ALOS-2 PALSAR-2 Cal/Val Updates

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

1. JAXA
2. RESTEC
3. Tokyo Denki University

Joint PI Meeting of Global Environment Observation Mission FY2017
2018/01/24@Tokyo

ALOS-2 Calibration and Validation (Cal/Val)

1. **Internal calibration**
   - ✓ Using the on-board calibration mode every 3 months
   - ✓ Keeping good condition after launch

2. **External calibration**
   - ✓ Product quality of major observation modes has been evaluated regularly using SAR data over the calibration sites.
     - Point target characteristics (resolution, etc.)
     - **Radiometric accuracy**
     - **Geometric accuracy**
     - **Polarimetric calibration**

There are two product types:

① **Standard products (L1.1 ~ L3.1) → This presentation**

② EORC product (SIGMA-SAR) used for the mosaic datasets

PALSAR-2 observation modes

JAXA Cal/Val mainly evaluated the following observation modes:

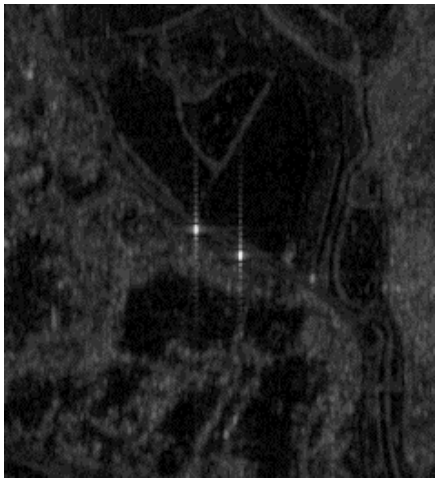
- ✓ Stripmap 3-m single-pol (**UBS**), beam U2-6～9
- ✓ Stripmap 6-m quad-pol (**HBQ**), beam FP6-3～7
- ✓ Stripmap 10-m dual-pol (**FBD**), beam F2-5～7
- ✓ ScanSAR 350-km swath dual-pol (**WBD/WWD**), beam W2

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

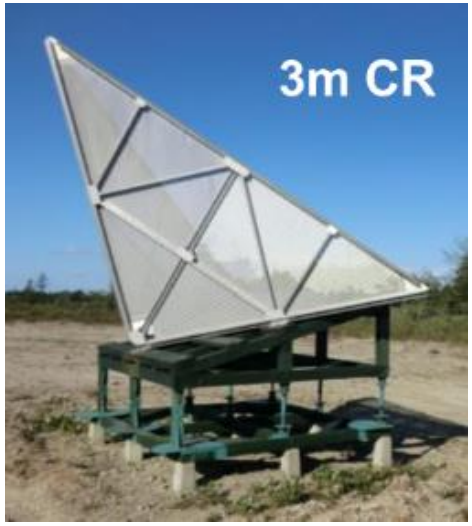
SP: HH or HV or VV, DP: HH+HV or VV+VH, QP : HH+HV+VH+VV
CP : Compact pol (experimental mode)

ALOS-2 Cal/Val sites (Japan)

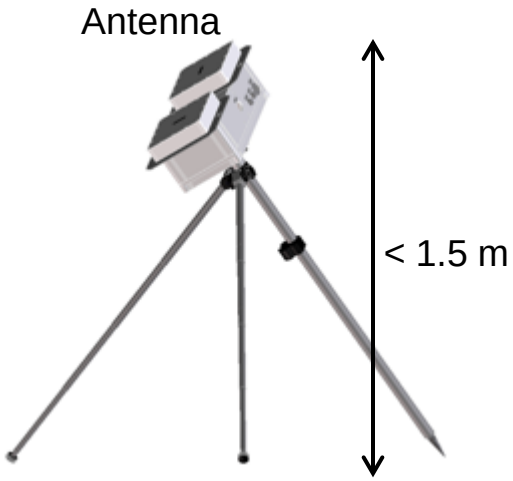
- **Tomakomai, Hokkaido**
  … 4 permanent CRs
- **Kanto region (around Tokyo)**
  … temporally (20-30 times/year)
  CR, ARC/GC, receiver



CR



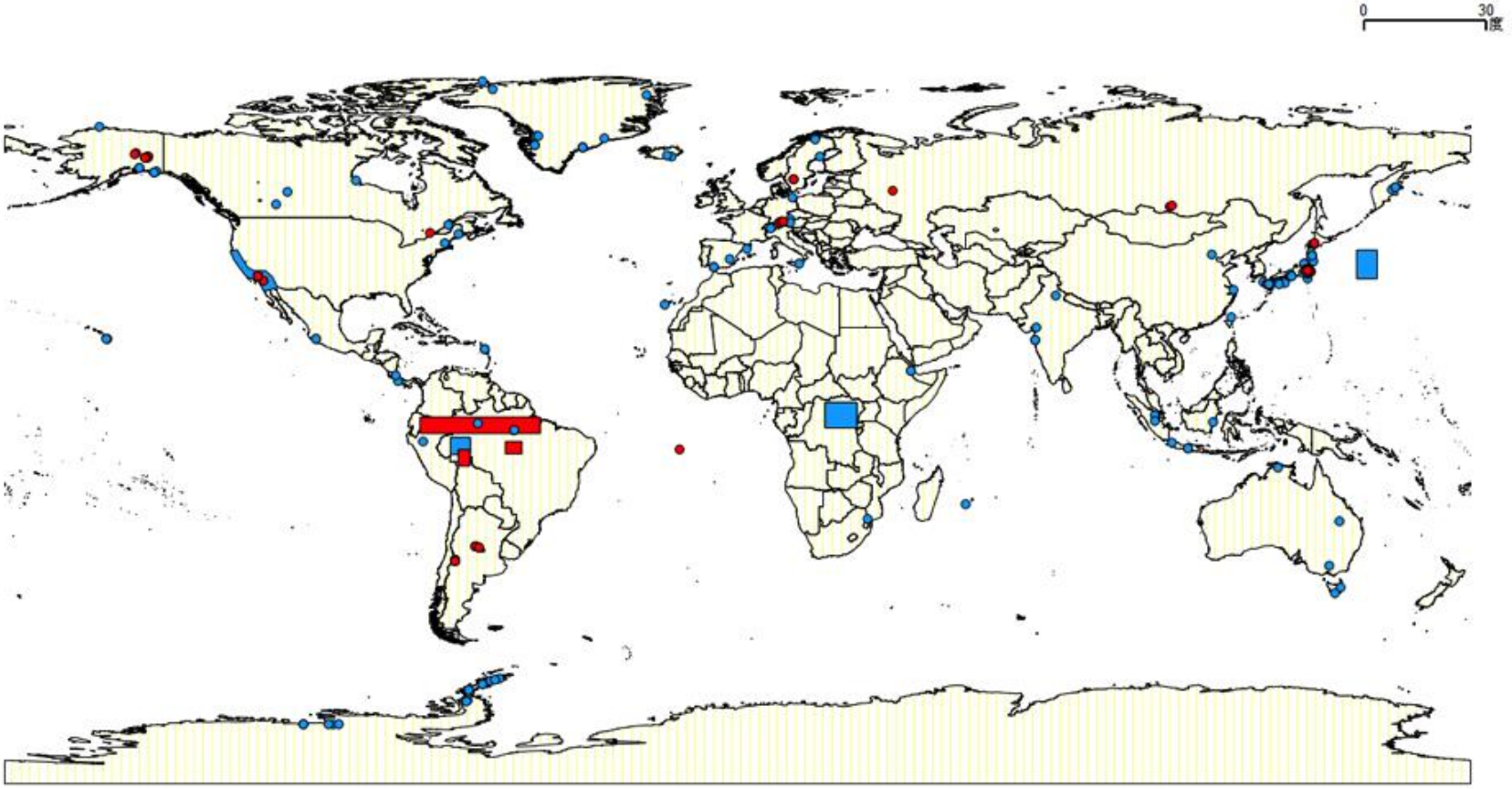
ARC/GC



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



Radiometric calibration

- The Calibration Factor (CF) for radiometric conversion are evaluated by measuring CRs.

