JAXAにおける地球観測と「だいち」ALOS利用研究プロジェクト

JAXA's EO Programs and "Daichi" (ALOS) Research and Application Project

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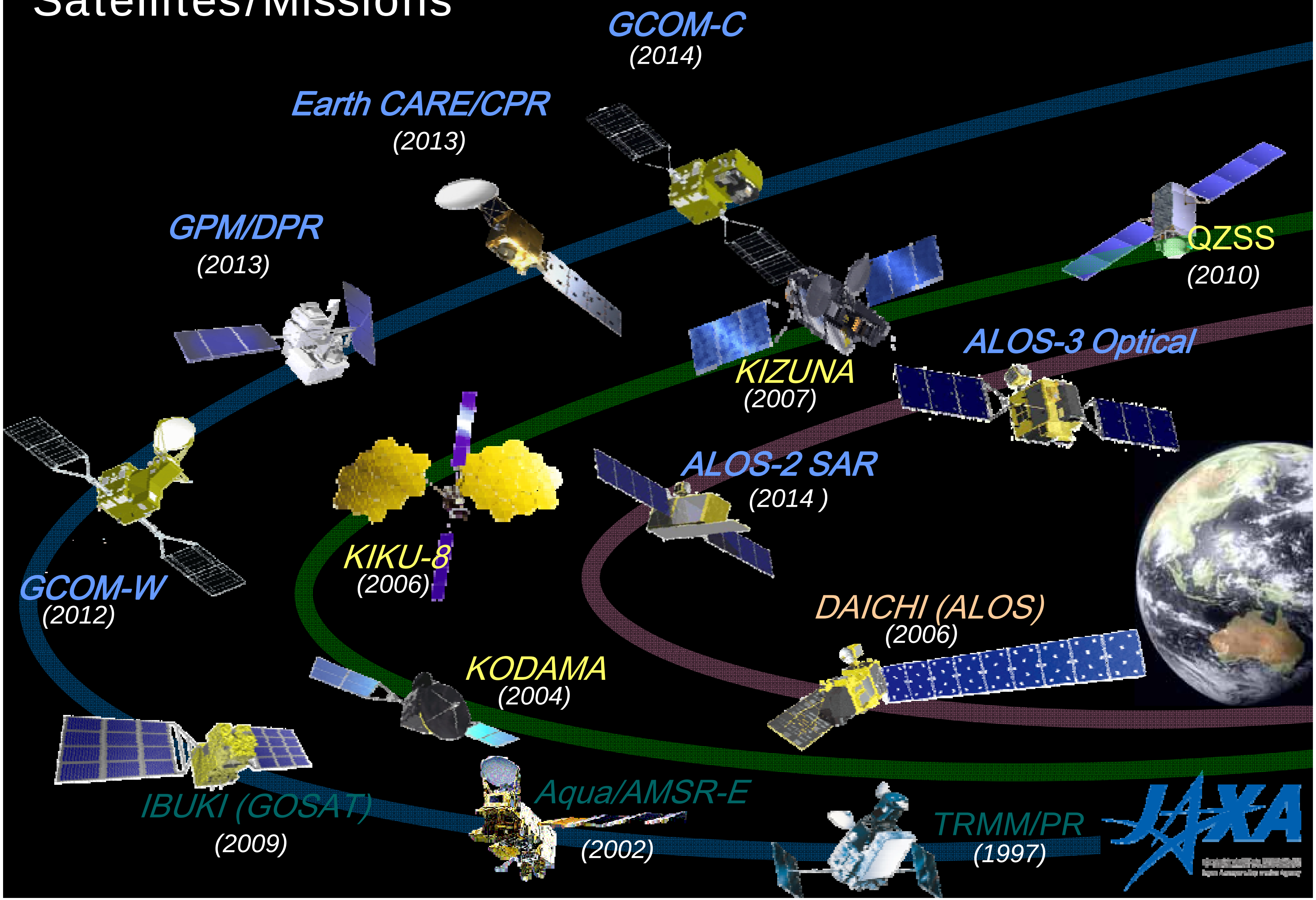
Bird's eye view of Lunana Region, Bhutan using PRISM DSM with AVNIR-2

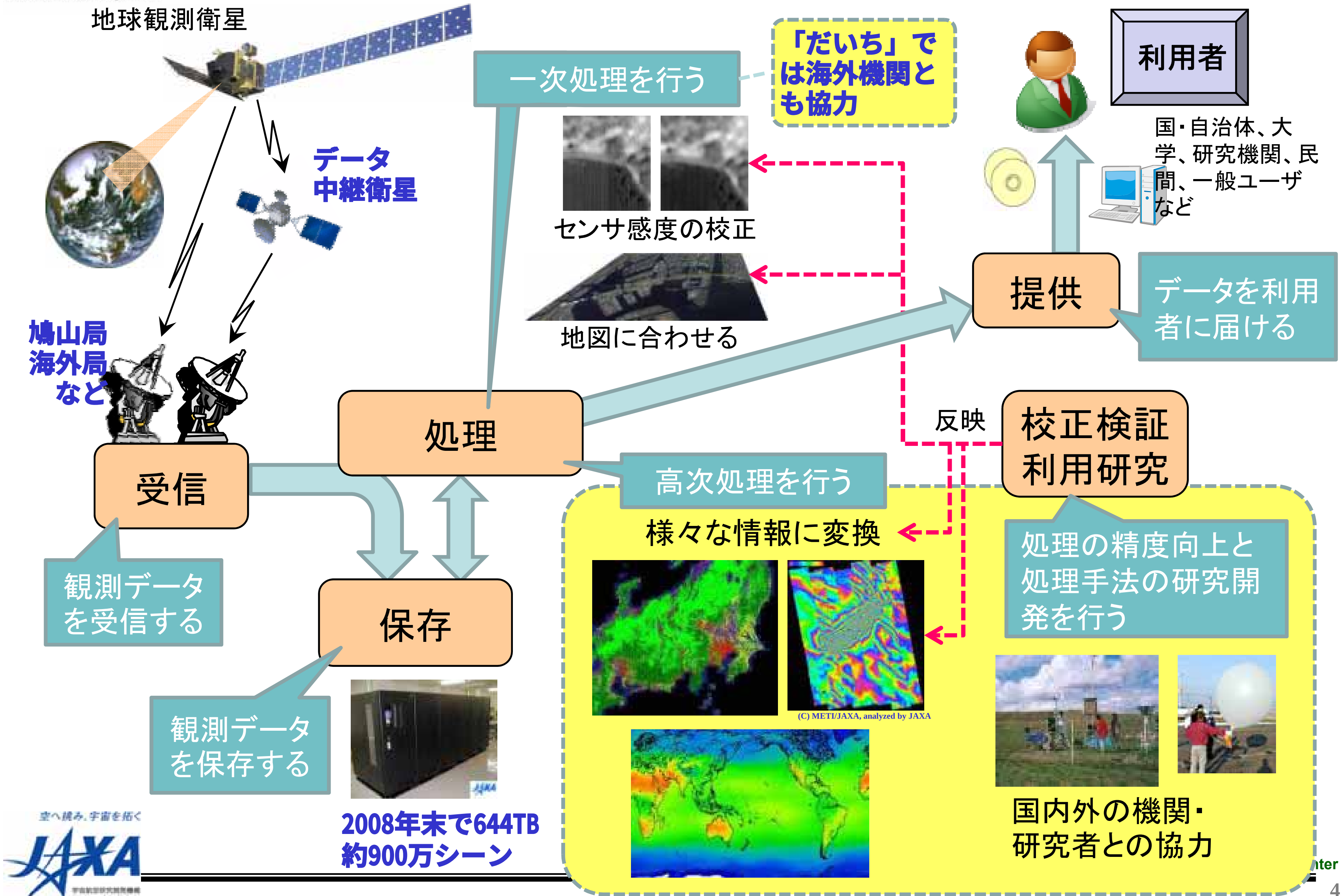
Outline

- ***Introduction***
  - ✓ JAXA's Earth Observation (EO) Program
  - ✓ Earth Observation Research Center (EORC), JAXA
- ***"Daichi" (ALOS) Research and Application Project***
  - ✓ Overview and status of *"Daichi"* (ALOS)
  - ✓ Sensor calibration
  - ✓ Product validation : PRISM Digital Surface Model (DSM)
- ***Data Analysis Examples***
  - ✓ Forest and LULC mapping by PALSAR and AVNIR-2
  - ✓ Disaster monitoring with the emergency observation
  - ✓ Glaciers and glacial Lakes in the Bhutan and Nepal Himalayan Regions: *"Glacial Lake Outburst Flood (GLOF)"*

JAXA Operating and **Planned** Satellites/Missions



JAXAにおける衛星データ処理:EORCの役割



Calibration and Validation (Cal/Val)

From space (satellite and sensor)

- -Digital number (DN)
- -Pixel, Line (x, y)
- -Position, attitude, time
- -…

Calibration

Characterization
Spatial and temporal variation, degradation
Parameter update, tuning

On the ground

- -Radiance, NRCS, BT
- -Lon, Lat (x, y)
- -(Altitude, z)
- -…

Accuracy Assessment

Requirement to specification of next mission

User

Geo-physical parameters

- -Surface reflectance
- -Classification
- -Altitude, height, map
- -Forest biomass
- -Soil moisture, snow
- -SST, Ocean color
- -Wind speed, vector
- -Precipitation
- -Aerosol
- -CO_2
- -Surface deformation
- -Disaster monitoring
- -…

Validation

Research and analysis
Knowledge
Accuracy evaluation

Reference data

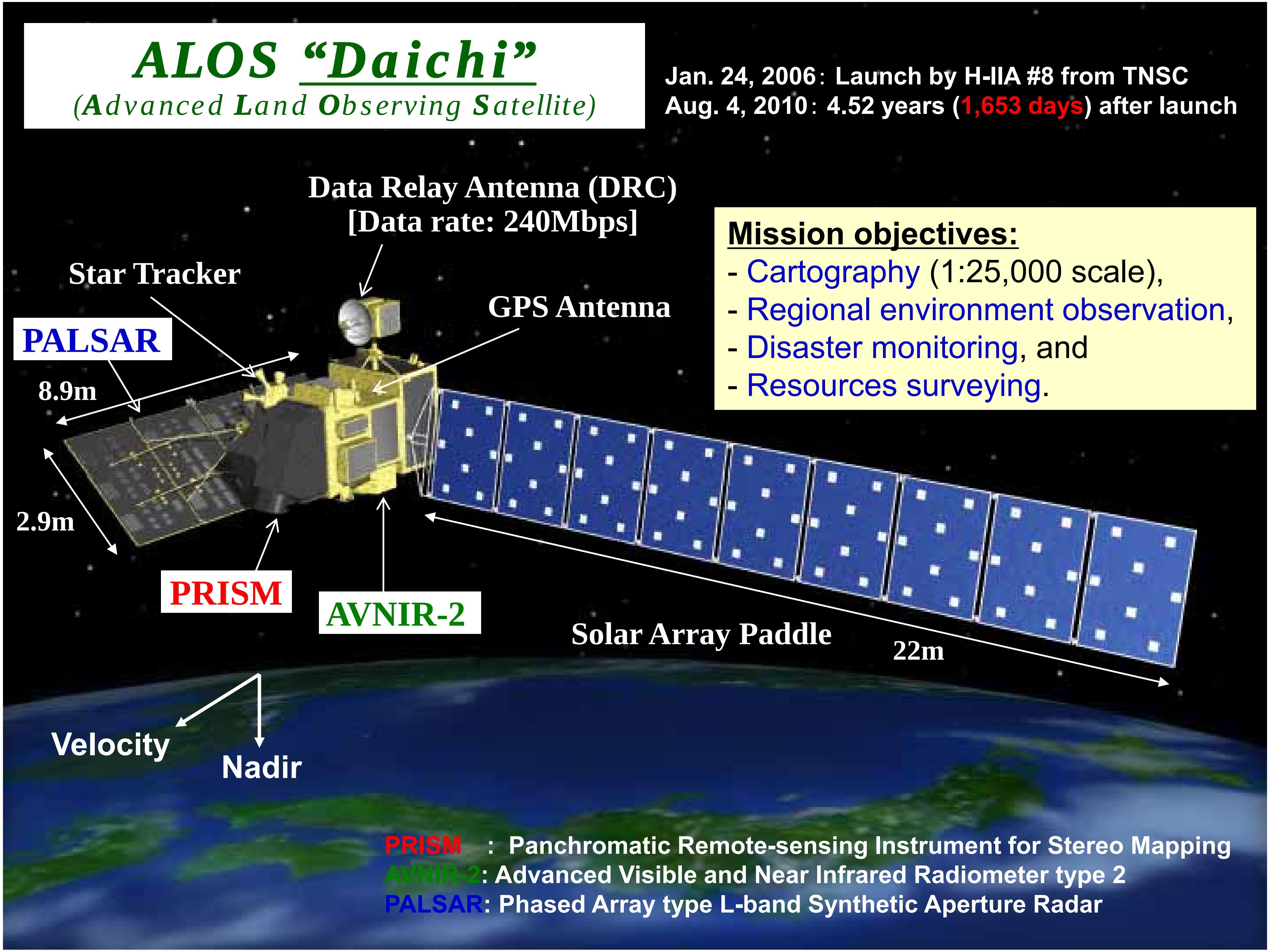
- -Truth data
- -In-situ measurement
- -Experiment
- -Simulation
- -…

Definitions at CEOS Working Group on Calibration and Validation (WGCV)

Calibration: The process of quantitatively defining the system responses to known, controlled signal inputs

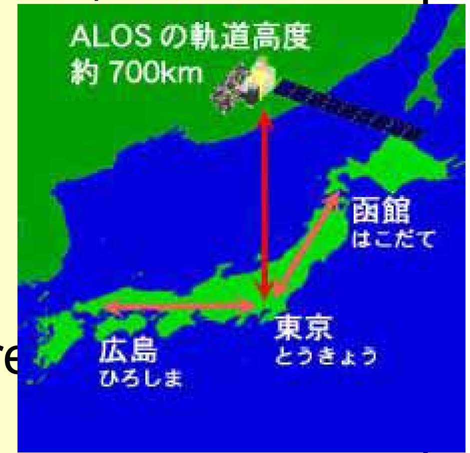
Validation: The process of assessing, by independent means, the quality of the data products derived from the system outputs

Pan-sharpened image of TKSC using PRISM (Mar. 27, 2006) and AVNIR-2 (Mar. 25)


ALOS "Daichi"
(Advanced Land Observing Satellite)
Jan. 24, 2006: Launch by H-IIA #8 from TNSC
Aug. 4, 2010: 4.52 years (1,653 days) after launch
Data Relay Antenna (DRC)
[Data rate: 240Mbps]
Star Tracker
GPS Antenna
PALSAR
8.9m
2.9m
PRISM
AVNIR-2
Solar Array Paddle
22m
Velocity
Nadir
Mission objectives:
- Cartography (1:25,000 scale),
- Regional environment observation,
- Disaster monitoring, and
- Resources surveying.
PRISM : Panchromatic Remote-sensing Instrument for Stereo Mapping
AVNIR-2: Advanced Visible and Near Infrared Radiometer type 2
PALSAR: Phased Array type L-band Synthetic Aperture Radar

"Daichi" (ALOS) Characteristics

Launch Date	10:33am, January 24th, 2006 (JST)
Orbit	Sun-synchronous
Local Time at DN	10:30am +/- 15 min.
Altitude	691.65 km @Equator
Inclination	98.16 degrees
Recurrent Period	46 days (Sub-cycle: 2 days)
Revolution	14 + 27/46 (/day), 671 (/recurre
Period	98.7 minutes
Longitude Repeatability	+/-2.5 km > +/-0.5km@Equator (Feb. 2, 2007)
Data Collection	1 DRTS (Data Relay Test Satellite), 240 Mbps HSSR (High Speed Solid state Recorder) + DT (X-band direct downlink), 120 Mbps
Yaw Steering	Off / On
Attitude Error each axis	2.0e-4 deg. (goal) 0.1 deg. (maintain)
Design Life	3 years > 5 years (expecting)
Satellite Mass	4,000.8 Kg
Generated Power	8.5KW@BOL (>7 KW@EOL)



ALOS Basic Observation Scenario

PRISM (Descending)

- ✓ One global coverage annually (OB1 Triplet; OB2 selected areas)
- ✓ 2 cycles (2 x 46 days) required for each region (+/-1.2deg. pointing angle)
- ✓ Timing based on cloud statistics, seasonality and sun elevation

AVNIR-2 (Descending)

- ✓ One global coverage annually (0deg. pointing)
- ✓ One observation within 2 cycles
- ✓ Timing based on cloud statistics, seasonality and sun elevation

PALSAR (Ascending / Descending)

- ✓ Asc.: 2-3 global coverage annually (Summer FBD34deg.; Winter FBS34)
  Global InSAR coverage every 2 yrs
  Pol-InSAR campaigns every 2 yrs
- ✓ Desc.: One global ScanSAR coverage annually
  Intensive ScanSAR sites

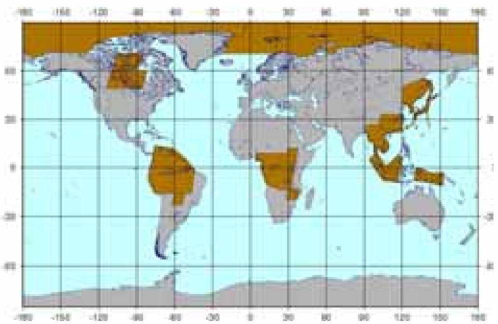
> Since Cycle 28: Prioritize no acquisition areas and cloud-covered areas for optical

* Observation Scenario can be find on web
http://www.eorc.jaxa.jp/ALOS/en/obs/overview.htm

PRISM (green: OB1, yellow: OB2)

AVNIR-2

PALSAR Asc. (FBD34.3)

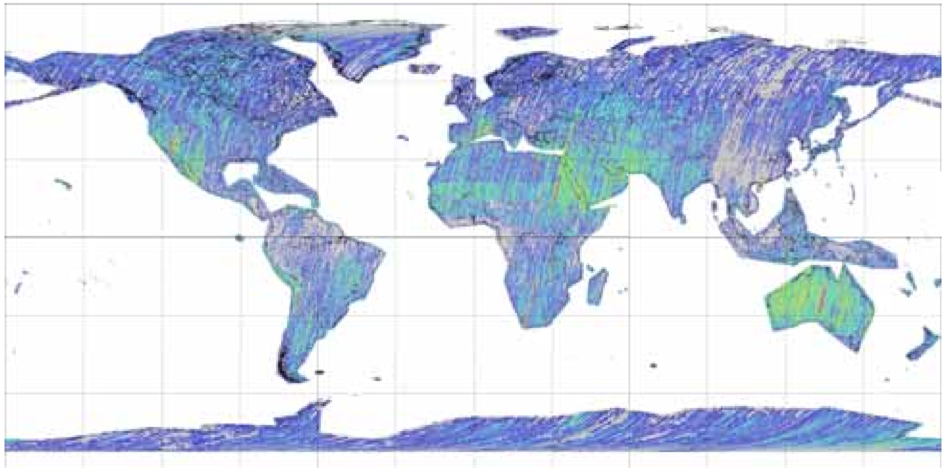


PALSAR Desc. (ScanSAR)

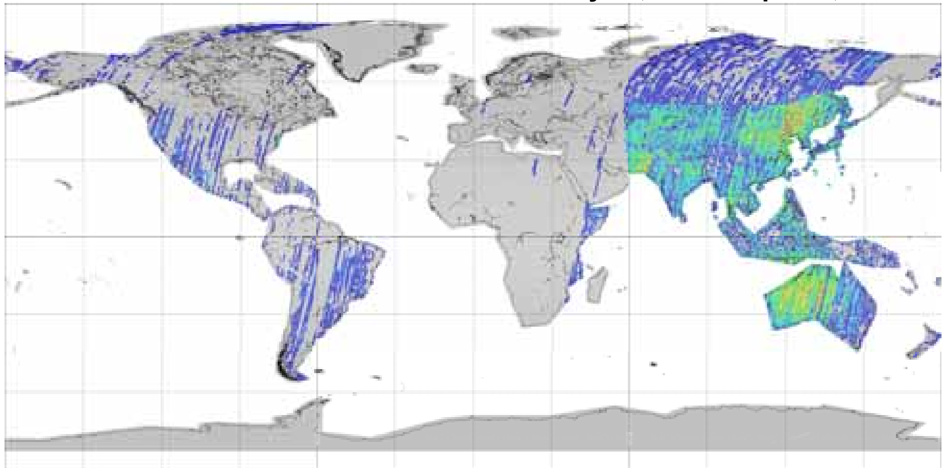
Basic Observation Scenario (Cycle28: Jun 12 - Jul 27, 2009)

Acquisition Status in the World

May 16, 2006 – Apr. 29, 2010

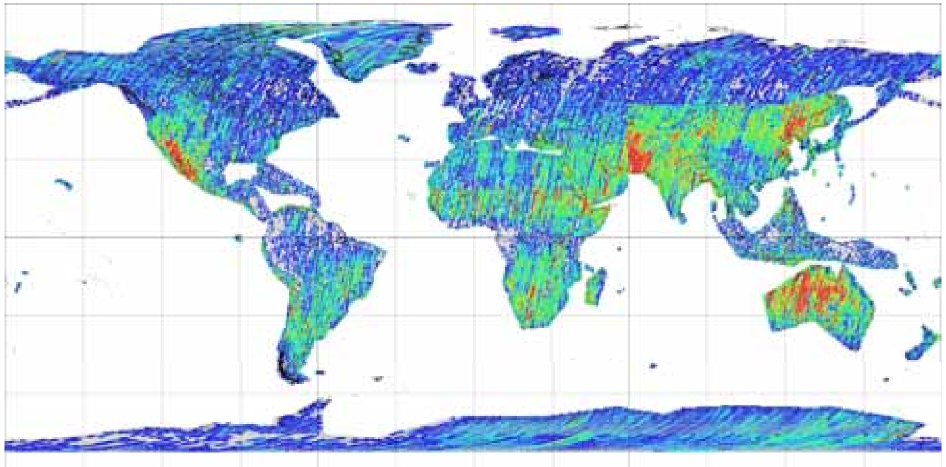


PRISM 35km (OB1) (Cloud cover: 0-2% / scene)



PRISM 70km (OB2) (Cloud cover: 0-2% / scene)

1回観測
2回観測
3回観測
4回観測
5回観測
6回観測
7回観測
8回観測
9回観測
10回以上観測



AVNIR-2 (Cloud cover: 0-2% / scene)

Image coverage map of PRISM and AVNIR-2 based on the basic observation scenario

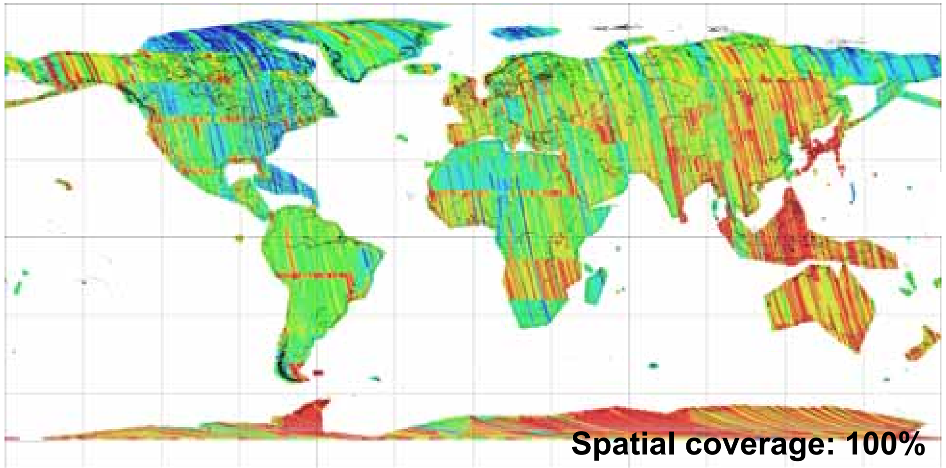
Spatial coverage: **PRISM OB1 65%** with 0-2% cloud cover in scene

