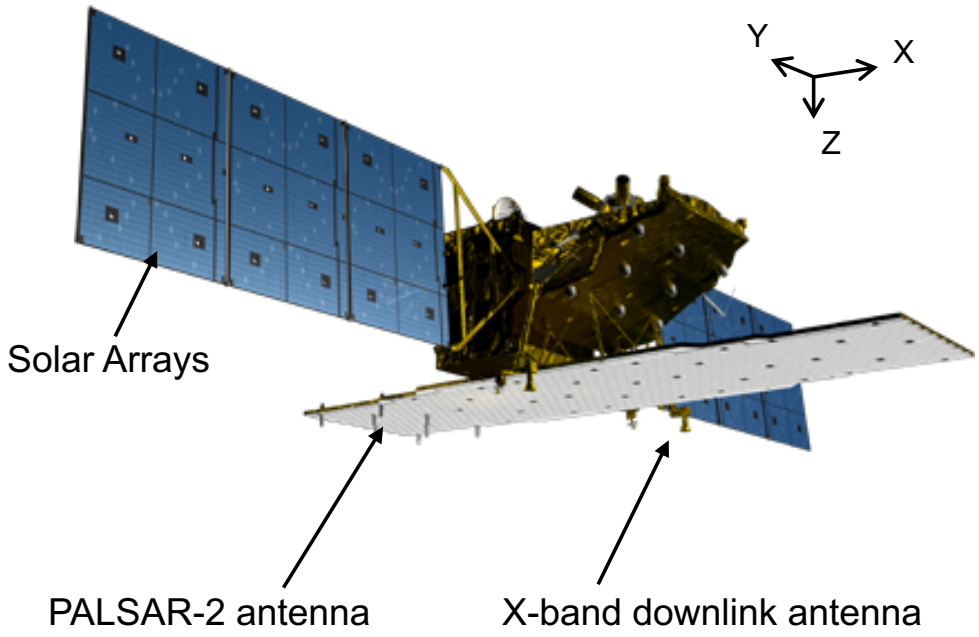
Status of ALOS-2 PALSAR-2 calibration and validation and its follow-on L-band SAR

○**Takeshi Motohka**[1], Osamu Isoguchi[2], Masanori Sakashita[2], Masanobu Shimada[1,3], and Shinichi Suzuki[1]

1. Japan Aerospace Exploration Agency (JAXA)
2. RESTEC
3. Tokyo Denki University

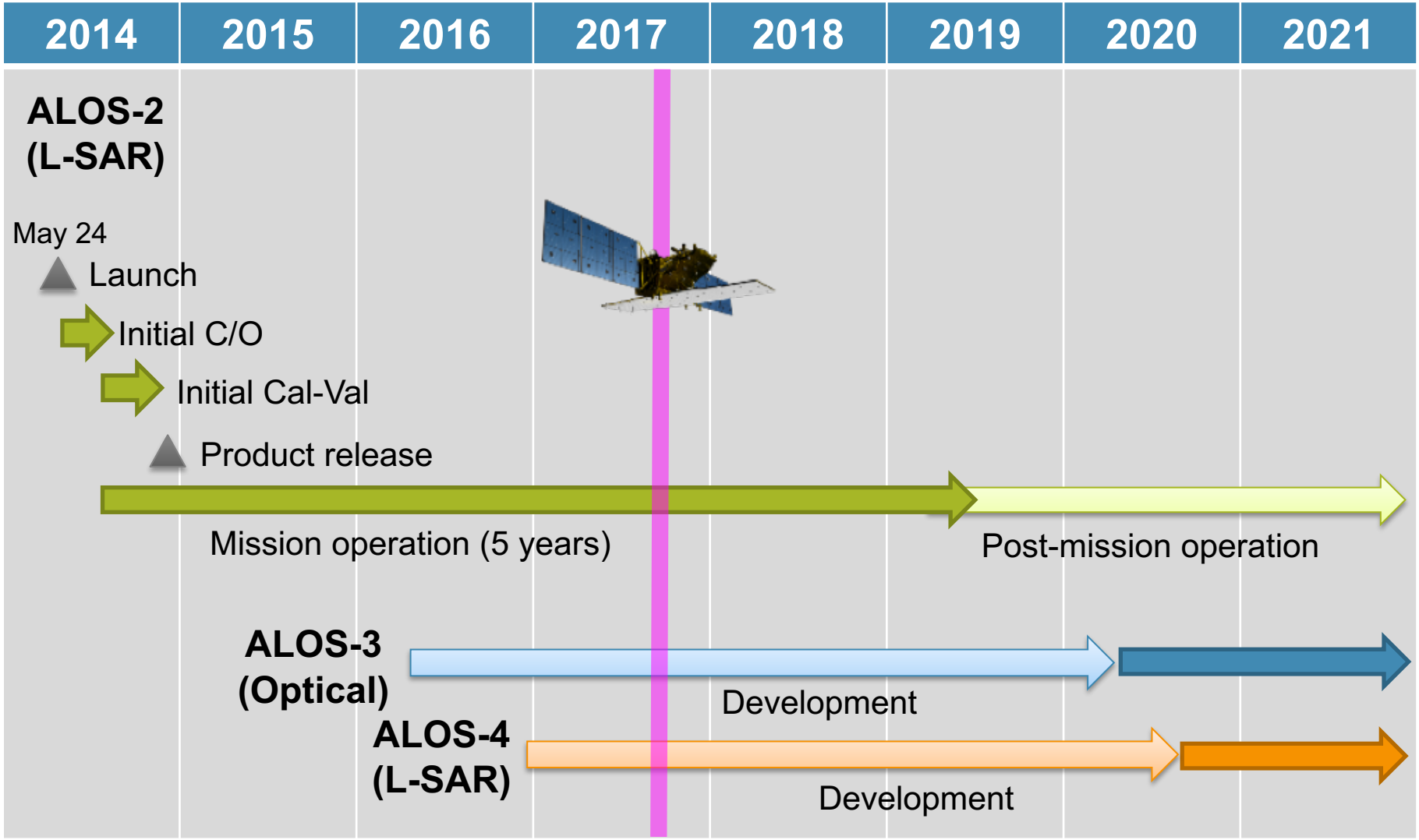
CEOS SAR CalVal Workshop, JPL Pasadena
Nov. 7, 2017

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



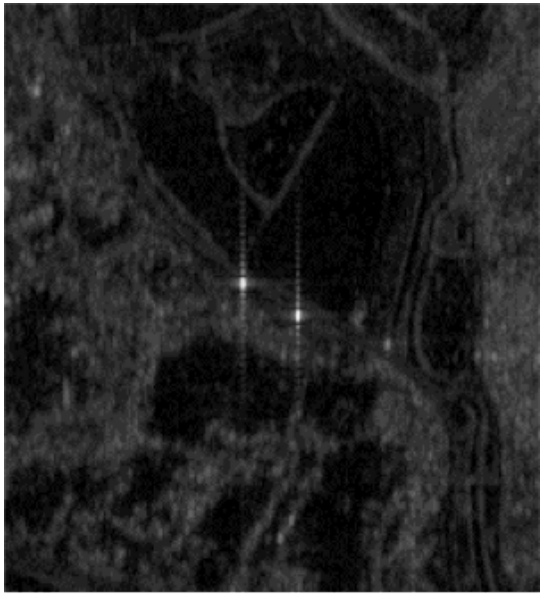
PALSAR-2 cal/val status

- 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 in March 2017.

