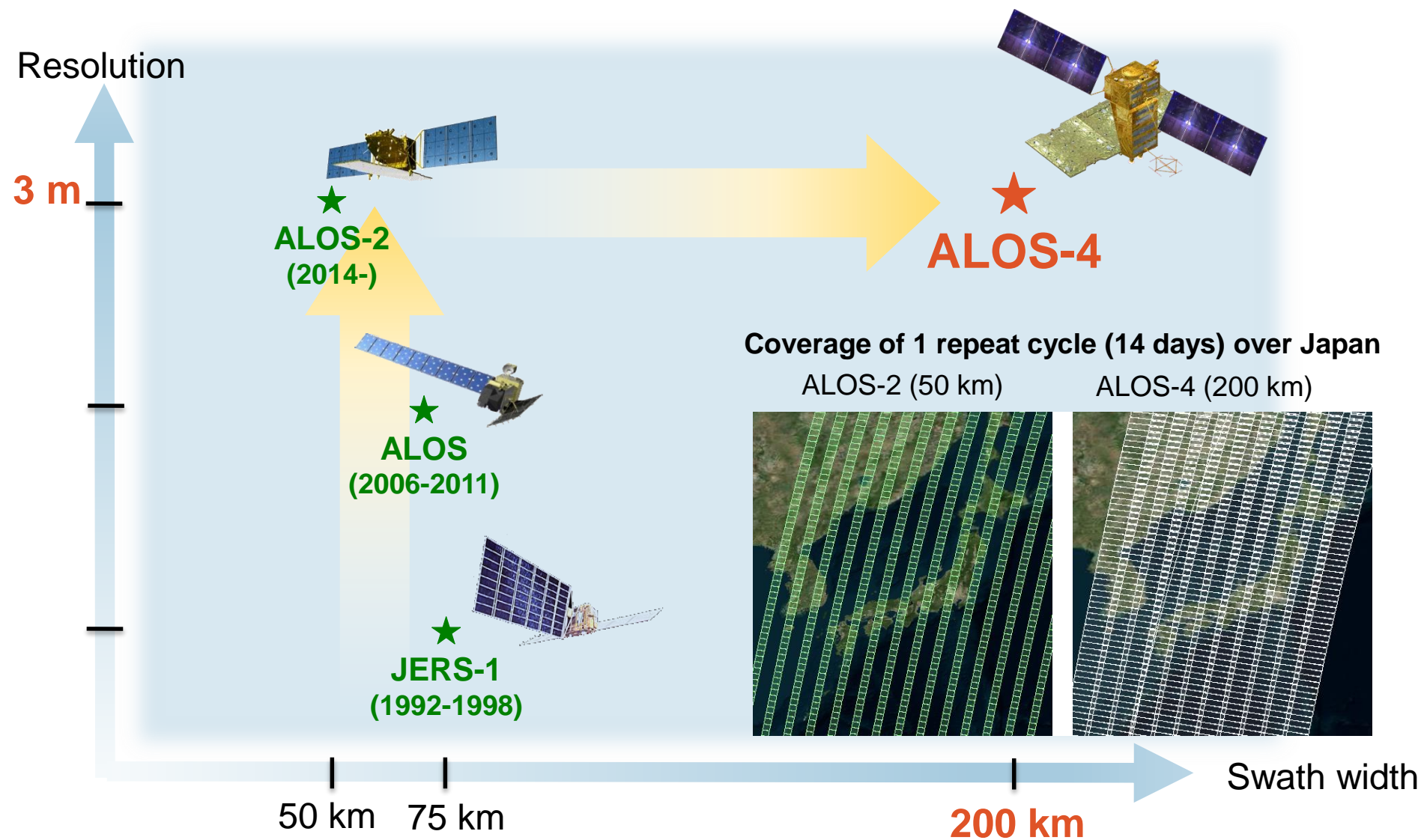
# Advanced SAR Satellite: ALOS-4

**Phase D**



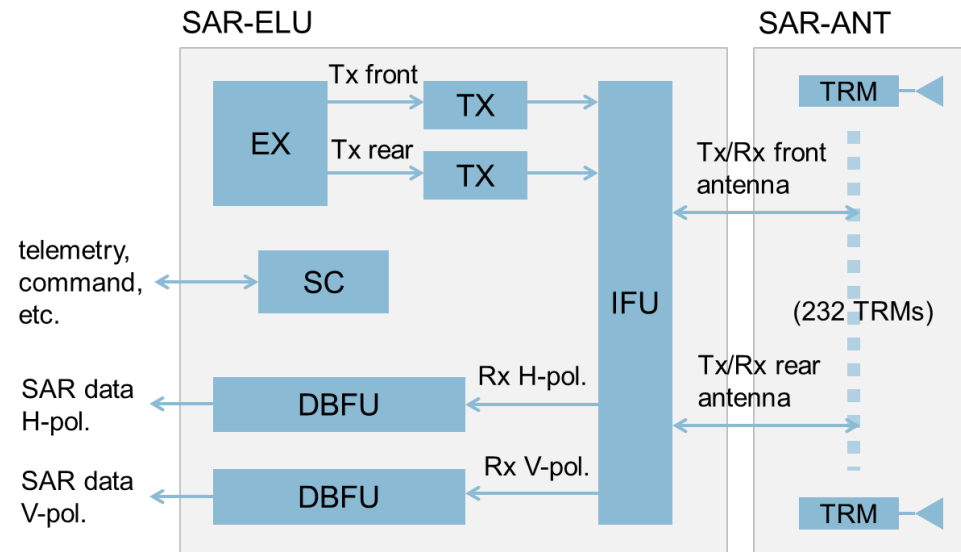
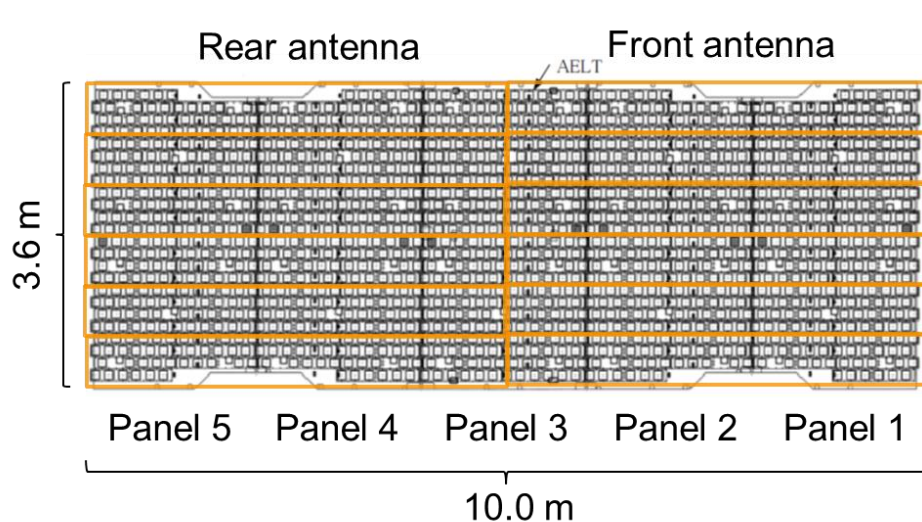
Launch	JFY 2021
Orbit	<b>Same orbit as ALOS-2</b> Sun-synchronous sub-recurrent orbit Altitude: 628 km Inclination angle: 97.9 degree Local sun time at descending: 12:00 ± 15 min. Revisit time: 14 day (15-3/14 rev/day)
Lifetime	<b>7 years</b>
Satellite Mass	Approx. 3 tons
Downlink	3.6 Gbps/1.8 Gbps (Ka-band)
Data recorder	1 TByte
Mission Instruments	<ul style="list-style-type: none"> <li>- <b>PALSAR-3</b> (Phased Array type L-band Synthetic Aperture Radar-3)</li> <li>- <b>SPAISE3</b> (SPace based AIS Experiment 3)</li> </ul>
Prime contractor	Mitsubishi Electric Corporation

