PRISM and AVNIR-2 Status
- Calibration and Validation -

- *Overview: Initial Calibration Results as of Oct. 23, 2006*
- *Radiometric Calibration*
  - ✓ PRISM Relative Calibration: Stripe, CCD gap
  - ✓ AVNIR-2 Absolute Calibration: Cross Cal with MODIS
- *Geometric Calibration Results*
  - ✓ Relative Calibration: Band-to-band registration, CCD alignments
  - ✓ Absolute Calibration: Sensor/Pointing alignments
- *Calibration Results as of March 29, 2007*
- *Validation of PRISM DSM*
  - ✓ Algorithm, Software Development and Validation
- *Conclusion*

Takeo Tadono

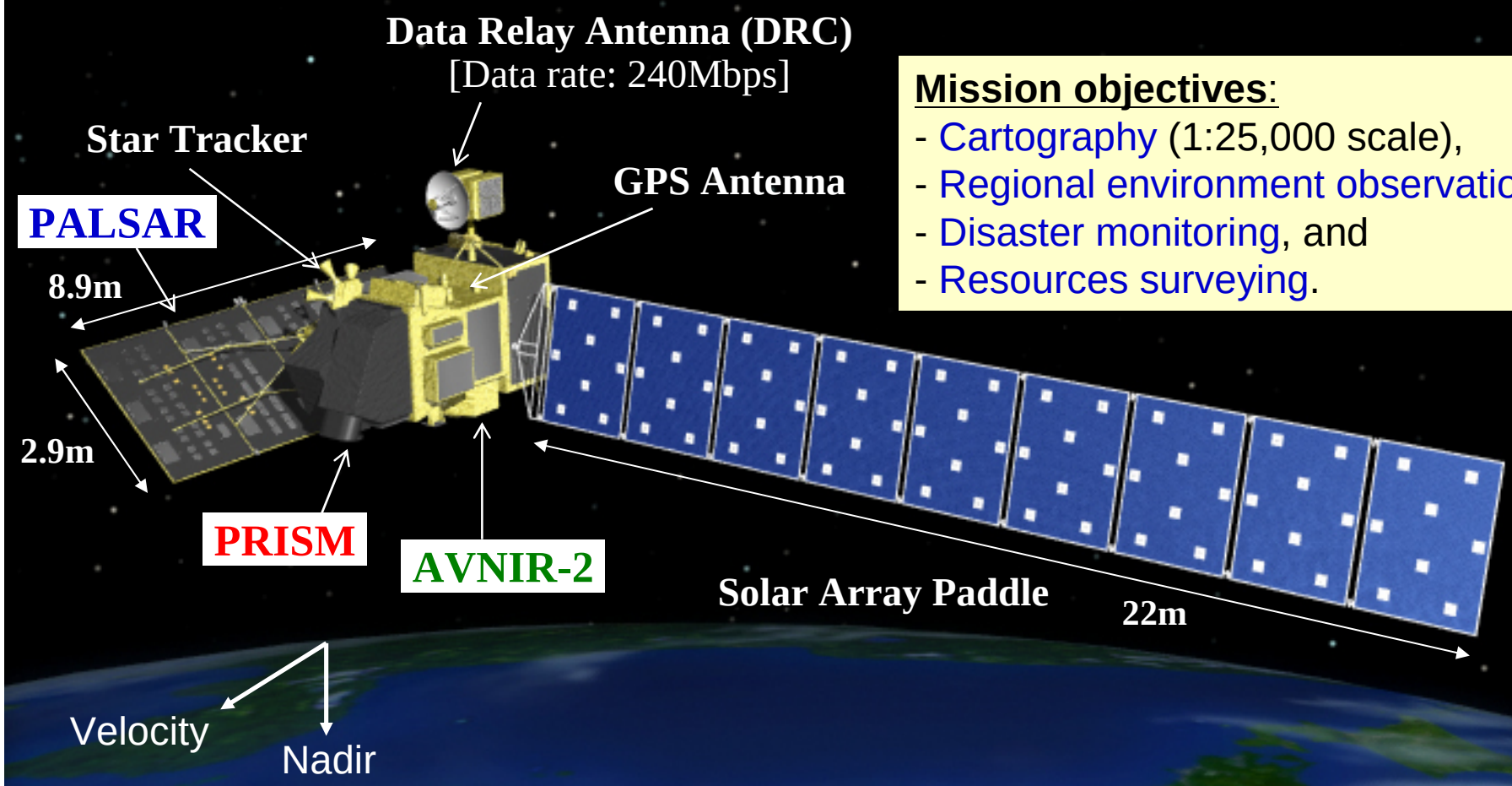
Earth Observation Research Center (EORC)
Japan Aerospace Exploration Agency (JAXA)

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

ALOS "Daichi"

*(**A**dvanced **L**and **O**bserving **S**atellite)*

Jan. 24, 2006: Launch by H-IIA #8 from TKSC
June 11, 2007: 1.4 year (503 days) after launch



Mission objectives:
- Cartography (1:25,000 scale),
- Regional environment observation,
- Disaster monitoring, and
- Resources surveying.

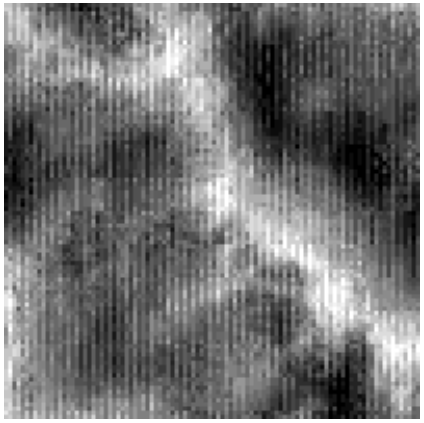
PRISM : Panchromatic Remote-sensing Instrument for Stereo Mapping
AVNIR-2: Advanced Visible and Near Infrared Radiometer type 2
PALSAR: Phased Array type L-band Synthetic Aperture Radar

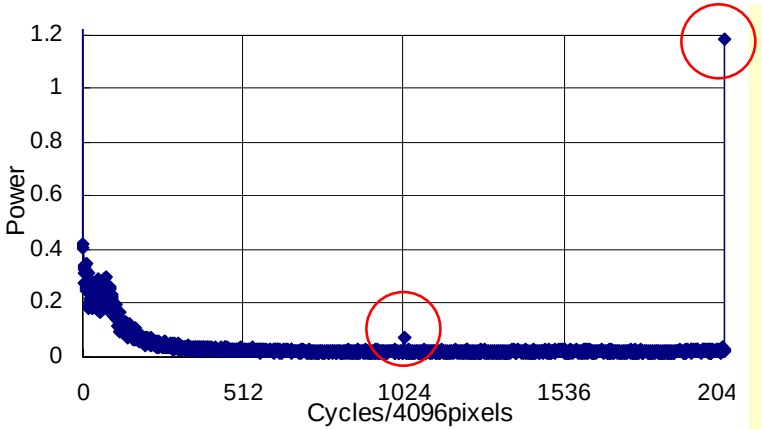
Results of Initial Cal (as of Oct. 23, 2006)

- ✓ **Geometry: PRISM 6m, AVNIR-2 14m(1σ), if 1GCP is available within a scene.**
  Sensor (Pointing) alignments of PRISM is still evaluating
- ✓ **Radiometry: Almost sufficient**
  Except for AVNIR-2 Band 4,and stripe noise of PRISM

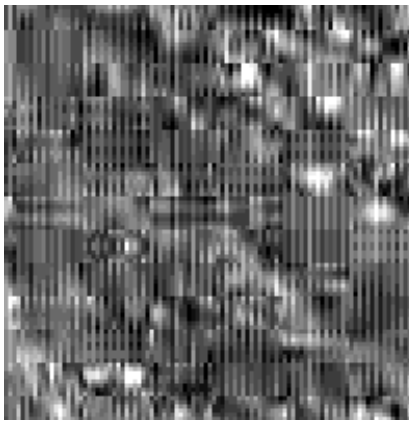
Standard Product	Target Accuracy	Results as of Oct. 23, 2006
PRISM 1B2	Radiometry Relative Accuracy 5% (1σ) Absolute Accuracy 10% (1σ) Geometry Absolute Accuracy (without GCP) 6.0m (3σ) for Nadir-looking radiometer with the Precise Pointing Geolocation Determination System (PPDS)	Radiometry Relative Accuracy less than 1.2% (3DN) →**Post processing is considering** Absolute Accuracy less than 6.2% Geometry Absolute Accuracy →**Sensor (Pointing) alignment** Error in RMS: Pixel (X) / Line (Y) Forward 13m / 64m Nadir 17m / 34m Backward 32m / 32m Relative Accuracy (with 1GCP/scene, 1σ) 3 radiometers 4m / 6m
AVNIR-2 1B2	Radiometry Relative Accuracy 5% (1σ) Absolute Accuracy 10% (1σ) Geometry Absolute Accuracy without GCP 283.7m (3σ) Relative Accuracy with GCP 7.7m (3σ) at 0 degree pointing angle	Radiometry Relative Accuracy less than 0.4% (1DN) Absolute Accuracy 6.2% (B1-3) , 15.8% (B4) Geometry (-41.5 to +41.5 deg.. pointing) Absolute Accuracy →**Sensor alignment updated on Dec.** Pixel (X) / Line (Y) RMS 520m / 370m Relative Accuracy (1σ) 14m / 6m

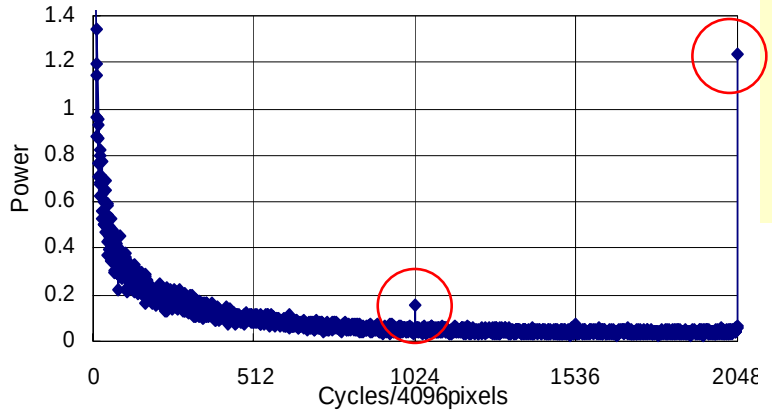
Radio Cal – PRISM Relative Accuracy





Evaluation of stripe noise by FFT (1B1).
Sahara 060427-B/CCD#5, right: power spectral.





Evaluation of stripe noise by FFT (1B1).
Ely 060813-B/CCD#4, right: power spectral.

