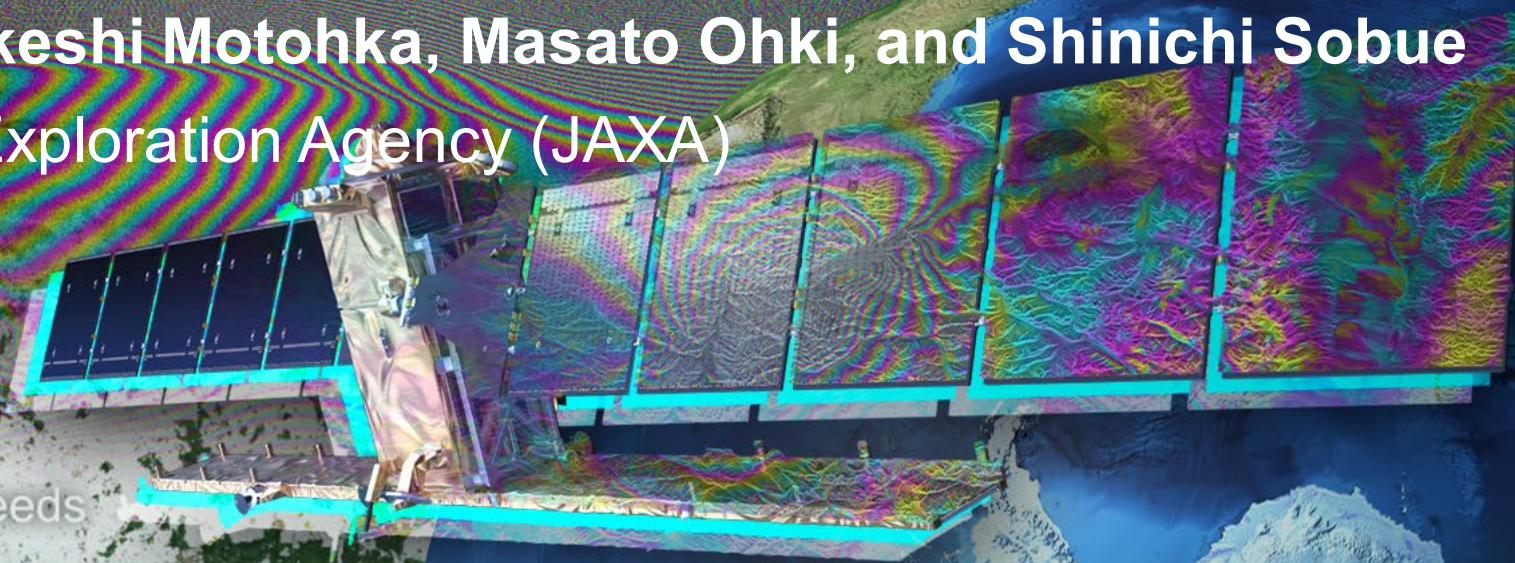


Status of ALOS-2 Mission Operation and Cal/Val Plan of ALOS-4

Takeo Tadono, Takeshi Motohka, Masato Ohki, and Shinichi Sobue

Japan Aerospace Exploration Agency (JAXA)



Bradford

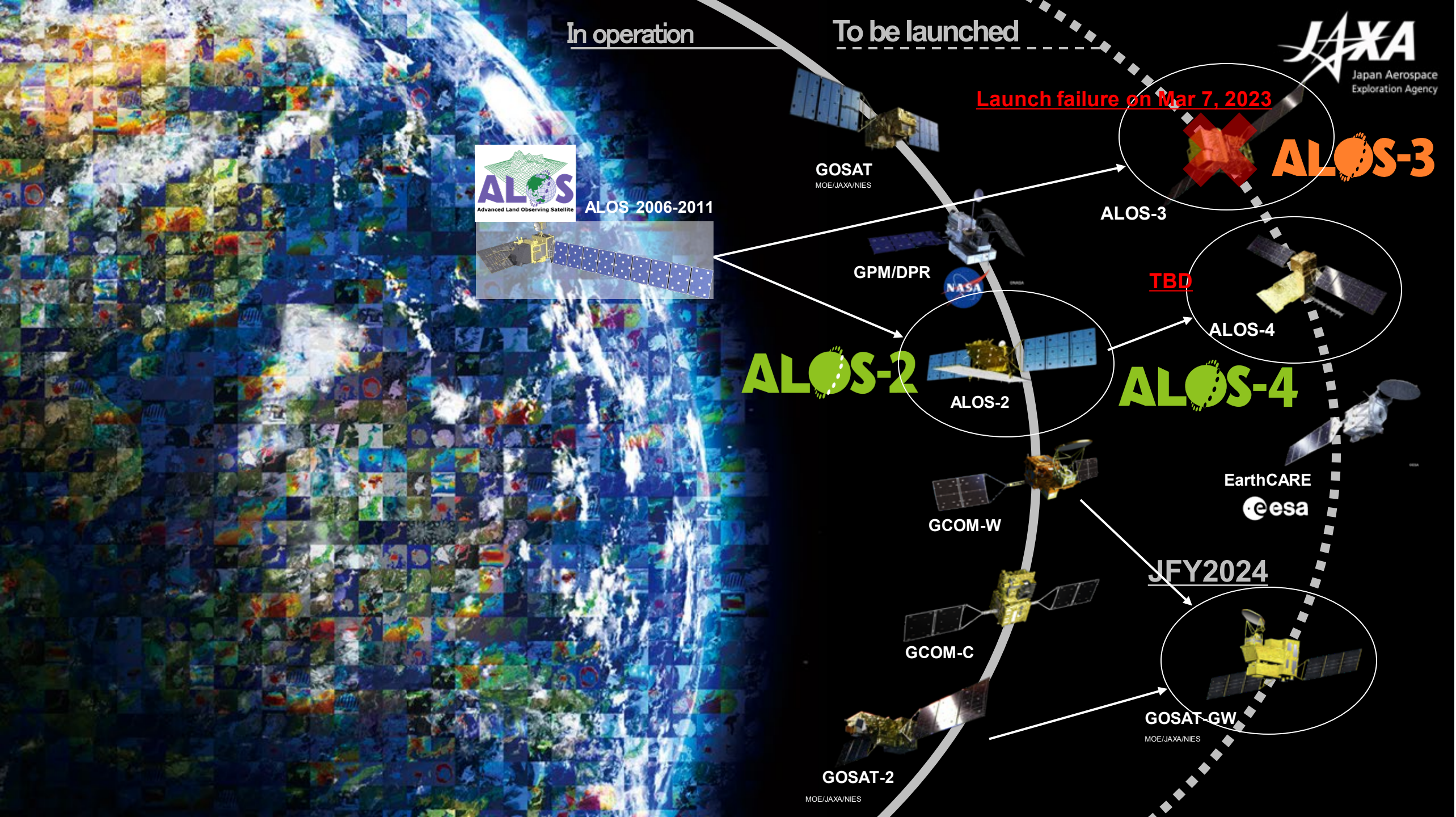
Leeds

FRINGE 2023

University of Leeds, UK | 11 - 15 September 2023.



- Overview of the JAXA's Earth Observation (EO) program and ALOS series missions
- Operation status and results of ALOS-2
- Development status of ALOS-4
- SAR international cooperation
- Application examples using L-band SAR
- Summary



In operation

To be launched



ALOS
Advanced Land Observing Satellite

ALOS 2006-2011

GOSAT
MOE/JAXA/NIES

Launch failure on Mar 7, 2023

ALOS-3

ALOS-3

GPM/DPR
NASA

TBD

ALOS-4

ALOS-4

ALOS-2

ALOS-2

ALOS-4

EarthCARE
esa

GCOM-W

JFY2024

GCOM-C

GOSAT-GW

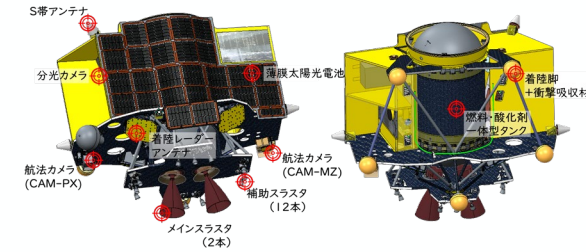
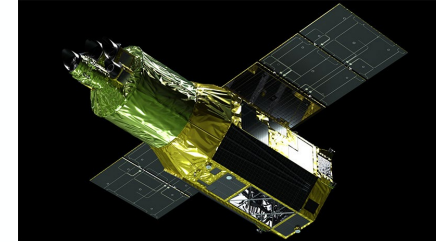
MOE/JAXA/NIES

GOSAT-2
MOE/JAXA/NIES

Successful H2A F47 Launch on 7th Sep., 2023



- **Date & Time:** 8:42 am, September 7, 2023 (JST)
- **Transports:** X-Ray Imaging and Spectroscopy Mission “XRISM” and Moon Explorer “SLIM”
- **Instruments of XRISM:** “Resolve” and “Xtend”, Total Mass: 2.3 tons
- **SLIM:** Precision landing by lightweight spacecraft, Mass: 210 kg