OB1 79% with 0-20% cloud cover in scene

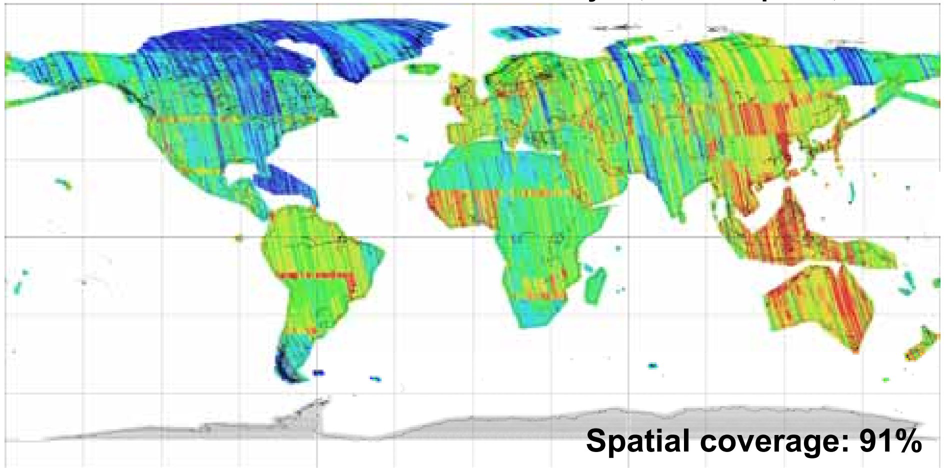
AVNIR-2 77% (0-2%); 89% (0-20%)

Acquisition Status of PALSAR

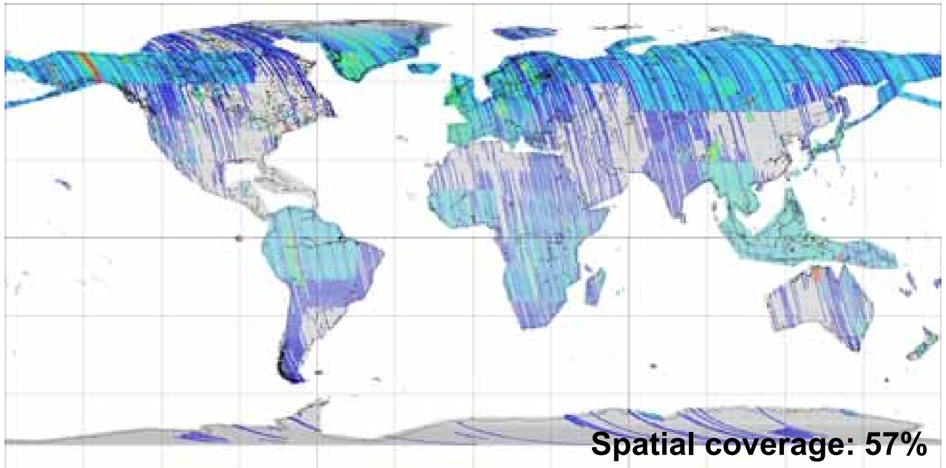
May 16, 2006 – Apr. 29, 2010



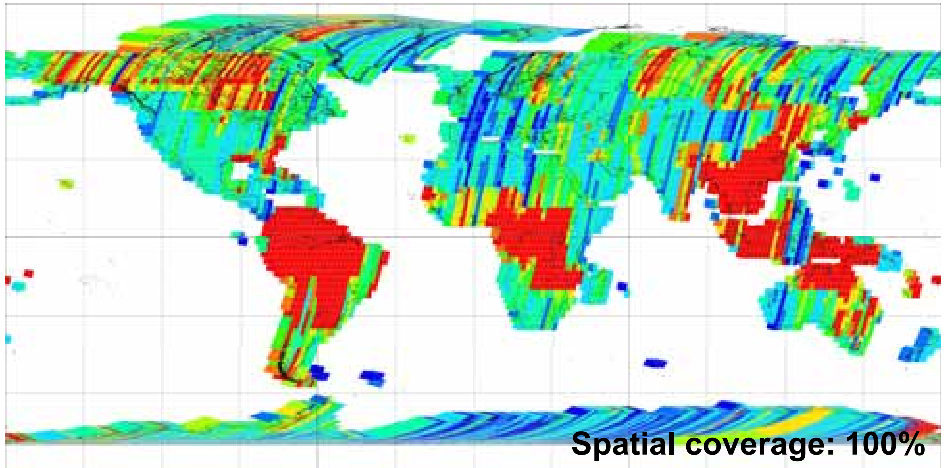
FBS Off-nadir:34.3deg (Asc.)



FBD Off-nadir:34.3deg (Asc.)



PLR Off-nadir:21.5deg (Asc.)

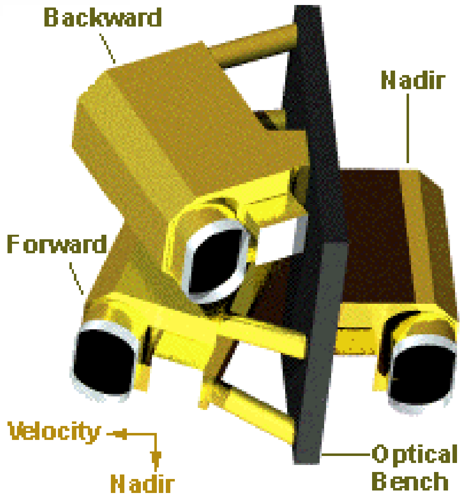


WB1/WB2 Off-nadir:27.5deg (Desc.)

1回観測	4回観測	7回観測	10回以上観測
2回観測	5回観測	8回観測	
3回観測	6回観測	9回観測	

Image coverage maps of PALSAR based on the basic observation scenario

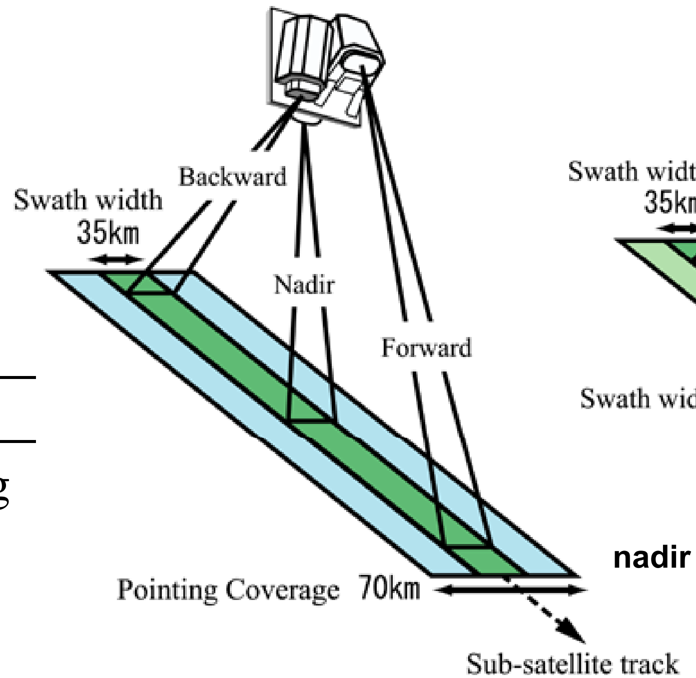
PRISM



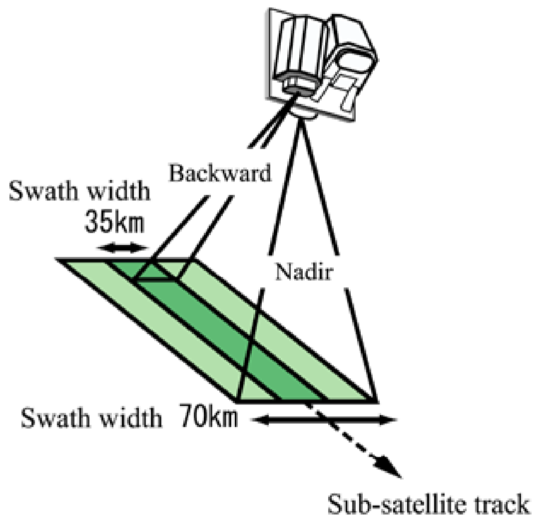
Panchromatic Remote-sensing Instrument for Stereo Mapping

0.52-0.77μm

Number of Optics : 3, AT +/- 23.8 deg
(Nadir / Forward / Backward)
Base/Height ratio : 1.0 (F / B)
Spatial resolution : 2.5m at Nadir
Swath width : 35km at Triplet mode
70km at Nadir only
Pointing angle : +/- 1.5 deg.
S/N : >70, MTF : >0.20
Scanning method : Push broom
Quantization : 8 bits
Data compression : JPEG extension



Observing geometry of triplet mode (OB1)

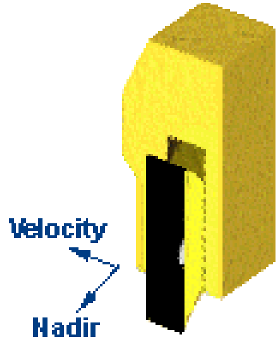


Nadir alone or nadir + backward modes (OB2)

✓Two observation (+/-1.20deg. pointing angle) per orbit are necessary for observing whole coverage by triplet mode except in high latitude areas.

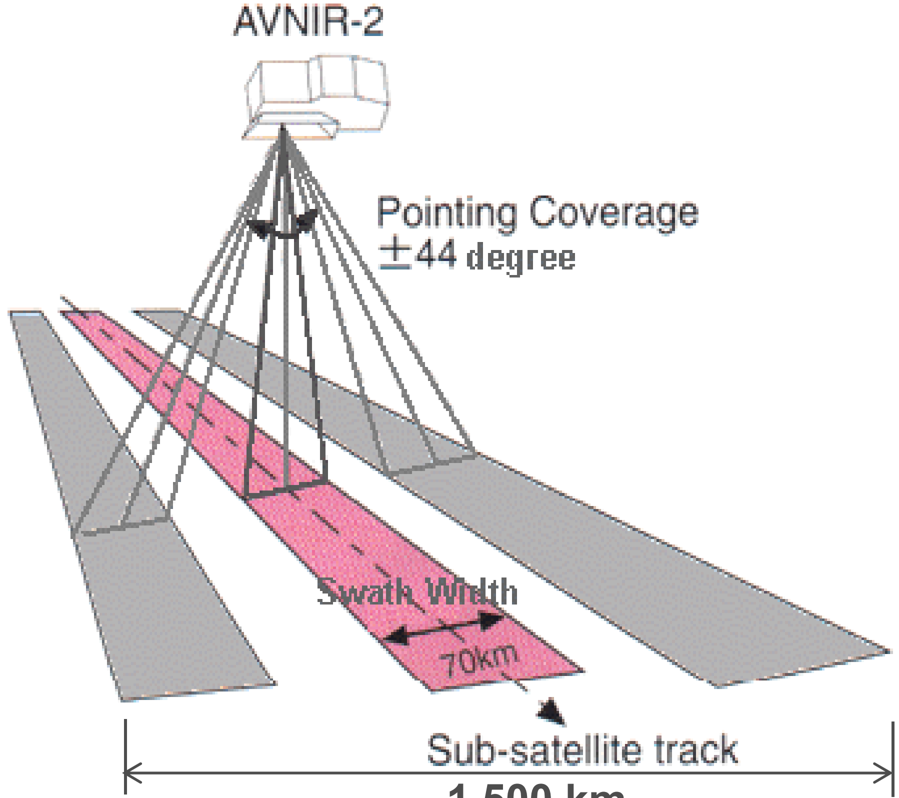
AVNIR-2

Advanced Visible and Near Infrared Radiometer type 2



Band 1 : 0.42-0.50μm
Band 2 : 0.52-0.60μm
Band 3 : 0.61-0.69μm
Band 4 : 0.76-0.89μm

Field of view : 5.8 deg.
Swath width : 70km at Nadir
Instantaneous FOV : 14.28 μrad
Spatial resolution : 10m at Nadir
Number of detectors : 7000 /band
Pointing angle : +/- 44 deg.
S/N : >200, MTF : >0.25 (1-3), >0.20 (4)
Scanning method : Push broom
Quantization : 8 bits

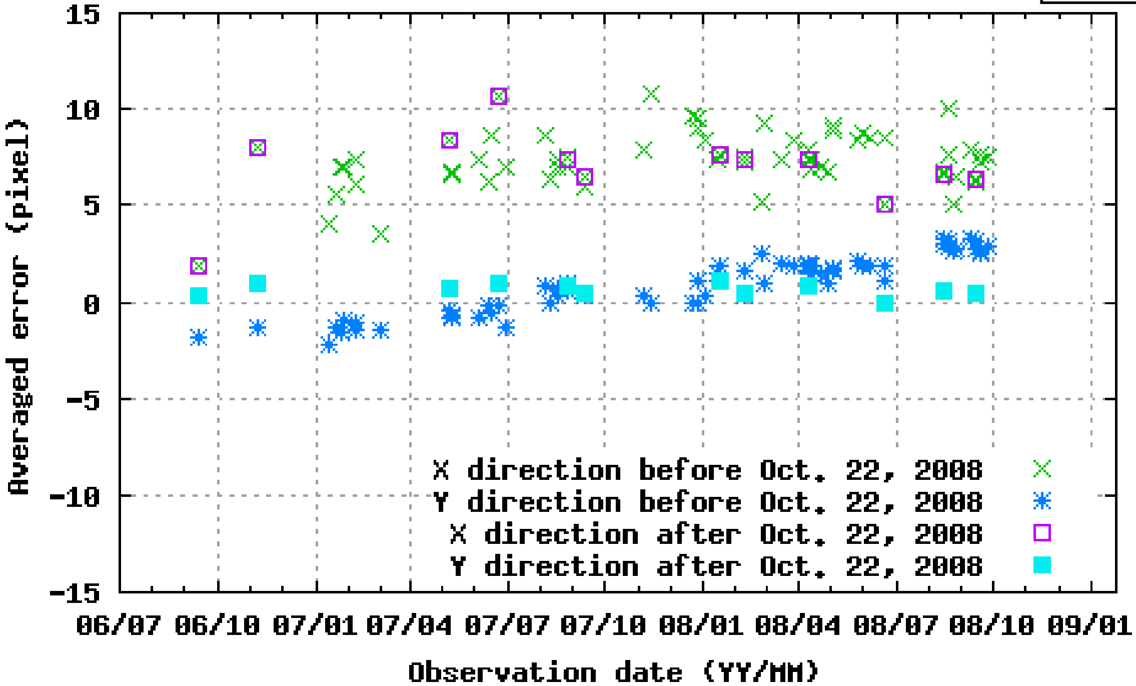


Improvements in AVNIR-2 from AVNIR
- ✓Resolution : 10m < 16m
- ✓Pointing angle : +/-44 deg < +/-40 deg
- ✓Calibration system : lamp 2 < lamp 1, Solar 1

EORC Earth Observation Research Center

Geo Cal – AVNIR-2 Geometric Correction Accuracy

Released on October 22, 2008

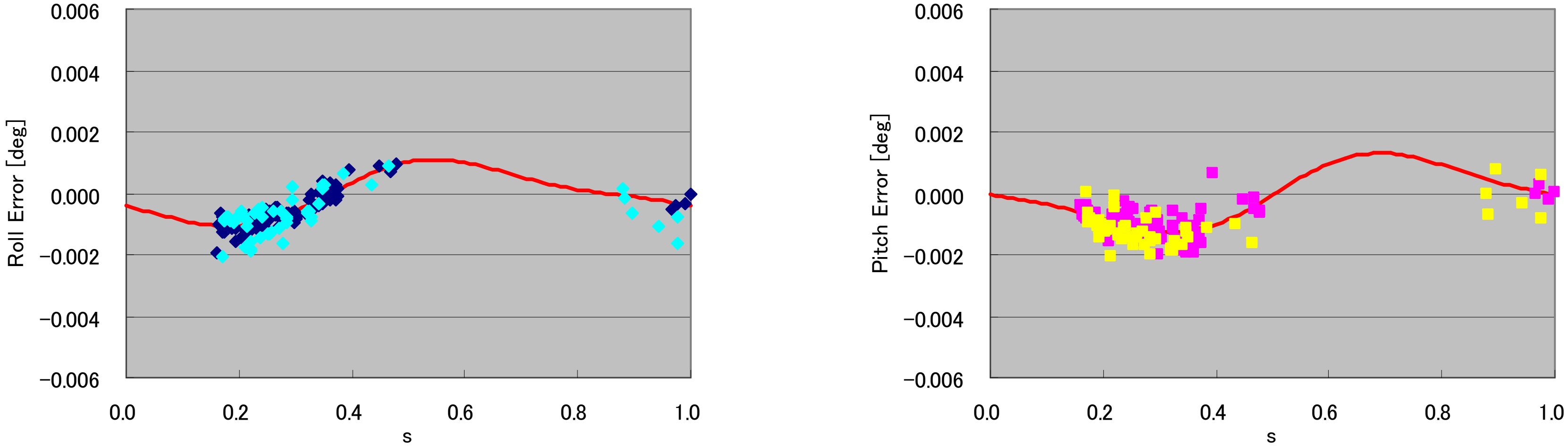


Time trend of geometric accuracies of AVNIR-2 0deg. compared between before and after alignment parameters updated (Oct. 22, 2008).

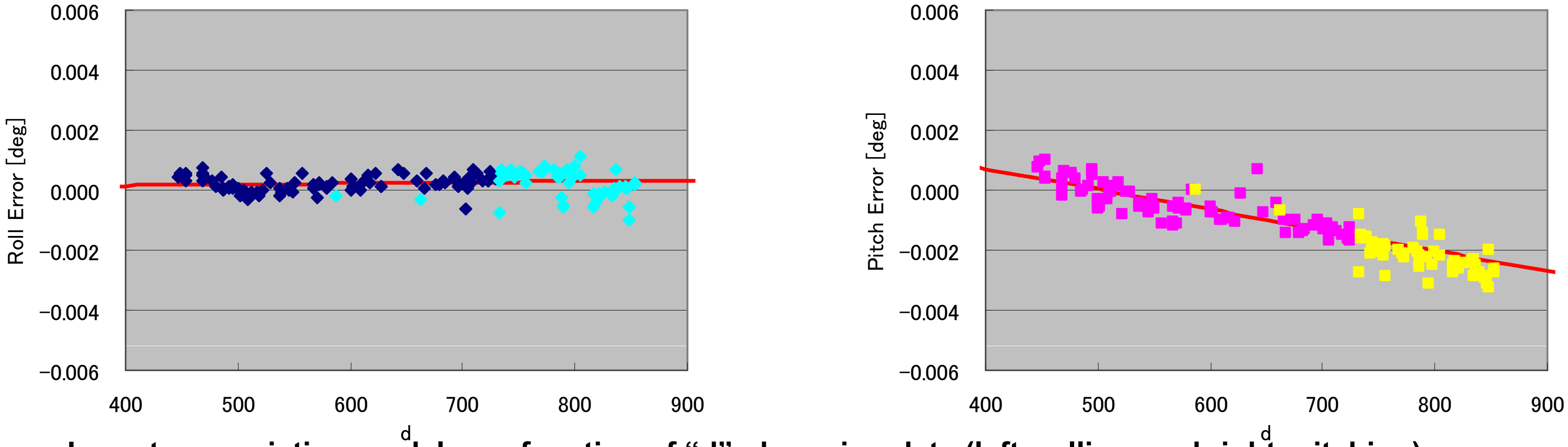
Geometric errors in Y direction of AVNIR-2 had a linear relationship between observation dates before updating alignment parameters (*).

- ✓ Normally, AVNIR-2 is operating as 0deg. pointing angle
- ✓ Satellite orbit inclination change (yaw maneuver) has been done on June and July 2008
- ✓ AVNIR-2 alignment parameters has been updated on October 22, 2008
- ✓ Errors in X direction (x) are caused by quantization of the pointing angle setting

Geo Cal – PRISM Alignment Variation Model



Short term variation model as a function of "s" normalized observing time in recurrent (left: rolling, and right: pitching).

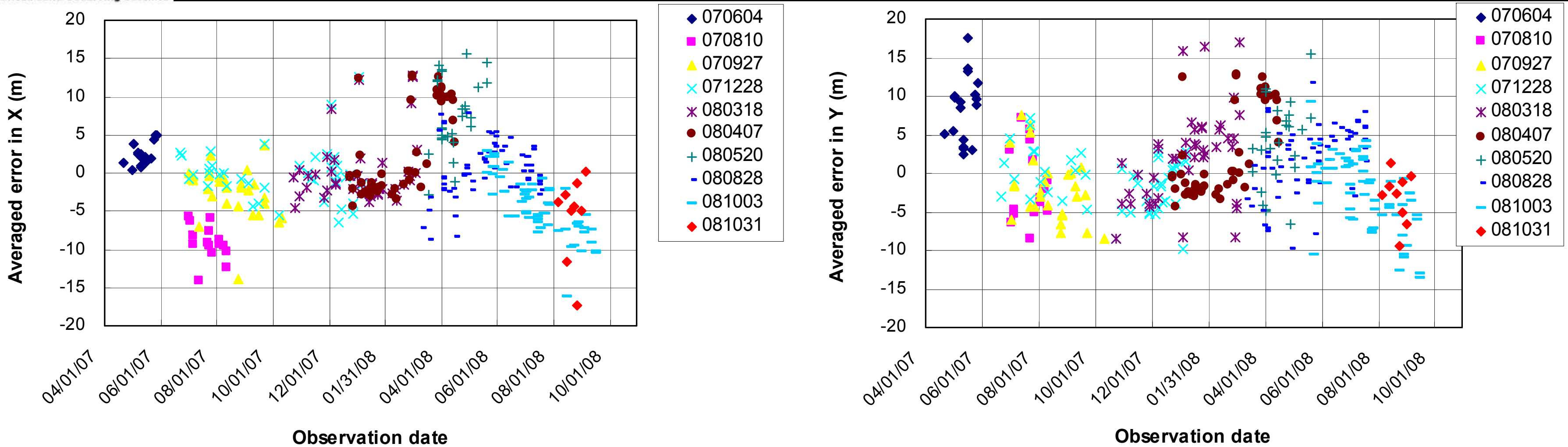


Long term variation model as a function of "d" observing date (left: rolling, and right: pitching).

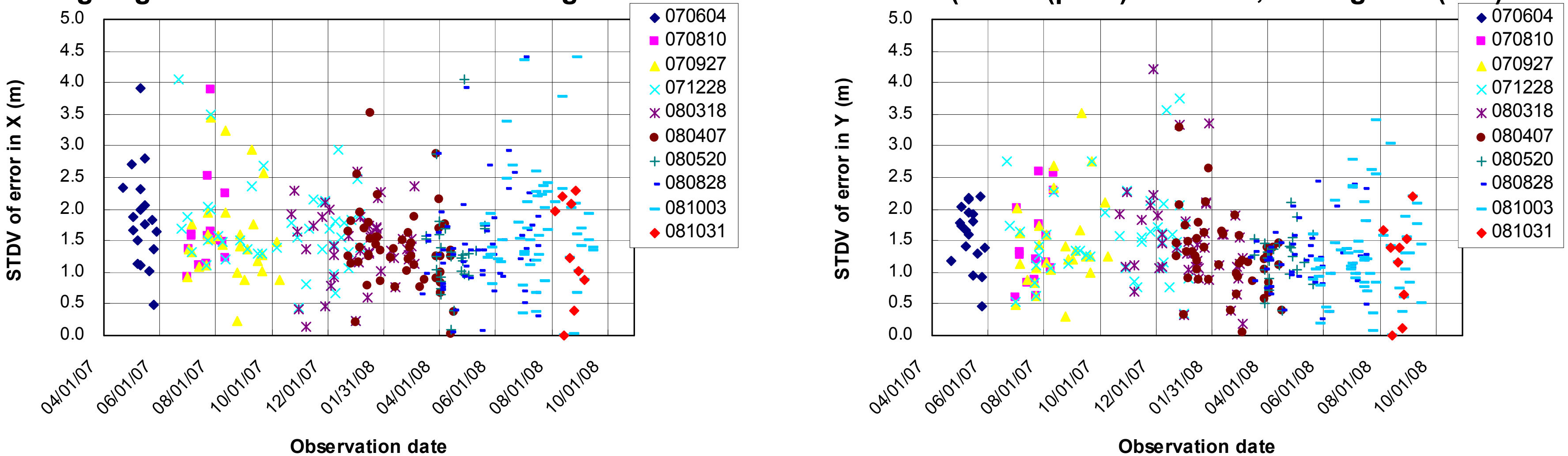
PRISM sensor alignment model (nadir) using GCPs

- ✓ Two time scale: short term - the time (2nd order Fourier series), long term - the date (linear)
- ✓ Similar analysis for forward- and backward-looking radiometers
- ✓ Validation of pointing alignment parameter and generation of high level products

Geo Cal – PRISM Geometric Correction Accuracy



Averaged geometric errors of nadir looking radiometer of PRISM L1B2 (left: X (pixel) direction, and right: Y (line) direction).



