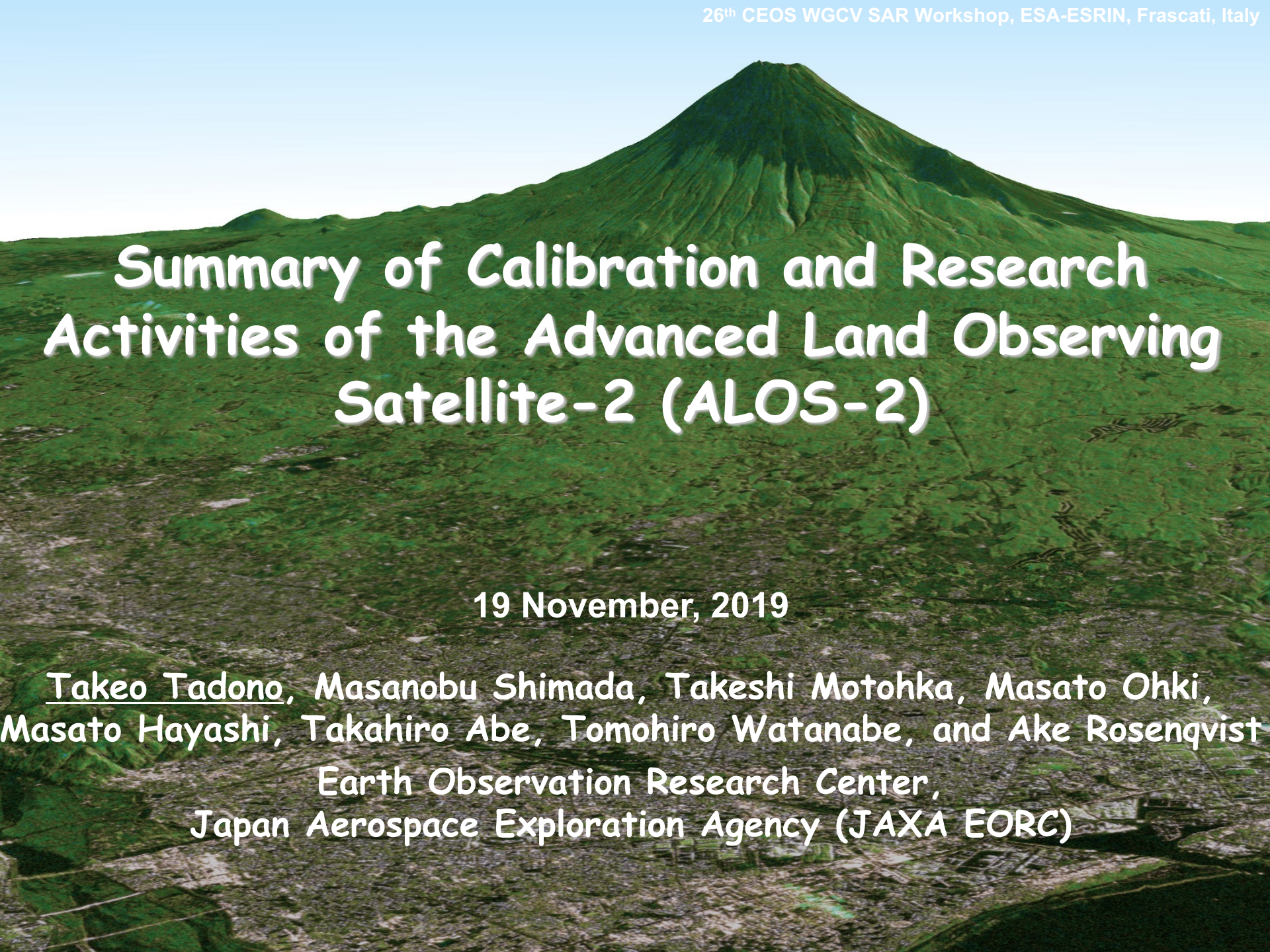


Summary of Calibration and Research Activities of the Advanced Land Observing Satellite-2 (ALOS-2)

19 November, 2019

Takeo Tadono, Masanobu Shimada, Takeshi Motohka, Masato Ohki, Masato Hayashi, Takahiro Abe, Tomohiro Watanabe, and Ake Rosenqvist

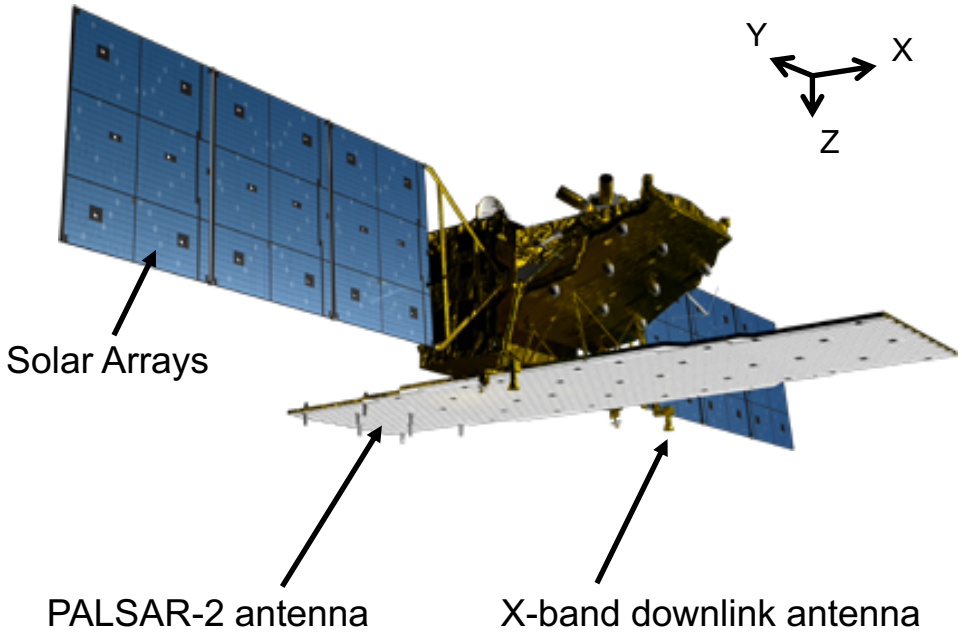
Earth Observation Research Center,
Japan Aerospace Exploration Agency (JAXA EORC)

