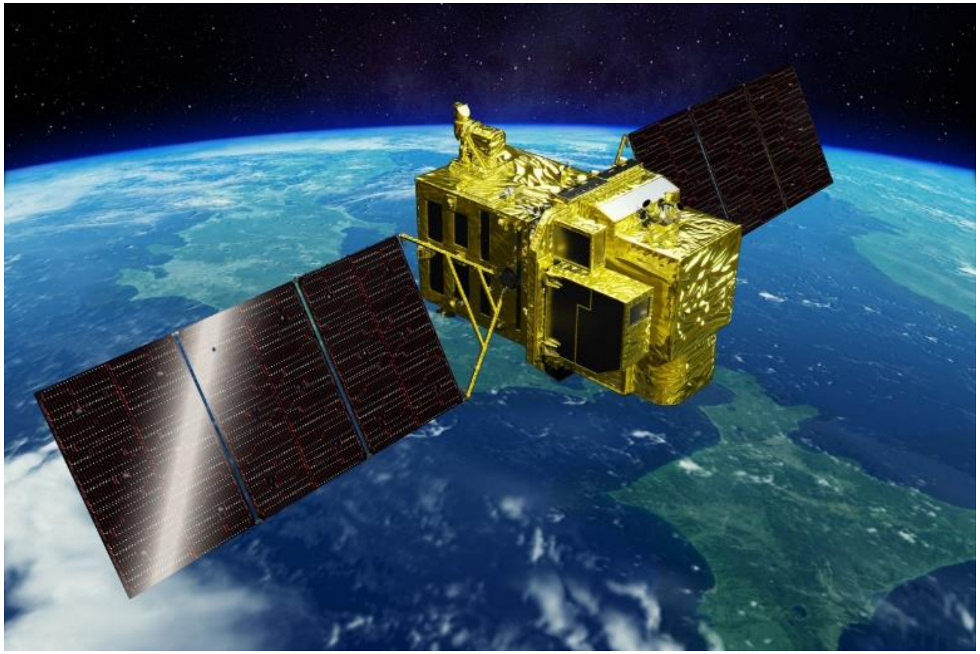
Calibration and Validation Plan of the Advanced Optical Satellite (ALOS-3)



21 November, 2019

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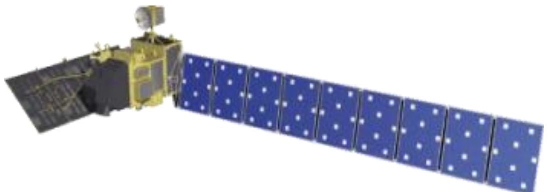
ALOS F/O Missions

- Continuous observation from the Advanced Land Observing Satellite (ALOS)
  - Contribute to ensure the <u>safety and security of the people</u>, *i.e.* disasters monitoring and management, national developing management, foods and natural resources, environmental issues in global etc. as common issues
  - Contribute to industrial development based on Earth observation data *i.e.* <u>National Spatial Data infrastructure (NSDI)</u>

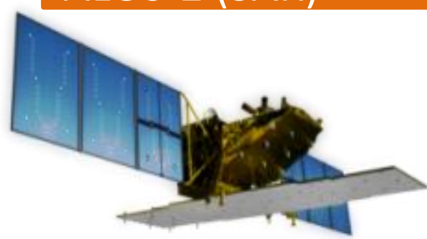
Jan. 2006 | May 2011 | May 2014 | JFY2020 (Target)

Daichi (ALOS)
(Optical & SAR)



Optical: PRISM, AVNIR-2
SAR: PALSAR

ALOS-2 (SAR)



May 24, 2014
SAR: PALSAR-2

- L-band Synthetic Aperture Radar
- Observe in night time and rain
- Wide swath (~490km) and fine resolution (1-3m)

Next Optical

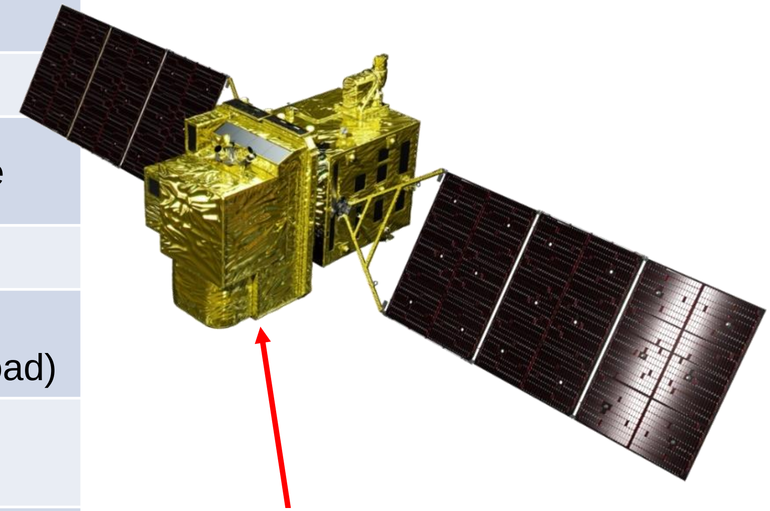
- Panchromatic band : 0.8m
- Multispectral band (6 bands): 3.2m
- Observation swath: 70km at nadir
- Body pointing capability for emergency disaster observation as well as stereo observation

Advanced Optical Satellite (ALOS-3)