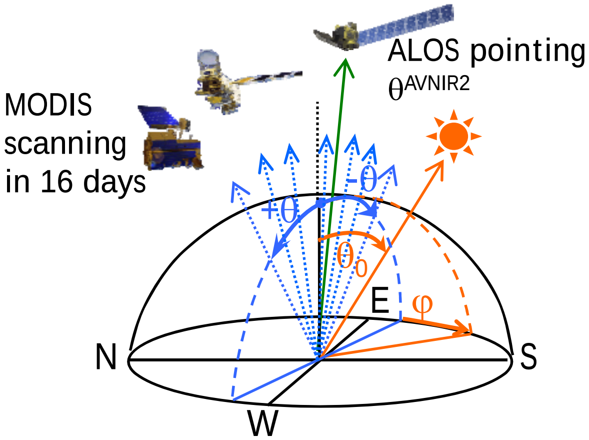
Standard deviations of geometric errors of nadir looking radiometer of PRISM L1B2 (left: X, and right: Y).

Time trends of geometric correction accuracy of PRISM/N since April 2007

- ✓ Averaged error: Absolute geometric correction (i.e. system correction) accuracy
- ✓ Each colored plot: different pointing alignment parameters (APs) to use image processing

Radio Cal – TOA Reflectance Function Scheme

- ✓ The scheme is a cross calibration using the **similar geometric condition**; solar zenith (θ_0), and relative azimuth (φ) angles which depend on local time and inclination angle of the orbit (ALOS ≅ Terra ≅ Aqua (N-S line symmetry) ≅ ENVISAT).
- ✓ We use **top-of-atmosphere (TOA) reflectance function of satellite zenith angle** (θ) at target points using MODIS observations for the reference.
- ✓ Merits: we can get **many samples, not only nadir, and don't need in-situ data**



geometric condition

Geometric condition of AVNIR-2 and PRISM (Nadir) are similar to geometries in 16 days MODIS observations.

ALOS and EOS observations

	ALOS AVNIR-2	*Terra MODIS*	*Aqua MODIS*
Orbit	**Sun-Synchronous Descending 10:30**	**Sun-Synchronous Descending 10:30**	**Sun-Synchronous Ascending 13:30**
Repeat Cycle	**46 days Sub Cycle: 2 days**	**Repeat Cycle: 16 days Sub Cycle: 2 days**	
Altitude	**691.65 km**	**705 km**	
Inclination	**98.16 deg**	**98.2 deg**	
Satellite zenith	**−44~+44 deg (pointing)**	**−65~+65 deg (scanning)**	
FOV (swath)	**70 km**	**2330 km**	
IFOV	**10 m**	**250~1000 m**	

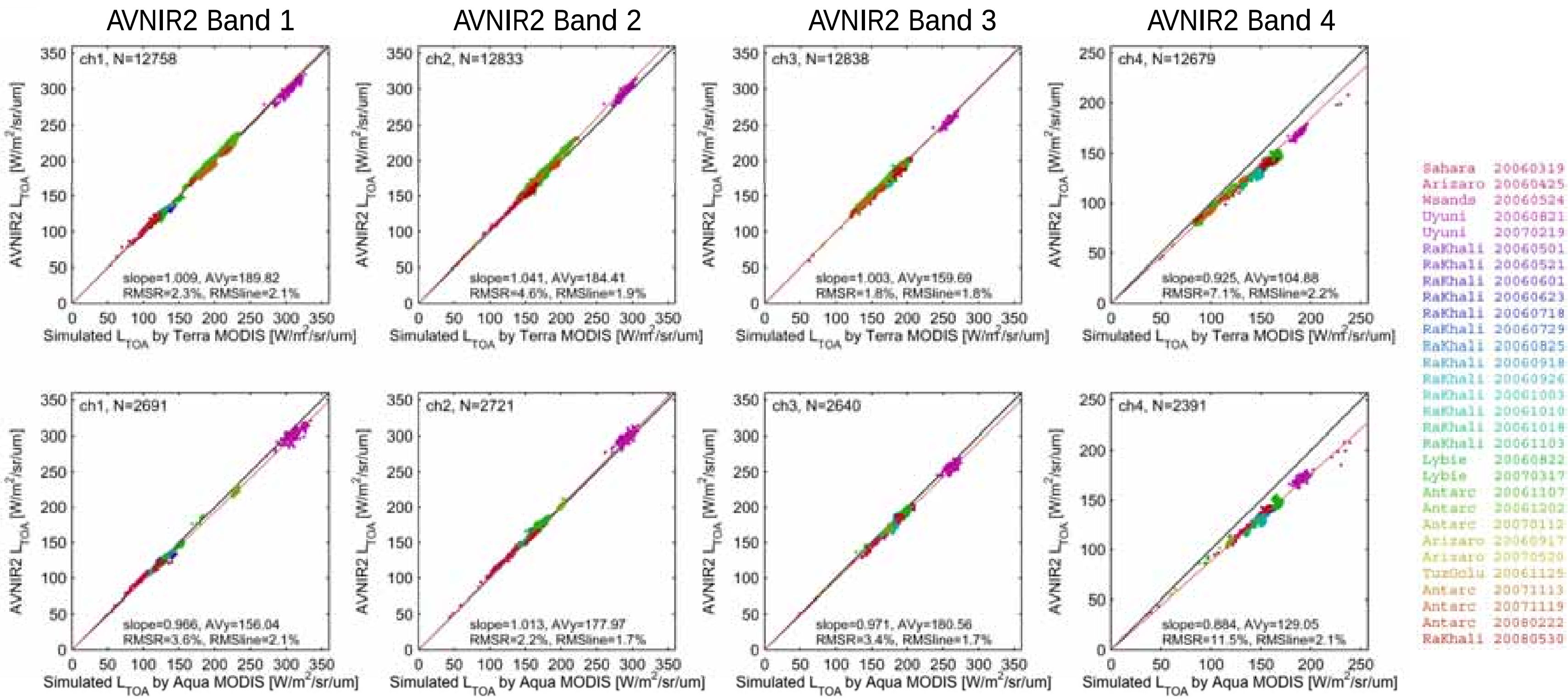
AVNIR-2 and MODIS channels

AVNIR2	*MODIS*
1 (463nm)	**3 (466nm)**
2 (560nm)	**4 (554nm)**
3 (652nm)	**1 (646nm)**
4 (821nm)	**2 (856nm)**
-	

Radio Cal – AVNIR-2 Cross-Cal with MODIS

X axis: Terra/ MODIS

X axis: Aqua/ MODIS



-	Number				AVNIR2/MODIS			
AV2 Band	1	2	3	4	1	2	3	4
Terra	**14813**	**17205**	**17067**	**16697**	**1.002**	**1.032**	**1.002**	**0.936**
Aqua	**14892**	**15128**	**15020**	**14586**	**0.981**	**1.025**	**0.989**	**0.927**

Difference caused by Antarctic data

- ✓Bands 1~3 agree Terra/Aqua MODIS within **3.2%**
- ✓Band 4 agree Terra/Aqua MODIS within **7.3%**. The half of error can be explained by water vapor absorption

Many samples can be obtained !

Advanced Land Observing Satellite

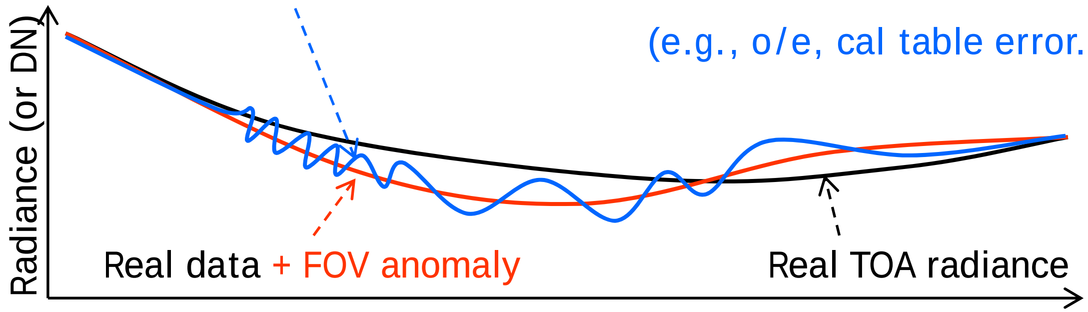
Radio Cal – AVNIR-2 FOV Calibration

Released on May 9, 2008

RGB Image 2007/11/13

Pixel (FOV; ~70km)

Unrealistic inter-channel difference



1. FOV noise

- Corrected by cross-calibration with MODIS (using a directional function of MODIS TOA reflectance)
- Temporal change is described using the internal lamp of AVNIR-2

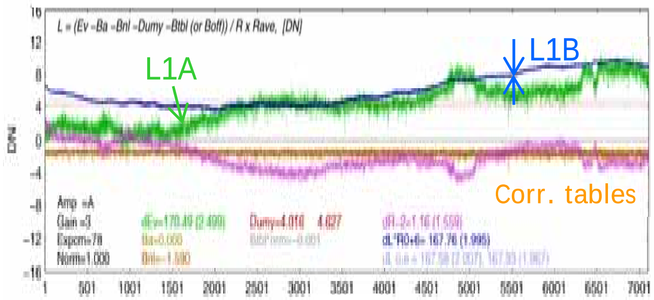
2. Gain-mode difference

- Gain-modes 2 and 3 are corrected using the lamp data

3. Small-scale noise (<~0.5DN)

- Corrected by small scale average of smooth & bright area (polar snow fields)

Line average plot of Band 3 on 2007/11/13



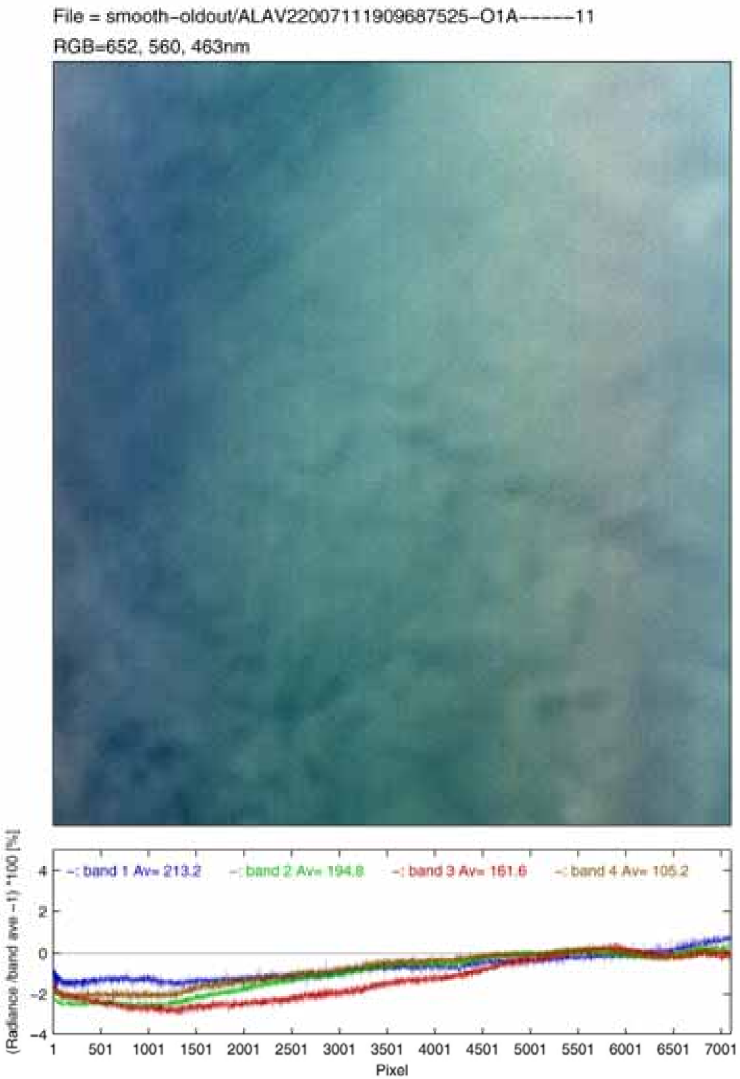
Radio Cal – AVNIR-2 FOV Calibration

Antarctic
2007/11/19

Band 3,2,1
RGB image

Band-1~4
line plot

old



new

Differences between old and new are +/- 2%

Radio Cal – PRISM Stripe Noise Reduction

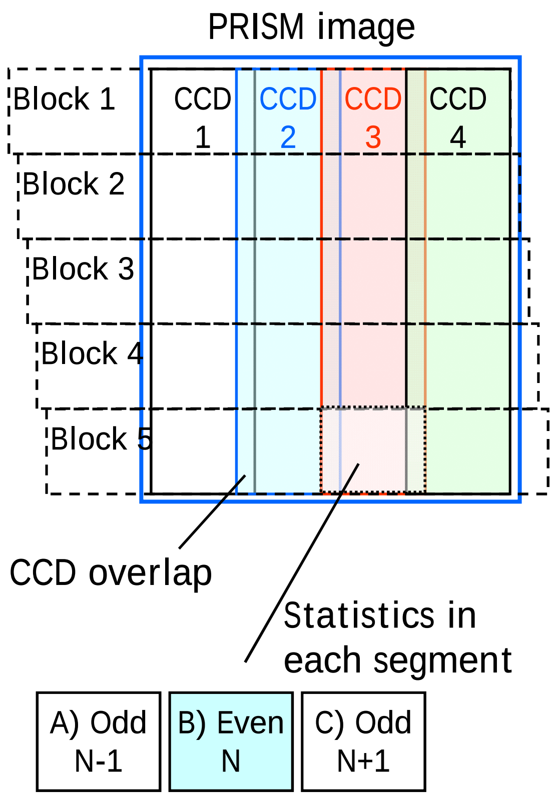
Released on October 19, 2007

✓ **Odd-Even pixel and inter-CCD unit difference** were large sometimes in PRISM images

✓ We assume **PRISM sensor itself is stable** and the error is caused by insufficient frequency of the **dark-current downlink** (optical black *i.e.* offset error)

✓ We estimate the dark current statistically using **each scenes**

1. Inter-CCD unit difference (offset) is corrected by overlap samples (32 pixels) after the default radiometric correction
   - The correction coefficients are tuned to keep mean radiance of all CCD unit
2. Odd-Even pixel difference (offset) is corrected by statistics of the Even minus neighboring two Odd samples in each CCD
3. Above statistics are processed in each one of five line-blocks, and correction offsets are linearly interpolated by the line number
   - Irregular and high-contrast samples are excluded in the statistics



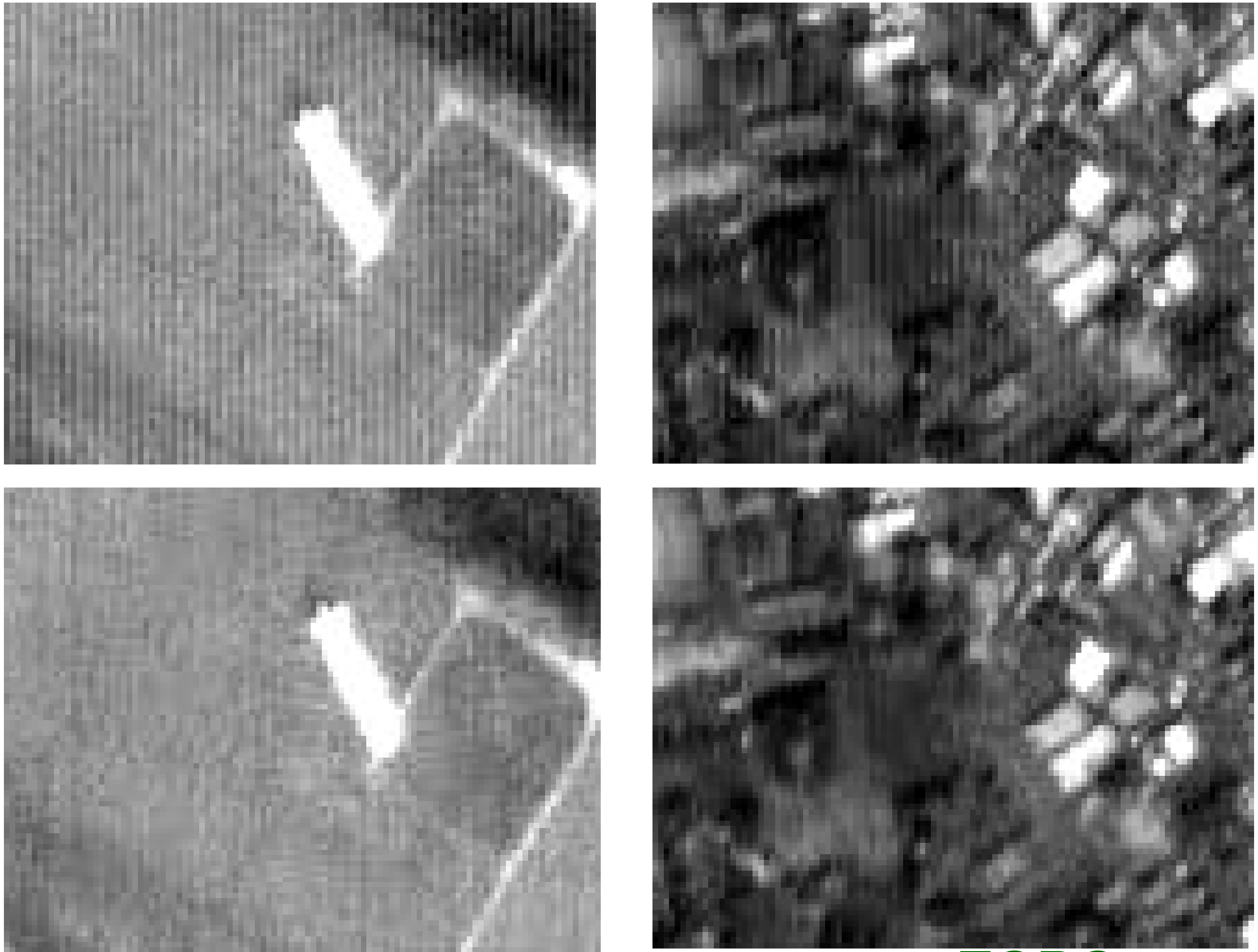
Dif = B – (A + C) / 2

Radio Cal – PRISM Stripe Noise Reduction

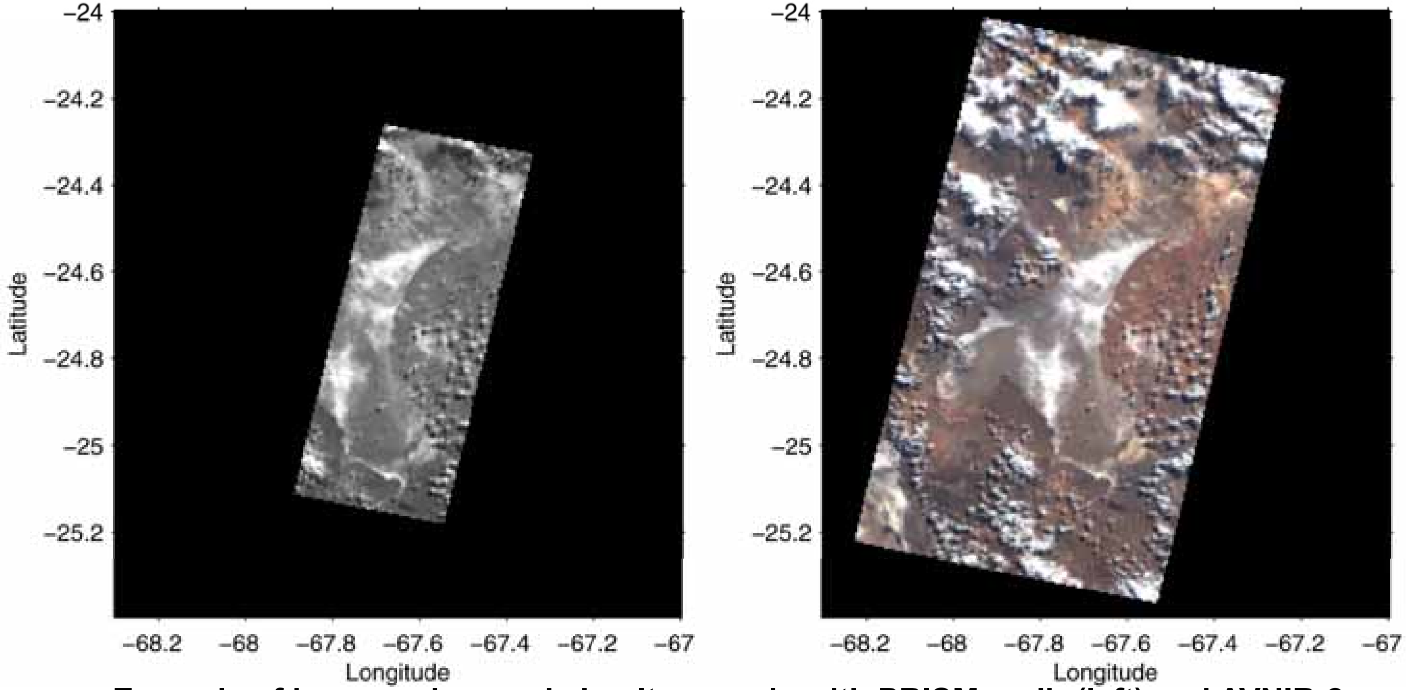
ALPSM200708030811102820 Forward

Before

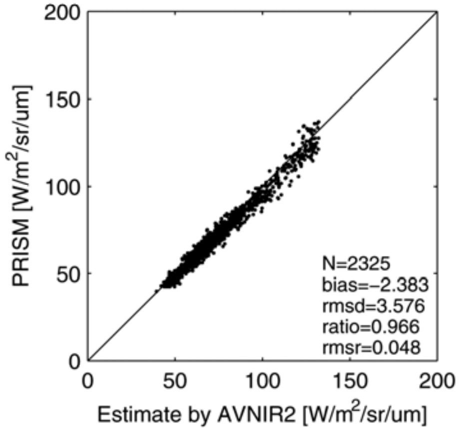
After



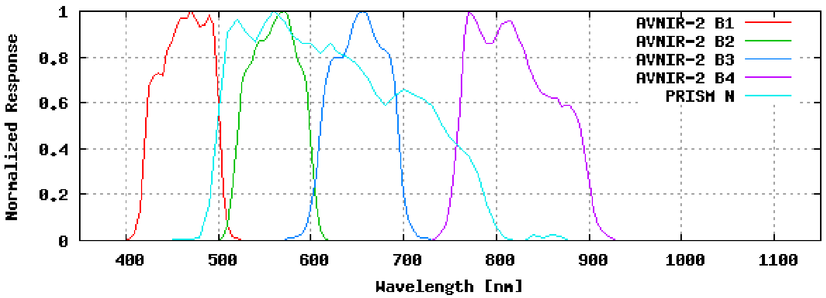
Radio Cal – PRISM Cross-Cal with AVNIR-2



Example of images observed simultaneously with PRISM nadir (left) and AVNIR-2 over Arizaro Salt Lake, Argentina on May 2, 2006.



Comparison of TOA radiances between simulated PRISM by AVNIR-2 (x axis) and actual PRISM (y axis).



