Introduction of GLI level-1 products

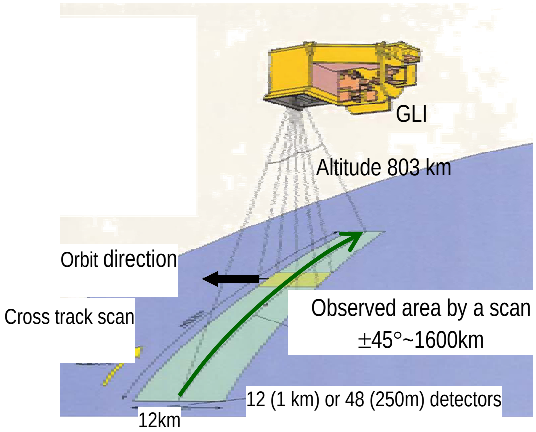
JAXA EORC December 24, 2003

http://www.eoc.jaxa.jp/homepage.html

1. JAXA Global Imager

The JAXA Global Imager (GLI) orbit and observation method are outlined below.

- Cross track scan swath: 1600km
- Resolution (at Nadir): 1 km, 250m (ch20-23, 28, 29)
- Mission period: Dec. 2002-Oct. 2003
- Orbit: Sun synchronous
  Descending local time: 10:30am
  Altitude: 803km, period: 101min
  Inclination: 98.6°
  Recurrent period: 4 days
- 12-bit digital resolution
- 36 channels from visible to thermal infrared
  380-865nm (VNIR 23 channels)
  1050-2210nm (SWIR 6 channels)
  3700-12000nm (MTIR 7 channels)
- Tilt operation along track direction



Center wavelength, dynamic ranges, and signal-noise-ratio derived from evaluation test on the ground are shown in Table 1.

Table 1 Characteristics of GLI channels *(From GLI Mission Data Evaluation Test)*

ch	Wave length [nm]	Dynamic range [W/m2/str/µm]	SNR (input L)	ch	Wave length [nm]	Dynamic range [W/m2/str/µm]	SNR (input L)	ch	Wave length [nm]	Dynamic range [W/m2/str/µm]	SNR (input L)
VNIR (1km) (#p: *piecewise linear channel*)				15	710.1	233 (369)	300 (10)	250 m channels			
1	380.7	683	467 (59)	16	749.0	11 (17)	991 (7)	20	462.4	691	241 (36)
2	399.6	162	1286 (70)	17	762.0	246 (473)	293 (6)	21	542.1	585	141 (25)
3	412.3	130	1402 (65)	18	866.1	8 (13)	1309 (5)	22	661.3	115 (156)	255 (14)
4p	442.5	110 /680	893 (54)	19	865.7	211 (339)	386 (5)	23	824.1	210 (287)	218 (21)
5p	459.3	124 /769	880 (54)	SWIR (1 km)				28	1644.9	76	298 (5)
6	489.5	64	1212 (43)	24	1048.6	227	381 (8)	29	2193.8	32	160 (1.3)
7p	519.2	92 /569	627 (31)	25	1136.6	184	412 (8)	MTIR (Kelvin, NEΔT at 300K)			
8p	544.0	96 /596	611 (28)	26	1241.0	208	303 (5.4)	30	3721.1	345 K	0.07 K
9	564.8	39	1301 (23)	27	1380.6	153	192 (1.5)	31	6737.5	307 K	0.03 @285K
10	624.7	28*1 (39*2)	1370 (17)					32	7332.6	322 K	0.03 K
11	666.7	22 (31)	1342 (13)					33	7511.4	324 K	0.02 K
12	679.9	23 (33)	1293 (12)					34	8626.3	350 K	0.05 K
13	678.6	342 (522)	235 (12)					35	10768.0	354 K	0.05 K
14	710.5	16 (24)	1404 (10)					36	12001.3	358 K	0.06 K

- Dynamic range and SNR are cited from "Tanaka, K., GLI Mission Data Evaluation Test results, JAXA ADEOS-II Project, ADEOS-II/GLI Workshop, November 14-16, 2001, Tokyo, Japan".
- Center wavelength is derived from GLI spectral response.
- S/N tests are in ambient (VN+SW) and high temp (MT) condition.
- *1 Maximum radiance for linear response (VN2)
- *2 Predicted maximum radiance for DN=4095 (12bit) or saturation.

