Time Trend Evaluations of Absolute Accuracies for PRISM and AVNIR-2


* Earth Observation Research Center (EORC), Japan Aerospace Exploration Agency (JAXA)
  E-mail: tadono.takeo@jaxa.jp
** Remote Sensing Technology Center of Japan (RESTEC)

Bird’s eye view of Keauhou, Hawaii, US using PRISM DSM with ortho-rectified pan-sharpened image by PRISM and AVNIR-2
**Outline**

- **Introduction**
  - Satellite and operation status
  - Data acquisition status in the world

- **Geometric Calibration**
  - AVNIR-2: Time trend of absolute geometric accuracy
  - PRISM: Time trend of absolute geometric accuracy
    - Circular Error 90% (CE90)

- **Radiometric Calibration**
  - AVNIR-2: Absolute radiometric accuracy updated
    - Field-of-view (FOV) calibration
  - PRISM: Stripe noises reduction
    - Absolute radiometric accuracy updated

- **ALOS Follow-On Mission: ALOS-2, ALOS-3**

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

ALOS “Daichi”
(Advanced Land Observing Satellite)

Jan. 24, 2006: Launch by H-IIA #8 from TNSC
Nov. 9, 2009: 3.8 year (1,385 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

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
**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
Acquisition Status in the world

May 16, 2006 – Apr. 26, 2009

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

Spatial coverage:
- PRISM OB1 55% with 0-2% cloud cover in scene
- PRISM OB2 69% with 0-20% cloud cover in scene
- AVNIR-2 70% (0-2%); 83% (0-20%)
Geo Cal – AVNIR-2 Geometric Correction Accuracy

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 0 deg. 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 Parameter (AP)

ALOS AOCS system and coordination

- Precise Orbit Determination from TAC
- Precise Attitude Determination (PAD)
- Pointing Alignment Parameter (AP)

Evaluation of variation during recurrent, seasonal change, and temporal change.

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

Pointing AP is basically updating every two months i.e. time gap is occurred between observed date and processed date.

Ex) #16 AP Release: **Sep. 25, 2008**
Evaluation: Mar. 18 – Sep. 17, 2008 > Go / No go
Valid period: **July 17 – Sep 17 2008** observation

Two months time gap!

- Standard product
- Evaluation
- GCP
- Sensor alignment estimation
- Evaluation
- GCP
- Sensor parameters

= We recommend the data order will be better to submit two months after observation date.
**Geo Cal – PRISM Geometric Correction Accuracy**


**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
Geo Cal – PRISM Circular Error 90% (CE90)


- Worldwide ground control points (GCPs) were used as check points
- Geometric accuracy (RMS): Nadir 7.8m, Forward 7.8m, and Backward 8.7m
The scheme is a cross calibration using the similar geometric condition; solar zenith ($\theta_0$), and relative azimuth ($\phi$) angles which depend on local time and inclination angle of the orbit (ALOS $\simeq$ Terra $\simeq$ Aqua (N-S line symmetry) $\simeq$ ENVISAT).

We use top-of-atmosphere (TOA) reflectance function of satellite zenith angle ($\theta$) 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.
Radio Cal – AVNIR-2 Cross-Cal with MODIS

X axis: Terra/MODIS

X axis: Aqua/MODIS

<table>
<thead>
<tr>
<th></th>
<th>Number</th>
<th>AVNIR2/MODIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>AV2 Band</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Terra</td>
<td>14813</td>
<td>17205</td>
</tr>
<tr>
<td>Aqua</td>
<td>14892</td>
<td>15128</td>
</tr>
</tbody>
</table>

- 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!
Radio Cal – AVNIR-2 FOV Calibration

Unrealistic inter-channel difference

L1B radiance = Real data + FOV noise + small-scale noise

(e.g., o/e, cal table error..)

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)
Radio Cal – AVNIR-2 FOV Calibration

Antarctic
2007/11/19

Band 3,2,1
RGB image

Band-1~4
line plot

Differences between old and new are +/- 2%
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 scene.

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.
Radio Cal – PRISM Stripe Noise Reduction

ALPSM20070803081102820 Forward

Before

After
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).
## Calibration Results of PRISM/AVNIR-2