Contents

ALOS-2 "Daichi-2"

Mission objectives:

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



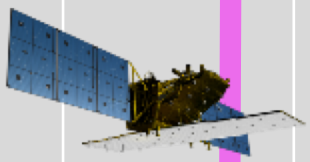
Mission sensor	**PALSAR-2 (Phased Array type L-band Synthetic Aperture Radar 2)**
Launch	**May 24, 2014** H-IIA launch vehicle FY24
Mass	2.1 tons
Lifetime	**5 years (Target: 7 years)**
Orbit	Sun-synchronous, 628 km altitude, 14 days revisit, Orbit control: ≦ +/- 500 m
Local sun time	12:00±15 min (descending)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

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

ALOS-2 Mission Operation

JFY2014	2015	2016	2017	2018	2019	2020	2021

ALOS-2 (L-SAR)



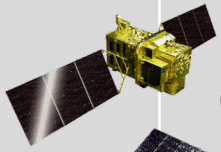
May 24, 2014

- Launch
- Initial C/O
- Initial Cal-Val
- Product release

Nominal Operation Review Meeting

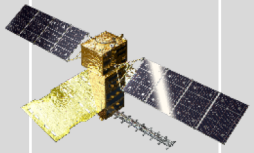
Mission operation (5 years)

Post-mission operation



ALOS-3 (Optical)

Development



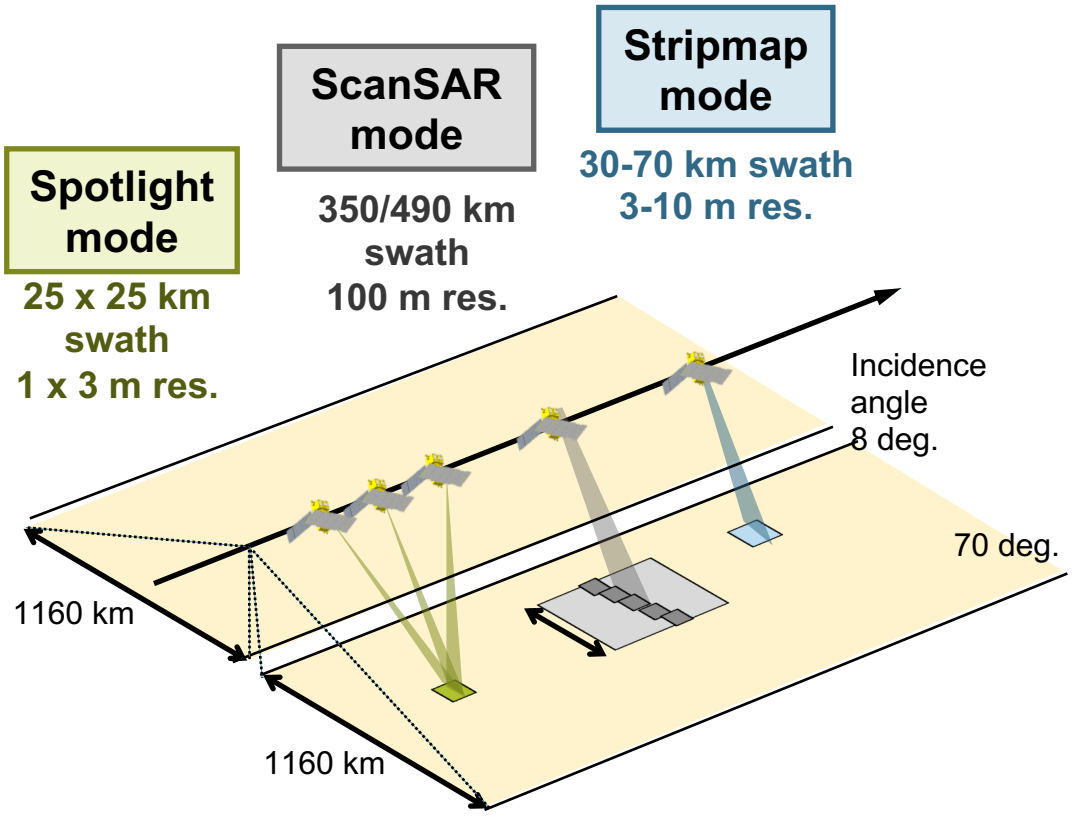
ALOS-4 (L-SAR)

