ASTER GDEM Version 3
Validation Report

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Background

The ASTER GDEM was released in 2009 and updated to version 2 in 2011. The GDEM version 3 is reproduced using an updated algorithm and contains new ASTER data observed after September 2010. Validation study of GDEM version 3 was carried out to investigate its characteristics such as geolocation error, elevation error, horizontal resolution, data voids, and anomalies.

Modification of version 3

There are three modifications in GDEM version 3.

1) Algorithm update

In water body detection, GDEM version 2 could detect lakes larger than about 1km2. In version 3, it improves to 0.2km2 in version 3. Also Band3B error in northern latitude 2.5 – 4.0 degree is corrected.

2) Addition of new observed data

GDEM version 3 incorporates new 350 thousands ASTER scenes observed after September 2010. The artifacts and anomalies caused by lack of ASTER data will be improved.

3) New dataset

GDEM version 3 contains new waterbody dataset separately.

Validation Study 1 "Horizontal shift and elevation error estimation"

Validation method

The ASTER GDEM version 2 was validated against the 10 m-mesh DEM produced by the Geographical Survey Institute (GSI) of Japan. The tiles selected for validation study were N35E136, N35E137, N36E136 and N36E137 (Fig. 1). They were located in central Japan which covers sea level to very steep over 3000 m high peaks.

1. Preprocessing

Two-by-two degree study site was divided into 24 sub-areas for analysis. ASTER GDEM was resampled to 0.4 arc second grid. As the GSI 10 m DEM uses special format and special datum and it is divided into small areas, the datasets were transformed to the same format, datum and grid as the ones used for the resampled ASTER GDEM and mosaicked.