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

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

DN: digital number

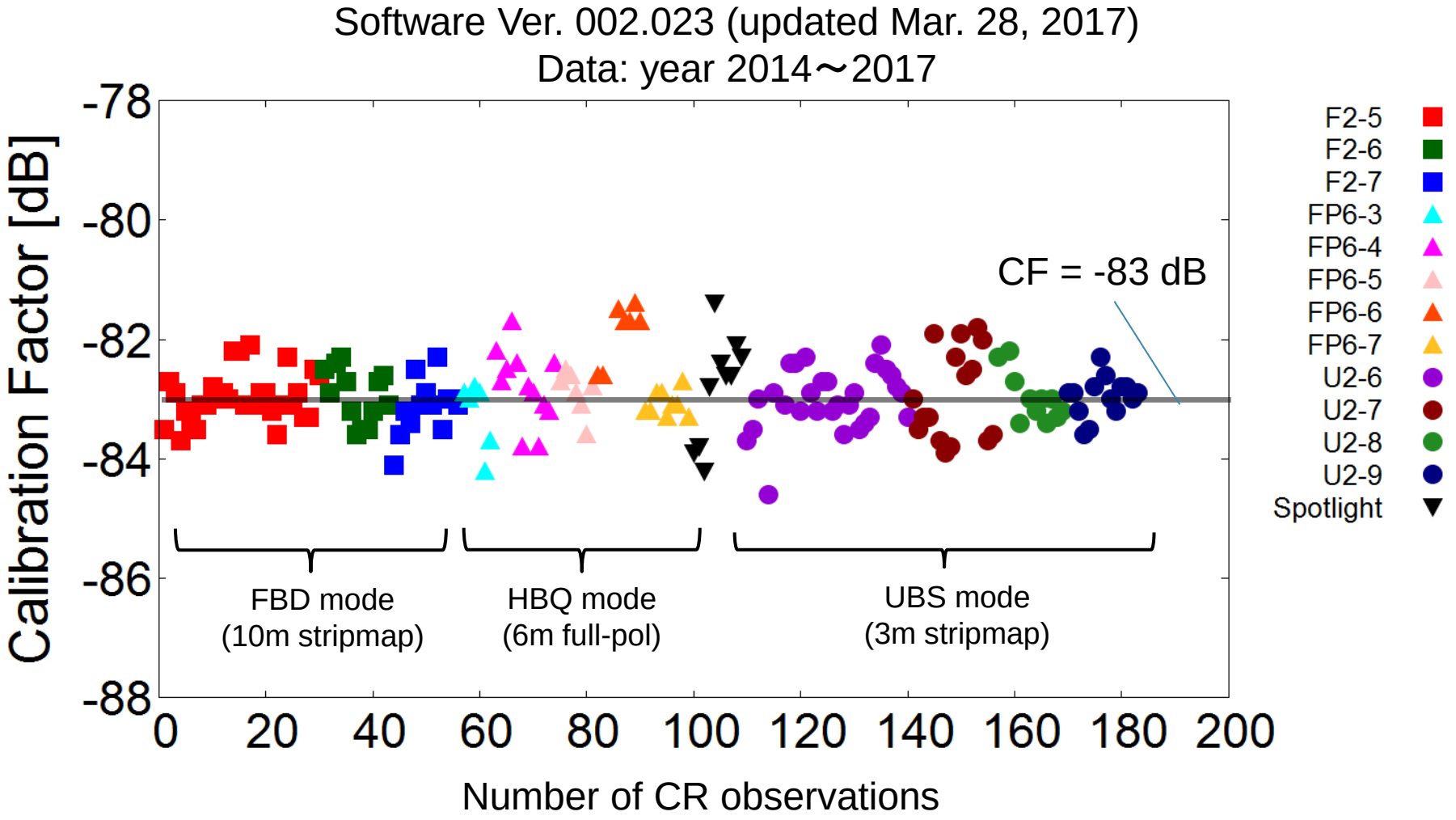
CF = -83 dB

A = 32 dB

- Radiometric calibration factors were updated in March 28, 2017.

Mode	Evaluation result (before update)			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

