

# EVALUATION OF ASTER OPERATION AT THE GROUND DATA SYSTEM

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## ABSTRACT:

ASTER ( Advanced Spaceborne Thermal Emission and Reflection Radiometer ) , which was built by METI ( Ministry of Economy, Trade and Industry, Japan ) has been nominally operated for more than four years after the launch in December , 1999, with cooperation of NASA ( national Aeronautic and Space Administration ) who operates the satellite called Terra . And ASTER has been acquiring more than 760 thousand scenes of data, and has been generating more than 640 thousand scenes. Currently, ASTER is being used as one of the standard mid-resolution space borne Earth Observing Remote Sensor worldwide. In fact, more than 1.5 millions of ASTER data were distributed. The authors has been conducting the operation of ASTER and performed evaluation of the performance of ASTER Ground Data System, based on the experience of the operation. ASTER succeeded in very complicated operation derived from the user requirement. Major features are as follows: (a) Flexible mission operation involving world weather forecast, (b) Correction for the misregistration caused by the Hardware constraints, (c) Data set generation including along track stereo pair which enables DEM generation (d) User friendly internet user interface including easy data search from huge amount of data set, on line data distribution, credit card payment, so on. (e) Achievement of high accuracy in geometry and radiometry..

## 1. INTRODUCTION

ASTER was launched on December 18, 1999 from Vandenberg, California, USA on the platform called Terra (EOS AM-1). ASTER is a sensor made by the Japanese Instrument Team funded by METI, and Terra is a platform provided by NASA. And the operation is performed by the intimate cooperation between US and Japan and, in both sides, Instrument/Science/Ground System have been cooperating for a better operation.. The detailed description on the Operation is described in the literature. Here, only following information is listed as a summary: Fig. 1 US-Japan Relation, Table 1 :Major Orbit Parameters of Terra, Fig. 2 Basic Specifications of ASTER

Orbit	Sun Synchronous
Local time at equator	10:30 a.m. @ ±15min.
Altitude range	700-737 km (705 km at equator)
Inclination	98.2° ± 0.15°
	16 days (233 revolutions/16 days)
Distance between adjacent orbits	172 km at equator
Repetition accuracy	± 20 km, 3σ

Table 1 Major Orbit Parameters of Terra Satellite

ASTER Mission Operation is conducted by the AOS ( ASTER Operation Segment ) with the help of SSSG ( Science Scheduling Support Group ) from ERSDAC and JPL. Every day, ODS ( One Day Schedule ) is generated, by using the "Scheduler" which takes into account the ASTER/Terra restriction ( 8 % duty cycle , XAR Data Base ( data base of all the data acquisition requests ), spacecraft information ( Planning Aid ), weather forecast of the target area ( GDAS data ), the cumulative number of the pointing which is an item to be controlled. The output of the scheduler plays a very important role to define switch on/off time, pointing angle to maximize the priority function defined by the ASTER Science Team. Then, generated ODS is sent to EOC ( EOS Operation Center ) in

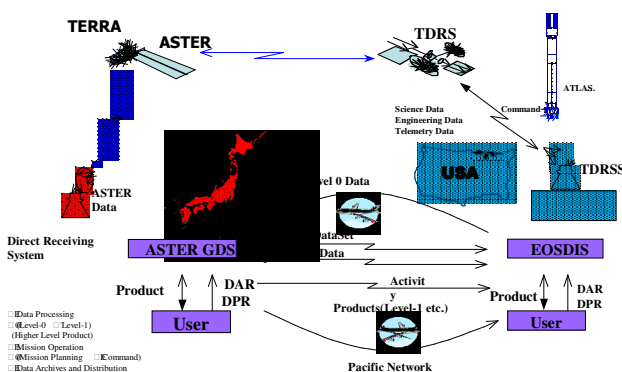


Fig. 1 Operational Relationship of ASTER between US and Japan

## 2. OPERATIONAL PERFORMANCE OF ASTER

### 2.1 Mission Operation of ASTER Sensor

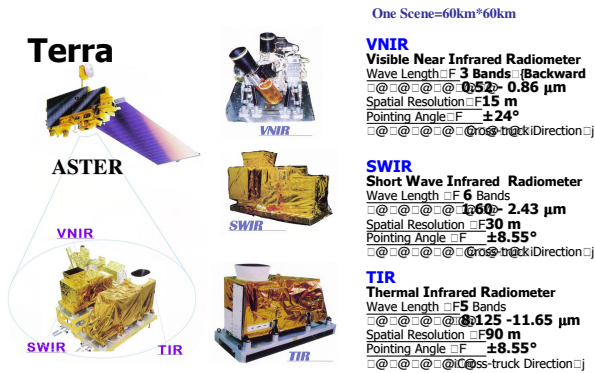


Fig. 2 Major Parameters of ASTER Sensors

NASA GSFC ( Goddard Space Flight Center ) under the form of the “ activity”. NASA uploads the total schedule to Terra under the form of command every day. The data acquisition request is classified to ETR (Instrument Team Request ), STAR ( Science Team Request ), and other individual DAR, totally called xAR, and they are stored in the xAR Data Base, which is referenced by the “Scheduler” when ODS is generated. For the detail of the xAR, please refer to Yamaguchi, et.al, 1995.