ALOS-3 Overview

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

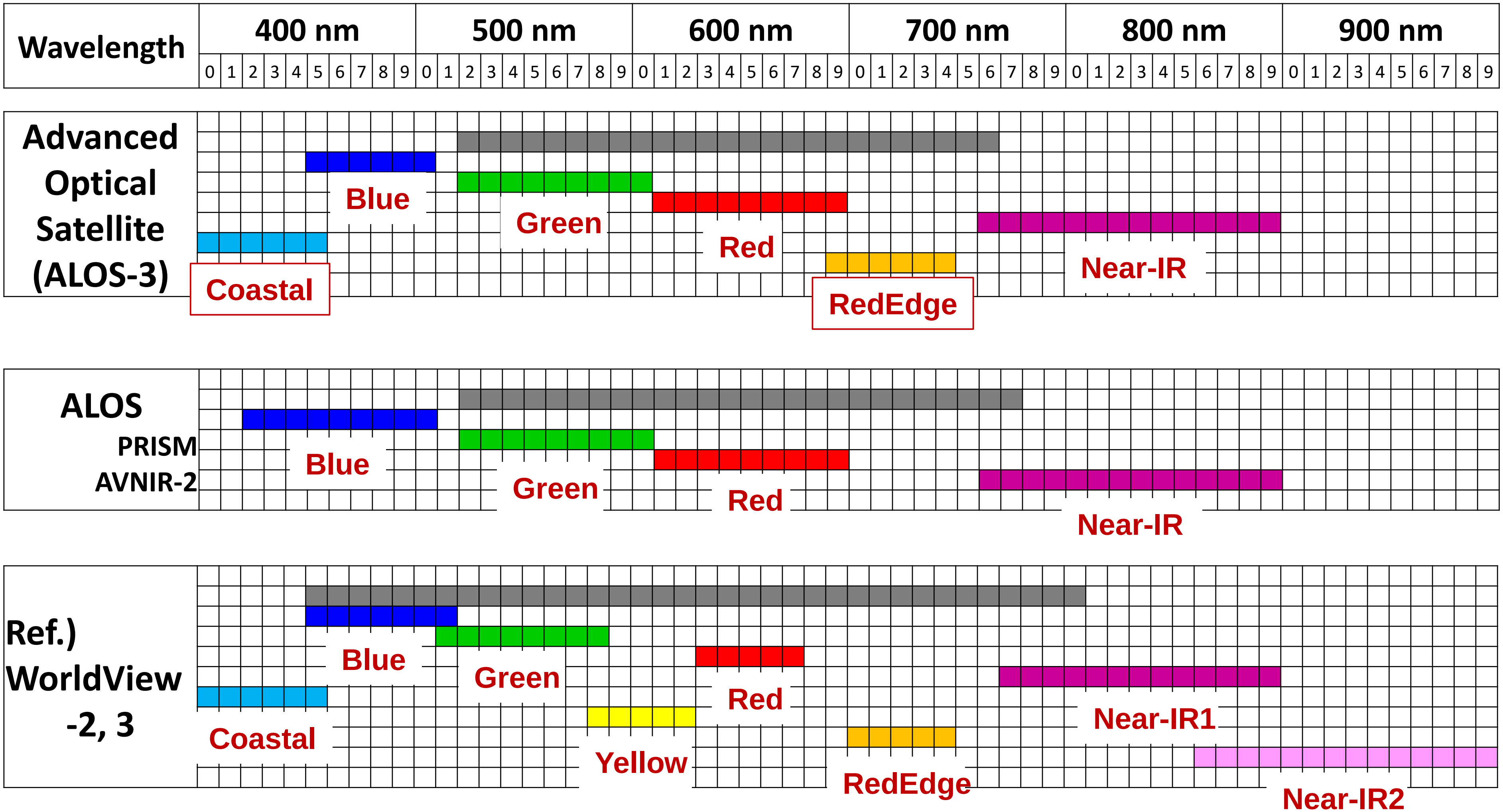


Wide-swath and high-resolution optical imager

In-orbit configuration

Wide-Swath and High-Resolution Optical Imager

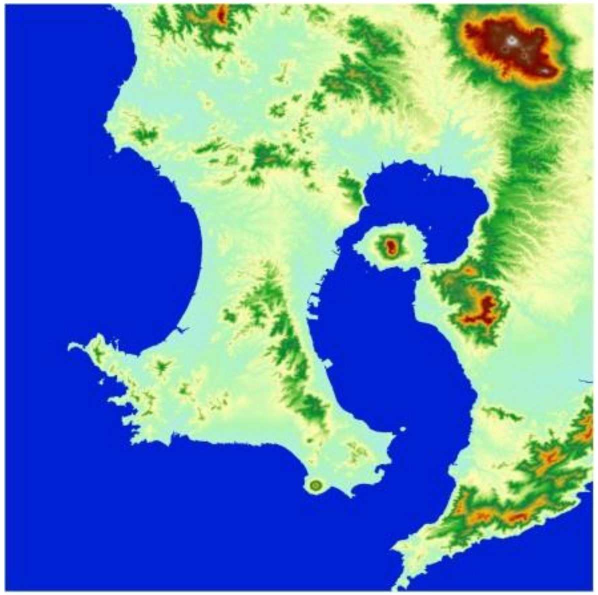
Observation channel band allocations among optical satellites (visible to near-infrared)



ALOS-3 Standard Product

Processing Level	Contents	Specifications Target accuracy
1A	Raw data	[not deliver to user]
1B1	Radiometric system correction	12 CCD units images
1B2 with RPC	Radiometric + Geometric system correction R: Geo-reference G: Geo-coded	Geometric accuracy (1 sigma): 5 m (h) without GCPs; 1.25 m (h), 2.5 m (v) with GCPs Radiometric accuracy (Mu band): +/- 10% (Abs.); +/- 5% (Relative)
1C	Rough ortho rectification using existing DEM/DSM *i.e.* PRISM DSM (AW3D)	

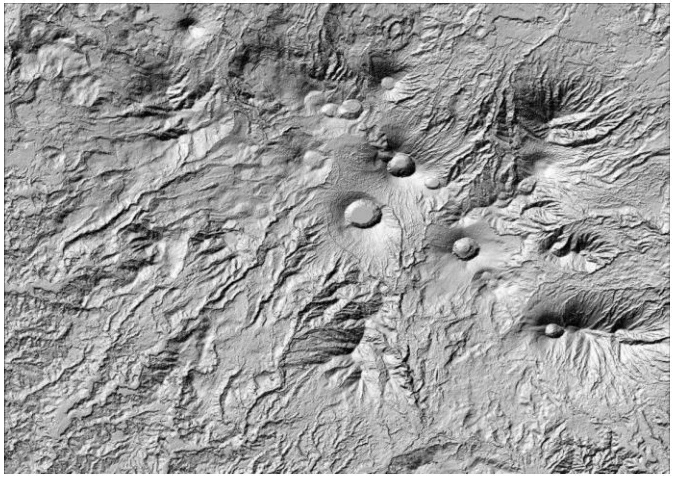
JAXA's "ALOS World 3D" (AW3D)



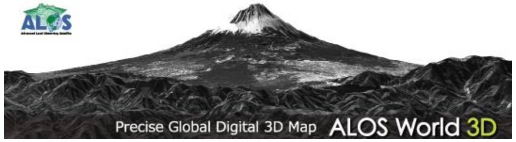
The Japan Aerospace Exploration Agency (JAXA) is starting to process the precise global digital 3D map using some 3 million data images acquired by the Panchromatic Remote sensing Instrument for Stereo Mapping (PRISM) onboard the Advanced Land Observing Satellite *"DAICHI"* (ALOS).

The digital 3D map consists of a DEM (or DSM) and ortho-rectified images (ORI) that indicate geolocation. DEM is compiled this time has a five meters in spatial resolution with five meters height accuracy (RMSE) that enables us to express land terrain all over the world. Hence its strong character will prove useful in various areas including mapping, damage prediction of a natural disaster, water resource research etc.

The global 3D map Version 1 have been completed on March 2016. JAXA commissioned the processing work and service provision to NTT DATA Corporation and Remote Sensing Technology Center of Japan (RESTEC).



In order to popularize the utilization of the 3D map data, JAXA started to publish the **30 m-mesh global DSM (AW3D30)** on April 2016, which is available free of charge for any users including commercial purposes. AW3D30 DSM was translated from original 5 m-mesh AW3D DSM dataset, therefore it still have a five meters height accuracy as expected. We expect that the 3D map will contribute to the expansion of satellite data utilizations and the industrial promotion, science and research activities as well as the Group on Earth Observations (GEO).



