7th Science Team Meeting, ALOS Kyoto & Carbon Initiative, TKSC

January 16-19, 2007

Results of Initial Calibration and Validation of PRISM and AVNIR-2

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AVNIR-2 image over Ishigaki, and Iriomote Islands

Outlines

- ***Result of Initial Cal/Val***
  - Overview of initial Cal/Val phase
  - First images acquisitions and analysis
  - Results of Initial Cal/Val
- ***Cal/Val Plan and Evaluation***
  - Geometric calibration: relative and absolute
  - Radiometric calibration: relative and absolute
  - Validations of PRISM/DSM and ortho-rectified images
- ***Future Work until March 2007***

陸域観測技術衛星「だいち」
Advanced Land Observing Satellite (ALOS)

- **History**
  - ✓ **Jan. 24, 2006: ALOS was launched**
  - ✓ Jan. 28, 2006: Critical Phase completed
    - Successful deployments and normal control
  - ✓ **Feb. 14-17, 2006: First images acquisition**
  - ✓ **May 15, 2006: Initial Check-out Phase completed**
  - ✓ **Oct. 23, 2006: Initial Cal/Val Phase completed / Normal Observation Phase started**
    - All bus & mission systems operational and in good conditions
- **Orbit and Attitude Determinations**
  - ✓ Precise Orbit Determination by GUTS: From March 27th, 2006
    - Very well, about **10cm orbit determined**
  - ✓ Large geometric error (about 7-8km in AT direction)
    - **1 second time error** > Onboard firmware updated on Sep. 22
  - ✓ Onboard Precise Attitude Determination (ATT3)
    - 0.1 sec time error > Corrected on Sep. 29, and now working well
  - ✓ Off-line Precise Position and Geolocation Determination System (PPDS)
    - Started on July 9 > **under evaluation**
- **PRISM & AVNIR-2**
  - ✓ PRISM: Brighter noise (Blooming), and Block noise by JPEG compression
  - ✓ Absolute geometric accuracies are not sufficient
  - ✓ AVNIR-2's mirror drive degrades pointing stability of PRISM
- **Mission Data (May 15 - Sep. 30)**
  - ✓ PRISM: 180,000 scenes; AVNIR-2: 70,000 scenes; and PALSAR: 150,000 scenes

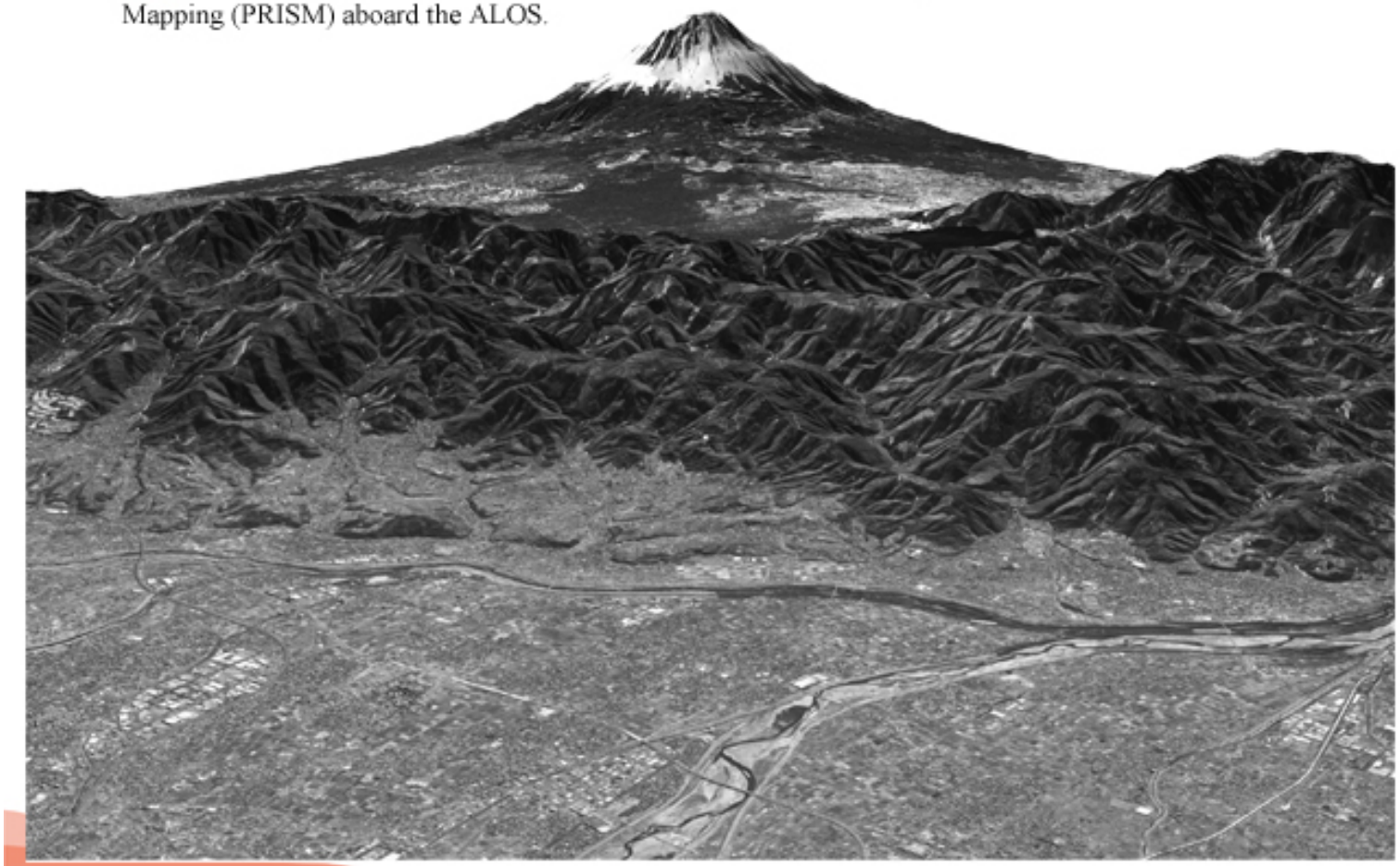
ALOS

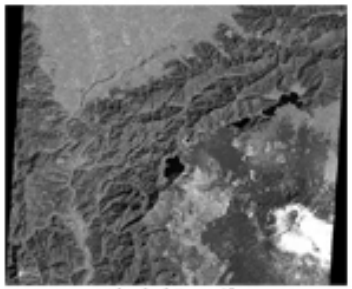
Advanced Land Observing Satellite

PRISM

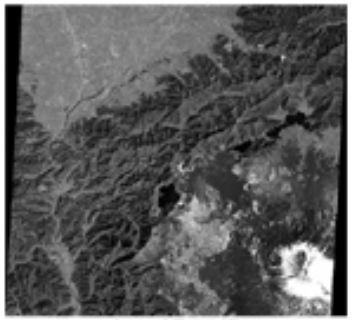
陸域観測技術衛星「だいち」(ALOS)パンクロマチック立体視センサ(PRISM)が観測した富士山

View of Mt. Fuji, Japan observed by the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) aboard the ALOS.

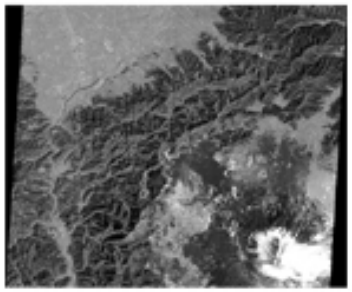




後方視画像



直下視画像



前方視画像

Observation date: 10:30am, February 14th, 2006 (Tue)
Data dawn/link to EOC: 11:00pm, February 14th, 2006

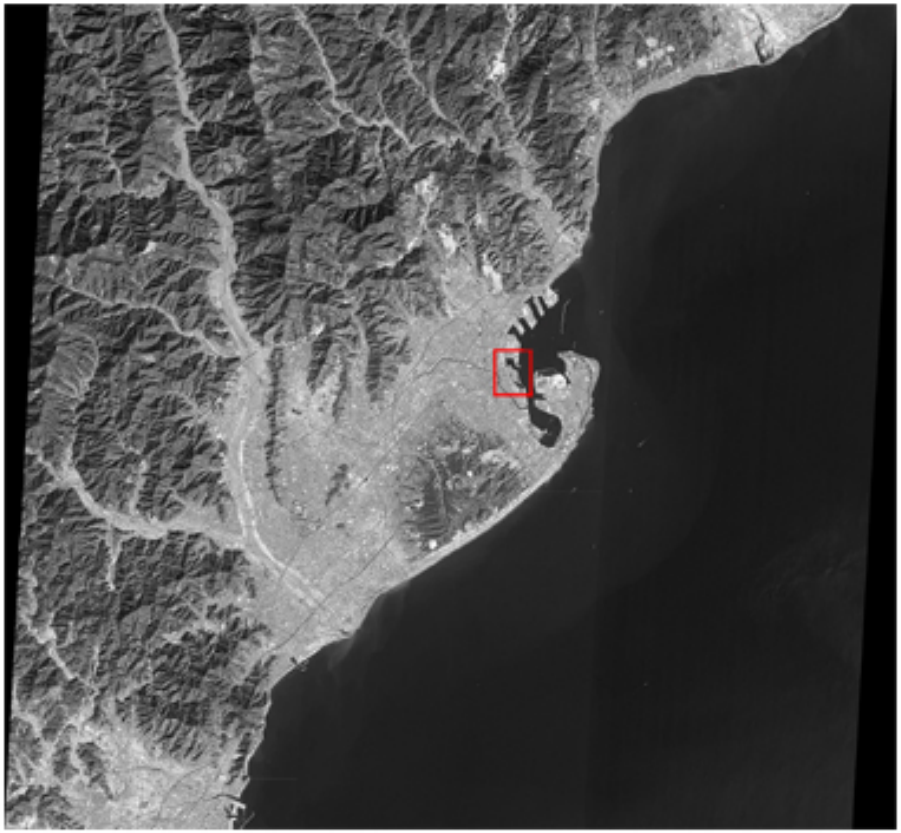
EORC Earth Observation Research Center

ALOS
Advanced Land Observing Satellite

PRISM

陸域観測技術衛星「だいち」(ALOS)パンクロマチック立体視センサ(PRISM)が観測した静岡県清水港

View of Shimizu Port, Japan observed by the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) aboard the ALOS.



http://www.eorc.jaxa.jp/ALOS/

Observation date: 10:30am, February 14th, 2006 (Tue)
Data dawn/link to EOC: 11:00pm, February 14th, 2006

ALOS
Advanced Land Observing Satellite
AVNIR-2

陸域観測技術衛星「だいち」(ALOS)高性能可視近赤外放射計2型(AVNIR-2)が観測した種子島

View of Tanegashima Island, Kagoshima Pref., Japan observed by the Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) aboard ALOS