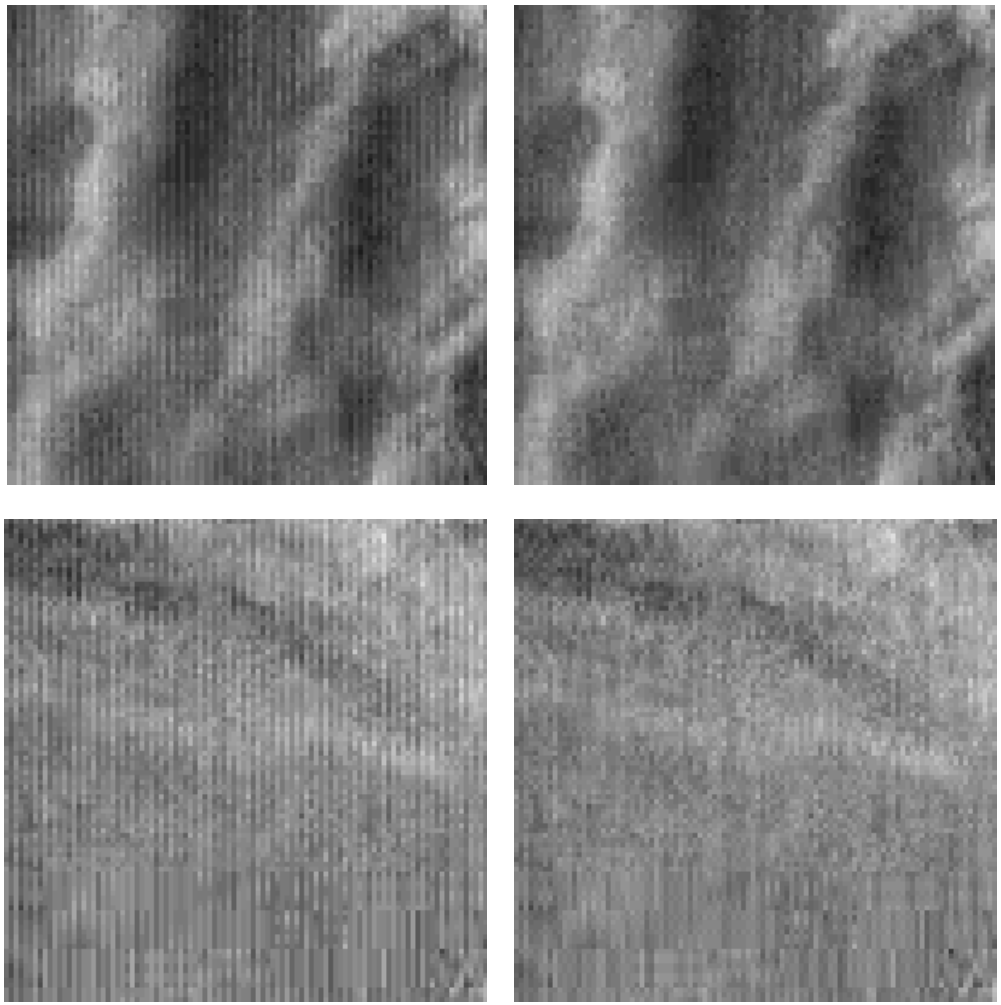
This is related to image quality *i.e.*,
1) Stripe noises are appeared sometime, and
2) Block noises due to JPEG compression are also appeared

1) Stripes noises depends on

- ✓ Stability of "Optical Black" (OB), which is used in radiometric sensor model as the reference, but one OB in each 22 seconds
- ✓ Characteristics of stripes
  - DN average between odd/even detectors
  - FFT: 4096 pixels / 4992 pixels are used

- ✓ Large powers are appeared at 2048 and 1024 cycles
  ＝Correlations on 1/2 and 1/4 samples
  → **1/2 sample shows stripe noise**
- ✓ **Implement a filter to EOC system on March 2007**

Radio Cal – PRISM Stripe Noise Correction



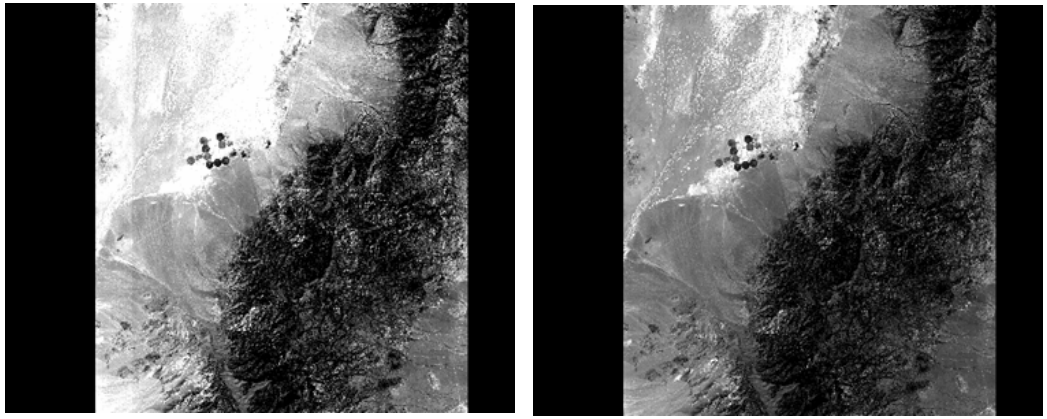
- ✓ Power spectral are calculated for each line by FFT
- ✓ Input 0 at 1/2 sample
- ✓ Calculate Inverse FFT (iFFT)

→ Implement to EOC processing system by March 2007

Example of applying iFFT filter
100x100 (DN scale : 120–160)
IMG-05-ALPSMB013623255-O1B1__B
Sahara, left: before correction; right: after correction

Example of applying iFFT filter
100x100 (DN scale : 100–140)
IMG-04-ALPSMB029422885-O1B1__B
Ely, left: before correction; right: after correction

Radio Cal – PRISM Sensitivity Variation between CCDs (CCD Gaps)



Correction of sensitivity variation between CCDs.
1B1, ALPSMN029422830-O1B1, left: before correction, right: after correction

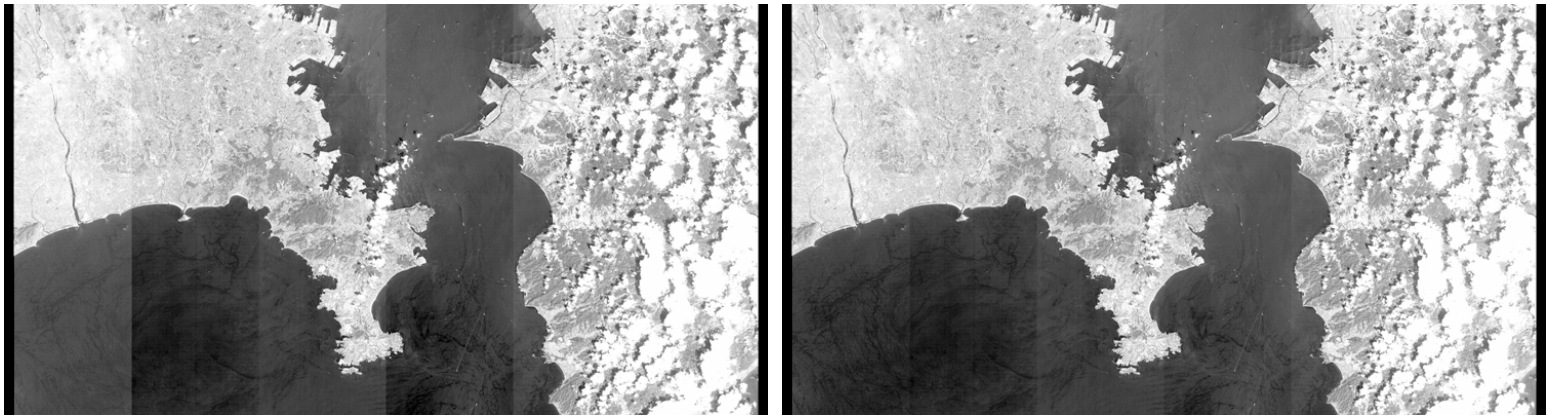
There are radiometric variations between CCDs in L1B2
- → Radiometric correction is not sufficient
- → Relative sensitivity variation between CCD

✓ Characteristic evaluation using overlap pixel (32 pixels)

✓ Corrected values estimation for each CCD, each gain and all radiometers.
  - Separate to stripe noises correction

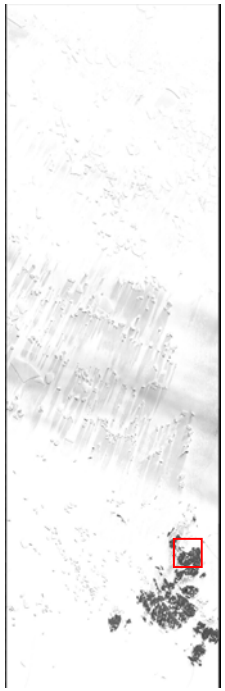
→ Implement to EOC processing system by March 2007

- Correct stripe noises
- **Some target remain stripe noises**



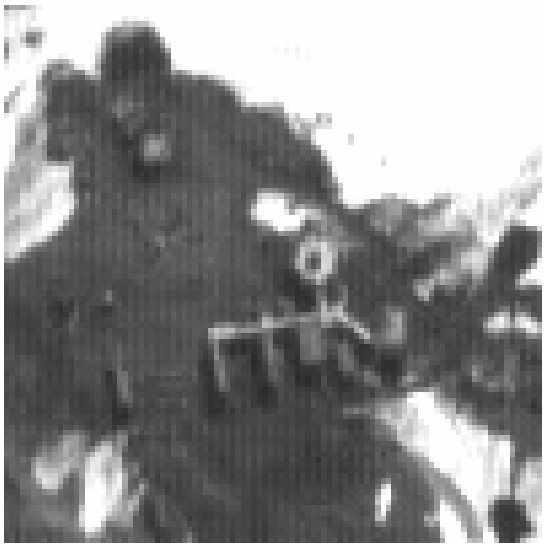
Correction of sensitivity variation between CCDs.
1B1, ALPSMW031652890-O1B1___W, left: before correction, right: after correction

Radio Cal – PRISM Sensitivity Variation between CCDs (CCD Gaps)



Before CCD gap correction

After CCD gap correction
processed on March 2007



After CCD gap and stripe noise correction (averaged filter)

2007/1/1 Showa base, Antarctica
IMG-03-ALPSMB049915065

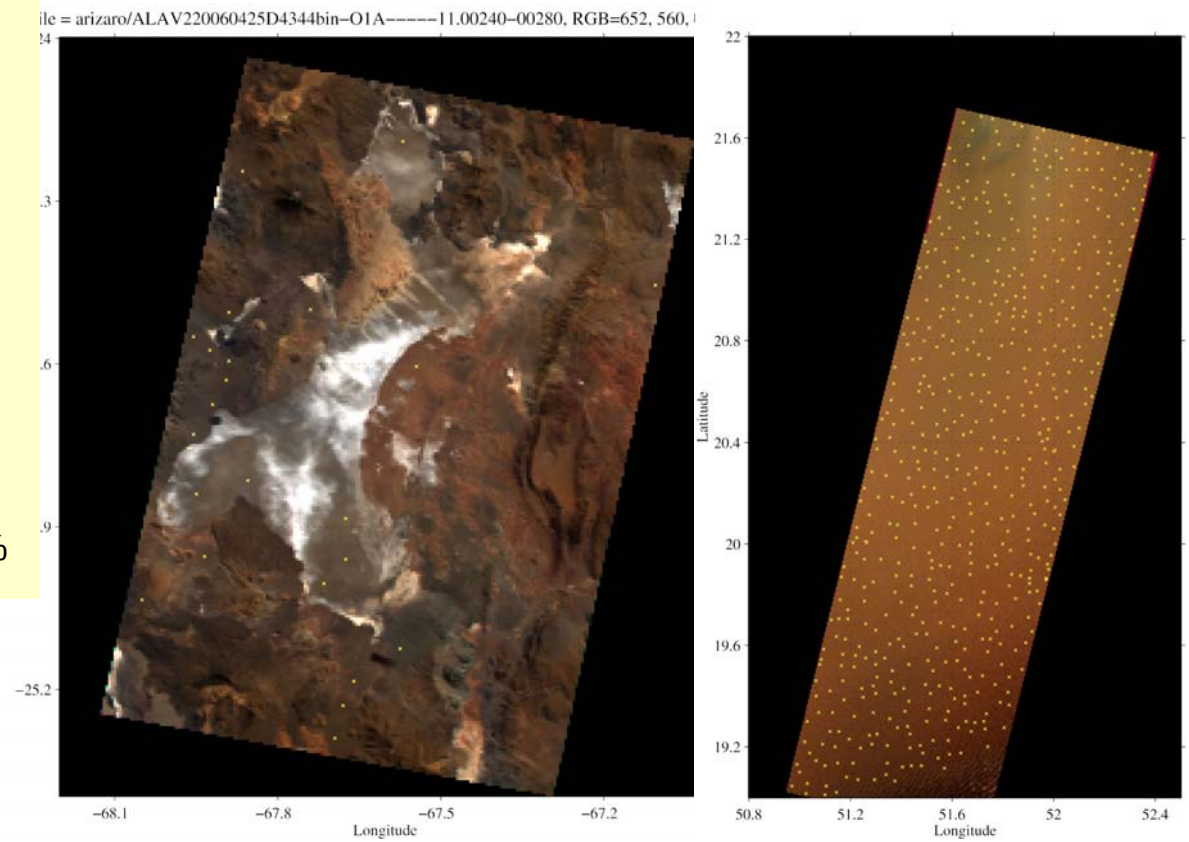
- ✓ Normally stripe noises can be corrected by CCD gap correction
- ✓ The overlap area between CCDs (32 pixels) are covered by bright (or dark) pixels, correct parameters can not be calculated
- ✓ The stripe noises may be amplified if use INCORRECTED parameter
- ✓ The stripe noises correction filter are also difficult
- ✓ But, many images are covered by clouds