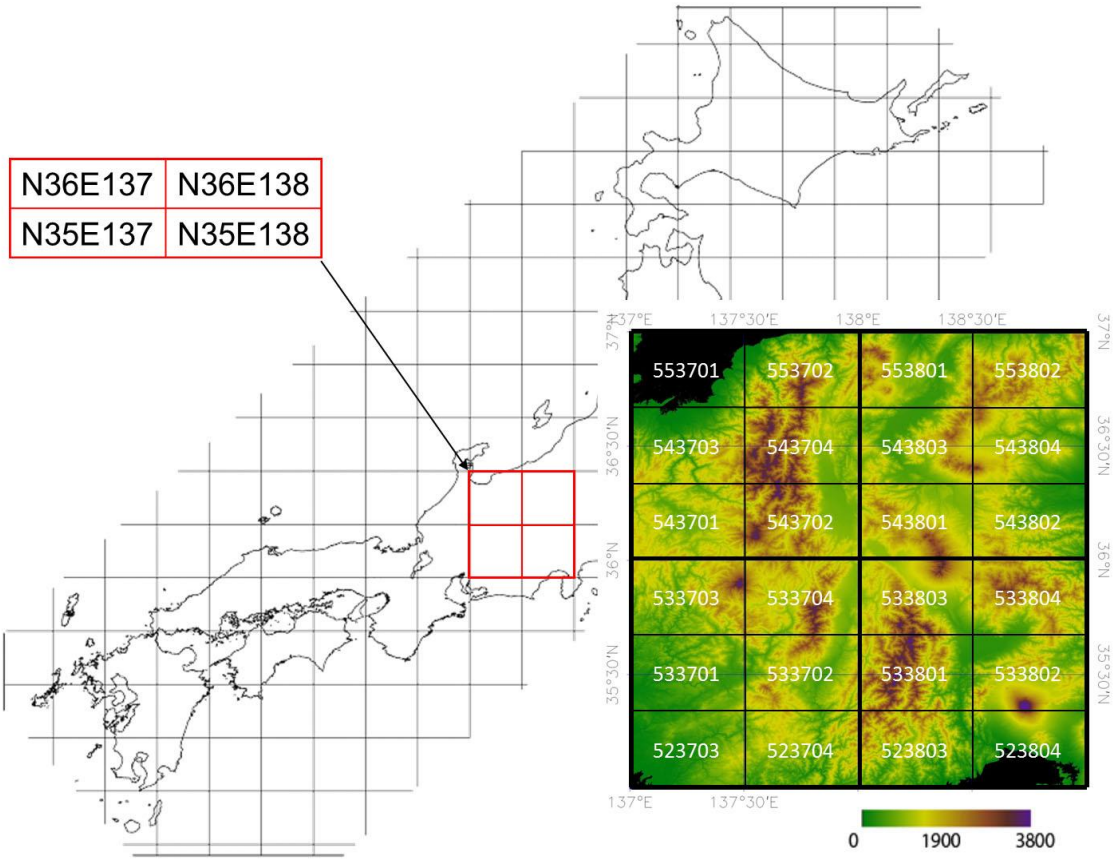

Fig. 1 Target Area

2. Horizontal shift analysis

The standard deviation of elevation difference between the ASTER GDEM and the GSI 10 m DEM was calculated by moving ASTER GDEM on the corresponding GSI 10 m DEM by 0.4 second grid basis. When geolocation of the GDEM and the GSI 10 m DEM is matched, the standard deviation of elevation residual becomes the lowest. The difference between the original position and the matched position indicates horizontal shift. Table 1 shows an example of standard deviation table. The lowest standard deviation "7.18" is observed at -3 of east-west and -4 of north-south, which means the horizontal shift is 1.2 arc-second to the west and 1.6 arc-second to the north. Then the shift in sub grid is calculated by interpolation.

3. Elevation analysis

After registration by horizontal shift, elevation error was calculated by taking the difference between GDEM and GSI 10 m DEM and statistically analyzed.

Table 1 SD table by moving

	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6
-6	7.46	7.36	7.31	7.29	7.31	7.37	7.46	7.60	7.76	7.95	8.17	8.42	8.69
-5	7.35	7.26	7.21	7.20	7.23	7.29	7.39	7.53	7.70	7.90	8.13	8.38	8.66
-4	7.31	7.23	7.19	7.18	7.21	7.28	7.39	7.53	7.71	7.91	8.15	8.40	8.68
-3	7.34	7.26	7.22	7.22	7.26	7.33	7.45	7.59	7.77	7.98	8.22	8.48	8.75
-2	7.43	7.36	7.32	7.33	7.37	7.45	7.57	7.72	7.90	8.11	8.35	8.60	8.88
-1	7.58	7.52	7.49	7.50	7.55	7.63	7.75	7.90	8.08	8.29	8.53	8.78	9.06
0	7.79	7.74	7.72	7.73	7.78	7.87	7.99	8.14	8.32	8.53	8.76	9.01	9.28
+1	8.06	8.01	7.99	8.01	8.07	8.15	8.27	8.42	8.60	8.80	9.03	9.28	9.54
+2	8.36	8.32	8.32	8.34	8.40	8.48	8.60	8.75	8.92	9.12	9.34	9.59	9.85
+3	8.71	8.68	8.68	8.71	8.76	8.85	8.97	9.11	9.28	9.48	9.69	9.93	10.1
+4	9.10	9.07	9.07	9.10	9.16	9.25	9.37	9.51	9.67	9.86	10.0	10.3	10.5
+5	9.51	9.49	9.50	9.53	9.59	9.68	9.79	9.93	10.1	10.2	10.4	10.7	10.9
+6	9.95	9.93	9.94	9.98	10.0	10.1	10.2	10.3	10.5	10.7	10.9	11.1	11.3

Validation result

Table 2 presents the validation results for 24 sub-areas from central Japan.

