living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE
OF OUR PLANET FROM SPACE

Initial Results of ALOS-3 the Successor of the Optical Mission by ALOS

Takeo Tadono, Yousei Mizukami, Sota Hirayama, and Hidenori Watarai
Japan Aerospace Exploration Agency (JAXA), Japan

B6.01.1 National EO satellite missions - 1
26 May 2022

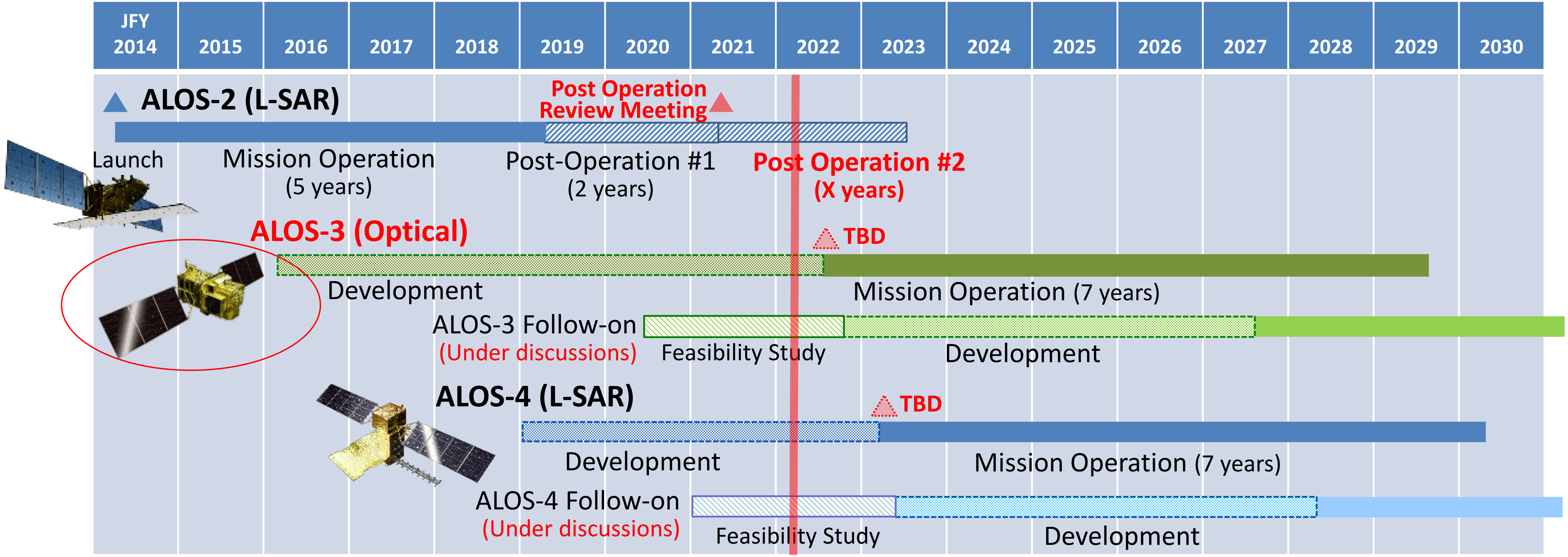
Contents

- Overview of ALOS-3, a Follow-on of the ALOS Optical Mission
- Calibration and Validation Plan
  - ✓ Target accuracies of the standard product
  - ✓ Algorithm development
  - ✓ Test generation of the high-level and research products
- Summary

Continuous Observations by ALOS Series Missions

■ Continuous observations successor *“DAICHI” (ALOS)* since 2006.

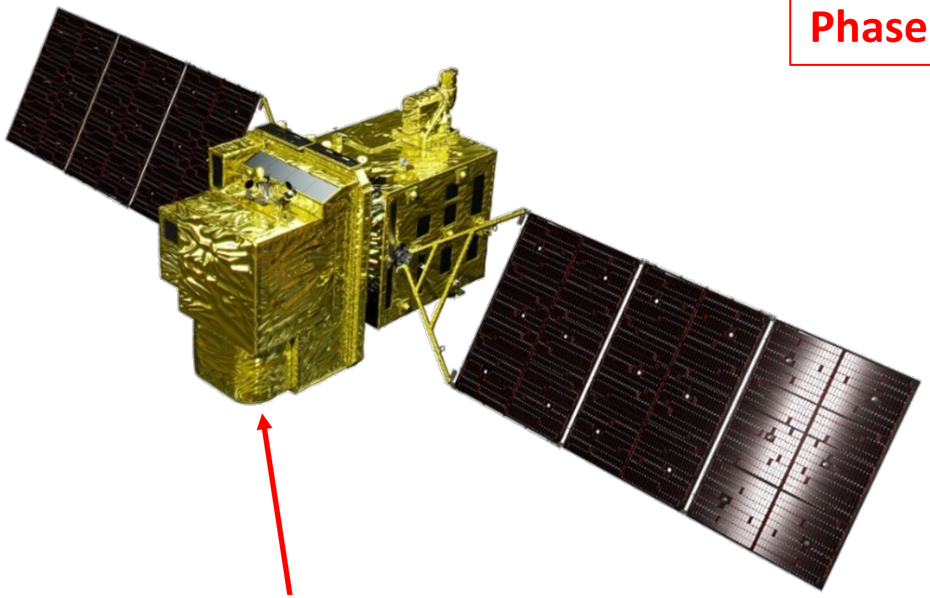
- Contribute to ensure the safety and security of citizens *i.e.,* disasters monitoring and management, land deformation monitoring, national developing management, foods and natural resources, environmental issues in global, *etc.* as common issues.
- Contribute to industrial development based on Earth observation data *i.e.,* National Spatial Data Infrastructure (NSDI) and new applications.