Validation results of standard products (as of Jul. 2017)

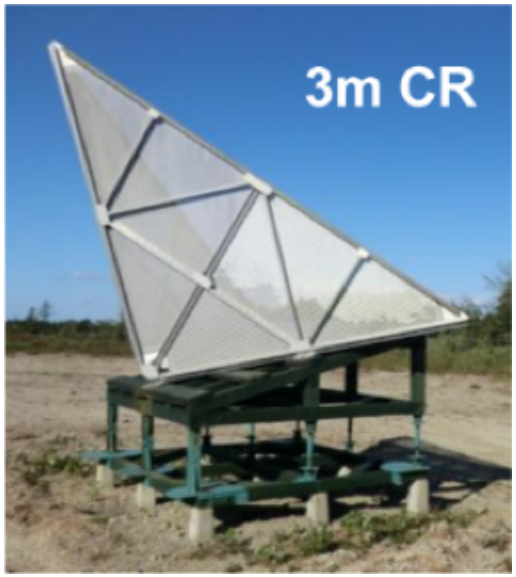
Items	Results	
Geometry (RMSE)	[Stripmap and Spotlight] **5.34 m (L1.1) / 6.73 m (L2.1)** [ScanSAR] **60.77 m (L1.1) / 29.93 m (L2.1)**	
Radiometry	RCS accuracy (1σ)	**0.56 dB (corner reflectors)** **0.77 dB (Amazonian forests)**
Polarimetry	VV-HH amplitude ratio	**1.004 (σ=0.012)**
	VV-HH phase difference	**-1.19 deg (σ=4.42)**
	Cross talk	**[HV/HH] -39.4 dB (σ=9.1)** **[VH/VV] -39.1 dB (σ=11.0)**

Cal/Val sites in Japan

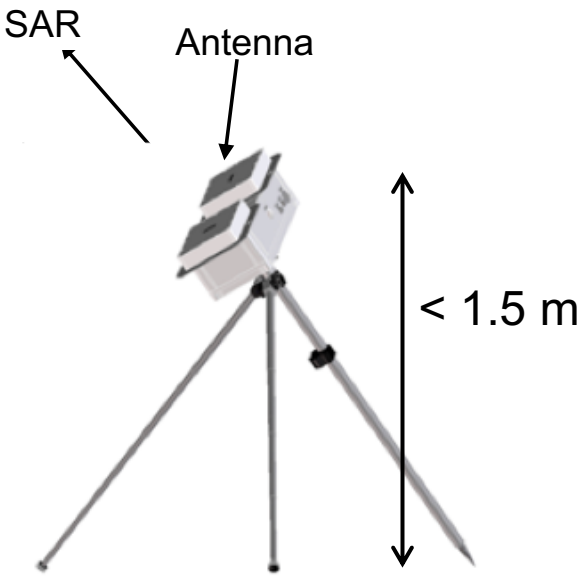


- **Tomakomai, Hokkaido**
  … 4 permanent CRs
- **Kanto region (around Tokyo)**
  … temporal (30 times/year)
  CR, ARC/GC, receiver

CR



ARC/GC



Signal receiver

Standard product updates (1)
Polarimetric calibration

- Corrected a bias of about 20 degrees in the phase difference between VV and HH for beam FP6-4 and FP6-6

Before update of the polarimetric calibration

Beam	**FP6-3**	**FP6-4**	**FP6-5**	**FP6-6**	**FP6-7**
Points	5	5	5	5	10
Amplitude ratio (VV/HH)	1.01 (σ = 0.01)	1.01 (σ = 0.01)	0.99 (σ = 0.01)	0.99 (σ = 0.06)	1.01 (σ = 0.01)
Phase difference (VV-HH) [deg.]	**0.7 (σ = 0.9)**	**23.4 (σ = 0.9)**	**1.8 (σ = 0.6)**	**22.0 (σ = 5.4)**	**1.8 (σ = 1.6)**
Cross-talk (VH/HH) [dB]	-46.9 (σ = 4.7)	-45.8 (σ = 8.2)	-44.4 (σ = 3.2)	-41.3 (σ = 13.0)	-43.2 (σ = 6.5)
Cross-talk (HV/VV) [dB]	-47.6 (σ = 4.6)	-39.8 (σ = 5.4)	-42.9 (σ = 5.1)	-38.8 (σ = 12.7)	-41.0 (σ = 4.7)

After update of the polarimetric calibration

Beam	**FP6-3**	**FP6-4**	**FP6-5**	**FP6-6**	**FP6-7**
Scene observation date	2014/12/26	2015/01/09	2015/01/23	2015/02/06	2014/08/13
Amplitude ratio (VV/HH)	0.99	1.00	1.00	0.99	1.00
Phase difference (VV-HH) [deg.]	**-0.02**	**-0.96**	**-0.21**	**-0.32**	**2.17**
Cross-talk (VH/HH) [dB]	-52.4	-37.6	-47.4	-42.3	-44.3
Cross-talk (HV/VV) [dB]	-44.3	-41.2	-56.6	-41.9	-40.8

Standard product updates (2)
Radiometric calibration factor (CF)

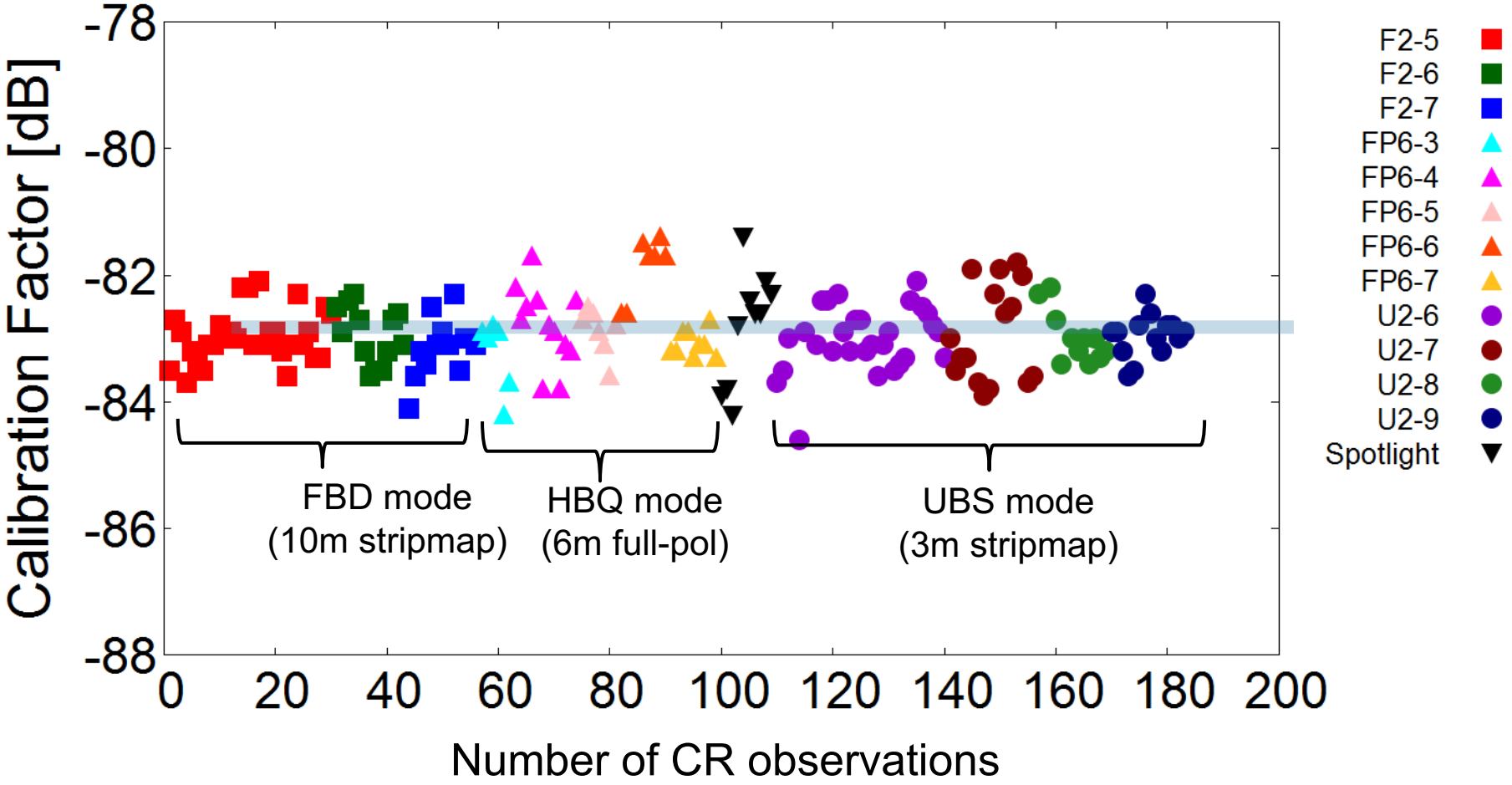
- Elevation antenna pattern correction and CF was updated in March 28, 2017.