①大型ロケット発射場
②種子島灯台
③総合指令棟
④竹崎展望台

2006年2月17日観測 ©JAXA

http://www.eorc.jaxa.jp/ALOS/

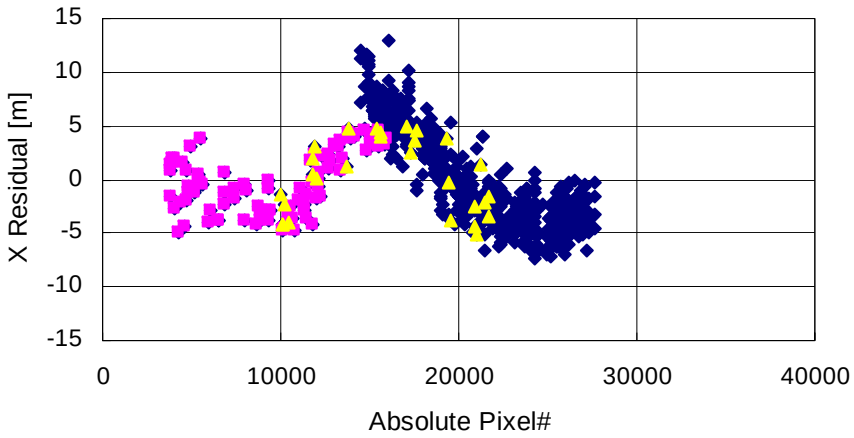
Observation and D/L: 10:50am, February 17th, 2006 (Fri)

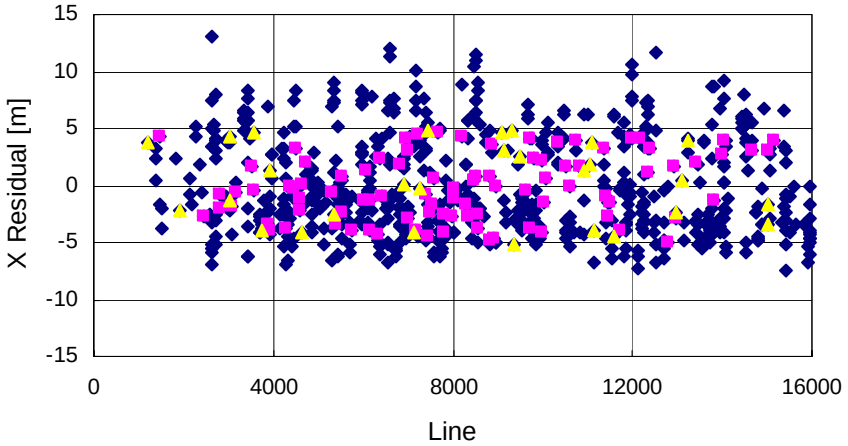
Results of Initial Cal/Val

- ✓ **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

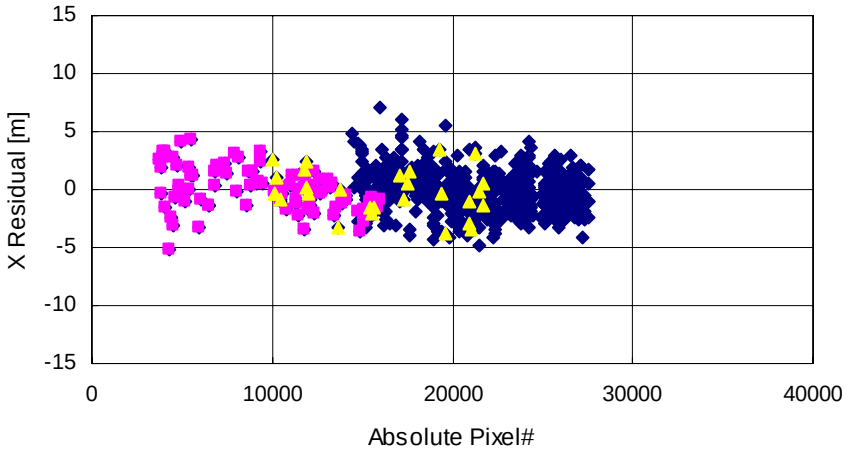
Standard Product	Target Accuracy	Results as of Oct. 23, 2006
PRISM 1B2	Radiometry Relative Accuracy 5% (1σ) Absolute Accuracy 10% (1σ) Geometry Absolute Accuracy (without GCP) 6.0m (3σ) for Nadir-looking radiometer with the Precise Pointing Geolocation Determination System (PPDS)	Radiometry Relative 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 →**200m** Relative Accuracy (1σ) 14m / 6m

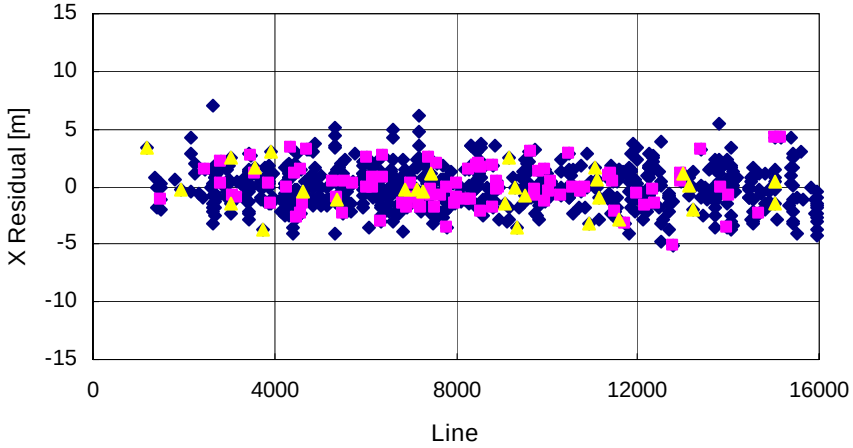
Geometric Cal #1 – PRISM CCD Alignments





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



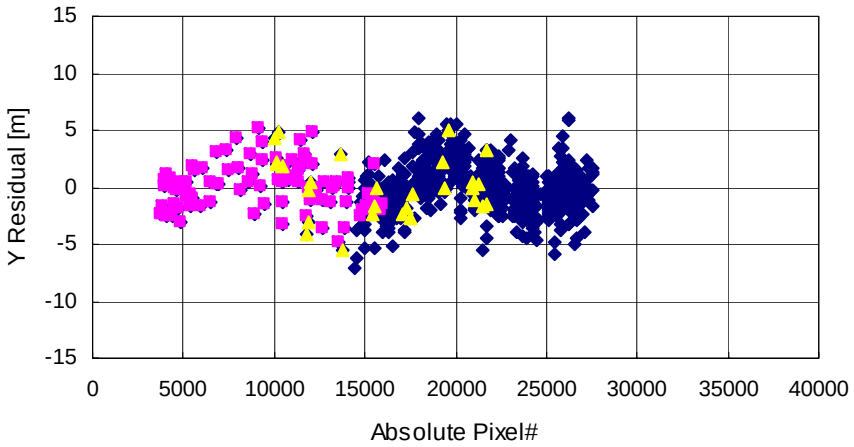


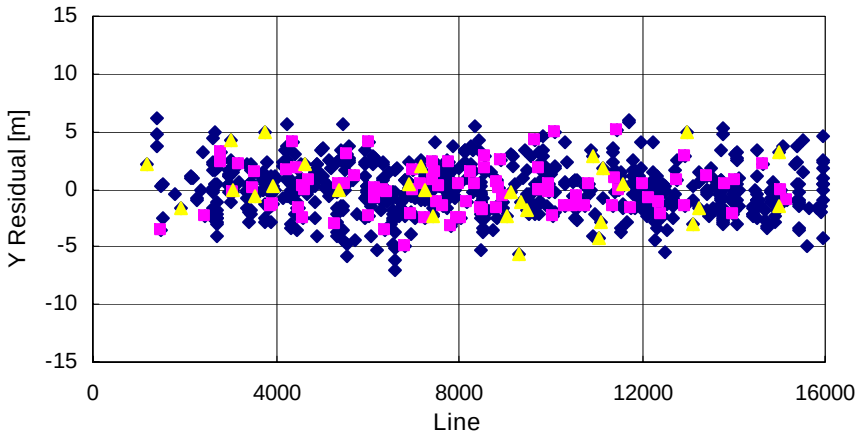
After correction of relative CCD alignments (orientation residual in X direction).

PRISM Relative CCD alignments estimation:

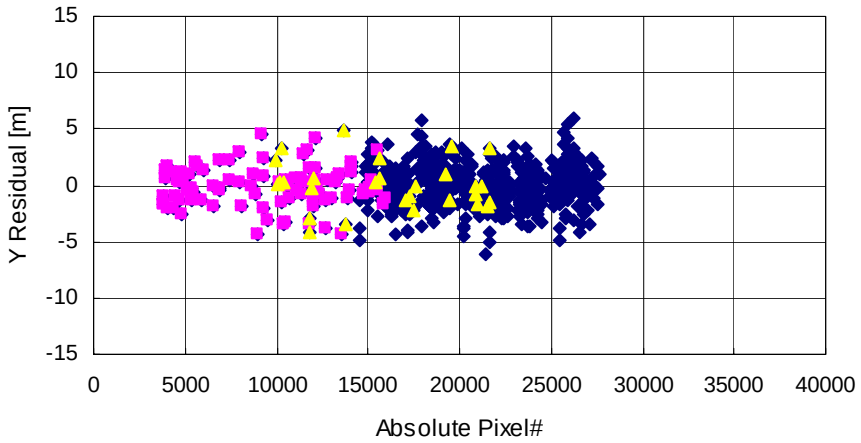
- ✓ External orientation technique with 943GCPs and 15 stereo pair images
- ✓ Almost of residuals of orientation are within +/-5m after correction
- ✓ Unevaluated CCDs have been observed on Sep. 20 and 23