Table 2 Validation result for 24 sub-areas from central Japan

Sub-area ID	Horizontal Shift (arc-second)		Elevation Error (m)		
	+ EW -	+ NS -	Mean	SD	RSM
553701	-0.02	-0.05	0.47	4.32	4.35
553702	0.24	-0.03	3.07	12.64	13.01
553801	-0.04	-0.13	2.16	10.61	10.82
553802	-0.17	-0.05	4.65	11.08	12.02
543703	-0.04	-0.18	7.30	11.35	13.49
543704	0.17	-0.02	3.70	13.18	13.69
543803	-0.17	-0.20	3.74	11.41	12.01
543804	-0.20	-0.12	5.51	14.44	15.45
543701	0.16	-0.16	3.89	11.13	11.79
543702	0.12	-0.09	8.99	13.74	16.42
543801	-0.29	-0.15	3.89	11.54	12.18
543802	-0.03	-0.18	5.04	11.53	12.59
533703	0.15	-0.19	7.54	10.33	12.78
533704	0.02	-0.12	5.83	13.29	14.51
533803	-0.35	-0.11	10.87	12.06	16.24
533804	0.13	-0.15	4.54	13.08	13.84
533701	0.21	-0.21	9.91	15.92	18.75
533702	-0.07	-0.20	6.18	11.53	13.08
533801	-0.34	-0.22	7.45	13.32	15.26
533802	0.13	-0.26	9.98	13.57	16.85
523703	0.10	-0.32	4.16	9.59	10.45
523704	-0.08	-0.40	13.66	14.53	19.94
523803	-0.14	-0.33	13.39	15.90	20.78
523804	0.18	-0.47	3.82	9.03	9.80
Mean	-0.01	-0.18	6.24	12.05	13.75
SD	0.18	0.11	3.42	2.43	3.49

1. Horizontal shift

The horizontal shift in 24 sub-areas and mean are shown in Fig. 2. They ranged from -0.35 to +0.24 arc-seconds in the east-west direction and from -0.47 to +0.02 arc-seconds in the north-south direction. (The plus means shift to the east and the north.) In average the error was 0.01 arc-seconds to the east and 0.18 arc-seconds to the south and the standard deviation of 24 sub-areas was 0.18 arc-seconds in the east-west and 0.11 arc-seconds in the north-south directions. The horizontal shift in version 3 is almost the same as version 2 as a result because there is no change in both versions.