> Other methods or threshold should be considered

Radio Cal – AVNIR-2 Cross Cal with MODIS

Cross calibration with MODIS onboard TERRA/AQUA satellites over homogeneous targets

- ✓ Number of evaluation scene can be increase
- ✓ Number of evaluation point can be increase
- ✓ MODIS are calibrating well
- ✓Comparison of surface radiance/ reflectance at TOA over stable surfaces
- ✓Aqua/Terra MODIS 500m resolution
- ✓AVNIR-2: 500m average, variation <3%

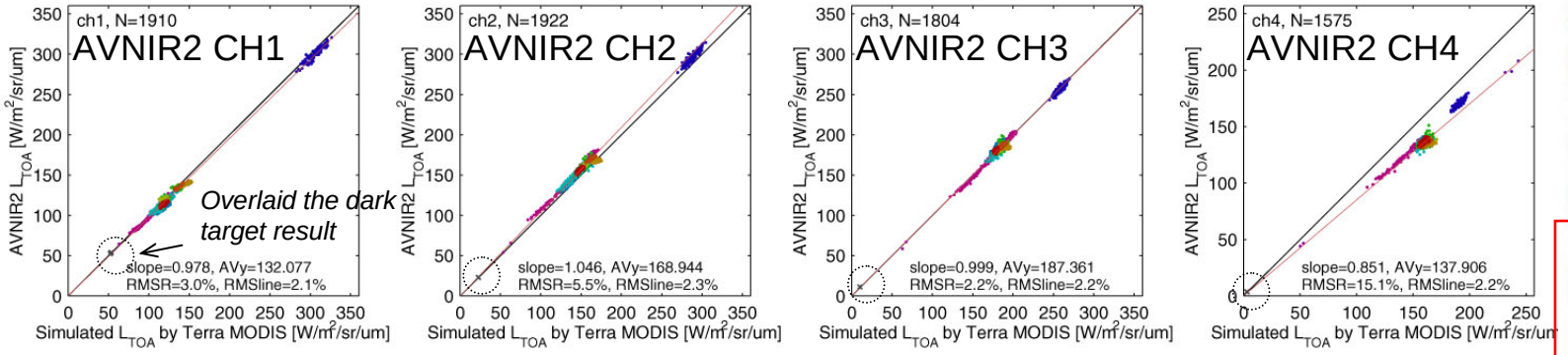


06/04/25 Arizaro, Argentine. **06/05/23 Rab Khali desert.**

Yellow dots shows evaluation points (variation<3%).

Radio Cal – AVNIR-2 Cross Cal with MODIS

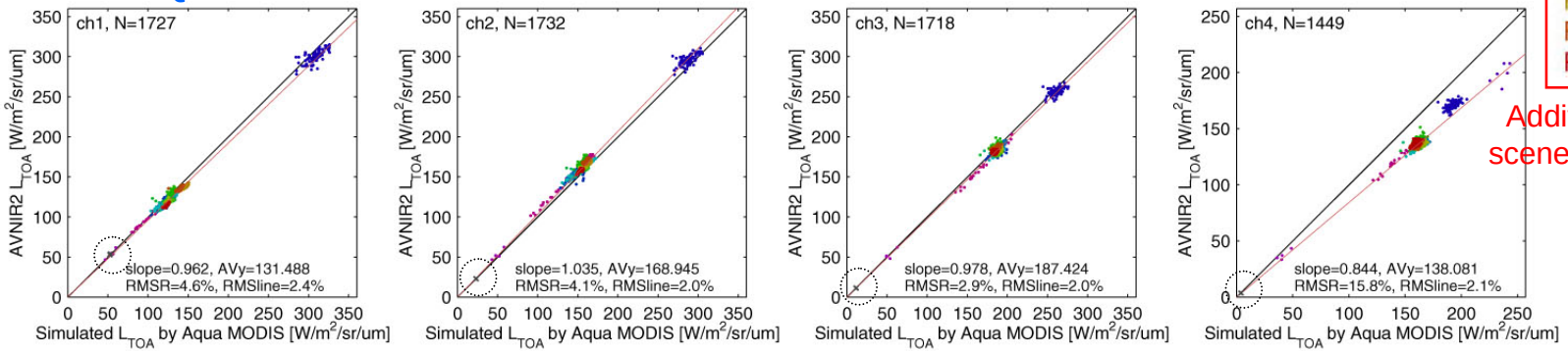
X axis: TERRA/MODIS



Sahara 20060319
Arizaro 20060425
Wsands 20060524
Uyuni 20060821
RaKhali 20060501
RaKhali 20060521
RaKhali 20060523
RaKhali 20060703
RaKhali 20060720
RaKhali 20060727
RaKhali 20060902
RaKhali 20060904
RaKhali 20060913
RaKhali 20060918
RaKhali 20060919

Additional evaluation scenes after Oct. 23, 06

X axis: AQUA/MODIS

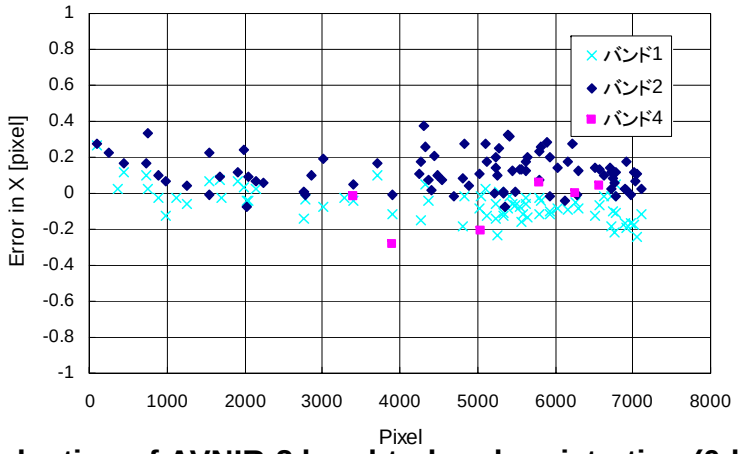


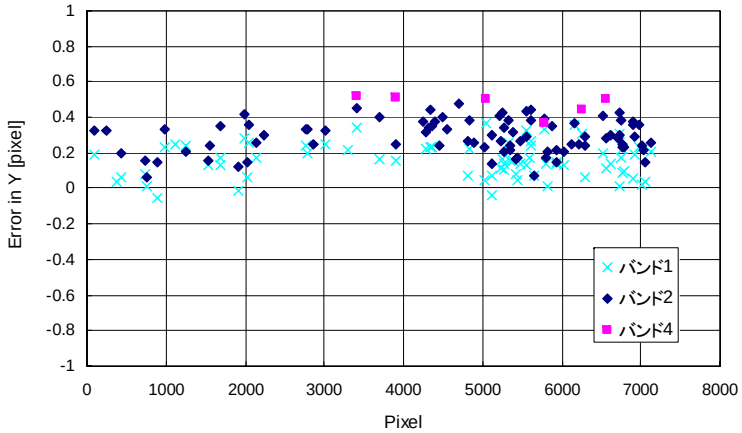
AVNIR-2	TERRA/MODIS			AQUA/MODIS		
Band	Number	Slope	RMSR	Number	Slope	RMSR
1	1910	0.978	2.2 %	1727	0.962	3.8 %
2	1922	1.046	4.6 %	1732	1.035	3.5 %
3	1804	0.999	0.1 %	1718	0.978	2.2 %
4	1575	0.851	14.9 %	1449	0.844	15.6 %

* Number: number of evaluation points; Slope: radiance ratio of AVNIR-2/MODIS; Ave: average of AVNIR-2's radiance (W/m2/str/micro-m); and RMSR: root mean square of residual.

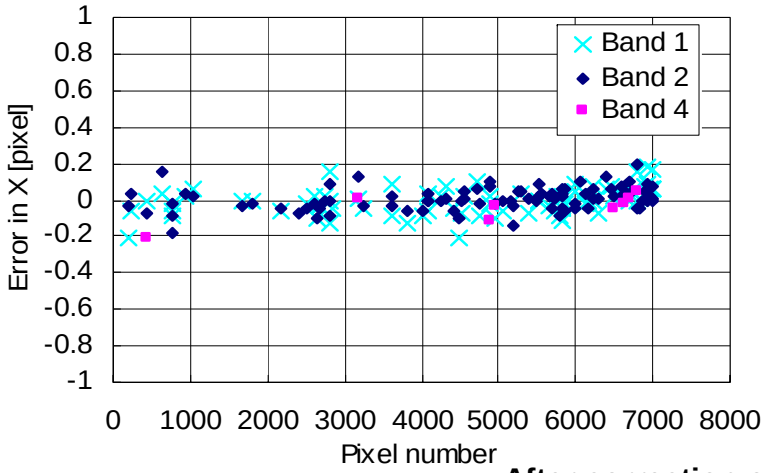
The half of error of band 4 can be described by atmospheric condition >Under evaluation

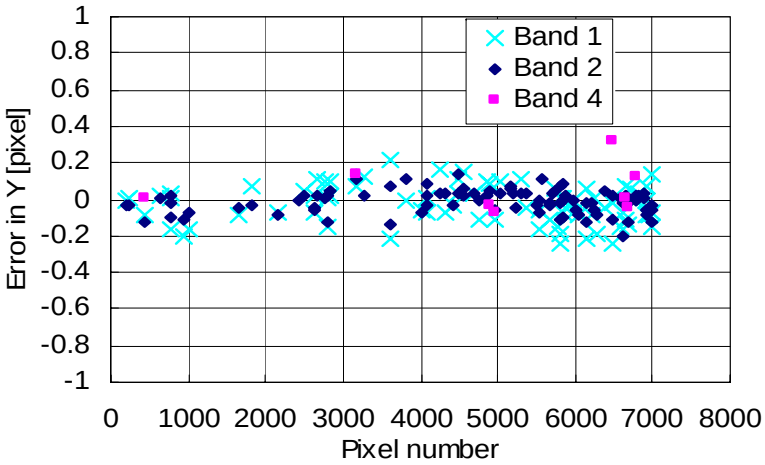
Geo Cal – AVNIR-2 Band-to-Band Registration





Evaluation of AVNIR-2 band-to-band registration (0deg. pointing angle, Sky blue: Band1, Blue: Band2, Pink: Band4).