Evaluation results of the calibration factor (CF) of previous version and correction values for update version

Mode	Evaluation result			Correction value [dB]
	Points	Mean [dB]	SD [dB]	
Spotlight	9	-81.058	0.729	+1.942
U2-6	29	-81.615	0.446	+1.385
U2-7	18	-81.237	0.812	+1.763
U2-8	14	-81.590	0.389	+1.411
U2-9	15	-81.668	0.329	+1.332
FP6-3	6	-81.040	0.369	+1.960
FP6-4	8	-81.733	0.572	+1.267
FP6-5	4	-82.770	0.495	+0.231
FP6-6	5	-82.477	0.851	+0.523
FP6-7	7	-80.812	0.404	+2.188
F2-5	23	-82.374	0.337	+0.626
F2-6	12	-82.351	0.424	+0.649
F2-7	7	-81.911	0.226	+1.089

Evaluation results of radiometric calibration factor (CF)

- Corner reflector (CR) data
- Observation date: Jul. 2014～Feb. 2017

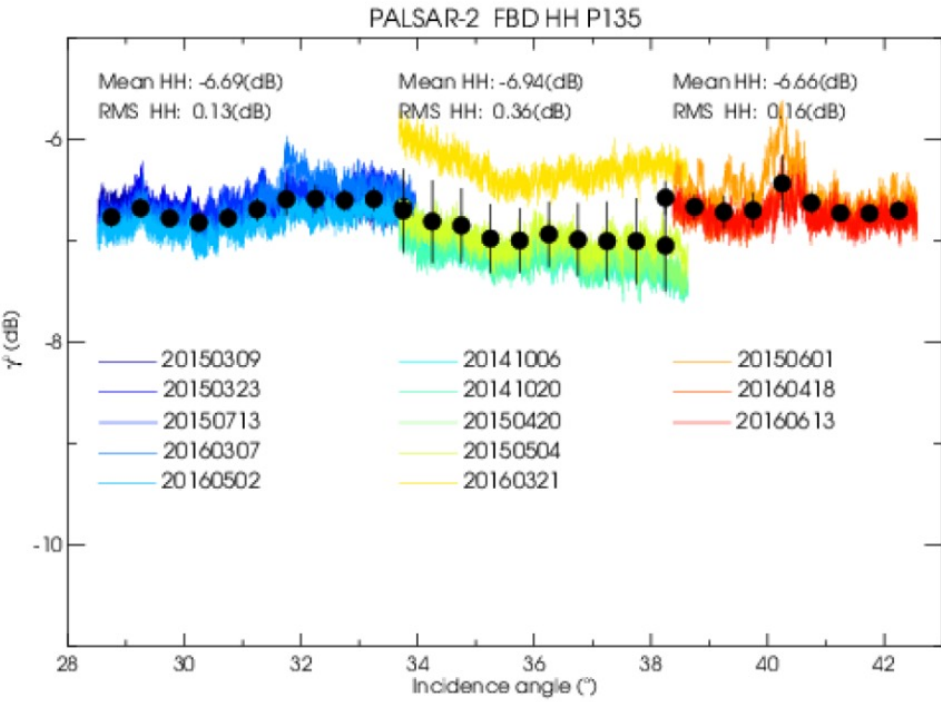


Backscattering coefficient (gamma zero) over Amazonian forests

Stripmap 10 m mode

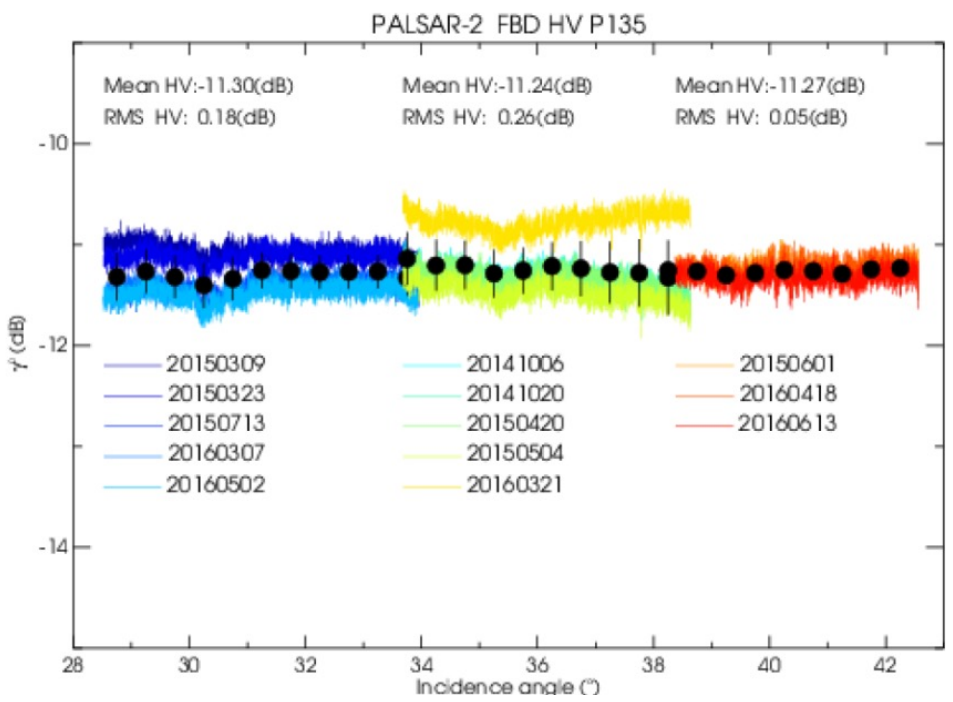
HH-pol.

Beam F2-5 | Beam F2-6 | Beam F2-7



HV-pol.