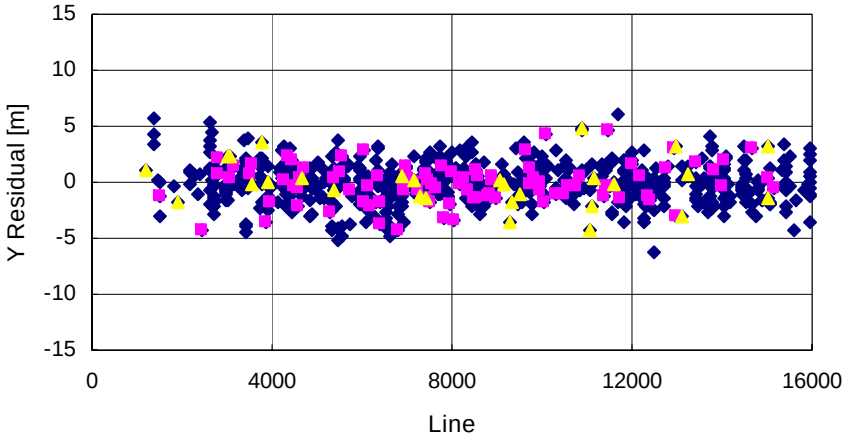
Geometric Cal #1 – PRISM CCD Alignments





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



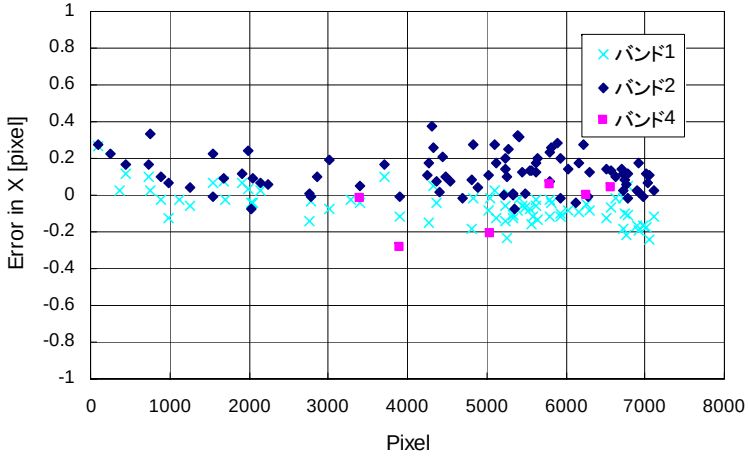


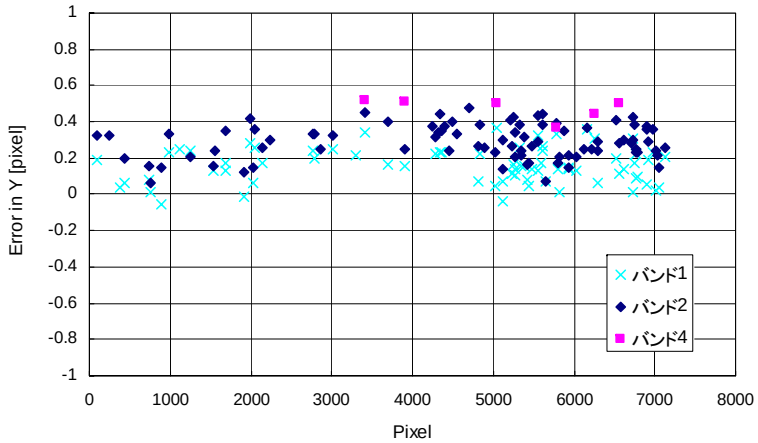
After correction of relative CCD alignments (orientation residual in Y direction).

PRISM relative CCD alignments estimation and correction:

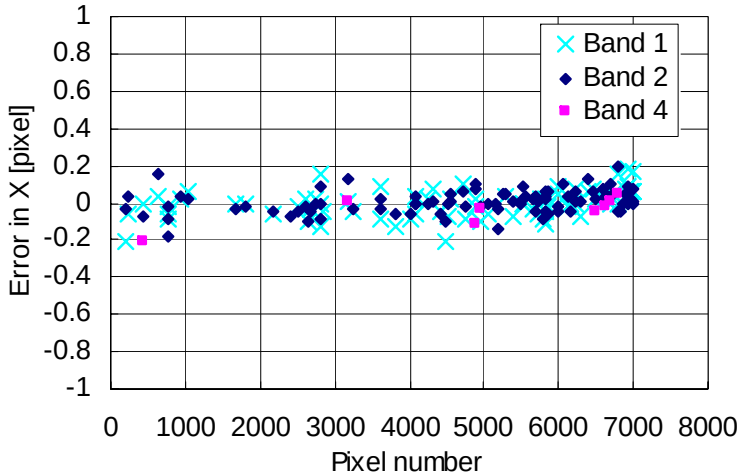
- ✓ External orientation technique with 943GCPs and 15 stereo pair images
- ✓ Almost of residuals of orientation are within +/-5m after correction
- ✓ Unevaluated CCDs have been observed on Sep. 20 and 23

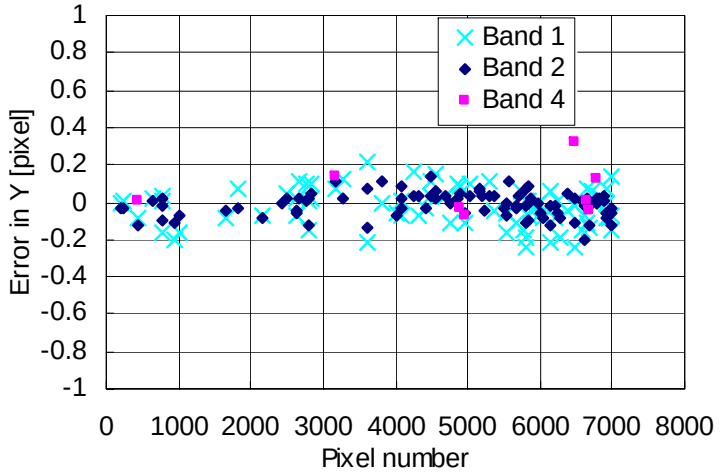
Geometric Cal #2 – AVNIR-2 Band-to-Band Registration





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





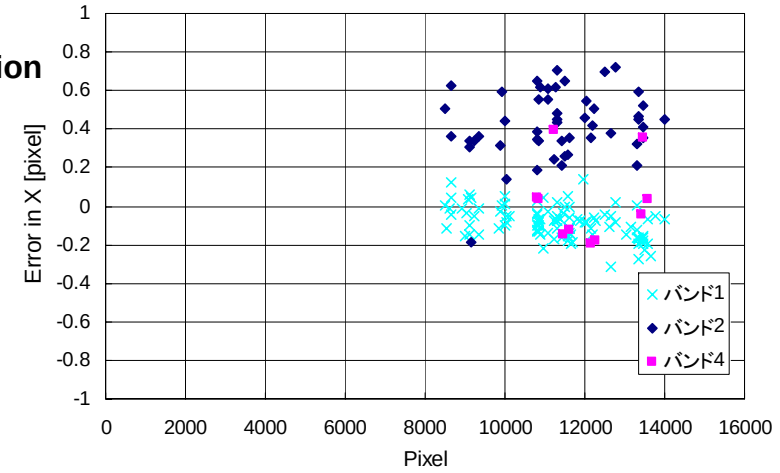
After correction of the registration (as of Sep. 26).

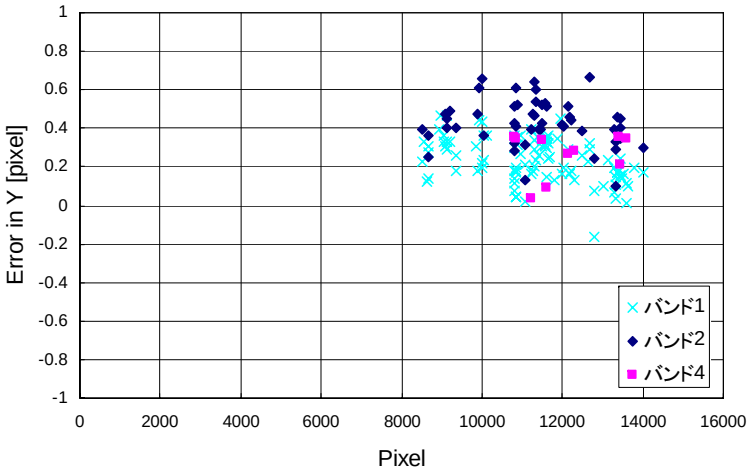
AVNIR-2 Band-to-Band registration estimation and correction:

- ✓ 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

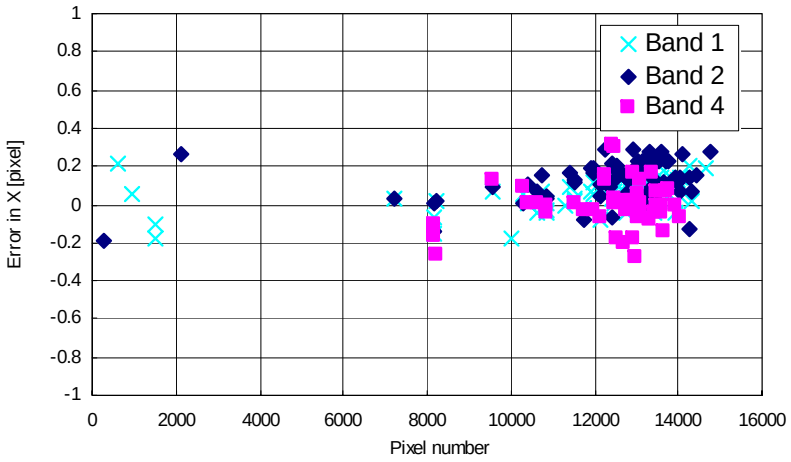
Geometric Cal #2 – AVNIR-2 Band-to-Band Registration

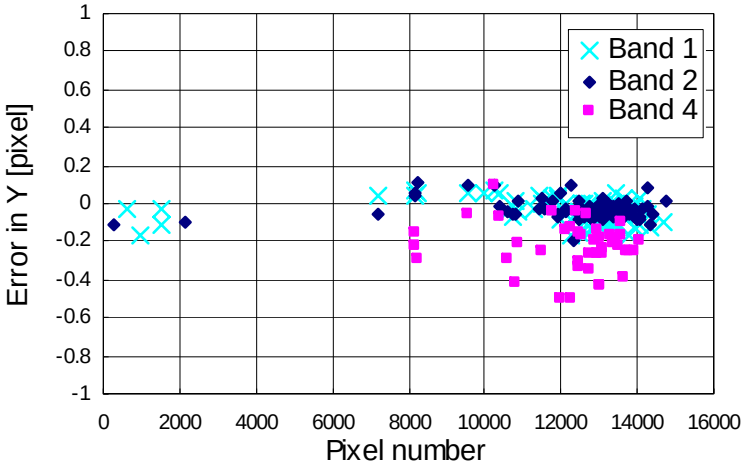
Before correction
Tomakomai
-41.5deg.
(May 4, 2006)





After correction





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

Geometric Cal #3 – Geometric Correction Accuracy

✓ External orientation using L1B1, orbit and attitude information
> Initial orientation residual is corresponds to geometric accuracy of L1B2 except for mapping error (resampling).