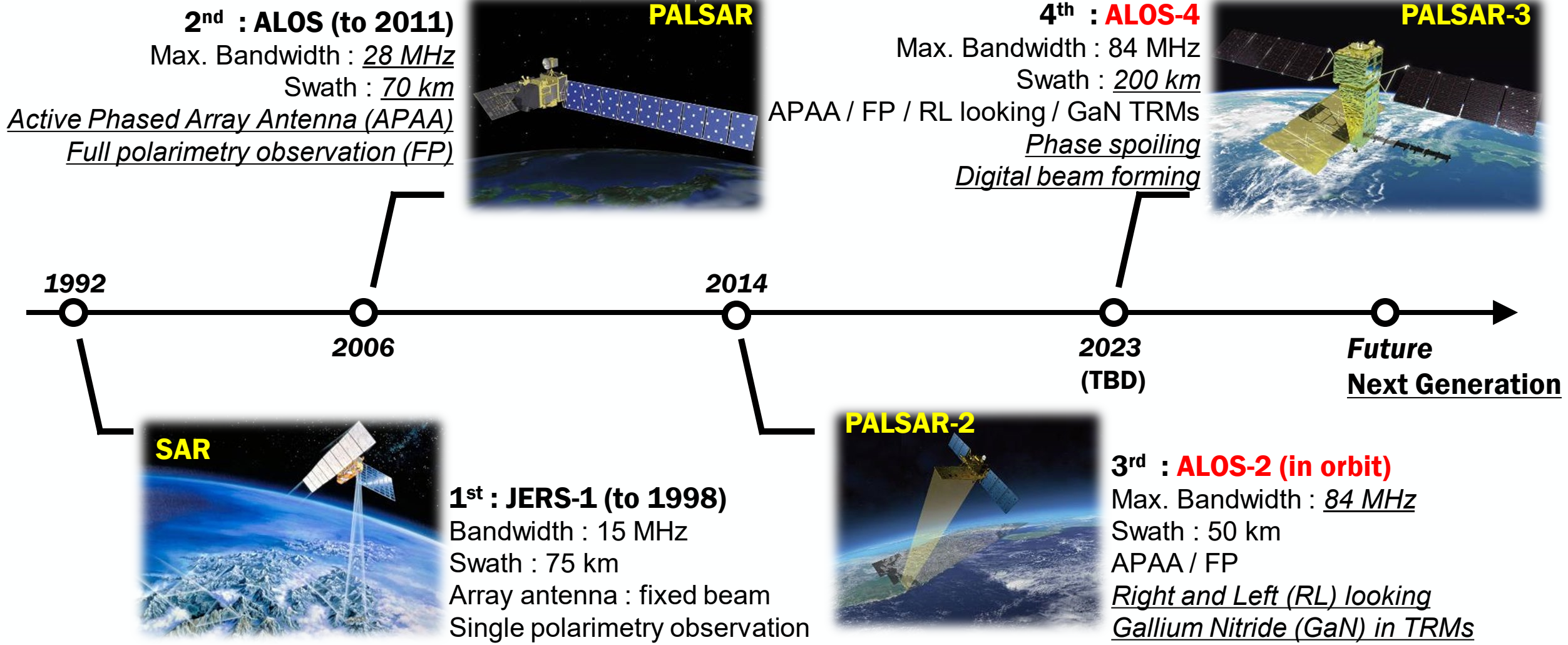


<https://youtu.be/5thA8iZvhmw?t=1982>

© MHI



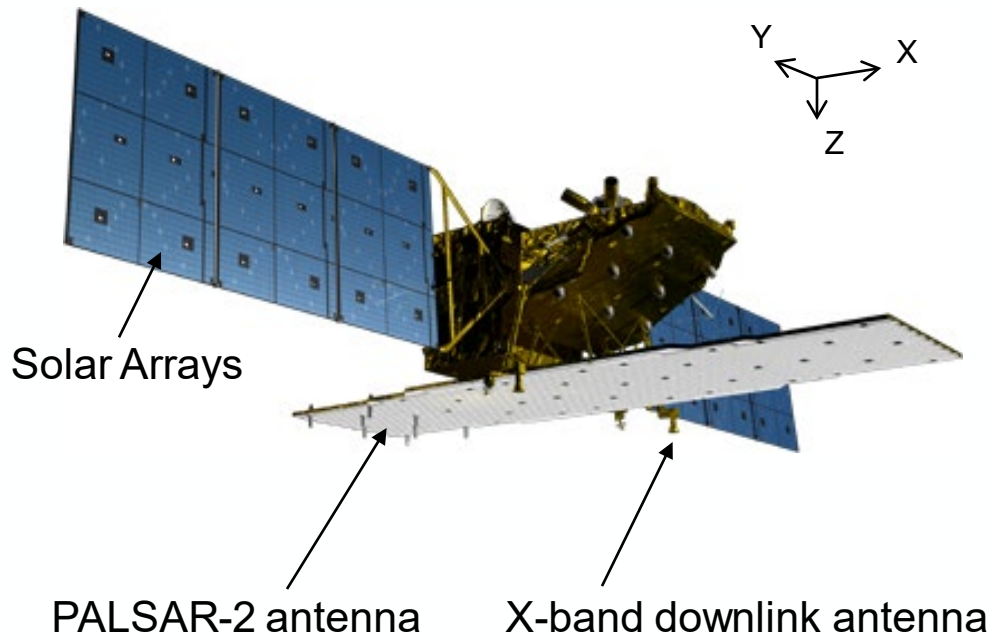
Japanese L-band SAR Missions



ALOS-2 Overview

Mission objectives:

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

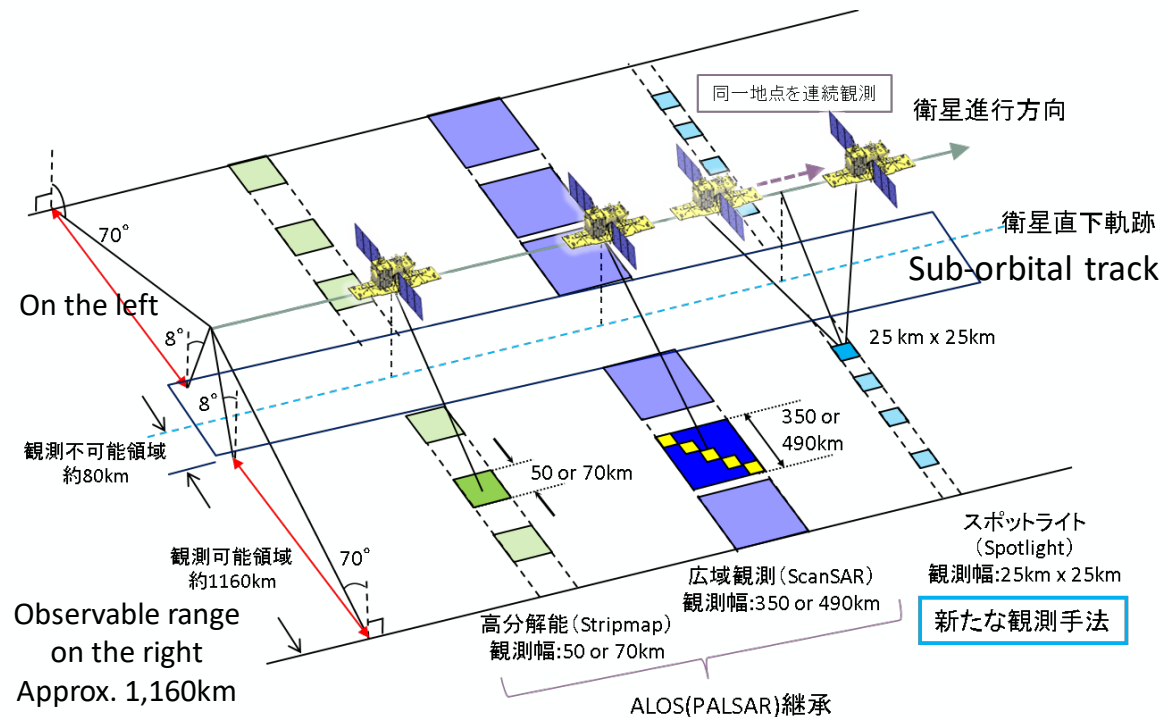


Mission sensor	PALSAR-2 (Phased Array type L-band Synthetic Aperture Radar 2)
Launch	May 24, 2014 H-IIA launch vehicle FY24
Mass	2.1 tons
Lifetime	5 years (Target: 7 years)
Orbit	Sun-synchronous 628 km altitude 14 days revisit Orbit control: $\leq \pm 500$ m
Local sun time	12:00 \pm 15 min (descending) 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.



Observation mode and specifications of ALOS-2 PALSAR-2.



Observation geometry of ALOS-2 PALSAR-2.