JAXA GLI CAL Group, May 1, 2002

2. Level-1 products

2.1 Definition of GLI reference orbit

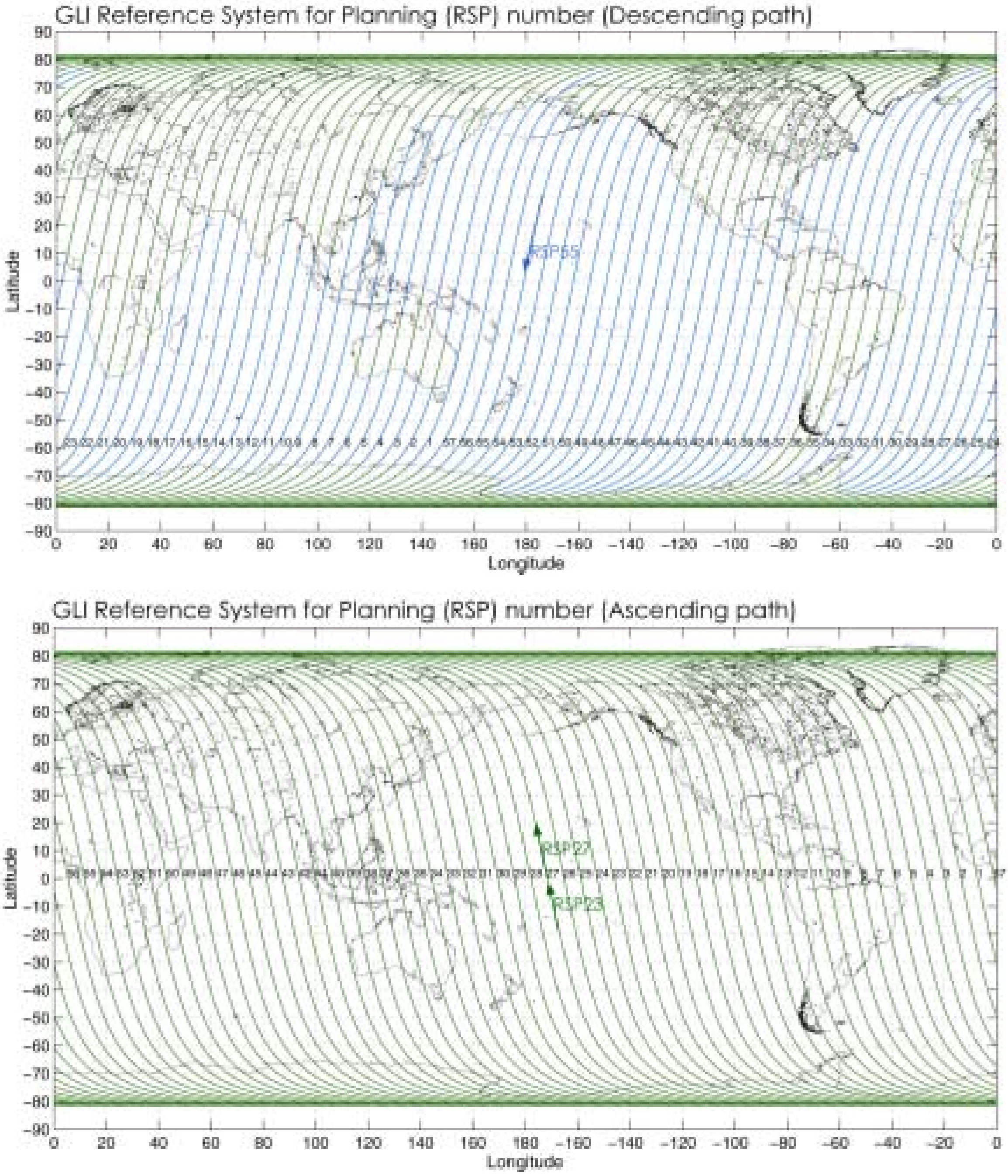


Figure 1 definition of GLI RSP. Upper panel shows descending, lower. Ascending path.