Development

ALOS-2 Mission Operations in 2019

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

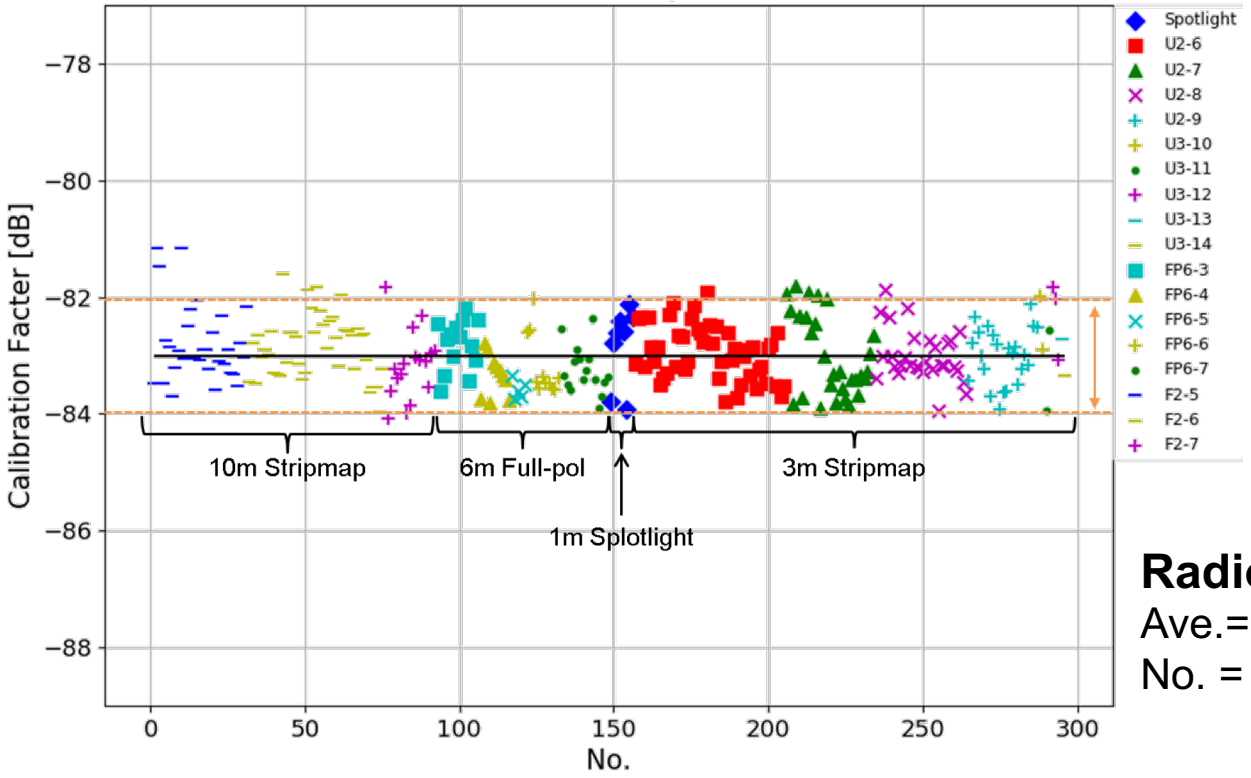
$$\sigma^0 = 10\log_{10}\langle DN^2\rangle - CF + A \qquad \text{(for L1.1)}$$

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

DN: digital number

CF = -83 dB

A = 32 dB



Radiometric accuracy evaluation.

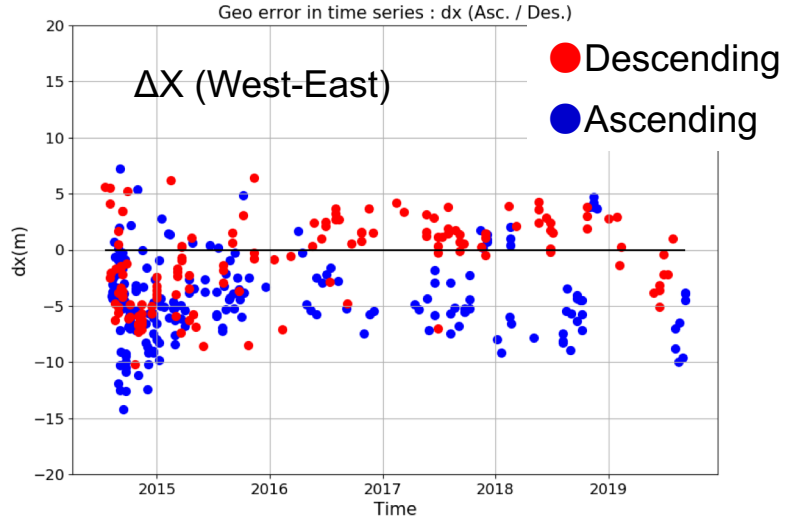
Ave.= -82.97 dB, 1-sigma = 0.55 dB

No. = 296 CRs

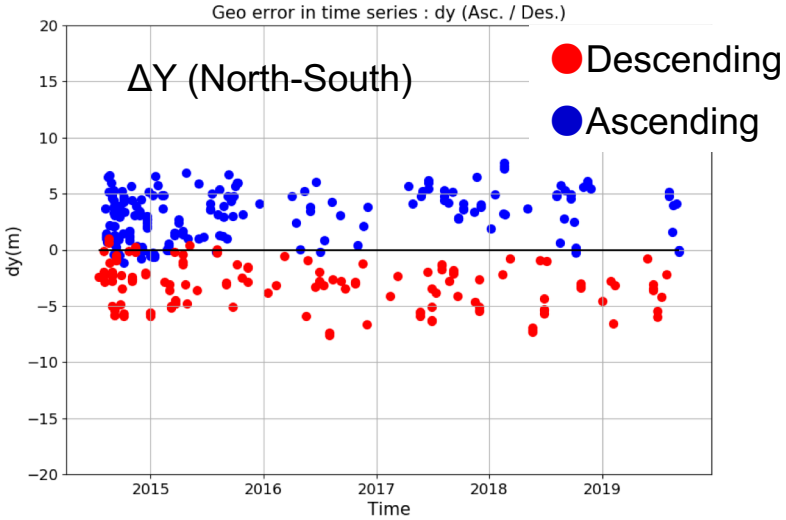
PALSAR-2 Geometric Calibration

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

Mode	ΔX (west-east) [m]			ΔY (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



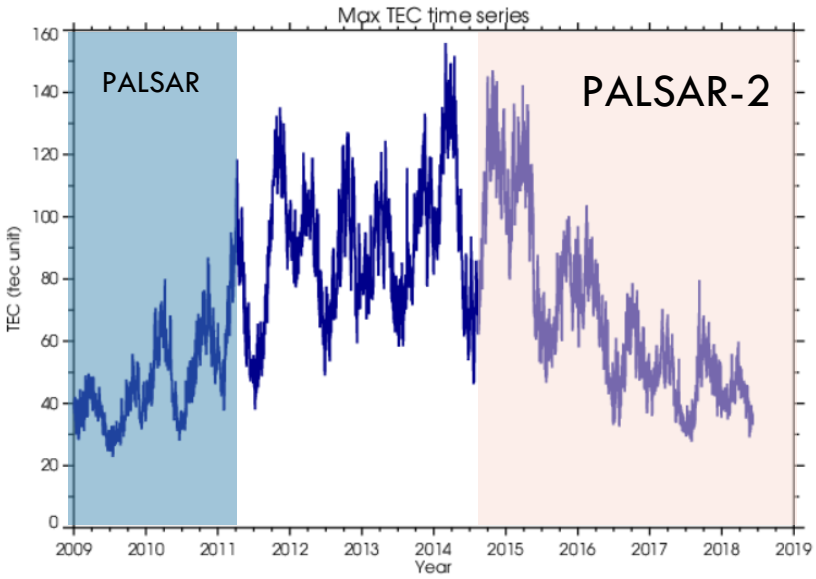
(a) Geometric error in EW direction.