Radiometric accuracy



Radiometric accuracy

Stability < 0.8 dB

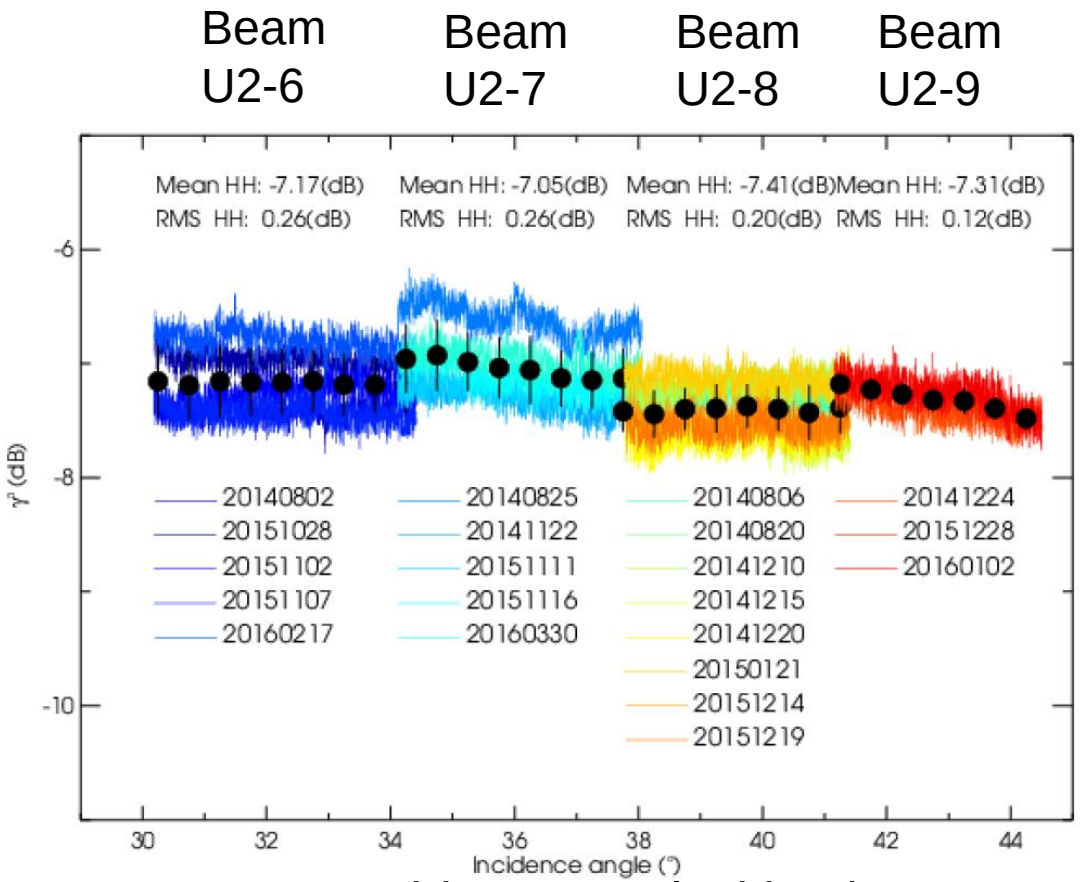
Absolute accuracy < 0.8 dB

Mode	Mean [dB]	SD [dB]	RMS to -83 dB [dB]	n
Spotlight	-83.05	0.79	**0.79**	8
U2-6	-82.92	0.39	**0.40**	28
U2-7	-82.98	0.74	**0.74**	18
U2-8	-82.96	0.36	**0.37**	14
U2-9	-82.97	0.34	**0.34**	14
FP6-3	-83.33	0.59	**0.69**	7
FP6-4	-82.78	0.63	**0.67**	12
FP6-5	-82.99	0.45	**0.45**	8
FP6-6	-82.59	0.03	**0.59**	2
FP6-7	-83.06	0.21	**0.22**	9
F2-5	-82.97	0.42	**0.42**	30
F2-6	-82.94	0.44	**0.45**	13
F2-7	-83.15	0.47	**0.48**	13

Radiometric accuracy

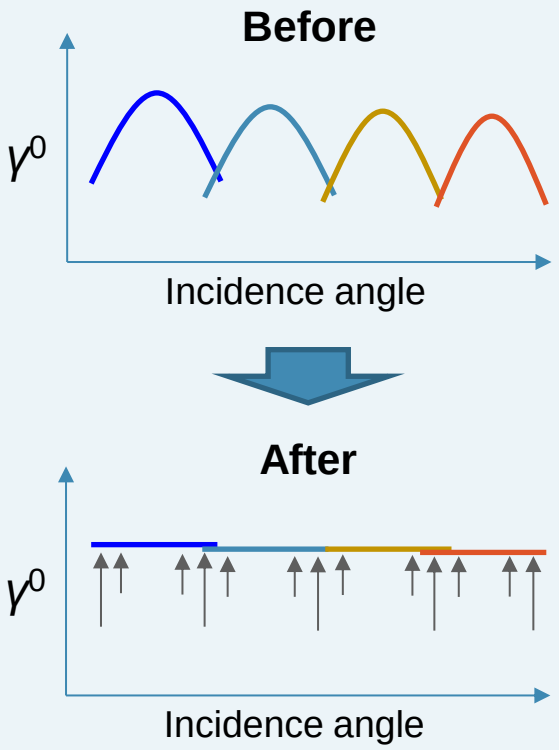
- Range profiles of backscattering coefficient (gamma naught format) at Amazonian forests

Stripmap 3 m mode (HH)



Incidence angle (deg.)

Antenna pattern correction



* Flat and homogeneous area

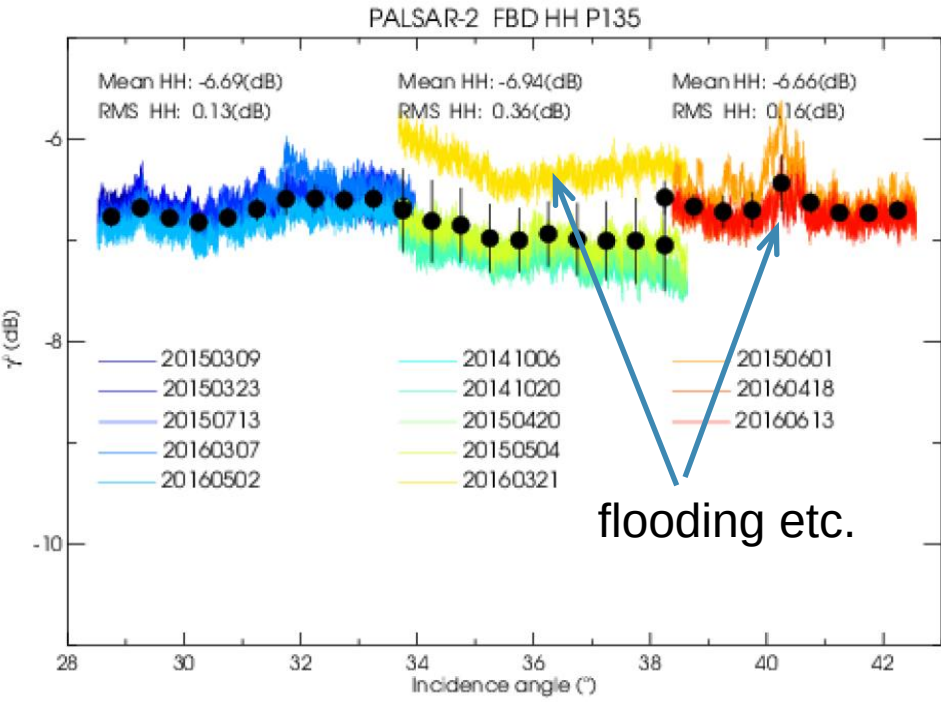
Radiometric accuracy

- Range profiles of backscattering coefficient (gamma naught format) at Amazonian forests

Stripmap 10 m mode

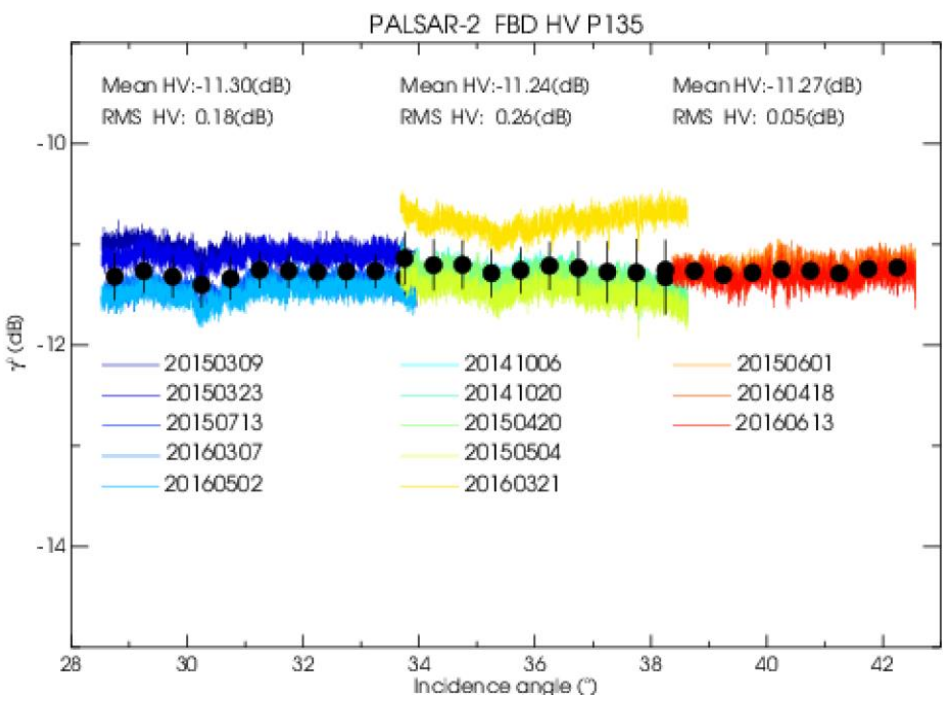
HH-pol.

