Cal/Val Results and Accuracy Assessment Plan for PRISM and AVNIR-2 Onboard ALOS

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Abstract
This paper introduces the updated results of calibration for optical instruments of the Advanced Land Observing Satellite (ALOS, nicknamed "Daichi"), was successfully launched on January 24th, 2006, and it continuously working very well. ALOS has three mission instruments; an L-band Synthetic Aperture Radar called PALSAR, and two optical sensors called PRISM and AVNIR-2. PRISM stands for the Panchromatic Remote-sensing Instrument for Stereo Mapping, and consists of three panchromatic radiometers, and those images are used to derive a Digital Surface Model (DSM) with high spatial resolution, which is also an objective of the ALOS mission. The geometric calibration is important in generating a highly accurate DSM by stereo pair images of PRISM. AVNIR-2 stands for the Advanced Visible and Near Infrared Radiometer type-2, and has four radiometric bands from blue to near infrared. The radiometric calibration is also important for PRISM as well as AVNIR-2.
This paper describes the updated results of geometric and radiometric calibrations of PRISM and AVNIR-2 in the operational phase after initial calibration phase, which are including methodology of analysis and experiment, update parameters related to the absolute accuracy, stability evaluations during about two years after the launch. These works are carrying out during mission life of the ALOS as operational calibration to keep absolute accuracies of the standard products.

Keywords: ALOS, Daichi, PRISM, AVNIR-2, Calibration

1. INTRODUCTION

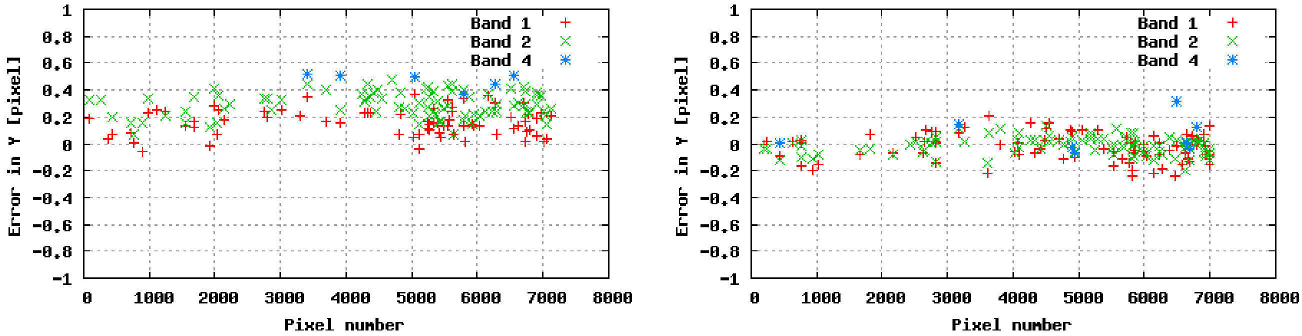
The Advance Land Observing Satellite (ALOS, the nickname is "Daichi") was successfully launched on January 24th, 2006 (Japan Standard Time, JST), and it continuously operating very well. The previous calibration and validation results and image quality evaluations of PRISM and AVNIR-2 have been presented [1], [2], [3], [4]. At that time, we analyzed data acquired during the initial mission check (IMC) and the initial calibration phase (ICP), which was spent about 9 months after the launch. The intensive calibration was carried out during ICP. As the results of initial calibration and validation after IMC, the sensor characterizations have been evaluated, and the radiometric accuracies of both PRISM and AVNIR-2 were almost sufficient except for band-4 of AVNIR-2. However, the geometric accuracies were not sufficient due to the satellite attitude have not been precisely determined yet, and the offset components (*i.e.*, sensor alignments) could not been evaluated after the launch. The satellite operation has been moved to the operational phase from October 24, 2006. Even so, we are continuously evaluating the data to improve the absolute accuracies of PRISM and AVNIR-2, and evaluate their stabilities, and some parameters that related to absolute accuracies were modified and updated.
This paper describes the updated results of calibration and validation and image quality evaluation for PRISM and AVNIR-2 in the operational phase after ICP, which are including methodology of analysis and experiment, update parameters related to the absolute accuracy, stability evaluations during about two years after the launch, and accuracy assessment plan during mission life of the ALOS.