(b) Geometric error in NS direction.

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

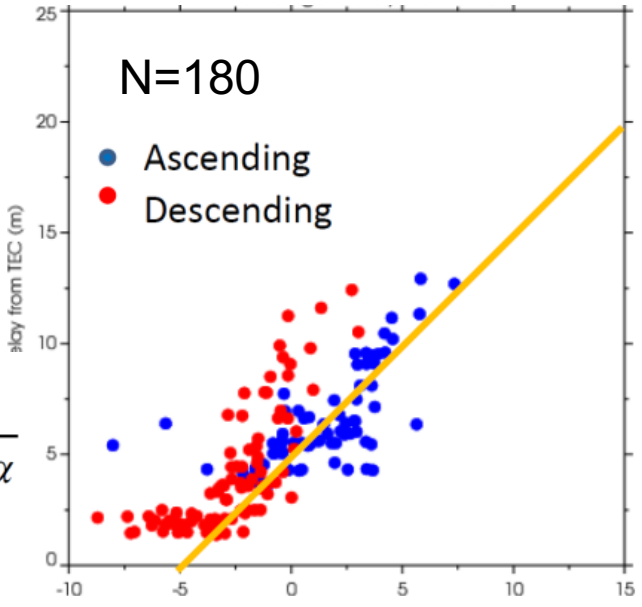
PALSAR-2 Geometric Calibration



Time series in global average TEC.

Range difference estimated by TEC (m)

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



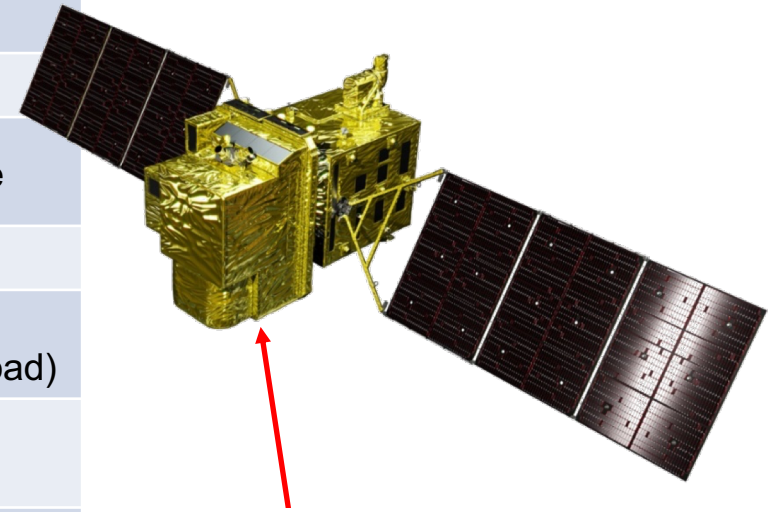
Geometric error in slant range (m).

Ionosphere effects on geometric accuracy.

Advanced Optical Satellite: ALOS-3

Phase D

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		- Wide-swath and high-resolution optical imager - Dual-frequencies Infrared sensor (hosted payload)
Ground Sampling Distance (GSD)		- Panchromatic band (Pa): 0.8 m - Multispectral band (Mu): 3.2 m (6 bands)
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		- Direct Transmission: Ka and X-band - *via.* the Optical Data Relay Satellite
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



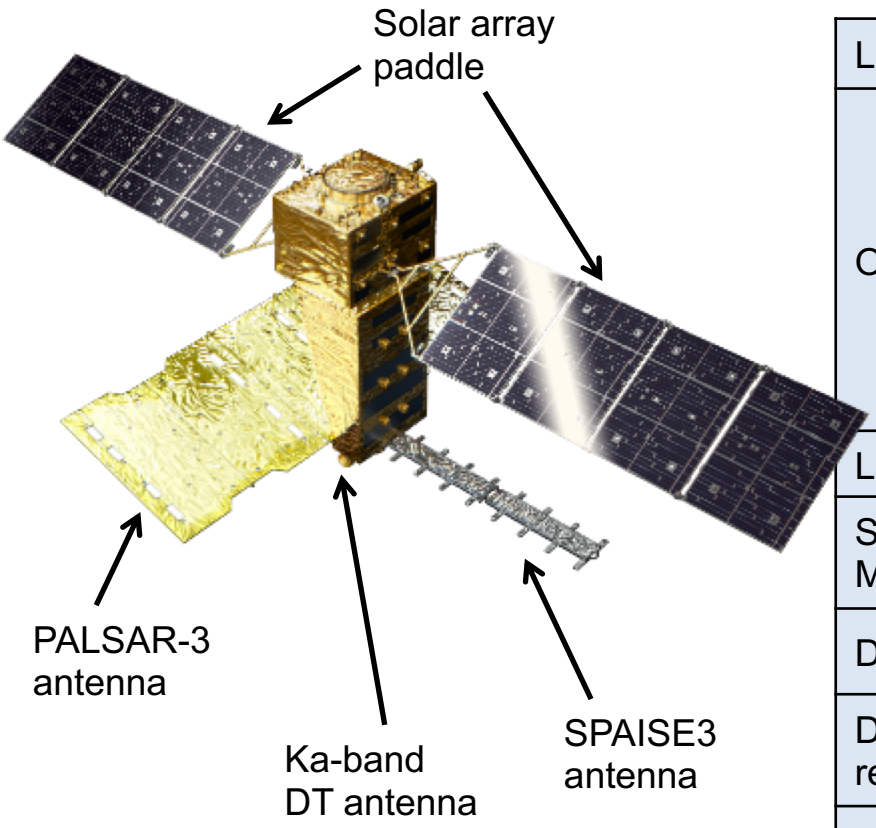
Wide-swath and high-resolution optical imager