Observation mode	Spotlight	Stripmap			ScanSAR				
		3 m	6 m	10 m	Normal	Wide			
Center Frequency (MHz)	1257.5	1236.5 / 1257.5 / 1278.5							
Bandwidth (MHz)	84	84	42	28	14	28	14		
Resolution (m)	3x1 (Rg x Az)	3	6	10	100 (3 looks)		60		
Swath width (km)	25x25 (Rg x Az)	50	50	40	70	30	350 (5 scans)	490 (7 scans)	
Incidence angle (deg.)	8 - 70	8 - 70	8 - 70	20 - 40	8 - 70	23.7	8 - 70	8 - 70	
Polarization*	SP	SP / DP	SP / DP / CP	FP	SP / DP / CP	FP	SP / DP	SP / DP	
NESZ (dB)	-24	-24	-28	-25	-26	-23	-26	-23	-26
S/A (dB)	Rg	25	25	23	23	25	20	25	20
	Az	20	25	20	20	23	20	25	20
Antenna size	3 m (Rg) x 10 m (Az)								

NESZ: Noise Equivalent Sigma Zero

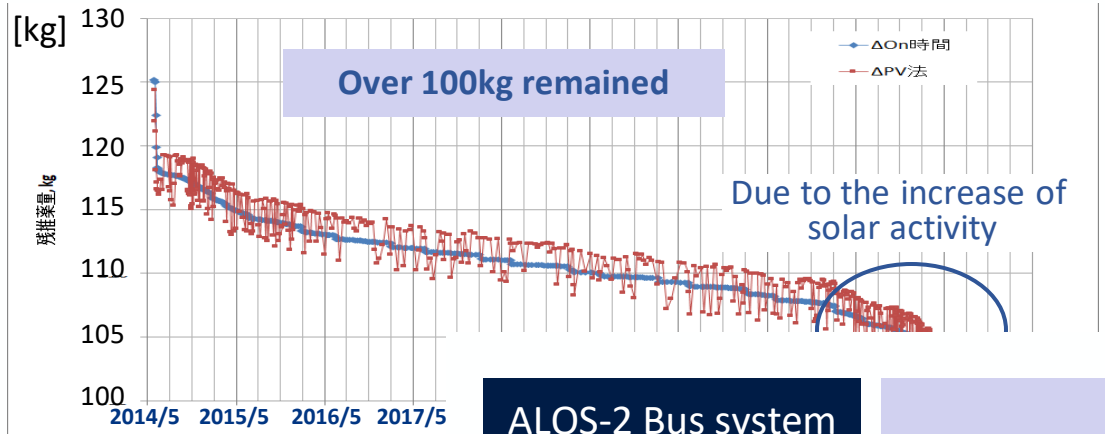
S/A: Signal-to-Ambiguity

* SP: HH / HV / VV / VH, DP: HH+HV / VV+VH, FP: HH+HV+VH+VV, CP: Circular or liner polarization by 45 deg. (Experimental mode)

ALOS-2 Operation Status

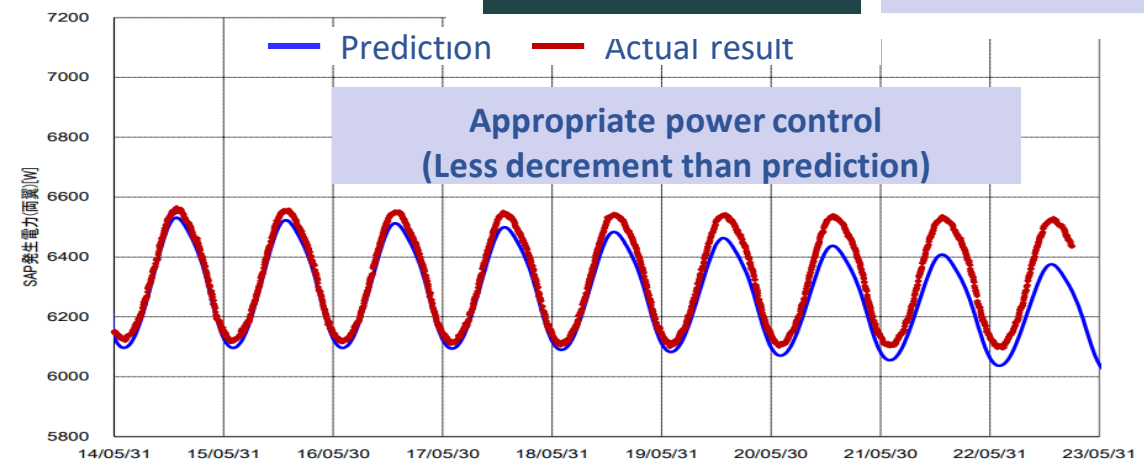


1. The amount of remaining fuel

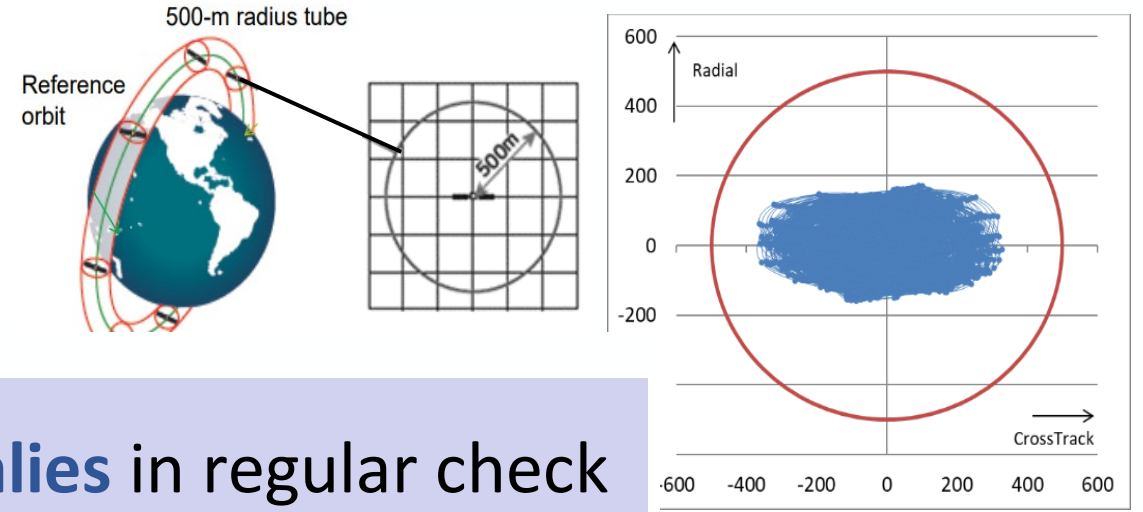


2. The transition of S

ALOS-2 Bus system
PALSAR-2 system



3. The result of orbit control



No anomalies in regular check

High efficiency for InSAR processing

Success rate of over 99%
Orbit control result (As of May 2023)

4. PALSAR-2 system evaluation

Three-month check-ups

- Thermal condition of components
- Phase shifter performance
- Onboard RF characteristics



ALOS-2 Calibration Status



- 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 several times e.g., in June 2018 (radiometric calibration), Nov. 2018 (correction of range offset), and April 2021 (updates the software for Spotlight and ScanSAR).

> PALSAR-2 keeps good conditions and performances.

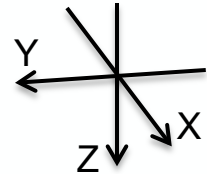
Calibration summary using PALSAR-2 acquired from July 2014 to Sep. 2022 (as of Oct. 2022).

Items	Results	
Geometry (RMSE)	[Stripmap and Spotlight] [ScanSAR]	5.59 m (L1.1) / 6.73 m (L2.1) 60.77 m (L1.1) / 29.33 m (L2.1)
Radiometry	RCS accuracy (1σ)	0.522 dB (corner reflectors) 0.41 dB (Amazonian forests)
Polarimetry	VV-HH amplitude ratio	1.003 ($\sigma=0.012$)
	VV-HH phase difference	-0.362 deg ($\sigma=1.404$)
	Cross talk	[HV/HH] -42.970 dB ($\sigma=6.609$) [VH/VV] -42.889 dB ($\sigma=5.590$)



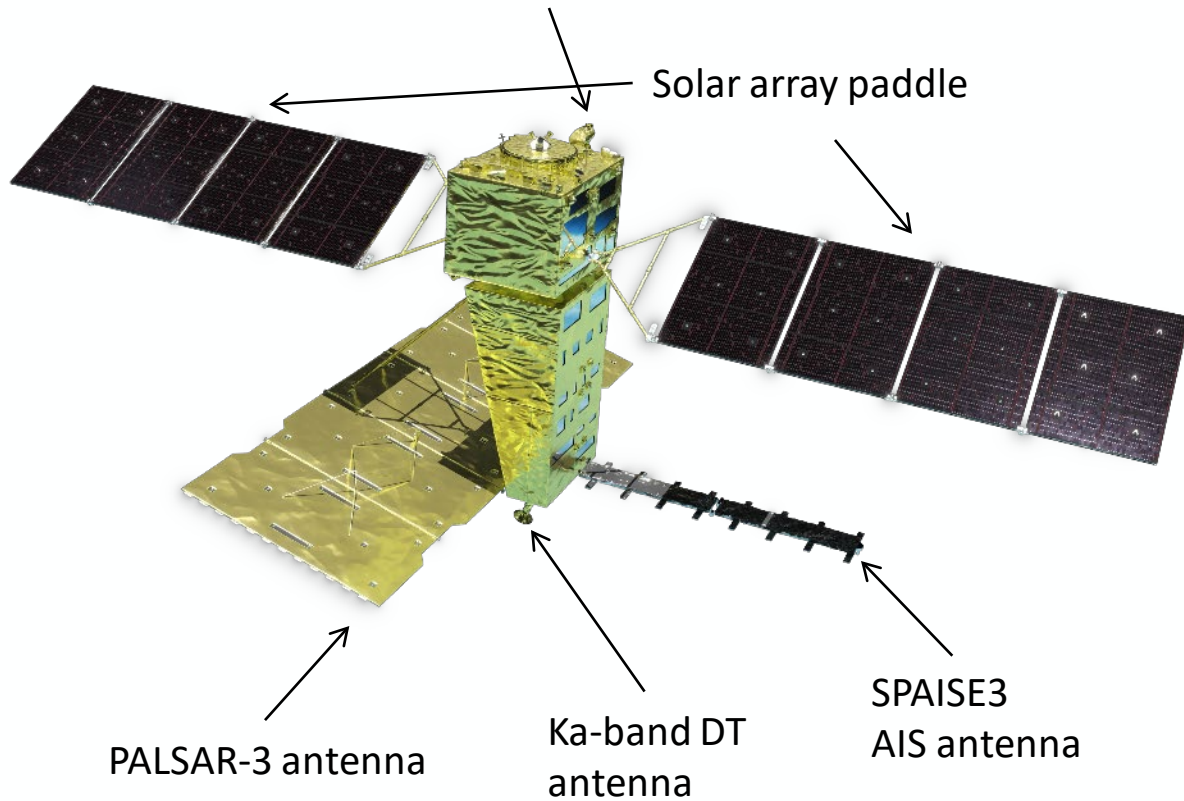
* https://www.eorc.jaxa.jp/ALOS/en/alos-2/a2_calval_e.htm