2. GEOMETRIC CALIBRATION

The geometric calibrations of both PRISM and AVNIR-2 were carried out as two steps *i.e.* relative calibration and absolute calibration. The relative geometric calibrations were done by evaluating and correcting parameters related to band-to-band registration for AVNIR-2, and relative CCD alignments for PRISM. The absolute geometric calibrations were done by evaluating the sensor alignments for both AVNIR-2 and PRISM.

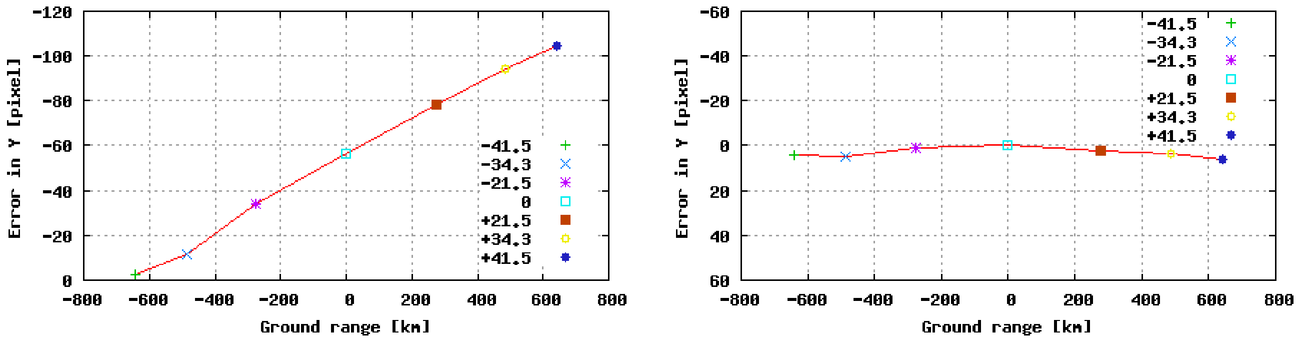
2.1. AVNIR-2

The band-to-band registration is important because if it accuracy is not sufficient the color composite image runs in level 1B2 (L1B2) standard product. The band-to-band registration is defined to adjust bands 1, 2, and 4 to band 3 that is as the base band into the geometric sensor model. Fig. 1 shows an example of relative geometric error for each band compared with band 3 that is band-to-band registration. This is using the image acquired by 0 degree pointing angle, and the left graph (a) of Fig. 1 indicates before correction in Y (line) direction. The plots show band 1, 2 and 4 in red, green, and sky blue, respectively. These geometric errors were calculated that the special feature points were automatically identified from image,



(a) Before correction. (b) After correction.

Figure 1. Example of band-to-band registration evaluation of AVNIR-2 (0deg. pointing angle, Y direction).



(a) Before correction. (b) After correction.

Figure 2. Example of sensor alignment evaluation of AVNIR-2 (Y direction).