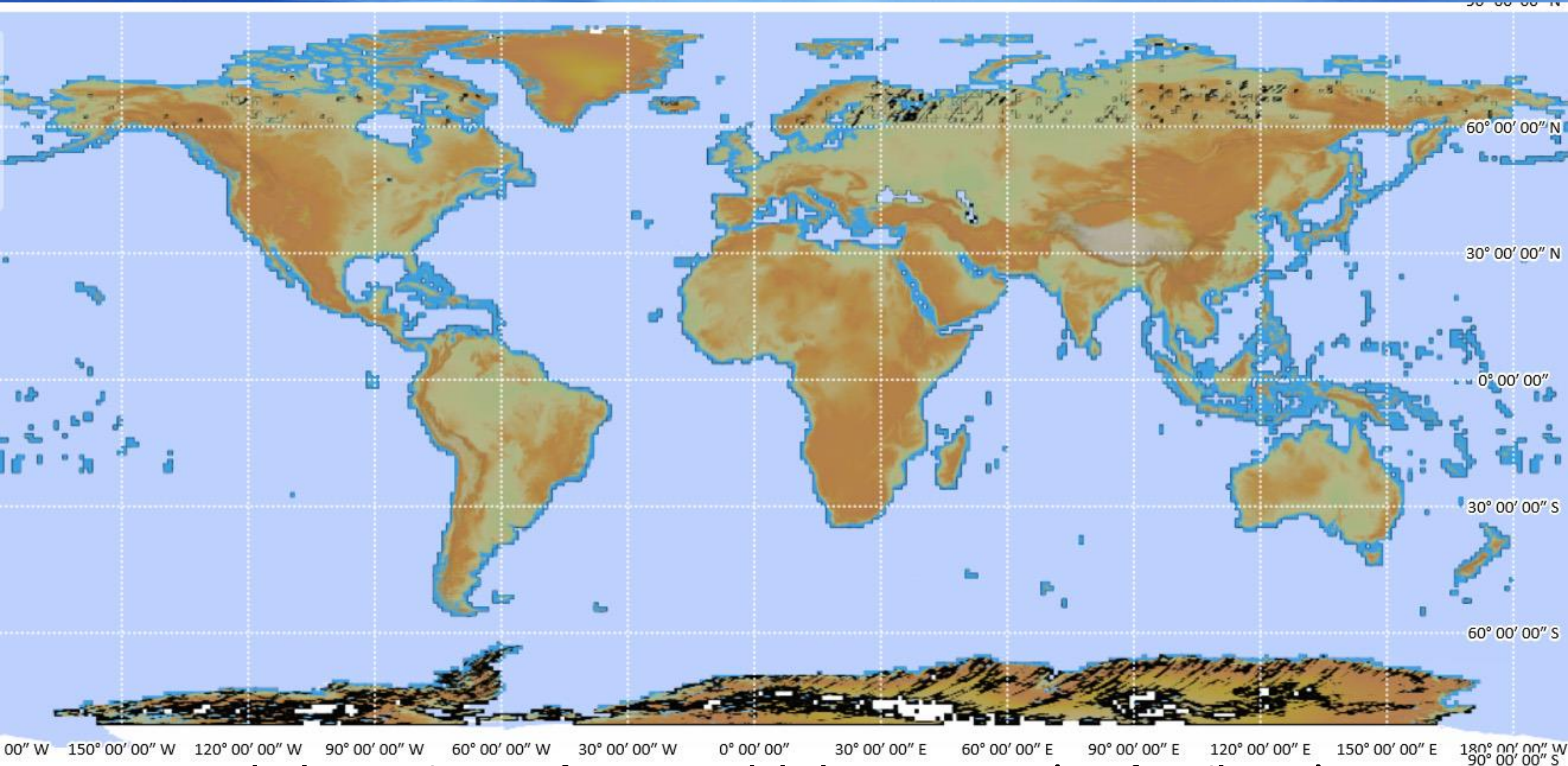
Related links

JAXA AW3D: https://www.eorc.jaxa.jp/ALOS/en/aw3d/index_e.htm

AW3D NTT DATA and RESTEC: https://aw3d.jp/en/index.html

Sample movies of the digital 3D map: https://www.youtube.com/watch?v=pZg78PXnlQc

AW3D30 DSM Ver. 2.2 Browse



The browse image of AW3D30 global DSM ver. 2.2 (as of April 2019).

©JAXA

AW3D ver. 2 was used as source dataset:

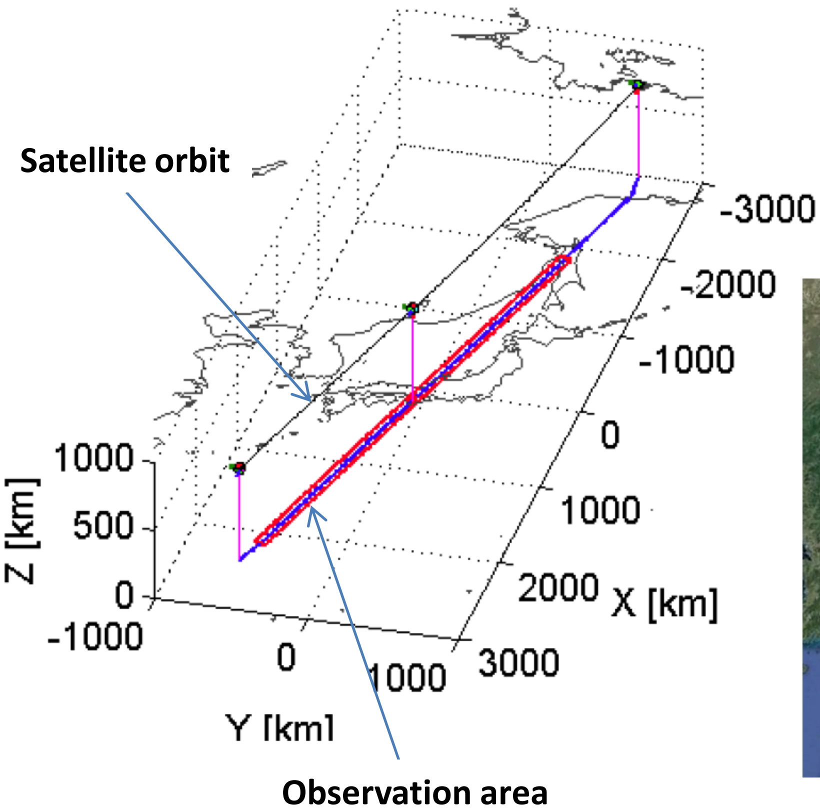
- Additional CCD alignment calibration (2,600 tiles), bias height correction (14,900 tiles): <u>Total 15,361 tiles</u>
- Out of them (i.e. over 60 deg. latitude areas) are same with ver. 1.1.
- Complemented > N60 deg areas by “ArcticDEM” using WorldView
- Land-water mask updates using AVNIR-2 ORI

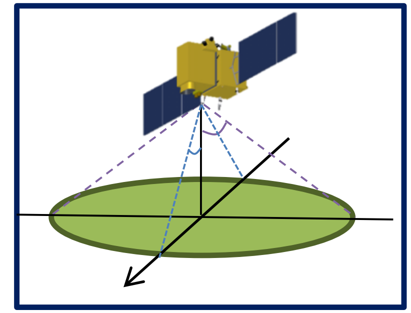
ALOS-3 Observation Modes

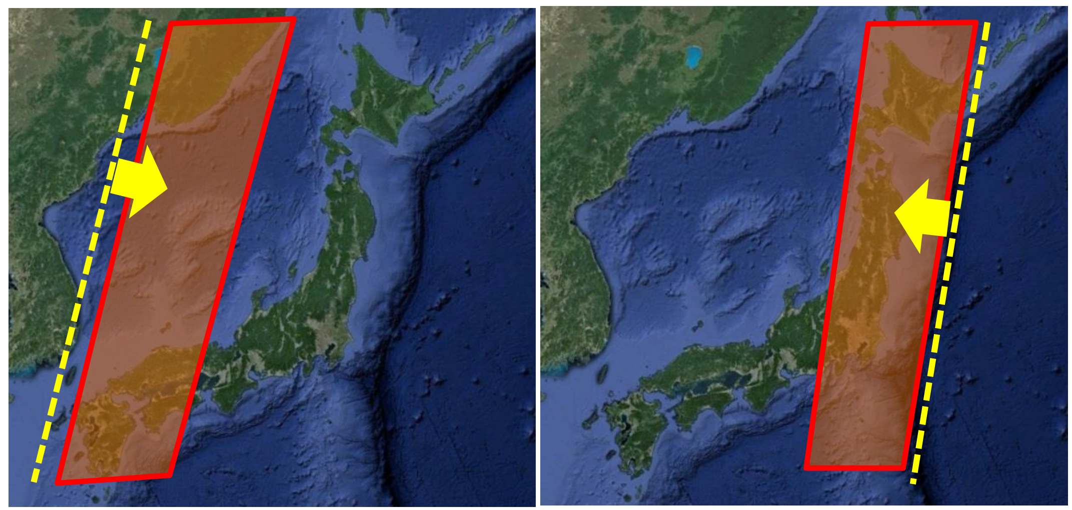
1	**Strip-map observation**	The satellite can normally perform observation covering 70 km in width and 4,000 km in along-track direction as the strip-map observation mode. To increase the acquisition frequency, the images will be taken by less than 25 deg. pointing angle in cross-track direction (GSD < 1m) when the satellite track is in oceans.
2	**Stereoscopic observation**	Two ways proposes to acquire stereo-pair image: 1) in single orbit path, and 2) combining two strip-map observations by nadir view and backward view in neighboring path after three days (sub-cycle revisit orbit). The way 1) will be however not sufficient base-to-height ratio (B/H) to derive terrain information. As the advantages of the way 2), that is possible to set suitable B/H, and can acquire images over large area. However, this will depend on weather conditions i.e. cloud covers, to success stereo image acquisition within short period as a disadvantage.
3	**Point observation**	If the user has a certain ground point or an area of interest (AOI), the satellite can observe there using pointing capability within 60 deg. This mode will be used for natural disaster monitoring, for example.
4	**Observation direction changing**	The satellite can observe any given point by the pointing capability up to 60 deg. in all direction against the satellite nadir. In the case of Japan, it can be activated within 24 hours after receiving the request. This will be used when the large natural disaster happens e.g. the expecting Nankai Trough large earthquake.
5	**Wide-area observation**	This mode can cover in wide-ranging area of 200 km (in along-track direction) x 100 km (in cross-track direction) by satellite's single orbital passage. This will be also used when the large natural disaster happens.