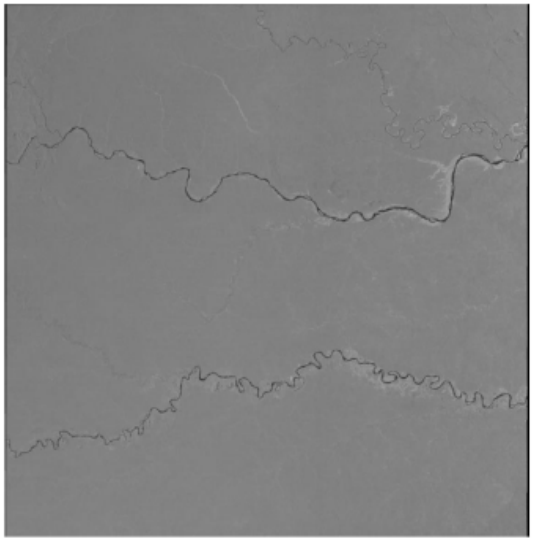
Beam F2-5 | Beam F2-6 | Beam F2-7

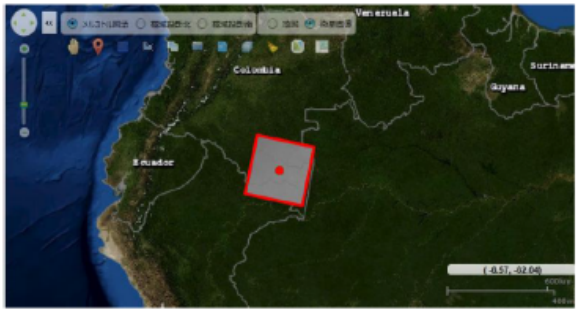


Incidence angle (deg.)

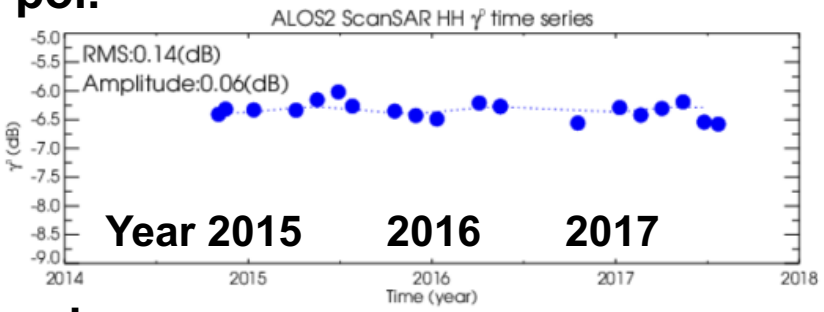
ScanSAR radiometric evaluation over Amazon

Beam W2 Path 135 Frame 3650

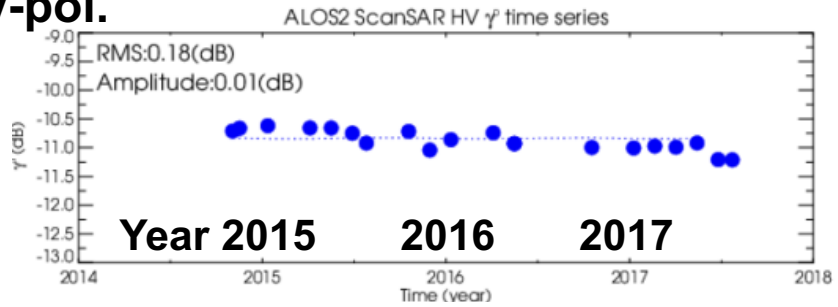


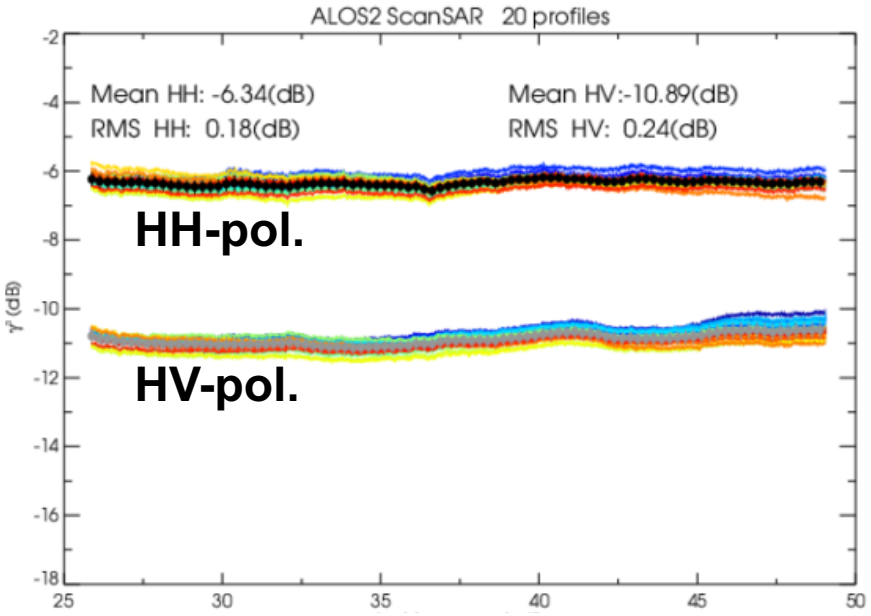


HH-pol.



HV-pol.