ALOS-4 Overview



Optical link terminal
via. JAXA Optical data relay satellite (JDRS)

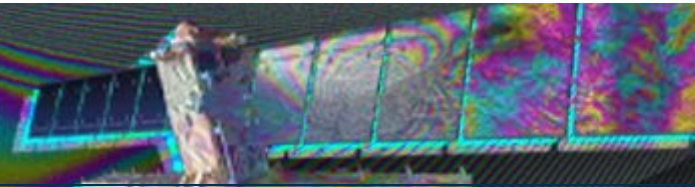
Solar array paddle



Launch	TBD
Orbit	Same orbit as ALOS-2 <ul style="list-style-type: none"> ✓ 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 days (15-3/14 rev/day)
Lifetime	7 years
Size	X 10.0 m x Y 20.0 m x Z 6.4 m
Satellite Mass	~2,990 kg
Downlink	1.8 (Optical link) / 3.6 Gbps (Ka-band)
Mission Instruments	<ul style="list-style-type: none"> - PALSAR-3 (Phased Array type L-band Synthetic Aperture Radar-3) - SPAISE3 (SPace based AIS Experiment 3)
Prime contractor	Mitsubishi Electric Corporation

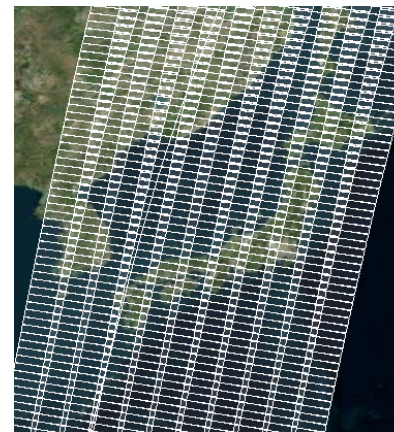


ALOS-4 PALSAR-3



Coverage of 1 repeat cycle (14 days)

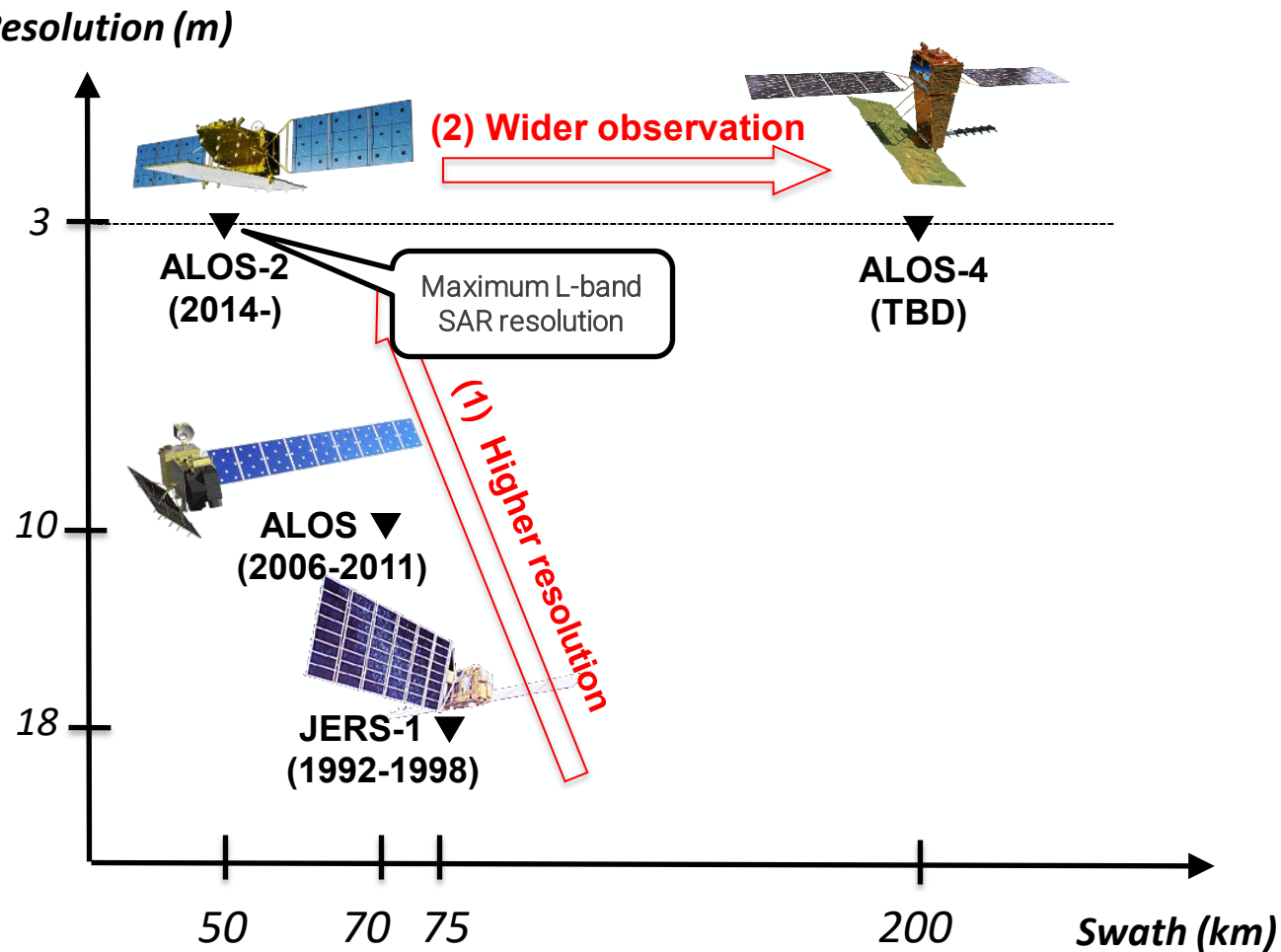
ALOS-4 PALSAR-3 (200 km) ALOS-2 PALSAR-2 (50 km)



Swath width of PALSAR-3/-2

Modes	PALSAR-3	PALSAR-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 x 35km	25km x 25km

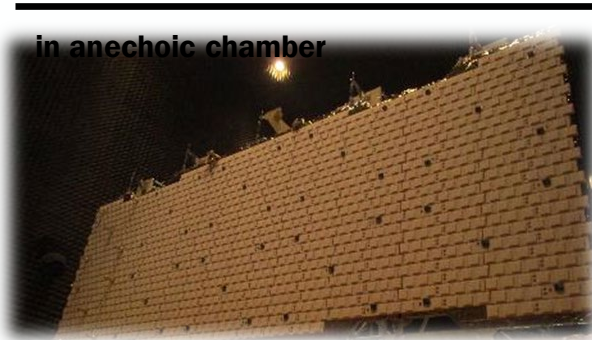
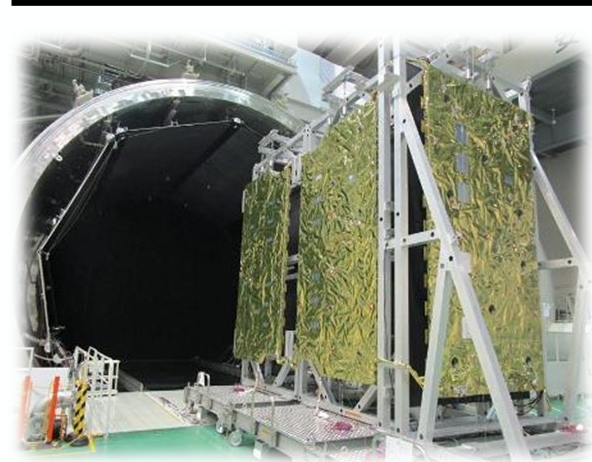
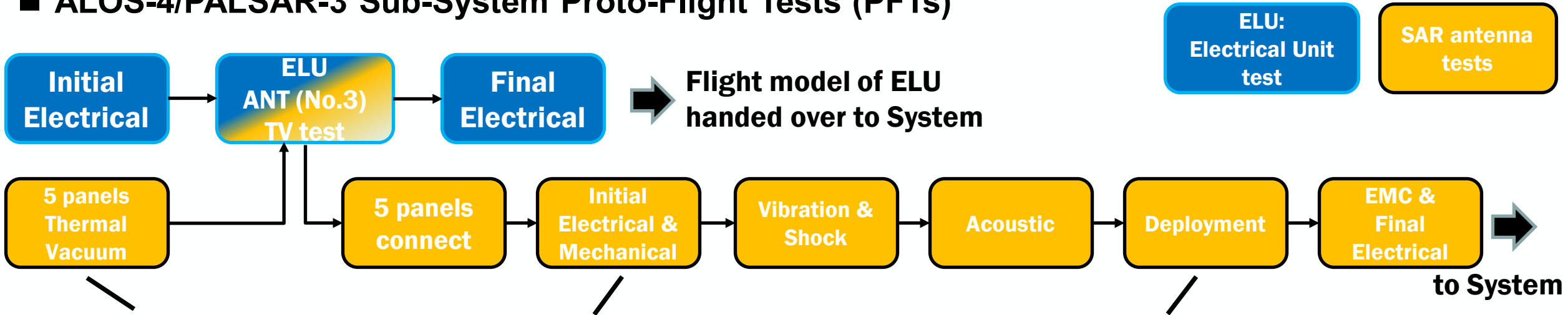
* Single look