In-orbit configuration

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

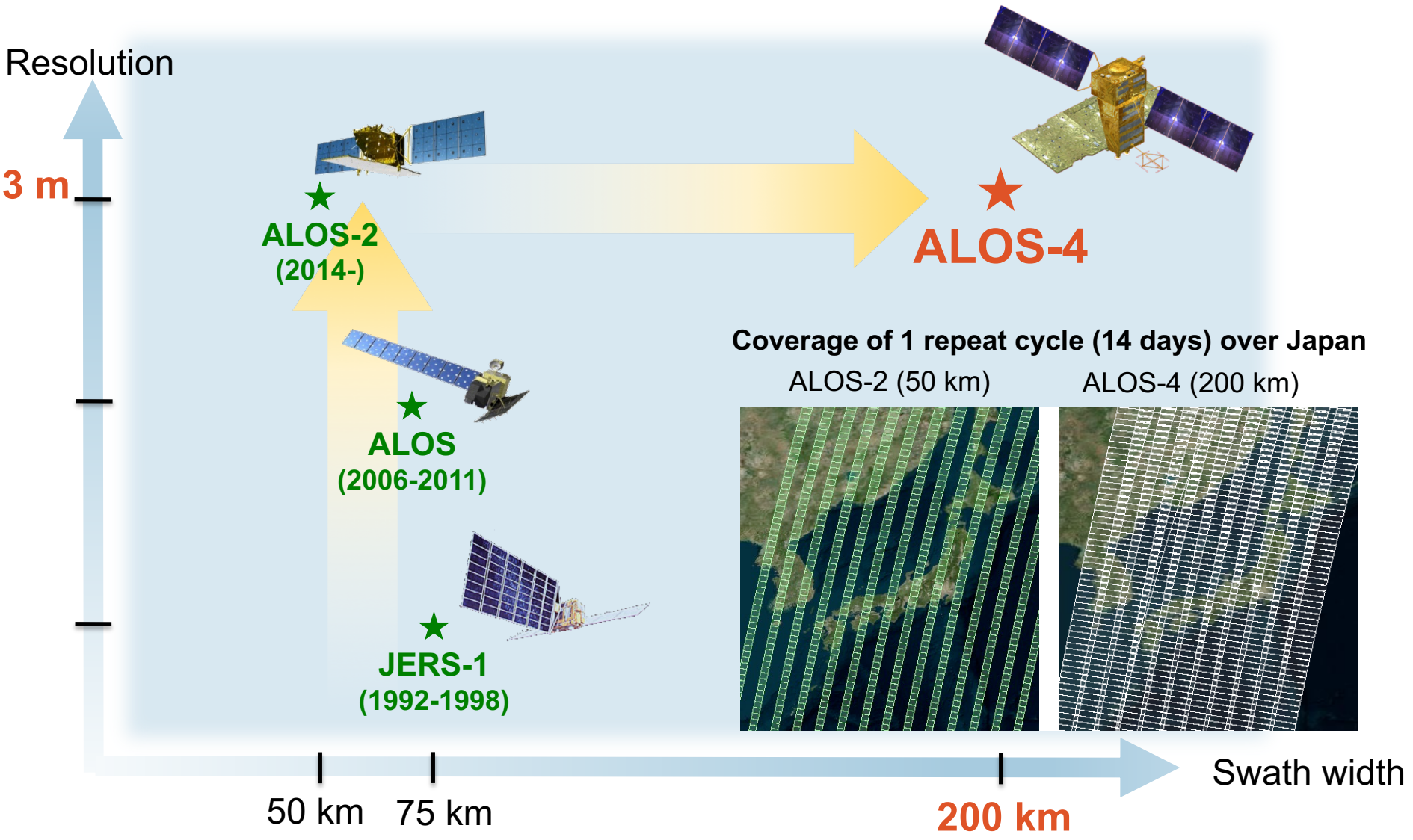
Advanced SAR Satellite: ALOS-4

Phase D



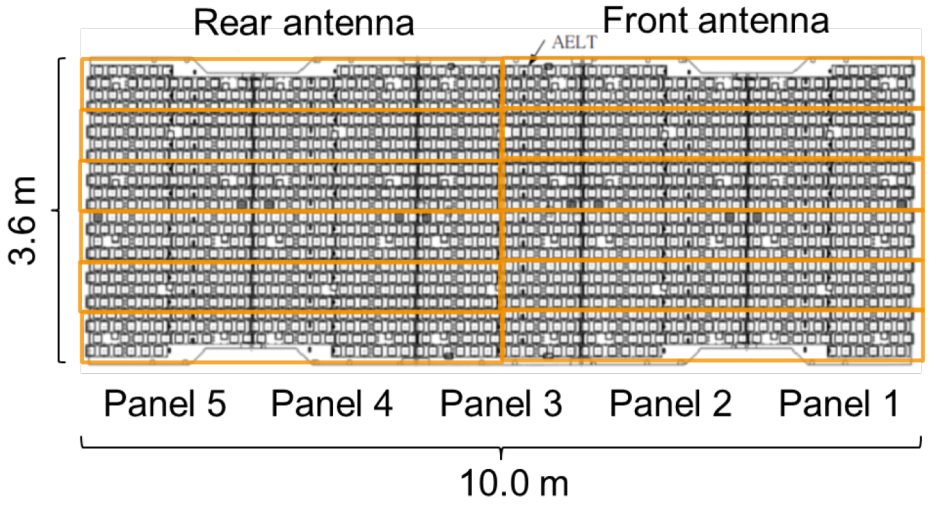
Launch	JFY 2021
Orbit	**Same orbit as ALOS-2** Sun-synchronous sub-recurrent orbit Altitude: 628 km Inclination angle: 97.9 degree Local sun time at descending: 12:00 ± 15 min. Revisit time: 14 day (15-3/14 rev/day)
Lifetime	**7 years**
Satellite Mass	Approx. 3 tons
Downlink	3.6 Gbps/1.8 Gbps (Ka-band)
Data recorder	1 TByte
Mission Instruments	- **PALSAR-3** (Phased Array type L-band Synthetic Aperture Radar-3) - **SPAISE3** (SPace based AIS Experiment 3)
Prime contractor	Mitsubishi Electric Corporation