Resulting scene number of daily data acquisition is shown in the figure 3, which shows that the data acquisition of ASTER is very stable and can be approximated as 600 scenes per day in most of the operation, but is slightly decreased to about 500 scenes per day, recently. The expected rate of data acquisition derived from the duty cycle was 780 scenes per day in design phase. But, considering the land area of the world, these statistics seem to be reasonable. The reason of the slight decrease of the data acquisition rate from 600 scenes per day to 500 is partly because of the damage in on board SSR ( Solid State Recorder ), and also partly because the target area has become scattered, resulting in the inefficiency of the data acquisition.

One challenging operation flow of the ASTER mission

### Acquired Scenes

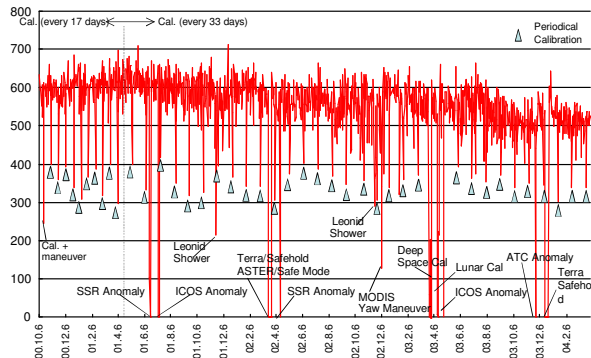


Fig3 Number of acquired ASTER scenes per day

operation is that the xAR is scheduled, referring to the successful ( cloud-free ) data acquisition, i.e. if the acquired data is cloud-free, ASTER will not try for this area, but if not, ASTER will try again for this area. For this detail, please refer to Miura,A. 2002.

Another challenging operation flow is to reflect weather forecast information to make the ODS. By taking into account weather forecast information, the cloud coverage is decreased from the 40 – 45 % to 35 %. For this detail, please refer to the same literature, Miura, A.,2002.

### 2.2 Data Processing of ASTER Data

As shown in the section 2.1, the data acquisition rate per day is about 600 scenes per day. And the data volume of one Level 0 scene is about 100 MB. On the other hand, nominal life time of ASTER is 5 year. Therefore, the estimated total scene number is about 1.1 million, and the total volume for 5 years is about 110 TB. Since Level 1A product is produced

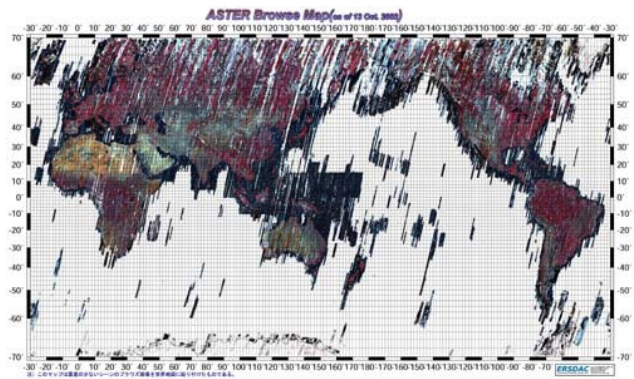


Fig.4 Coverage map of cloud free ASTER Data

for all the acquired data, estimated total number of L1A is 1.1 Million scenes and 110 TB. As for the Level 1B product, corresponding estimated total number is about 275 thousand scenes and 27.5TB, assuming the scenes to be requested to be processed up to L1B is 25% and one L1B product has 120 MB. Actual rule for the selection of the automatic L1B generation is that L1B product will be generated if the cloud cover of a scene is below 20 %, judged by the automatic cloud evaluation algorithm. In addition, if there is a request to generate the L1B scenes, L1B data will be generated regardless with the cloudiness.

Since this data volume is very large, and for the easy access to the archived data, automatic data storage system was introduced. At the first stage, a robot system called “Powder Horn” using 50 GB D3 cassettes was installed. But, by the reasons described below, it was replaced to “Peta Site System” using 200 GB DTF2 tape.