ALOS-4 Proto-Flight Testing (PFT)



ALOS-4/PALSAR-3 Sub-System Proto-Flight Tests (PFTs)

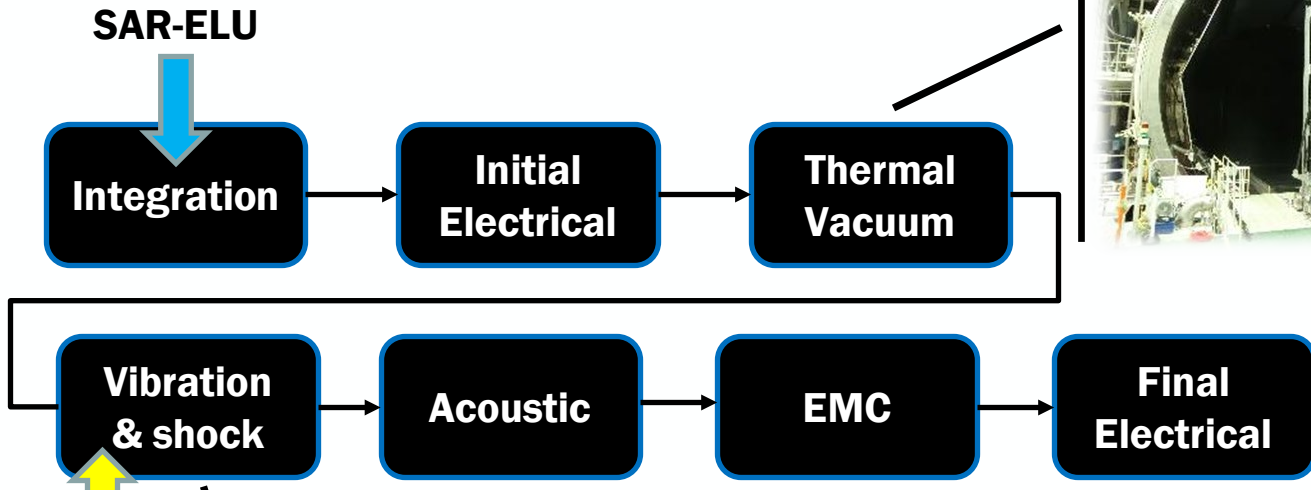


ELU EM was used

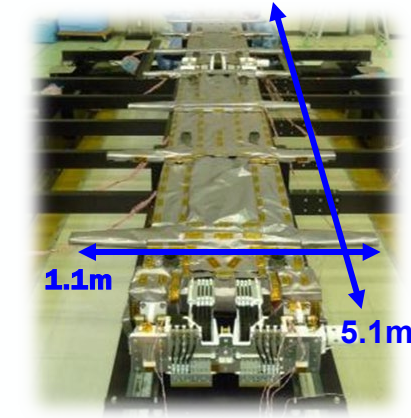


ALOS-4 Proto-Flight Testing (PFT)

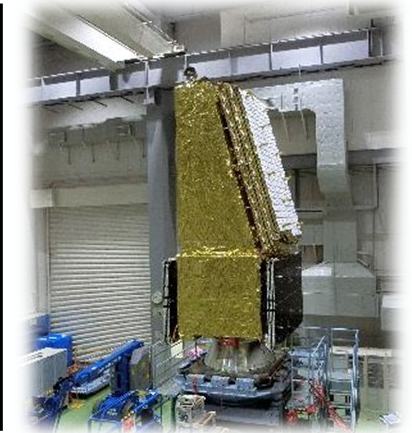
ALOS-4 System PFTs



SPAISE3 had also already completed the PFTs individually.



©NEC



SAR Antenna

ALOS-4 System PFTs Conclusions:

- System PFT had completed and confirmed there is no issue for flight.
- System PFT include “End to End test” were conducted with assuming realistic operation scenarios with ground segments.
- **ALOS-4 including PALSAR-3 sub-system had completed preparation for launch.**

ALOS-4 PALSAR-3 Specifications



SAR mode	Spotlight (sliding)	Stripmap						ScanSAR		
	1257.5		1236.5 (or 1257.5/1278.5)							
Center frequency [MHz]	1257.5		1236.5 (or 1257.5/1278.5)							
Bandwidth [MHz]	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									

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



ALOS-4 PALSAR-3 Specifications



SAR mode	Spotlight (sliding)	Stripmap						ScanSAR	
		1236.5 (or 1257.5/1278.5)							
Center frequency [MHz]	1257.5	1236.5 (or 1257.5/1278.5)							
Bandwidth [MHz]	84	42	28	28+10	28				
Resolution [m]	3 x 1 (Rg x Az)	6	10	10	25 (1 look)				
Swath width [km]	35	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		
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							

Wider

Add dual-pol

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



ALOS-4 PALSAR-3 Specifications

SAR mode	Spotlight (sliding)	Stripmap							
		1257.5		1236.5 (or 1257.5/1278.5)					
Center frequency [MHz]		1257.5		1236.5 (or 1257.5/1278.5)					
Bandwidth [MHz]		84		42	28	28+10	28		
Resolution [m]	2 x 1	3		6	10	10	25 (1 look)		
Swath width [km]		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							

Add split-band for ionospheric correction

Wider

Add full-pol

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

ALOS-4 PALSAR-3 Specifications

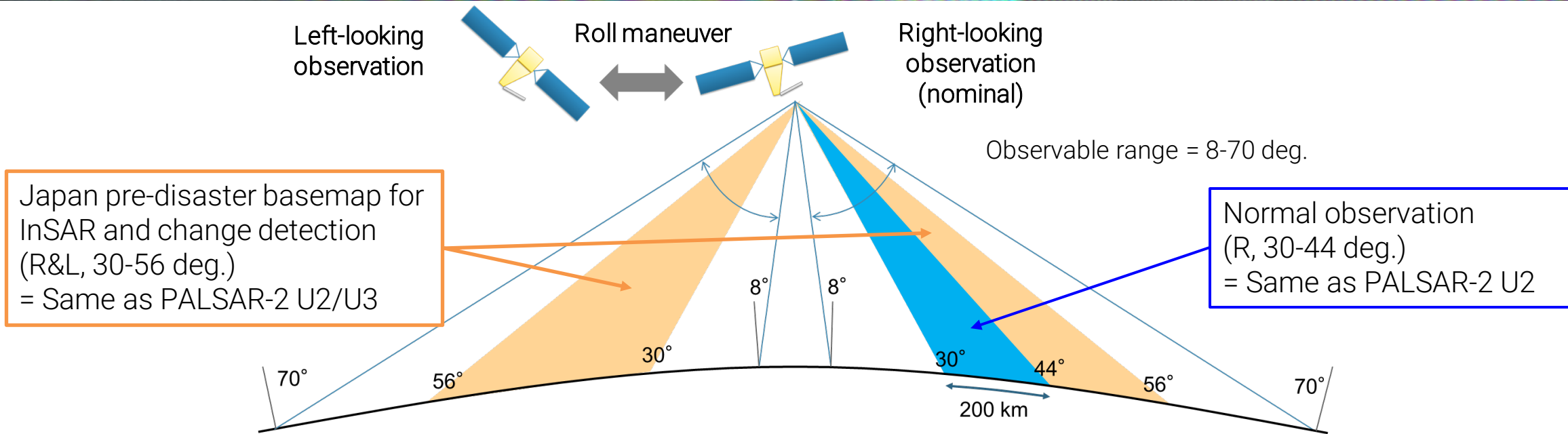
SAR mode	Spotlight (sliding)	Stripmap							ScanSAR
						1236.5 (or 1236.5)			
Center frequency [MHz]	1257.5								
Bandwidth [MHz]	84	42		28		28+10		28	
Resolution [m]	3 x 1 (Rg x Az)	3		6		10		25 (1 look)	
Swath width [km]	35	200	100	200	100	200	100	200	700 (4 scans)
Polarization	1, 2	1, 2	1, 2, 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								