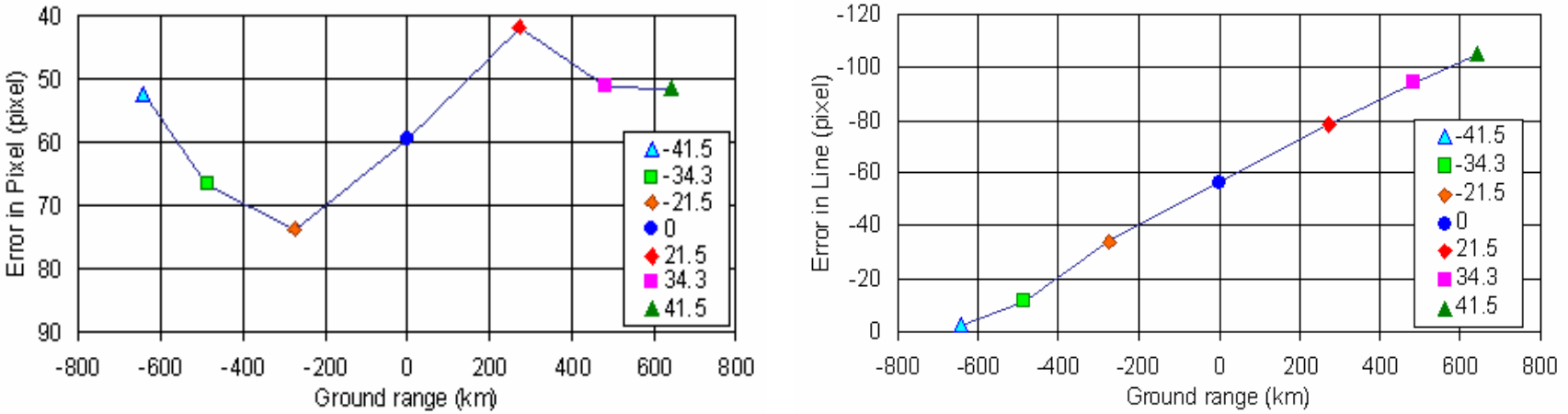


After correction of the registration (as of Sep. 26).

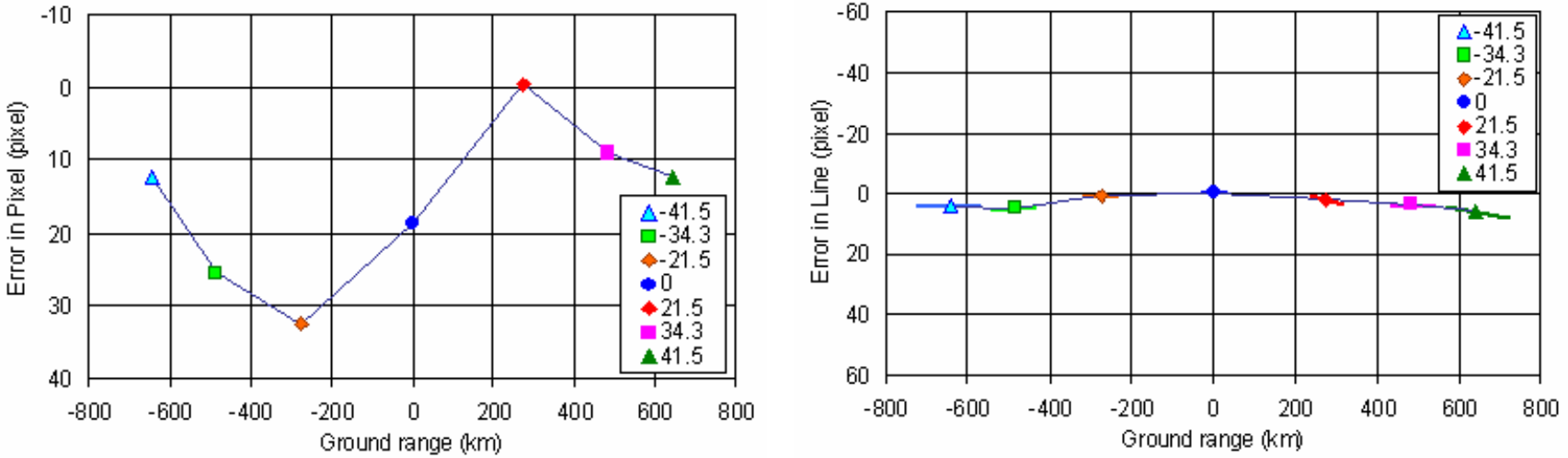
AVNIR-2 Band-to-Band registration estimation and correction:

- ✓ 19 scenes, various pointing angles (-41.5 to +41.5deg.), Band 3 is base image
- ✓ Automatic image matching technique (least square matching)
- ✓ Parameters were modified in geometric sensor model

Geo Cal – AVNIR-2 Alignment Correction



Geometric error trend analysis before correction of sensor alignment (as of Dec 2006).

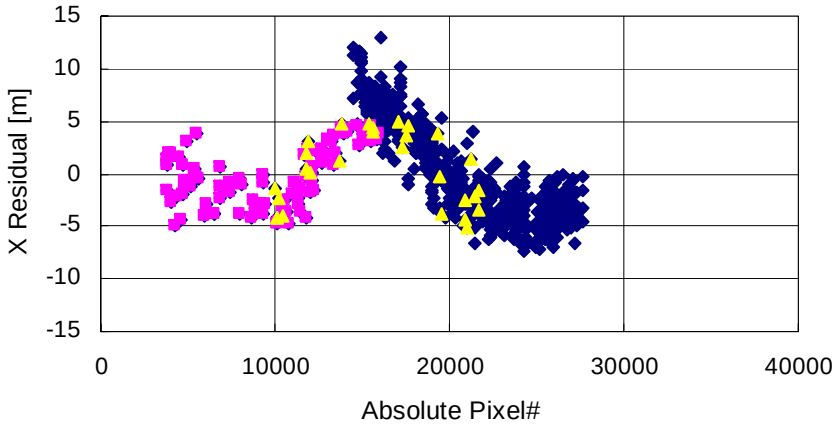


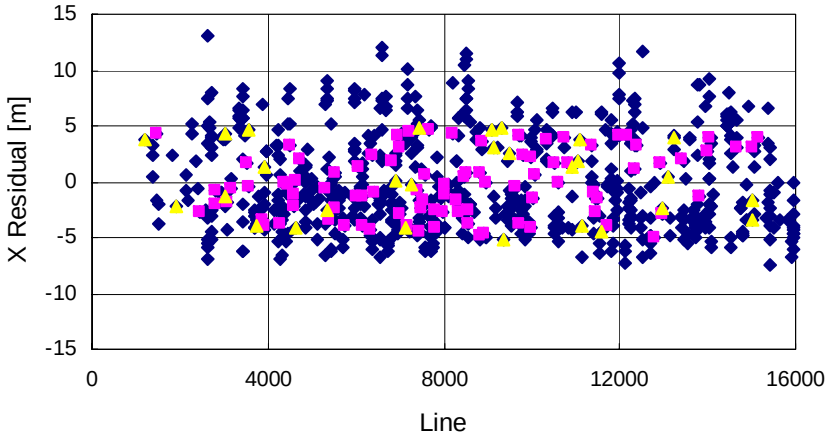
After correction of sensor alignment (as of Dec 2006).

AVNIR-2 sensor alignments estimation (Dec. 7, 2006):

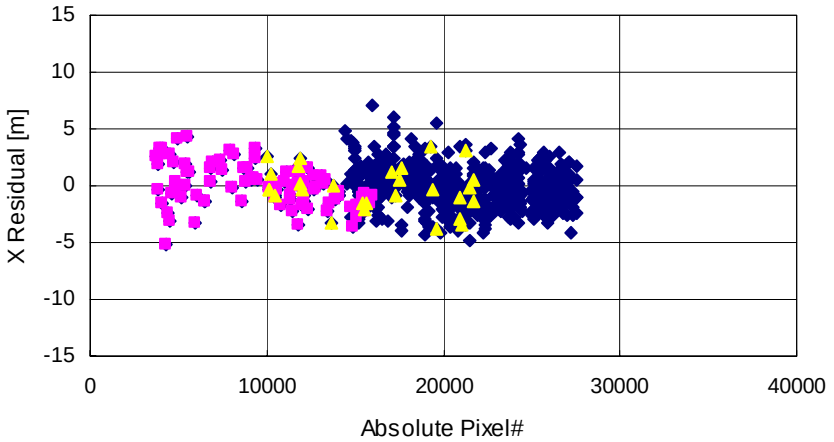
- ✓ External orientation technique using GCPs for various pointing angles
- ✓ Error trends were analyzed and parameters were updated

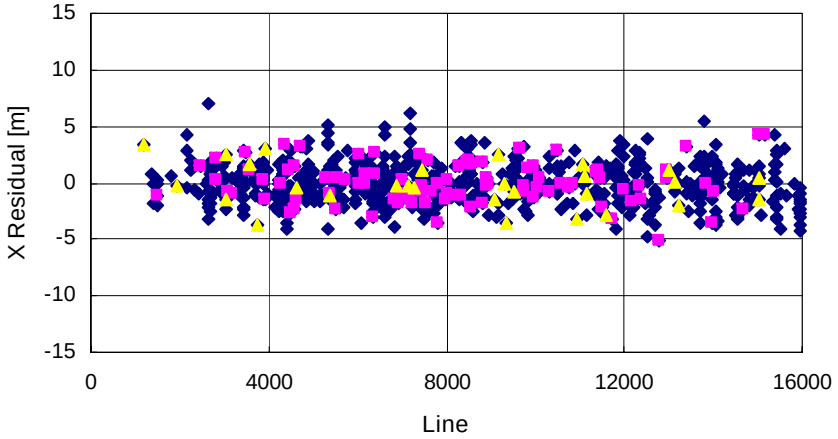
Geo Cal – PRISM relative CCD Alignment (2)





CCD alignments evaluation of PRISM Backward radiometer (Pink: CCD#1-3, Yellow: CCD#3-5, Blue: CCD#4-6).





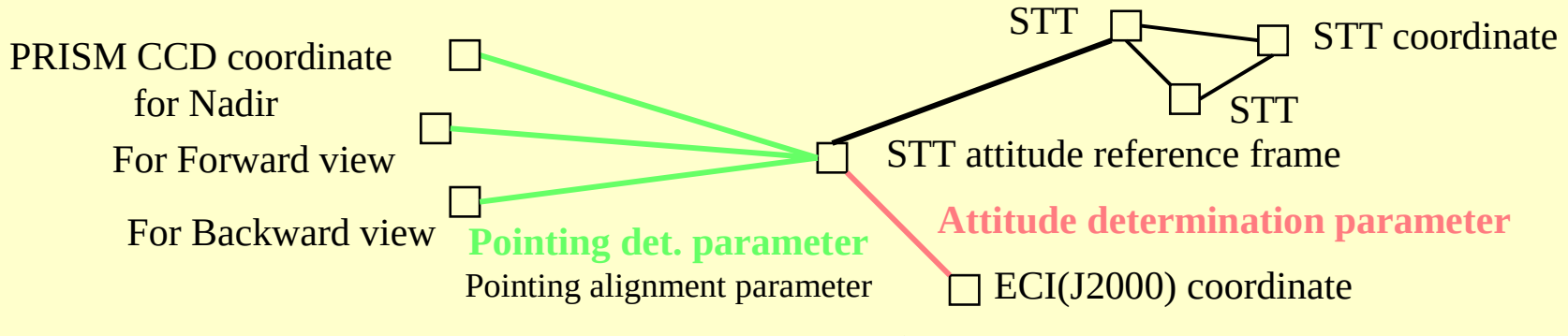
After correction of relative CCD alignments (orientation residual in X direction).