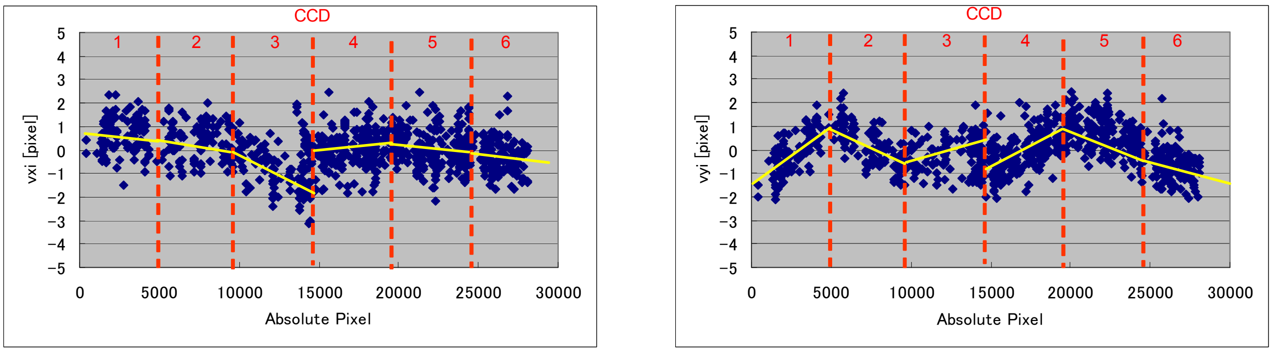


Figure 3. Evaluation and correction of relative CCD alignments of PRISM nadir-looking radiometer (left: geometric error in X (pixel) direction, right: Y (line) direction).

than compared between bands by the least square matching technique. It has about +0.1 to +0.5 pixels errors from Fig. 1 (a). Fig. 1 (b) shows same relationship using the image corrected band-to-band registration, which was processed by adjusting parameters of the sensor model. The error becomes less than 0.2 pixels the absolute values except for a few points, which are probably due to matching error when calculation of geometric errors.

Fig. 2 (a) shows the geometric error in Y direction for each pointing angle of AVNIR-2 using ground control points (GCPs) to estimate sensor alignments. There is a linear relationship with pointing angle that corresponds to ground range. We derived the updated parameters of geometric sensor model from Fig. 2 (a) and similar error in X direction to reduce geometric errors in whole pointing ranges. Fig. 2 (b) shows similar relationship with Fig.2 (a) using updated parameters. The geometric error is significantly reducing and approaching zero in Y direction.

2.2. PRISM

The nadir-looking radiometer of PRISM has six CCD units, which is covered 70km observation swath width. The forward- and backward-looking radiometers of PRISM have eight CCD units to observe same area with nadir's one even the earth rotating on its axis due to time gaps between those observations (about 46 seconds each). The image is independently obtained by each CCD unit, and combining by ground system into Level 1B2 (L1B2) standard product processing based on the geometric sensor

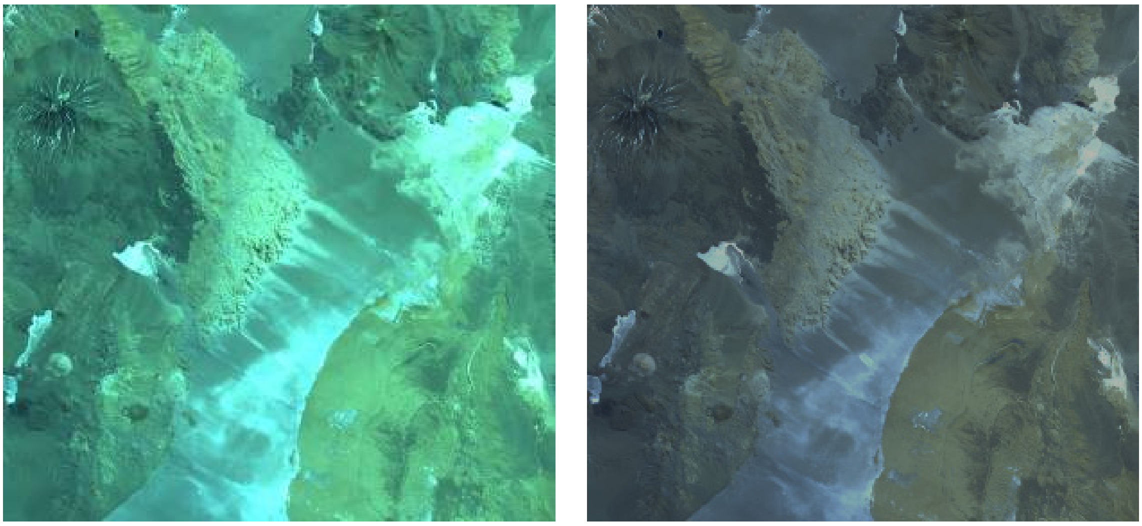


Figure 4. Example of simultaneous observed images with AVNIR-2 (left image) and ASTER VNIR (right image) over Arizaro Salt Lake, Argentina on September 17th, 2006. The AVNIR-2 image was acquired about two minutes after ASTER's acquisition with almost similar geometry.