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



HV-pol.

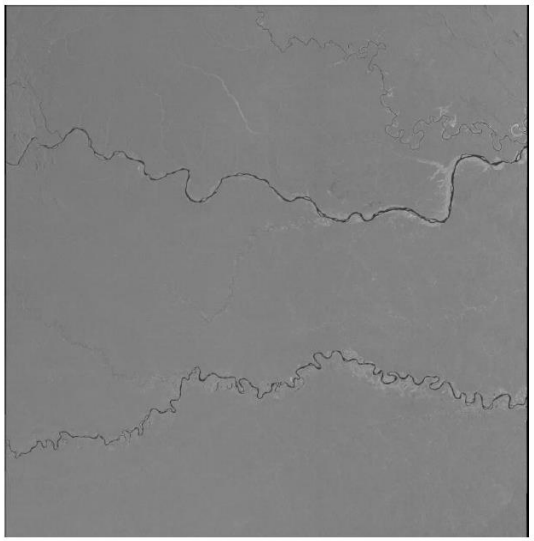
Beam F2-5 | Beam F2-6 | Beam F2-7

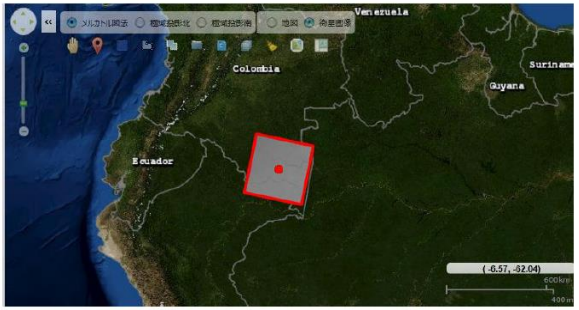


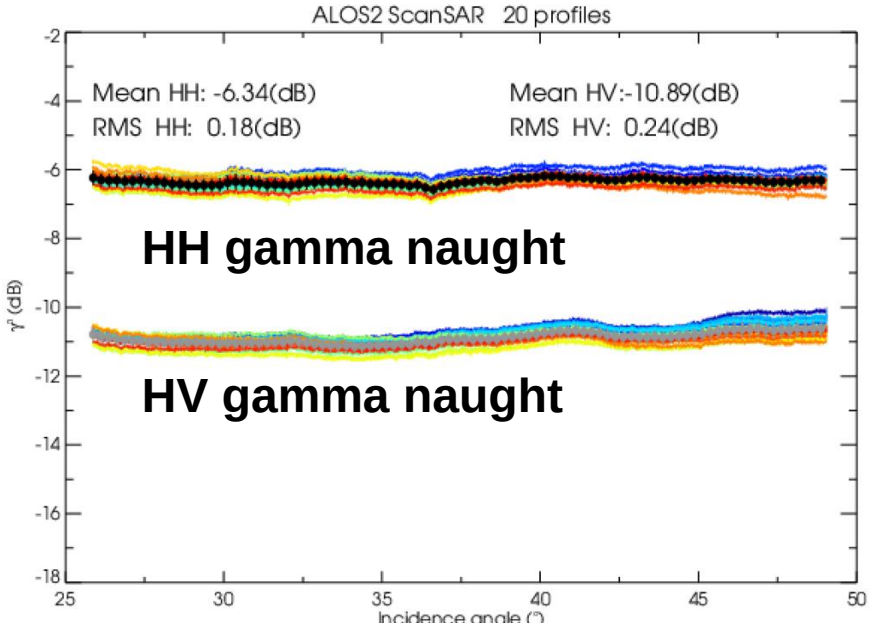
Incidence angle (deg.)

ScanSAR radiometric evaluation over Amazon

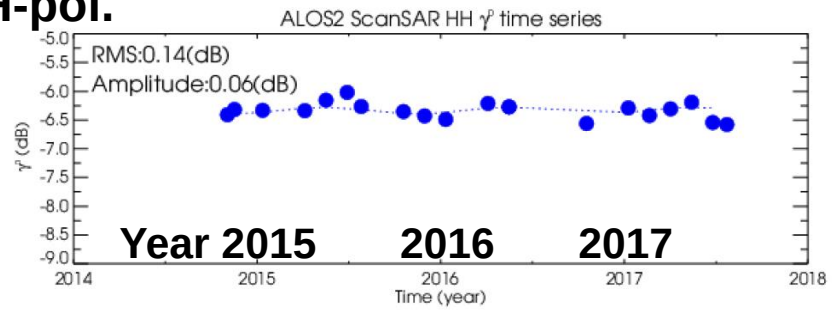
Beam W2 Path 135 Frame 3650



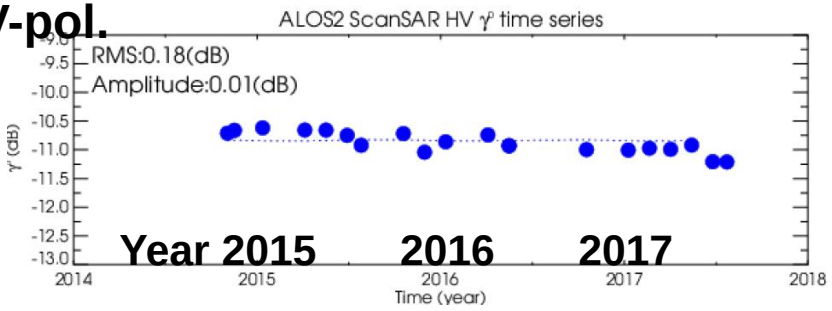




HH-pol.