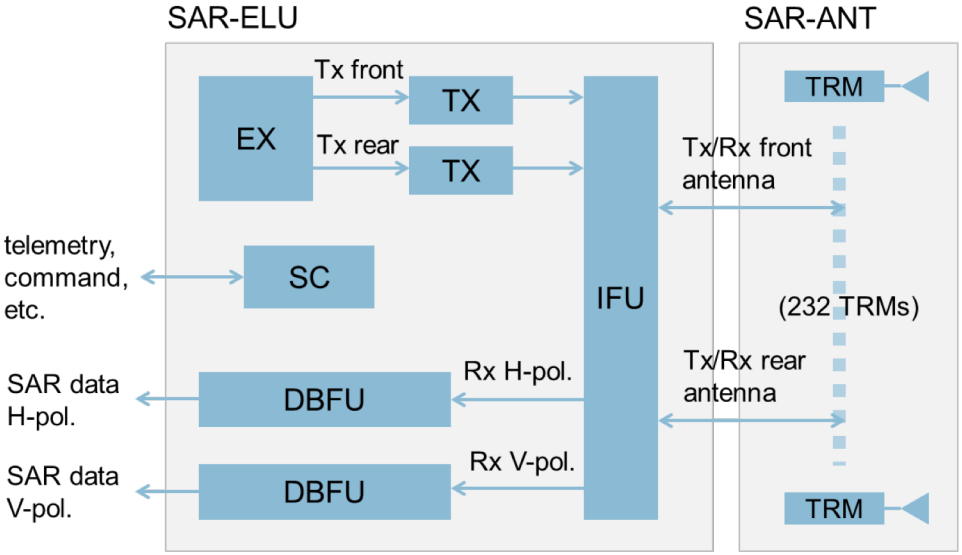
Improvements of L-band SARs



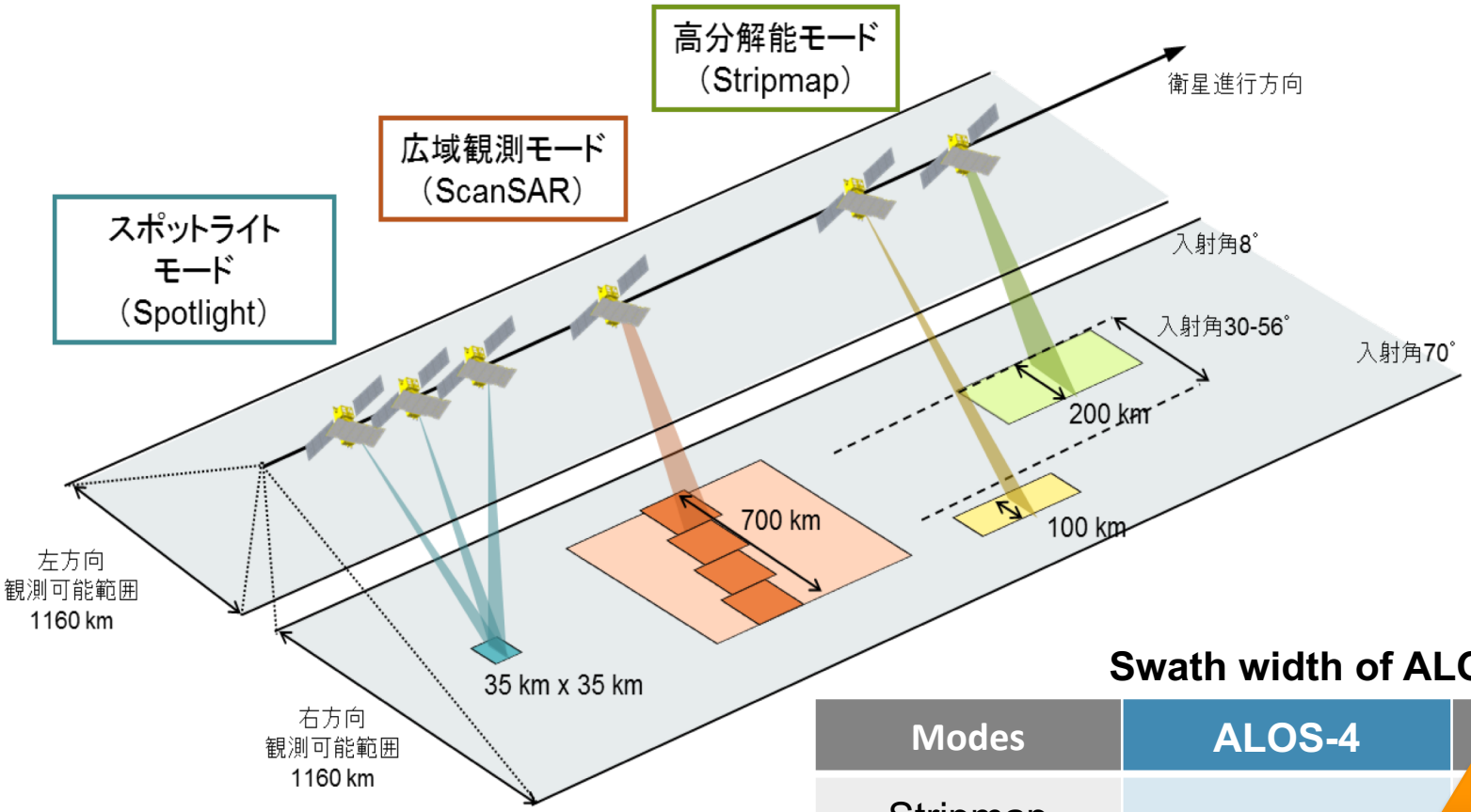
PALSAR-3 (Phased Array-type L-band SAR-3)