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 (WISH) - 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 (~12) mins / recurrent
Design lifetime		**Over 7 years**

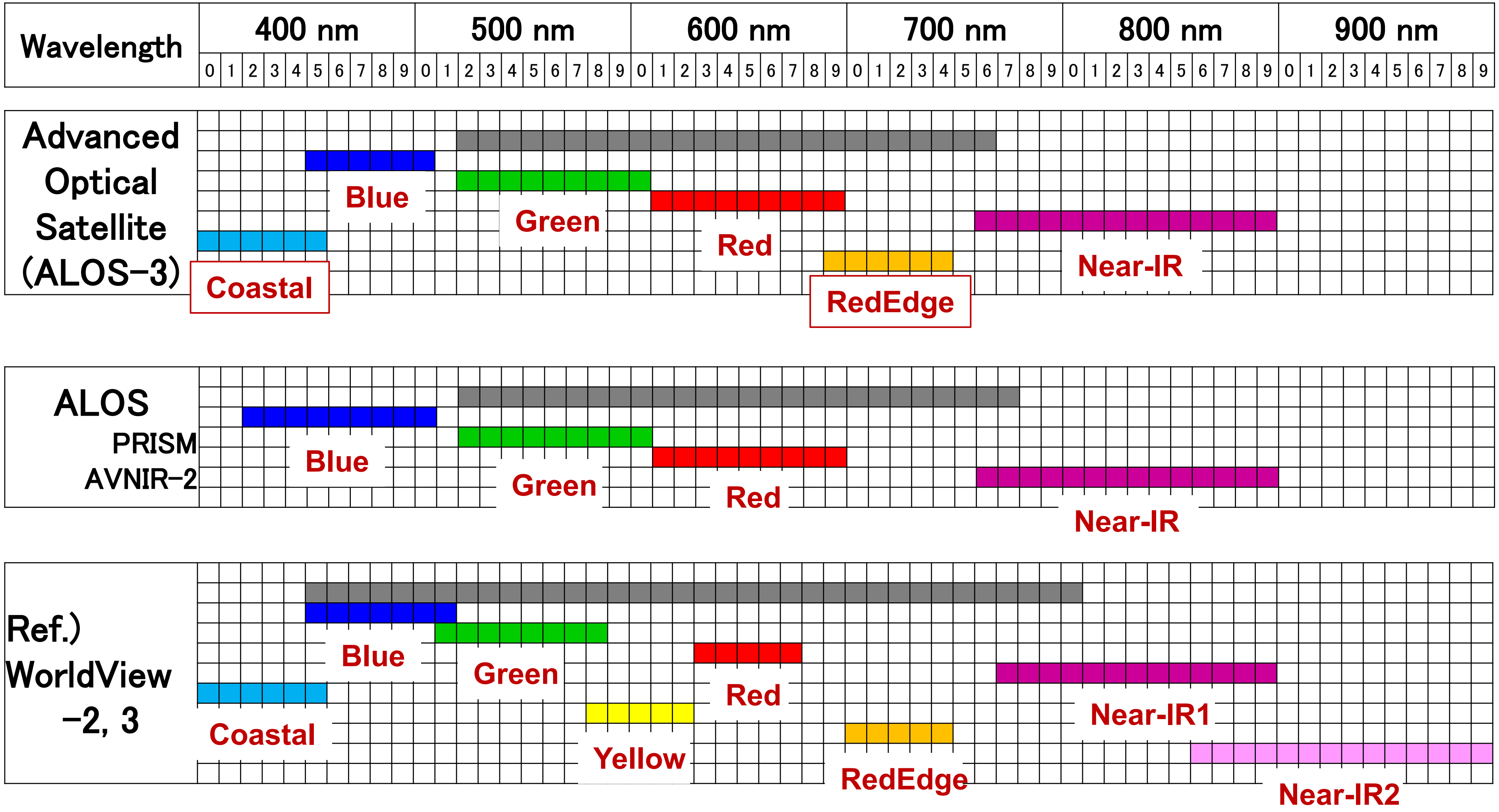


In-orbit configuration

- The ALOS-3 launch was originally scheduled for 2021.
- The launch date is currently under consideration due to a review of the development schedule for the H-3 launch vehicle to be used for the launch.

Band Allocations of ALOS-3 WISH

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



ALOS-3 Observation Mode

1	**Strip Map Observation "STM"**	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 "3D1", "3D2"**	Two ways propose to acquire stereo-pair image: 1) in single orbit path **"3D1"**, and 2) combining two strip-map observations by nadir view and backward view in the neighboring path after three days (sub-cycle revisit orbit, **"3D2"**). Way 1) will be however not sufficient base-to-height ratio (B/H) to derive terrain information. As the advantages of way 2), that is possible to set suitable B/H, and can acquire images over a large area. However, this will depend on weather conditions i.e., cloud covers, to succeed stereo image acquisition within a short period as a disadvantage.
3	**Pointing Observation "PNT"**	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	**Changing Direction Observation "DRC"**	The satellite can observe any given point by the pointing capability up to 60 deg. in all directions 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 a large natural disaster happens e.g., the expecting Nankai Trough large earthquake.
5	**Wide-Area Observation "WID"**	This mode can cover a 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 a large natural disaster happens.

#1 and #2 will be used in the basic observation, and #3~5 for *responding to natural disasters*.

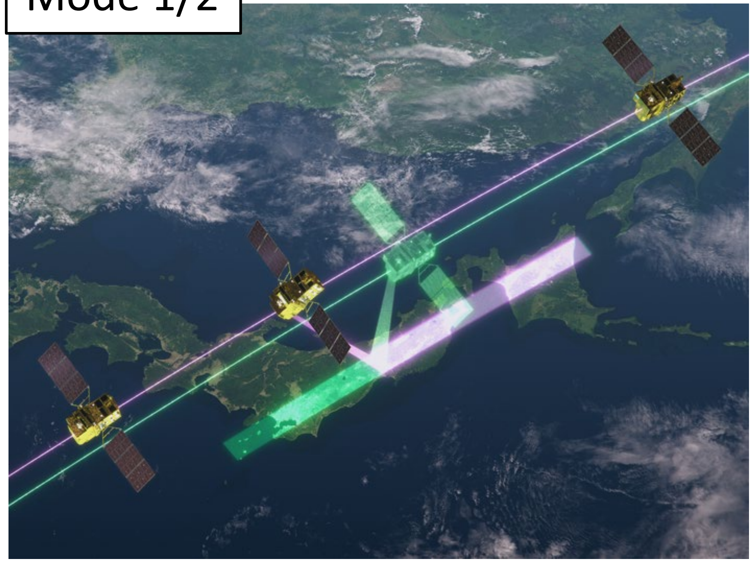
ALOS-3 Observation Mode

ALOS-3 Observation Mode

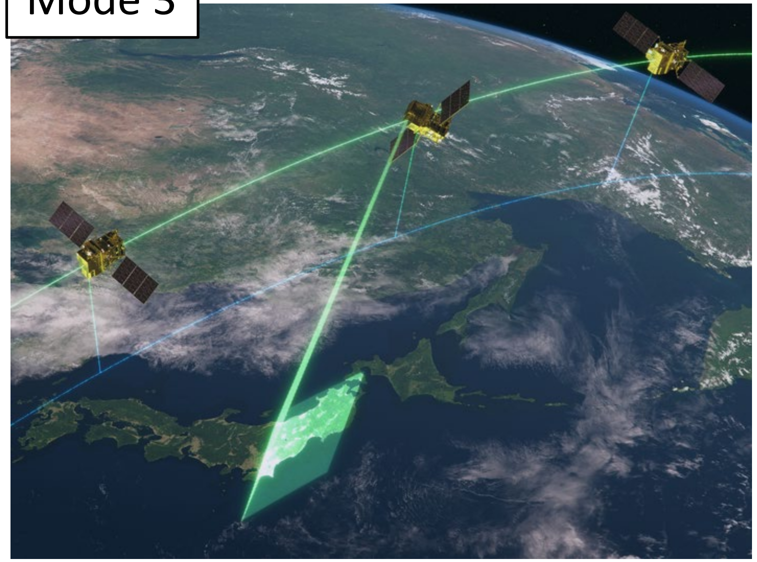
1	Strip-Map Observation (STM)
2	Stereoscopic Observation (3D1, 3D2)
3	Pointing Observation (PNT)
4	Changing Direction Observation (DRC)
5	Wide-Area Observation (WID)

Mode #3 to 5 are for emergency observation only.