1 and 2 will be used in the basic observation, and 3-5 for response natural disasters.

Strip-Map Observation Mode



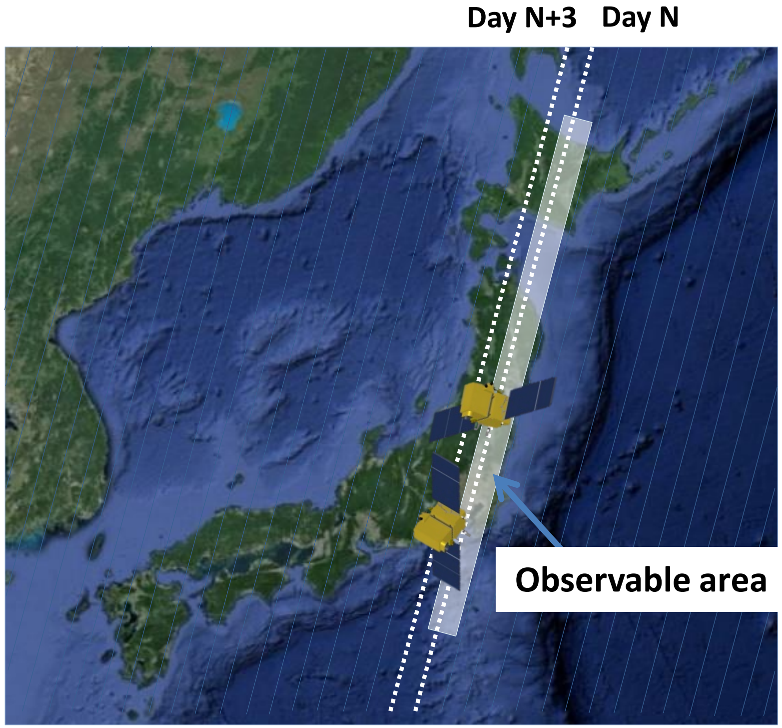




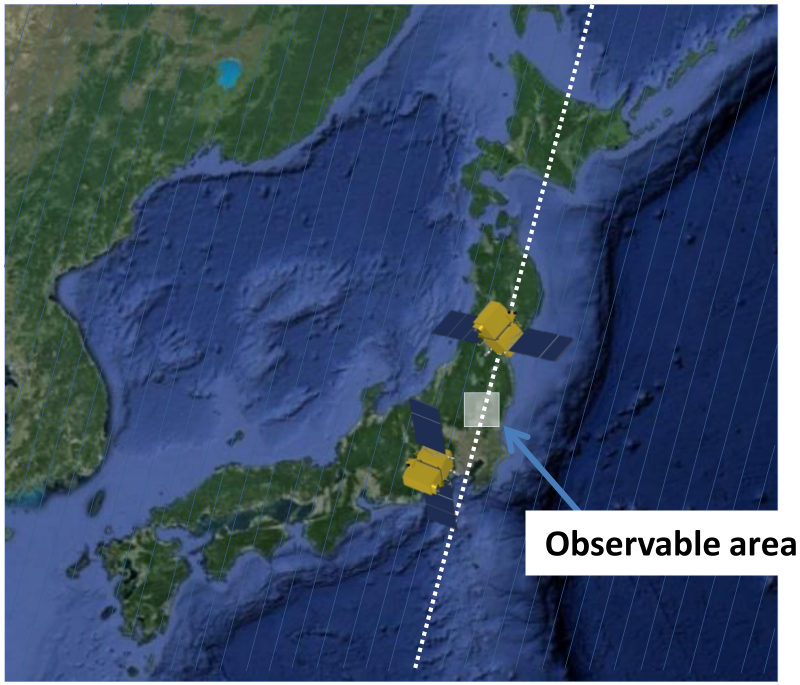
Example of nadir observation
70 km x 4000 km (10 mins/path).

The satellite can normally perform observation covering 70 km in width and 4,000 km in along-track direction as the strip-map observation mode. To increase the acquisition frequency, the images will be taken by less than 25 deg. pointing angle in cross-track direction (GSD < 1m) when the satellite track is in oceans.

Stereoscopic Observation Mode



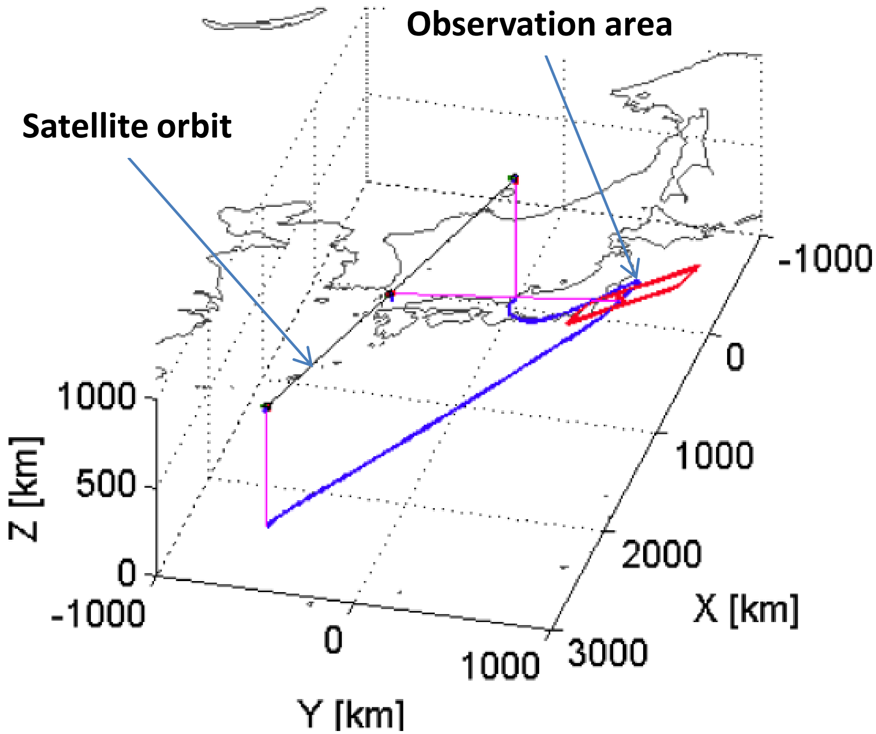
Combined two strip-map in neighboring paths after three days.



Single-path stereo.

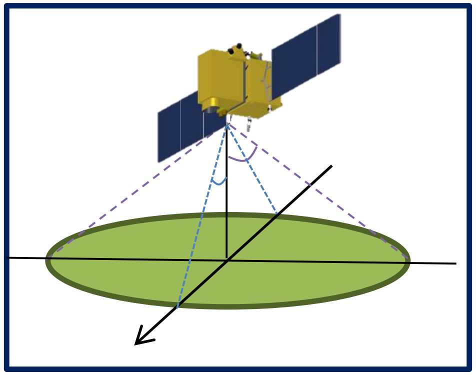
Two ways proposes to acquire stereo-pair image: 1) in single orbit path, and 2) combining two strip-map observations by nadir view and backward view in neighboring path after three days (sub-cycle revisit orbit). The way 1) will be however not sufficient base-to-height ratio (B/H) to derive terrain information. As the advantages of the way 2), that is possible to set suitable B/H, and can acquire images over large area. However, this will depend on weather conditions i.e. cloud covers, to success stereo image acquisition within short period as a disadvantage.