On the other hand, ASTER has been operated for more than 4 years, there is a statistics of the data acquisition, L1A/L1B production. The cumulative sum of L1A and L1B data are 640 thousand and 170 thousand scenes. The statistical values are slightly smaller than the expected values for both L1A and L1B. The major reasons for statistics for L1A are a) the tape read errors b) bit flip. As for the tape read errors, relatively high error rate had been experienced by the time of the media change from D3 cassettes to DTF2 tapes ( Transition from D3 cassettes to DTF2 were performed during 2002 October and 2004 April). Change of the error rate was statistically evaluated. As for the bit flip, a automatic correction algorithm has been applied if bit flip occurs in a very critical portion of the data such as time tag. This counter measure was applied in 2002 October. The L1A processing error has been occurred less frequently. However, bit flip could occur in the science data. In such case, processing

will not stop, but, error pixels or lines could be included in the data set.

### 2.3 Radiometric Performance

As shown in the Figure 3, data acquisition for the radiometric calibration has been periodically performed, firstly in 33 days, then 17 days, after having confirmed the stability of the sensor responsibility. The result of the calibration has been listed in the form of the radiometric calibration table and reflected to the Level 1 Processing. In summary, 3 band data in VNIR have been degraded 15 to 20 % for these 4 year's operation. This degradation is strongest in the Band 1 and weaker in the longer wavelength. This degradation in SWIR is relatively weaker compared with VNIR. On the other hand, this change rate in TIR is significant. The detail of the radiometric performance should be referred to the literature. The calibration table is updated every time the change exceeds the predetermined criteria. By this calibration, the DN value in the Level 1B data can be converted to the radiance value, by using a simple formula  $(DN-1) \times \text{conversion factor}$ . The interval of the change of the radiometric calibration table is shortest in TIR as expected. And, the change of the responsibility is shown in the figure 5, Tonooka, 2003, where the discrepancy before and after correction is significant when the interval of the change of the calibration table is too long. In the worst case, this difference can be larger than 2 degrees in Band 12 in terms of temperature. To compensate this discrepancy, a formula of 3<sup>rd</sup> order polynomial in function of the data acquisition time is proposed by Tonooka, 2003.

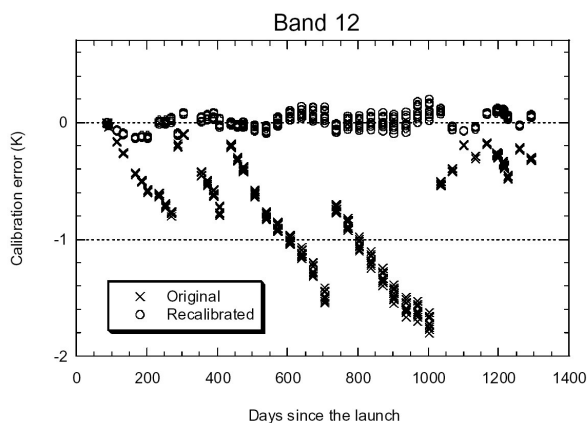


Fig. 5 Error in TIR and recalibrated values (Tonooka, 2003)

In the mean time, a phenomenon called “cross talk” was found in 2002 in the decorrelation stretch image by SWIR. The cross talk is the phenomena that a strong light in the Band 4 is diffused to the adjacent bands, especially in band 9, which has relatively weaker light. Since each band of the SWIR has different look direction, sometimes, the light in Band 4 appears in the Band 9 image, in a different location in along track direction. This effect is most significant in the shoreline in cross track direction. Again, a formula to compensate the cross talk was proposed by Iwasaki, A, 2003 and can be applied to the Level 1B processing when requested. But, it should be noted that the cross talk is so subtle that it cannot be seen in a simple 3 SWIR band image in most cases.

In addition, in March/April of 2003, the Deep Space and Lunar Calibration were conducted by making a pitch maneuver of

Terra Satellite. The purpose of the Deep Space Calibration was to check the Deep Space where there is no radiance, and that for the Lunar Calibration was to check the radiometric calibration without any atmospheric effect. The investigation is still underway. But, some unexpected ghosts similar to the cross talk were observed not only in SWIR bands.

### 2.4 Geometric Performance

As mentioned in the beginning of this manuscript, ASTER sensor has three different telescopes, VNIR, SWIR and TIR, where the first two are push bloom types and the last, whisk bloom type. In addition, in SWIR, each band looks different direction to obtain sufficient radiance value. As a result, the intra- and inter- telescope band to band registration becomes very important. All the processing of the registration is described in the literature by Fujisada[ and Watanabe, 1994. Target of the registration accuracy was to keep in 0.2 pixel in intra-telescope registration and 0.3 pixel of the coarser telescope in inter-telescope registration. Since the band to band registration is a key factor to the success of the ASTER sensor, a continuous effort to check the result of the band to band registration has been performed. And all the band is registered to the VNIR Band 2. The result of the effort shows that the band to band registration satisfies the above mentioned target.