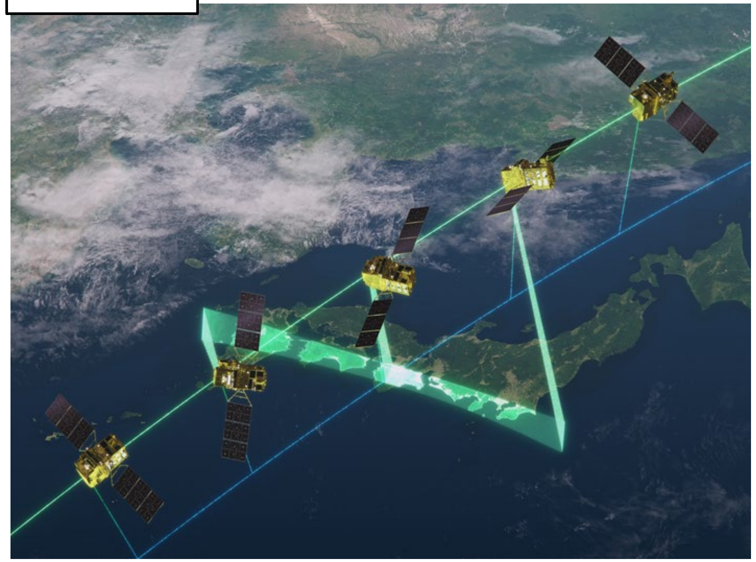
Mode 1/2



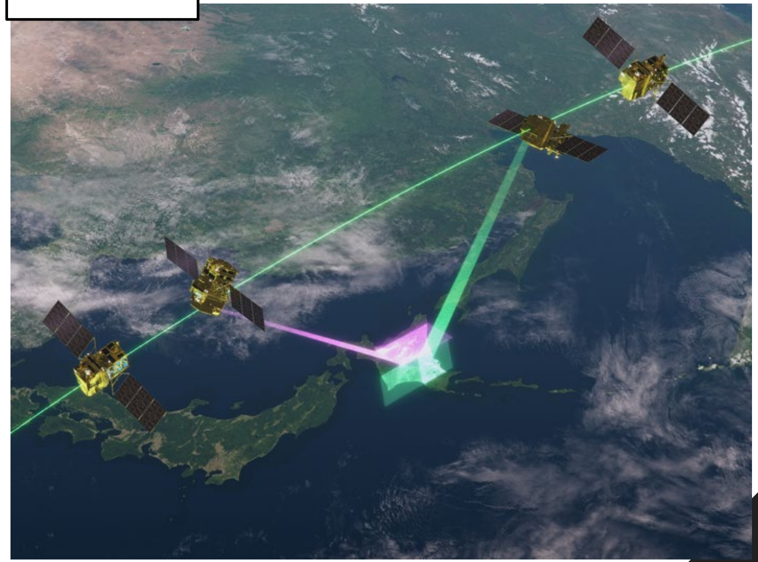
Mode 3



Mode 4



Mode 5



ALOS-3 Standard Products and Target Accuracy

Processing Level	Contents	Specifications Target accuracy
1A	Raw data	[not deliver to user]
1B1 with RPC	Radiometric system correction	12 CCD units separated 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 5m mesh DSM)	

- Validation of High-level and Research Products is performed in conjunction with calibration.