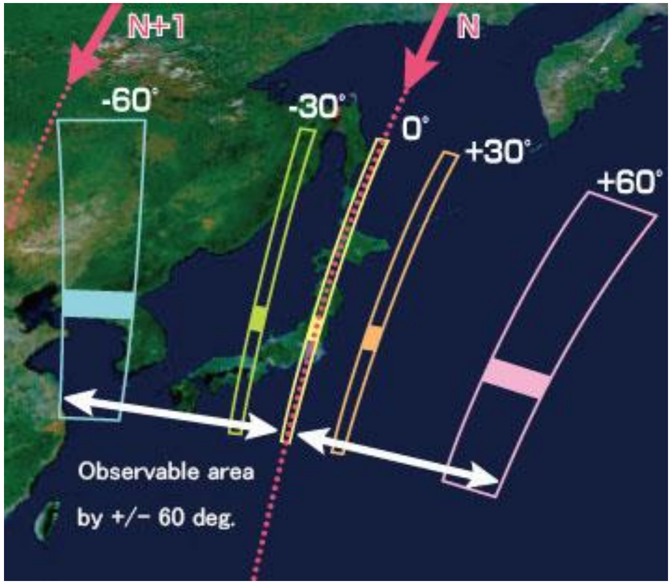
Point Observation Mode



Example of point observation
by pointing function.

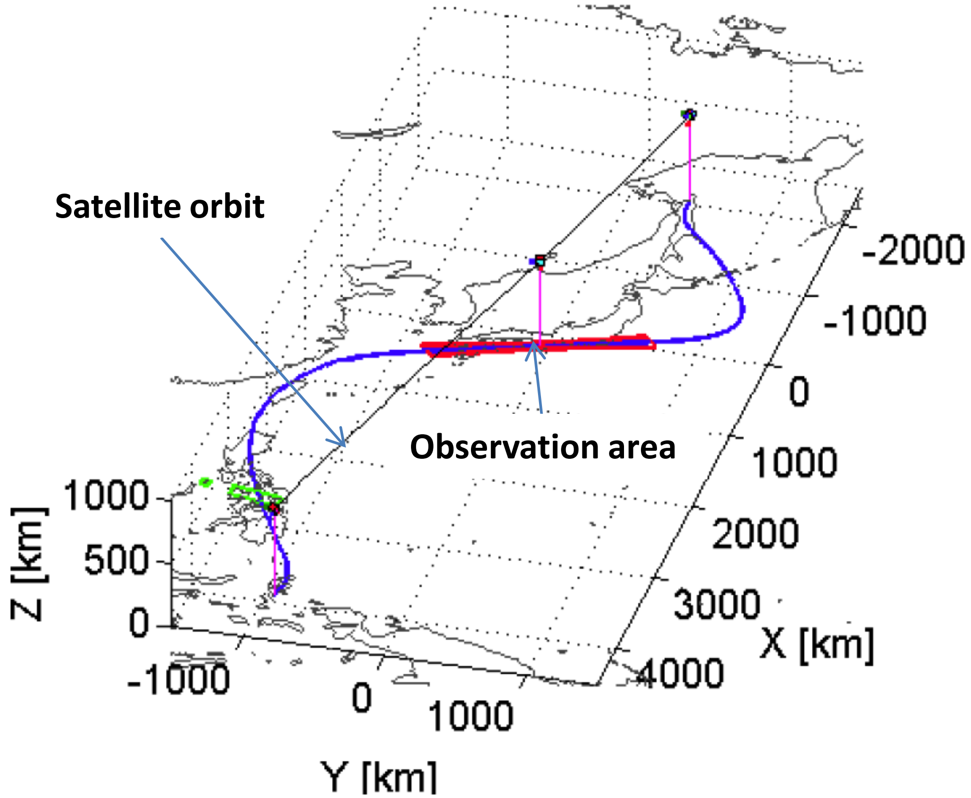
If the user has a certain ground point or an area of interest (AOI), the satellite can observe there using pointing capability within 60 deg. This mode will be used for natural disaster monitoring, for example.



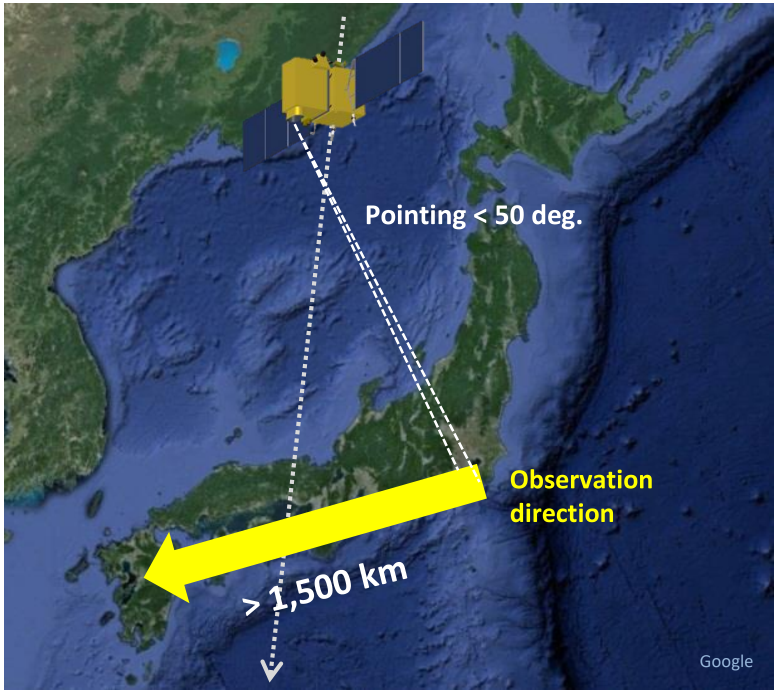


Example of coverage by
+/- 60 deg. pointing function.

Observation Direction Changing Mode

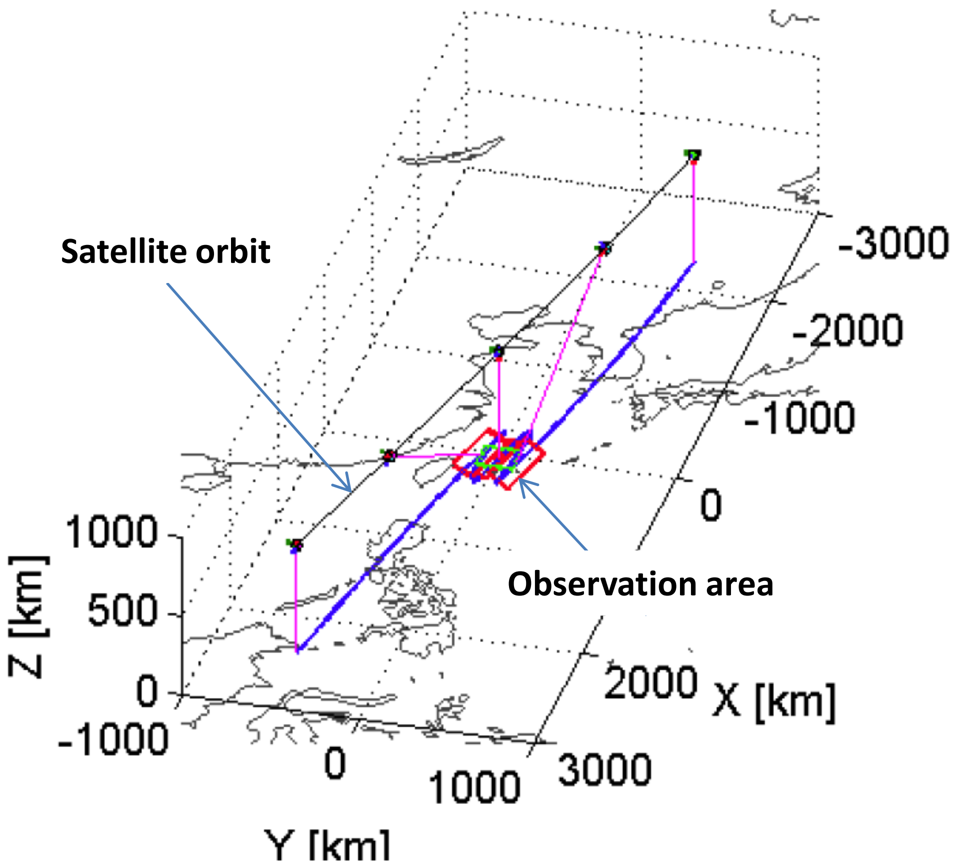


Example of observation direction changing mode.