# Improvements of L-band SARs



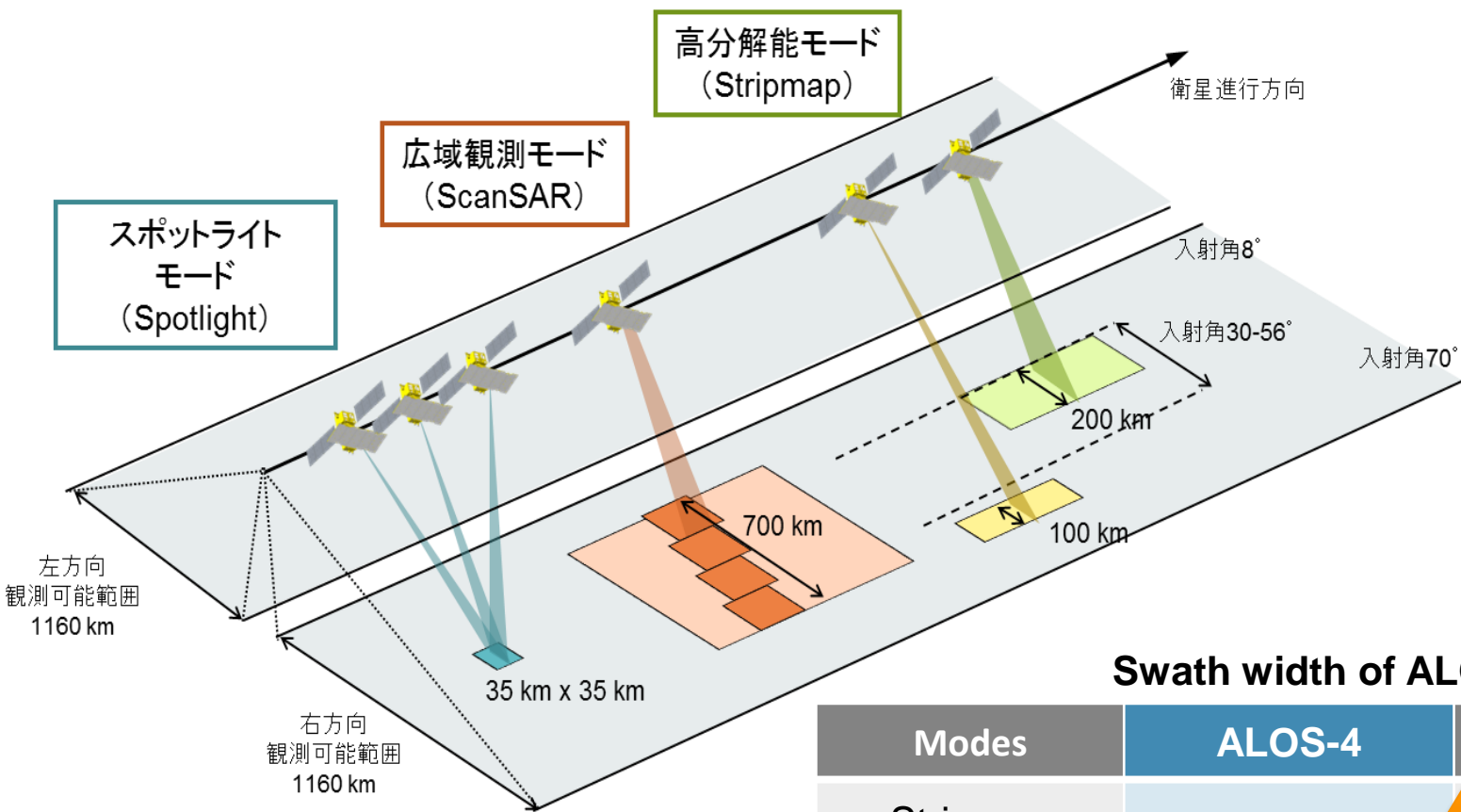
# PALSAR-3 (Phased Array-type L-band SAR-3)