Delete 14 MHz

Wider

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

ALOS-4 PALSAR-3 Specifications



InSAR capability between PALSAR-2 and PALSAR-3

InSAR pair		PALSAR-3		PALSAR-2	
		Stripmap 100/200 km	ScanSAR 700 km	Stripmap 50/70 km	ScanSAR 350/490 km
PALSAR-3	Stripmap 100/200 km	○	○	○	○
	ScanSAR 700 km	○	○	○	×

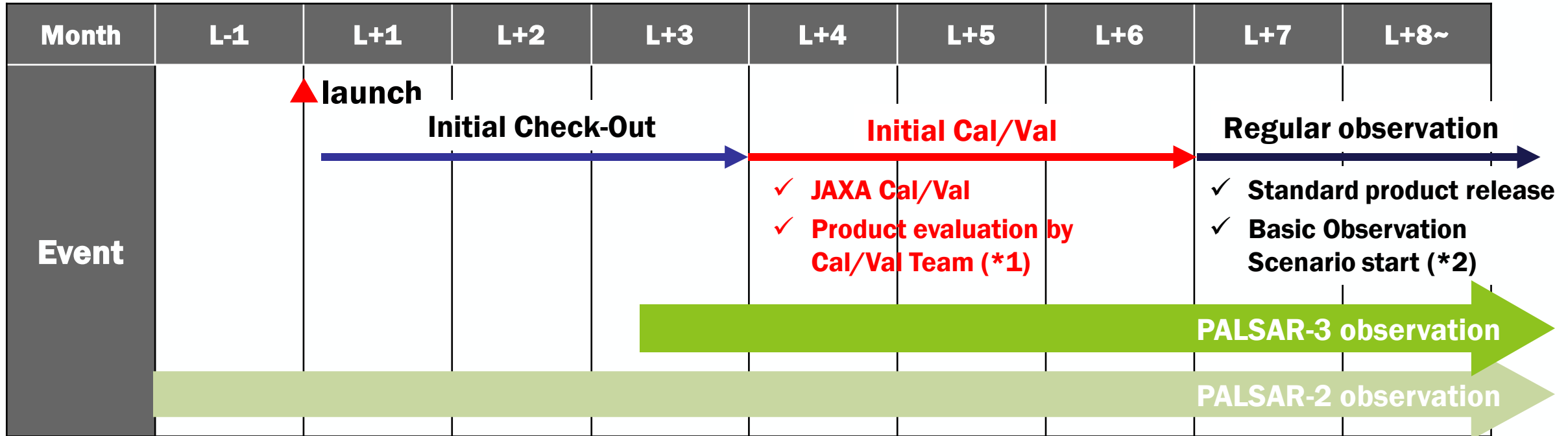
- ✓ ALOS-4 reference orbit is the same as ALOS-2
- ✓ Controlling accuracy is within +/- 500 m (= small baseline)



ALOS-4 Initial Operation Plan



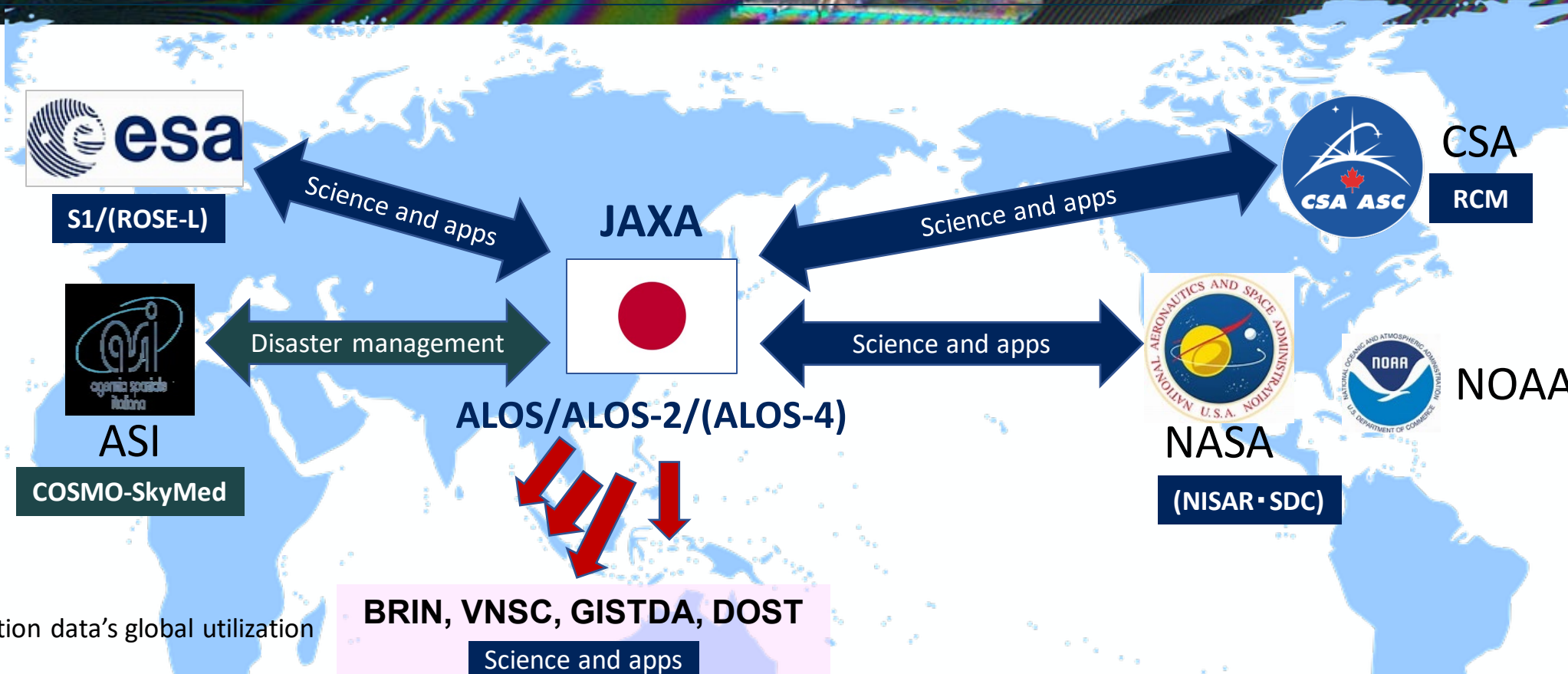
- Focus on the observation modes/beams that will be used by most of the users (SM 3 and 10 m, WD, Spotlight)
- Calibration and compatibility check with ALOS-2
 - ✓ Radiometry & PolCal: Amazon and African rain forests,
 - ✓ Geometry & PolCal: CRs and ARCs including Ionospheric correction with TEC model, and
 - ✓ Image quality, InSAR (ALOS-4/ALOS-4 pairs, ALOS-2/ALOS-4 pairs), and other high-level products.



*1: ALOS-4 Cal/Val & Science Team URL: https://www.eorc.jaxa.jp/ALOS/en/alos-4/a4_calval_e.htm

*2: Current version of BOS URL: https://www.eorc.jaxa.jp/ALOS/en/alos-4/a4_observation_e.htm

SAR International Cooperation



ALOS-2 observation data's global utilization

● **Science and apps:**

- ✓ Ocean: Sea Ice, ship, oil spill, surface wind
- ✓ Land: agriculture, soil moisture, SWE, crustal deformation - volcano, subsidence, LULCC, forest with disaster response

- Promote the innovative collaborative research synergies by **multi-frequency analysis (L/C/X-band)**

Apps. 1: L-SARs Annual Global Mosaic and FNF

Global PALSAR-2/PALSAR/JERS-1 Mosaic and Forest/Non-Forest map

ALOS Home > about PALSAR-2/PALSAR Global Forest / Non-forest Map > Global PALSAR-2/PALSAR/JERS-1 Mosaic and Forest / Non-forest Map

Global PALSAR-2/PALSAR/JERS-1 Mosaic and Forest / Non-forest Map

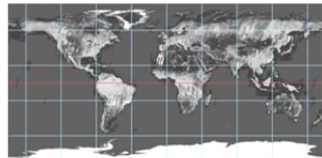
+ These map uses Javascript. Please enable JavaScript on your browser.