Response functions comparison

- ✓ **Absolute radiometric calibration of PRISM is achieved by cross-cal with simultaneously acquired AVNIR-2**
  - The nadir image can observe under same geometry and same atmospheric condition at the same time
- ✓ **Comparison is done by top-of-atmosphere (TOA) radiances calculated from simulated PRISM reflectance by AVNIR-2 and actual PRISM radiance**
- ✓ **The radiances agree well with 3.6% (RMSE)**

Earth Observation Research Center

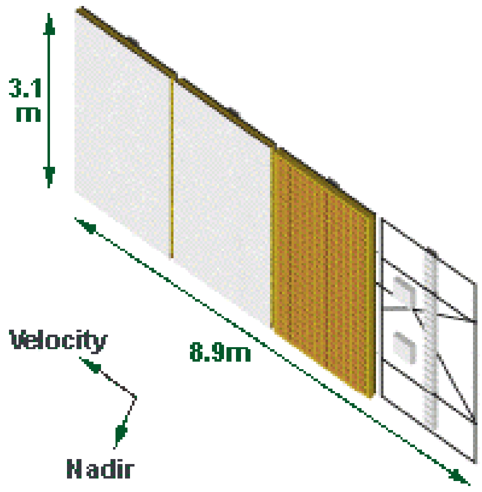
Calibration Results of PRISM/AVNIR-2

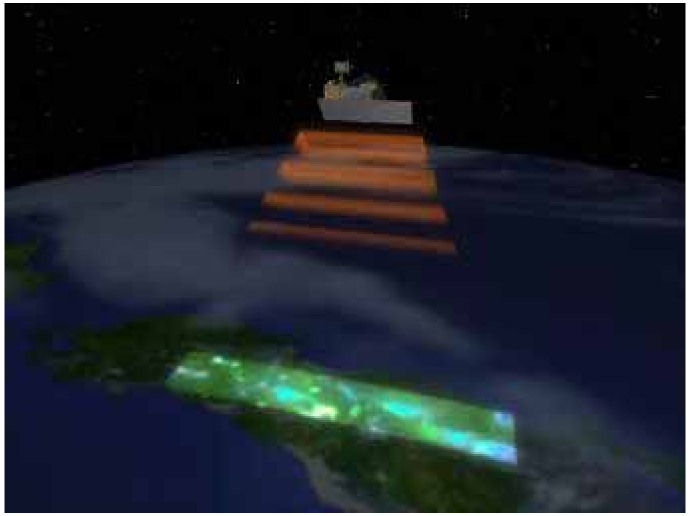
Standard Product	Previous results as of Sep. 29, 2007	Results as of July 1, 2009 (Public*)
PRISM 1B2	Geometry Absolute Accuracy (RMS): using 1,390 GCPs Pixel (X) Line (Y) Distance Nadir 6.5m 7.3m **9.8m** Forward 8.0m 14.7m 16.7m Backward 7.4m 16.6m 18.1m Relative Accuracy (1σ) 3 radiometers 1.9m 2.3m 3.0m	Geometry (Jun. 22, 2007-Jun. 4, 2009) Absolute Accuracy (RMS) Pixel (X) Line (Y) Distance Nadir **5.6m** **5.3m** **7.8m** using 5,499 GCPs, 586 scenes Forward **4.9m** **6.1m** **7.8m** using 1,771 GCPs, 225 scenes Backward **5.0m** **7.1m** **8.7m** using 4,839 GCPs, 525 scenes Relative Accuracy (1σ) 3 radiometers 1.4m 1.8m **2.4m** CE90 **Nadir 11.8m, Forward 12.4m, Backward 13.4m** Radiometry Absolute accuracy: similar to that of AVNIR-2
AVNIR-2 1B2	Geometry (-41.5 to +41.5 deg. pointing) Pixel (X) Line (Y) Distance Absolute Accuracy (RMS) 106m 19m **108m** Relative Accuracy (1σ) 4m 4m 6m	Geometry (all period) Absolute Accuracy (RMS) Pixel (X) Line (Y) Distance 0 deg. pointing **71.1m** **7.5m** **71.9m** +/-41.5 deg. 60.9m 96.6m 114.2m Relative Accuracy (1σ) 3.4m 7.7m **8.5m** using 1,035 GCPs, 54 scenes Radiometry (all period) Absolute accuracy **Band 1-3: 3.2%, Band4: 7.3%**

*** Latest ALOS calibration result can be find at http://www.eorc.jaxa.jp/hatoyama/satellite/data_tekyo_setsumei/alos_hyouka_e.html in English**

PALSAR

Phased Array type L-band Synthetic Aperture Radar



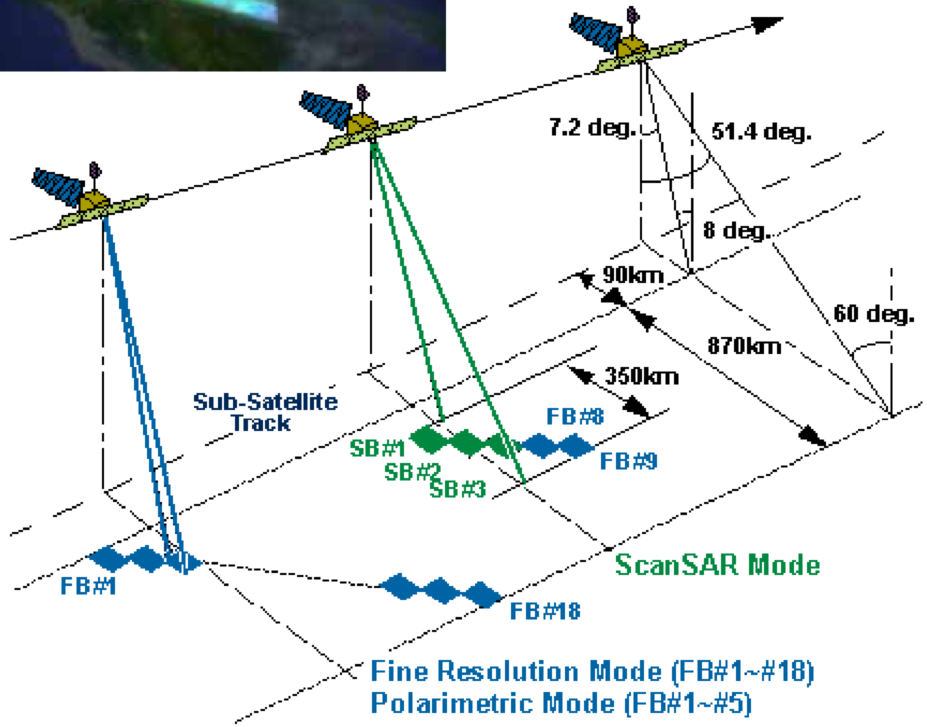


L-band (1.27GHz)

Fine Resolution Mode
8.0-60.0 deg.
HH or VV / HH+HV or VV+VH
7.0-44.3m / 14.0-88.6m
40-70km / 40-70km

ScanSAR Mode
18.0-43.0 deg.
HH or VV / 100m / 250-350km

Polarimetric Mode
8.0-30.0 deg.
HH + HV + VH + VV
24.1-88.6m / 20-60km



Calibration Results of PALSAR

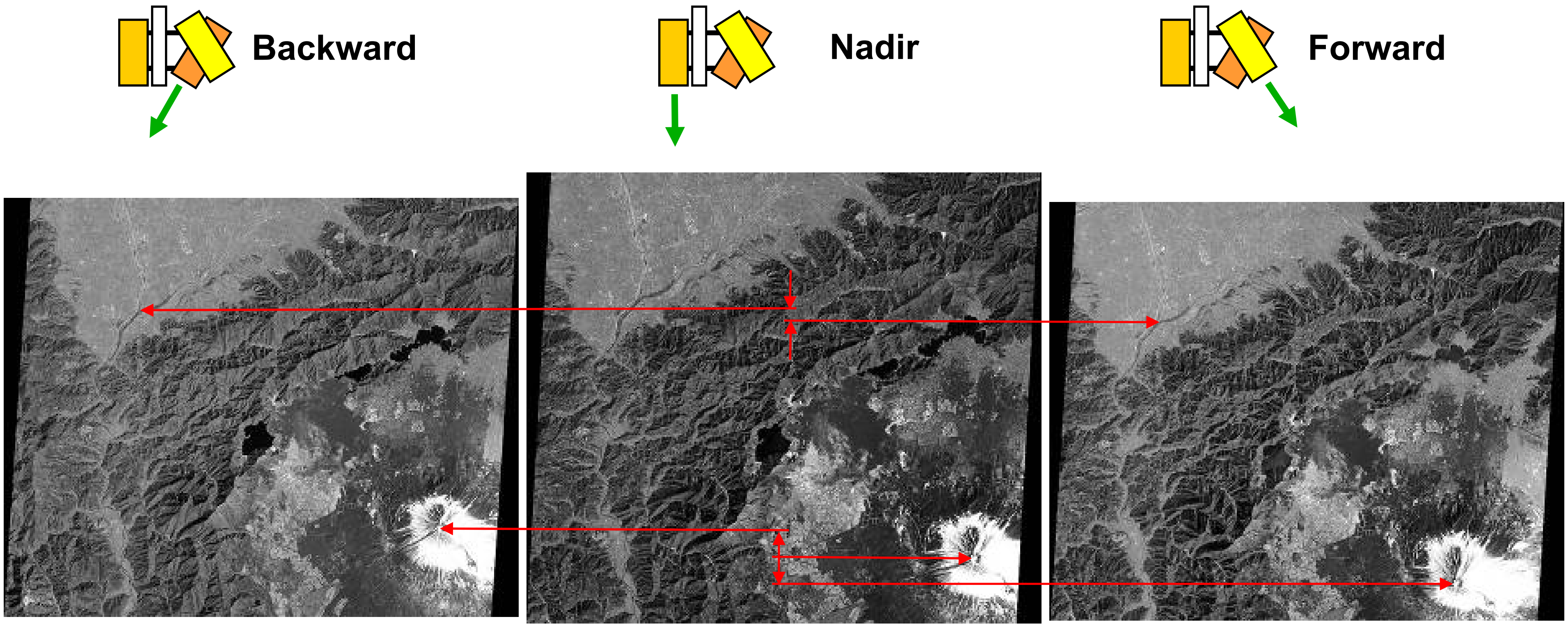
as of July 1, 2009

Radiometric calibration accuracy (common for all the off-nadir angles)[1]		
Absolute accuracy		0.76dB（1σ）: Corner reflector 0.22dB（1σ）: Amazon Forest *
Noise equivalent sigma-naught		-34dB (FBD-HV) -32dB (FBD-HH) -29dB (FBS-HH)
Amplitude ratio of VV/HH for PLR		1.013（0.062：1σ）
Phase difference of VV and HH for PLR		0.612deg (2.66deg：1σ)
Cross talk (PLR)		31.7dB
Resolution	Single look in azimuth	4.49m
	Range	9.6m (FBD, PLR, DSN)
	Range	4.8m (FBS)
Side lobes	In azimuth	-16.6dB
	In range	-12.6dB
	Two-dimensional	-8.6dB
Ambiguity	Azimuth	—
	Range	23dB
Geometric accuracy (common for all the incidence angles)[2]		
FBS, FBD, PLR, DSN		9.7m (RMS)
WB1, WB2		70m (RMS)

[1] Measurements of radiometric accuracy: Statistical analysis of the impulse response of the corner reflectors (CRs) at the calibration site and the responses from the Amazon rainforest. * Standard deviation of the incidence angle dependence of the gamma-naught** measured for five off-nadirs (e.g. 9.9, 21.5, 34.3, 41.5, and 50.8 degrees). ** Gamma-naught: normalized radar cross section (NRCS or sigma-naught) divided by the cosine of incidence angle.

[2] Measurements of geometric accuracy: Statistical evaluation of the worldwide CRs in total 572 and calculation of the root sum square of the distance between the position of the CRs, that is identified in the PALSAR image and obtained from the PALSAR geometric conversion formula, and its true location on the GRS80 that is calculated from the CR true measurement and the SAR observation geometry.

Height Estimation using PRISM Triplet Images

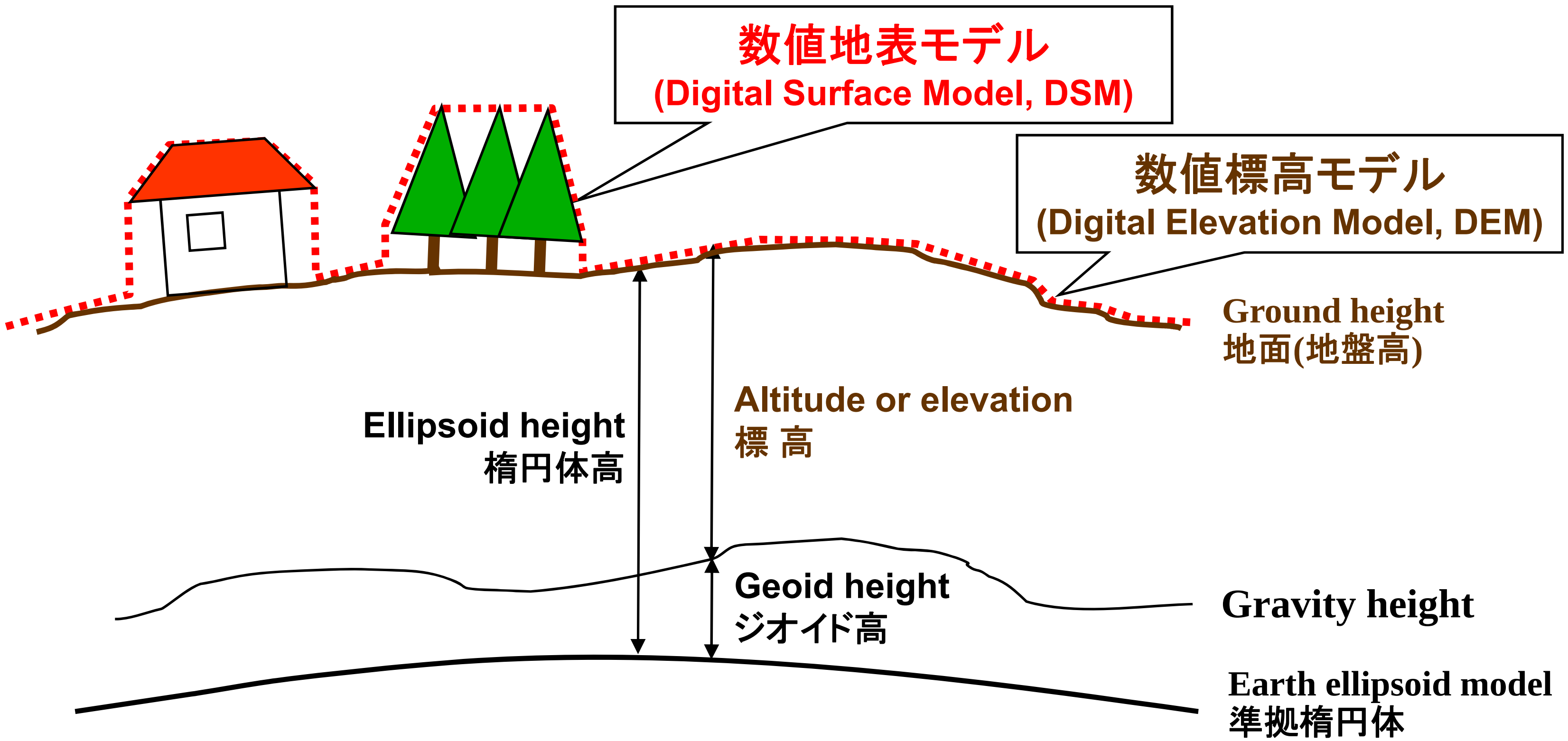


Satellite velocity

Location differences in images are depends on the terrain height
> Derive digital elevation model (DEM)
or digital surface model (DSM)

(on GRS80 ellipsoid height, ITRF97 coordination ≃ WGS84)

Terrain Height Measurement by PRISM



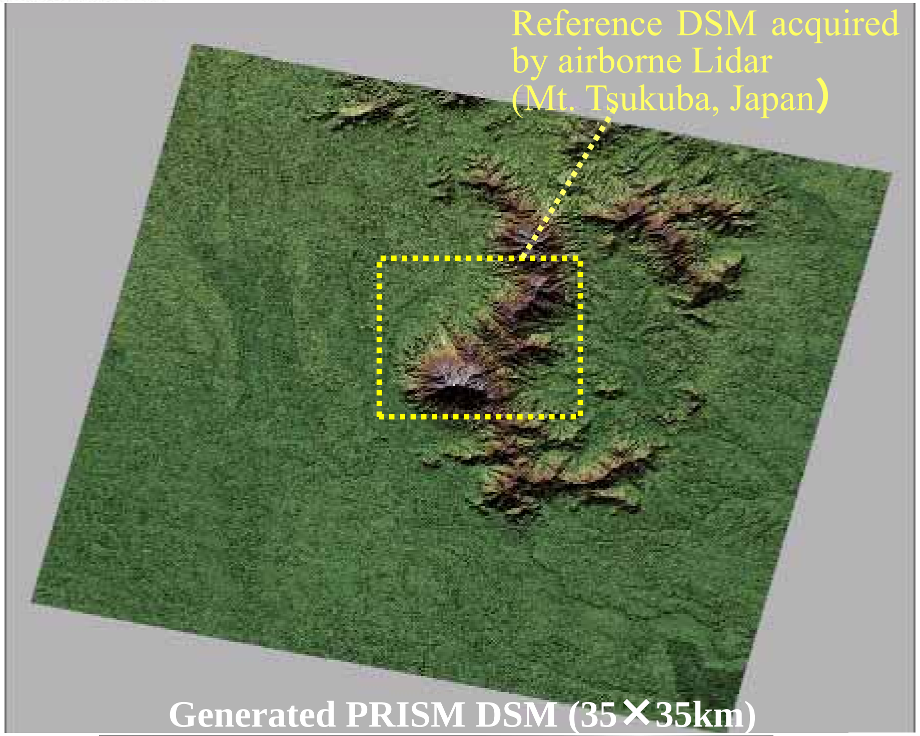
"Height" shown by digital data > Gray scale color in raster image

- ✓ Digital Elevation Model (**DEM**): ground height = digital terrain model (**DTM**)
- ✓ Digital Surface Model (**DSM**): height including the features (*i.e.* canopy of trees, buildings)

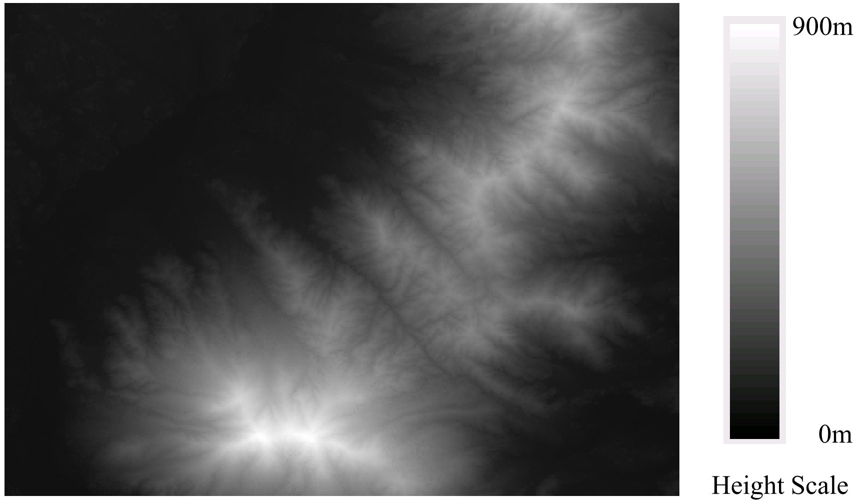
Definition of "height"

- ✓ Altitude: above sea level *i.e.* gravity height (= 0 m), corresponds to geographical map
- ✓ Ellipsoid height: above Earth model = altitude + geoid height

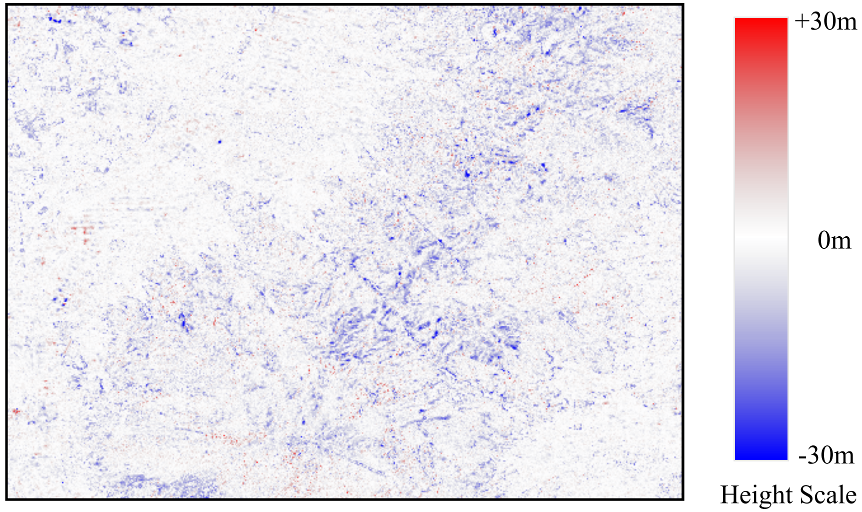
Validation – PRISM Digital Surface Model (DSM)



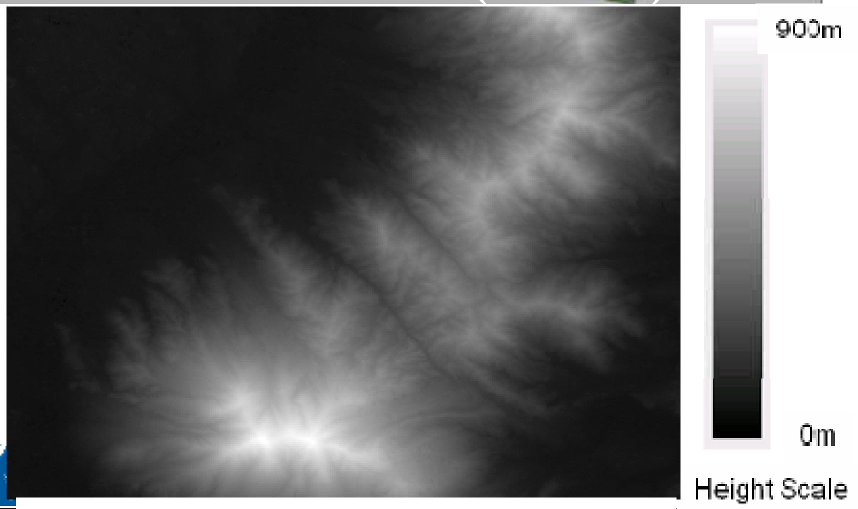
Generated PRISM DSM (35×35km)



Reference DSM by Lidar onboard Cessna 206



Height difference = PRISM DSM − Lidar DSM (8x8km)



Generated PRISM DSM (0.3 arc-sec, 8x8km)

Validation – PRISM Digital Surface Model (DSM)

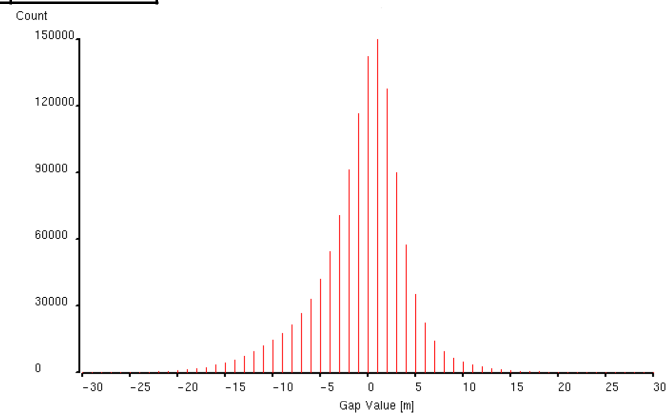
Statistics of PRISM DSM - Reference Lidar (whole area)

Site	Terrain	GCP	Points	Bias [m]	SD [m]	RMSE [m]	Max [m]	Min [m]
Mt.Tsukuba	Mountainous & Flat	42	1287801	-1.70	4.92	5.21	32	-73