1. Onboard Digital Beam Forming (DBF) for 6 receiving channels in elevation
2. Azimuth multi-beam for 2 receiving channels in azimuth
3. Multiple Transmit Channel in azimuth (front and rear) **Rx: 12 ch., Tx: 2 ch.**
4. Phase spoiling for wide beam transmission in elevation





# PALSAR-3 Observation Modes



Swath width of ALOS-2/4

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

\*single look

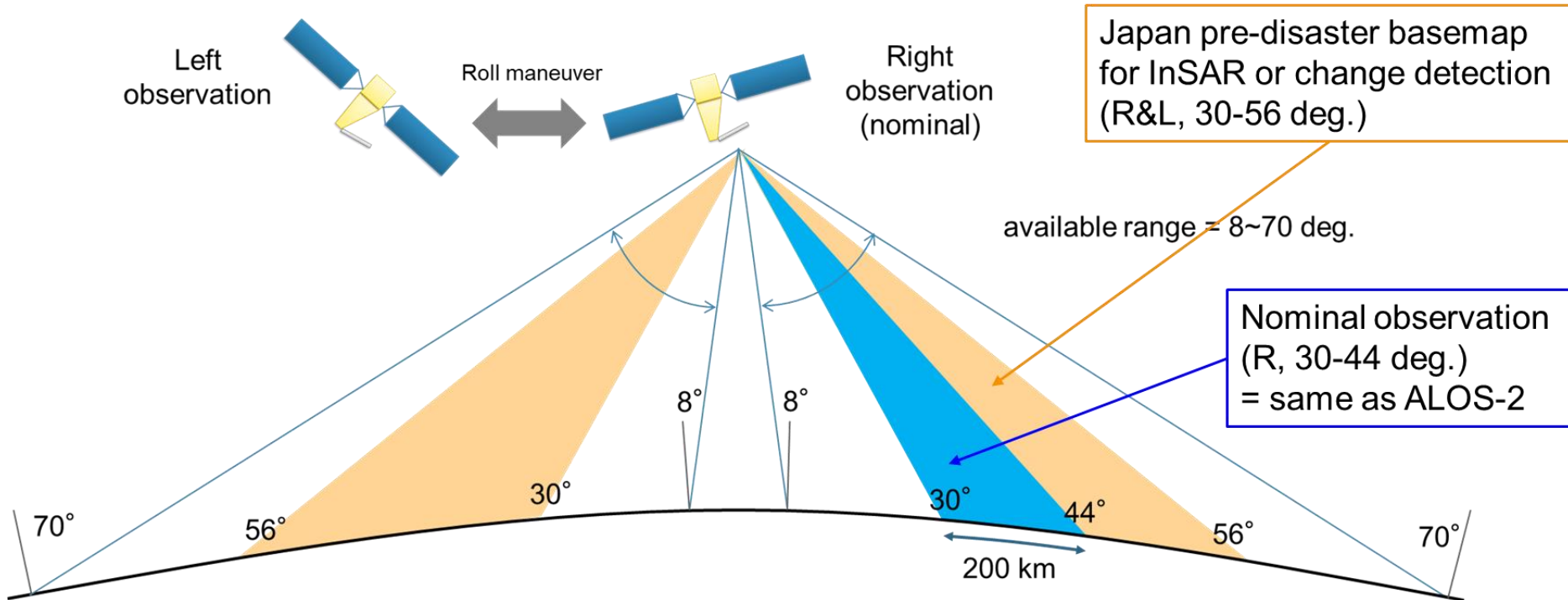
# PALSAR-3 Observation Modes

SAR mode	Spotlight (sliding)	Stripmap						ScanSAR	
Center frequency [MHz]	1257.5	1257.5		1236.5 (or 1257.5/1278.5)				1236.5 (or 1257.5/ 1278.5)	
Bandwidth [MHz]	84	84		42	28		28+10	28	
Resolution [m]	3 x 1 (Rg x Az)	3		6		10		10	25 (1 look)
Swath width [km]	35	200	100	200	100	200	100	200	700 (4 scans)
Polarization	1, 2	1, 2	1, 2, 4	1, 2	1, 2, 4	1, 2	1, 2, 4	1, 2	1, 2
Incidence angle range	8-70	30-56	8-70	30-56	8-70	29-56	8-70	29-42	8-70
NESZ [dB] *	< -20	< -20		< -24		< -28		< -24	< -20
Range S/A [dB] *	> 15	> 15		> 15		> 20		> 20	> 15
Azimuth S/A [dB] *	> 15	> 15		> 15		> 20		> 20	> 15
Pol. X-talk [dB] *	< -30	< -30						< -30	

\* Specifications for one observation swath including 37 deg. incidence angle.