PRISM CCD alignments estimation (Ver. 2 released on Feb 28, 2007):

- ✓ External orientation technique: Yaw axis fixed > 1GCP can be corrected
- ✓ Almost of residuals of orientation are within +/-5m after correction
- ✓ Some CCDs have not been evaluated

Geo Cal – PRISM Alignment Parameter (AP)

ALOS AOCS system and coordination: Pointing Management



- Precise Orbit Determination from TACC (<1m)

PPDS

- Precise Attitude Determination (PAD)
- Pointing Alignment Parameter (AP)
  Evaluation of variation during recurrent, seasonal change, and long term change.

> It is better to use high latitude and night time GCPs

- GCP
- Evaluation
- Sensor alignment estimation

- Standard product
- Evaluation

EOC ⇄ **EORC**

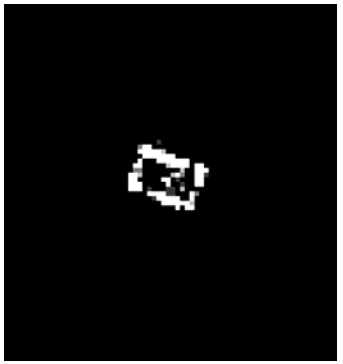
- GCP
- Evaluation
- Sensor parameters

#5, #6 Pointing APs were released on Feb 2007.
#7 AP was released on March 26, 2007.
#8 AP was released on April 23, 2007.
#9 AP will update on E/June or B/July, 2007.

Geo Cal – PRISM Alignment Parameter (AP)

- Nighttime GCP collection
  - Preliminary experiment: PRISM G1, AVNIR-2 G4
    - ✓ RSP391 2007/01/31 -1.2 Morioka, Aomori
    - ✓ RSP410 2007/02/01 -1.2 Hiroshima, Kure
    - ✓ RSP383 2007/02/02 -1.2 Kushiro, Kitami
    - ✓ RSP402 2007/02/03 -1.2 Yokkaichi

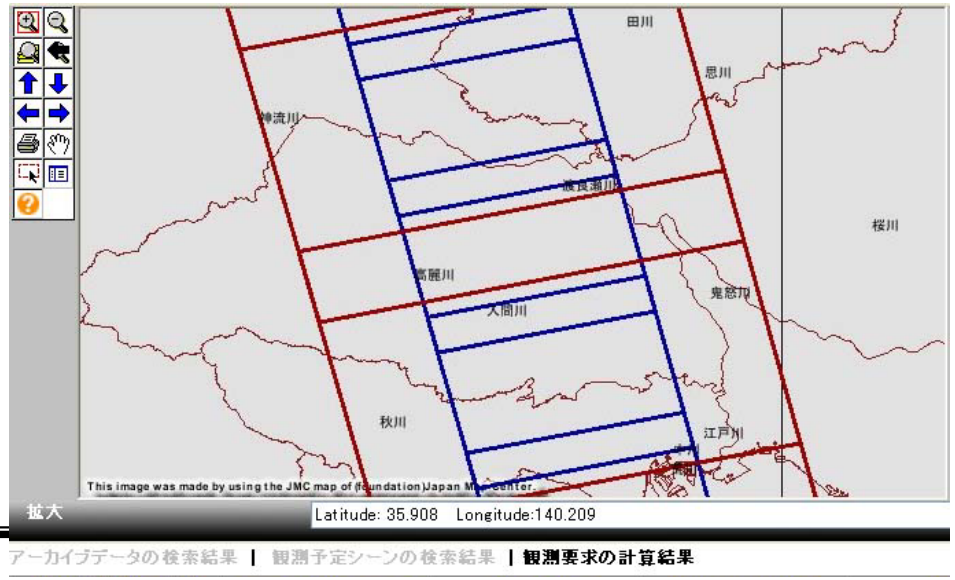
2/3 PRSIM Yokkaichi Artificial feature can be found, but the exact location could not be identified yet.



  - Simultaneous experiment: PRISM G2-3, AVNIR-2 G4
    - ✓ Use power lump for construction as target
    - ✓ 07/2/5: Cloudy, but one brighter target could be find
    - ✓ 07/2/22: Cloudy, but find brighter targets in Tokyo in AVNIR-2
    - ✓ 07/3/23: Cloudy; 07/3/11, 4/9: Canceled
    - ✓ 07/4/26: Cloudy, brighter targets in Tokyo and Yokohama. GPS measured on Jun. 6, 07
    - ✓ 07/6/11: Experiment around northern part of Saitama
- High latitude GCP collection: Antarctica
  - ✓ Collaboration with GSI

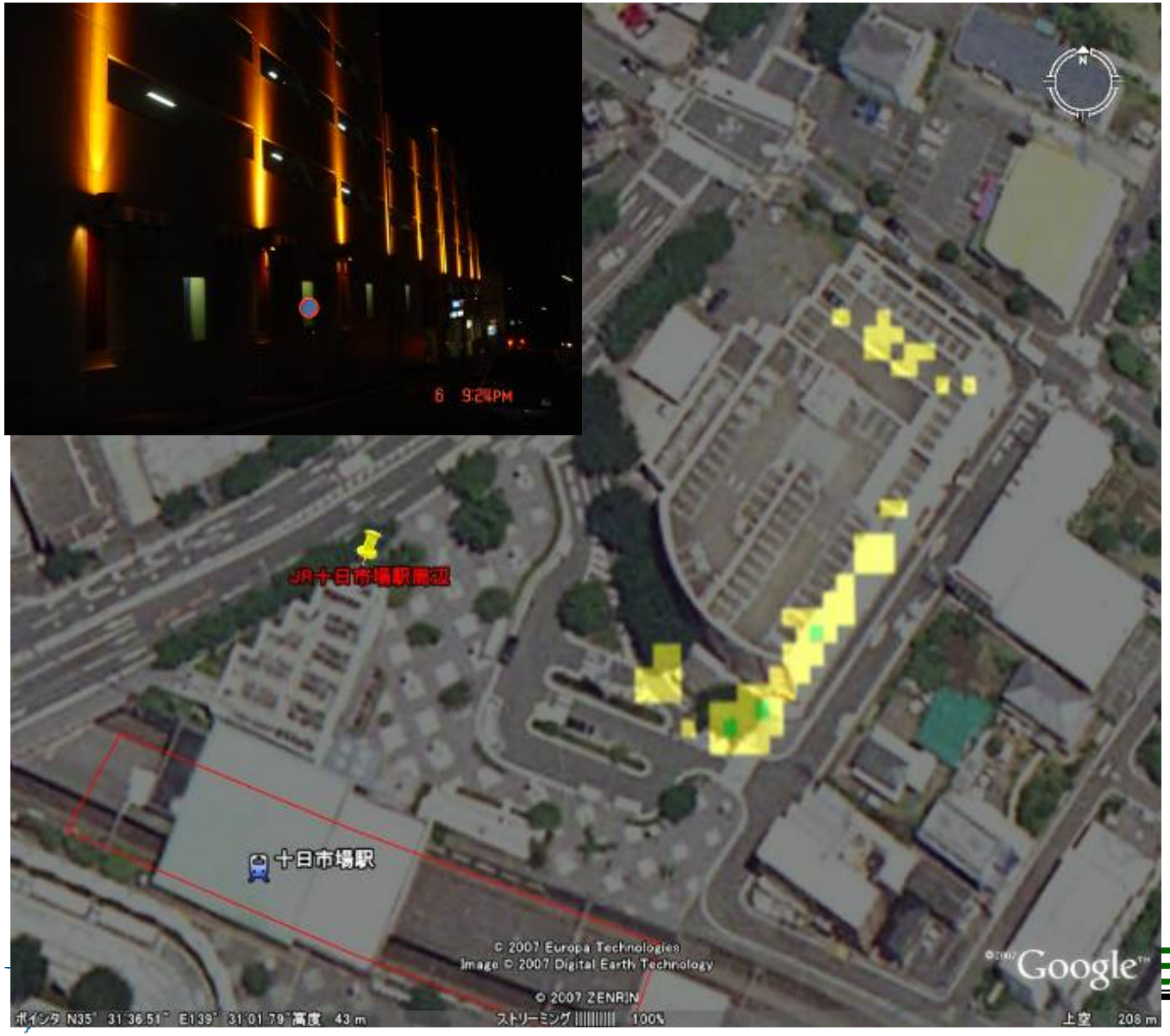
Power lump for construction to use as Nighttime GCP

3/11 RSP396



Geo Cal – PRISM Alignment Parameter (AP)

- Nighttime GCP collection: Tokyo and Yokohama measured on June 6, 2007



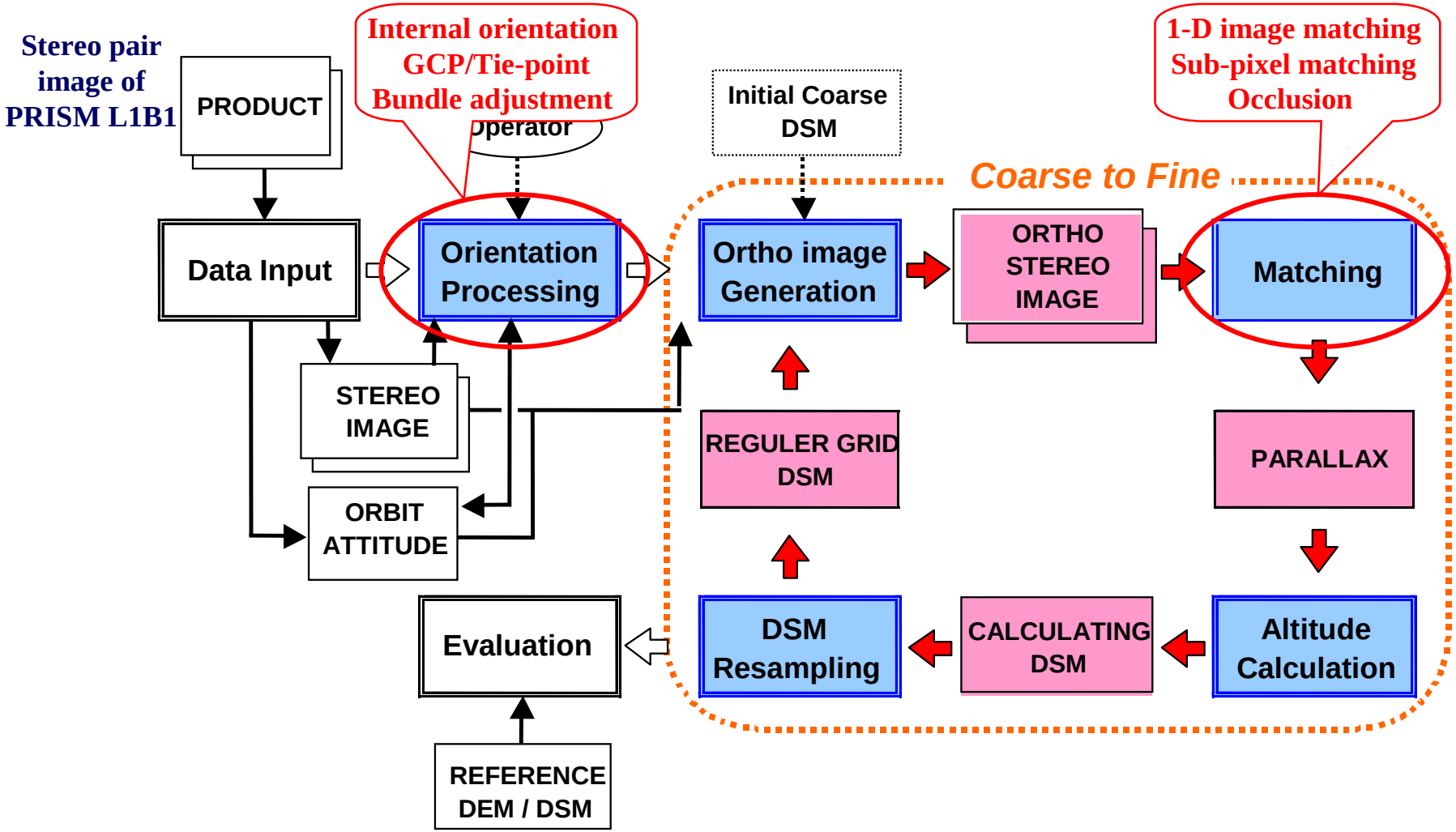
PRISM image acquired in ascending node on April 26 2007 were overlaid to Google-Earth.
PRISM image were colored by yellow and green that corresponds less then 200 DN. We have been measured there location by VRS-GPS.