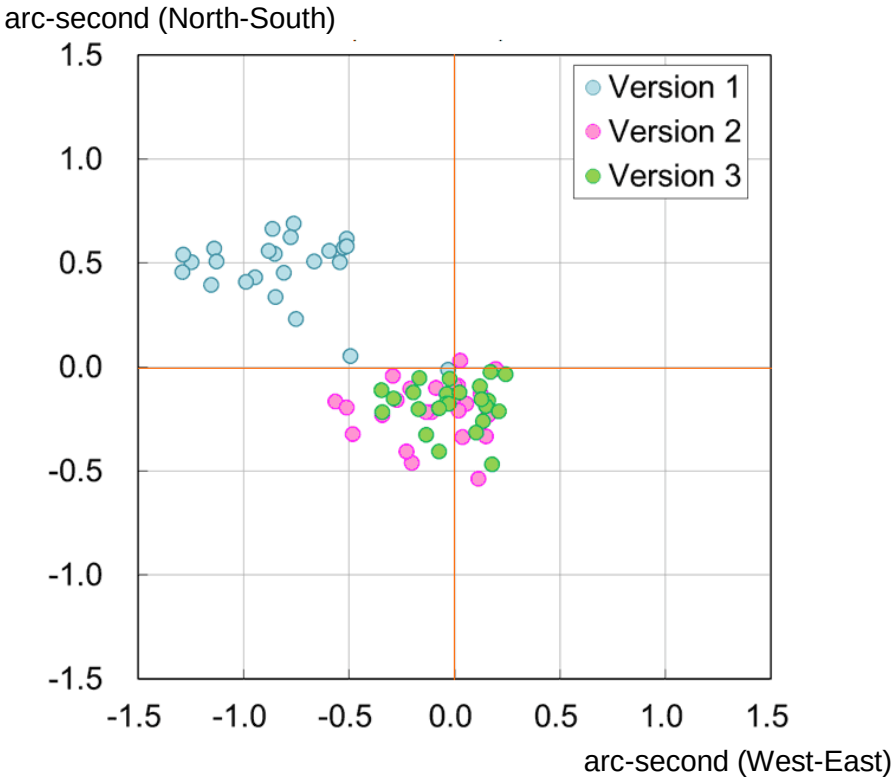

Fig. 2 Horizontal shift

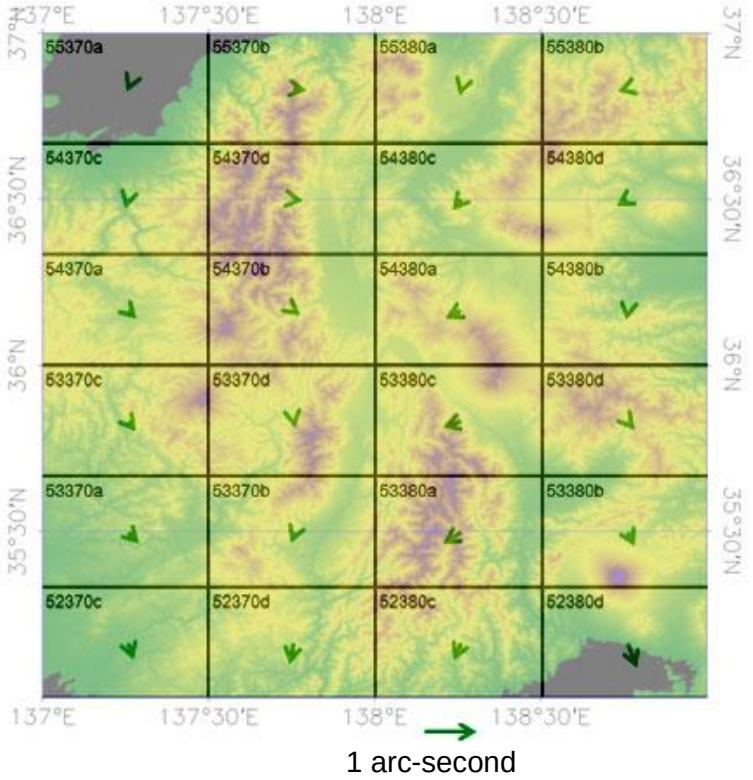

Fig. 3 Horizontal shift distribution in version 3

2. Elevation error

The mean of elevation error in 24 sub-areas ranged from -5.58 to +15.45 m with +7.4 m in average (Fig. 4) and the standard deviation (SD) from 6.20 to 16.19 m with 12.7 m in average (Fig. 5). The plus 7.4 m offset of the mean results from a forest coverage in which GDEM shows the elevation of treetop whereas reference DEM shows the elevation of ground.

Fig.4 Offset of elevation error

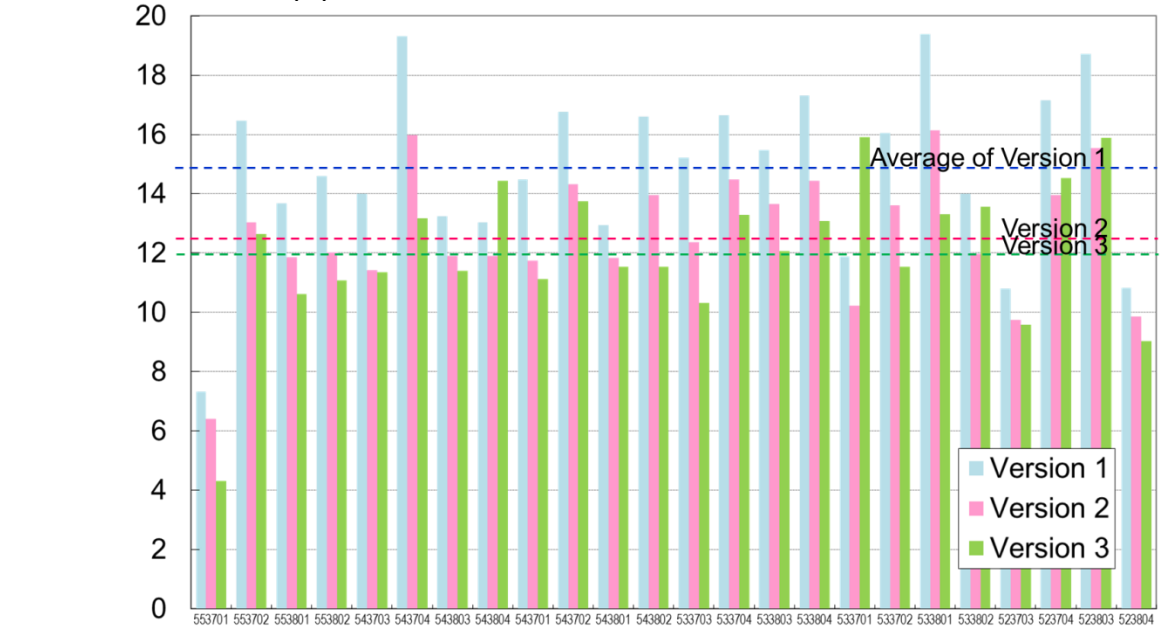

Fig.5 Standard deviation of elevation error

Validation Study 2 “Horizontal resolution estimation”