On the other hand, geolocation information is one of the significant characteristics of ASTER sensor. In the level 1 S/W, the geolocation is calculated as a cross point of the look vector of each pixel and reference ellipsoid. Therefore, there are following contributing factors to get the exact geolocation : location and attitude knowledge of the space craft ( obtained by TONS : TDRS Orbit Navigation System and Star Tracker /Rategyro ), stability of the attitude, accuracy of the pointing angle and its knowledge. To calculate the look vector, geometric configuration of the sensors was carefully calibrated during the Initial Checkout period. And the geolocation has been periodically checked. The result shows the geolocation in VNIR of the L1B product is about 50 m in 3 sigma in the low altitude area. This location is more accurate in L3A ( Ortho-rectified ) data even in the high mountain, since geometric distortion caused by the altitude is corrected. This amount of geometric distortion could be more than hundred meters if the pointing angle is large in the mountain. All of the geolocation information is obtained without any use of geometric control point. This geolocation accuracy is achieved in mid-latitude region, and could be larger especially in high latitude region. Again, a formula to correct this accuracy is proposed in the Web site[###]. The height information in the L3A or L4 product is about 15 m except for the sharp edge of the mountain or the landform, taking into account the height means here the height is against the reference ellipsoid and not against the geoid surface. This is because of the spatial correlation with 9 by 9 windows. Since all the processing is automatic, there are some mismatching, especially in case of the very flat and monotonous area like playa. But in most area, the above mentioned accuracy is well kept.

### 2.5 Data Distribution

All the processed ASTER data is available from ASTER GDS in ERSDAC, Japan and EROS data in LP DAAC, in USA. The data is separated as a scene. In most cases, data is acquired in full mode. The product used in general cases is processed in Level 1B. A significant characteristics is that data set in full mode is associated with backward looking data covering

approximately the same area, although such data is acquired approximately 55 second later than the nadir looking data. Higher level data is also available. Higher level product includes relative reflectance/emissivity, reflectance/temperature/emissivity after atmospheric correction, DEM/Ortho-rectified image. To keep the quality of the product, version up of the algorithm is sometimes conducted.

#### ASTER Standard & Semi-standard Products

Product Name	Description	
Level 1A		V:15m,S:30m, T:90m
Level 1B		V:15m,S:30m, T:90m
2A02	Relative SpecialEmissivity	90m
2A03 V, 2A03 S	Relative Spectral Reflectance VNIR, SWIR	15m 30m
2B01 V, 2B01 S, 2B01 T	Surface Radiance VNIR, SWIR, TIR	15m 30m 90m
2B05 V, 2B05 S	Surface Reflectance VNIR, SWIR	15m 30m
2B03	Surface Temperature	90m
2B04	SurfaceEmissivity	
3A01	Orthographic Image	V15m+DEM, S30m+DEM, T90+DEM
4A01Z	Relative DEM Z	Z (Default 30m)

Table 2 Product List of ASTER Data

Once product is generated in the ASTER GDS, data can be distributed in form of CD-ROM or by network. In the beginning of the ASTER operation, most of the data distribution are by CCD, but, recently, reflecting the development of high speed network, on line distribution becomes more and more popular. One scene of L1B product is about 120 MB, and that of L3A, 240 MB. Therefore, the time for data transfer is not significant. This network distribution becomes available not only in North America, Europe, Korea, Japan, but also in some countries in South-Eastern Asia. This capability increases the world wide data use, jointly because of the payment by credit card.

Data search is one of the key factors for data distribution. Since the archived scene number already exceeds 700 thousands, efficient data search is mandatory requirement. Since the orbit of Terra could be shifted by +/- 20 km from the nominal orbit, and also because the 60 km swath is less than the distance between two adjacent path, simple sorting by the path cannot be applied and a special S/W is devised for quick search. But, for specific area, faster search method from selected data set is also in operation.

Once data is distributed, user should read the data as the first step. ASTER GDS is distributed aster data in EOS HDF and CEOS. Initially, the EOS HDF format was not very popular. But, recently, there are more and more Image Processing S/W or GIS S/W began supporting EOS HDS data. By this way, full capability of ASTER data can be efficiently used.

### 3. CONCLUSION

- 1) By checking ASTER data, we will be able to conclude that the overall performance is as expected. Especially, following factors seemed to be technologically difficult, but were successful: a) Band to Band registration; b) Geometric accuracy; c) S/N, especially in 5 band TIR; d) Dynamic scheduling
- 2) There were a few features to be improved: a) Cross talk in SWIR. b) Coverage of the target area : The swath of the data is 60 km, while the distance between two adjacent paths is 172 km. To cover the target area, ASTER sensor should pass

more than 3 times c) Improvement of cloud evaluation algorithm.

In addition, ASTER has been operating for more than 4 years without major problem. So, its operation will be extended to 2007, beyond the design life time..

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