✓ It is difficult to remove the terrain and height effects of GCPs in L1B2
> Ortho-rectified image should be used to evaluate the geometric accuracy of products

Sensor	Sample number	RMSE in X (m)	RMSE in Y (m)	Scene-averaged STDEV of error in X (m)	Scene-averaged STDEV of error in Y (m)
PRISM Forward	5 scene, 83 GCP	13	64	4	6
Nadir	6 scene, 292 GCP	17	34		
Backward	5 scene, 83 GCPs	32	32		
AVNIR-2	7 scene, 211 GCP includs -41.5～+41.5 deg.	520	370	14	6

Results of Geometric accuracy evaluation (as of Oct. 23, 2006)

✓ Relative accuracy: PRISM 4m (X, 1σ), 6m (Y, 1σ)
AVNIR-2 14m (X, 1σ), 6m (Y, 1σ)

✓ Absolute accuracy: PRISM > depends on pointing determination
AVNIR-2 520m > 200m (as of Dec. 7, 2006)

→ If one GCP/scene available, above relative accuracies are achieved.

Radiometric Cal #1- AVNIR-2 Relative Accuracy

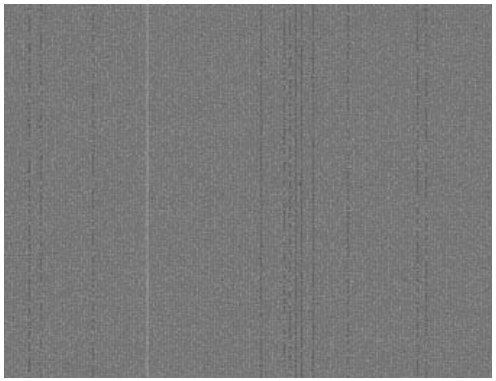
DN differences between odd and even detectors into dark time

	Band 1		Band 2		Band 3		Band 4	
	DN	E-O	DN	E-O	DN	E-O	DN	E-O
Gain 1	0.424	0.282	0.418	-0.385	0.427	-0.533	0.401	-0.549
Gain 2	0.345	0.260	0.345	-0.402	0.382	-0.584	0.314	-0.382
Gain 3	0.200	0.154	0.251	-0.502	0.283	-0.587	0.231	-0.372
Gain 4	0.204	0.004	0.195	-0.468	0.230	-0.340	0.187	-0.322

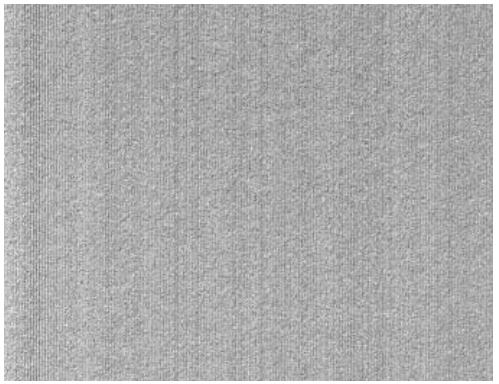
DN differences between odd and even detectors into daytime

	Band 1			Band 2			Band 3			Band 4		
	Input	DN	E-O	Input	DN	E-O	Input	DN	E-O	Input	DN	E-O
ゲイン1		-			-			-			-	
ゲイン2		-			-			-			-	
ゲイン3	170	0.122	0.475	155	0.092	0.359	148	0.098	0.357	132	0.109	0.343
ゲイン4	165	0.095	0.714	153	0.084	0.174	147	0.090	0.351	133	0.101	0.056

- ✓ Pixel-to-pixel radiometric variation (difference between odd and even, stripe) is averaged **less than one DN** in all bands and all gains.
- ✓ Time trend have to monitor in the future

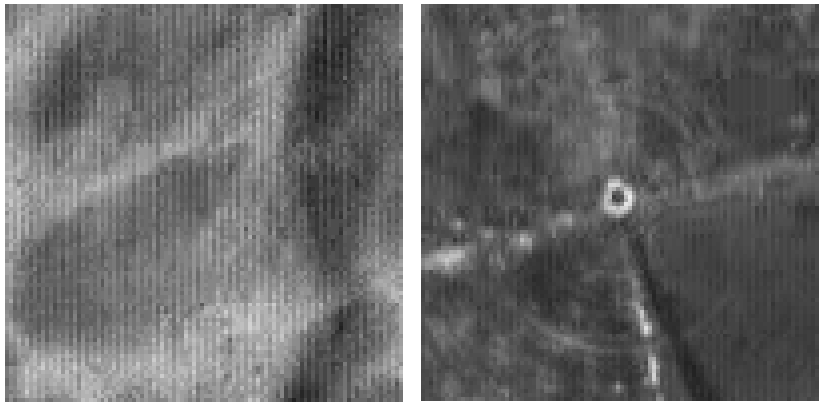


AVNIR-2 20060623 021916050
Band 1, Gain 3, nighttime obs.



AVNIR-2 20060917 034512030
Band 1, Gain 3, daytime obs. over Greenland

Radiometric Cal #2 – PRISM Relative Accuracy



Examples of stripes.
Left: Sahara 060427-B/CCD#5, Right: Ely 060813-B/CCD#4.

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.

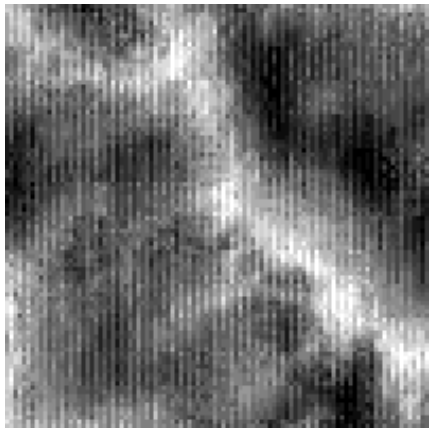
1) Stripes noises depends on
✓ Stability of "Optical Black" (OB), which is used in radiometric sensor model as the reference, but one OB in each 22 seconds
✓ Evaluation of characteristics of stripes
- DN average between odd/even detectors
- FFT

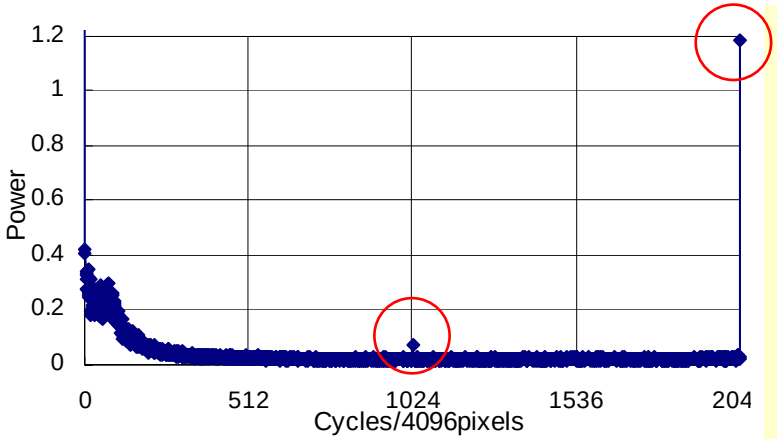
✓ Difference between odd/even detectors is **1 to 3 DNs**
✓ **Back- and Forward-images are not satisfied**

＊( ) is include dummy pixels.

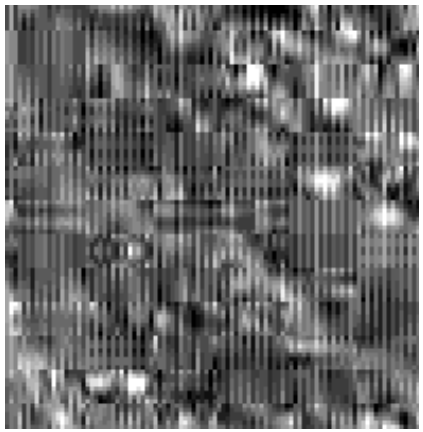
PRISM Scene ID	CCD#			CCD#+1			CCD#+2			CCD#+4		
Ave. DN / Diff. DN (E-O)	Odd	Even	E-O	Odd	Even	E-O	Odd	Even	E-O	Odd	Even	E-O
Sahara 060427 ALPSMB013623255-01B1 (#=3)	(825.08)	(826.47)	+1.39	138.08	137.54	-0.54	137.84	135.46	-2.37	(174.68)	(174.0)	-0.68
Sahara 060427 ALPSMN013623200-01B1 (#=3)	(595.44)	(595.99)	+0.55	134.98	133.78	-1.20	135.77	136.76	+0.99	(215.35)	(214.56)	-0.79
Sahara 060427 ALPSMF013623145-01B1 (#=5)	(142.43)	(142.97)	+0.54	134.87	134.76	-0.11	138.26	136.54	-1.73	(320.36)	(321.79)	+1.43
Ely 060813 ALPSMB029422885-01B1 (#=3)	(805.11)	(807.59)	+2.48	116.80	114.33	-2.47	87.42	86.06	-1.37	(99.62)	(97.44)	-2.18
Ely 060813 ALPSMN029422830-01B1 (#=3)	(569.07)	(569.02)	-0.05	99.59	99.44	-1.15	75.11	74.96	-0.15	(111.11)	(111.97)	+0.86
Ely 060813 ALPSMF029422775-01B1 (#=5)	(99.64)	(102.29)	+2.65	80.82	80.72	-0.10	55.71	57.81	+2.09	(168.55)	(166.78)	-1.77

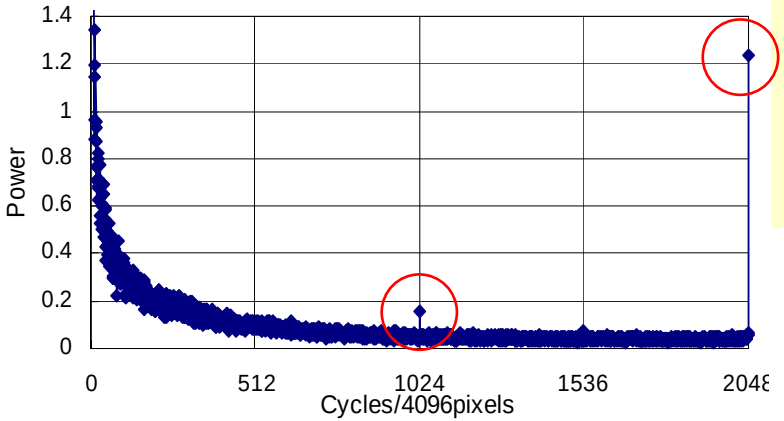
Radiometric Cal #2 – PRISM Relative Accuracy





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.