25m resolution product

Global

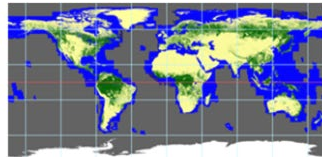
- JERS-1 SAR Mosaic:

>> 1996



- PALSAR/PALSAR-2 mosaic and forest/non-forest (FNF) map:

>> 2007 >> 2008 >> 2009 >> 2010 >> 2015
>> 2016 >> 2017 >> 2018 >> 2019 >> 2020



Tropical region (Amazon, Africa, and SE-Asia)

- JERS-1 SAR Mosaic:

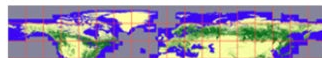
>> 1993 >> 1994 >> 1995 >> 1996 >> 1997
>> 1998



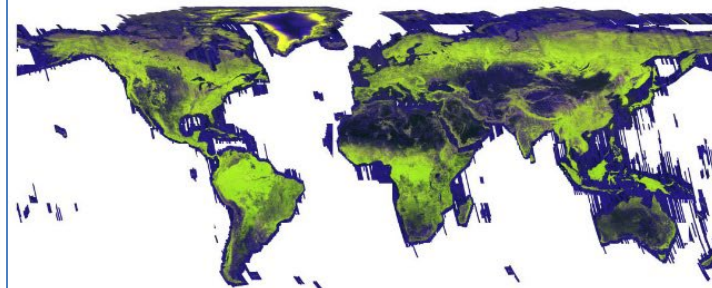
Low resolution product

PALSAR-2/PALSAR

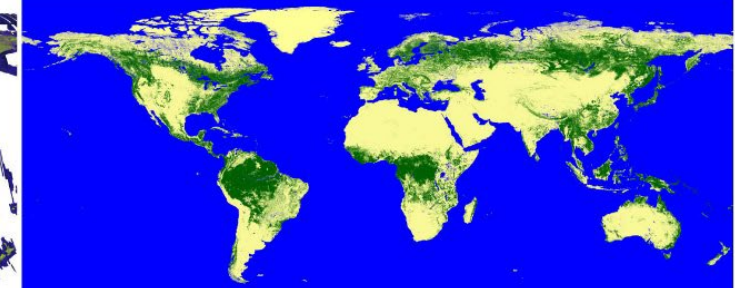
- 100m resolution product (mosaic and FNF map):



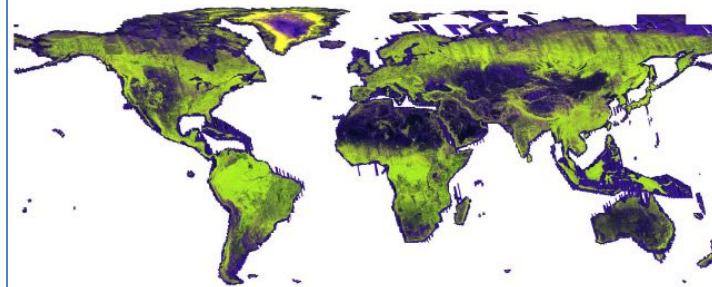
* https://www.eorc.jaxa.jp/ALOS/a/en/dataset/fnf_e.htm



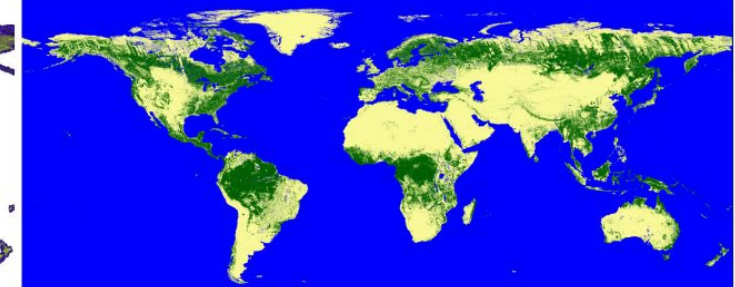
2009 PALSAR 25m Mosaic



2009 PALSAR Forest/Non-Forest



2015 PALSAR-2 25m Mosaic



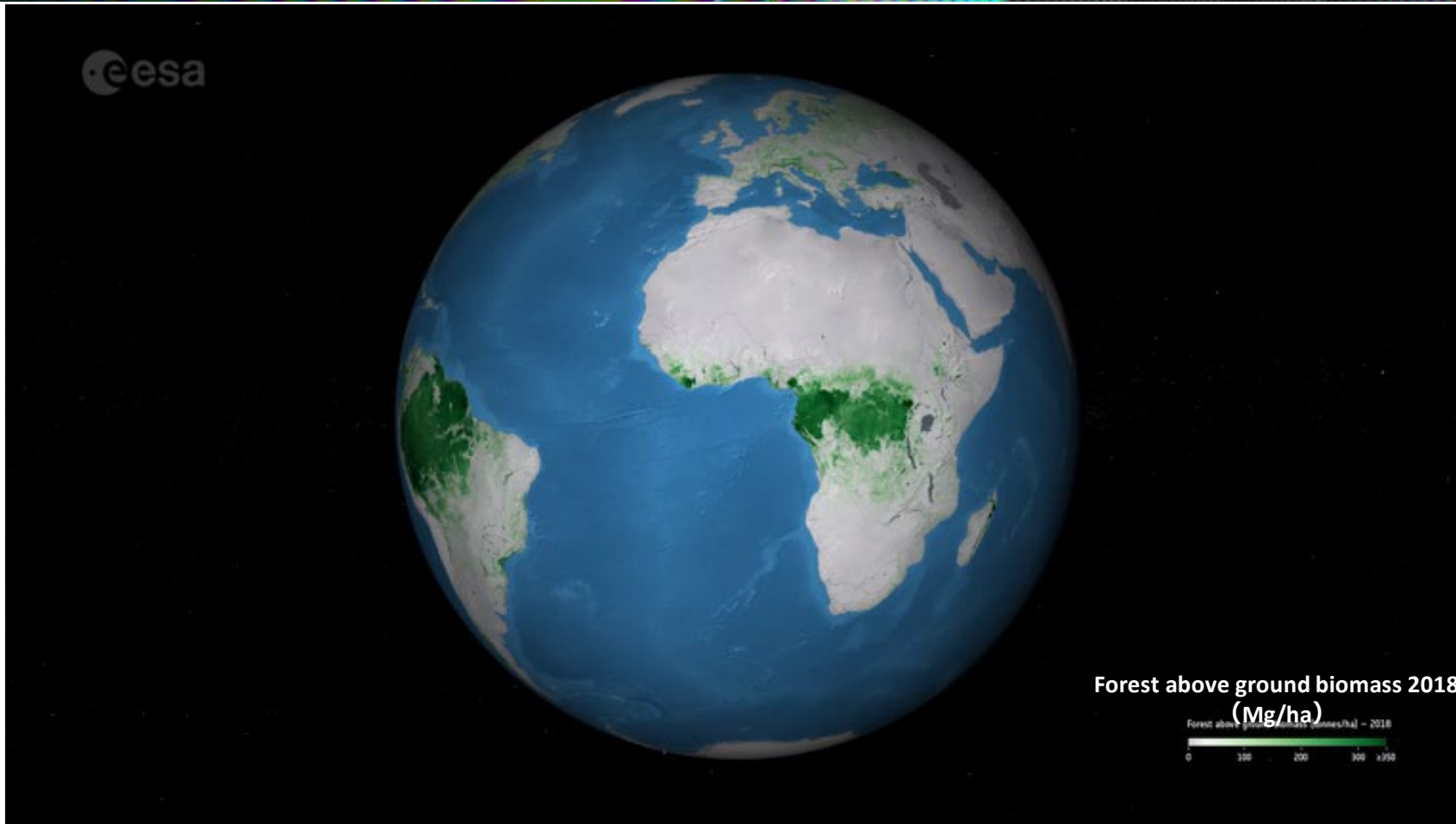
2015 PALSAR-2 Forest/Non-Forest

(c) JAXA

Annual Global 25 m Resolution Mosaics & FNF Maps:

- PALSAR-2: 2015 – 2022 (Plan for reprocessing before 2018)
- PALSAR: 2007 – 2010
- JERS-1: 1996
- + Low resolution 100 m mosaics
- Reprocessing Forest/Non-Forest classifications (FNF Map)

Forest Above Ground Biomass Ver. 4 by ESA Climate Change Initiative (CCI)



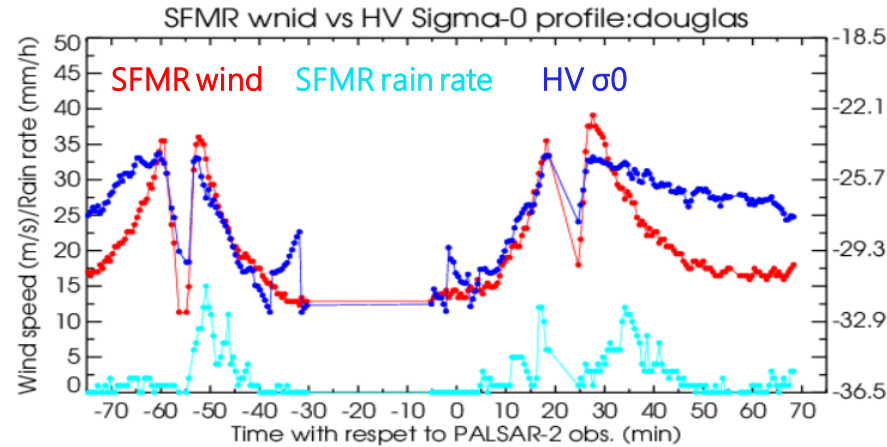
- ✓ Based on an agreement with the European Space Agency (ESA), the global forest biomass map Ver. 4 was created and released.
- ✓ The dataset covers 2010 (utilizing ALOS/PALSAR) and 2017 to 2020 (utilizing ALOS-2/PALSAR-2) for five annual periods with a spatial resolution of 100 meters.