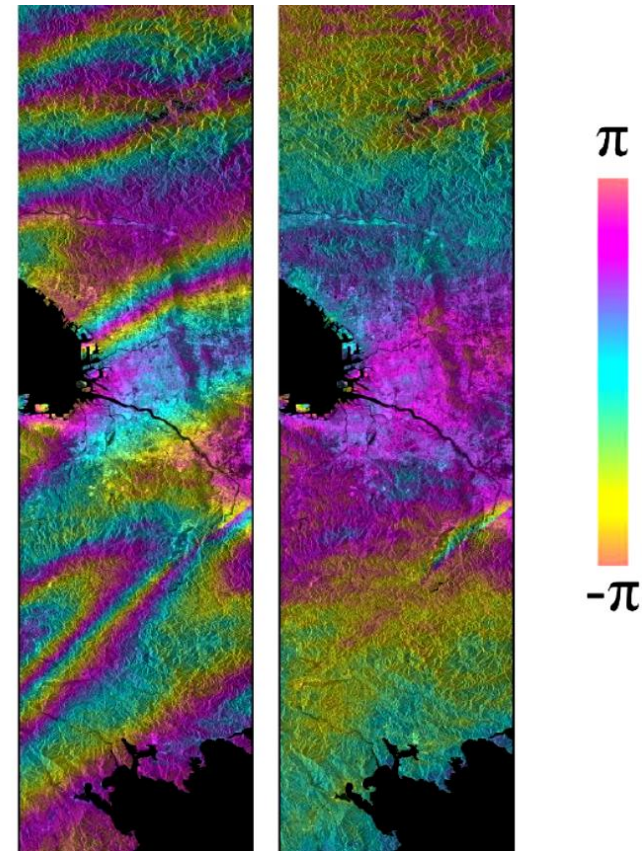
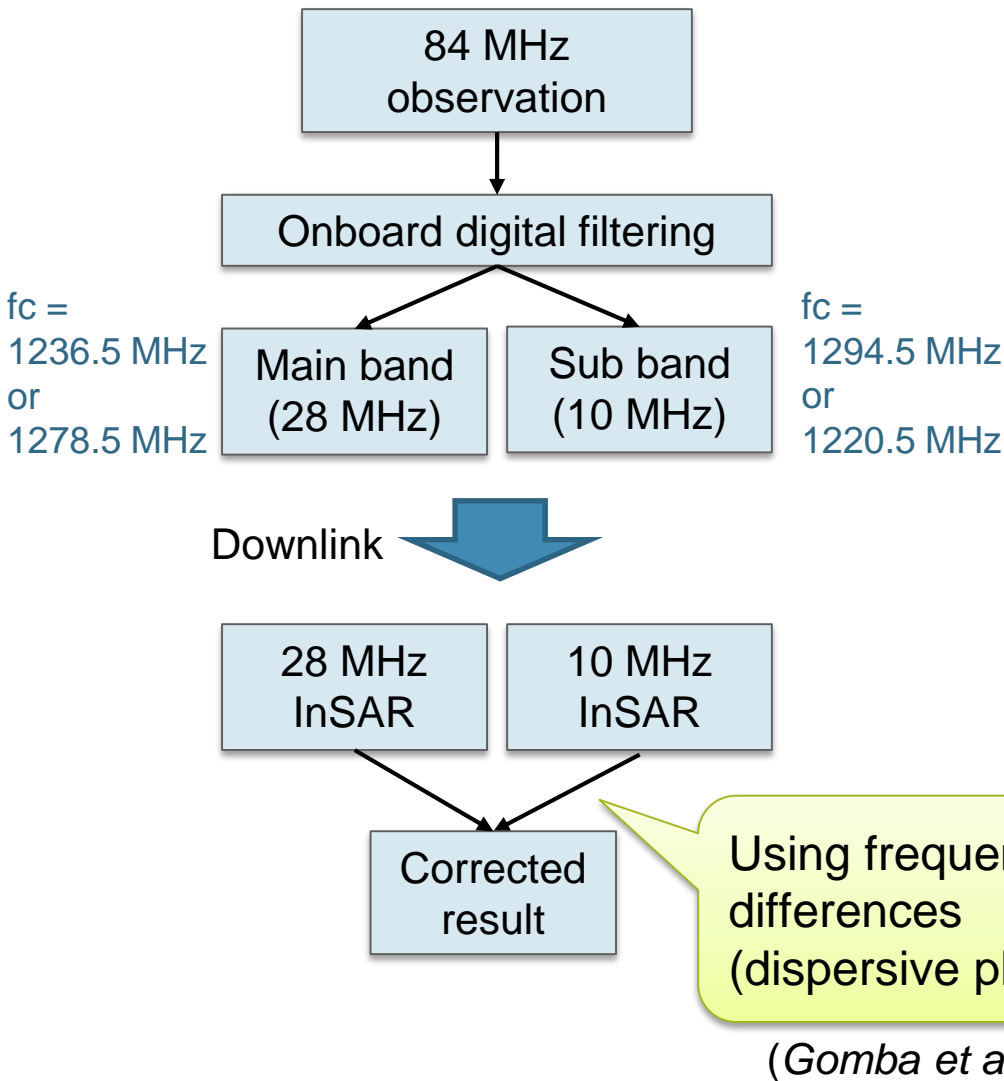
# PALSAR-3 Basic Observation

- Regular stripmap mode observation is right-side, incidence angle of 30-44 deg. in 200 km swath.
- The other beams and left-side observation are used for quick disaster monitoring.