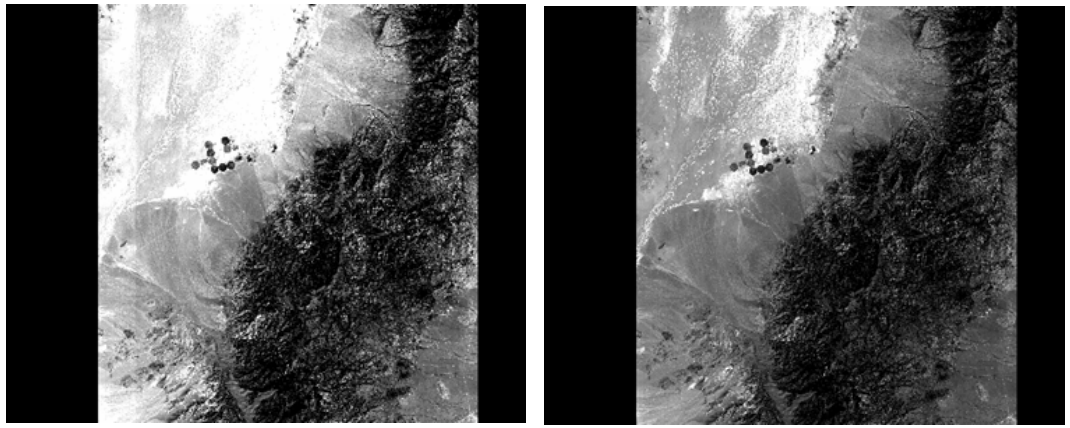
This is related to image quality *i.e.*,
1) Stripe noises are appeared sometime, and
2) Block noises due to JPEG compression are also appeared

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**

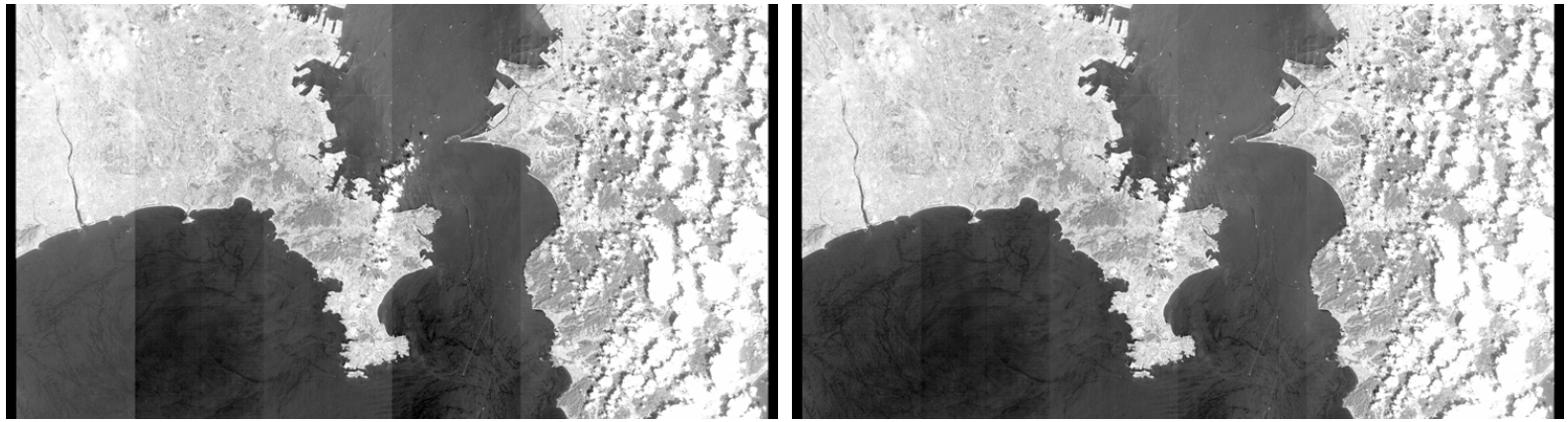
Radiometric Cal #3 – PRISM Sensitivity Variation between CCDs



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 pixel-to-pixel variation

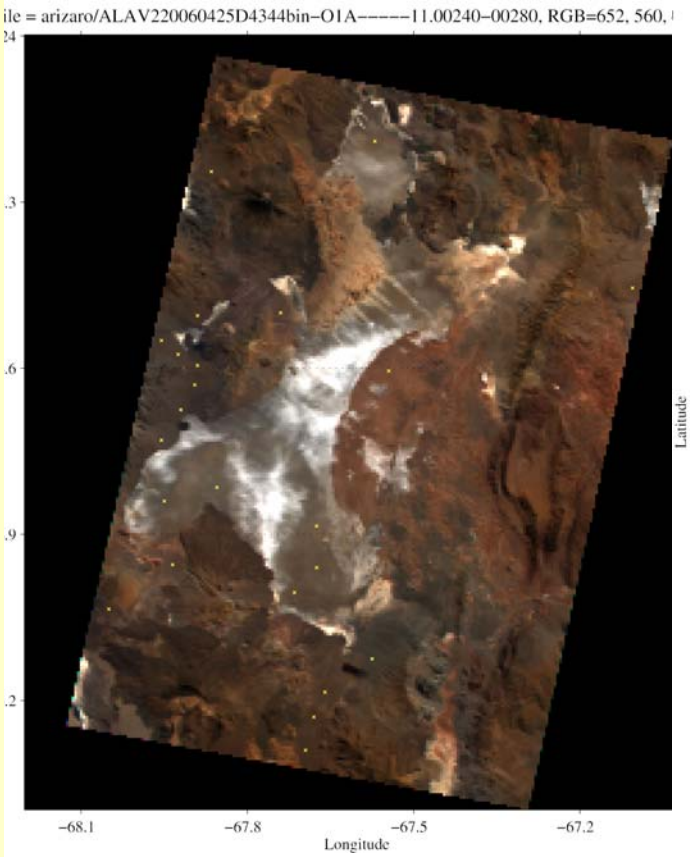


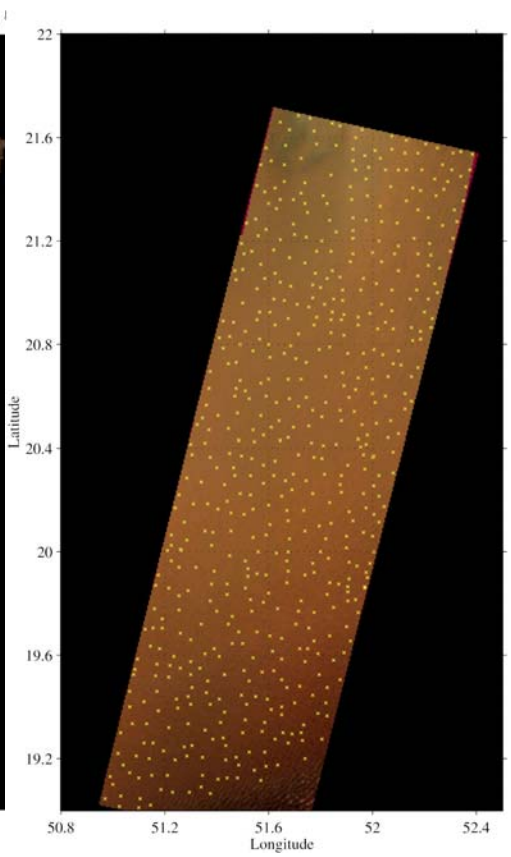
Correction of sensitivity variation between CCDs.
1B1, ALPSMW031652890-O1B1___W, left: before correction, right: after correction

Radiometric Cal #4 – 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 reflectance at TOA over stable surfaces
- ✓Aqua/Terra MODIS 500m resolution
- ✓AVNIR-2: 500m average, variation <3%
  - 06/03/19 Sahara desert
  - 06/04/25 Arizaro, Argentine
  - 06/05/01 Rab Khali desert
  - 06/05/21 Rab Khali desert
  - 06/05/23 Rab Khali desert
  - 06/05/24 WhiteSands, US
  - 06/08/21 Salar de Uyuni

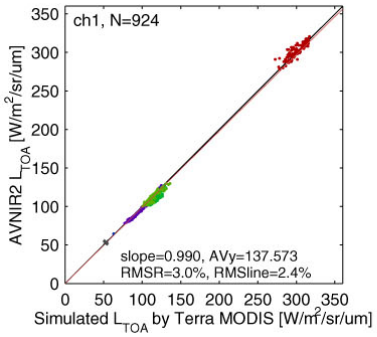


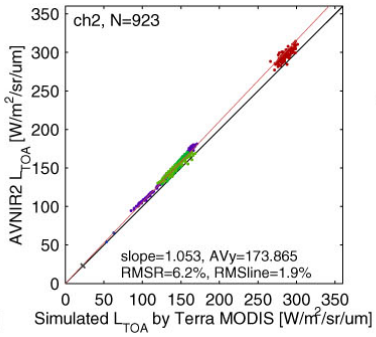


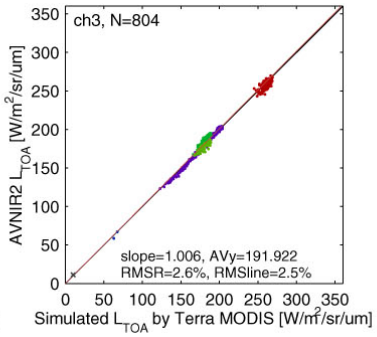
06/04/25 Arizaro, Argentine. **06/05/23 Rab Khali desert.**

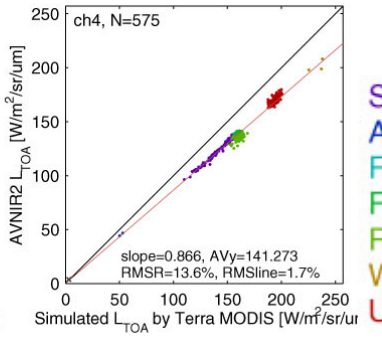
Yellow dots shows evaluation points (variation<3%).