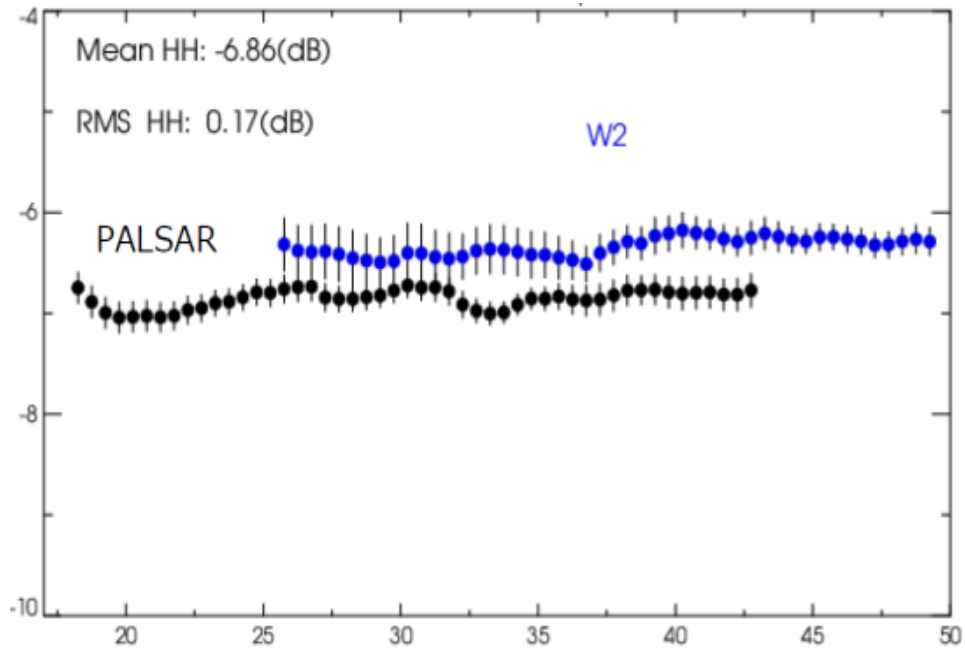




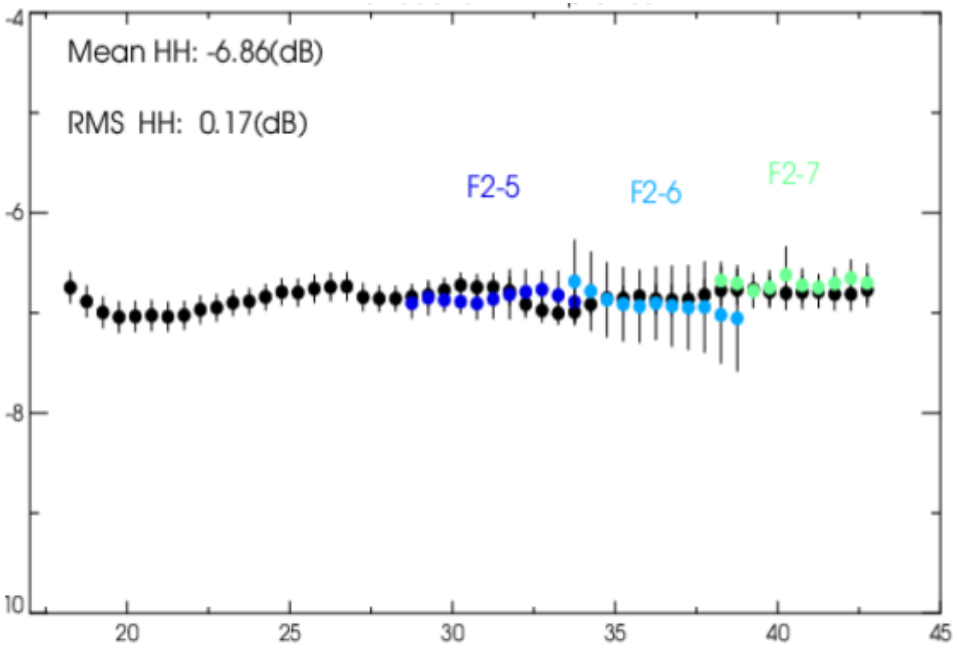
Incidence angle

Comparison with PALSAR ScanSAR data

ScanSAR beam W2



Stripmap 10 m beam F2



Incidence angle (deg.)

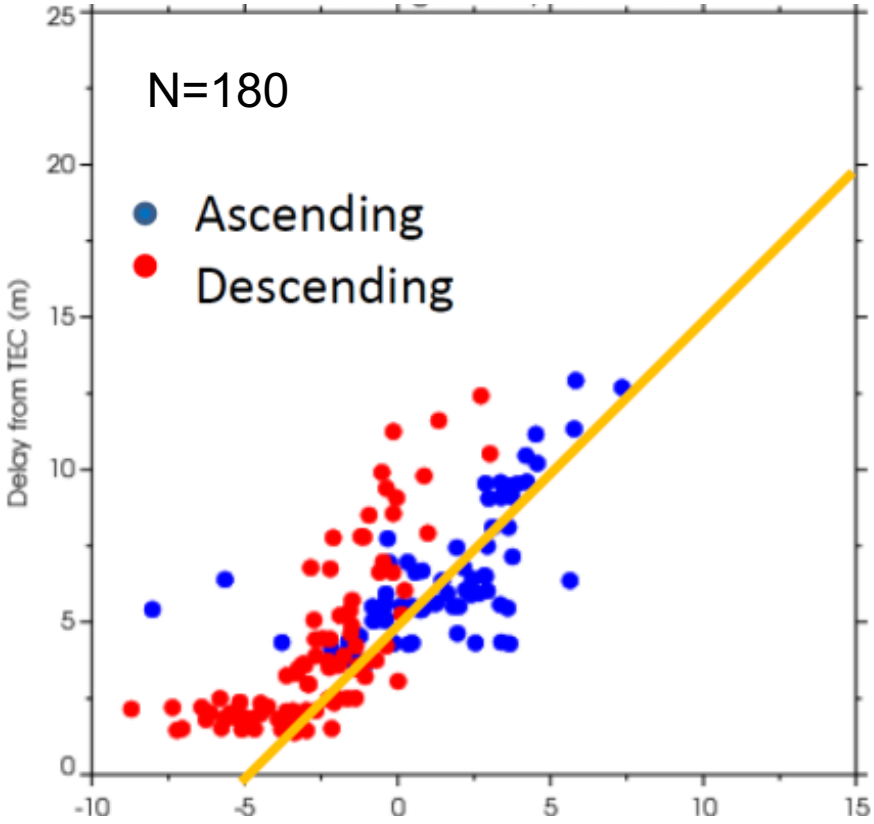
Ionospheric effects on geometric error

Range delay estimated by TEC

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

Δ*s*: path delay due to TEC [m]
K: refractive constant = 40.28 [m3/s2]
TEC: Total electron content [TECU]
f: center frequeny [Hz]
α: off-nadir angle [deg.]