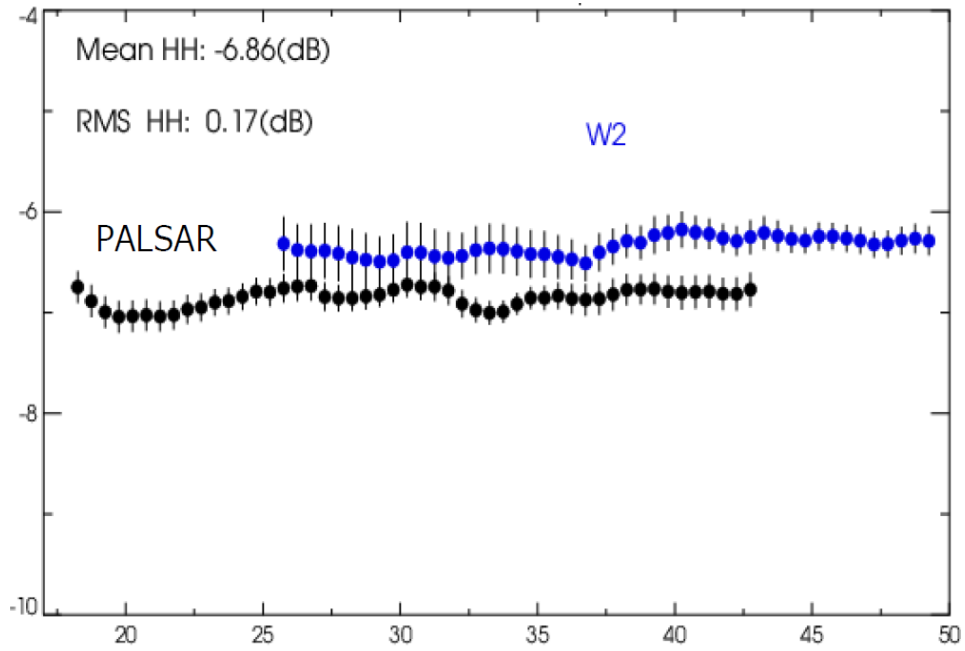
HV-pol.



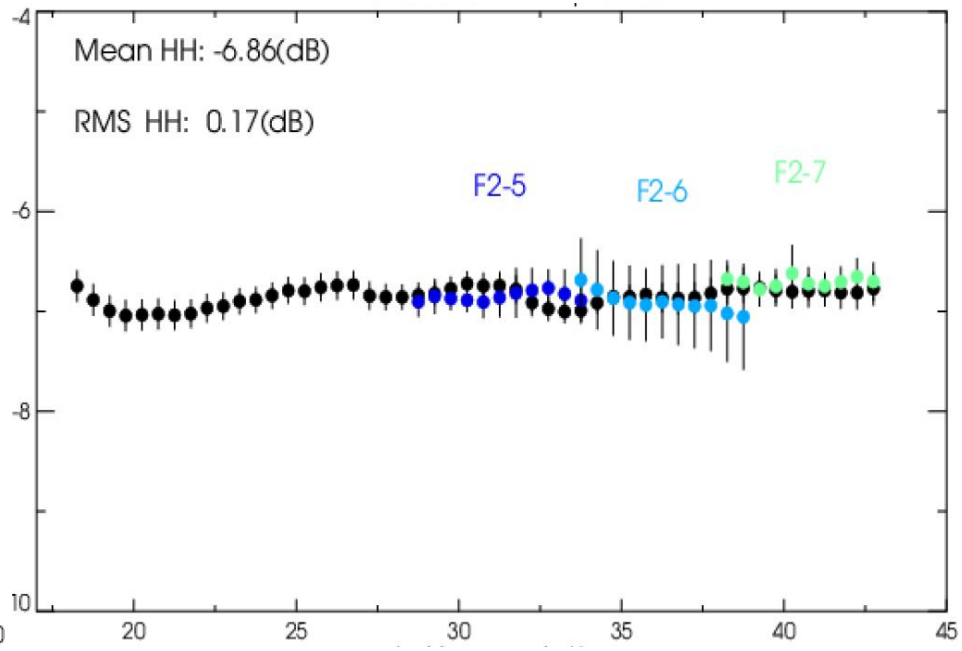
Incidence angle

Comparison with PALSAR ScanSAR data

ScanSAR beam W2



Stripmap 10 m beam F2



Incidence angle (deg.)

Geometric accuracy

- Differences between CR responses in L1.1/L1.5 images and in situ GPS measurements.

Absolute accuracy (RMS) < 9 m

Mode	X (west-east) [m]		Y (north-south) [m]		n
	bias	RMS	bias	RMS	
Spotlight	-6.35	8.24	1.50	3.47	10
U2-6	-2.55	7.57	-2.22	4.42	37
U2-7	-2.28	4.58	-0.53	2.72	18
U2-8	-2.32	4.15	0.25	3.93	20
U2-9	-2.33	4.38	-1.77	3.99	17
FP6-3	-3.60	4.01	3.31	3.56	8
FP6-4	-6.25	8.00	3.65	4.02	12
FP6-5	-3.56	4.29	3.88	4.17	9
FP6-6	1.65	4.15	0.90	3.27	12
FP6-7	-1.48	3.46	4.08	4.44	10
F2-5	-4.07	6.15	-1.05	4.25	33
F2-6	-7.86	8.84	-1.53	2.69	14
F2-7	-1.86	3.95	-2.12	3.71	14

Geometric accuracy

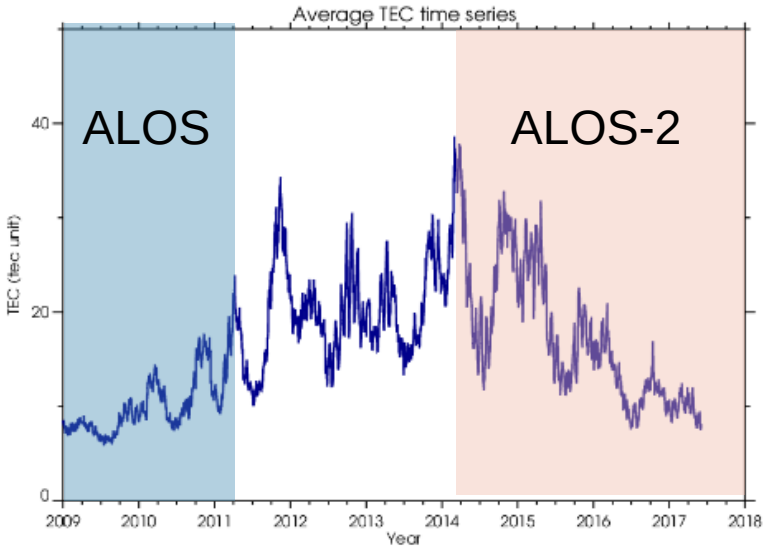
■ Geometric accuracy and orbit data → small differences

Beam U2 and FP6, May-Sep. 2017, Japan

Orbit data type	X [m]		Y [m]	
	bias	SD	bias	SD
On-board (accuracy < 100 m)	0.02	4.07	-0.79	4.12
Precise (accuracy < 1 m)	-0.77	3.32	-0.85	4.72

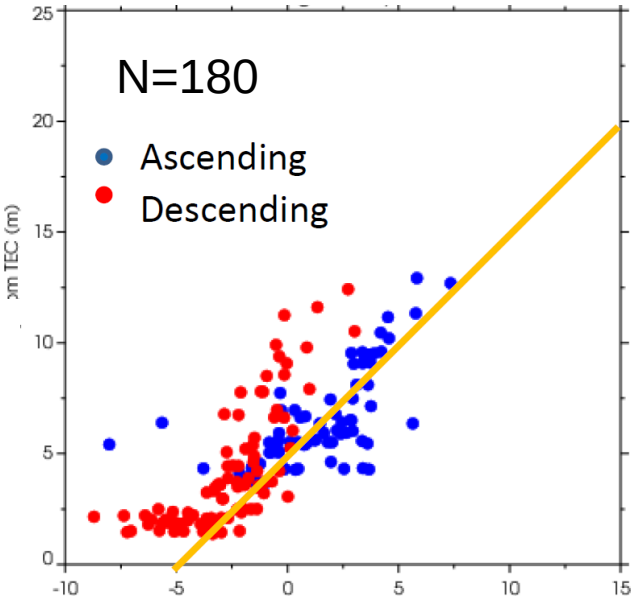
■ Geometric accuracy and TEC → strong correlation