Radiometric Cal #4 – Cross Cal with MODIS

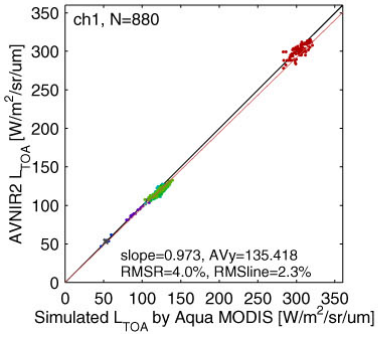


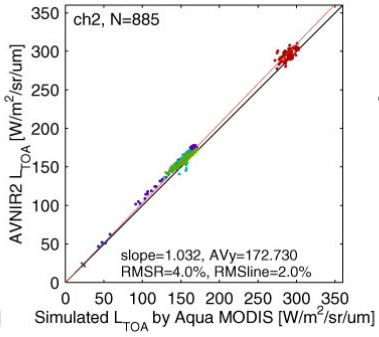


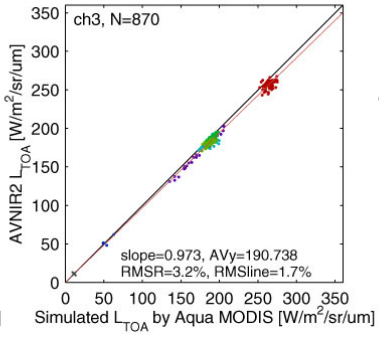


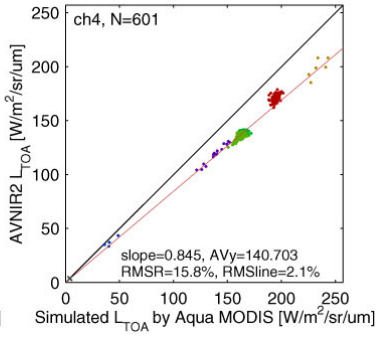


Sahara 20060319
Arizaro 20060425
RaKhali 20060501
RaKhali 20060521
RaKhali 20060523
Wsands 20060524
Uyuni 20060821







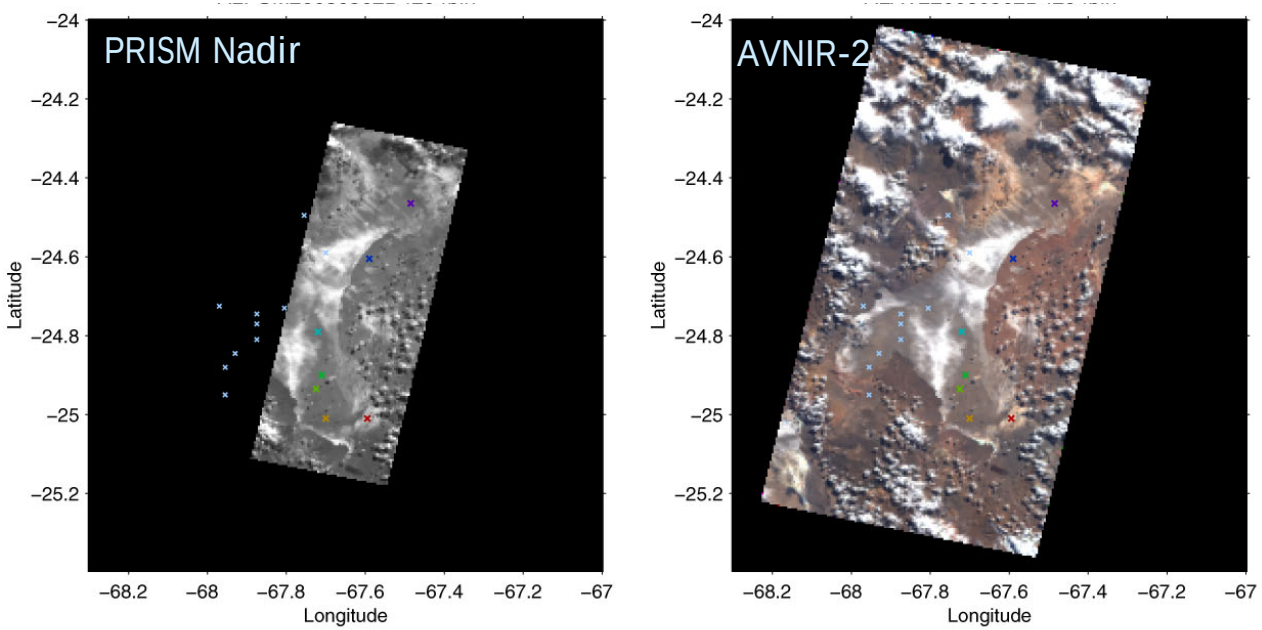


AVNIR-2	TERRA/MODIS				AQUA/MODIS			
Band	Number	Slope	Ave.	RMSR	Number	Slope	Ave.	RMSR
1	924	0.990	137.573	3.0 %	880	0.973	135.418	4.0 %
2	923	1.053	173.865	6.2 %	885	1.032	172.730	4.0 %
3	804	1.006	191.922	2.6 %	870	0.973	190.738	3.2 %
4	575	0.866	141.273	13.6 %	601	0.845	140.703	15.8 %

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

Radiometric Cal #5 – Cross Cal with AVNIR-2

Arizaro 2006/05/02



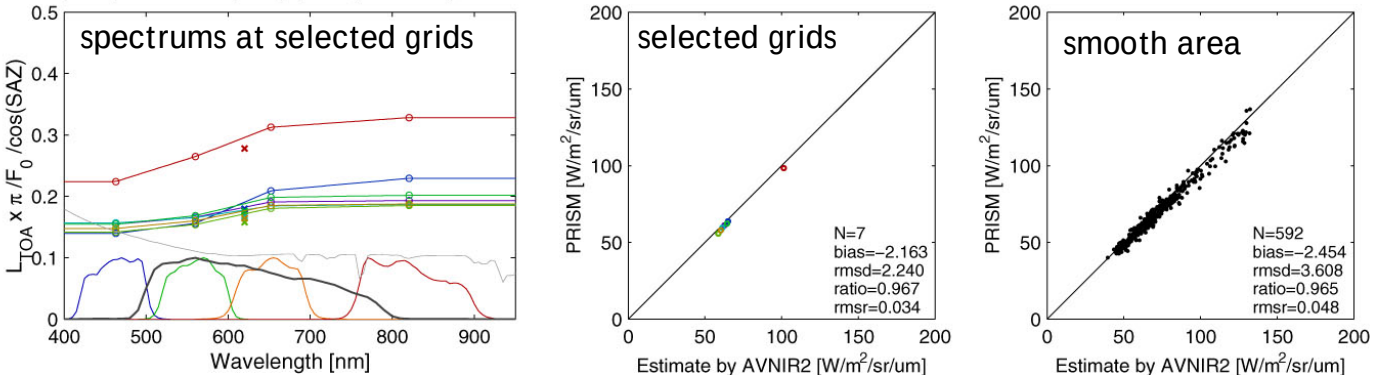
Absolute radiometric calibration of PRISM was done by cross Cal with calibrated AVNIR-2.

left image:
Sample area and points

Geometric condition:
SAZ: around Nadir
SOZ: 47deg
REA: 114deg

Shift
PRISM L:-8km P:+1km
AVNIR2 L:-7km P:0km

psm0=0.086*avn(1)+0.378*avn(2)+0.409*avn(3)+0.127*avn(4)
psm=(0.979+0.040*psm0) *psm0 (Alt=3000m)



- ✓ **Both values are agree well**
- ✓ Time dependence have to monitor in the future.

Radiometric Cal – Summary

Results of Radiometric accuracy evaluation (as of Oct. 23, 2006)

✓ Absolute accuracy: AVNIR-2

- Band 1-3 less than 6.2 % (RMSE)
- Band 4 less than 15.8% (RMSE) > Cross cal with high resolution sensors

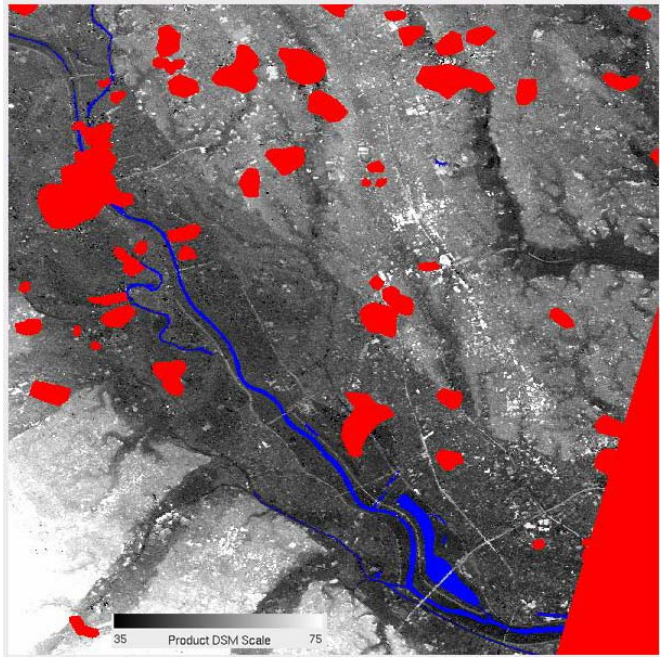
PRISM is 6.2% (similar with AVNIR-2)

→ Time trend have to monitor in the future (sensitivity degradation, characteristic change etc.)

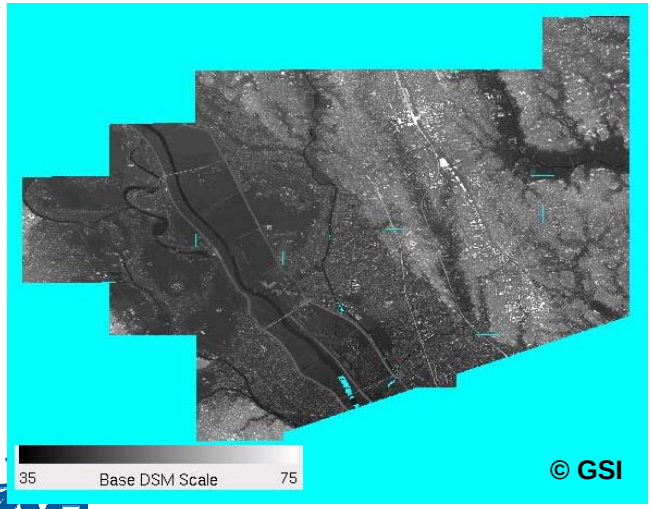
✓ Relative accuracy: AVNIR-2 less than 1DN (0.4 %)

PRISM 3DN (1.2%) > **Post processing should be added**

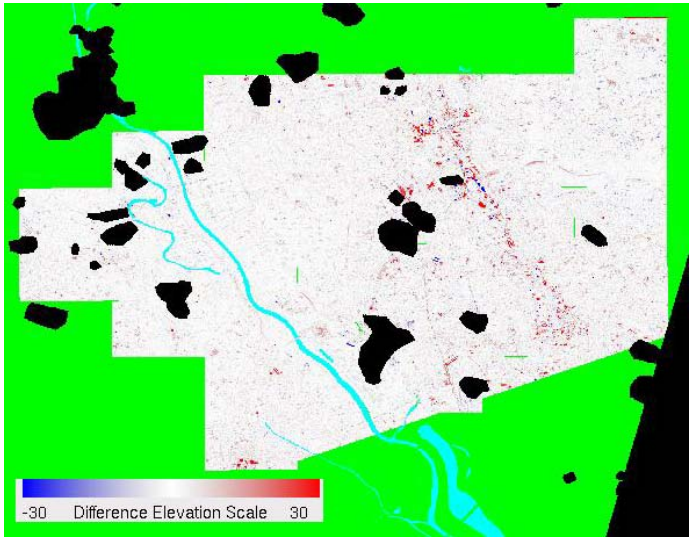
Validation #1 – PRISM/DSM Test Generation



Example of generated DSM by PRISM Triplet (OB1).