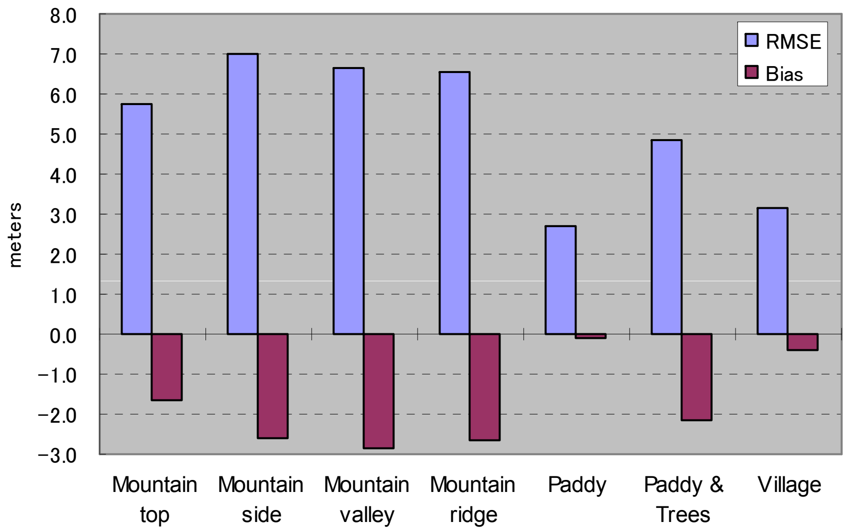
Statistics of PRISM DSM – Reference Lidar (individual land use and land cover)

Terrain	Points	Bias [m]	SD [m]	RMSE [m]	Max [m]	Min [m]
Mountain top *)	10000	-1.64	5.50	5.73	31	-38
Mountain side *)	10000	-2.59	6.49	6.99	24	-37
Mountain valley *)	10000	-2.85	6.02	6.66	20	-31
Mountain ridge *)	10000	-2.65	5.98	6.54	22	-55
Paddy	10000	-0.09	2.68	2.68	15	-17
Paddy & Trees	10000	-2.15	4.37	4.87	15	-32
Village	10000	-0.39	3.12	3.14	10	-22

*) Mountainous areas are including forests



Height differences (8x8km)



Validation of generated PRISM DSM for individual land cover (blue: RMSE, purple: bias error)

Results of analysis and validation

- Height accuracy (whole area) = 4.92m (1σ), 5.21m (RMS)
- Except forest areas = 3.57m (RMS)

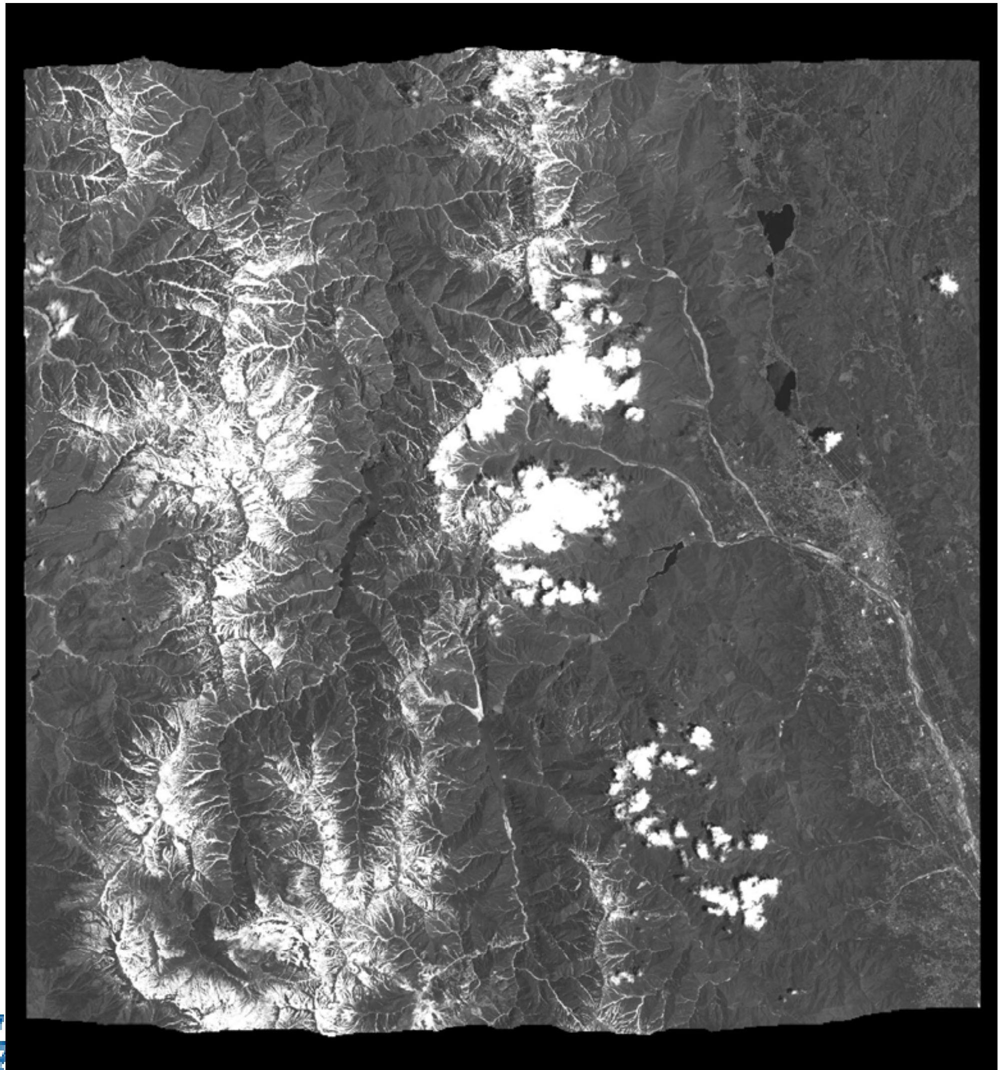
✓ Forest areas are including bias error

✓ The correlation coefficients may become high at the inside of boundaries (e.g. edges) of forests, buildings *etc.* It causes under estimations of the height > limitation of correlation matching

EORC Earth Observation Research Center

Validation – PRISM DSM in Snow Region

Mt. Tateyama, Japan acquired on June 23, 2007: Covered by snow
> Test validation of PRISM DSM for glacier regions



- ✓ PRISM Ortho Rectified Image (ORI)
  - ✓ Using PRISM DSM
- ✓ 8 bits binary raw data: 14878 x 16000 pxls

Validation – PRISM DSM in Snow Region

ALPSMLR01_07512N2865F2810B2920_UR_MSK: Mask file (8bit Raw)
ALPSMLR01_07512N2865F2810B2920_UR_DSM : DSM product (16bit Raw)

✓ PRISM DSM product consist of Signed 16 bits binary raw data: 14878 x 16000 pxls
✓ Dark image because digital number (DN) corresponding to ellipsoid height (meter)

↓

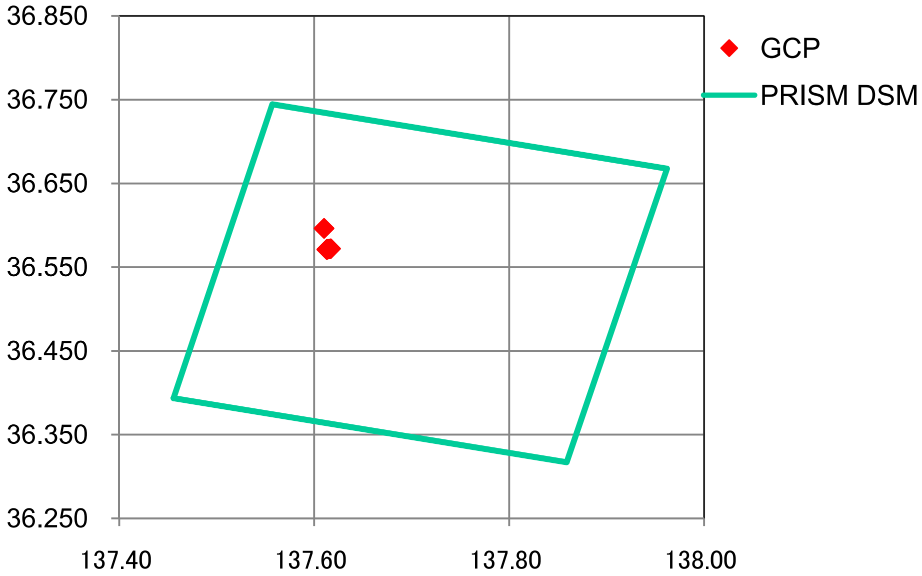
✓ Data scaling of DSM product to show the image

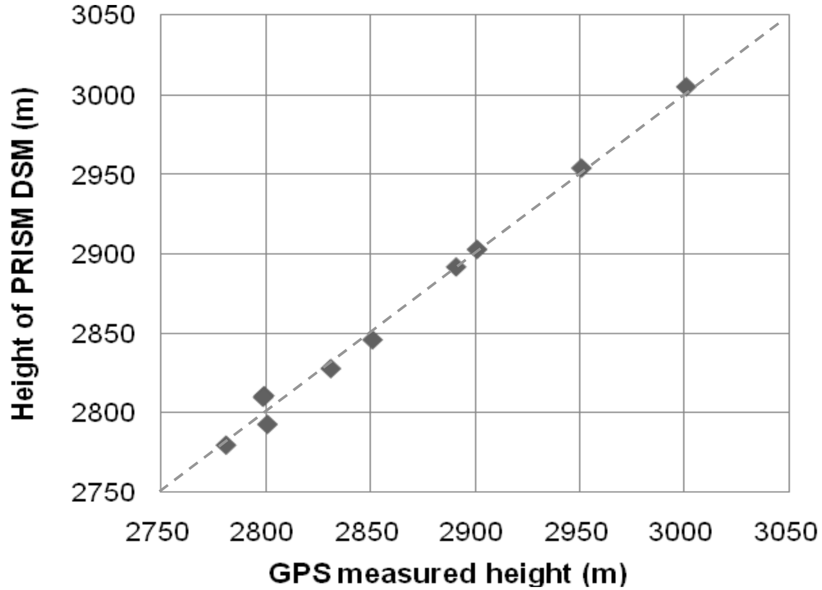
↓

✓ Mask file contains information of valid regions, which shows white color.
Blue: land water area, Green: clouds and invalid regions

Validation – PRISM DSM in Snow Region

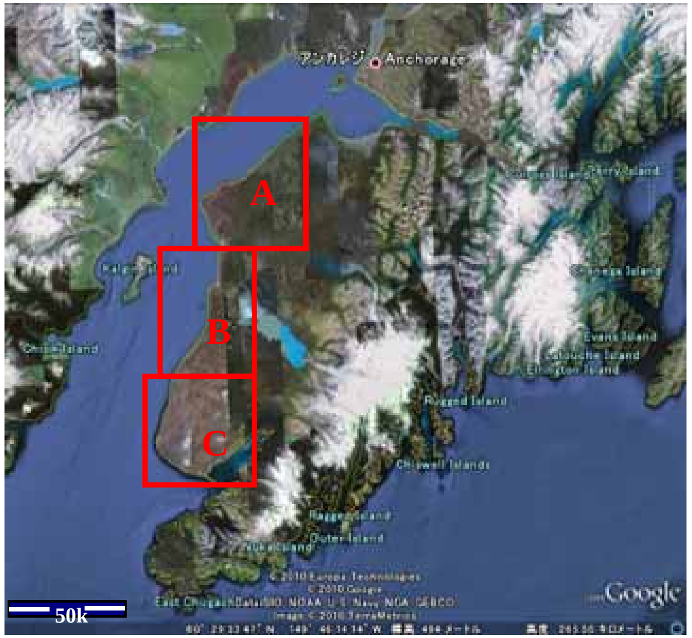
■ **Reference data: GPS measurement by Nagoya University**





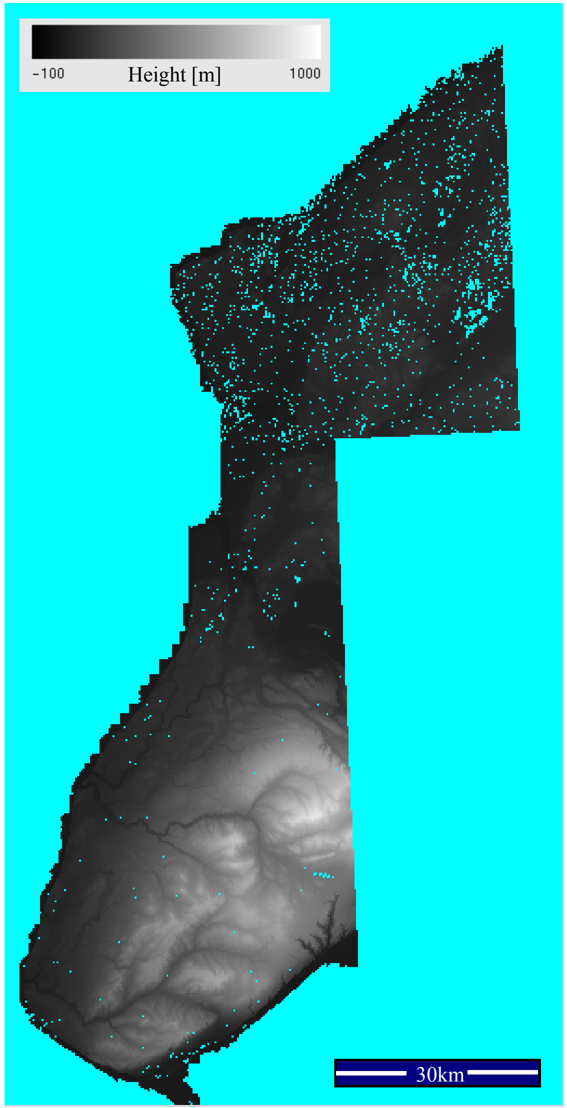
GPS measurement			Difference	PRISM DSM		
Lat	Long	HEIGHT	PRISM-GPS	Height	Lat	Long
36.596376	137.610255	2799.047	11.953	2811	36.596380	137.610261
36.572209	137.616978	3000.995	4.005	3005	36.572208	137.616979
36.571992	137.616021	2950.888	3.112	2954	36.571989	137.616022
36.571770	137.614717	2900.946	2.054	2903	36.571769	137.614718
36.571800	137.614526	2890.920	1.080	2892	36.571798	137.614527
36.571598	137.613884	2850.952	-4.952	2846	36.571597	137.613885
36.571513	137.613558	2830.965	-2.965	2828	36.571511	137.613558
36.571302	137.613006	2800.679	-7.679	2793	36.571302	137.613007
36.571122	137.612817	2780.878	-0.878	2780	36.571119	137.612819
36.596359	137.609946	2798.587	11.413	2810	36.596357	137.609947
		Average_diff	1.714			
		STDEV_diff	6.394			
		RMSE_diff	6.303			

Validation of PRISM DSM in Alaska, US

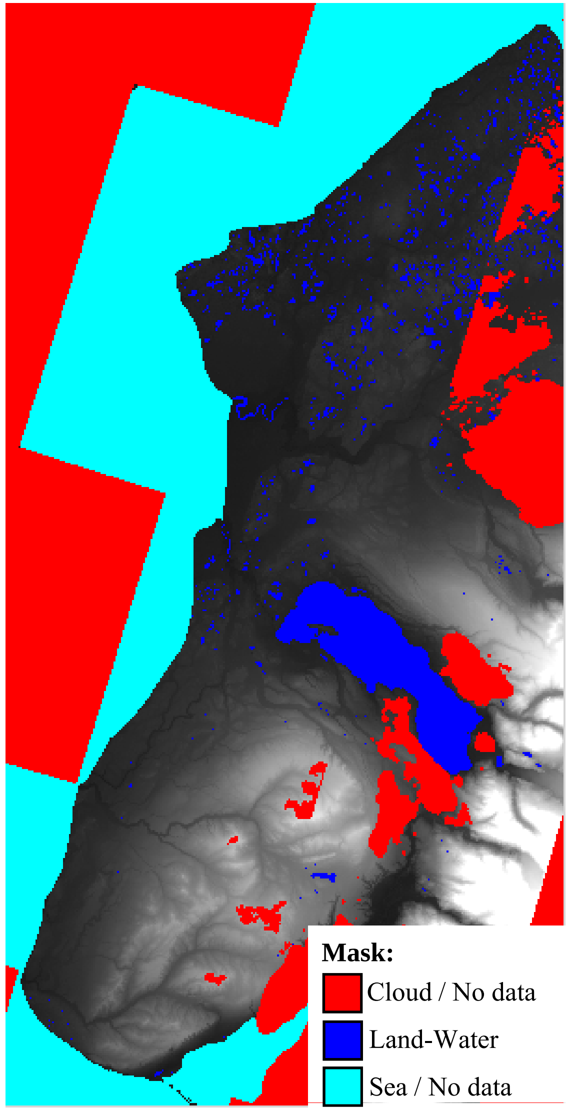


Location of validation test site of PRISM DSM in the Kenai Peninsula, Alaska, US

- ✓ New validation test site of PRISM DSM
  - Airborne Lidar DEM
  - Large area: 60 x 150km
  - Height variation: 0 - 1,500m
  - Mountainous region with snow and glaciers in the eastern part
- ✓ 16 scenes PRISM DSM was processed



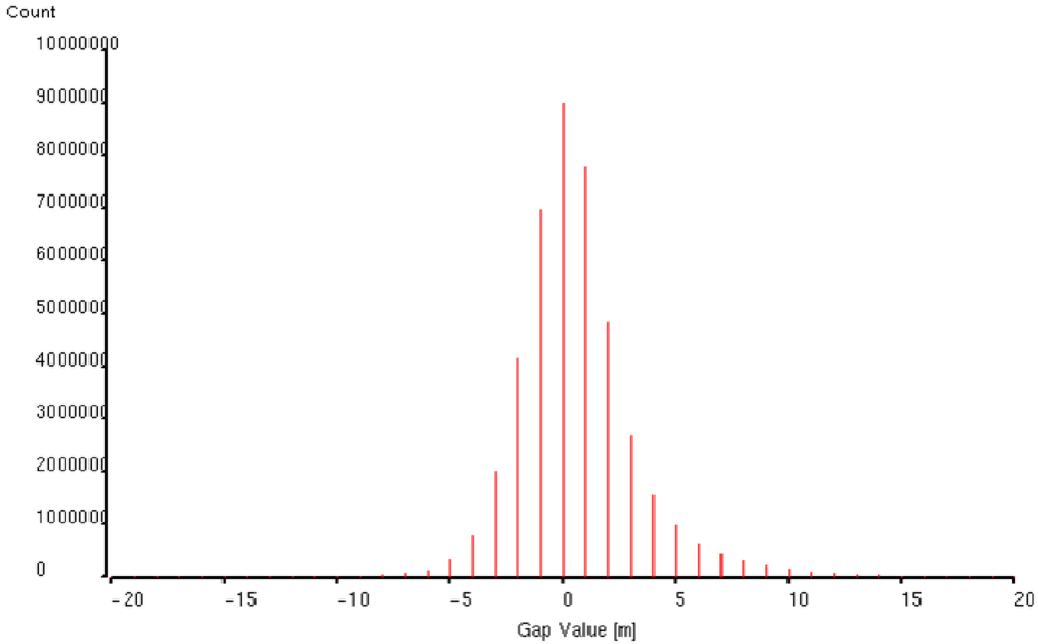
Reference DEM by airborne Lidar provided by the ASF, UAF



Generated PRISM DSM (16 scenes mosaic)

Validation of PRISM DSM in Alaska, US

Height difference = PRISM DSM − Lidar DEM (60 x 150 km)



Histogram of height differences in the Kenai Peninsula, Alaska

Results of analysis and validation

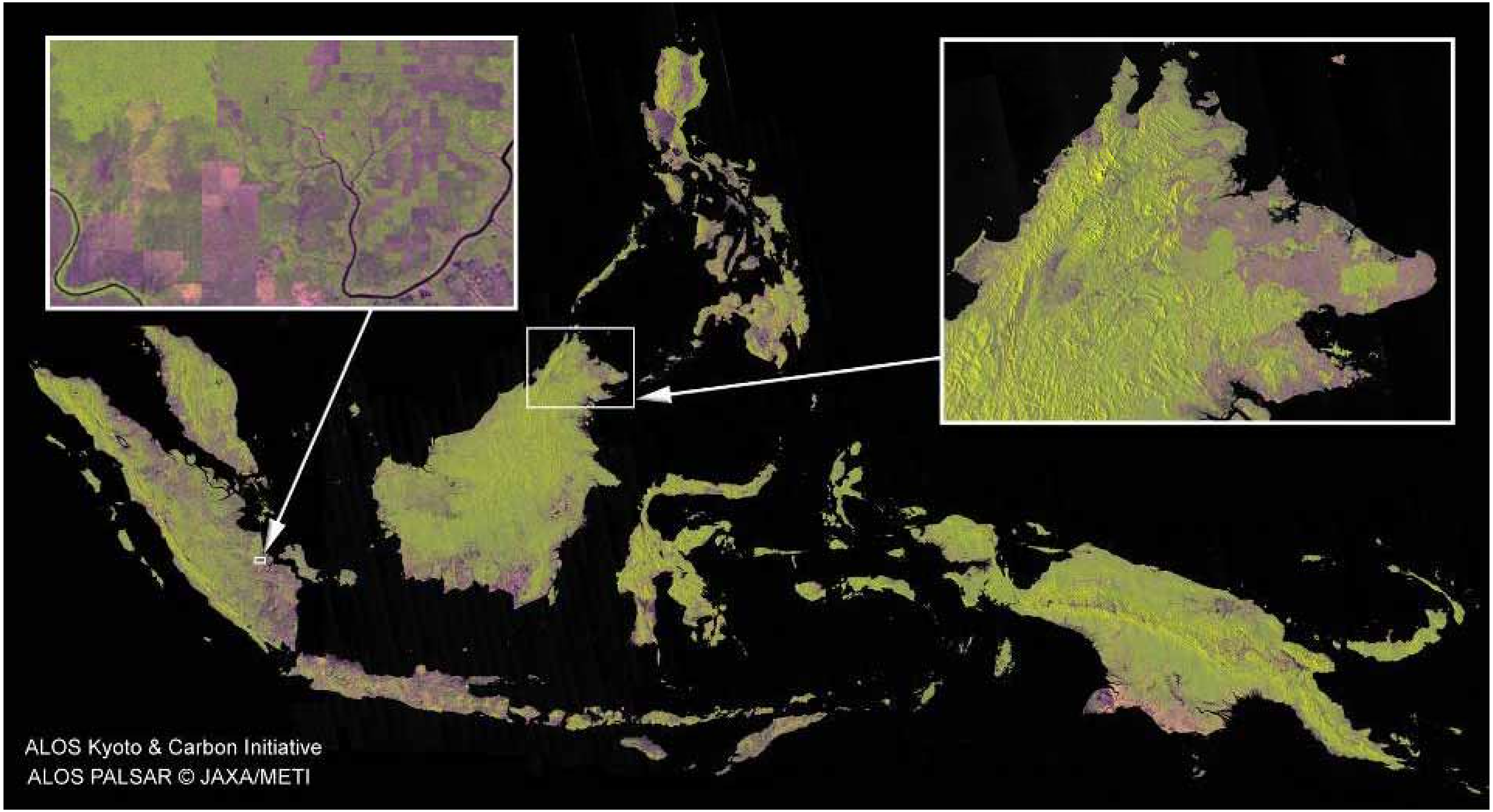
- Height accuracy (whole area) = 2.88m (RMSE), 2.82m (1σ), 0.60m (bias) / 43,669,079 evaluation points

✓ This result is consist of other validation results in natural terrains

↓

✓ PRISM DSMs can be sufficient to generate precise glacial lake and glacier inventories with terrain height information.