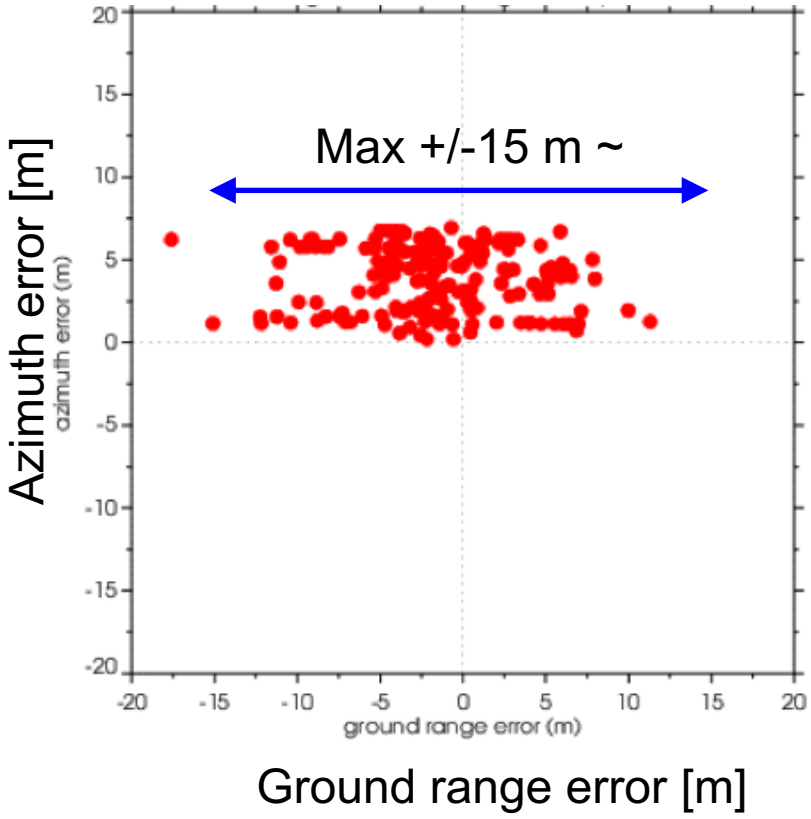
* TEC data from BERN university



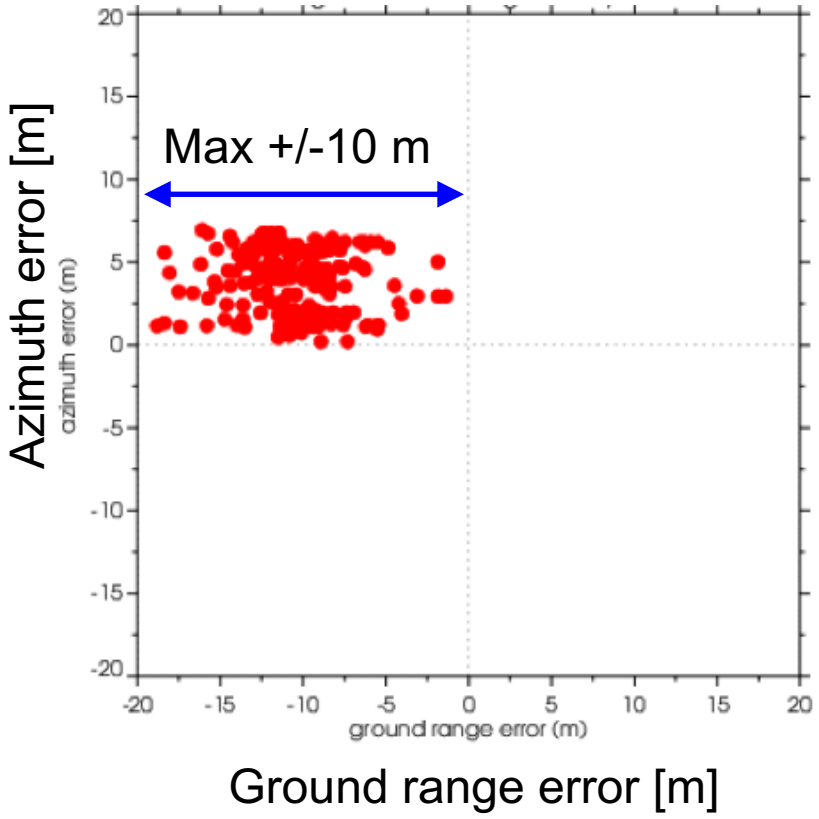
Slant range error (m) from CR data

Correction by TEC information

Before TEC correction

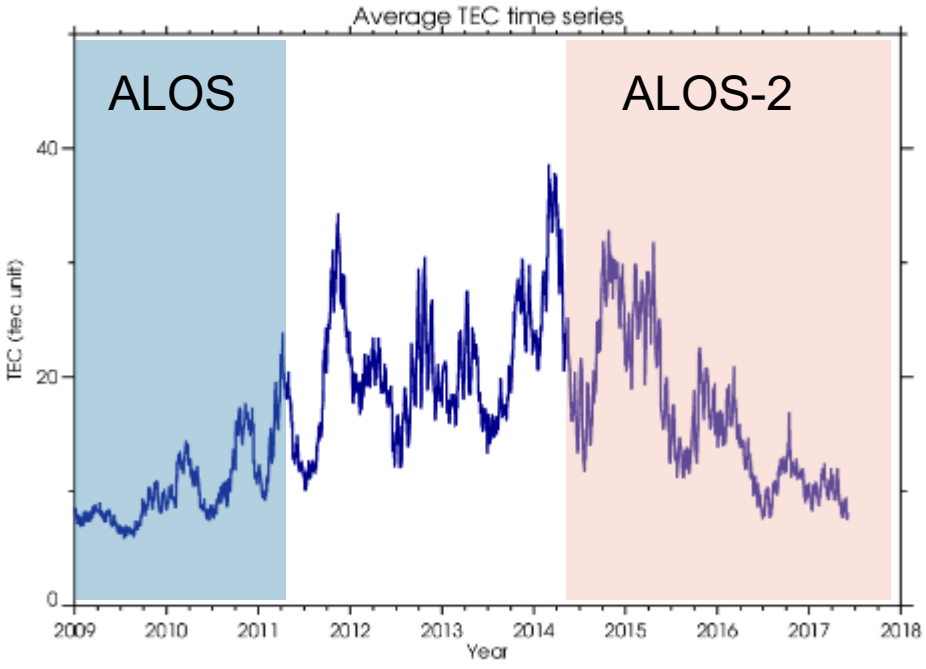


After TEC correction

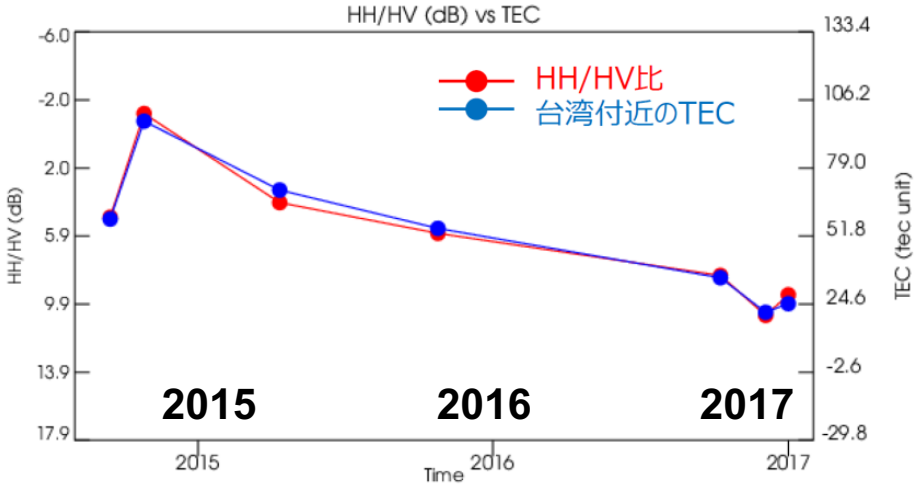


Ionospheric effects on ALOS-2

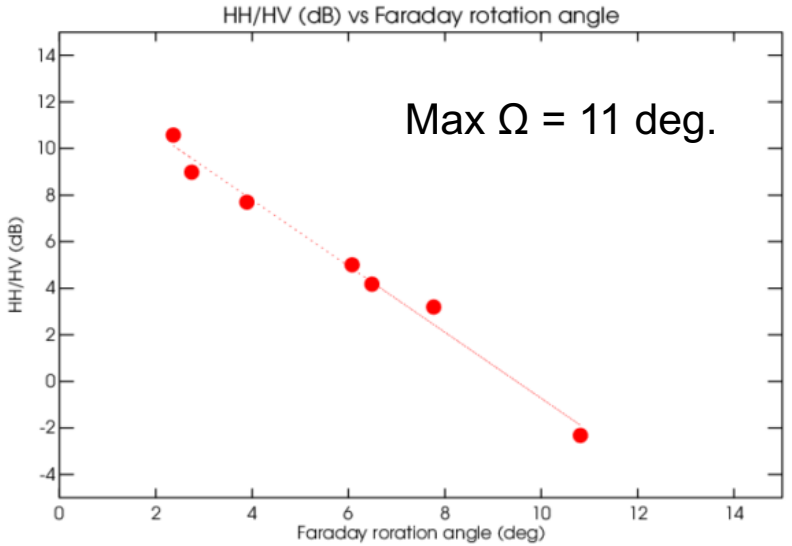
Time-series in average TEC (global)