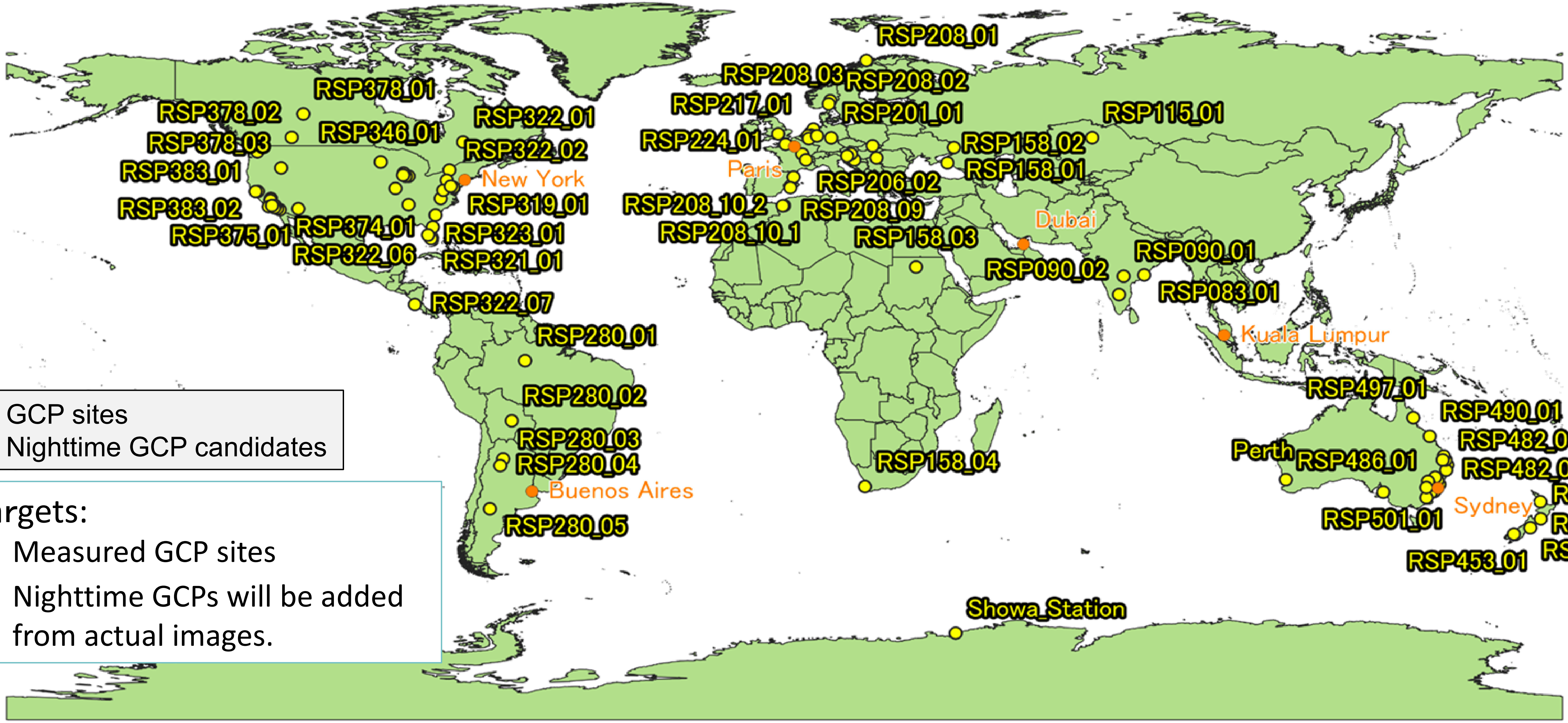
ALOS-3 Calibration

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 Validation of High-Level and Research Products

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

ALOS-3 Cal/Val Test Sites - Geometry

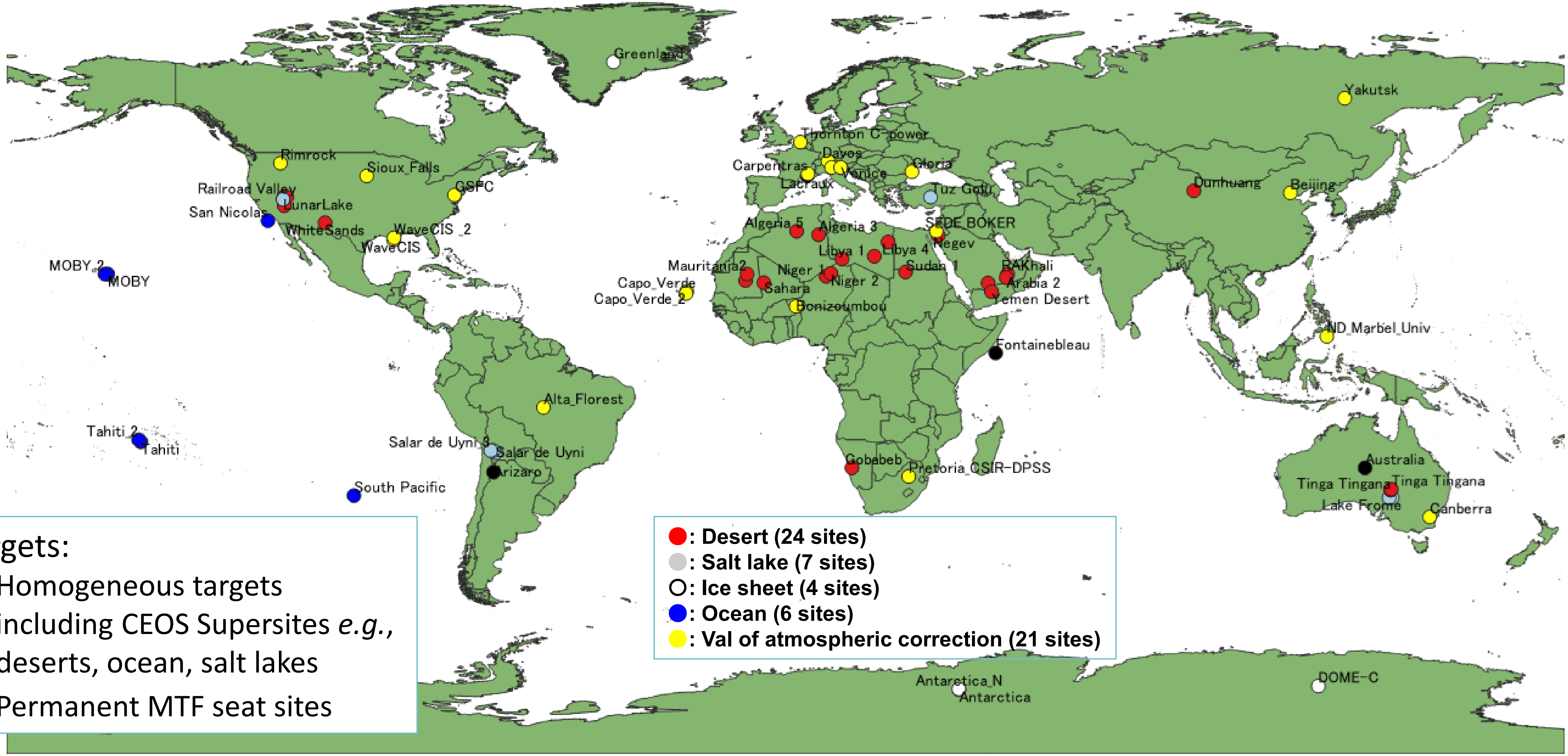


Targets:

- ✓ Measured GCP sites
- ✓ Nighttime GCPs will be added from actual images.

Geometric Cal Sites in the world (101 Sites, as of Sep 2021).