Result of PRISM/AVNIR-2 Cal (as of Mar. 29, 2007)

Standard Product	Target Accuracy	Results as of Mar. 29, 2007
PRISM 1B2	Radiometry Relative Accuracy 5% (1σ) Absolute Accuracy 10% (1σ) Geometry Absolute Accuracy (without GCP) 2.0m (1σ) for Nadir-looking radiometer with the Precise Pointing Geolocation Determination System (PPDS)	Radiometry (RMS) Relative Accuracy less than 0.4% (1DN) →Depends on target, post processing Absolute Accuracy less than 4.6% Geometry Absolute Accuracy →Pointing alignment evaluation Pixel (X) / Line (Y) (RMS) Forward 11m / 21m Nadir **8m** / **9m** Backward 10m / 20m Relative Accuracy (1σ) 3 radiometers 4m / 3m
AVNIR-2 1B2	Radiometry Relative Accuracy 5% (1σ) Absolute Accuracy 10% (1σ) Geometry Absolute Accuracy without GCP 94.6m (1σ) Relative Accuracy with GCP 2.6m (1σ) at 0 degree pointing angle	Radiometry (RMS) Relative Accuracy less than 0.4% (1DN) Absolute Accuracy 3.8% (B1), 4.6% (B2), 2.2%(B3), 15.6% (B4) Geometry (-41.5 to +41.5 deg.. pointing) Pixel (X) / Line (Y) Absolute Accuracy (RMS) **106m** / **19m** Relative Accuracy (1σ) 4m / 4m

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

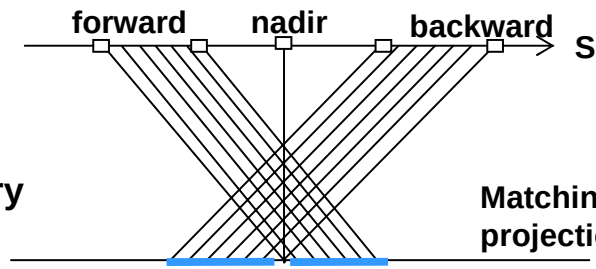
PRISM DSM and Ortho Image Generation Software (DOGS)

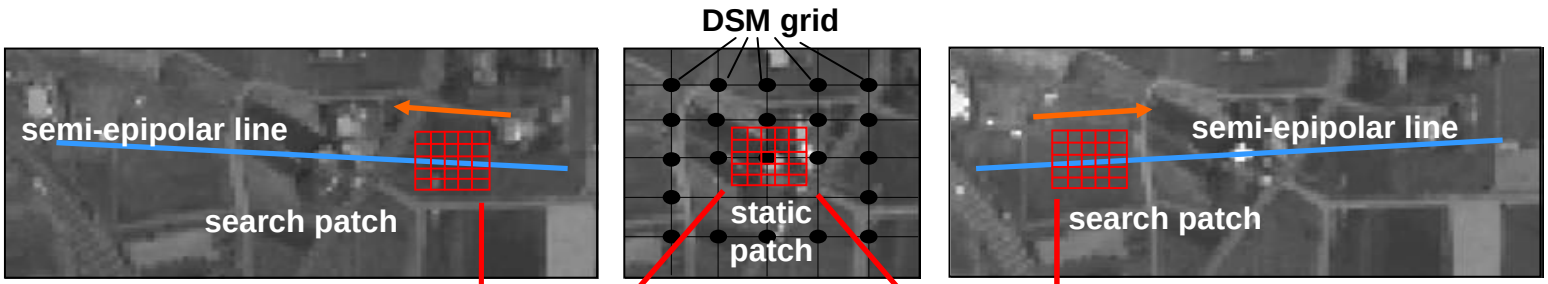


Processing flowchart of PRISM DSM generating software.

PRISM DSM and Ortho Image Generation Software (DOGS)

Two epipolar lines are calculated for each DSM grid based on the epipolar geometry





$$\rho = \frac{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y})}{\sigma_x \sigma_y}$$

nadir-backward correlation

$$\rho = \frac{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y})}{\sigma_x \sigma_y}$$

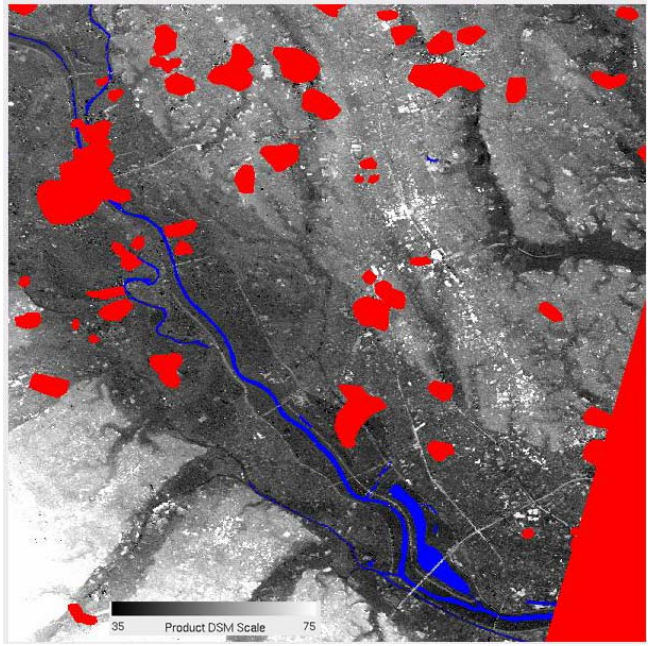
nadir-forward correlation

sum

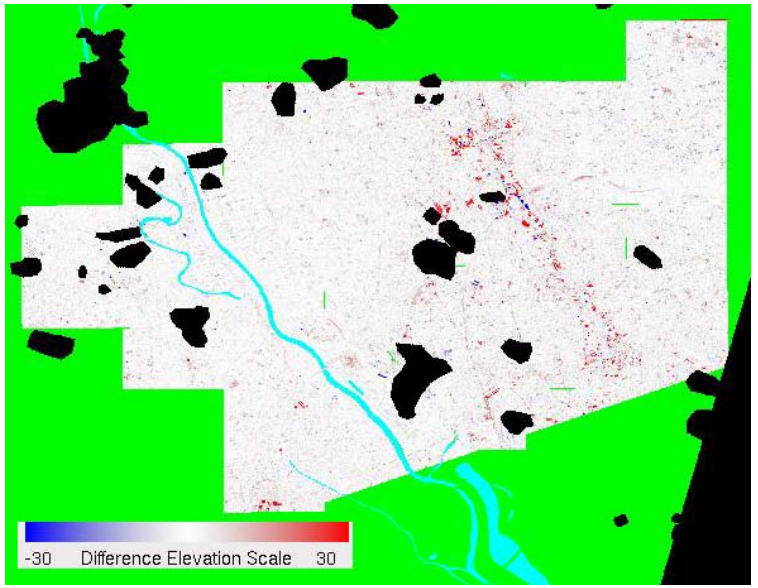
total correlation

Sub-pixel parallaxes are calculated using Parabola fitting with neighbor correlations

Validation – PRISM/DSM Test Generation

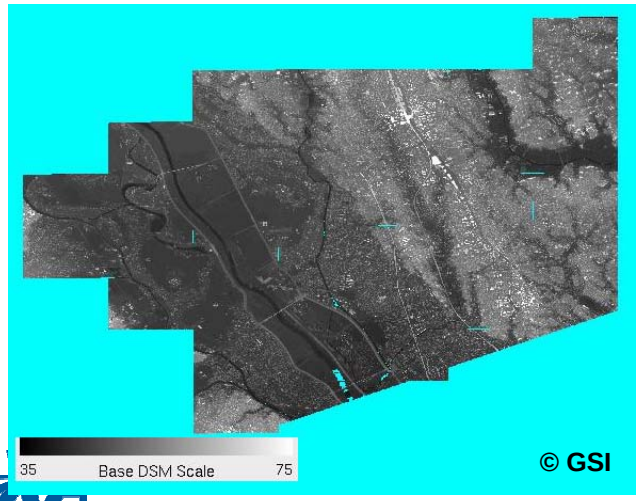


Example of generated DSM by PRISM Triplet (OB1).



Height differences between Lidar/DSM – PRISM/DSM.

as of March 8, 2007



Reference Lidar/DSM by GSI.

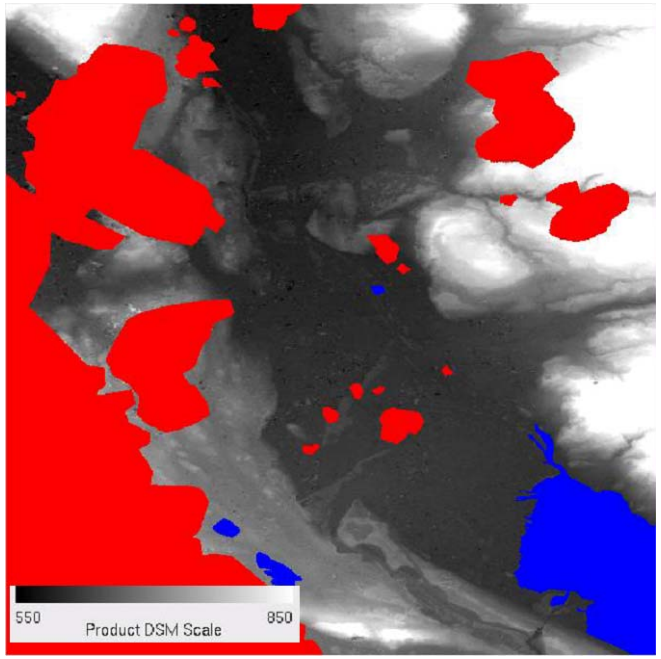
Test generation of PRISM/DSM using stereo pair image acquired in Saitama Pref. Japan on April 30 ("Cal/Val Dataset").