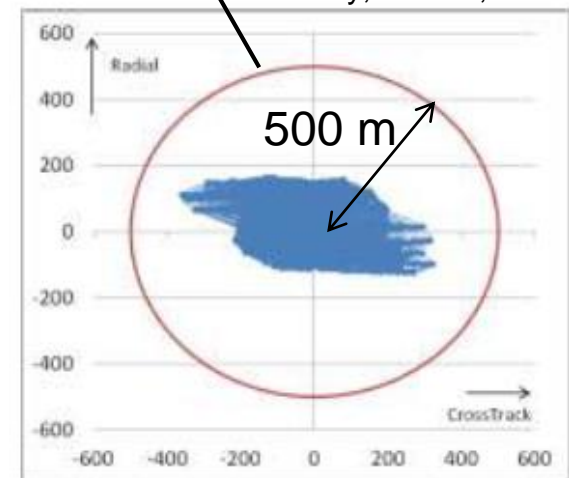
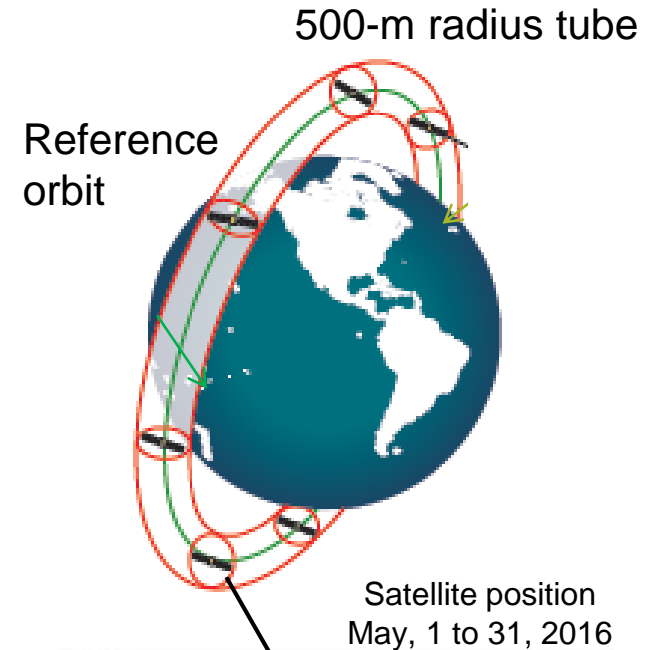
## Onboard split-band for InSAR ionospheric correction



Test result of the InSAR ionospheric correction using PALSAR-2 data

Stripmap 3 m mode  
 Master = 2015/2/25  
 Slave = 2016/6/1  
 Central Japan

- The same orbit and observation geometry as ALOS-2
  - ALOS-2/4 data can be used together.
- Orbit control is performed autonomously and its accuracy is within +/- 500 meters.
- Improved orbit determination accuracy by improvement of GPS signal reception and calibration using a laser reflector
  - ~3 m (RMS) for onboard orbit
  - ~0.1 m (RMS) for offline orbit



**Orbit control of ALOS-2**

- ◆ Promote Open and Free
- ◆ Principle available spatial resolution
  - ✓ 10 meter resolution or coarser
- ◆ Enhance provision of available products on the internet
  - ◆ To be open upon processed
    - ALOS/AVNIR-2 Global → ALOS PALSAR Global
  - ◆ G-Portal (Standard Products)
  - ◆ JJ-FAST, JASMES, JASMIN (for GFOI, GEOGLAM)
  - ◆ ARD or **CARD4L compliant by format conversion software**