ALOS-3 Cal/Val Test Sites – Radiometry and AC

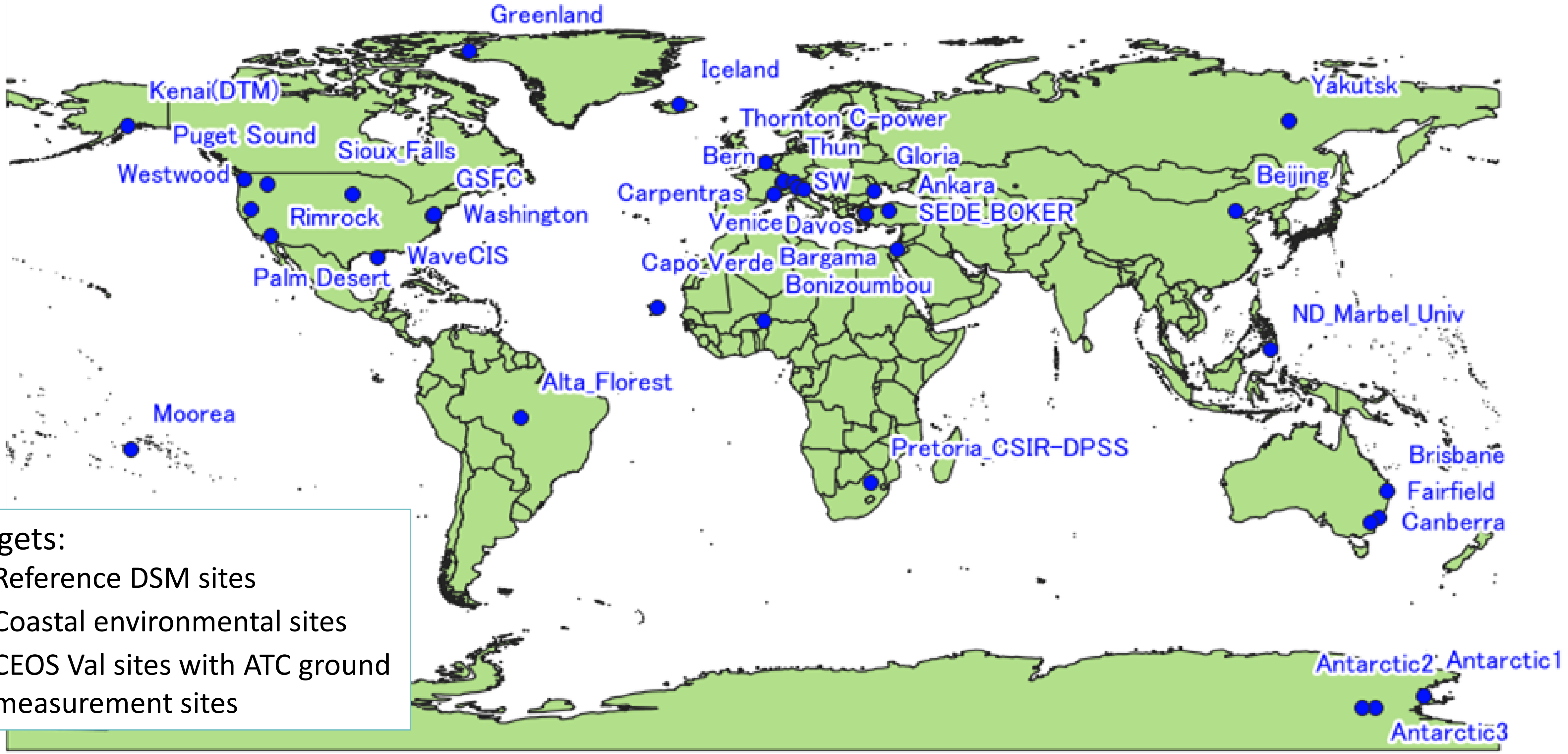


Targets:

- ✓ Homogeneous targets including CEOS Supersites *e.g.*, deserts, ocean, salt lakes
- ✓ Permanent MTF seat sites

Radiometric Cal/Val Sites in the world (66 Sites, as of Sep 2021).

ALOS-3 Cal/Val Test Sites - Validations



Targets:
- ✓ Reference DSM sites
- ✓ Coastal environmental sites
- ✓ CEOS Val sites with ATC ground measurement sites

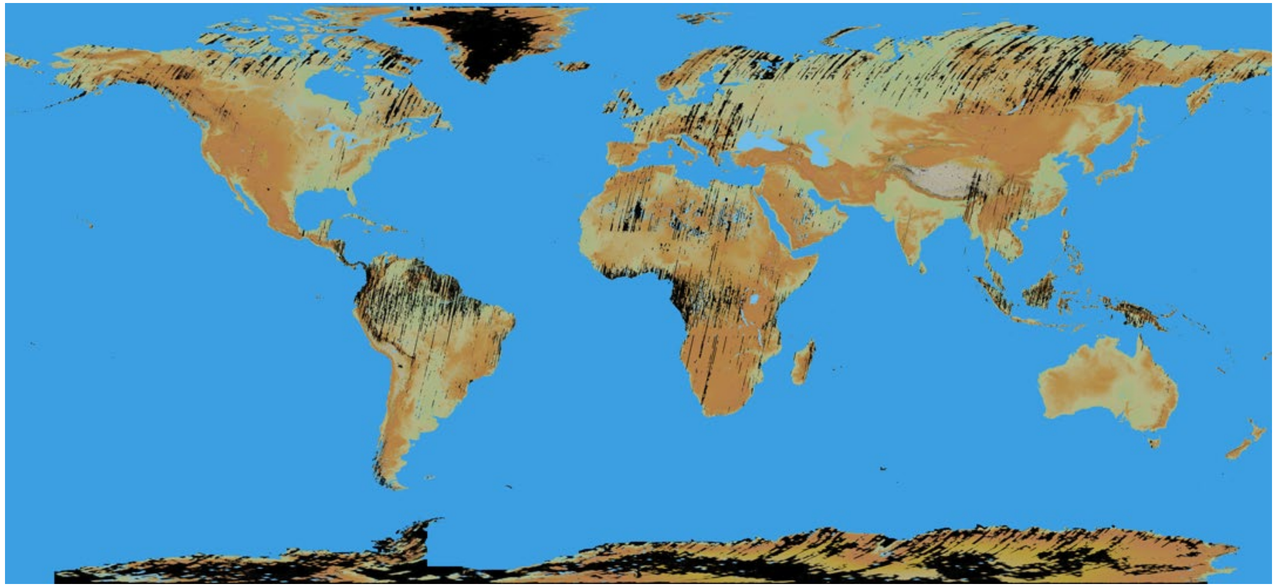
Validation Sites in the world (37 Sites, as of Sep 2021).