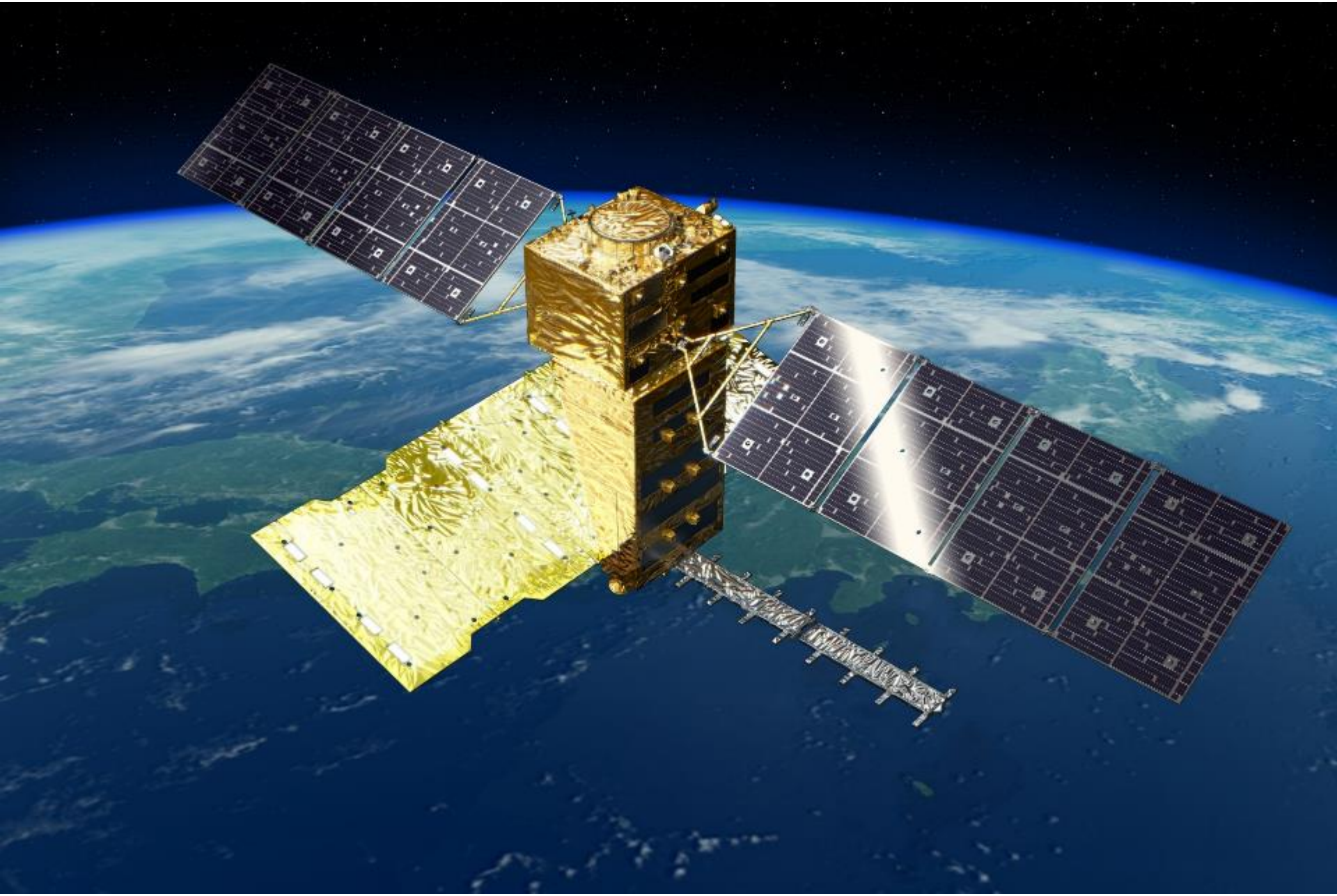
ScanSAR HH/HV over ocean and TEC (around Taiwan)



ScanSAR HH/HV over ocean and Faraday rotation (around Taiwan)



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

High spatial resolution
(1~10 m)

High observation frequency
(> 20 times/year)

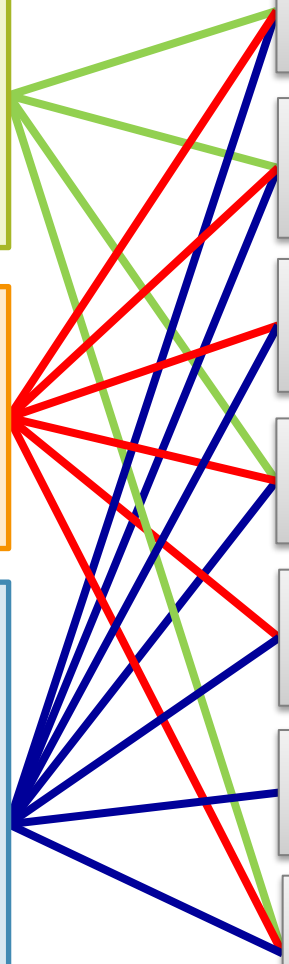
Wide area coverage
(> 200 km swath)

Repeat-pass orbit and the same orbit as ALOS-2

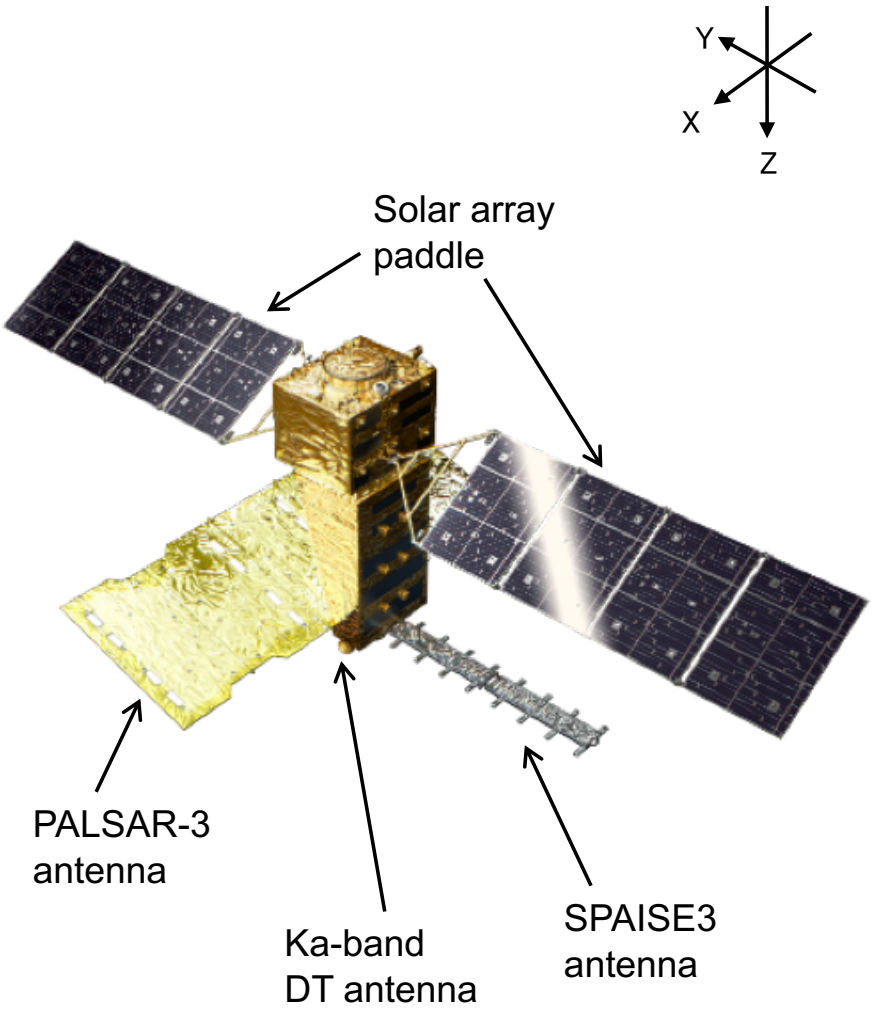
Wide observable range and high-speed data transmission