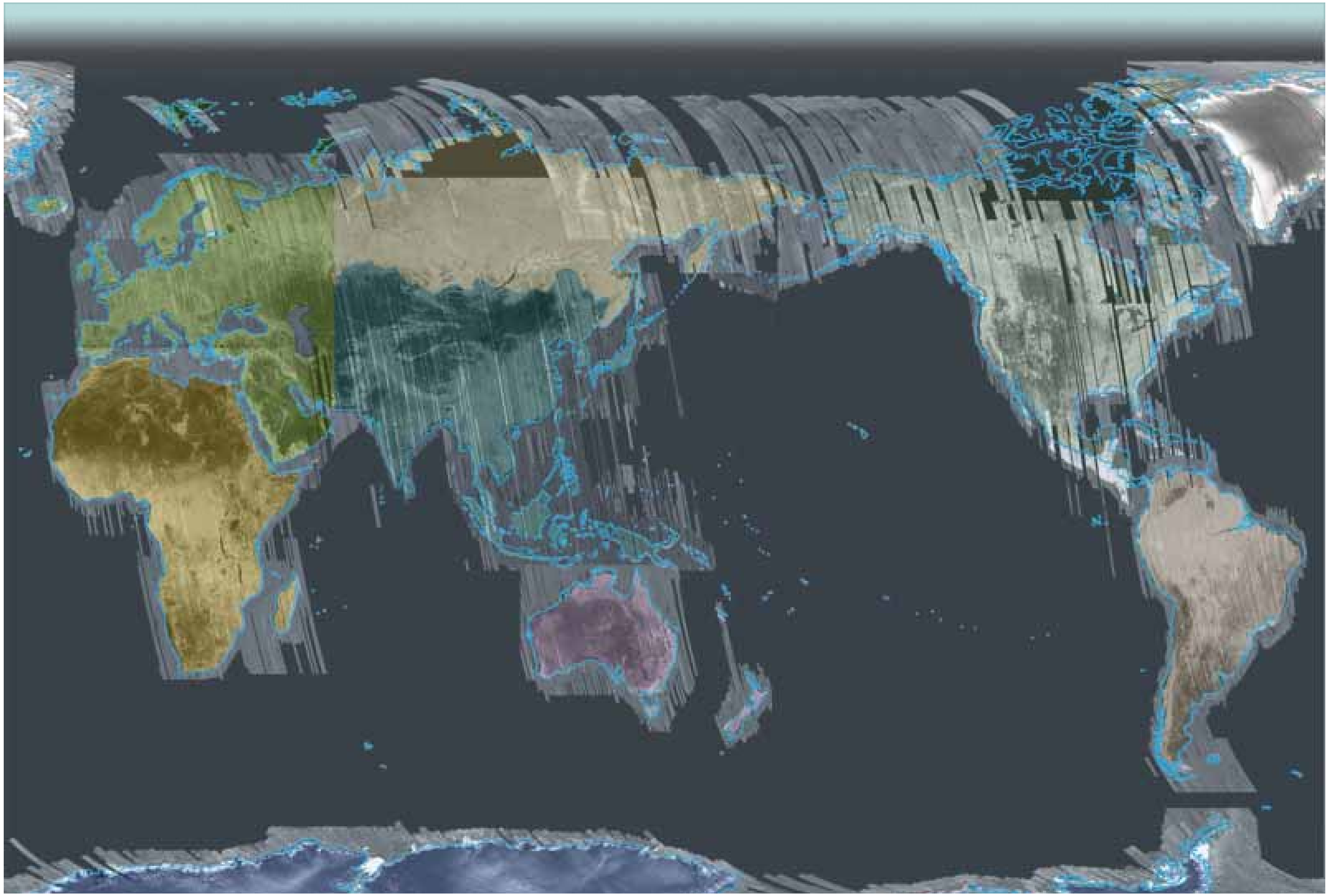
Forest Monitoring: ALOS Kyoto & Carbon (K&C) Initiative



PALSAR 50m-mesh Ortho-rectified Mosaic Products in Asia and Oceania regions (once / year)

- ALOS *"Kyoto & Carbon Initiative" (K&C)* is an international collaboration project led by JAXA
- Monitoring forest change (deforestation and reforestation), wet land *etc.* as carbon source and sink
- Global PALSAR mosaic images are available on http://www.eorc.jaxa.jp/ALOS/en/kc_mosaic/kc_mosaic.htm

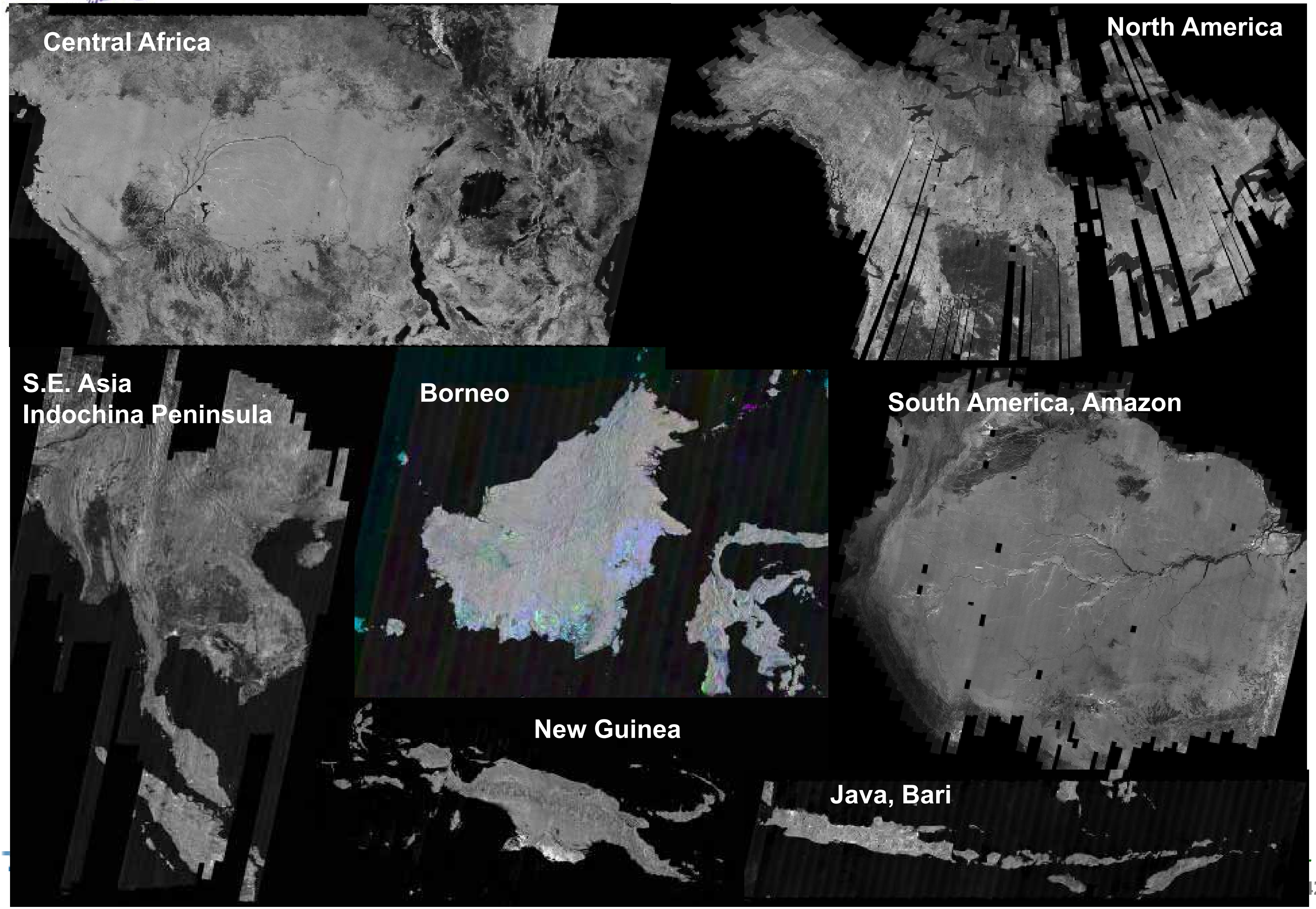
ALOS Kyoto & Carbon (K&C) Initiative



PALSAR Browse Mosaic Products (every cycle)

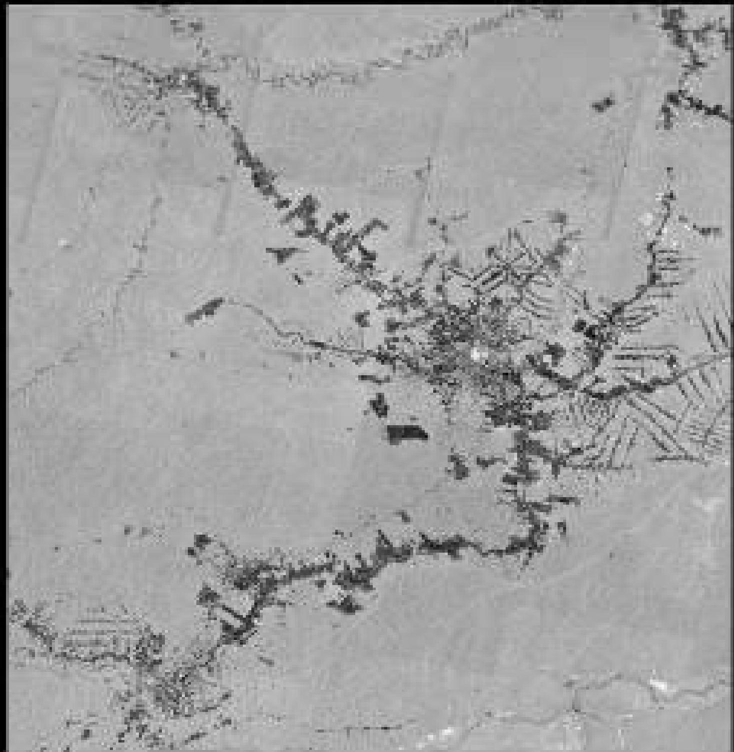
- 500m-mesh, entire global land areas
- Global PALSAR mosaic images are available on http://www.eorc.jaxa.jp/ALOS/en/kc_mosaic/kc_mosaic.htm

JERS-1 Global Forest Mapping (GFM) Projects

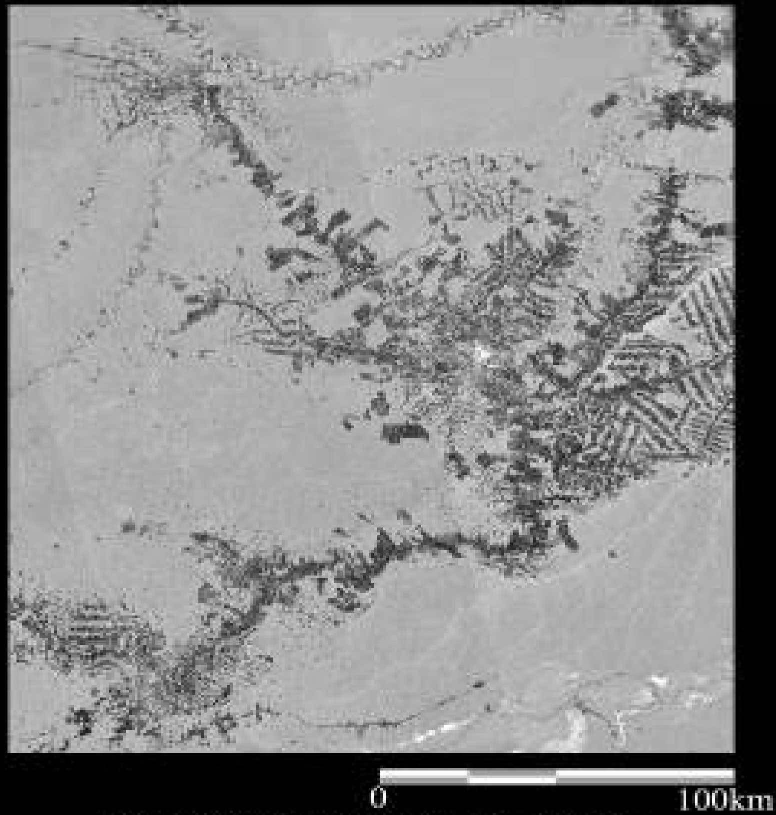


JERS-1 GFM vs. ALOS K&C

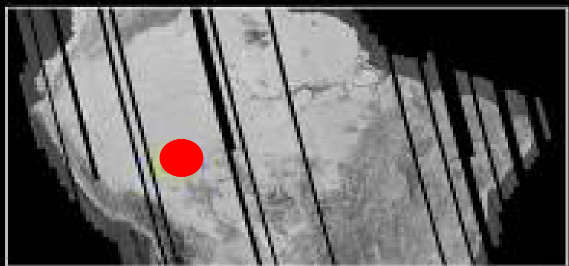
アマゾン西ロンドニア地方森林伐採領域の変化



JERS-1/SAR : Sep/Dec, 1995



PALSAR : May/Aug, 2006

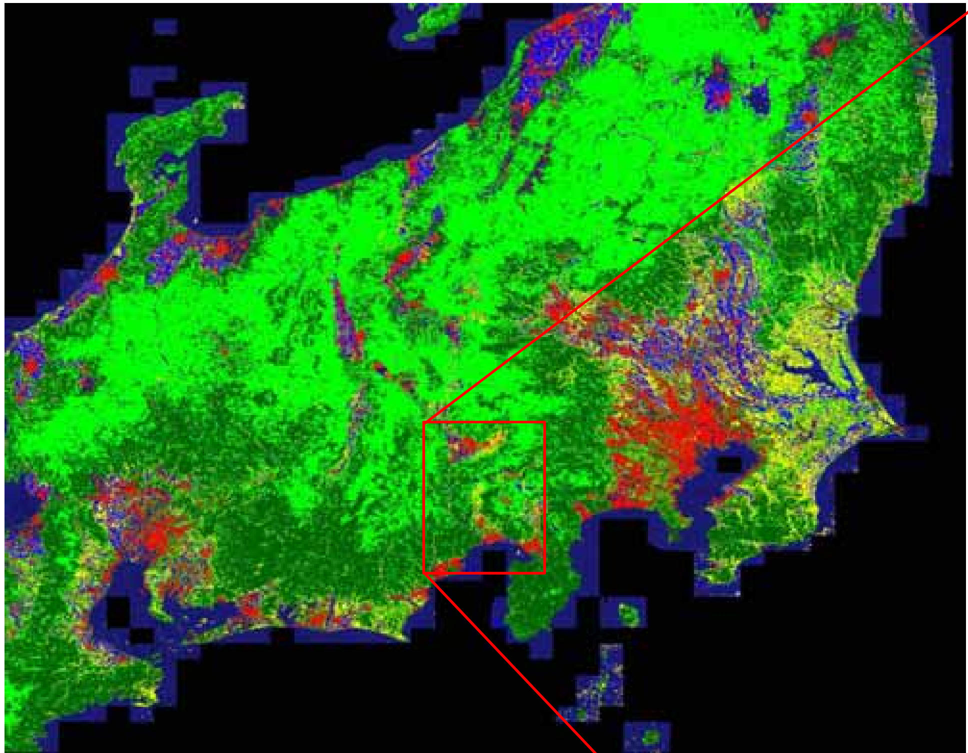


	画素数		画像面積 [km^2]	伐採域の抽出画素数	伐採域面積 [km^2]
	pixel	line			
JERS	2471	2949	72869.8	433590	4335.9
PALSAR	2286	2707	61882.0	629915	6299.2
				伐採増加面積	1963.3

※pixel spacing≒100m

(c)JAXA,METI Analyzed by JAXA

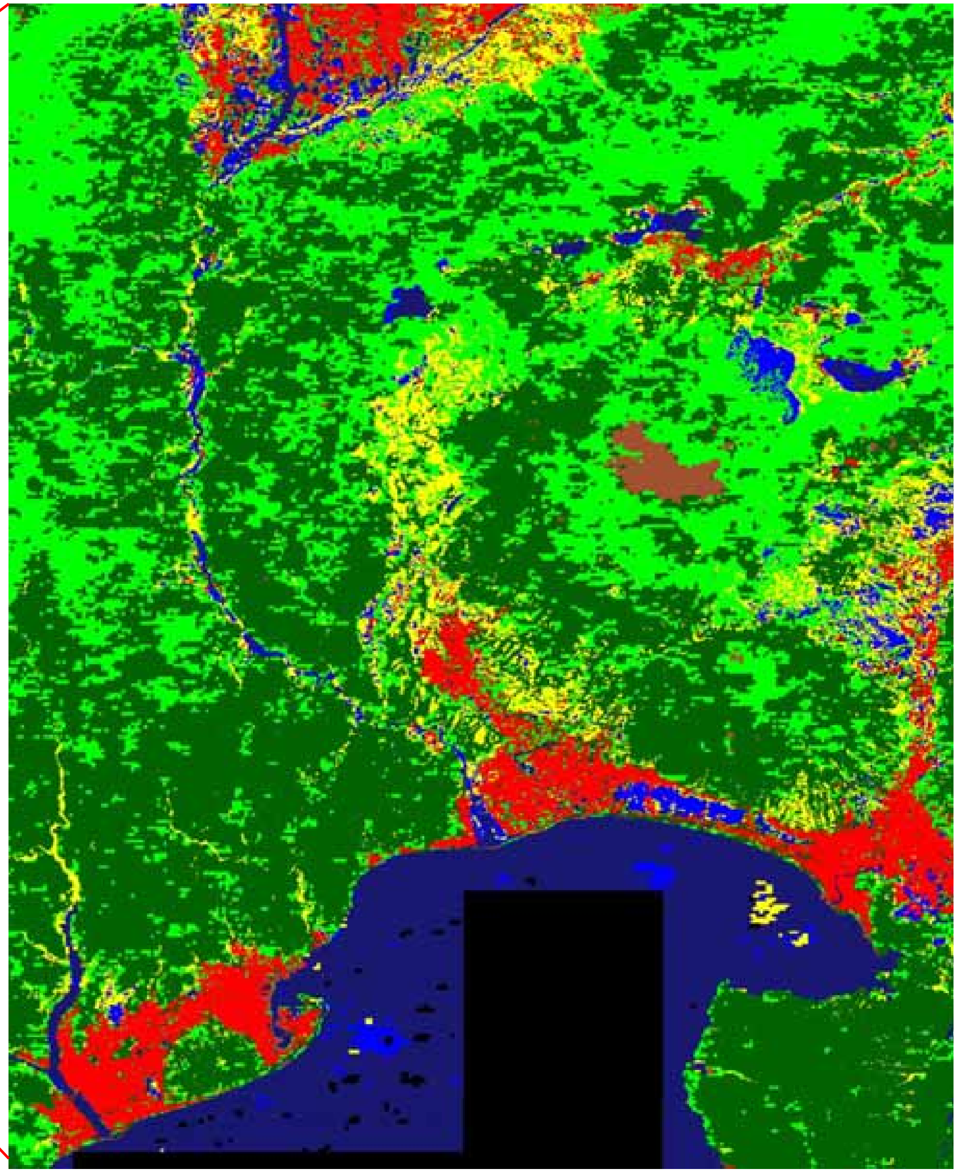
Precise Land-Use and Land-Cover (LULC) Map using AVNIR-2



LULC map by AVNIR-2
20m spatial resolution

カテゴリー

1	裸地, 砂地 Bare surface
2	水体 Water
3	都市 Urban
4	水田 Paddy
5	畑地 Crop
6	落葉樹 Deciduous forest
7	常緑樹 Evergreen forest
8	雪氷 Snow and ice
9	その他 other



Land-Use and Land-Cover (LULC) Map using Pol-In-SAR by PALSAR

Advanced Land Observing Satellite

By 大木(EORC)

- Combination of PolSAR + InSAR
- PolInSAR data contains many feature parameters: amplitudes and coherences of different scattering mechanisms

Master

$$\mathbf{k}_1 = \frac{1}{\sqrt{2}} \begin{bmatrix} S_{HH1} + S_{VV1} \\ S_{HH1} - S_{VV1} \\ 2S_{HV1} \end{bmatrix}$$

Slave

$$\mathbf{k}_2 = \frac{1}{\sqrt{2}} \begin{bmatrix} S_{HH2} + S_{VV2} \\ S_{HH2} - S_{VV2} \\ 2S_{HV2} \end{bmatrix}$$

$$\langle \mathbf{T}_{11} \rangle = \langle \mathbf{k}_1 \mathbf{k}_1^{*T} \rangle$$

$$\langle \mathbf{T}_{22} \rangle = \langle \mathbf{k}_2 \mathbf{k}_2^{*T} \rangle$$

$$\langle \mathbf{T}_{12} \rangle = \langle \mathbf{k}_1 \mathbf{k}_2^{*T} \rangle$$

$$\langle \mathbf{T}_6 \rangle = \begin{bmatrix} \mathbf{T}_{11} & \mathbf{T}_{12} \\ \mathbf{T}_{12}^{*T} & \mathbf{T}_{22} \end{bmatrix}$$

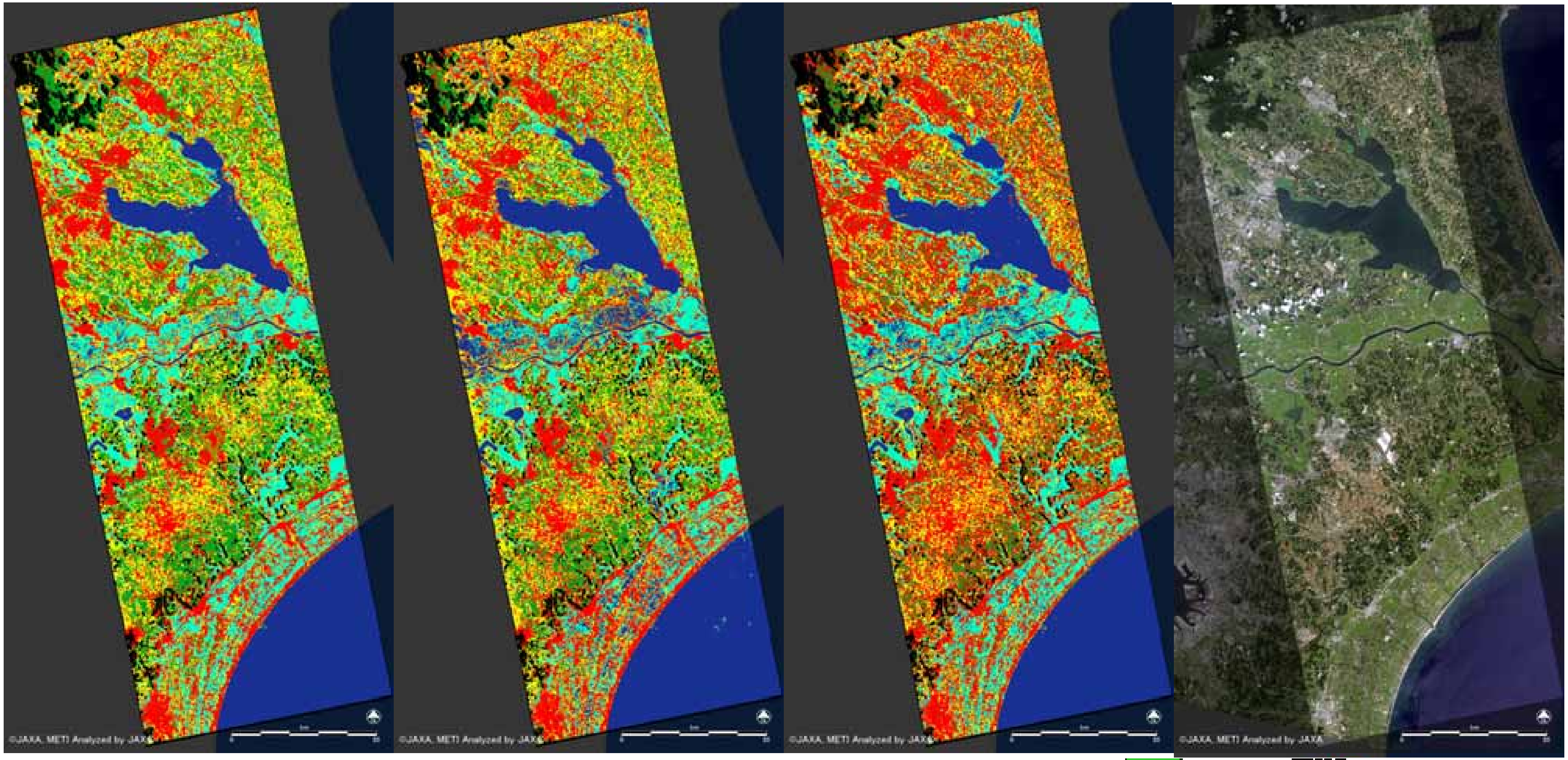
- Feasibility study on LC classification by PALSAR PolInSAR
  - Simple 6 classes supervised LC classification in Japan region
  - Comparison between different classification methods (SVM and Wishart)
  - Comparison between different datasets (Full-PolInSAR, Dual-PolInSAR, Full-Pol and Dual-Pol)