For example, Fig. 6 shows the comparison of the shaded relief images between GDEM versions 1 and 2 over the same area. The finer horizontal resolution such as version 2 shows more clear topographic features. The quantitative resolution is estimated as described below.

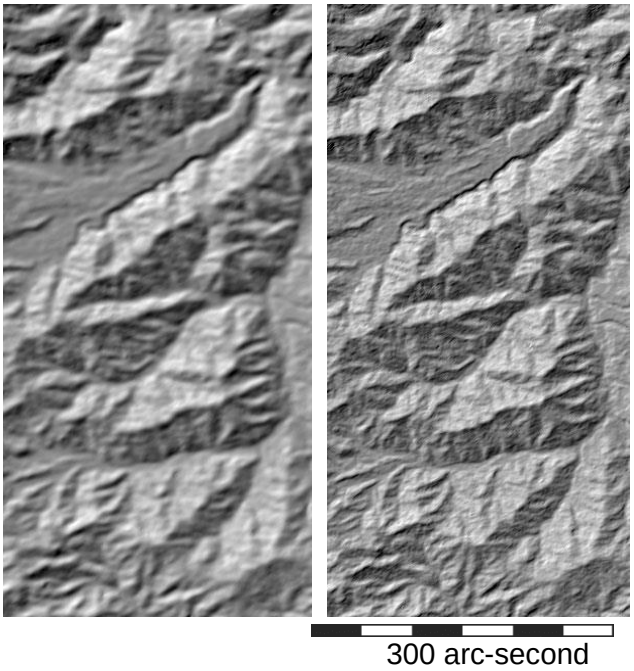

Fig.6 Comparison of shaded relief between version 1 and 2
(Left: Ver.1 / Right: Ver.2)

Validation method

DEMs with nine different resolutions, from 1 arc-second to 9 arc-second (Fig. 7), were created from the reference GSI 10 m DEM. The standard deviations of the elevation difference between GDEM and nine each resolution DEMs were calculated to determine the DEM showing the lowest standard deviation. The matched DEM resolution represents the practical horizontal resolution of GDEM.

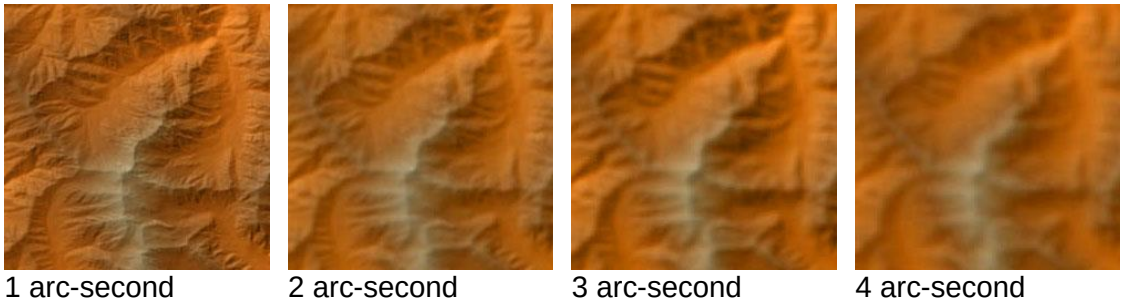

Fig. 7 DEMs with different resolutions

Validation result

Fig.8 shows the standard deviation of elevation difference between the ASTER GDEM and nine different resolution DEMs. Resampling by parabola fitting showed the lowest standard deviation near 2.4 arc-second (72 m, 1 arc-second converted into 30 m). This value is considered to be the practical horizontal resolution of the GDEM version 3. It is demonstrated that the horizontal resolution in version 3 was the same as the version 2 because the algorithm is no change. And both versions are much improved than the version 1 that indicates 3.8 arc-second (114m).