Polarimetric observation

Long time continuous operation



ALOS-4 System characteristics



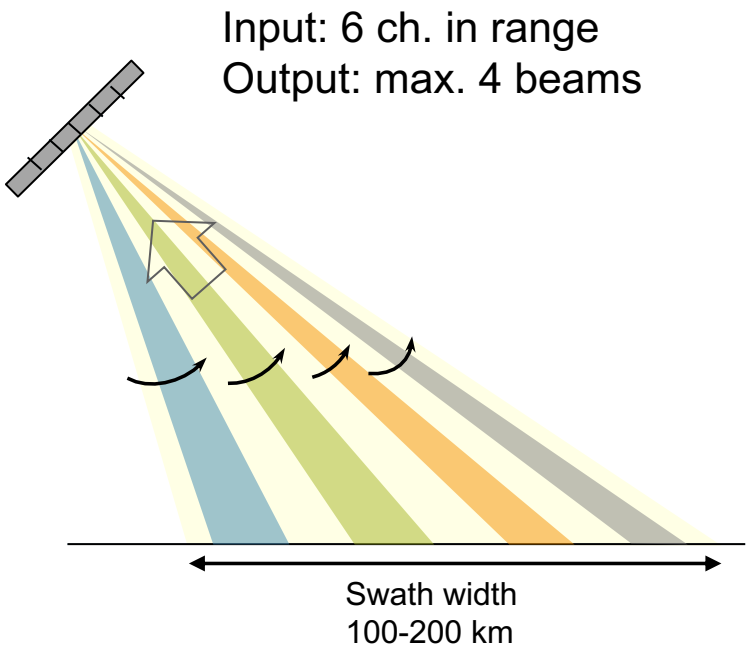
Launch	**JFY 2020** **H3 launch vehicle**
Orbit	**Same orbit as ALOS-2** Sun-synchronous sub-recurrent orbit Altitude: 628 km Inclination angle: 97.9 degree Local sun time at descending: 12:00 ± 15 min. Revisit time: 14 day (15-3/14 rev/day)
Lifetime	**7 years**
Satellite Mass	approx. 3 tons
Downlink	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 3 years and a lot of L-band SAR data have been accumulated.
- 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 B (Preliminary design phase).

JAXA Joint PI Meeting (including ALOS-2 PI meeting)

Date: Jan. 22 (Mon) - 25 (Thu), 2018
Place: Tokyo, Japan
Abstract deadline: Nov. 17 (Fri), 2017

http://suzaku.eorc.jaxa.jp/meeting/jointpi2017/index_en.html
or
Please check EORC ALOS-2 website

PALSAR-2 observation modes

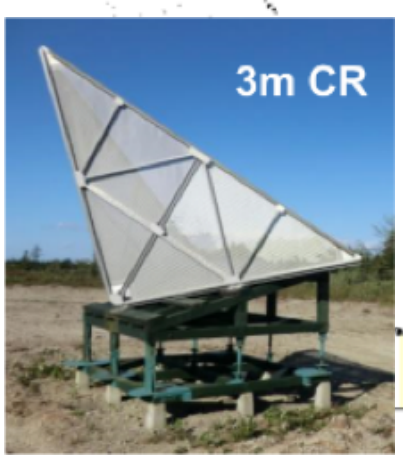
		Spotlight	Ultra Fine	High sensitive	Fine	ScanSAR nominal		ScanSAR wide
Bandwidth		84MHz	84MHz	42MHz	28MHz	14MHz	28MHz	14MHz
Resolution		Rg × Az: 3 × 1m	3m	6m	10m	100m (multilook)		60m (multilook)
Swath		Rg × Az: 25 × 25km	50km	50km	70km	350km (5-scan)		490km (7-scan)
Polarization		SP	SP/DP	SP/DP/QP/CP		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 VV or HV , DP : HH+HV or VV+VH ,
QP : HH+HV+VH+VV , CP : Compact pol (Experimental)

Main applications:

- Fine beam (DP): Forest and land cover monitoring, InSAR
- ScanSAR (DP): Rapid deforestation, wetlands, InSAR
- Spotlight (SP): Emergency observations
- Ultra Fine (SP) : Global map, InSAR base-map
- High sensitive (QP): Global map
- ScanSAR wide (SP) : Polar ice, ocean

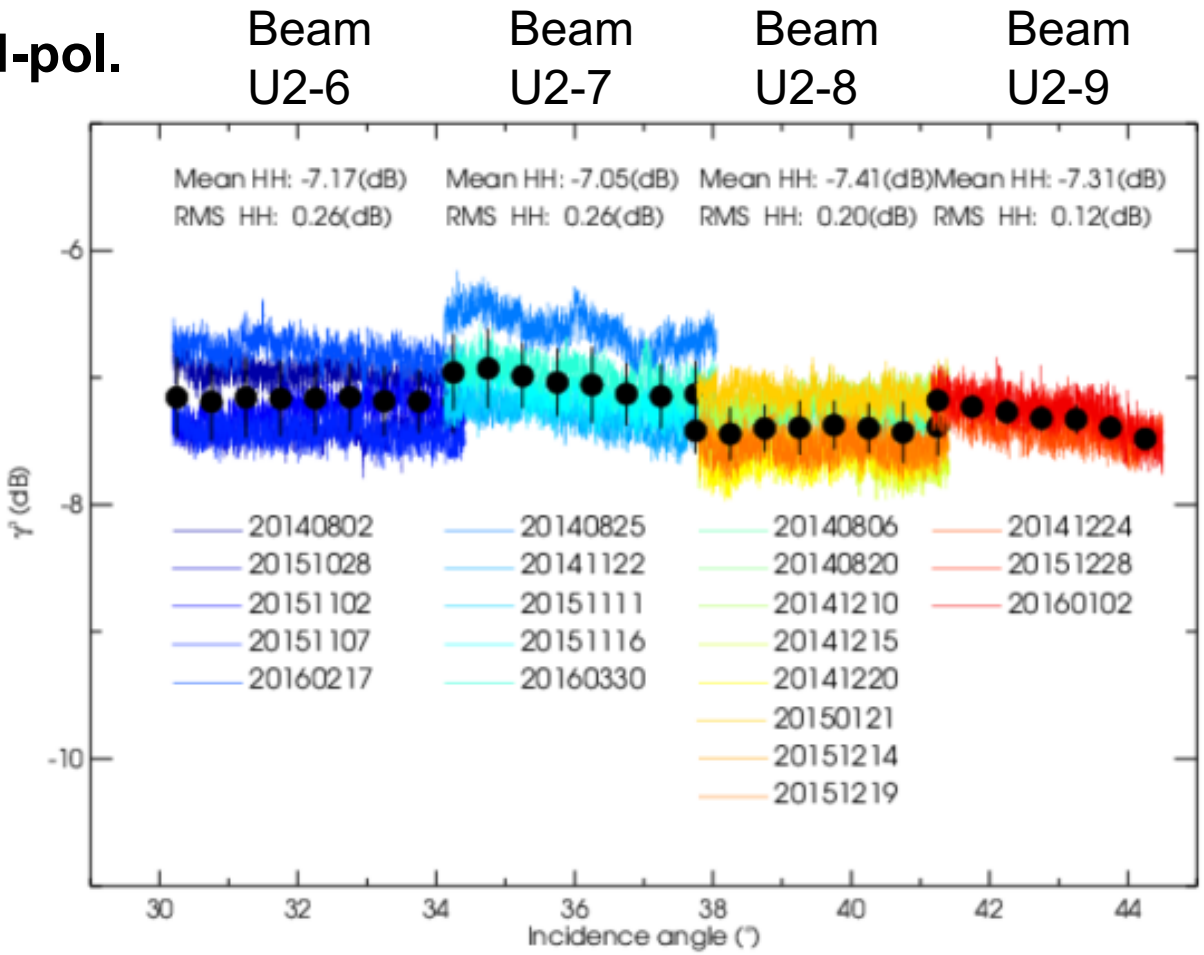
ALOS-2 calibration & validation team sites



Backscattering coefficient (gamma zero) at Amazonian forests

Stripmap 3 m mode

HH-pol.



Incidence angle (deg.)