Land-Use and Land-Cover (LULC) Map using Pol-In-SAR by PALSAR

Advanced Land Observing Satellite

Classification Result by PLR data (SVM)

Full-PolInSAR | Dual-PolInSAR | Full-PolSAR | Optical (AVNIR-2)



- 1 Water
- 2 Paddy (rice)
- 3 Field (vegetables, wheat ...)
- 4 Forest
- 5 Urban
- 6 Bare soil (ground)
- Mask (layover, shadows)

Land-Use and Land-Cover (LULC) Map using Pol-In-SAR by PALSAR

◆ Method: SVM

Dataset	Full-Pol-InSAR	>	Dual-Pol-InSAR	>	Full-Pol	>	Dual-Pol
Polarization (m):master (s):slave	HH, HV, VV (m) HH, HV, VV (s)		HH, HV (m) HH, HV (s)		HH, HV, VV (m)		HH, HV (m)
Overall Accuracy	**91.30**		85.69		80.09		69.05
Kappa coefficient	**0.886**		0.810		0.736		0.577
Calc. time (sec)*	329		206		272		197

◆ Method: Wishart

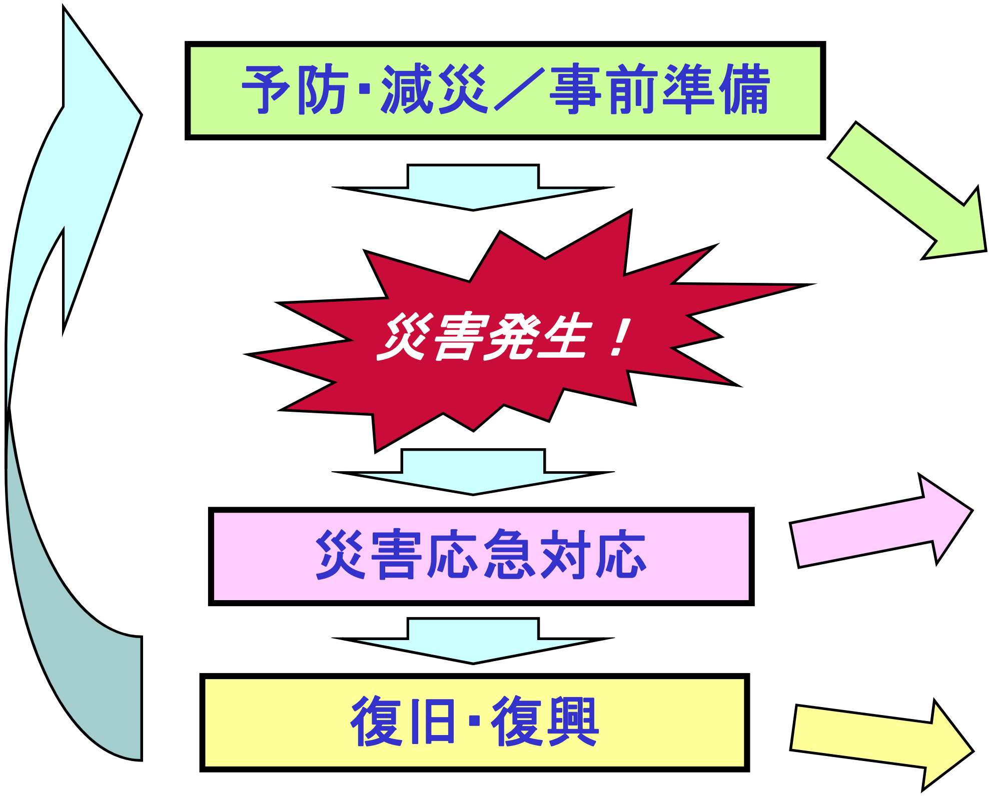
Dataset	Full-Pol-InSAR	>	Dual-Pol-InSAR	>	Full-Pol	>	Dual-Pol
Polarization (m):master (s):slave	HH, HV, VV (m) HH, HV, VV (s)		HH, HV (m) HH, HV (s)		HH, HV, VV (m)		HH, HV (m)
Overall Accuracy	64.87		62.40		60.22		58.41
Kappa coefficient	0.578		0.549		0.524		0.502
Calc. time (sec)*	21.6		9.43		5.35		6.72

*CPU elapsed time for training and classifying

災害における衛星観測データの利用

衛星観測の特長を活かした「夜間・悪天候時の観測」、「広域の観測」、「繰り返しの観測」により得られた情報を防災活動に提供する。

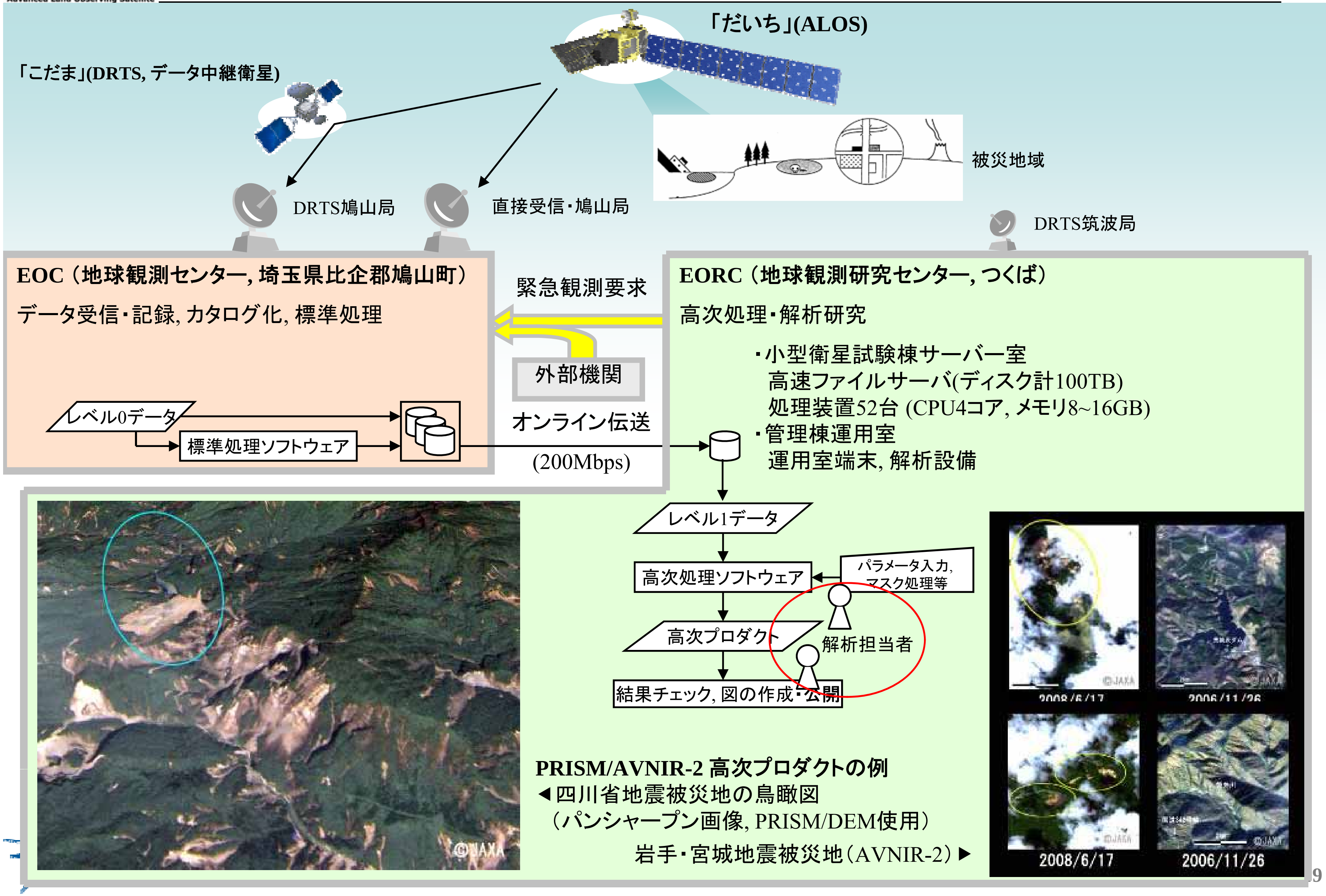
航空機やヘリコプタ等による情報収集を補い、防災活動に貢献



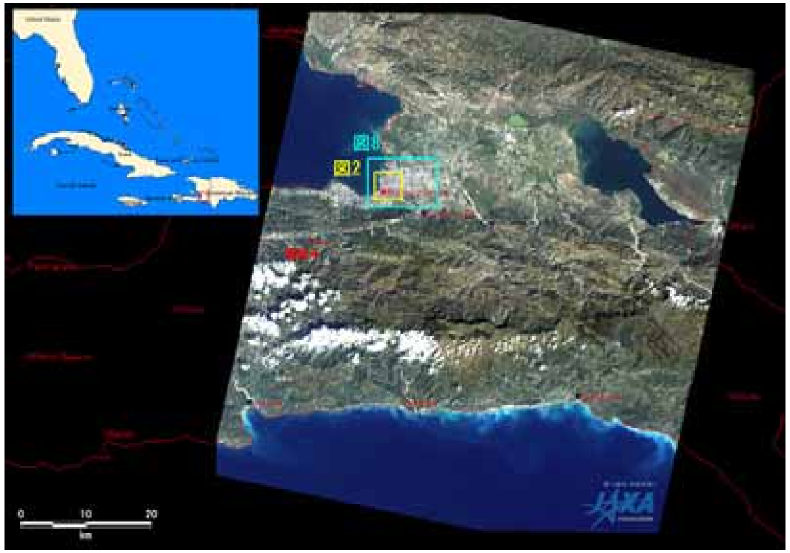
防災活動のサイクル

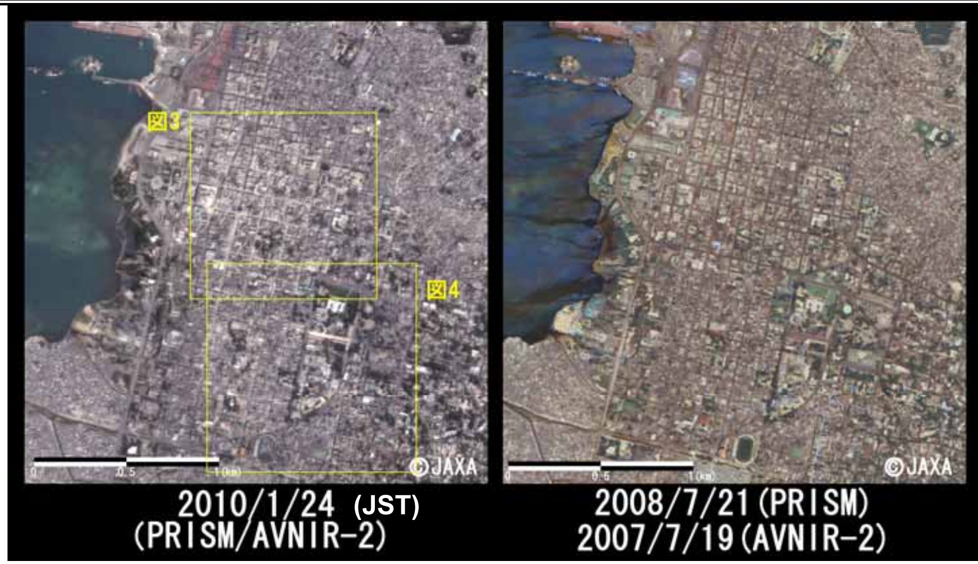
衛星が提供できる情報	左記に基づく対応活動
火山・地すべり危険地域モニタ、地形図修正情報など【広域、繰り返し】	防災計画の策定、ハザードマップの更新
家屋被害、道路・鉄道被害、火災・浸水などの状況【夜間・悪天候、広域】	救助活動・避難ルート・救助隊集結・ヘリ発着場所確保、交通規制
復興進捗状況、火山変化、土地利用状況など【広域、繰り返し】	二次災害の防止、復旧・復興対応の検討

「だいち」による災害緊急観測 ～観測から公開まで



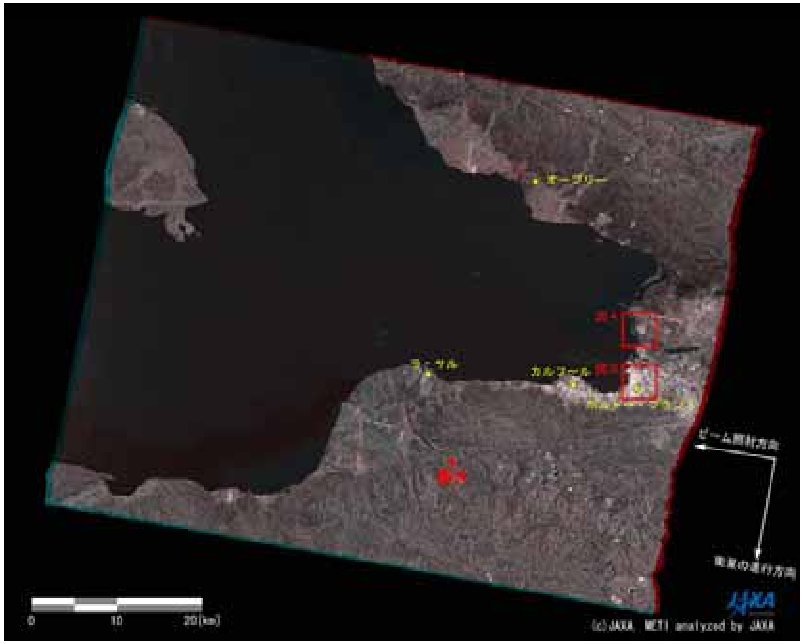
M7.0 Earthquake in Haiti (Jan. 12, 2010 UTC)

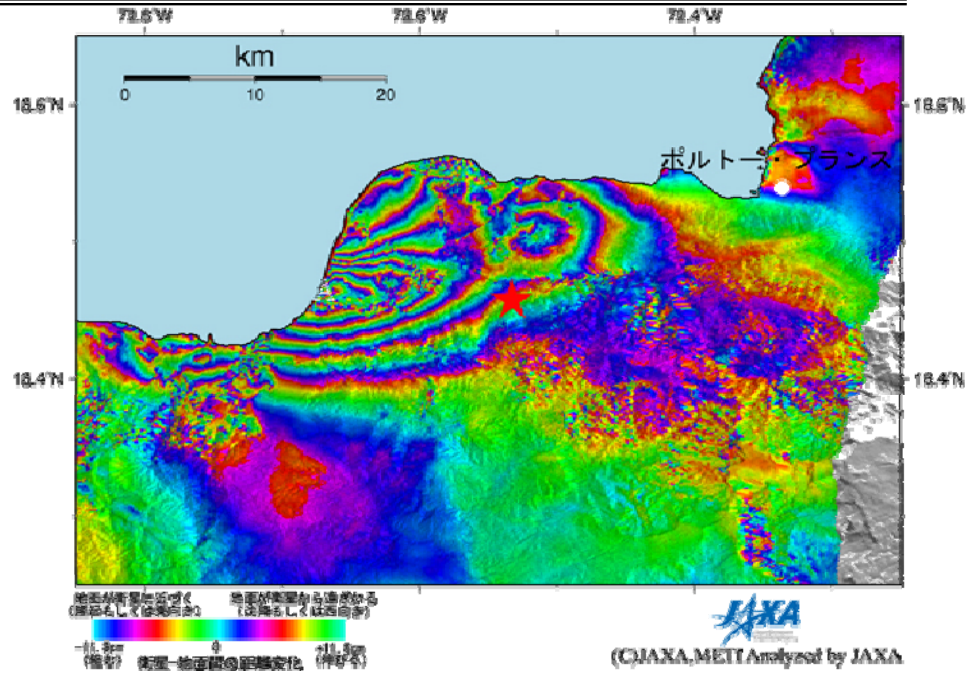


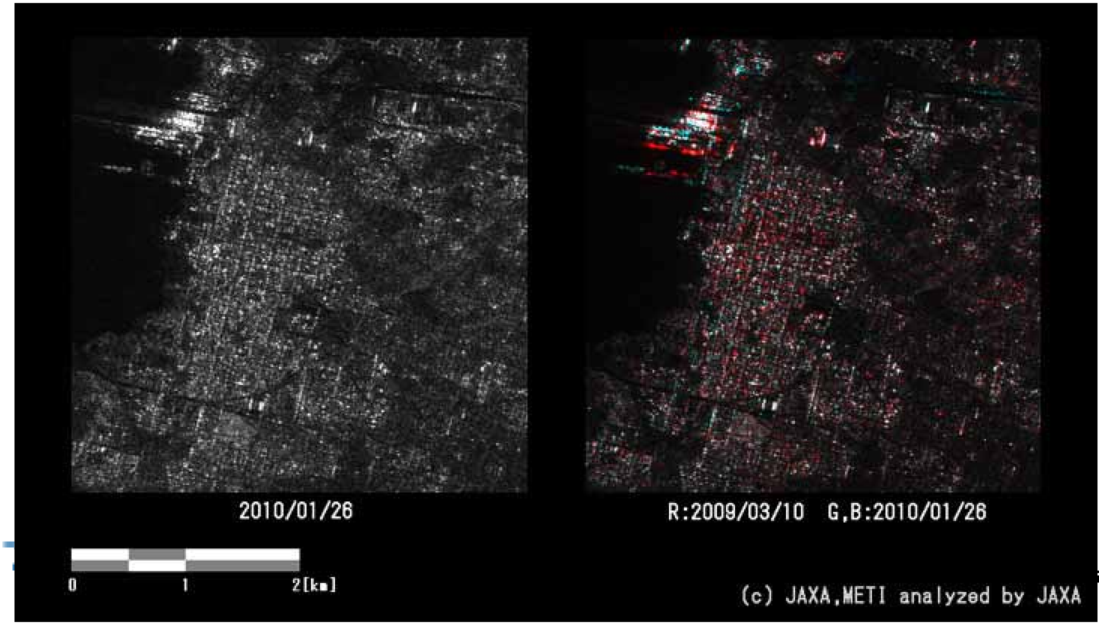


- **First emergency obs.**
  AVNIR-2 on Jan. 13 (UTC)
- **Second emergency obs.**
  PRISM and AVNIR-2 on Jan. 23 (UTC) (Jan. 24 JST)
- **Pan-sharpened images**
  Pre-disaster: 2007 and 2008
- **Breaking buildings**
- **Escaping disaster**

M7.0 Earthquake in Haiti (Jan. 12, 2010 UTC)

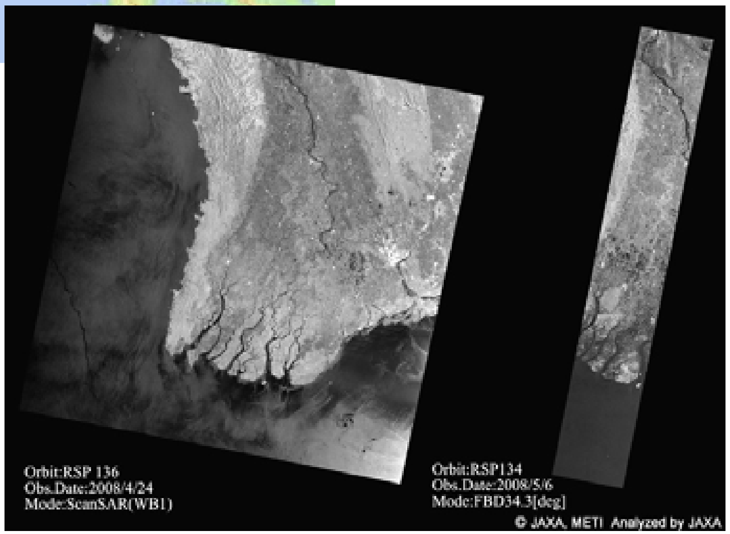


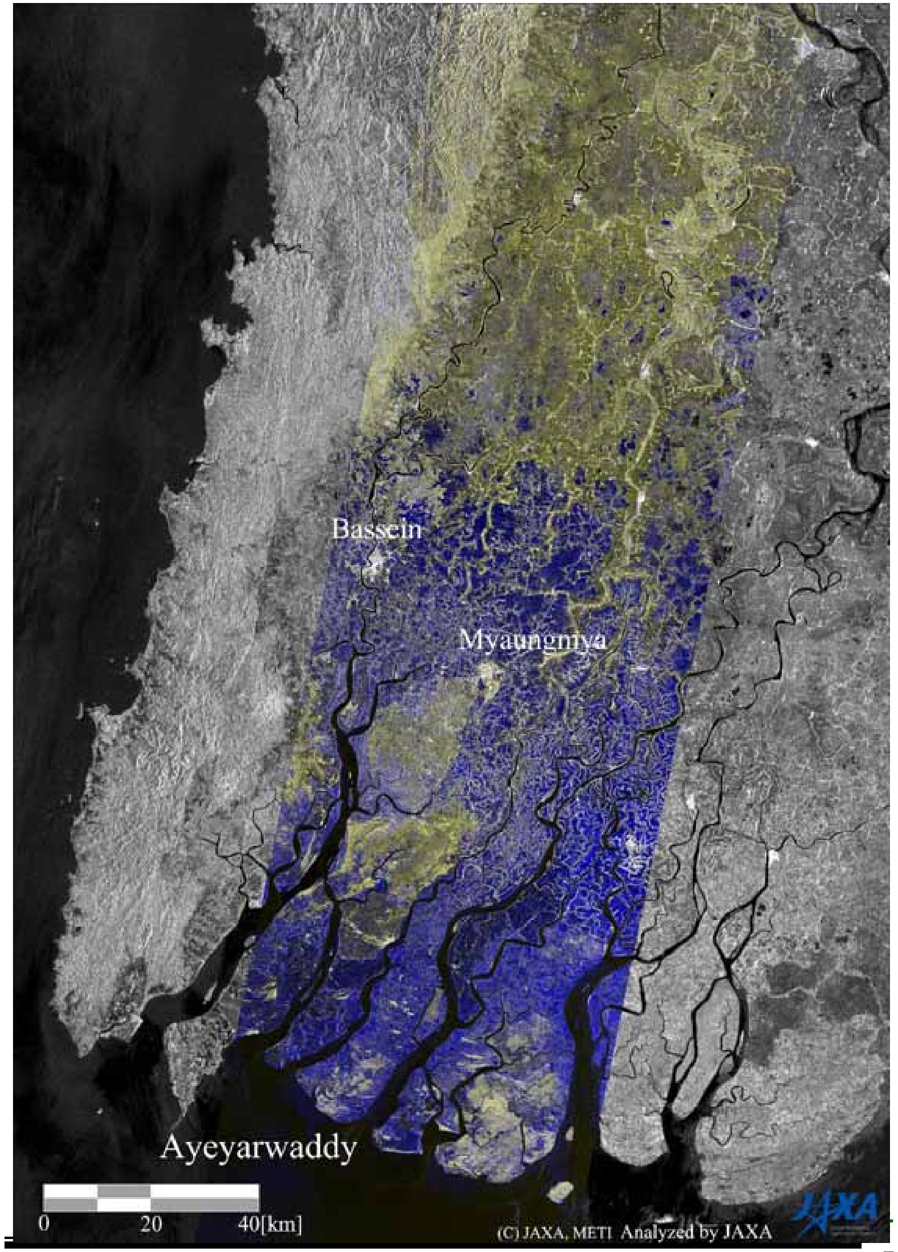




- **Emergency observation by PALSAR**
  Jan. 16 (JST): west part of Haiti
  Jan. 26 (JST): capital Port-au-Prince
- **Amplitude images comparison (left)**
  Red and blue areas: expecting damaged
- **Interferometry (upper)**
  Crustal movement due to the earthquake.
  At #A, 6 cycle fringes = at least 70.8 cm

Flooding by Cyclone in Myanmar (May 2008)

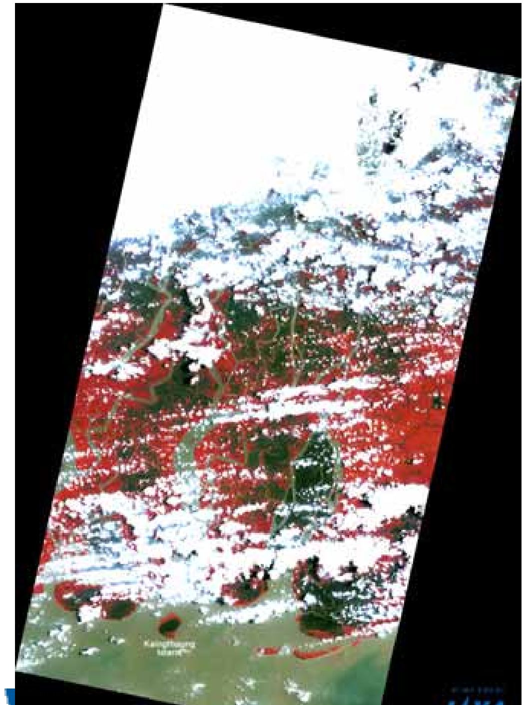




Myanmar was heavily flooded from May 2 to May 3, 2008, due to Cyclone "Nargis". JAXA decided to activate the ALOS/PALSAR to observe the area quickly, and succeeded to acquire image the area on May 6.