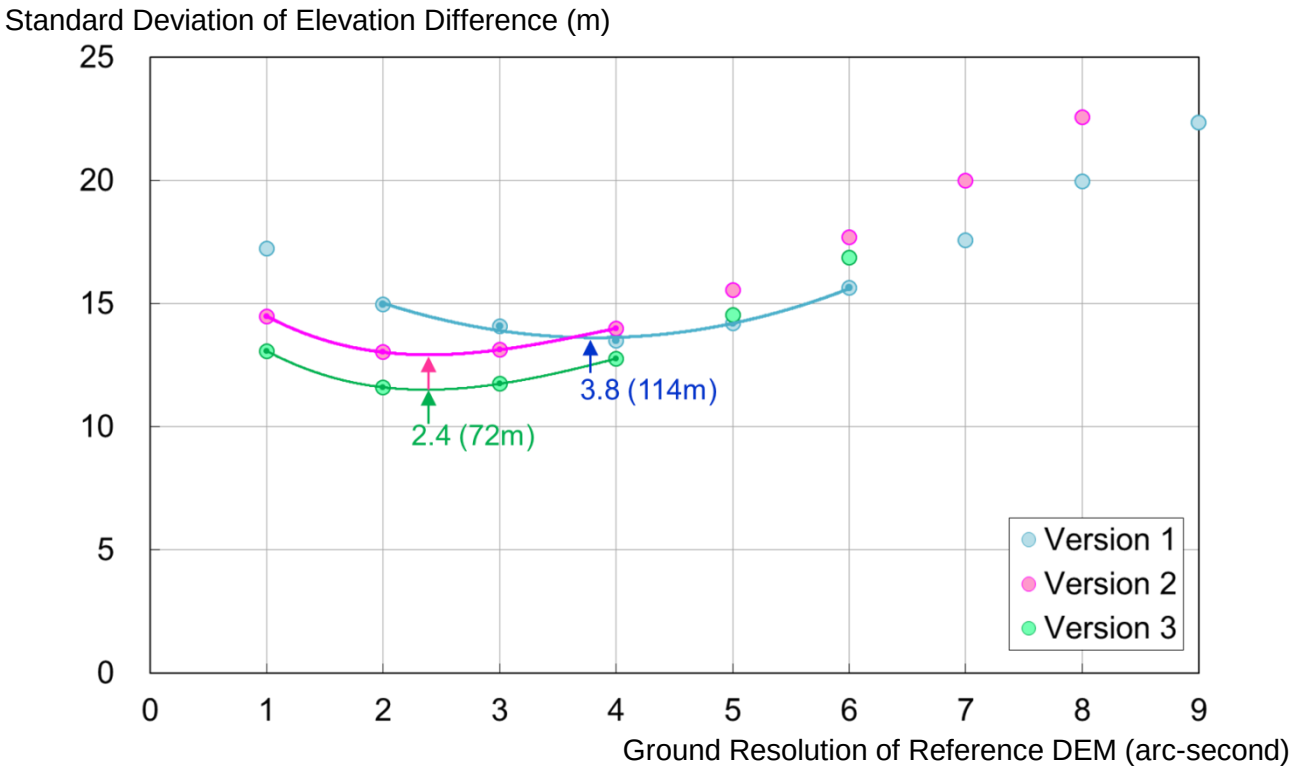

Fig.8 Estimation of practical ground resolution

Validation Study 3 “Correction of Band3B Error”

ASTER level 1A software has an error that Band3B backward viewing image data between northern latitude 2.5 and 4.0 degree shift 1 pixel. The error made abnormal DEM but it is corrected in version 3. Fig.15 shows shaded relief image in northern latitude 2.5 degree. In northern area, the abnormal DEM is improved in version 3. And Fig.16 shows the geolocation difference in north-south direction referred by SRTM. The abnormal boundary is disappeared in version 3.