Time series in global average TEC



Range delay estimated by TEC (m)

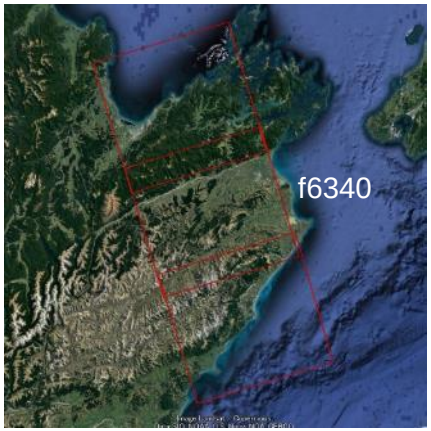
$$\Delta s = K \frac{TEC}{f^2 \cos\alpha}$$



Geometric error in slant range (m)

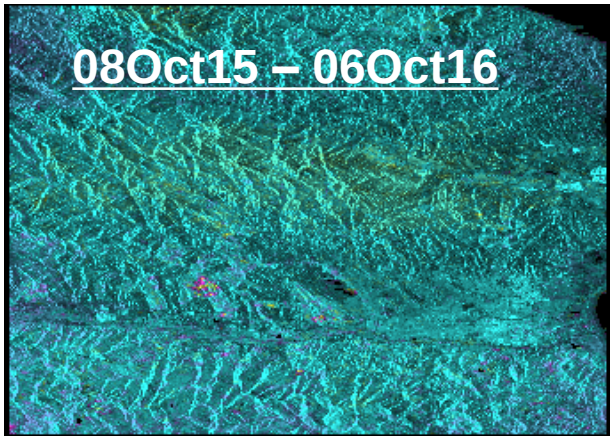
Geometric accuracy

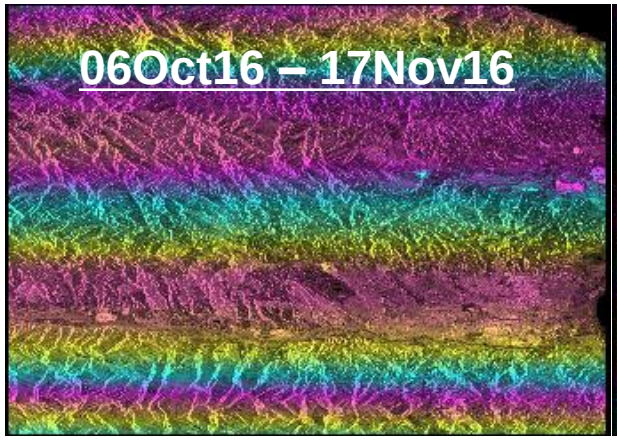
- Range offset anomaly occurred in some Stripmap 10-m observations … under investigation
  - -6 to +8 meters in the following example