GLI orbits can be identified by Reference System for Planning (RSP) number, which starts from an ascending orbit at the equator (see Figure 1). The RSP number increases by four (RSP 1→5→9…) from 1 to 57, and repeats every four days.

Following URL shows how to identify daily path number pattern from observation date and satellite position at certain observation time.

http://sharaku.eorc.jaxa.jp/GLI/index_j.html

2.2 Definition of the GLI scene

The GLI scene number is defined as 1 to 26 areas separated by 13.8528° along path from ascending node (scene-1 is defined that center corresponds to ascending node). The scene size is 130 scan (about 1560km) on average. The scene number corresponds to observation latitudes on each ascending or descending path (tilt operation shifts the latitude about 2.5 degrees). Figure 2 illustrates an example of the GLI scene boundaries along RSP2-RSP54 without tilt operation.

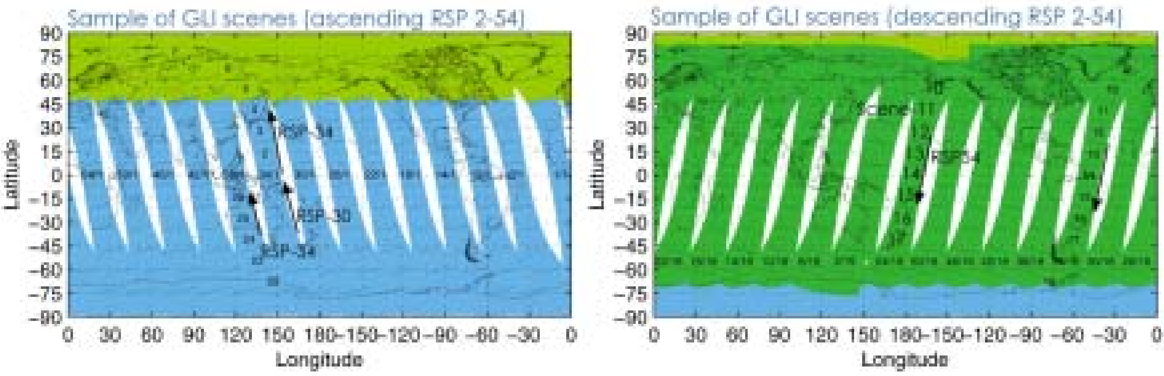


Figure 2 GLI scene boundaries on ascending (left) and descending (right) paths. Numbers in the panels indicate RSP and scene number.

2.3 Observation modes

GLI has daytime (OBD) and nighttime (OBN) modes; visible and near infrared (VNIR), short-wave infrared (SWIR), and middle and thermal infrared (MTIR) are all available in OBD; only MTIR is available in OBN. For both modes, the scan mirror can be tilted by +/–18.5° as mirror incident angle along track (+ means to the satellite moving direction). The tilt operation modes are presented in the HDF file (opr_mode) and file name (OD2: –20°, OD3: +20°). In addition, GLI has the following calibration modes: solar calibration (SCA), interior lamp calibration (LCA, LC1: Nadir, LC2: +20° tilt), and electrical calibration (ECA, EC1: Nadir, EC2: +20° tilt). Earth observation data is obtained as OBD on SCA and OBN on LCA; no data is obtained on ECA (see Table 2).