- ✓ Corrected CCD alignment images
- ✓ Compared the results with Lidar/DSM by GSI
- ✓ Averaged error= **0.84m**, STDEV= **4.76m** /1258857

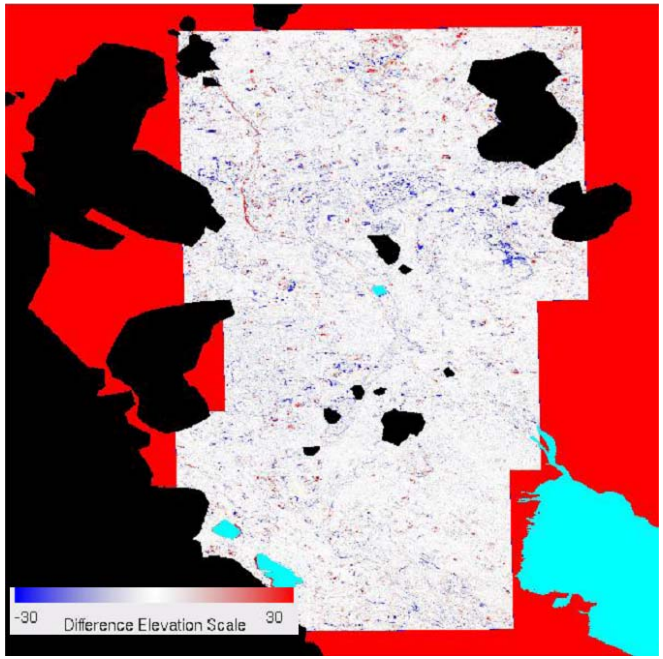
▼

- ✓ Large errors were identified due to buildings
- ✓ Filtering and tuning of matching processing

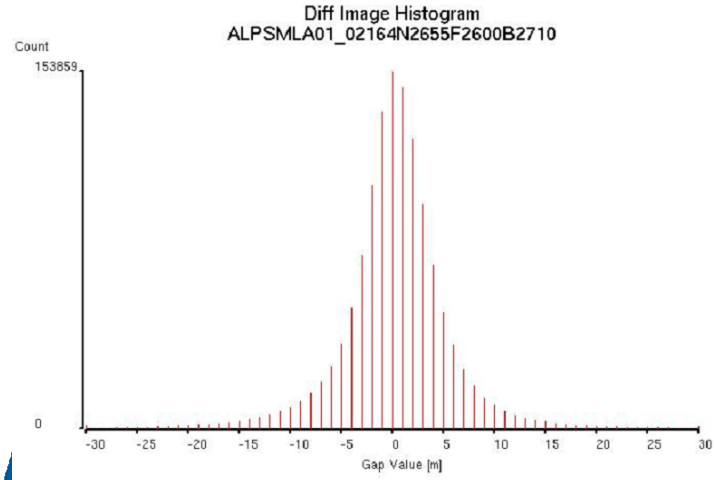
Validation – PRISM/DSM Test Generation



Example of generated DSM by PRISM Triplet (OB1).



Height differences between PRISM/DSM – Photogrametry/DSM.
as of March 8, 2007



Histogram of height difference.

Test generation of PRISM/DSM using stereo pair image acquired in Thun, Switzerland on June 20, 2006 (next "Cal/Val Dataset").

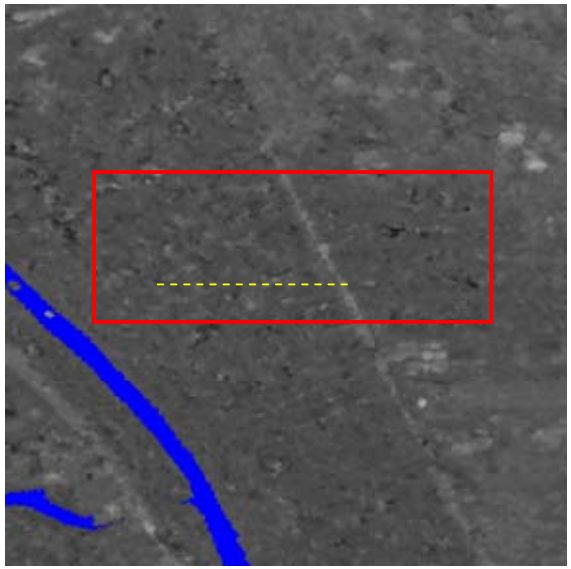
- ✓ Compared the results with DSM by aerial photo
- ✓ Averaged error= **-0.64m**, STDEV= **5.73m** / 1292184

▼

- ✓ Differences of observed year and date
- ✓ Large errors were identified due to edges of forest area
- ✓ Filtering and tuning of matching processing

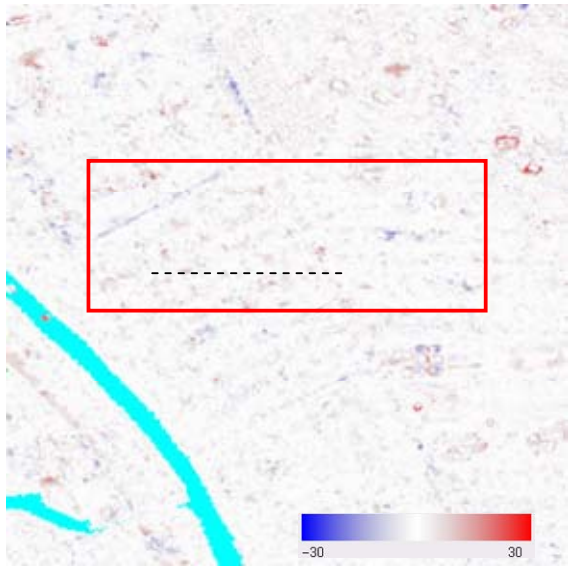
Validation – PRISM/DSM Test Generation

Paddy area in Saitama



PRISM-DSM

LiDAR-DSM



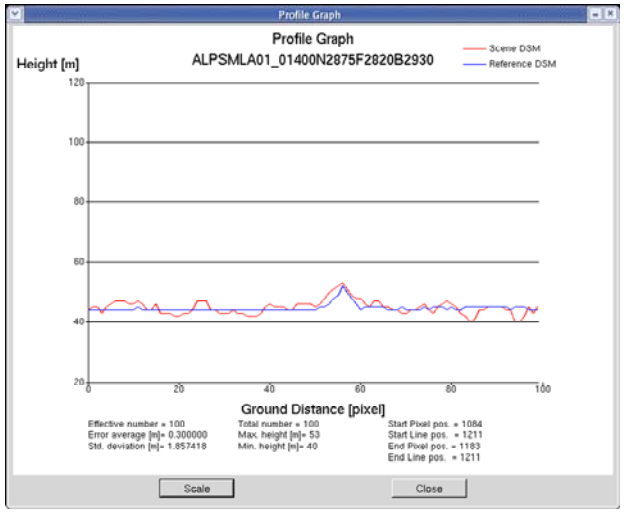
Difference (PRISM-LiDAR)

PRISM-Image(Nadir)

Area No. 1
Category Paddy

DSM Error Stats (Red Rectangular Area)

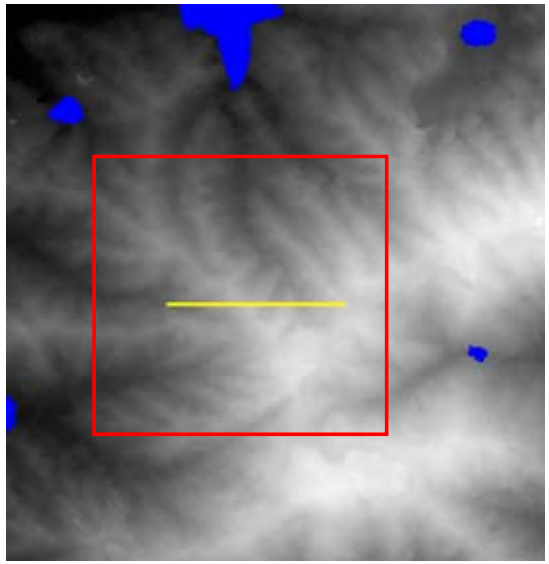
Points	17892
Bias[m]	0.48
SD[m]	2.73
RMS[m]	2.77
Max[m]	22
Min[m]	-16



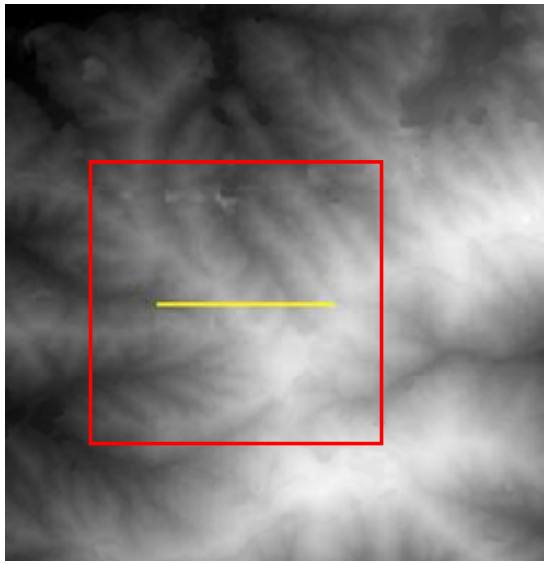
DSM profile (Yellow Line)

Validation – PRISM/DSM Test Generation

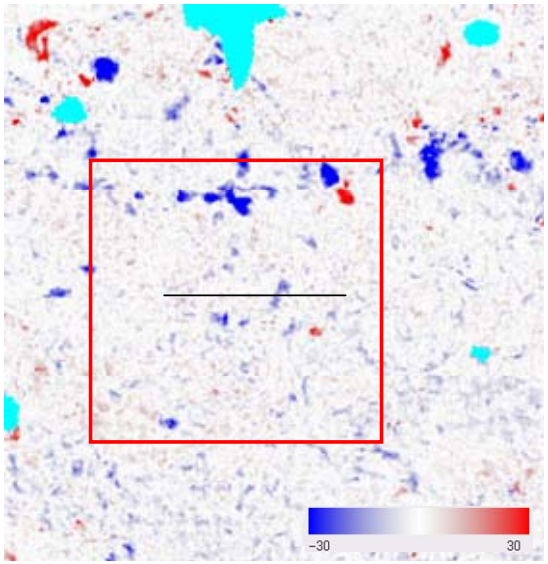
Dense trees area in steep terrain in Okazaki



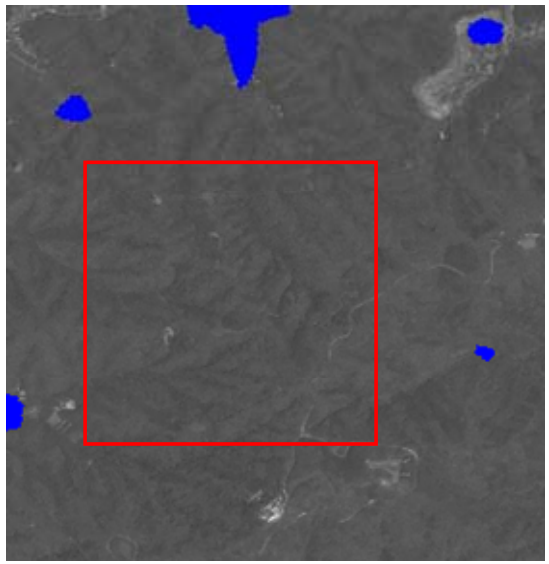
PRISM-DSM



AP-DSM



Difference (PRISM-AP)

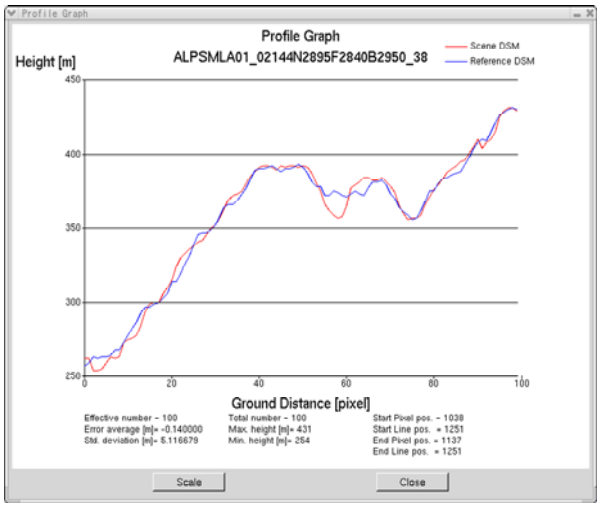


PRISM-Image(Nadir)