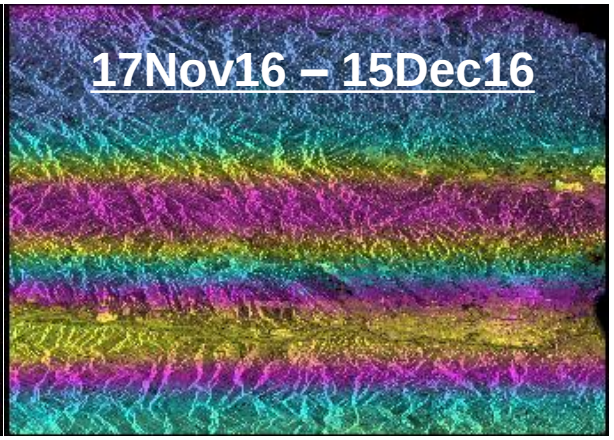


Observations over NZ

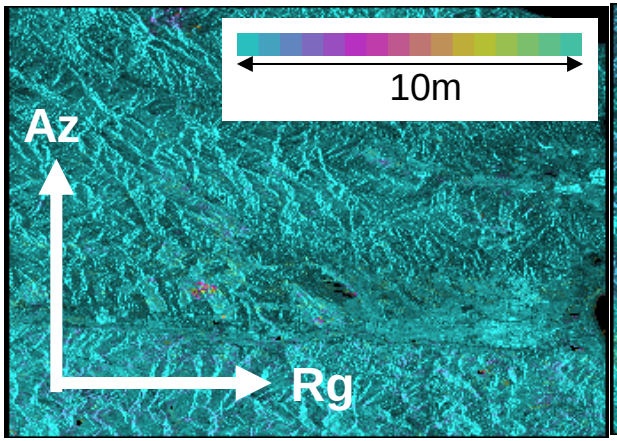
Range offset

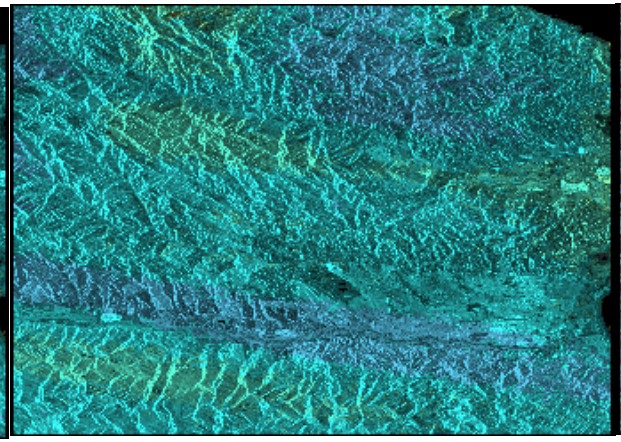


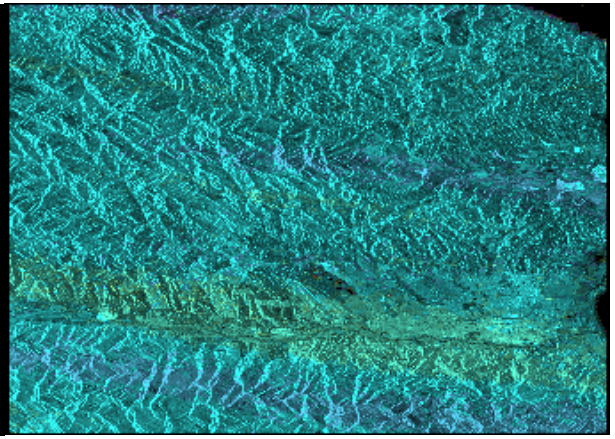




Azimuth offset





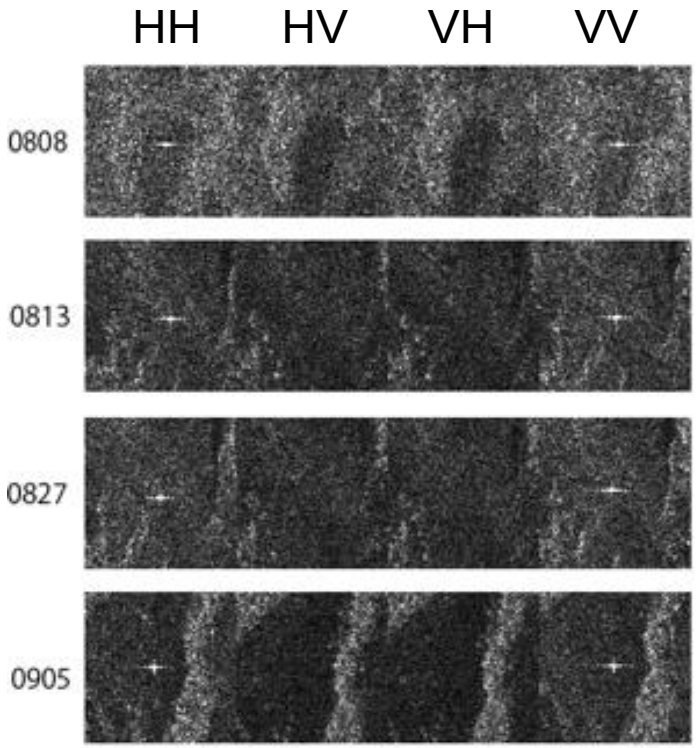


Polarimetric calibration

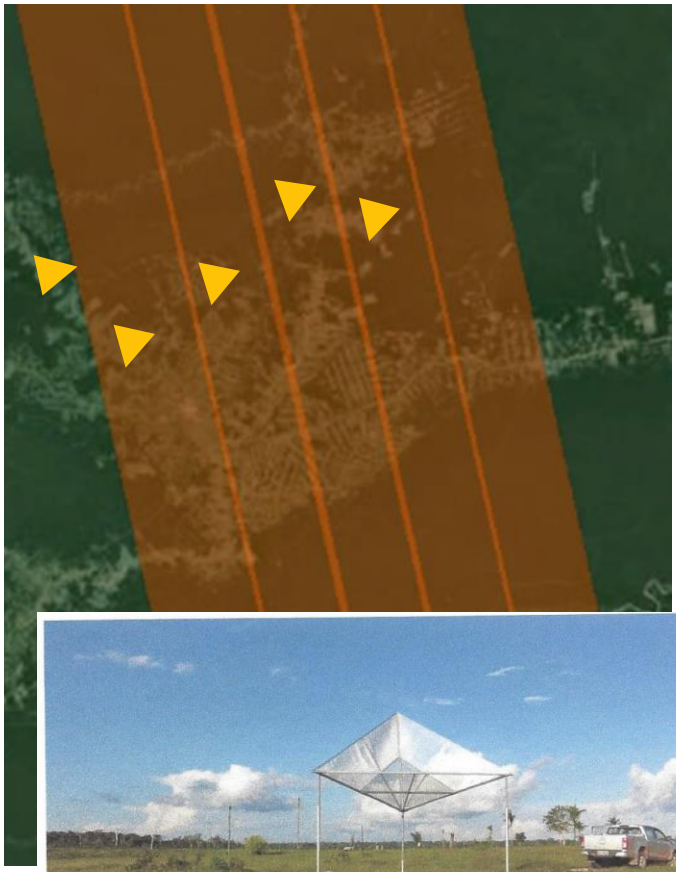
- ✓ Determine unknown parameters (Amazon forest+CRs, reflection symmetry and Model-based analysis)

$$\begin{pmatrix} Z_{hh} & Z_{hv} \\ Z_{vh} & Z_{vv} \end{pmatrix} = Ae^{\frac{-4\pi r}{\lambda}} \begin{pmatrix} 1 & d_3 \\ d_4 & f_2 \end{pmatrix} \begin{pmatrix} \cos\Psi & \sin\Psi \\ -\sin\Psi & \cos\Psi \end{pmatrix} \begin{pmatrix} S_{hh} & S_{hv} \\ S_{vh} & S_{vv} \end{pmatrix} \begin{pmatrix} \cos\Psi & \sin\Psi \\ -\sin\Psi & \cos\Psi \end{pmatrix} \begin{pmatrix} 1 & d_1 \\ d_2 & f_1 \end{pmatrix} + \begin{pmatrix} N_{hh} & N_{hv} \\ N_{vh} & N_{vv} \end{pmatrix}$$

PALSAR-2 images over CR



5 CRs (3.0 x 3.0 x 4.24 m) in Rio Branco, Brazil



Polarimetric calibration

- JAXA has corrected a bias of about 20 degrees in the VV-HH phase difference for beam FP6-4 and FP6-6 (software updated in **March 28, 2017**)

Before update of the polarimetric calibration

Beam	VV-HH Imbalance		Cross talk	
	Amplitude ratio	Phase difference [deg.]	HV/HH [dB]	HV/VV [dB]
FP6-3	1.01	0.7	-46.9	-47.6
FP6-4	1.01	**23.4**	-45.8	-39.8
FP6-5	0.99	1.8	-44.4	-42.9
FP6-6	0.99	**22.0**	-41.3	-38.8
FP6-7	1.01	1.8	-43.2	-41.0

After update of the polarimetric calibration

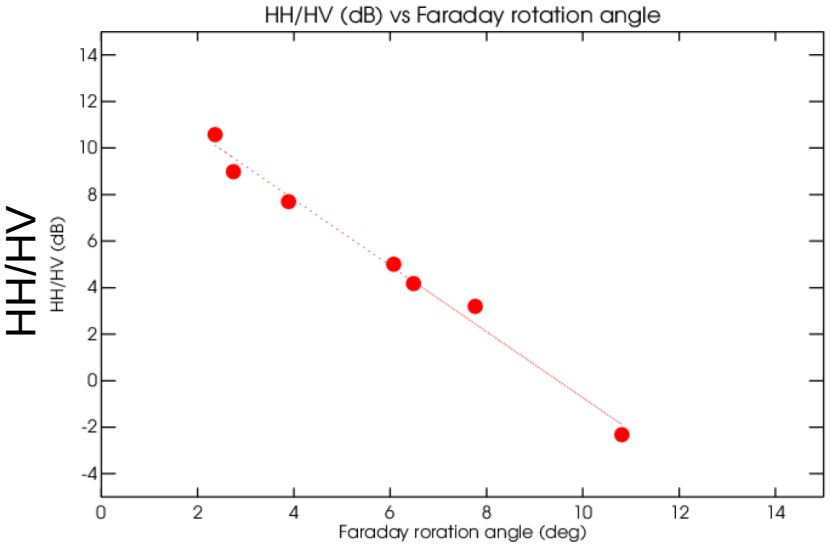
Beam	VV-HH Imbalance		Cross talk	
	Amplitude ratio	Phase difference [deg.]	HV/HH [dB]	HV/VV [dB]
FP6-3	1.00	0.04	-47.8	-47.6
FP6-4	1.00	**0.14**	-41.3	-40.3
FP6-5	1.00	-0.11	-43.5	-43.6
FP6-6	1.00	**0.41**	-48.9	-44.4
FP6-7	1.00	0.69	-42.4	-41.5