Table 2 Observation mode and outputs

Observation mode	Earth observation data		Calibration data
	VNIR/SWIR	MTIR	
OBD (OD1,2,3)	Processed	Processed	–
OBN (ON1,2,3)	Not processed	Processed	–
SCA (SC1)	Processed	Processed	Processed
LCA (LC1,2)	Not processed	Processed	Processed
ECA (EC1,2)	Not processed	Not processed	Processed

These modes can be identified by “opr_mode” in the L1 file or OD, ON.. in the file name (see table 3).

For 3.5 months from the ADEOS-II launch, 14 December 2002, GLI was operated on special schedule for satellite and sensor evaluations. GLI operation planning systems in EOC and EORC have prepared observation plans for OBD /OBN, tilt, calibration, and 250m modes since 2 April 2003. These observation modes are identified by a product file name. (see 2.4)

2.4 Level-0 to Level-1B products

Level-0 (L0) data is raw data consisting of packet (1 km) or minor frame (250m) data. Level-1A (L1A) data is reformatted, un-calibrated data from the L0 to HDF appended calibration parameters. Level-1B (L1B) data is derived from the L1A data applying detector registration, inter-band registration, and several radiometric corrections. L1B data includes satellite, solar angles, and footprint locations at 12 pixel/line intervals. Earth-observation images in L1B are not projected; mapped L1B is defined as the L1B-map produced by ordering specified scenes. Higher-level products (Level-2) are produced from the L1B data.

L1A /L1B data are separated into three files by wavelength categories, VNIR, SWIR, and MTIR. Furthermore, detector, scan, and sample numbers of VNIR and SWIR are stored in a sampled line pixel table (SLPT); the detector and scan numbers are also included in VNIR, SWIR, and MTIR L1B files.

Names of the Level-1 files (granule ID) are listed in Table 3. The name consists of the satellite, sensor names, year, month, day, RSP, scene number, operation mode, tilt, and product categories.

Table 3 File names of GLI level-1 products

	Channel	HDF file name (granule ID)
L1A	MTIR	A2GL1*YYMMDDPPSSOOT*_PM1A0000000.00
	VNIR	A2GL1*YYMMDDPPSSOOT*_PS1A0000000.00
	SWIR	A2GL1*YYMMDDPPSSOOT*_PV1A0000000.00
	250m	A2GL2*YYMMDDPPSSOOT*_P01A0000000.00
	CAL	A2GL*RYYMMDDPPSSOOT*_PC1A0000000.00
L1B	MTIR	A2GL1*YYMMDDPPSSOOT*_PM1B0000000.00
	SWIR	A2GL1*YYMMDDPPSSOOT*_PS1B0000000.00
	VNIR	A2GL1*YYMMDDPPSSOOT*_PV1B0000000.00
	SLPT	A2GL1*YYMMDDPPSSOOT*_PP1B0000000.00
	250m	A2GL2*YYMMDDPPSSOOT*_P01B0000000.00

YY: year, MM: month, DD: day, PP: RSP, SS: scene, OO: mode (OD: day, ON: night, SC: sun cal, LC: lamp cal, EC: electrical cal), T: tilt (1: 0°, 2: –20°, 3: +20°), R: 1, 1km, 2, 250m

3. L1B format

3.1 NCSA HDF

GLI data is stored in Hierarchical Data Format (HDF4.1r1) that was developed by the National Center for Supercomputing Applications (NCSA). To read HDF data by C or Fortran programs, you must install HDF libraries distributed by the NCSA WWW site on your machine. The installation procedure is described in several web sites, e.g., the NCSA web sites (http://hdf.ncsa.uiuc.edu/ in English).

3.2 Outline of GLI L1B format

GLI L1B file includes the following information.

- Inter-band and Inter-detector registered and radiometric corrected radiance [W/m^2/str/μm], which is converted to a 2-byte unsigned integer Digital Number (DN). HDF SD name is **l1b_ch[ch]_data**; [ch] is GLI channels, 1~36.
- Conversion coefficients from 2byte DN to radiance [W/m^2/str/μm]. SD name is **gsys** or **gsys_2km**, or **c1**.