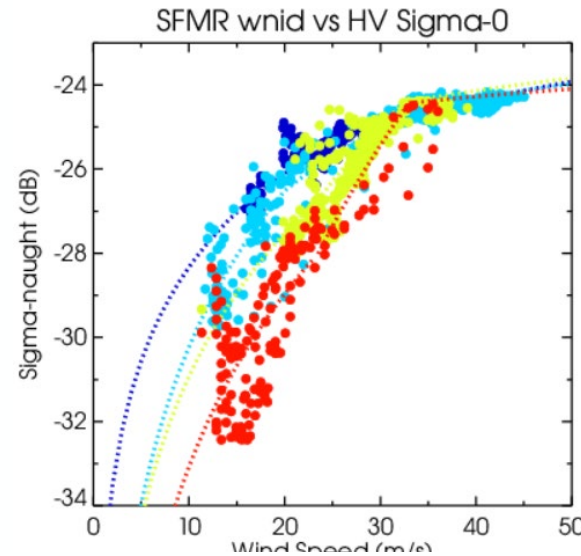
Apps. 2: Sea Surface Wind (SSW)



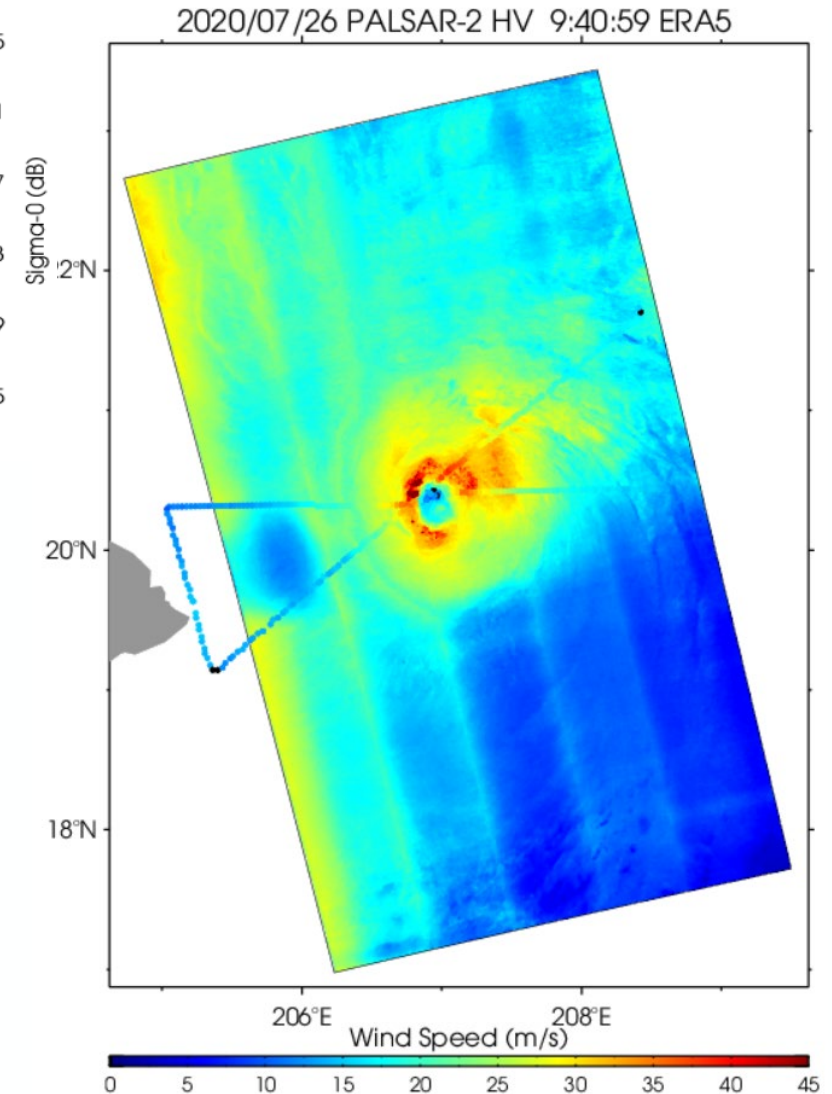
- The Sea Surface Wind (SSW) estimation under typhoon / tropical cyclone is essential to improve the forecasting.
- The emergency observations conducted several times in 2020.
- SFMR, the Airborne Passive Microwave Radiometer observations were used to develop model function collaboration with MRI.



Comparison between wind speed and rain rate derived by SFMR and PALSAR-2 σ^0 .



Updates of the model function (GMF).
DORIAN(2019/9/5), DOUGLAS(2020/7/26)

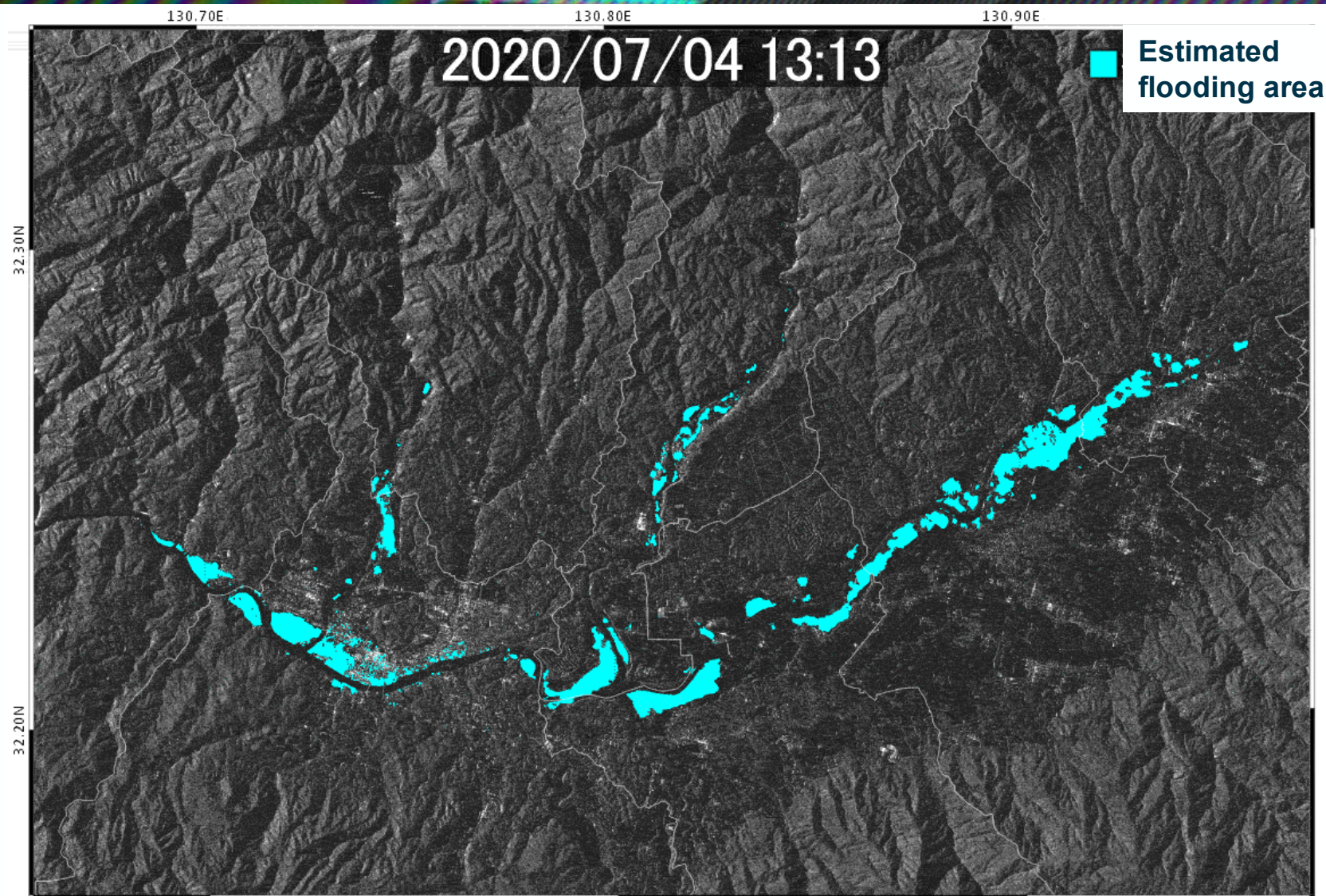


Estimated SSW by PALSAR-2/HV for DOUGLAS.
Overlaid SFMR SSW



Apps. 3: Flooding Area Estimation

- A heavy rain caused by *BAIU front* since July 3rd, 2020.
- It caused river flooding and landslides in Kumamoto Pref. and surrounding regions.
- ALOS-2 conducted emergency observations on July 4-6th, 2020, and derived flooding areas.



■ JAXA EO program and ALOS series missions

- ✓ Unfortunate failure of ALOS-3 high-resolution optical mission and H3 TF1
- ✓ Launch of the H2A F47 was successfully

■ Operation status and results of ALOS-2

- ✓ Good performance in 9 years operation

■ Development status of ALOS-4

- ✓ Ready to launch and is waiting the H3 F3?

■ SAR international cooperation

■ Application examples using L-band SAR

- ✓ Collaboration with international agencies and private sectors is expanded.

SUMMARY



Thanks for attentions.