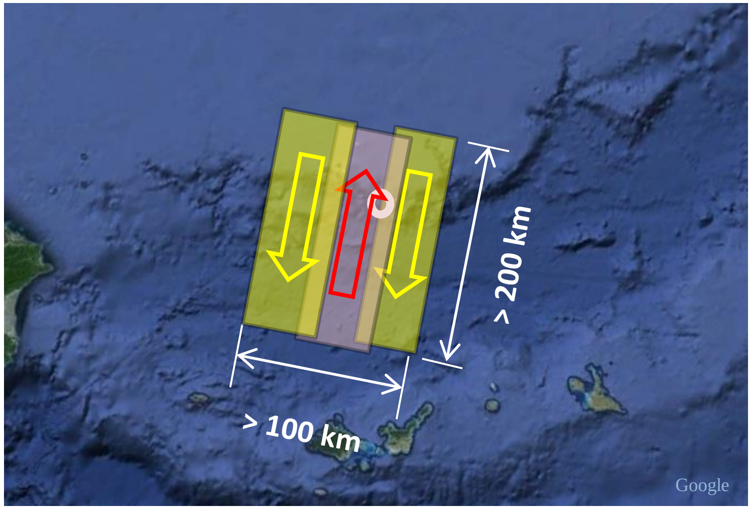


The satellite can observe any given point by the pointing capability up to 60 deg. in all direction against the satellite nadir. In the case of Japan, it can be activated within 24 hours after receiving the request. This will be used when the large natural disaster happens e.g. expecting the Nankai-Trough large earthquake.

Wide-Area Observation Mode



Example of wide-area observation mode.



Example of three scans observation covered >200 x 100 km.

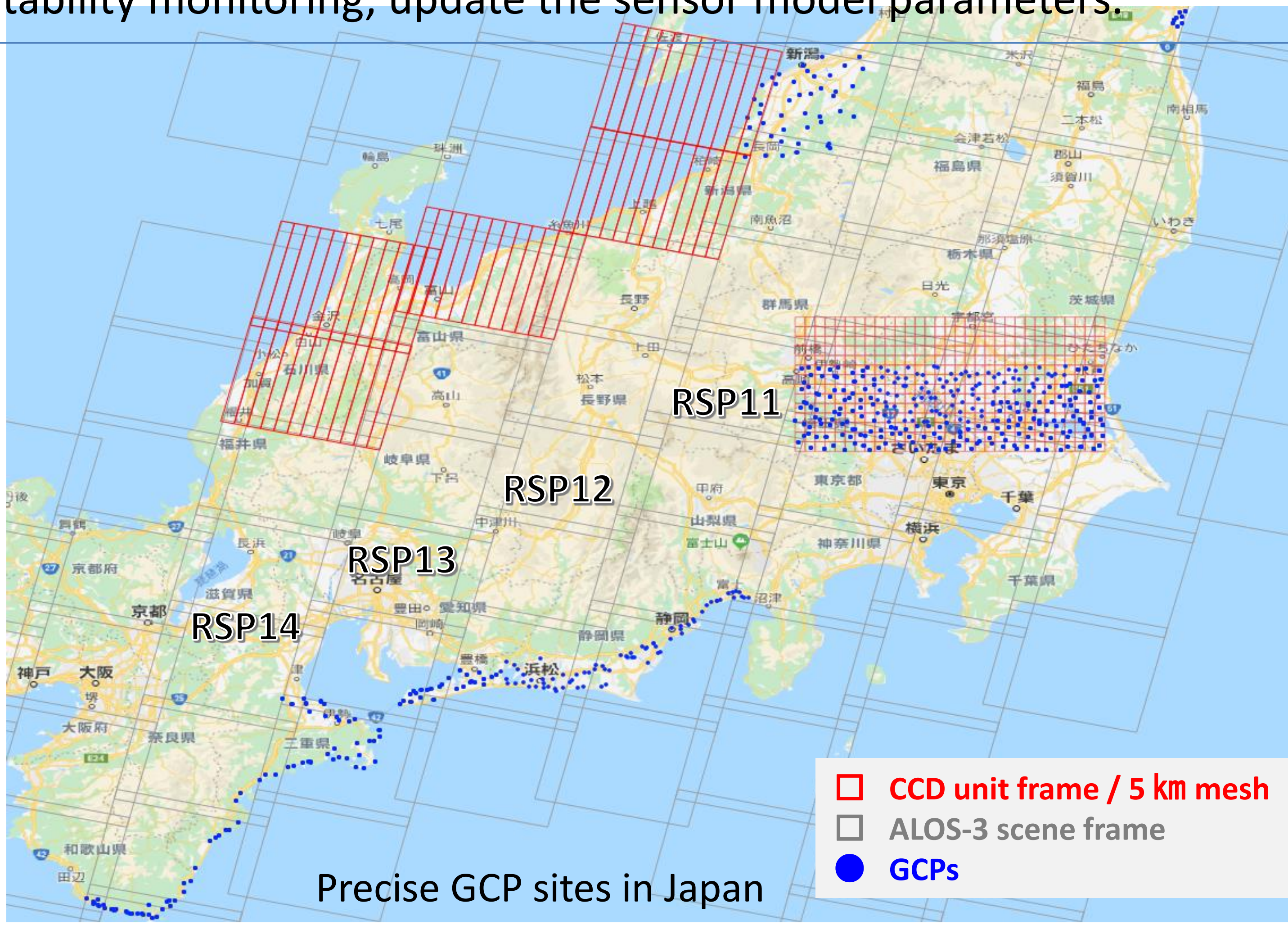
This mode can cover in wide-ranging area of 200 km (in along-track direction) x 100 km (in cross-track direction) by satellite's single orbital passage. This will be also used when the large natural disaster happens.

ALOS-3 Calibration Items

No	Item		Contents
Calibration			
	Geometric Cal (Relative / Absolute)		
1	Relative CCD-to-CCD alignment		Relative alignment between CCDs and their changes in temperature, temporal, etc.
2	Pointing determination accuracy		External orientation parameters (orbit and attitude errors, sensor alignment etc.)
3	Distortion within scene (middle- and long-frequencies)		Pointing stabilities in individual time-scale (within 400 lines, and 1 scene)
4	Pointing control accuracy		Pointing accuracy evaluation
5	Geometric correction accuracy		Use L1B2 and L1C products acquired in GCP test sites.
6	Pa/Mu co-registration		Use L1B2 and L1C products of Pa and Mu.
7	Band-to-band registration		Relative error between base band and individual band of Mu
	Radiometric Cal (Relative / Absolute)		
1	Absolute	Pre-flight Cal	Spectral radiance evaluation
2		Dark Cal	Sensitivity and temporal stability of the images acquired in nighttime
3		Lunar Cal mode (CT/AT) Deep space Cal	Sensitivity and temporal stability of the images acquired Lunar and deep space
4		Vicarious Cal	Absolute cal will be done by vicarious calibration at the radiometric test sites over homogeneous targets.
5		Cross Cal	The simultaneous observation will be done with the calibrated other satellites/instruments.
6	False dark data		Stability and temporal changes using the onboard dark data.
7	Pixel-to-pixel sens. Variation	Operational evaluation	Acquired images in the test sites.
8		CT Cal mode	Sensitivity and temporal stability using images acquired by 90 degrees yaw-around.
9		Dark Cal	Sensitivity and temporal stability of the images acquired in nighttime.
10		Deep space Cal	Sensitivity and temporal stability of the images acquired the deep space.
11	CCD-to-CCD and Channel-to-Channel sensitivity variations		Sensitivity and temporal stability of the images acquired at the radiometric test sites over homogeneous targets.
12	Linearity		Brighter and darker homogeneous targets.
	Image Quality Evaluation / Sensor Characterization		
1	MTF evaluation		Modulation Transfer Function (MTF) evaluation using the Point Spread Function (PSF) or edge target.
2	Signal-to-noise ratio		Brighter and darker homogeneous targets.
3	Data compression		Image quality evaluation using difference onboard compression rates (nominal: Pa 1/4, Mu 1/3).
4	TDI characterization		TDI number and its differences.
5	Wavelength characterization		Pre-flight test data
6	Defocus evaluation		Defocus (research)
7	Image quality improvement		Image quality improvement method (research)

ALOS-3 Geometric Cal

- ■ Geometric errors analysis using reference data > Cal/Val Test Sites
  - ✓ Orientation by Ground Control Points (GCPs)
  - ✓ Relative correlation using Reference optical images
    > Stability monitoring; update the sensor model parameters.