- Calibration coefficients derived by Cal/Val activities. SD name is **gcal**, 1.0 at launch.
- Latitude and longitude for 12 pixel /line intervals. (**l1b_blk_lat**, **l1b_blk_lon**)
- Satellite zenith and azimuth angles for 12 pixel /line intervals (**sc_zenith**, **sc_azimuth**)
- Solar zenith and azimuth angles for 12 pixel /line intervals (**solar_zenith**, **solar_azimuth**)
- Milliseconds for each scan (**msec**)

GLI observed radiance is calculated as follows.

GLI radiance [W/m^2/str/μm]=**l1b_ch[ch]_data**$\times$**gsys[i]** ($\times$**gcal[i]***)

* **gcal** is applied only for VNIR and SWIR channels.

Relation between the “ch” and “i” is shown in Table 4.

Table 4 Correspondence of dimensions between radiance and conversion coefficients in the GLI HDF file

<table>
<tr><td>Ch.</td><td>SD_name</td><td colspan="23">Dimension</td></tr>
<tr><td rowspan="2">VNIR</td><td>l1b_ch[ch]_data</td><td>1</td><td>2</td><td>3</td><td colspan="2">4*</td><td colspan="2">5*</td><td>6</td><td colspan="2">7*</td><td colspan="2">8*</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td></tr>
<tr><td>gsys[i]</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td></tr>
<tr><td rowspan="4">SWIR</td><td>l1b_ch[ch]_data</td><td>24</td><td>25</td><td>26</td><td>27</td></tr>
<tr><td>gsys[i]</td><td>1</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>l1b_ch[ch]_data_2km</td><td>28</td><td>29</td></tr>
<tr><td>gsys_2km[i]</td><td>1</td><td>2</td></tr>
<tr><td rowspan="2">MTIR</td><td>l1b_ch[ch]_data</td><td>30</td><td>31</td><td>32</td><td>33</td><td>34</td><td>35</td><td>36</td></tr>
<tr><td>c1</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
</table>

High low gain

Sign * indicates piecewise linear channels of VNIR; Values are stored in high (ocean gain) and low (land gain) order in the “gsys”. The gain is defined at 13th bit in l1b_ch[ch]_data; high gain when 13th bit is on (1), low gain when off (0).

Table 5 shows the flag bit field in the l1b_ch[ch]_data; the lower 12 bits (0-4095) are used for observation radiance, and the higher bits are used for the flags. To use piecewise linear gain channels (CH4, 5, 7, 8), you must see bit 12 first, and apply “gsys” as shown in Table 4.

When you display “l1b_ch[ch]_data” using general visualization software, the image may seem to be reverse right and left in the case of descending paths because GLI samples earth signals in order as the scan direction shown in Figure 1 (left to right in the satellite direction). The inversion can be corrected if you project the data using geo-location information stored in the L1 file (lat and lon, or l1b_blk_lat and l1b_blk_lon).