ALOS-3 Validation - DSM Generation

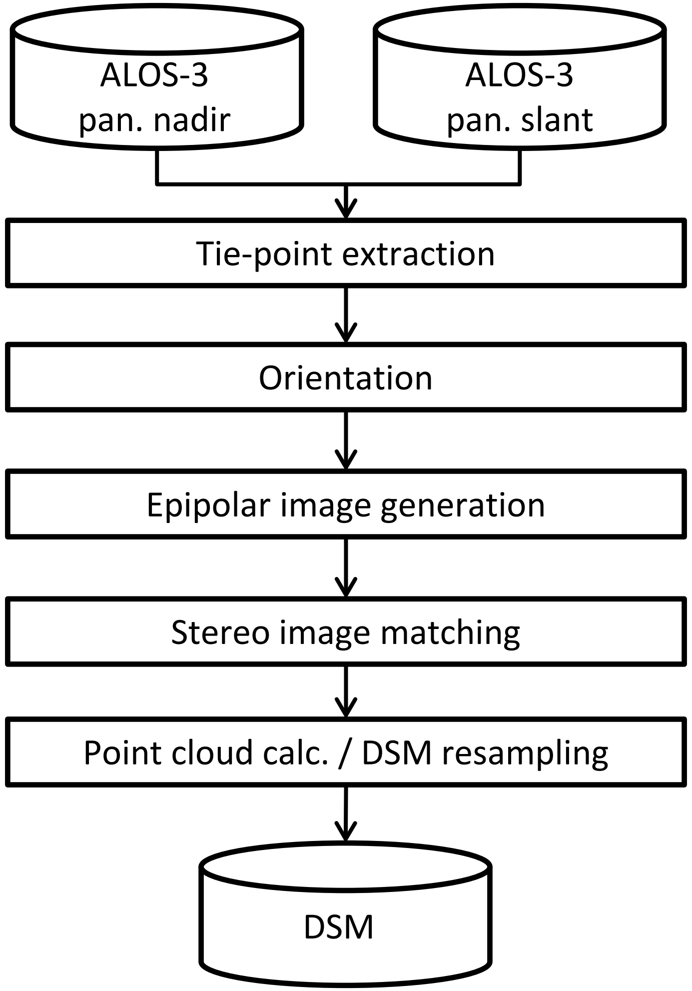
- **The digital surface model (DSM) generation using "3D1" and "3D2" obs. mode**

Algorithm: based on the AW3D's (ALOS/PRISM)

- RPCs for representing the sensor geometry
- Orientation with feature based tie-points
- Triangulation (XYZ) with RPCs at GCPs
- The semi-global matching (SGM) for the stereo image-matching

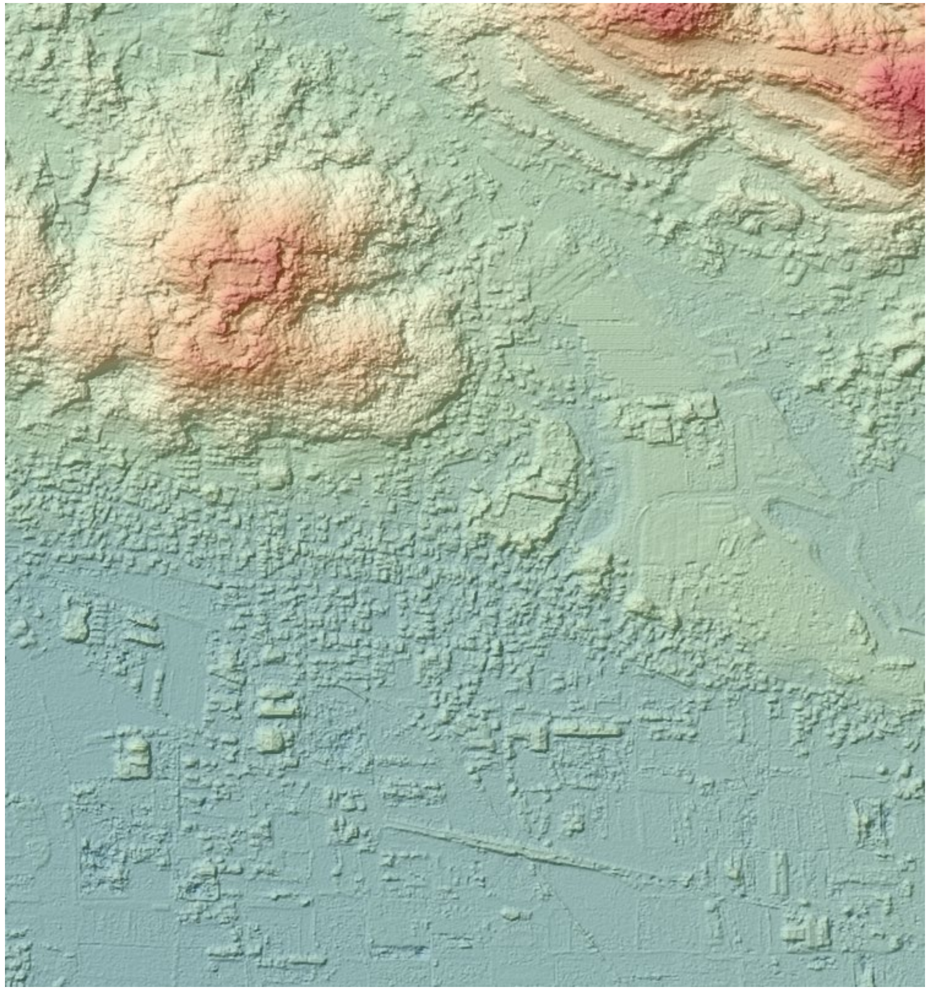


ALOS Global Digital Surface Model "ALOS World 3D - 30m (AW3D30)"