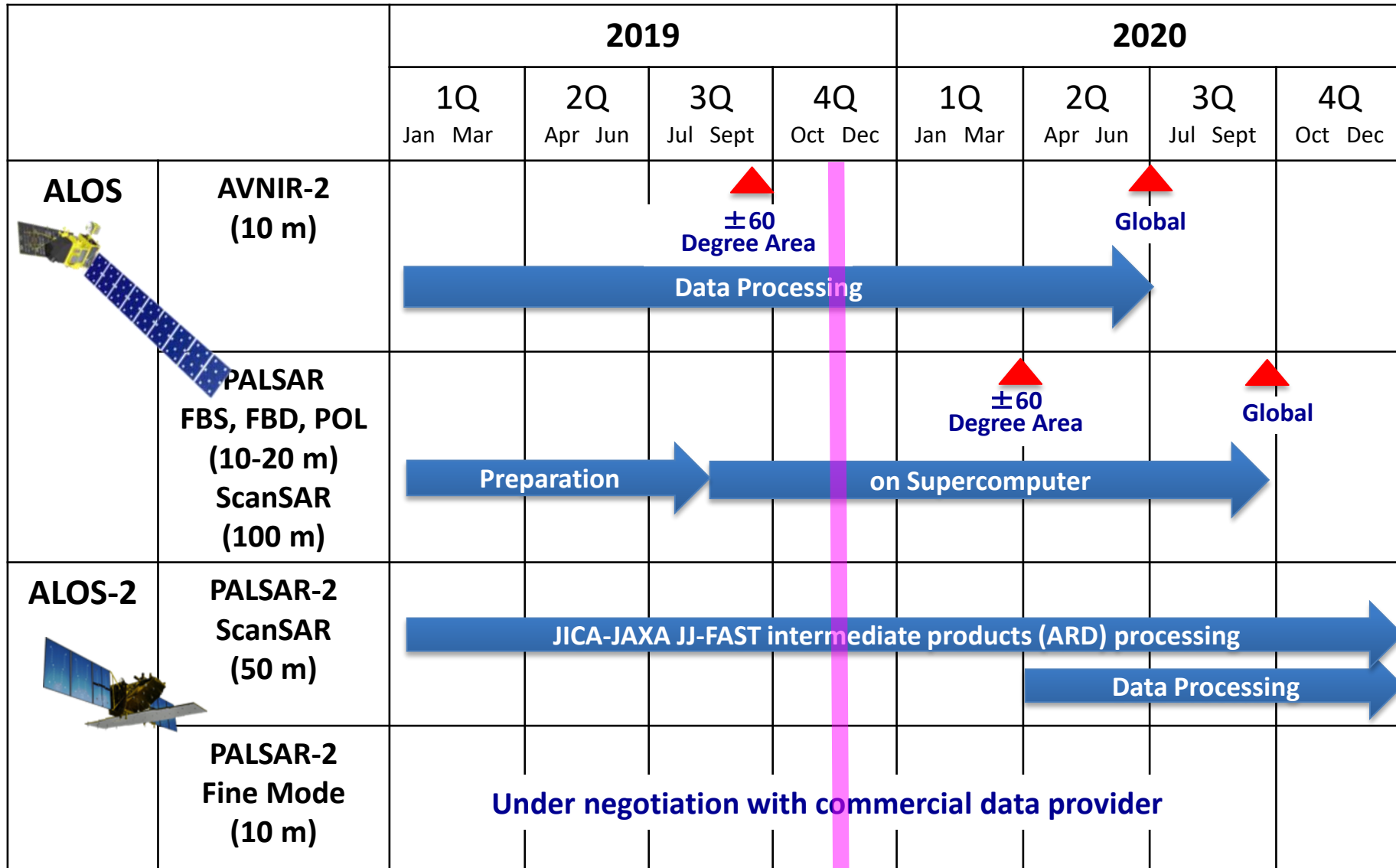
# JAXA's EO Data Open & Free Plan

Satellite/ Sensor		Before	NOW
MOS/JERS/ADEOS/ADEOS-2/ AMSR-E/TRMM		○	○
GOSAT		○	○
GCOM-W and GCOM-C		○	○
GPM		○	○
ALOS	AVNIR-2 (10m)	—	○
	PALSAR (10m, 100m)	—	○
	DSM (30m)	○	○
	Annual Global Forest map / mosaic (25m)	○	○
ALOS-2	ScanSAR (50m)	—	Partially
	Fine mode (10m)	—	Under Negotiation with PD



# ALOS/ALOS-2 Data Processing Schedule

As of November 2019



The operation status of ALOS-2 and the overview of ALOS-4 were introduced:

1. ALOS-2 is working well, and entering to post-operation phase,
2. The calibration results of PALSAR-2 was updated,
3. Due to hand over to ALOS-4 successfully, the duty cycle is reducing from 50 % to 30 % that has impact to BOS of ALOS-2,
4. The overviews of ALOS-4/PALSAR-3 were introduced, and the international Cal/Val and Science Team (CVST) is established based on the Earth Observation Research Announcement (EORA), and
5. The processing schedule for the open & free ALOS/ALOS-2 data explained.