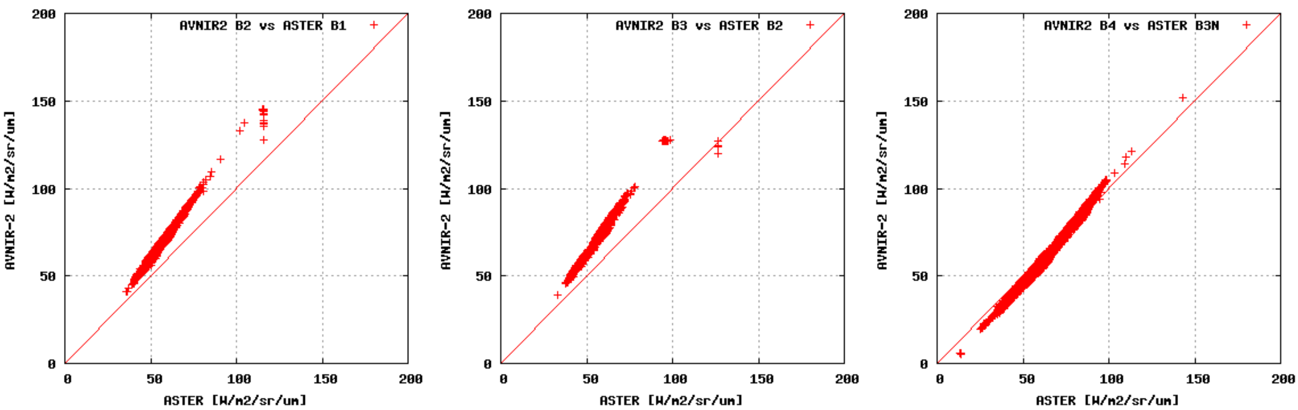


Figure 5. Comparison of surface radiance between AVNIR-2 and ASTER VNIR over Arizaro, Argentina (right: band 2 of AVNIR-2 vs. band 1 of ASTER, middle: band 3 of AVNIR-2 vs. band 2 of ASTER, left: band 4 of AVNIR-2 vs. band 3N of ASTER).

model. One of parameters of the model is a relative alignment between CCD units (called "CCD alignment"). All of relative CCD alignments were measured on the ground before launch the satellite. However, it may be changed due to vibrations of the launch, changes of thermal condition into space *etc*. Therefore, we estimate the alignments using obtained images over GCP [5]. As the relative geometric calibration of PRISM, relative CCD alignments were evaluated and released of updated parameters on July 17 2007 as version 3.

To evaluate the relative CCD alignment, GCP residuals of exterior orientations were used. Total 706, 943 and 734 GCPs were measured in 13, 15 and 14 scenes including the dense GCP test sites for forward, nadir and backward images, respectively. Figure 3 shows the GCP residuals of scene by scene exterior orientations back-projected on the image space for nadir images with un-calibrated CCD alignment models. The residuals vxi and vyi indicates the X (pixel) and Y (line) residuals with detector address of each CCD. These systematic errors depending on CCD units were confirmed at forward-, nadir-, and backward-images, respectively. We applied the linear regression models for each CCD unit in each sensor model that is relative systematic errors between CCD alignments as the on-orbit self-calibration [3].

The geometric system correction of standard product of PRISM is carried out using position and attitude information and the pointing alignment parameter, which is derived by the Precision Pointing and Geolocation Determination System (PPDS) [6]. PPDS is a ground processing system to achieve determinations of precise attitude and pointing vectors for each PRISM radiometer. To improve geometric absolute accuracy as well as geolocation determination accuracy of PRISM, the pointing alignment parameters have to estimate precisely including variations of recurrent and seasonal. The current pointing alignment parameters are version 11 released on October 30th, 2007. We will update them to keep the accuracy if accuracy degradation is confirmed.