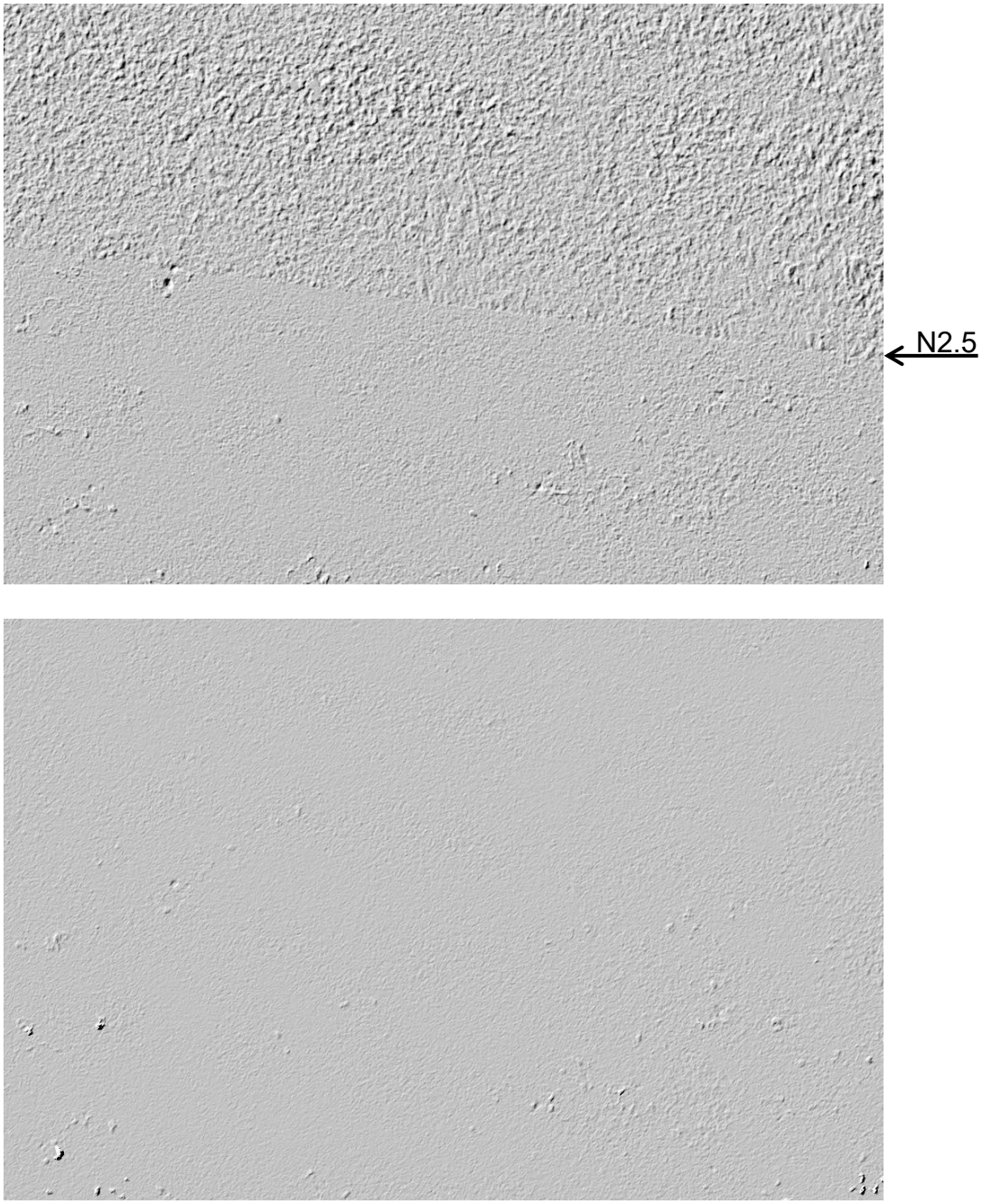

Fig.15 Comparison of shaded relief at northern latitude 2.5 degree between Ver.2 and 3
(Top: Ver.2 / Bottom: Ver.3)