Polarimetric calibration

- Faraday rotation by ionosphere may affect on PALSAR-2 observations

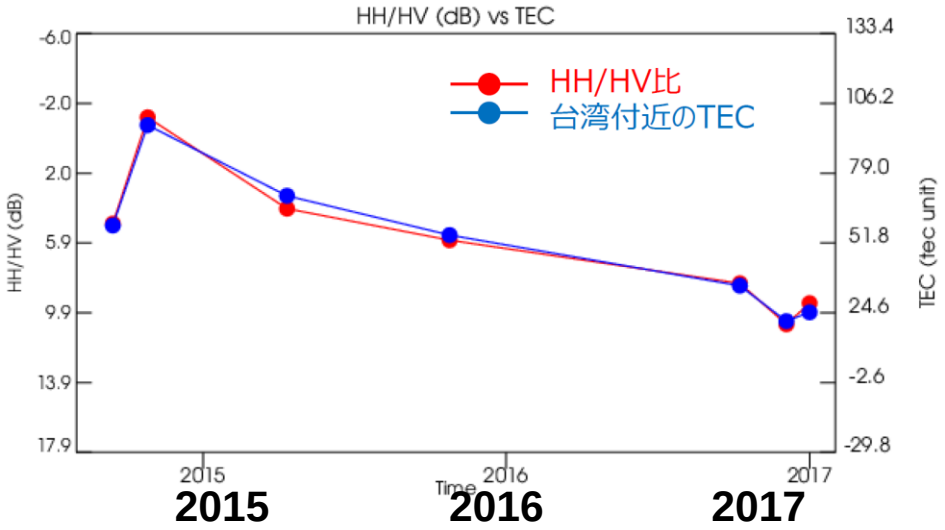
ScanSAR data over ocean around Taiwan

ScanSAR HH/HV ratio v.s. Faraday rotation angle by TEC



Faraday rotation angle derived from TEC

Time-series in ScanSAR HH/HV ratio and TEC



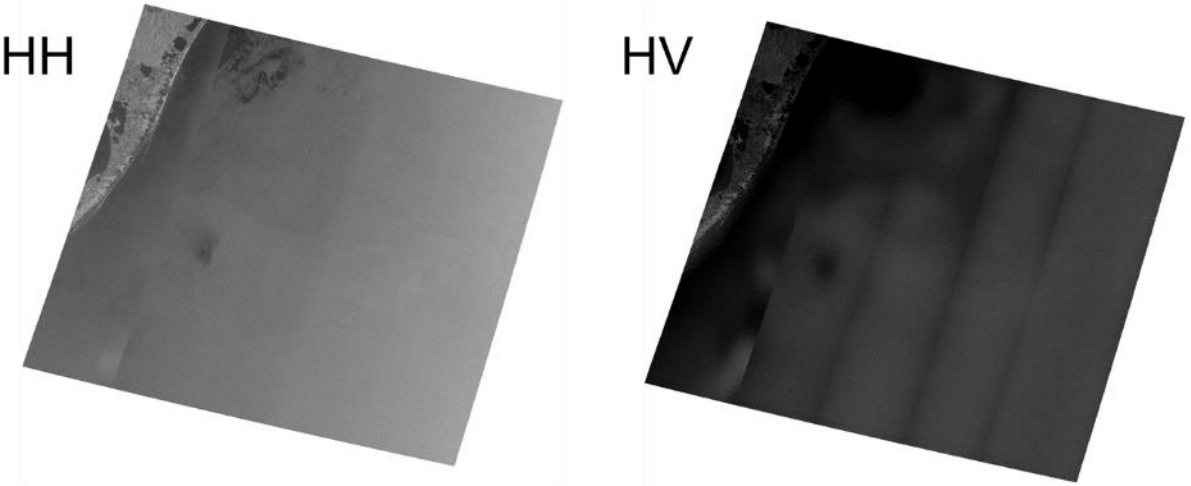
Other issues

- ScanSAR HV-pol images near ocean sometimes become blurred or dark
  … To solve the issue, changing the attenuator (ATT) setting is planned.

Now

ALOS2117174250_160724

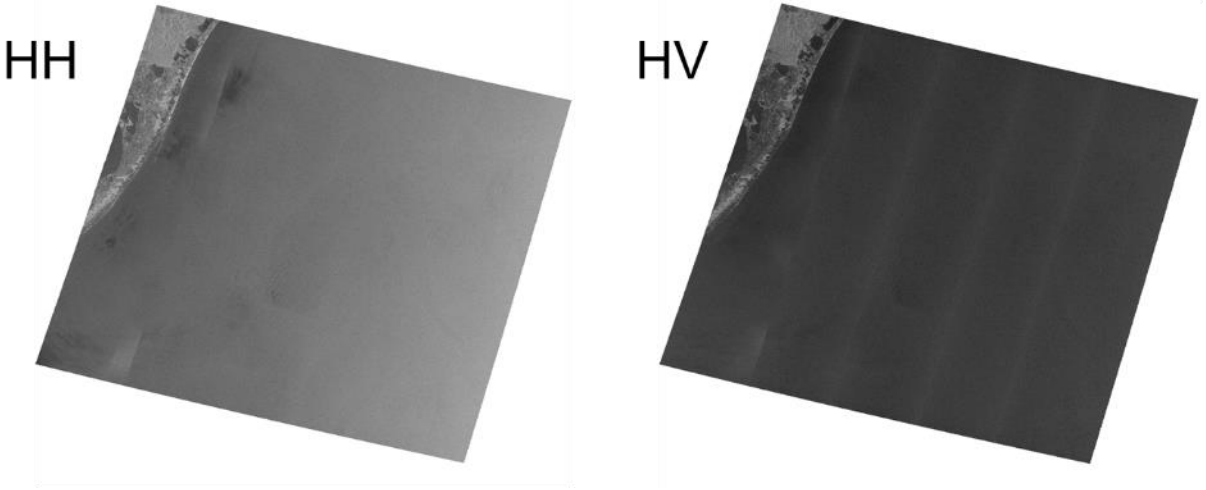
ATT 25 dB
2016/07/24



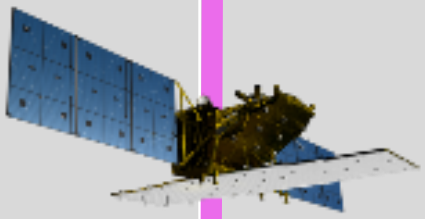
After change

ALOS2191694250_171210

ATT 20 dB
2017/12/10



ALOS series development/operation



2014	2015	2016	2017	2018	2019	2020	2021

ALOS-2 (L-SAR)

May 24 Launch

Initial C/O

Initial Cal-Val

Product release

Mission operation (5 years)

Post-mission operation

ALOS-3 (Optical)

Development

ALOS-4 (L-SAR)

Development

Cal/Val activities for ALOS-4

For ALOS-4 cal/val activities …

- Calibration method for new system (e.g., DBF-SAR)
- Calibration sites
- Cross calibration with ALOS-2 and increasing L-band satellites
- Experimental operation for future R&D

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.

- Update information of Cal/Val are on the JAXA/EORC ALOS website:

  http://www.eorc.jaxa.jp/ALOS-2/en/calval/calval_index.htm

  - ✓ Cal/Val results
  - ✓ Radiometric calibration factor (CF)
  - ✓ Distortion matrices for pol-cal.