3. RADIOMETRIC CALIBRATION

Absolute radiometric calibration is usually performed by vicarious calibration with ground- or airborne-based experiments. However, such experiments depend highly on weather conditions as well as the atmosphere. Furthermore, radiative transfer models still involve uncertainties and dependencies even when the atmospheric parameters are measured or estimated. Therefore, cross-calibration was performed with calibrated satellite data as absolute radiometric calibration. We used two types of existing satellite data for cross-calibration, a moderate spatial resolution sensor and a high-resolution sensor. Moderate spatial-resolution sensors are used to increase the number of evaluation images of AVNIR-2 and PRISM; high spatial-resolution sensors (*e.g.* ASTER and SPOT-5) were used to evaluate their pixel scale. In this paper, cross-calibration with ASTER is described.

The normalized response functions of AVNIR-2 and ASTER VNIR is very similar. It have similar responses between band 2 of AVNIR-2 with band 1 of ASTER, band 3 of AVNIR-2 with band 2 of ASTER, and band 4 of AVNIR-2 with band 3N of ASTER, respectively. The orbit conditions are also similar with ALOS and TERRA *i.e.* flight altitude, inclination and local time of descending node. The ASTER itself is well calibrated [7]. Timing simultaneous observation with ALOS and other high-resolution satellites is important. We are already inputting many test sites for radiometric calibration of AVNIR-2 and PRISM worldwide, where homogeneous and stable regions are located, and for use in calibrating other satellite images (*e.g.* White Sands, Lunar Lake, Rail Road Valley, Ivanpah Playa). We have been simulated the timing simultaneous observation with AVNIR-2 and ASTER with the condition of within one-day time difference and five degrees line of sight (LOS) difference. Figure 4 shows an example of simultaneous observed images over Arizaro Salt Lake, Argentina with AVNIR-2 and ASTER on September 17th, 2006. In this case, ASTER was observed at 14:42:04 (UT) then AVNIR-2 was observed at 14:44:13 (UT) with five degrees angle difference. Arizaro is located on 3,500m altitude, and used for radiometric calibration of Hyperion sensor onboard EO-1 satellite [8]. Therefore, the atmospheric effects are not significant. The ASTER image of Fig. 4 (b) was geometrically corrected to (a) AVNIR-2. To use only homogeneous area, we calculated the standard deviations in 10 by 10 pixels areas of both images of AVNIR-2 and ASTER. If the standard deviations were less than 1 digital number (DN), the surface radiances (W/m2/str/micro-m) were calculated by nominal transformation and coefficients, and compared both AVNIR-2 and ASTER. Figure 5 shows the comparison of surface radiances of same area for each band. The surface radiance of band 4 of AVNIR-2 is agreed well with band 3N's one of ASTER. However, some differences appeared in bands 2 and 3 of AVNIR-2. It is necessary more investigations using other simultaneous observations. As another radiometric calibration of AVNIR-2, the cross calibration with MODIS was described [5].

4. CONCLUSIONS

In this study, we introduced calibration of PRISM and AVNIR-2 onboard ALOS including methodologies and updating parameters regarding sensor models that are used to generate standard products. The satellite position and attitude are precisely determined that is directly affected to geometric accuracy of the standard products. The relative geometric accuracies of PRISM and AVNIR-2 were almost sufficient to revise the parameters using geometric sensor models *i.e.* band-to-band registration of AVNIR-2 and CCD alignments for PRISM that described in this paper. The absolute geometric accuracy of both sensors are improved by evaluate sensor alignments. These parameters are continuously evaluated and updated if necessary. The radiometric accuracies of both PRISM and AVNIR-2 are almost sufficient except for JPEG block noises of PRISM. These items will be evaluated as the operational calibration for accuracy assessments during the ALOS mission life.

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