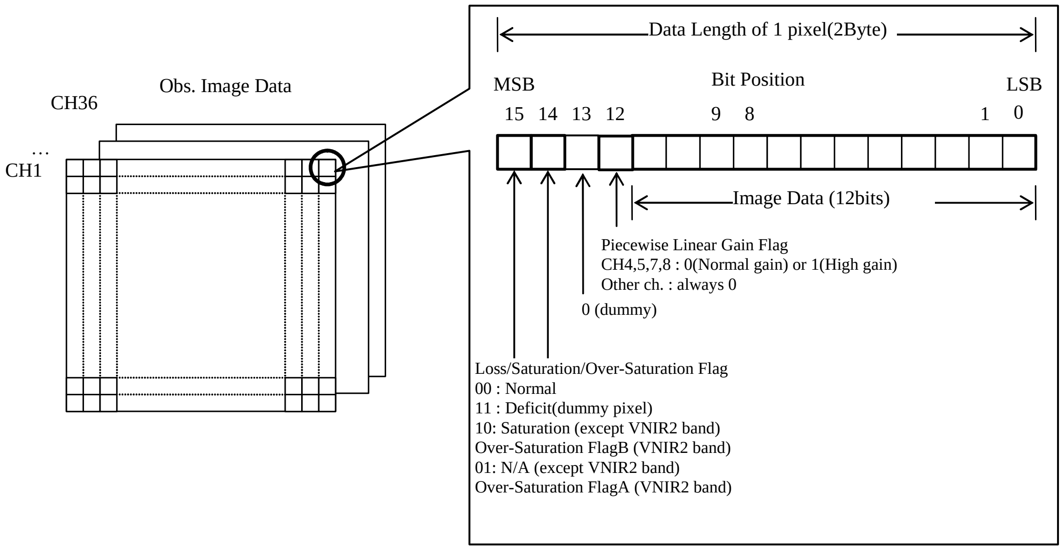


Figure 3 GLI L1B Product Flag Composition

Table 5 GLI L1B product Flag description

Position	Value	Item	Definition and description	Remarks
12	4096	Piecewise-linear gain flag	This flag is always set to 0 except for ch4, 5, 7, and 8. When the most significant bit of 13-bit data distributed from the GLI sensor is the piecewise-linear gain flag and is set to 1, high gain is indicated. When it is set to 0, normal gain is indicated for ch4, 5, 7, and 8.	Use for DN – radiance conversion
13	8192	(dummy)	always 0	
14 15	16384 32768	Loss/Saturation/Over-Saturation flag	11: Deficit Pixel(Dummy Pixel) 10: Saturation(except VNIR2), Over-saturation Status B(VNIR2(CH 10~19)) 01: N/A(except VNIR2) Over-Saturation Status A(VNIR2(CH 10~19)) 00: Normal	Deficit and saturation / over-saturation status B, pixel must not be used. Over-saturation status A flag can be used with care. (see 4.1.3 Over-saturation)

4. GLI calibration information

4.1 Radiometric performance

4.1.1 Sensor basic functions

All VNIR, SWIR, MTIR and 250m channel detectors work well as evaluations on the ground until ADEOS-II anomaly. Tilt, scan systems, and calibration functions (solar, lamp and electrical calibration) also worked well.

In this section outline of GLI product characteristics are shown. Recent status is published following JAXA/EORC web site.

http://sharaku.eorc.jaxa.jp/GLI/index.html

4.1.2 Saturation

The saturation level is almost consistent with pre-launch testing (Table 1). High-gain channels (CH 6, 9, 10, 11, 12, 14, 16, 18) and a near infrared 250m channel (CH 22) are often saturated as estimated by the pre-launch analysis. CH 13, 15, 19 and 250m CH23 are sometimes saturated at the top of high-altitude clouds where radiance exceeds specification levels. Piecewise linear gain channels CH 4, 5, 7, and 8 are rarely saturated at a part of ice clouds, possibly due to concentrated reflection of solar irradiance.

Saturation flag (over-saturation status B flag for VNIR2 channels) can be used to identify saturated pixels. These pixels must not be used.

4.1.3 Over saturation

We found that the DN of VNIR2 (CH 10~19) turns down partly in the range exceeding the saturation level (called “over saturation”, below) in the pre-launch analysis. Over saturation seems to recover gradually after it starts in a continuous saturation area. This causes a kind of “bivalent” count against radiace value. Over-saturation status A flag is used to identify the “bivalent” pixels. These pixels can be used with care.

4.1.4 Zero value of CH30

The L1B DN of CH30 (3.7μm) frequently becomes zero in low-temperature (<240K) areas distributed at the top of high-altitude clouds and in polar regions in the nighttime. One reason is that the sensitivity of 3.7μm radiance to temperature is very low and comparable to 1 DN step. Another may be a negative 0th order coefficient; L1B radiance of MTIR is derived by a second order equation of DN that is corrected by deep-space DN.