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)	**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

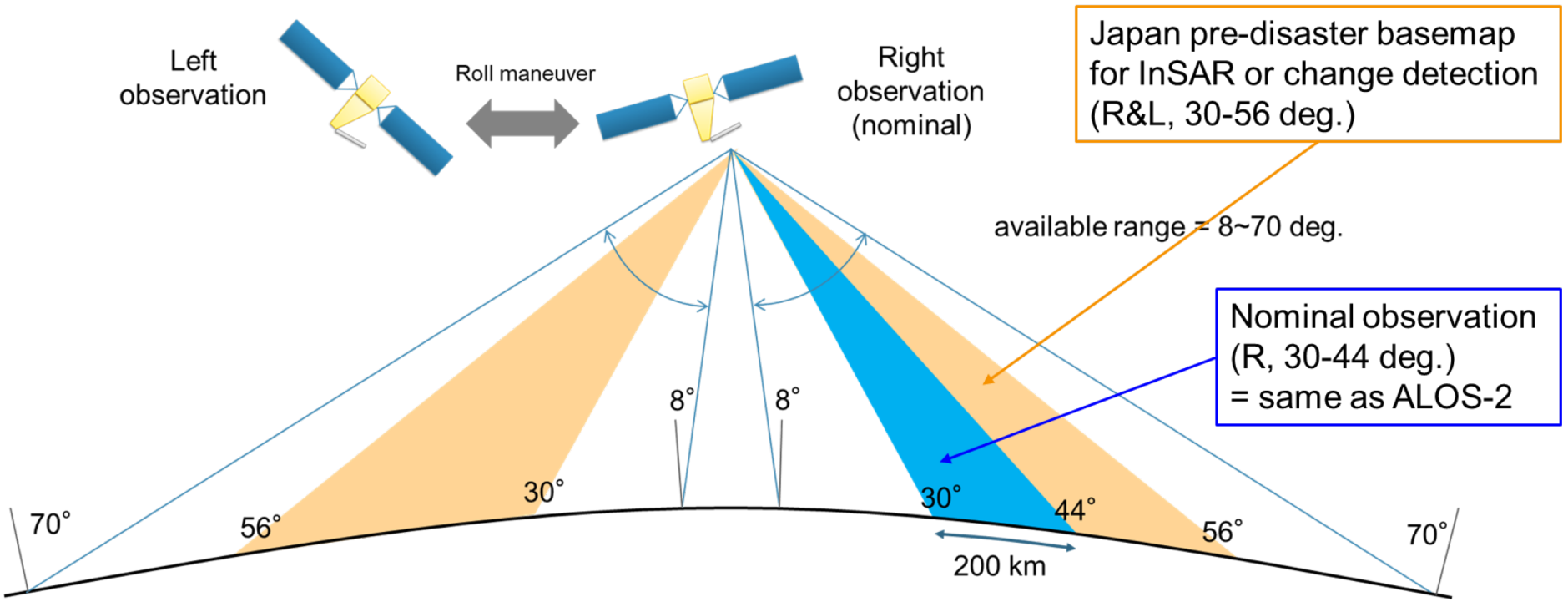
PALSAR-3 Observation Modes

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.