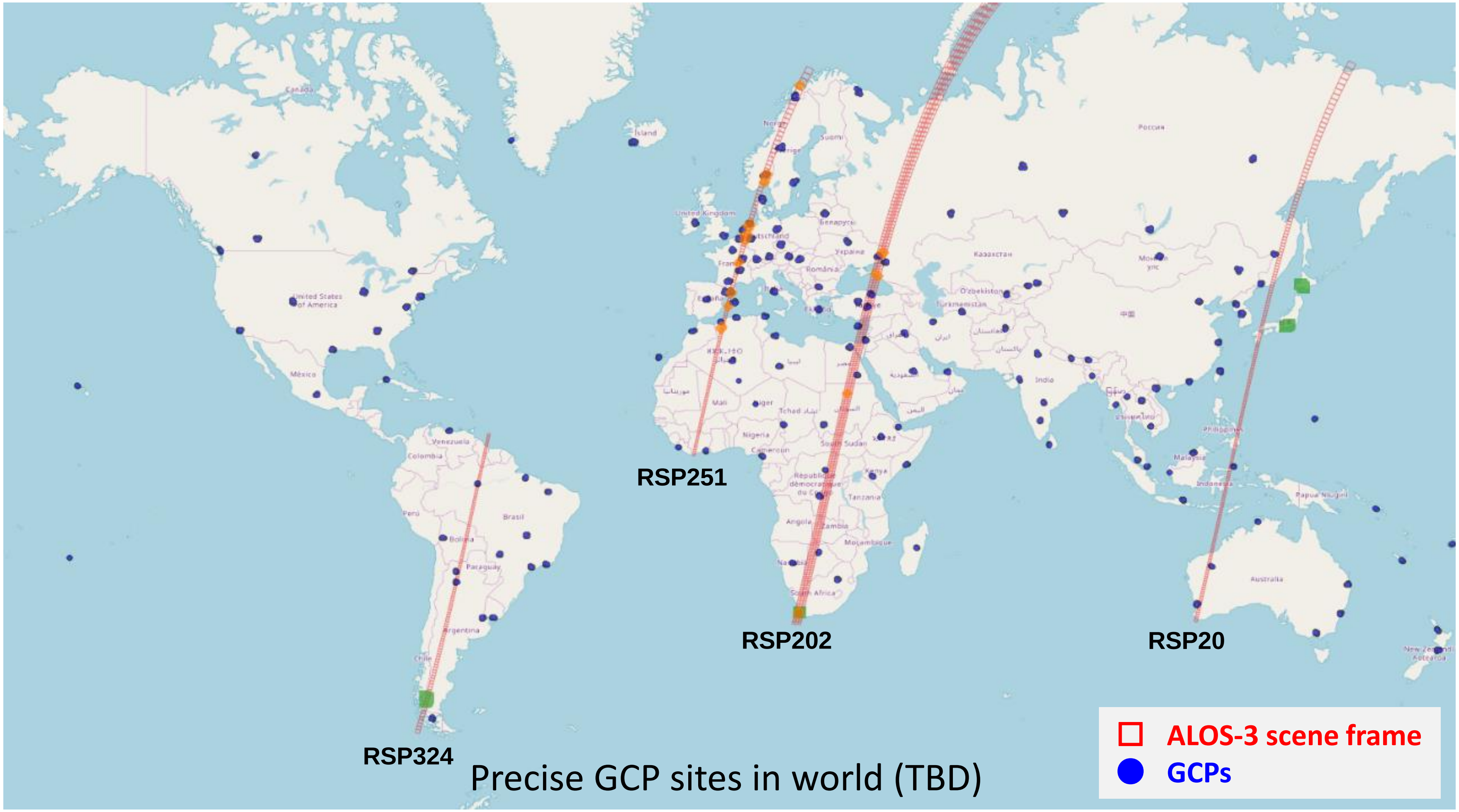


Precise GCP sites in Japan

ALOS-3 Geometric Cal

■ Geometric errors analysis using reference data > Cal/Val Test Sites

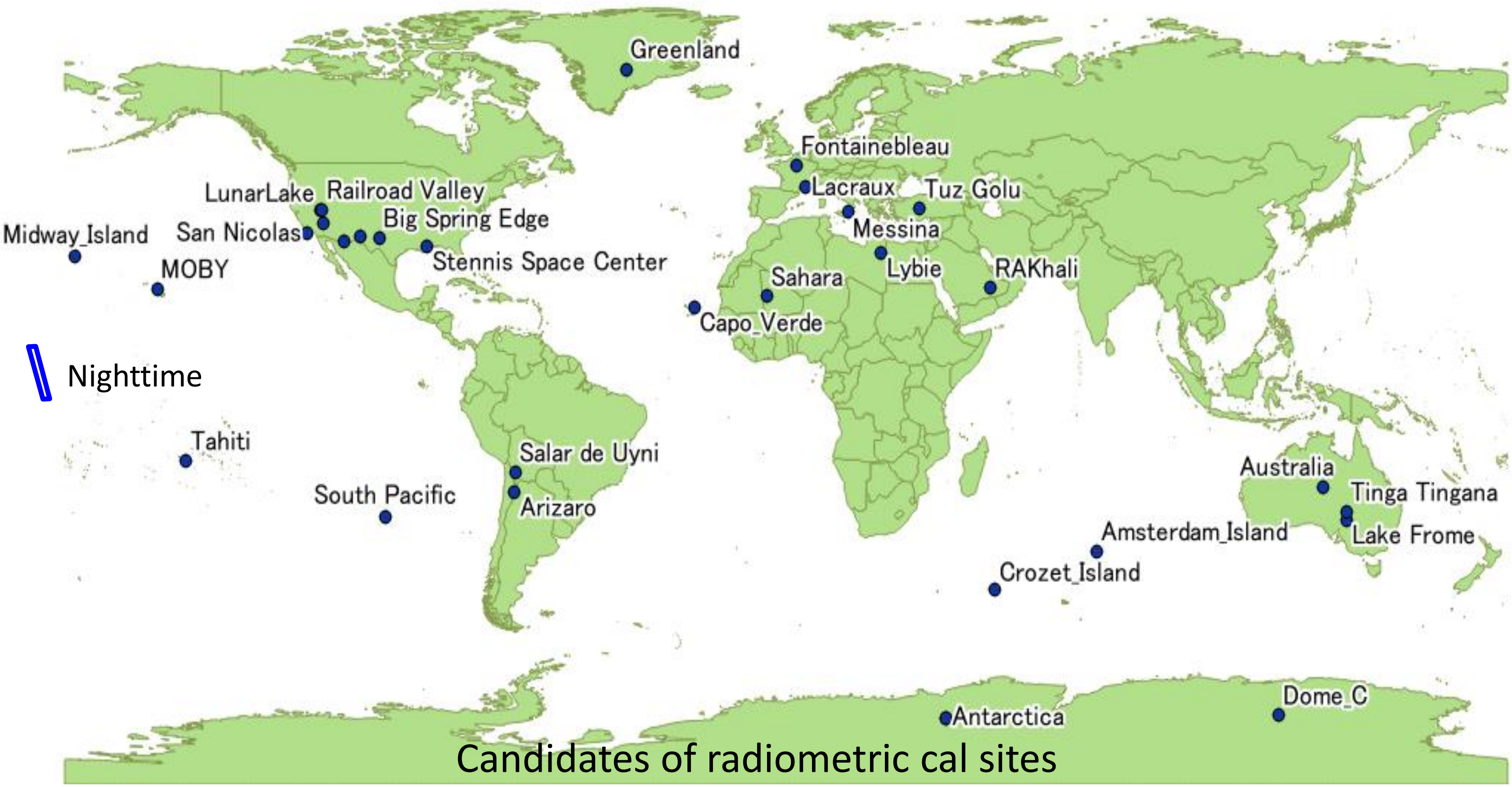
- ✓ Orientation by Ground Control Points (GCPs)
- ✓ Relative correlation using Reference optical images
  > Stability monitoring; update the sensor model parameters.