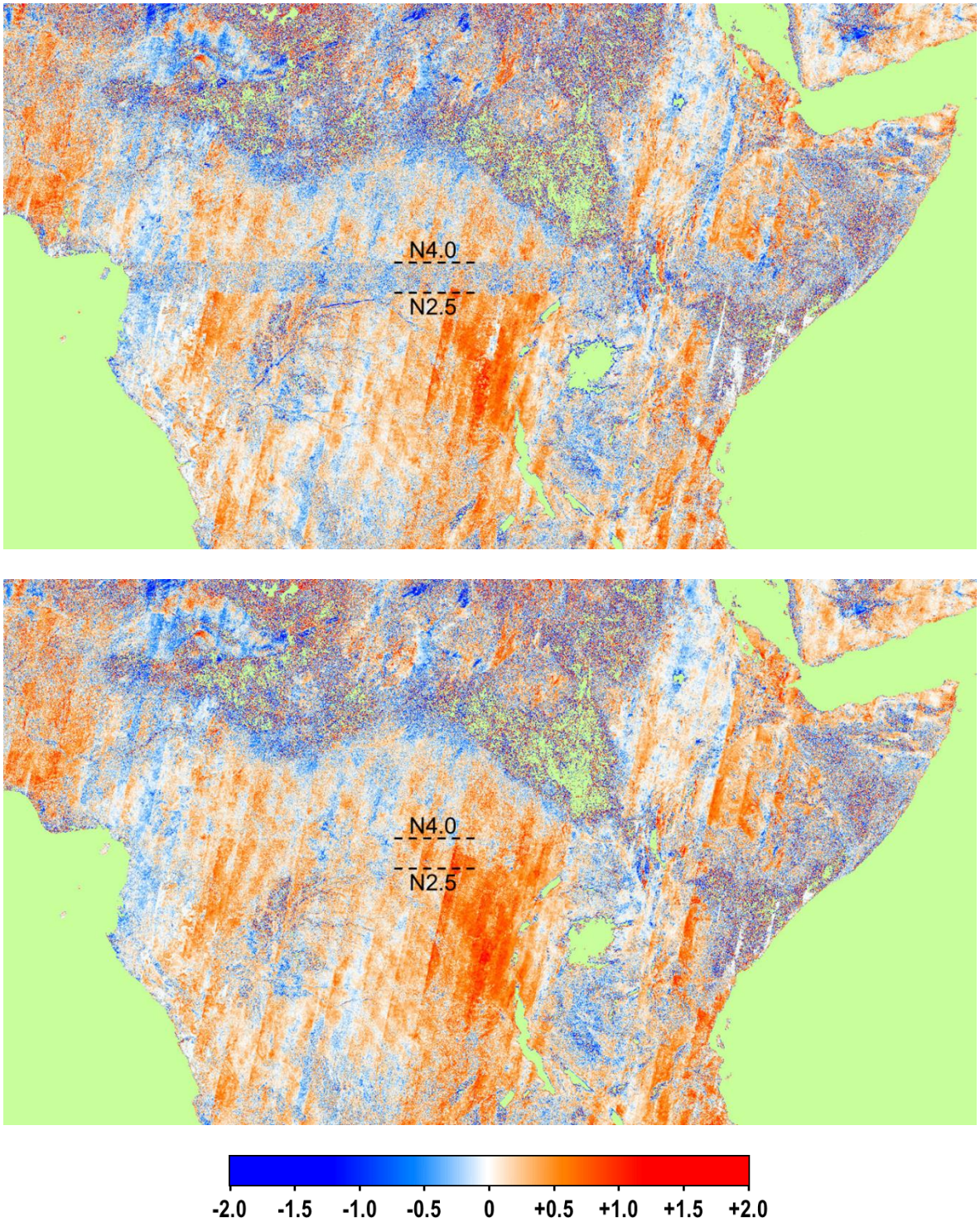

Fig.16 Comparison of geolocation error in north-south direction between Ver.2 and 3 in Africa (Top: Ver.2 / Bottom: Ver.3)

Conclusion of Validation Study

The ASTER GDEM version 1 was released in July 2009 and then updated to version 2 in October 2011. The GDEM version 3, now under processing, will be released in 2019. Validation study confirms that the horizontal and vertical error of version 3 are kept as small as version 2. And the following three improvements are obtained from the update of algorithm and addition of new ASTER data.

- ✓ The voids in northern area decreased by new ASTER data.
- ✓ The artifacts are mostly disappeared by new ASTER data.
- ✓ Band3B error in northern latitude 2.5 - 4.0 degree is corrected by the updated algorithm.