Reference Lidar/DSM by GSI.



Height differences between Lidar/DSM – PRISM/DSM.

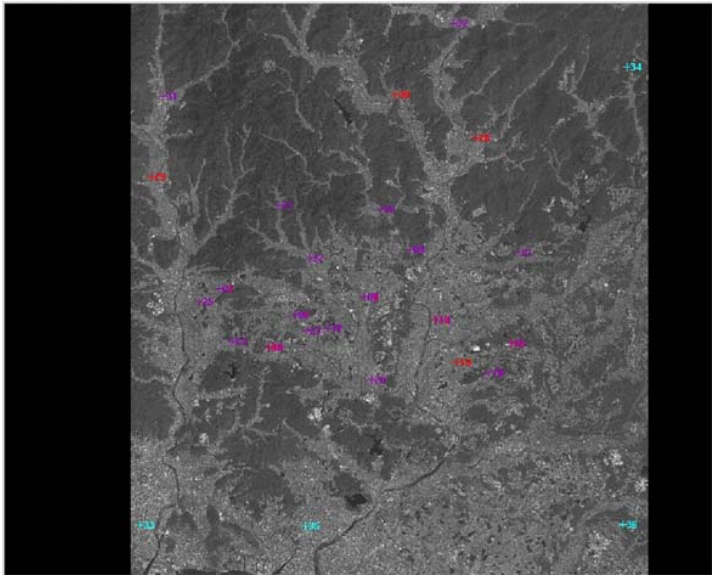
Test generation of PRISM/DSM using stereo pair image acquired in Saitama Pref. Japan on April 30 ("Cal/Val Dataset").

- ✓ Corrected CCD alignment images
- ✓ Compared the results with Lidar/DSM by GSI
- ✓ Averaged error= **0.94m**, STDEV= **4.85m**

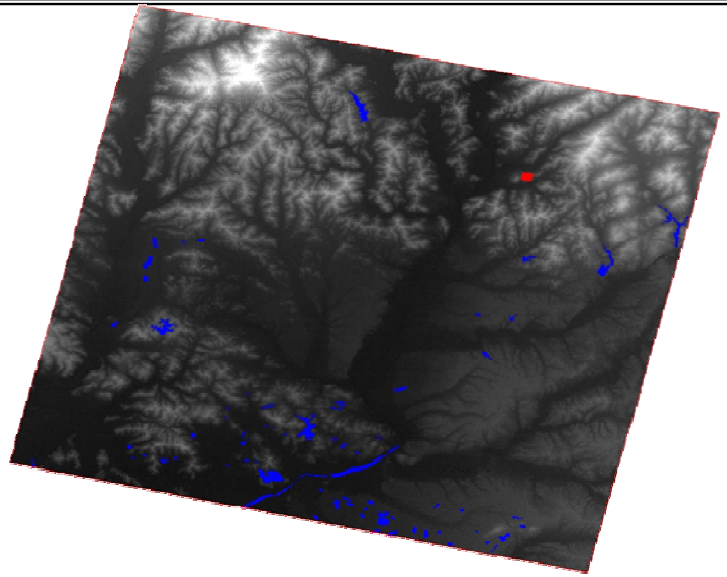
▼

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

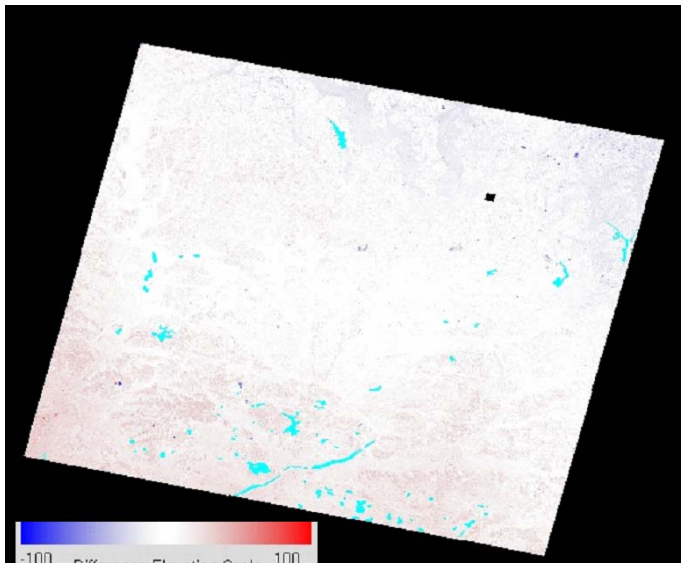
Validation #2 – PRSIM/DSM Test Generation



PRISM Triplet (OB1) over Hyogo Pref. on Apr. 28, 2006.



Example of generated DSM by PRISM Triplet (OB1).



Height differences between GSI 50m/DEM – PRISM/DSM.

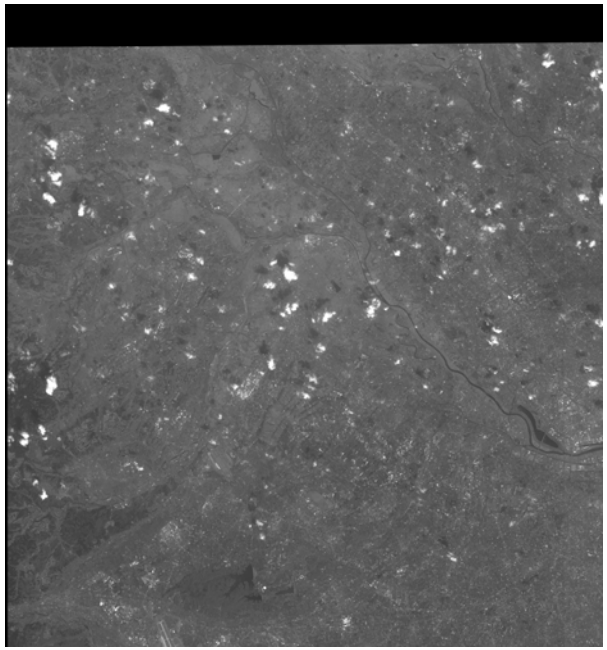
Test generation of PRISM/DSM using 17 pair images acquired in the world.

- ✓ External orientation with GCPs
- ✓ Compared the results with GSI 50m-mesh DEM (Japan), SRTM-DEM, and existing DEM.
- ✓ Averaged error= 13.6m, averaged STDEV= **30.9m**

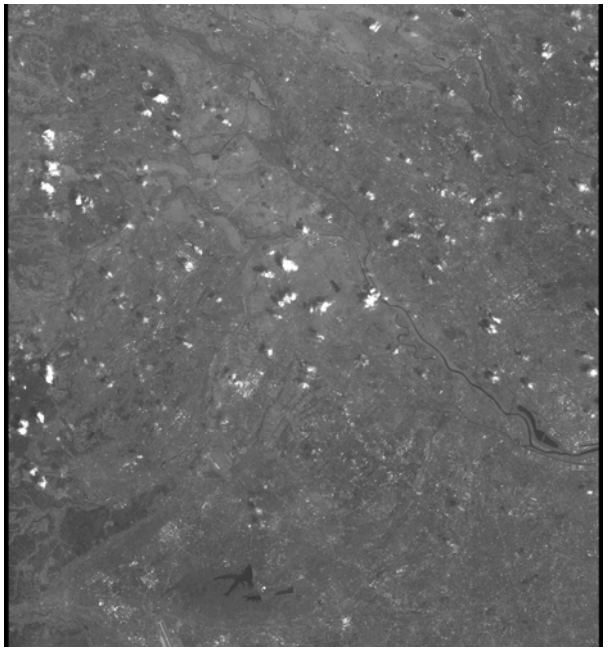
▼

- ✓ Reference DEM is coarse (1:25,000 or more)
- ✓ Differences between DEM – DSM
- ✓ Accuracies of some GCPs were not satisfied

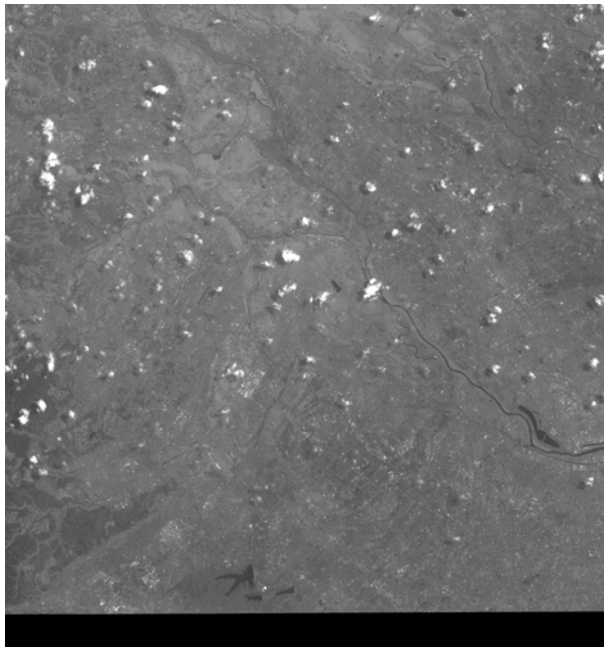
Validation #3 – PRISM Ortho-rectified Image



Ortho-rectified image of Forward.



Ortho-rectified image of Nadir-image.
ALPSMN014002875, “Saitama Dataset”.



Ortho-rectified image of Backward.