ALOS-3 Validation - DSM Generation

■ **A pre-launch study of DSM generation using simulated ALOS-3 images**

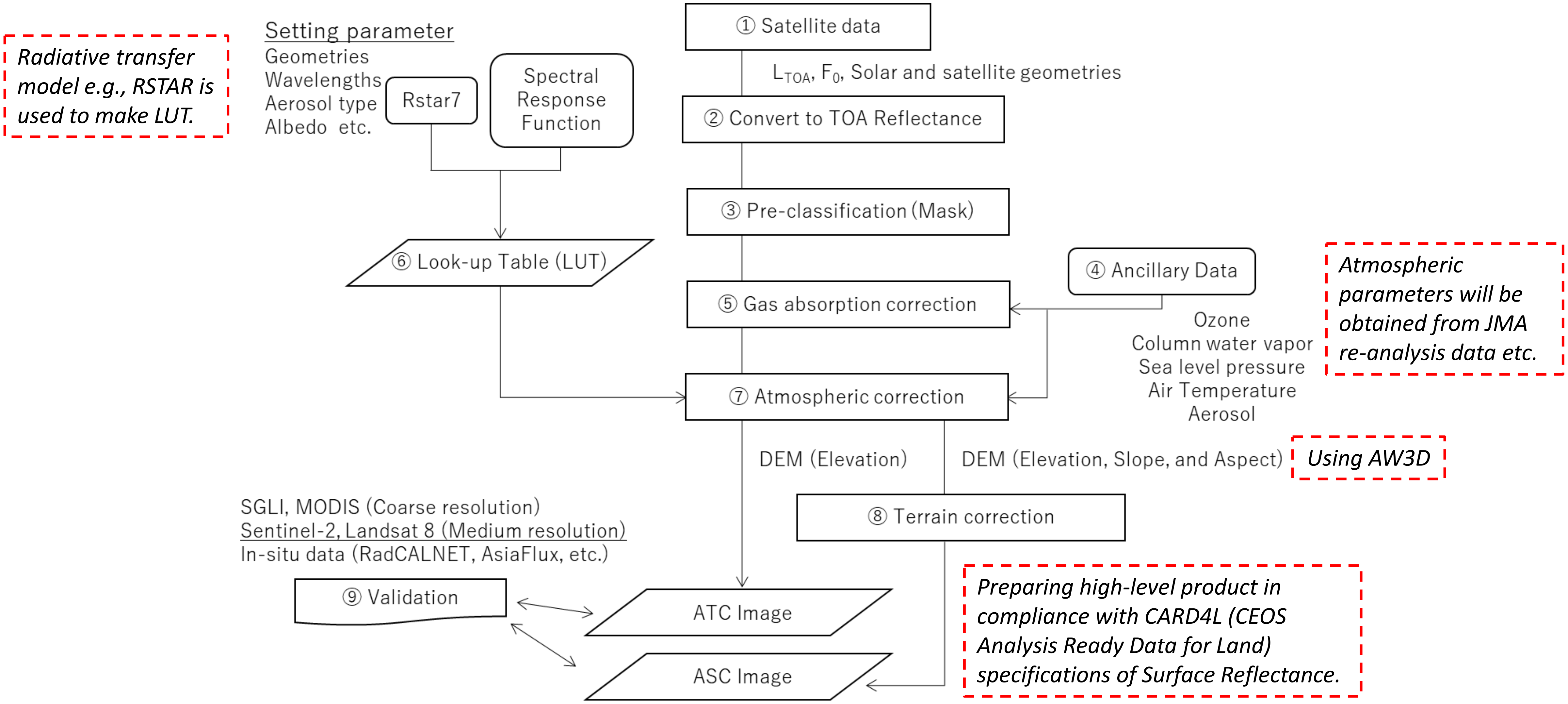


ALOS-3 DSM in 0.8 m generated with the software prototype.

ALOS/PRISM DSM (AW3D) in 2.5 m.

ALOS-3 Validation - Atmospheric Correction

■ Atmospheric Correction (ATC) and Terrain Correction *i.e.,* Radiometric Slope Correction (ASC)



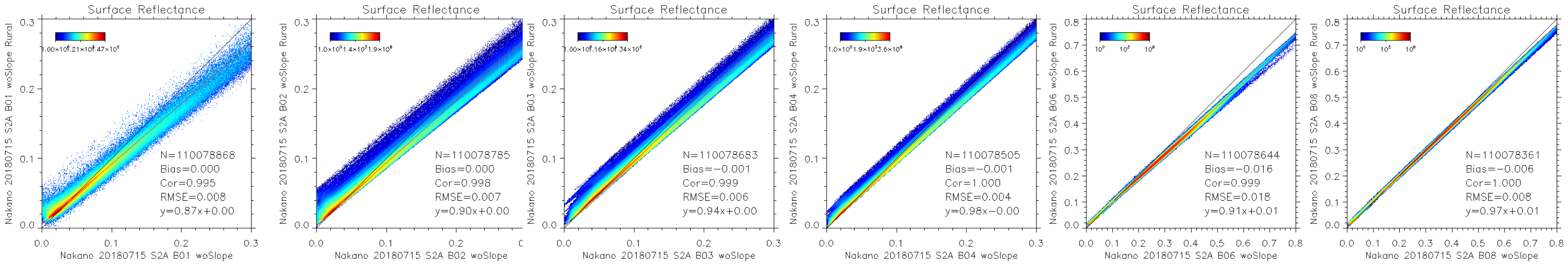
Processing flowchart of ATC and ASC of ALOS-3.

ALOS-3 Validation - Atmospheric Correction

- **Evaluation of the algorithm are applied using WorldView-2 and Sentinel-2 as pseudo data.**

(a) TOA Reflectance **(b) ATC image** **(c) ASC image**

Applied atmospheric and terrain correction algorithm to Sentinel-2 L1C data (20180715, Nagano)



Compared surface reflectance of ATC images with Sentinel-2 Level-2A product

ALOS-3 Validation - Land-Use & Land-Cover Classification

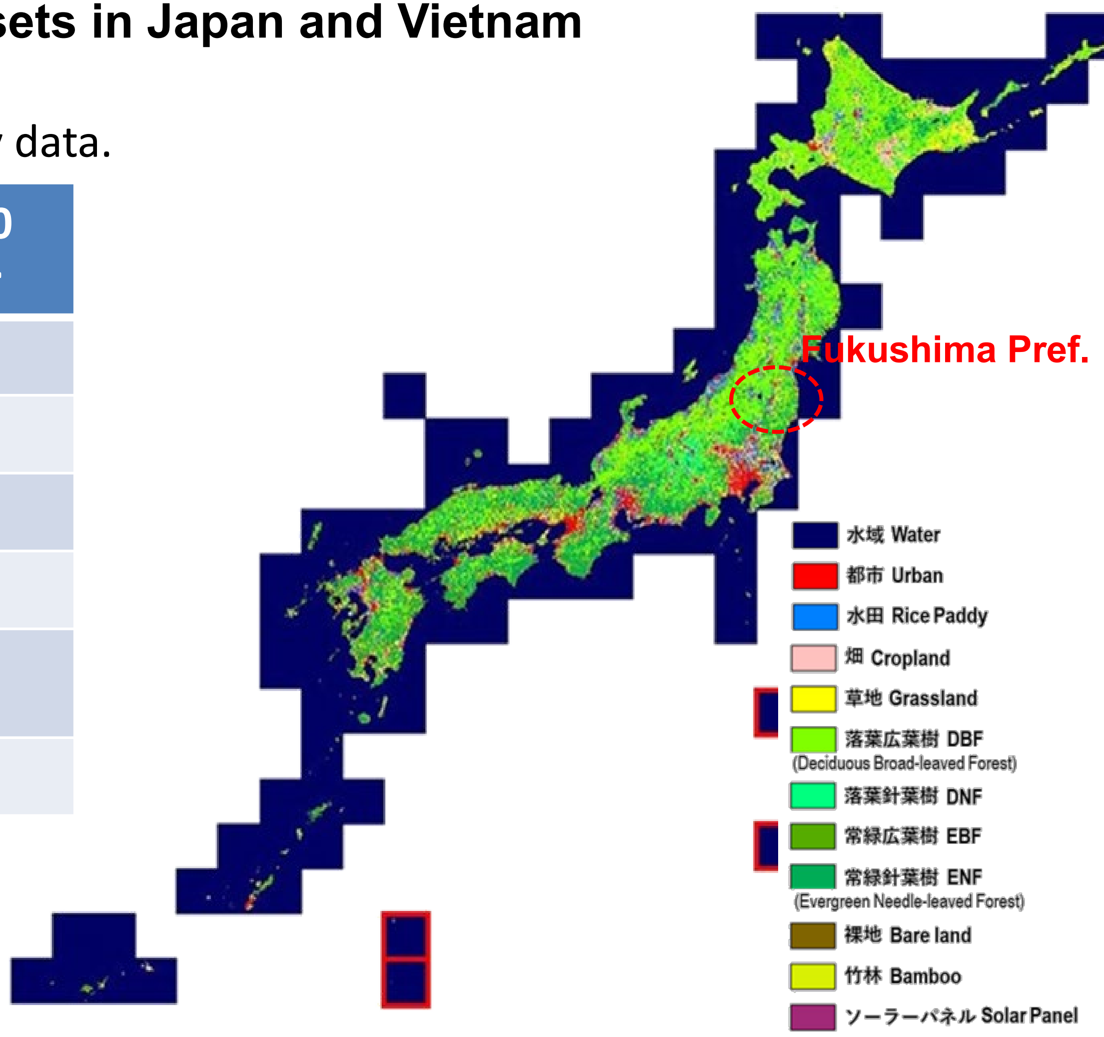
■ High-resolution Land-Use Land-Cover (HRLULC) map datasets in Japan and Vietnam