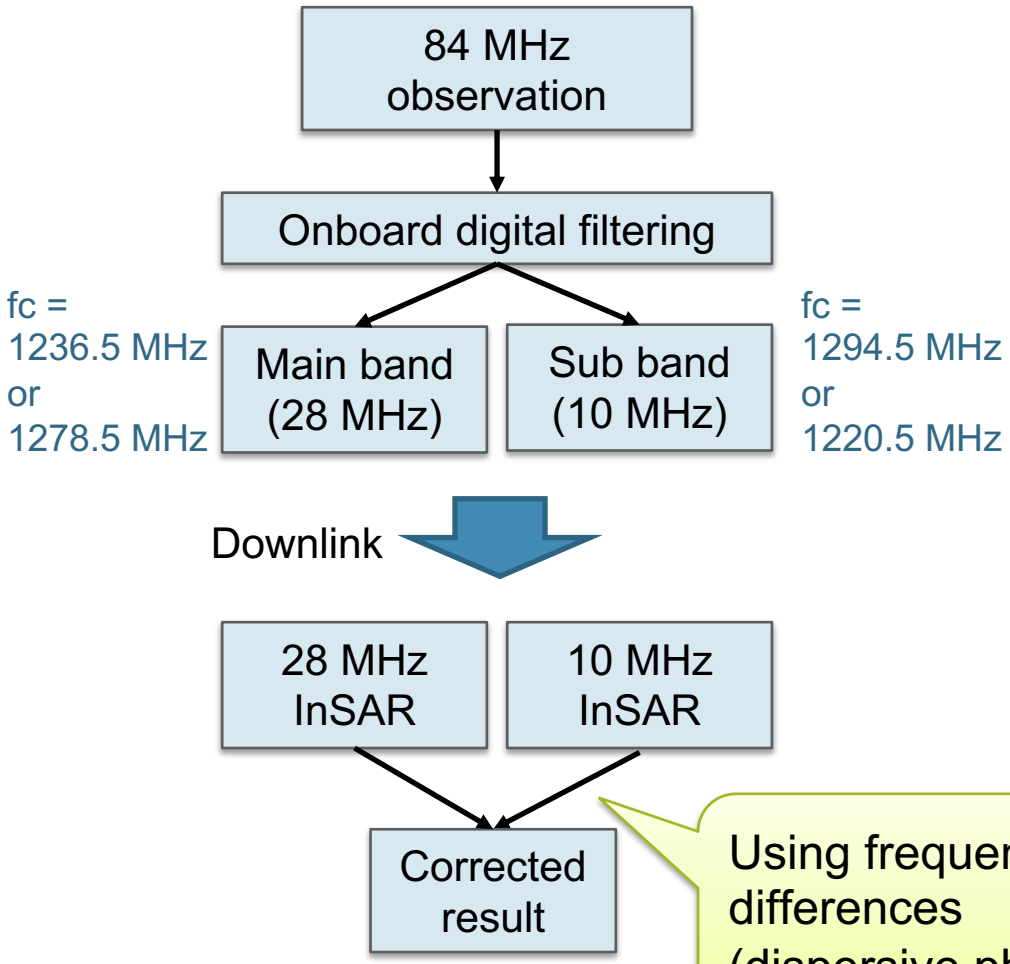
PALSAR-3 Basic Observation

- 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.

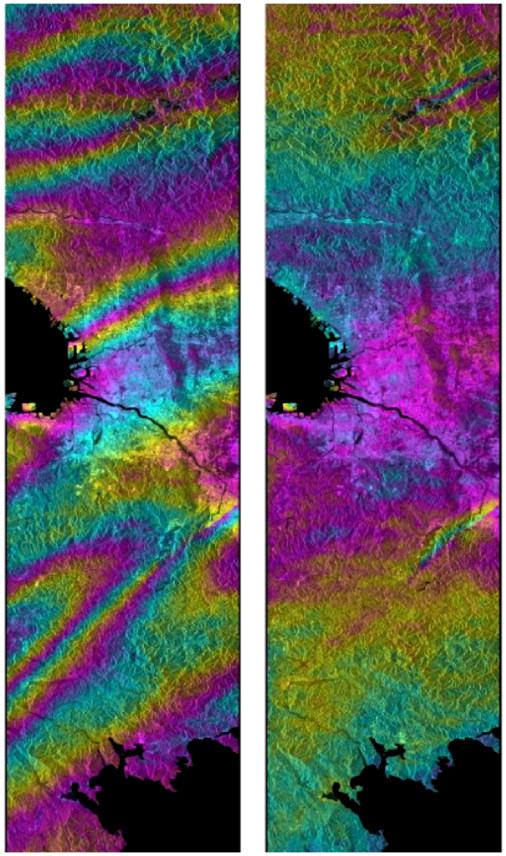


PALSAR-3 Ionospheric Correction

Onboard split-band for InSAR ionospheric correction



(*Gomba et al., 2015*)



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

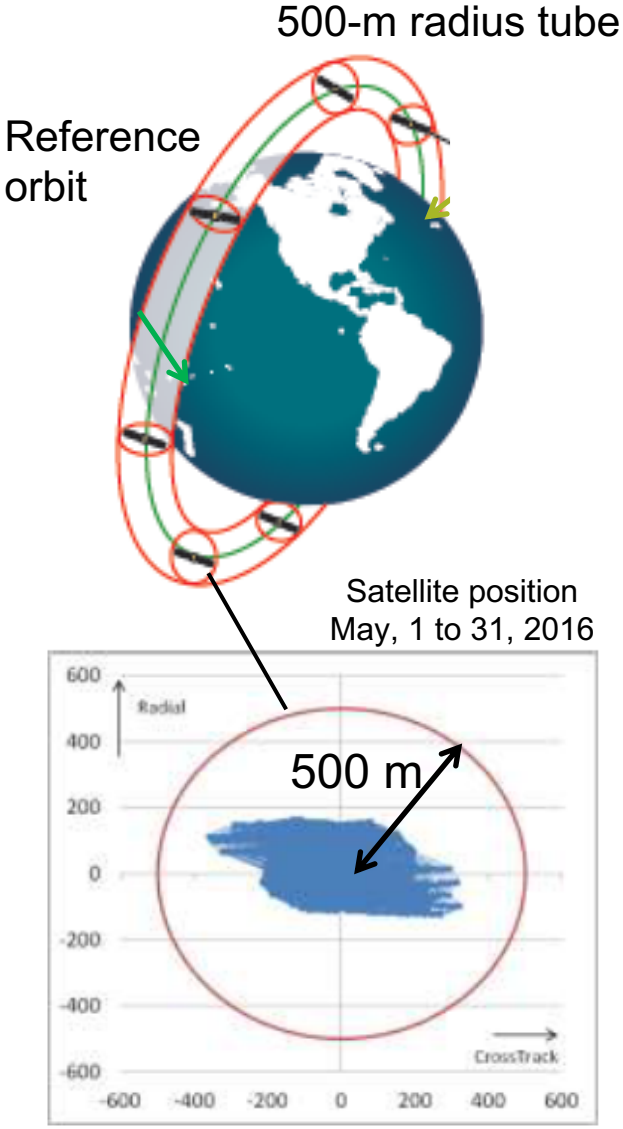
ALOS-4 Orbit Control

- 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

JAXA's EO Data Distribution Policy

- 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

		2019				2020			
		1Q Jan Mar	2Q Apr Jun	3Q Jul Sept	4Q Oct Dec	1Q Jan Mar	2Q Apr Jun	3Q Jul Sept	4Q Oct Dec
ALOS	AVNIR-2 (10 m)			±60 Degree Area			Global		
				Data Processing					
	PALSAR FBS, FBD, POL (10-20 m) ScanSAR (100 m)					±60 Degree Area		Global	
				Preparation		on Supercomputer			
ALOS-2	PALSAR-2 ScanSAR (50 m)								
				JICA-JAXA JJ-FAST intermediate products (ARD) processing					
							Data Processing		
	PALSAR-2 Fine Mode (10 m)								
				Under negotiation with commercial data provider					

Summary

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.