Area No. 11
Category dense trees

DSM Error Stats (Red Rectangular Area)

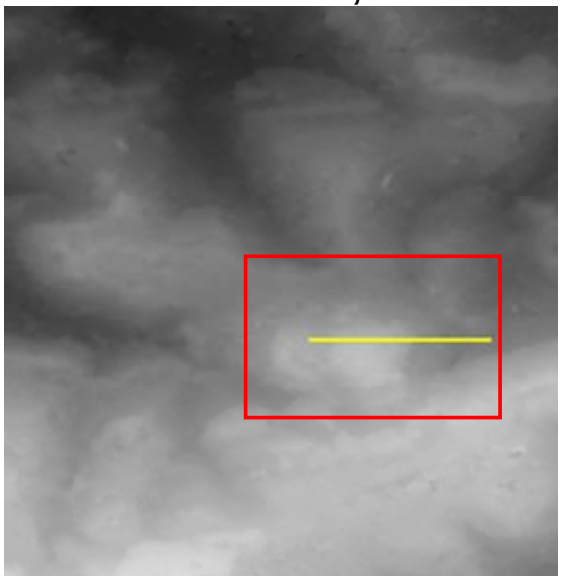
Points	31243
Bias[m]	-0.92
SD[m]	6.32
RMS[m]	6.38
Max[m]	48
Min[m]	-72



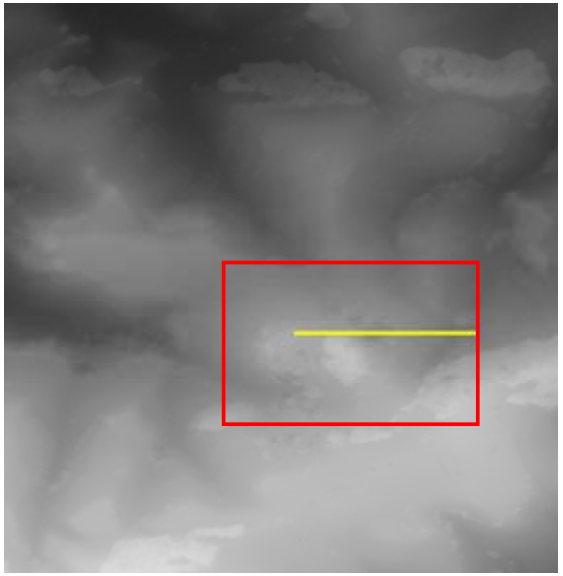
DSM profile (Yellow Line)

Validation – PRISM/DSM Test Generation

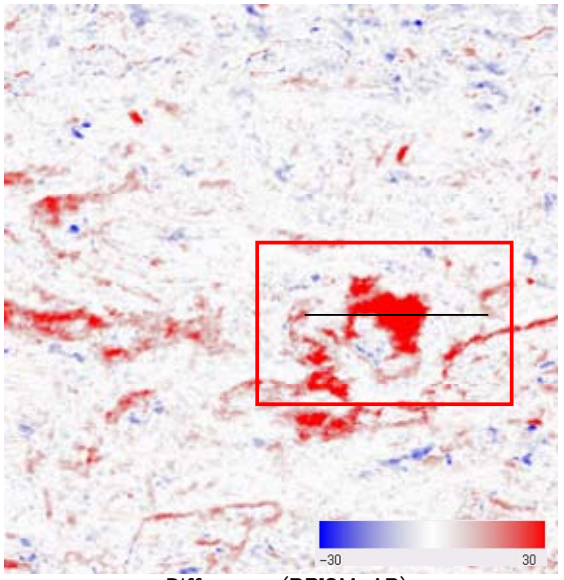
Dense tree area in SW, Thun



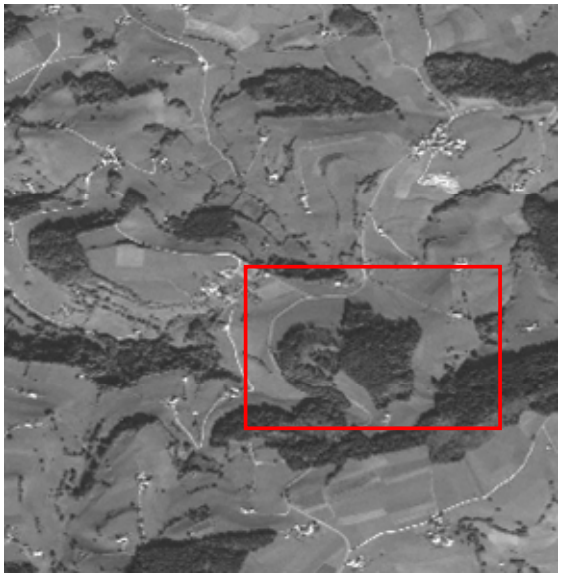
PRISM-DSM



AP-DSM



Difference (PRISM-AP)

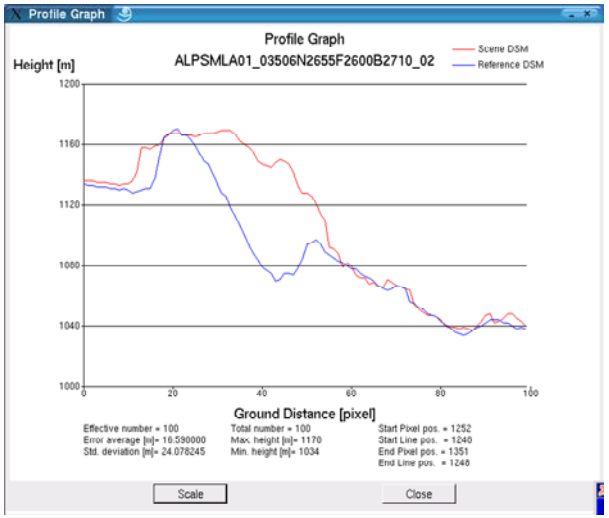


PRISM-Image(Nadir)

Area No. 22
Category dense trees

DSM Error Stats (Red Rectangular Area)

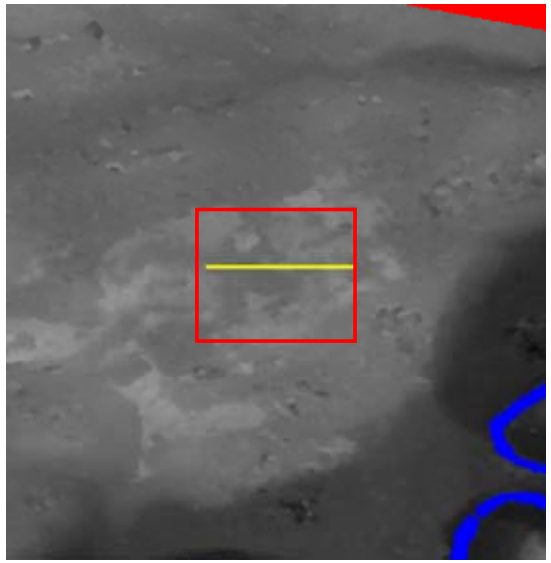
Points	6930
Bias[m]	9.65
SD[m]	14.80
RMS[m]	17.67
Max[m]	90
Min[m]	-19



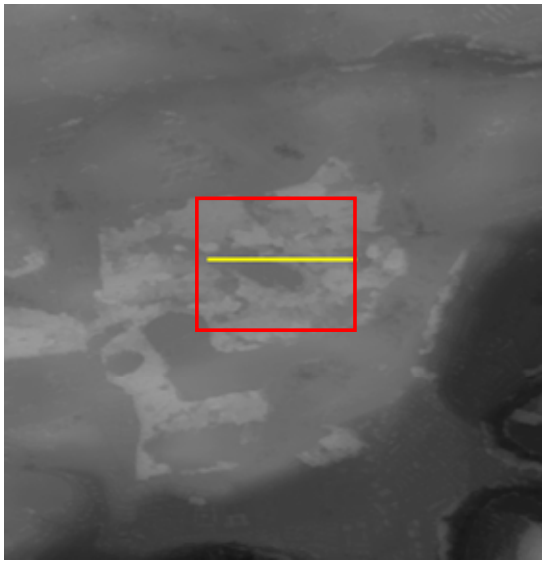
DSM profile (Yellow Line)

Validation – PRISM/DSM Test Generation

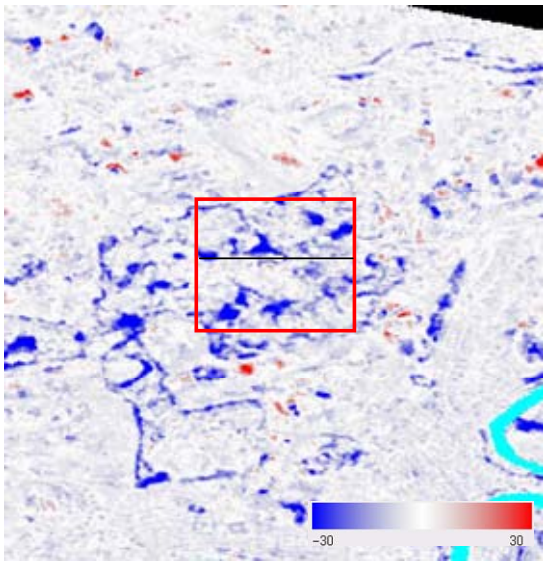
Sparse tree area in Bern, Thun



PRISM-DSM



AP-DSM



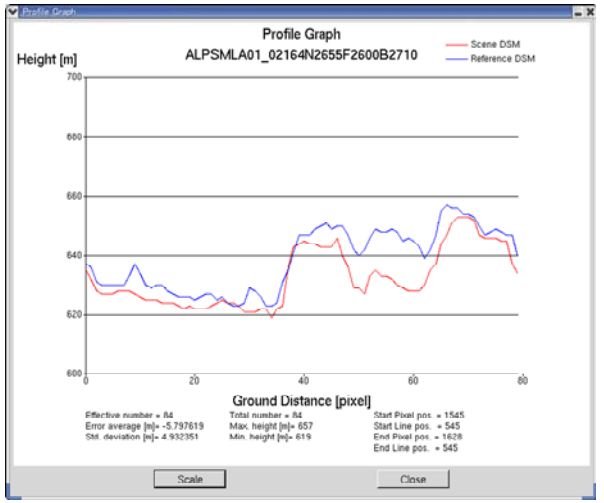
Difference (PRISM-AP)

PRISM-Image(Nadir)

Area No. 10
Category sparse trees

DSM Error Stats (Red Rectangular Area)

Points	6132
Bias[m]	-8.71
SD[m]	8.45
RMS[m]	12.13
Max[m]	17
Min[m]	-48



DSM profile (Yellow Line)

Conclusion

I introduced the results of Cal/Val of ALOS optical sensors, in particular,

1) Summary of calibration results as of March 2007,
   - Geometric calibrations of AVNIR-2 and PRISM,
   - Radiometric calibration of AVNIR-2 / correction of PRISM, and

2) PRISM/DSM validation.

As a proposal to contribute K&C, validation of PRISM/DSM over homogeneous forest areas to estimate tree height.

For more information related to research, application and science,

- **EORC/ALOS** : New images, data acquisition plan and technical documents
  http://www.eorc.jaxa.jp/ALOS/index.htm

For data search and order,

- **EOC/ALOS User Interface Gateway (AUIG)**
  https://auig.eoc.jaxa.jp/auigs/en/top/index.html
- **RESTEC/CROSS** : Data search, data order for Asian Node
  https://cross.restec.or.jp/cross/CfcLogin.do?locale=en