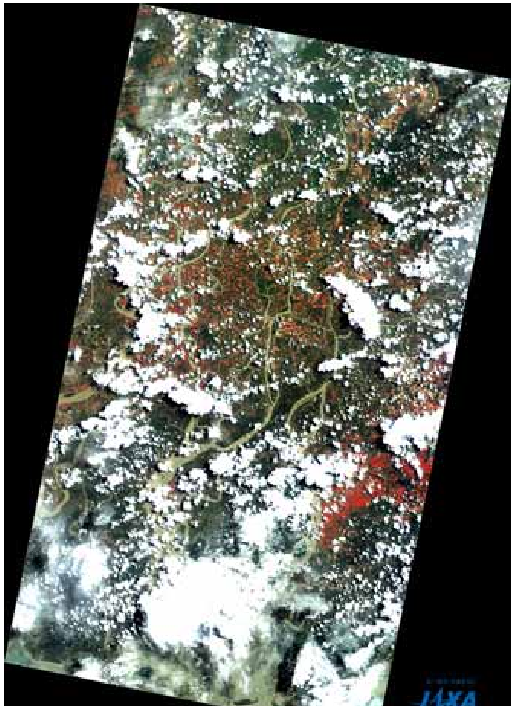
- Overlaying images with Apr. 24, 2008 ScanSAR (right)
  Blue: inundation area
  Yellow: expecting soil moisture increased

Flooding by Cyclone in Myanmar (May 2008)



Expecting inundation area by post AVNIR-2 (May 4, 2008)

Pre AVNIR-2 image overlaying inundation area by PALSAR

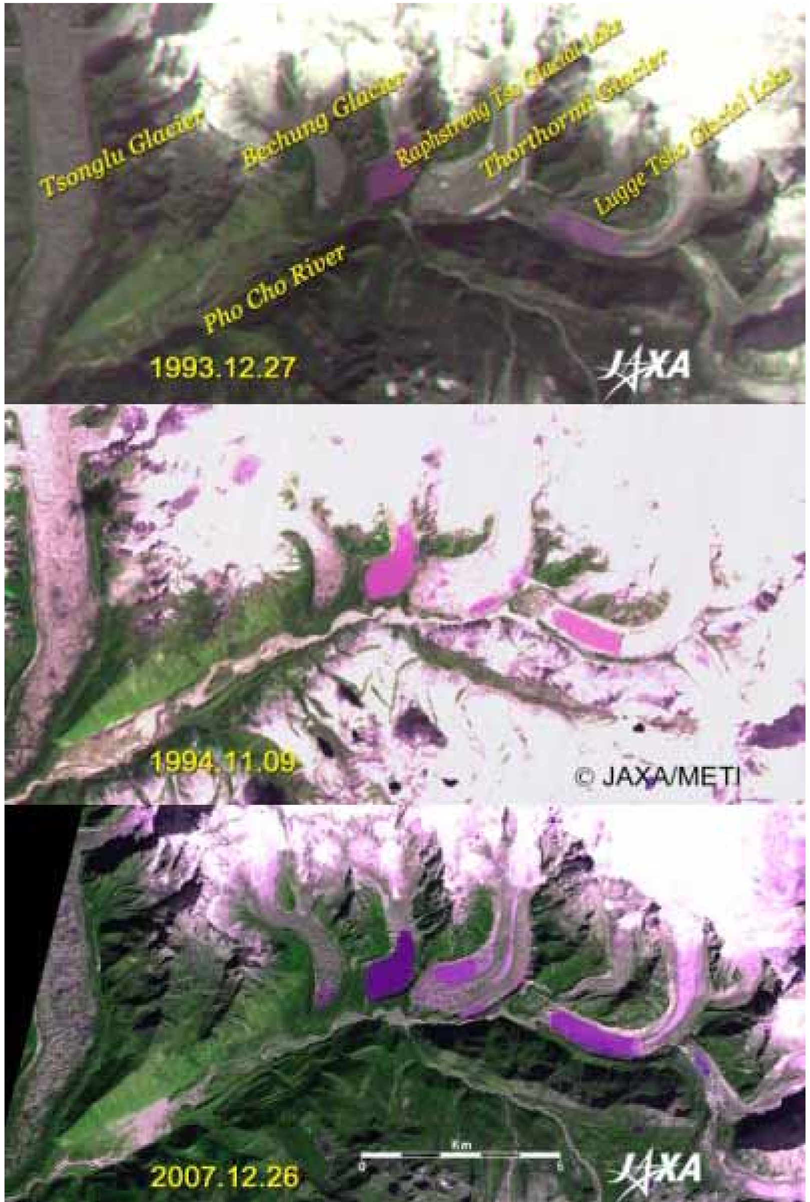


Expecting inundation area by post AVNIR-2 (Jun. 19, 2008)

Advanced Land Observing Satellite

Glacial Lake Outburst Flood (GLOF) Monitoring in the Bhutan and Himalayas

3D view of Lunana region, Bhutan by PRISM DSM and AVNIR-2 acquired on Dec. 26, 2007



Temporal change of area of glacial lake in Bhutan

(ha)	Bechung	Raphstreng Tso	Thorthormi	Lugge Tsho
1993.12.27	1	127	0	118
1994.11.9	4	130	41	96
2007.12.26	18	126	88	127

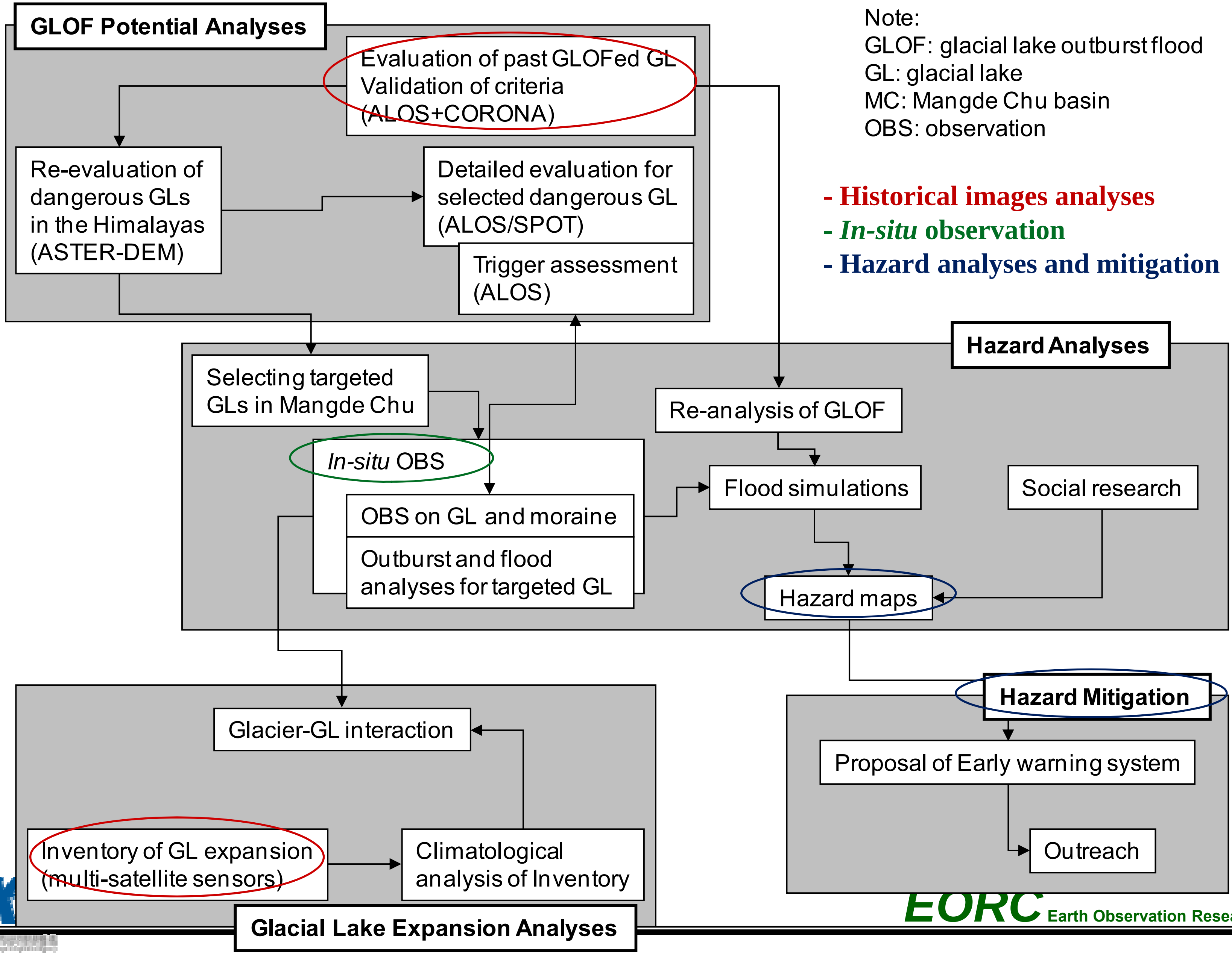
*** This project is conducted in "Science and Technology Research Partnership for Sustainable Development" sponsored by JST and JICA.**

Glacial Lake Outburst Flood (GLOF) Monitoring in the Bhutan and Himalayas

Advanced Land Observing Satellite

Note:
GLOF: glacial lake outburst flood
GL: glacial lake
MC: Mangde Chu basin
OBS: observation

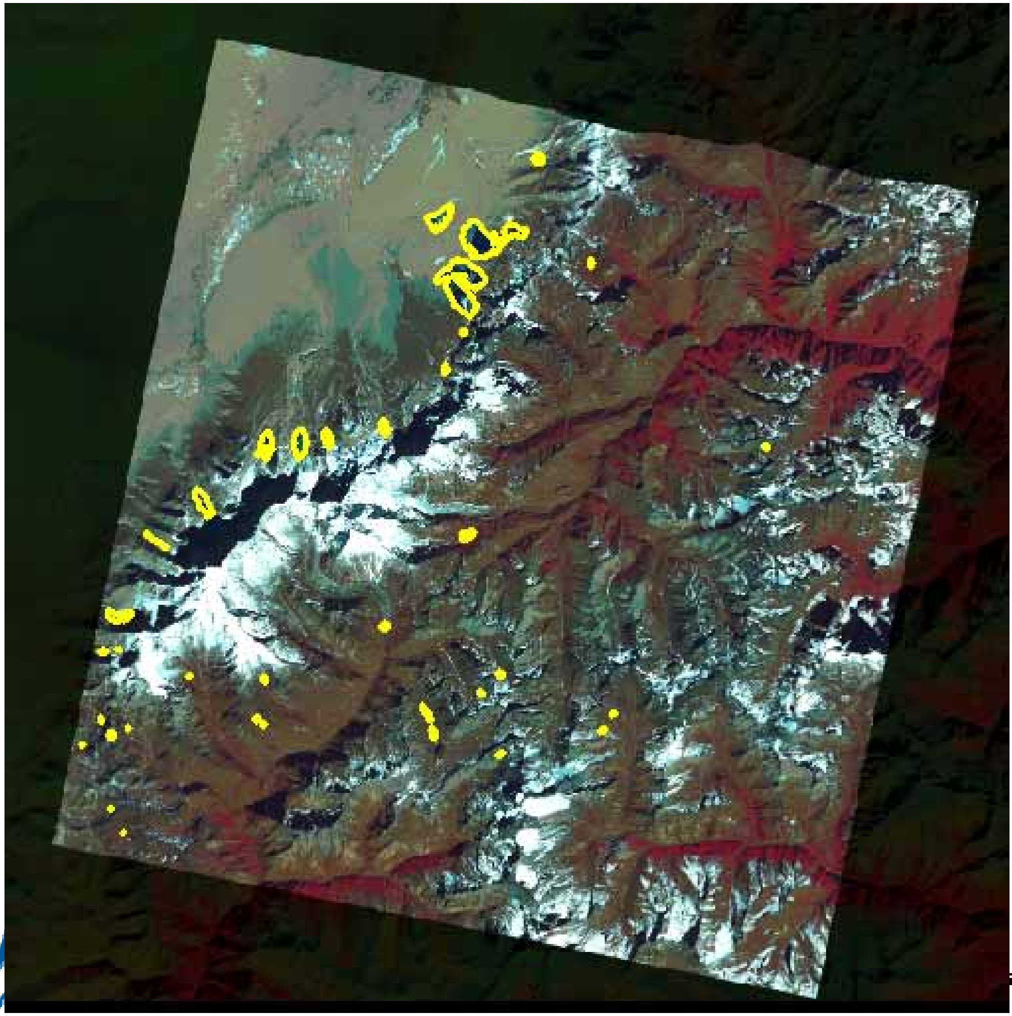
- **Historical images analyses**
- ***In-situ* observation**
- **Hazard analyses and mitigation**

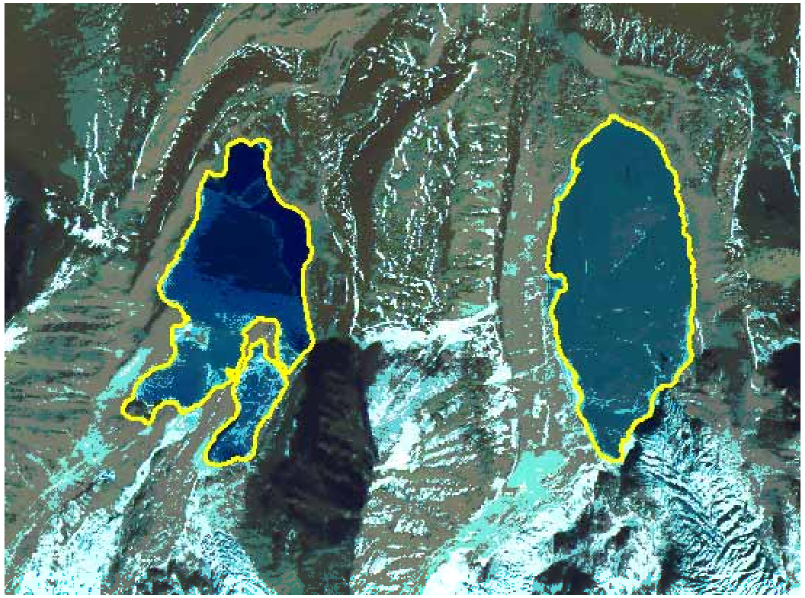


Glacial Lake Outburst Flood (GLOF) Monitoring in the Bhutan and Himalayas

PRISM / AVNIR-2 = Pan-sharpened images generation in Bhutan, Nepal, and Himalayan regions

- ✓ Ortho-rectified image bases with possible digital elevation models (DEMs) by satellite imageries
- ✓ Digitizing glacial lakes by manual
- ✓ Glaciers / Glacial lakes inventories: Corona (HK-9), SPOT, Landsat, JERS-1/OPS, ASTER, and ALOS





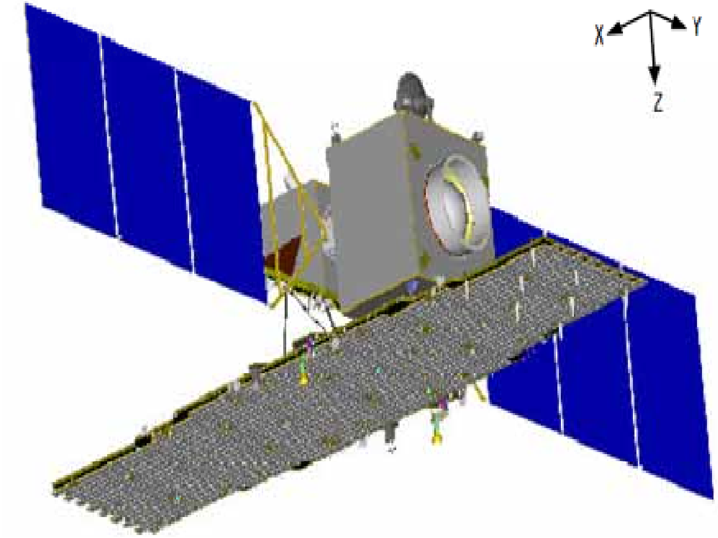
Concept of ALOS F/O Mission

ALOS F/O Mission: ALOS-2 (SAR) and ALOS-3 (Optical)

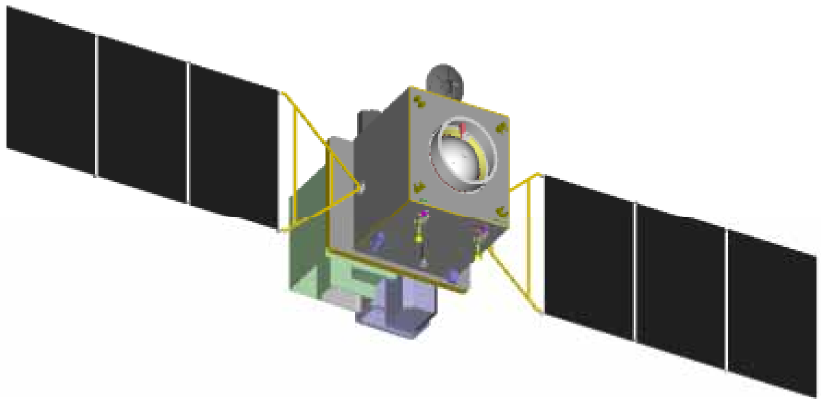
- National land monitoring and managements
- Resources managements
- Disaster monitoring
- ALOS-2 is planed to be launch in 2012-13, and ALOS-3 is hoped in 2014-15 (TBD)

Current System Concept (under investigation)

- Monitoring disaster area affected by earthquake, volcano, flood, etc.
- Observing the disaster affected area within 3 hr (6 hr in night)
- A satellite constellation of two optical sensor satellites and two SAR satellites
- ALOS-2: 3m resolution (3x1m in spotlight mode) with 50km swath (SAR)
- ALOS-3: Panchromatic - 0.8m resolution in 50km swath; multi - 5m in 90km swath; and hyper-spectral 30m in 30km swath (TBD)

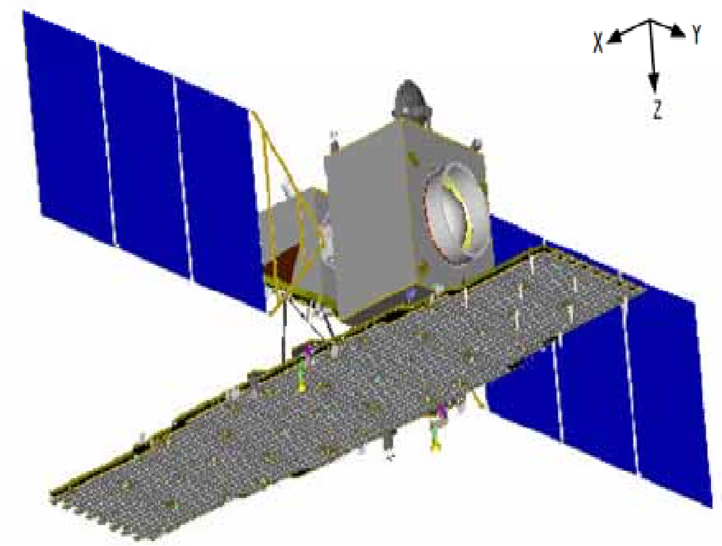


ALOS-2: SAR Satellite



ALOS-3: Optical Sensor Satellite

ALOS-2 Specification

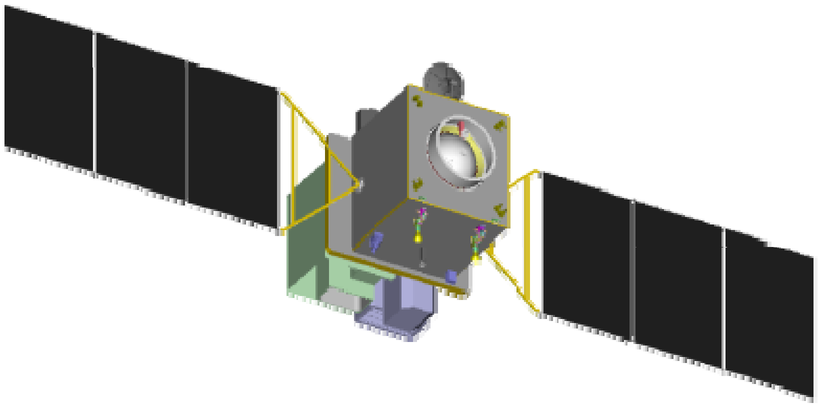


ALOS-2: SAR Satellite

- ✓ August, 2009-: Project Team was established
- ✓ -December 2009: Preliminary Design Phase
- ✓ -October 2010: Critical Design Phase

Orbit		Sun-Synchronous Sub-Recurrent
		Altitude: Approx. 630km
		LST: 12:00 in descending orbit
Design Life		5 years
Launch	Target	JFY2012-2013
	Rocket	H-2A
Satellite	Mass	Approx. 2 ton
	Solar Paddle	Two-wings type panel
Mission Data Transmission		Direct / via. Data Relay Satellite
Mission Sensor		Synthetic Aperture Radar (SAR)
Frequency		L-band (1.2GHz)
Major Observation Mode	Fine	Resolution: 1-3 m, Width: 25 km
	Basic	Resolution: 3 m, Width: 50 km
	Wide	Resolution: 100 m, Width: 350 km
Mission Objectives		Crustal change, volcano monitoring, surface deformation
		Sea ice, river, forest and agriculture monitoring etc.

ALOS-3 Specification (TBD)



ALOS-3: Optical Sensor Satellite

Orbit		Sun-Synchronous Sub-Recurrent
		Altitude: Approx. 620km
		LST: 13:30 in descending orbit
Design Life		5 years
Launch	Target	JFY2013-2014
	Rocket	H-2A
Satellite	Mass	Approx. 2 ton
	Solar Paddle	Two-wings type panel
Mission Data Transmission		Direct / via. Data Relay Satellite
Mission Sensor		Optical instruments
Major Observation Mode	Panchromatic	Resolution: 0.8 m, Width: 50 km
	Multi spectral	Resolution: 3.2 m, Width: 90 km
	Hyper spectral	Resolution: 30 m, Width: 30 km
Mission Objectives		Cartography, volcano monitoring, surface change detection
		Sea ice, river, forest and agriculture monitoring etc.

- ✓ 11 bits quantization
- ✓ JPEG 2000 onboard compression
- ✓ Stereo function (two telescopes?)
- ✓ Body pointing function (+/-60 deg.)

IEEE IGARSS 2011 in Sendai

IEEE International Geoscience and Remote Sensing Symposium (IGARSS 2011)

- **Date:** August 1 - 5, 2011
- **Venue:** Sendai International Center, Sendai, Japan
- **Website:** http://igarss11.org/
- **Important dates**
  - ✓ Invited Session Proposal Deadline: Oct. 11, 2010
  - ✓ Abstract Submission System On-line: Dec. 10, 2010
  - ✓ Abstract Submission Deadline: Jan. 7, 2011
  - ✓ Travel Support Application Deadline: Jan. 14, 2011
  - ✓ Student Paper Competition Deadline: Jan. 14, 2011
  - ✓ IGARSS 2011 Sendai: Aug. 1 - 5, 2011
  - ✓ Sendai "TANABATA" Festival: Aug. 6 – 7, 2011

- IGARSS 2010 Honolulu: July 26 - 30, 2010
  - ✓ Submitted abstract: 2,857 papers
  - ✓ Presentation: 1,890 papers
  - ✓ Attendees: 2,000