Precise GCP sites in world (TBD)

ALOS-3 Radiometric Cal

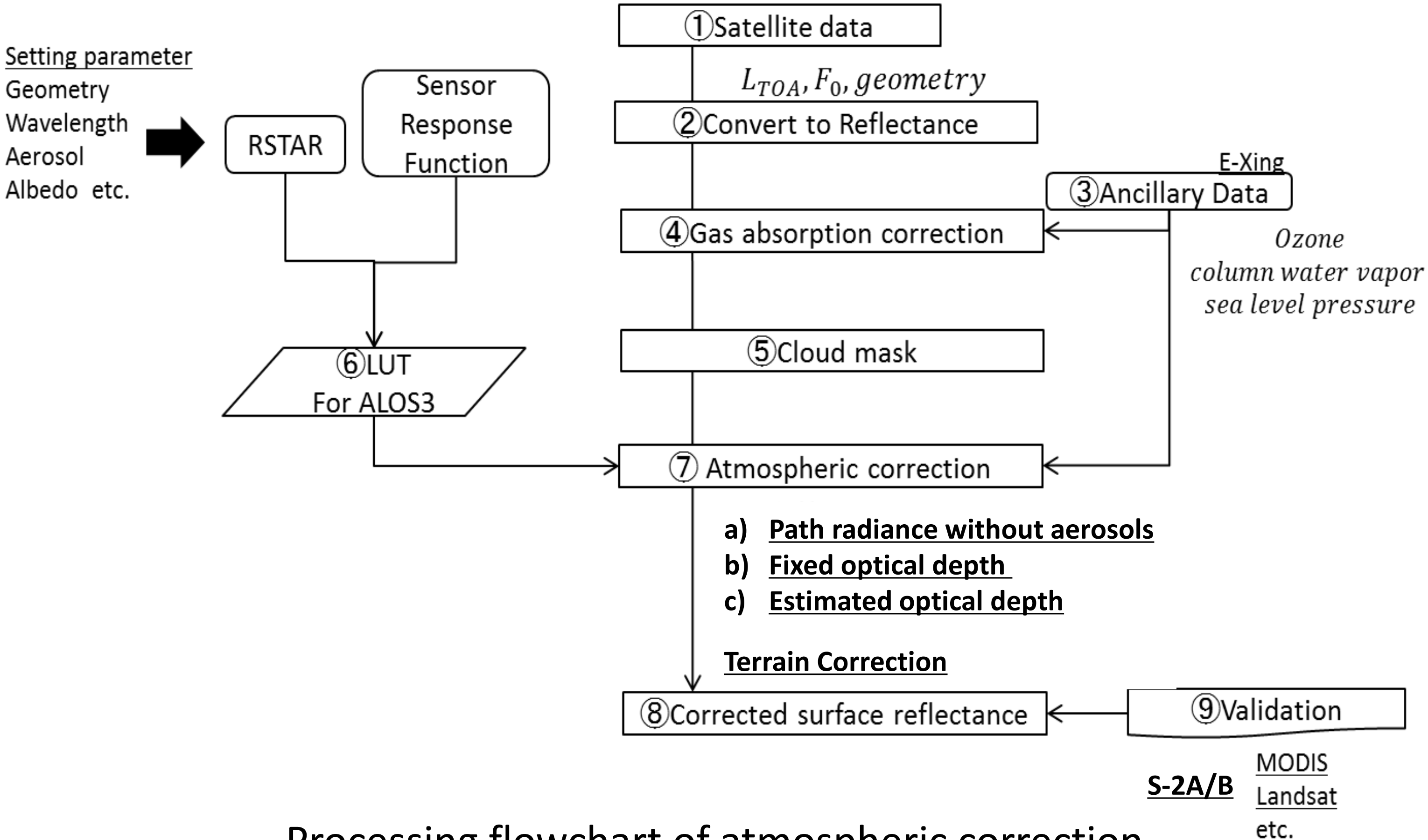
- Radiometric accuracy evaluations in *common* sites > Cal/Val Test Sites
  - ✓ Cal mode: dark cal., moon, deep-space
  - ✓ Radiometric cal. sites using existing optical satellites: Vicarious-cal, cross-cal
  - ✓ Relative cal. will be done by homogenous targets *i.e.* nighttime, ocean, ice
    > Stability monitoring; update the sensor model parameters.



Candidates of radiometric cal sites

ALOS-3 Radiometric Cal

- Surface reflectance evaluation: Atmospheric correction
  - ✓ Preparation of high-level product: *Analysis Ready Data (ARD)*
  - ✓ Radiative transfer model (e.g. RSTAR) is used to make LUT
  - ✓ Atmospheric parameters will be obtained from JMA re-analysis data etc.



Processing flowchart of atmospheric correction

ALOS-3 Validation Items

No	Item	Contents
Validation (High-level and Research Products)		
	High-level Product	
1	RPC (RPC-Pan/RPC-Mul)	
	Physical sensor model approximation	The physical sensor model validation by ・the pointing stability in the different frequency domain, ・using the Attitude Reference System (ARS), and ・using L1B1/L1B2
	Absolute accuracy	Geo-reference accuracy by RPC using GCPs
2	Ortho-rectified Image (ORI-Pan/ORI-Mul)	
	Geolocation accuracy	Geolocation accuracy validation (different DEM/DSM)
	Multi-temporal images registration (Relative accuracy)	Relative registration by multi-temporal acquired images.
3	Pan-sharpened Image	
3-1	Standard product (PSI)	Created using the standard products
3-2	Ortho-rectified, pan-sharpened image (ORI-PSI)	Created by ORI-Pan and ORI-Mul
4	Digital Surface Model (DSM)	
	3-D geolocation determination accuracy	Orientation and bundle adjustment to calculate 3-D geolocation ・GCP and CP residuals ・TP residual between stereo pair image
	Height accuracy	Generated DSM and image matching accuracy ・Absolute accuracy ・Relative accuracy ・with and without GCP ・characterized in LULC differences
	Horizontal geolocation accuracy	Horizontal geolocation accuracy in generated DSM ・Absolute accuracy ・Relative accuracy ・with and without GCP ・characterized in LULC differences
	Mask layer evaluation	Automatic generation of clouds, snow and ice, and water bodies layers (TBD)
5	Atmospheric and Terrain Corr. Image	
5-1	Atmospheric correction (ATC)	Atmospheric correction accuracy and tuning
5-2	Terrain correction (ASC)	Atmospheric and terrain collection accuracy and tuning
6	Research Product	
6-1	Auto- and Semi-auto Change Detection (ACDI/MCDI)	Algorithm development and tuning
6-2	Precise LULC (HRLULC)	Algorithm development and tuning
6-3	Coastal-zone map (CZM)	Algorithm development and tuning
7	New Utilization	
7-1	Hot-spot estimation (HS)	Volcanic activity, forest wild fires, and see surface temperature anomaly

Summary

The overview and cal/val plan of ALOS-3 were introduced.

- ALOS-3 is next high-resolution optical mission in JAXA, and ongoing Phase D *i.e.* the flight model development and to be launched in 2020.
- After launch the satellite, the initial calibration is shortly started then moved to the operational cal/val during the operational phase.
- JAXA is therefore starting to prepare cal/val activities i.e. drafting the cal/val plan, collecting reference data, established the international Cal/Val and Science Team (CVST) under the EO research announcement (EO-RA2).
- This is not sufficient yet, and still seeking international collaborators.