4.1.5 Stripe pattern noise

Striped pattern noise appears sometimes in GLI images. Causes are assumed to be (1) detector sensitivity normalization error, (2) mirror reflectance normalization error, and (3) electric system noise of MTIR channels.

Detector-related noise (1), which is corrected by calibration coefficients derived in the evaluation test on the ground, is relatively lower than others. In a peculiar case for CH 10-19, 22, and 23, detector signals show inconsistent values in near-saturated areas (e.g., around clouds), which produces detector-related stripe noise. These channels have non-linearity near their saturation levels. We are now investigating the calibration table for non-linearity correction using GLI Earth-observation images.

Mirror-oriented noise (2) looks like striking in some areas. The reason may be differences of A/B surface reflectance (regressed by quadratic function) between real scan-mirror and witness mirror samples. We are estimated correction parameter with statistical method and applied to current version of L1B, but some noises remain in certain area.

Electrical noise (3) appears as oblique lines at 1 to 2-pixel intervals and only on MTIR images. It also appeared in pre-launch evaluation tests, and we assumed that the reason might be a combination of electric circulation noise and sample timing of 12 detectors(see Figure 4). We are examining the possibility of correction now and not corrected yet.

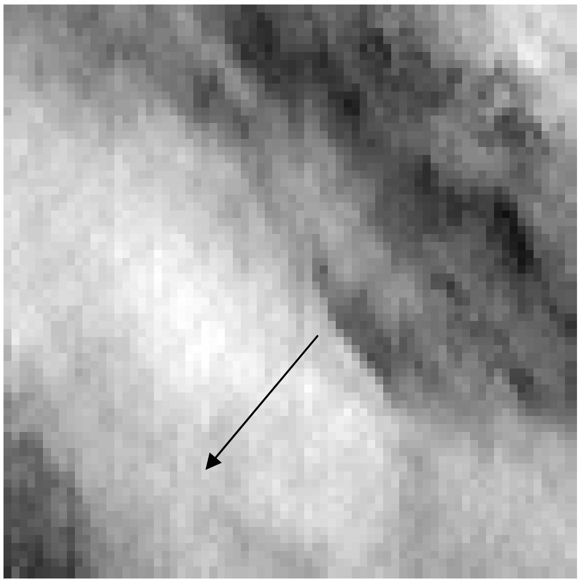


Figure 4 Example of MTIR electrical nose (L1B ch.30)

4.1.6 Stray light

Some observation data show the possibility of effection of stray light. The details are under evaluation and any corrections are not applied to current version of L1B product.

4.2 Geometric performance

4.2.1 Position Determination by Global Positioning Satellite system Receiver (GPSR)

Position determinatin accuracy of GLI is less than 1km (RMS), that corresponds to 1 pixel (1km resolution channel) or 2 – 3 pixels (250m resolution channels). GPS time (TT) derived from GPSR is used for GLI position determination.

GPSR stopped its operation several time during ADEOS-II mission time. When GPSR stopped, a time estimated from satellite time counter (ST) is used instead of TT. An estimation error is about 70 – 80m, and that is enough small compared with GLI sensor resolution.

GPSR status is identified by global attribute “GPS Flag” in product file.

Table 6 GPS Flag Description

GPS Flag	Orbit	Scan Start Time	Remarks
“OK”	GPS orbit data is used	GPS time data (TT) is used	
“NG”	External orbit file is used	GPS time data (TT) is used	
“TX”	External orbit file is used	Estimated time form ST is used	

4.2.2 Inter-band Registration

Inter-band registration is less than 0.5 pixel.

4.2.3 Geometric Shape

L1B pixels are generated from L1A by resampling because a pixel of each channels at certain line / sample number points same observation location. As resampling method, nearest neighbour is used. This causes some disturbance of smoothness, for example, coast line staggers within 1 pixel. This is not anomaly. The exmaple is shown in Figure 5.