<table>
<thead>
<tr>
<th>Standard Product</th>
<th>Previous results as of Sep. 29, 2007</th>
<th>Results as of July 1, 2009 (Public*)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pixel (X) Line (Y) Distance</td>
<td>Pixel (X) Line (Y) Distance</td>
</tr>
<tr>
<td></td>
<td>Nadir 6.5m 7.3m 9.8m</td>
<td>Nadir 5.6m 5.3m 7.8m</td>
</tr>
<tr>
<td></td>
<td>Forward 8.0m 14.7m 16.7m</td>
<td>Forward 4.9m 6.1m 7.8m</td>
</tr>
<tr>
<td></td>
<td>Backward 7.4m 16.6m 18.1m</td>
<td>Backward 5.0m 7.1m 8.7m</td>
</tr>
<tr>
<td></td>
<td>Relative Accuracy (1σ) 3 radiometers 1.9m 2.3m 3.0m</td>
<td>Relative Accuracy (1σ) 3 radiometers 1.4m 1.8m 2.4m</td>
</tr>
<tr>
<td></td>
<td>CE90 Nadir 11.8m, Forward 12.4m, Backward 13.4m</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Radiometry Absolute accuracy: similar to that of AVNIR-2</td>
<td></td>
</tr>
<tr>
<td>AVNIR-2 1B2</td>
<td>Geometry (-41.5 to +41.5 deg. pointing) Absolute Accuracy (RMS) 106m 19m 108m</td>
<td>Geometry (all period) Absolute Accuracy (RMS)</td>
</tr>
<tr>
<td></td>
<td>Pixel (X) Line (Y) Distance</td>
<td>Pixel (X) Line (Y) Distance</td>
</tr>
<tr>
<td></td>
<td>0 deg. pointing 71.1m 7.5m 71.9m</td>
<td>0 deg. pointing 71.1m 7.5m 71.9m</td>
</tr>
<tr>
<td></td>
<td>+/-41.5 deg. 60.9m 96.6m 114.2m</td>
<td>+/-41.5 deg. 60.9m 96.6m 114.2m</td>
</tr>
<tr>
<td></td>
<td>Relative Accuracy (1σ) 3.4m 7.7m 8.5m</td>
<td>Relative Accuracy (1σ) 3.4m 7.7m 8.5m</td>
</tr>
<tr>
<td></td>
<td>Radiometry (all period)</td>
<td>Radiometry (all period)</td>
</tr>
<tr>
<td></td>
<td>Absolute accuracy Band 1-3: 3.2%, Band4: 7.3%</td>
<td>Absolute accuracy Band 1-3: 3.2%, Band4: 7.3%</td>
</tr>
</tbody>
</table>

*Latest ALOS calibration result can be find at [http://www.eorc.jaxa.jp/en/hatoyama/satellite/data_tekyo_setsumei/alos_hyouka_e.html](http://www.eorc.jaxa.jp/en/hatoyama/satellite/data_tekyo_setsumei/alos_hyouka_e.html) in English*
Concept of ALOS Follow-On Mission

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

- National land monitoring and managements
- Resources managements
- Disaster monitoring
- ALOS-2 is planned 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 series will be continued

ALOS-2: SAR Satellite

ALOS-2 will be introduced at 15:00- on Wednesday.

✓ August, 2009-: Project Team was established
✓ December 2009: Preliminary Design Phase
✓ October 2010: Critical Design Phase
# ALOS-3 Specification (TBD)

**Orbit**
- Sun-Synchronous Sub-Recurrence
  - Altitude: Approx. 620 km
  - 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

<table>
<thead>
<tr>
<th>Major Observation Mode</th>
<th>Panchromatic</th>
<th>Resolution: 0.8 m, Width: 50 km</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Multi spectral</td>
<td>Resolution: 3.2 m, Width: 90 km</td>
</tr>
<tr>
<td></td>
<td>Hyper spectral</td>
<td>Resolution: 30 m, Width: 30 km</td>
</tr>
</tbody>
</table>

**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.)
ALOS-3 Image Simulation

ALOS PRISM (2.5 m GSD)
Jan. 19, 2009

<table>
<thead>
<tr>
<th></th>
<th>ALOS</th>
<th>ALOS-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantization</td>
<td>8bit</td>
<td>11bit</td>
</tr>
<tr>
<td>Data compression</td>
<td>JPEG</td>
<td>JPEG2000</td>
</tr>
</tbody>
</table>

ALOS-3 Pan simulation (0.8 m GSD)
Using airborne optical sensor (ADS40)
acquired on Dec. 21, 2007. (Pasco co., Ltd.)
**ALOS-3 Pointing Simulation**

<table>
<thead>
<tr>
<th>Time Pointing</th>
<th>Spring</th>
<th>Summer</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 deg.</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>60 deg.</td>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
</tbody>
</table>

* GSD, quantization, S/N, MTF, data compression, and atmospheric effect were considered.*
Conclusions

I introduced updated Cal/Val results of PRISM and AVNIR-2, in particular,

1) satellite condition, operation and data acquisition status,
2) the time trends of geometric accuracy of AVNIR-2 and PRISM (NDR: 7.8m),
3) radiometric calibration updated for AVNIR-2 (B1-3: 3.2%) and PRISM,
4) stripe noises reduction of PRISM as relative radiometric calibration, and
5) ALOS F/O Mission introduced.

ALOS and instruments are working very well, and data are available for all users. Cal/Val is also continuously carrying out to keep accuracies and qualities of products as operational Cal/Val.


For more information of ALOS,

- **JAXA/EORC** : New images, data acquisition plan and technical documents

For data search and order,

- **ALOS User Interface Gateway (AUIG)** [https://auig.eoc.jaxa.jp/](https://auig.eoc.jaxa.jp/)
  All archived data can be searched with Guest account

- **RESTEC** : Commercial data distributor
  [http://www.alos-restec.jp/index_e.html](http://www.alos-restec.jp/index_e.html)