- Multi-temporal optical images using seasonal changes.
- SAR images, elevation data (AW3D30), etc. were used as auxiliary data.

Period (Japan dataset)	2006～2011 Before	2014～2016 5 yrs later	2018～2020 10 yrs later
Main source of EO data	ALOS/AVNIR-2	Landsat-8/OLI	Sentinel-2
Spatial resolution	10 m	30 m	10 m
Method	SACLASS	SACLASS	CNN
Number of categories	10	10	12
Overall accuracy (%) By 2,700 of validation points	78.0	81.6	88.9
Dataset Ver. (Release YY.MM)	16.09	18.03	21.11

Example of optical images

Mar 14, 2011 **Oct 27, 2016** **Oct 31, 2020**

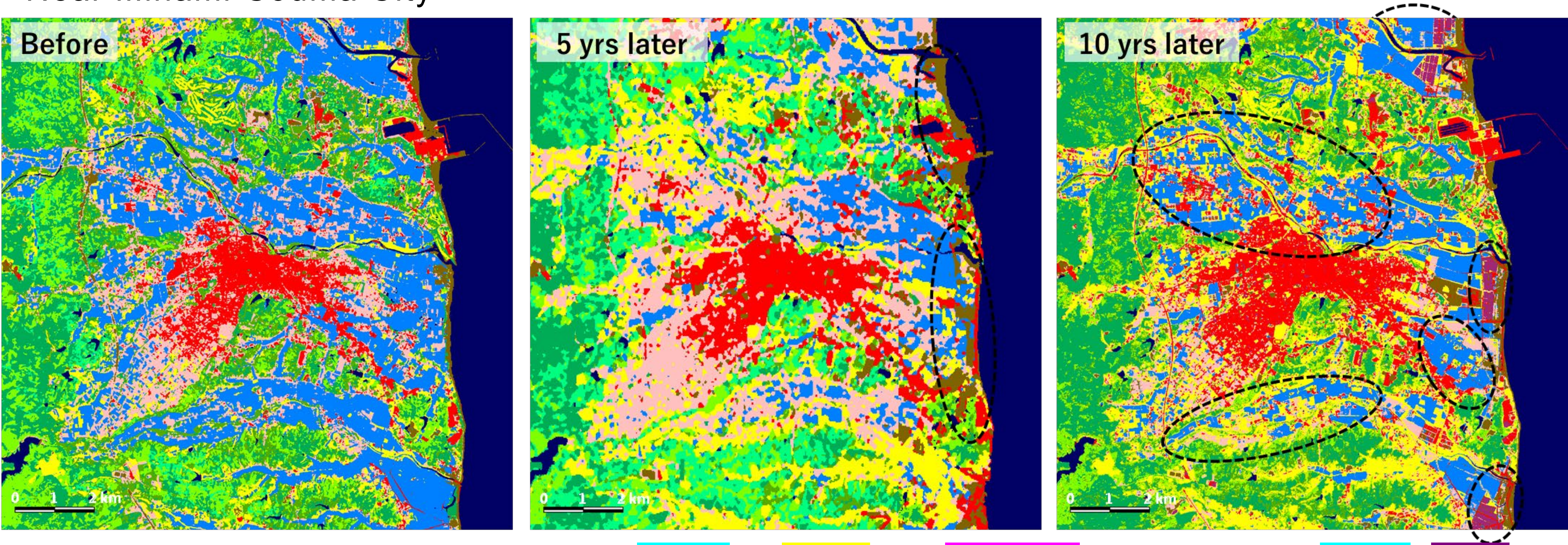


High-resolution LULC map in Japan (Ver. 21.11)

https://www.eorc.jaxa.jp/ALOS/en/dataset/lulc_e.htm

LC Changes #1 in Fukushima Pref., Japan

Near Minami-Souma City



Paddy → Grass and Cropland → Recovery of Paddy, Solar

水域 Water	畑 Cropland	落葉針葉樹 DNF	裸地 Bare land
都市 Urban	草地 Grassland	常緑広葉樹 EBF	竹林 Bamboo
水田 Rice Paddy	落葉広葉樹 DBF (Deciduous Broad-leaved Forest)	常緑針葉樹 ENF (Evergreen Needle-leaved Forest)	ソーラーパネル Solar Panel

Summary

The overview of ALOS-3 and its Cal/Val plan were introduced. ALOS-3 will be operating soon as expected, the satellite and ground system development, an operation plan establishment, and Cal/Val activities etc. are ready to launch. More information is given on

- *ALOS-3 and ALOS-4* :
  - ✓ Continuous contributions in applications based on the ALOS-series satellites.

    https://www.eorc.jaxa.jp/ALOS/en/alos-3/a3_about_e.htm

    https://www.eorc.jaxa.jp/ALOS/en/alos-4/a4_about_e.htm

JAXA Earth Observation Research Center (EORC) conducts the EO Research Announcement (EO-RA) program. The 3rd EORA (*EO-RA3*) was called last year, and the late proposal of EO-RA3 will be opened to call in June and July 2022 timeframe, which covers Cal/Val and application research themes of ALOS-3 for your proposal. Selected Principal Investigator (PI) will be able to access limited numbers of ALOS-3 data. Please refer to our web if you have interesting in it

https://earth.jaxa.jp/en/research/cooperation/index.html

Thanks for attentions.

Any questions or comments?

E-mail: tadono.takeo@jaxa.jp

FP backscatter
ALOS-2 © JAXA