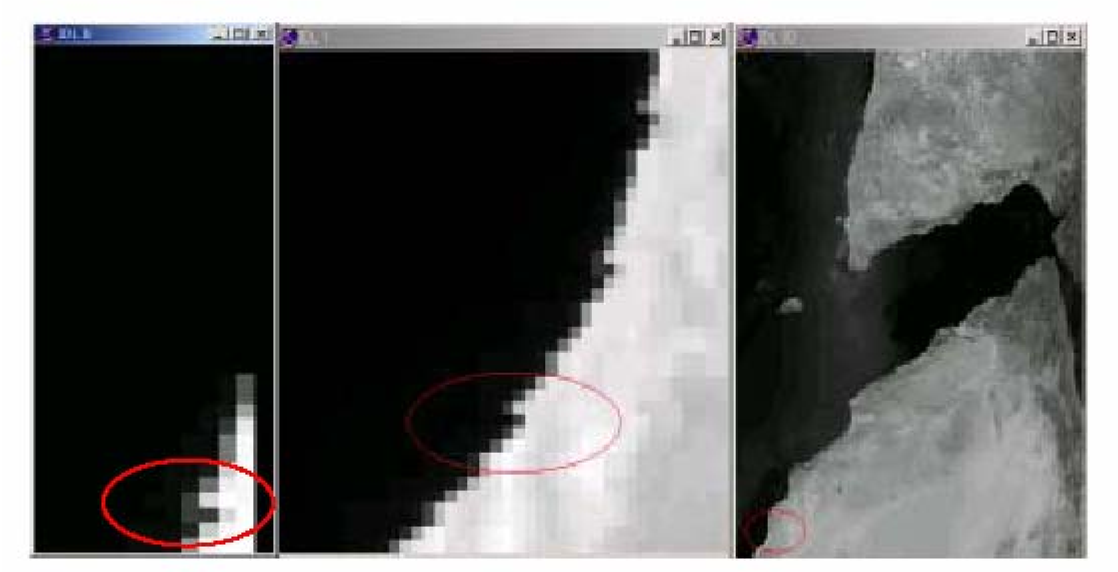


Figure 5 Coast line stagger in L1B product (1km ch.24)

4.2.4 A kind of lack at the edge of L1B image

Edge of right side in L1B image looks a little lack of data(see Figure 6). This appears only MTIR ch.30 and 36. These channels are located far from center of focal plane. This lack of data appears when no L1A pixels are corresponded to L1B pixel in the resampling procedure. This is not anomaly.

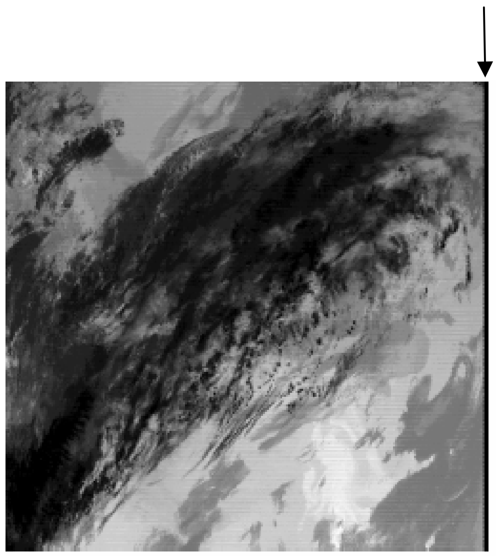


Figure 6 Example of a kind of lack at the edge (L1B ch.30)

5. About Node Crossing Time

5.1 Target Product

All Product of Level 1A, 1B, 1BMAP

5.2 Influence

In case of the pass crossing the observation date, date value of "Node Crossing Time" in global attributes should be modified like below.

Pass No.	Scene No.	Modification
01	19～26	Decrease 1day
02	01～12	Increase 1day
03	01～05	Increase 1day
57	26	Decrease 1day