ALPSM01400	Number of GCP	Location error (pixel)*					
		Average		STDEV		RMSE	
		Pixel	Line	Pixel	Line	Pixel	Line
Forward	211	−0.377	−0.243	0.509	0.426	0.634	0.490
Nadir	214	−0.423	−0.267	0.519	0.467	0.670	0.538
Backward	210	−0.220	−0.109	0.400	0.310	0.462	0.333

* Location errors at GCP ware calculated
“measured vale” – “calculated value”
STDEV is standard deviation of error

Validation #4 – AVNIR-2 Ortho-rectified Image

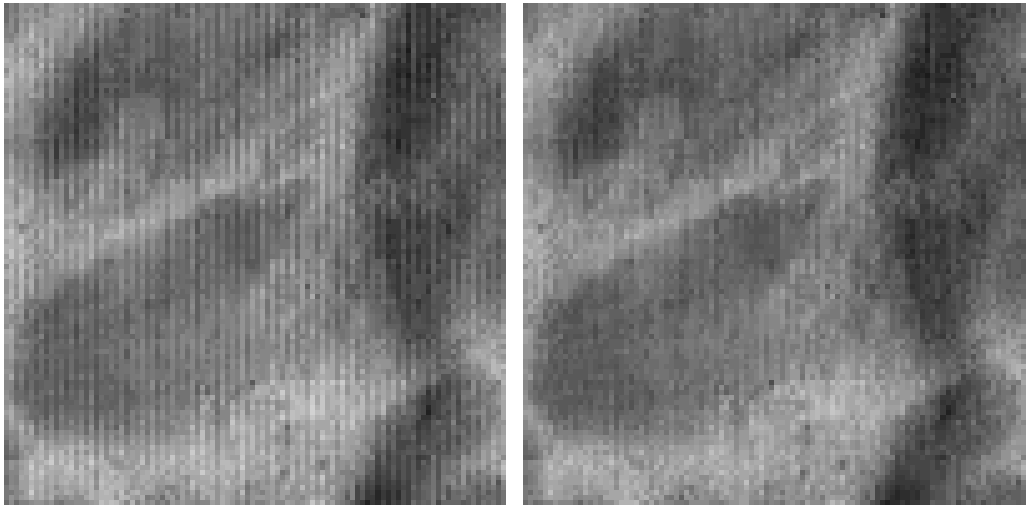
Sakura-jima, Kagoshima, Japan of AVNIR-2 L1B1 image.
34.3 deg. pointing, ALAV2A030782940.

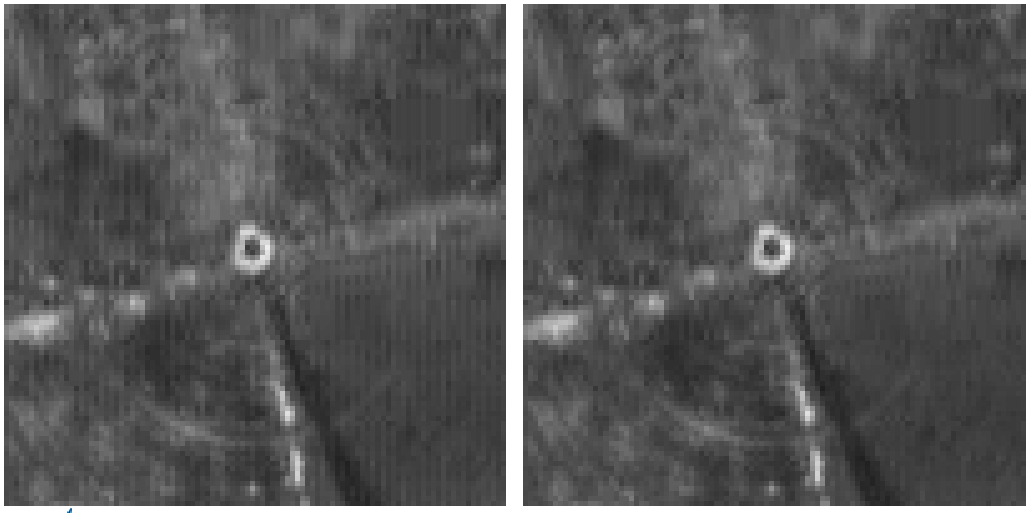
Ortho-rectified image of AVNIR-2.
GSI 50m-DEM was used

Number of GCP	Location error (pixel)*					
	Average		STDEV		RMSE	
	Pixel	Line	Pixel	Line	Pixel	Line
43	0.153	0.144	0.557	0.417	0.578	0.441

* Location errors at GCP ware calculated
"measured vale" – "calculated value"
STDEV is standard deviation of error

Future Work #1 – PRISM Relative Accuracy





- ✓ Calculation of DN difference between odd/even detectors
- ✓ Add DN difference
- ✓ As results, it looks reduction of block noise due to JPEG compression

  → Processing each 8 lines (unit of JPEG compression)

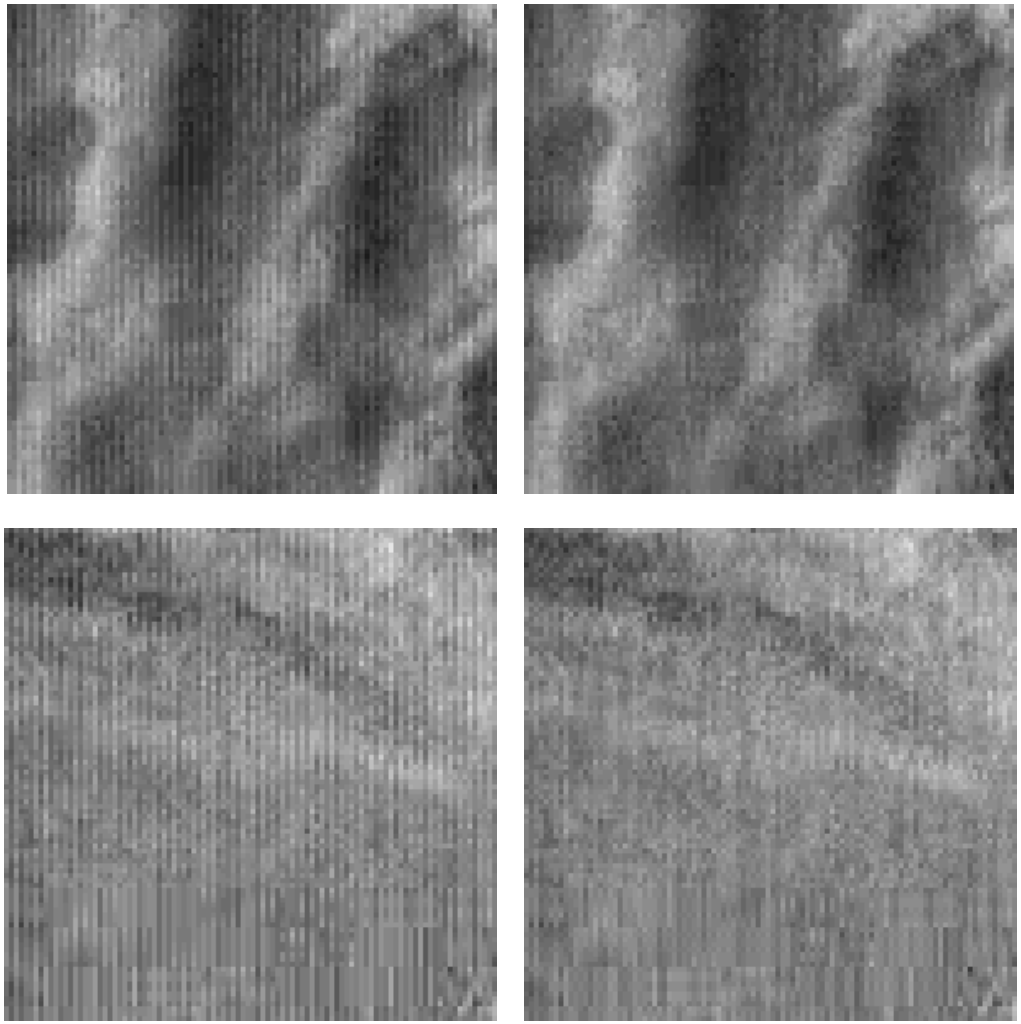
Example of applying odd/even difference filter
100x100 (DN scale : 120–160)
IMG-05-ALPSMB013623255-O1B1__B
Sahara, left: before correction; right: after correction

Before: E-O= -2.37
After: E-O= -0.37

Example of applying odd/even difference filter
100x100 (DN scale : 50–180)
IMG-04-ALPSMB029422885-O1B1__B
Ely, left: before correction; right: after correction

Before: E-O= -2.47
After: E-O= -0.48

Future Work #1 – PRISM Relative Accuracy



- ✓ Power spectral are calculated for each line by FFT
- ✓ Input 0 at 1/2 sample
- ✓ Calculate Inverse FFT (iFFT)
- ✓ It looks reduction of JPEG block noises

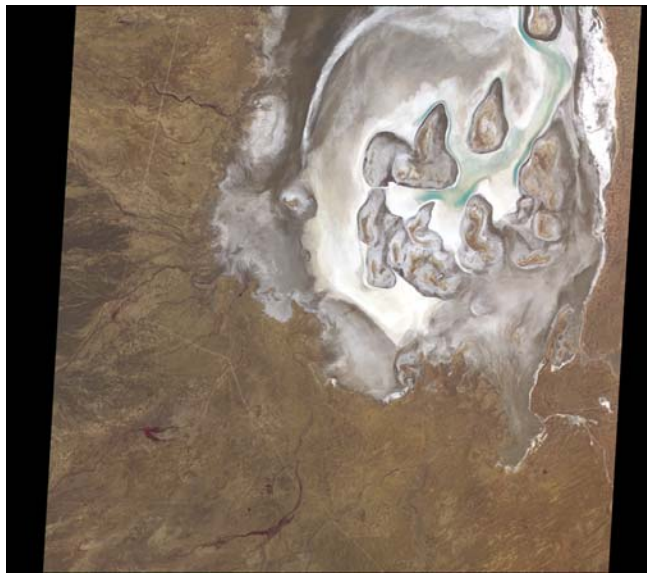
Example of applying iFFT filter
100x100 (DN scale : 120–160)
IMG-05-ALPSMB013623255-O1B1__B
Sahara, left: before correction; right: after correction

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

Future Work #2 – Cross Cal with HRS

- **Cross calibration with high-spatial resolution satellite *i.e.*, ASTER, SPOT-5 over homogeneous targets**
  - ✓ Pixel-scale evaluation: Frequency is decrease
  - ✓ SPOT-5 HRG-X (4 scenes) and ASTER (12 scenes) are planed to observe simultaneously.
  - ✓ Angle differences within 5 degree, and time differences within one day.
  - ✓ Comparison of surface reflectance at TOA over stable surfaces

AVNIR-2 image over Lake Frome, Australia (June 28, 2006).



ASTER image over Lake Frome, Australia (June 28, 2006).

> Many test sites are already inputted to observation requests

- ✓ White Sands, RR Valley, Ivanpah Playa, Lunar Lake, Lake Frome *etc.*
- ✓ Arizaro (Argentina) : AVIRIS, EO-1/Hyperion test site.
- ✓ Orbit/observation timing simulations :
  both AVNIR-2/PRISM and other sensors
- ✓ Submitting observation requests