

AN ACCURACY ASSESSMENT OF DSMS AND ORTHOIMAGES DERIVED FROM ALOS/PRISM AND THEIR AVAILABILITY IN FORESTRY

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ABSTRACT:

ALOS PRISM is designed to gather 2.5m resolution triplet images to obtain accurate terrain data. The PRISM triplet images are expected to be used for generating high-precision stable Digital Surface Models (DSMs). In this study, we set two purposes. The first purpose is to generate PRISM_DSMs and orthoimages and to make an accuracy assessment of them. The second purpose is the examination of the availability of PRISM_DSMs and orthoimages in forestry. As a result, the following facts were found. The divergence between a PRISM_DSM and a LIDAR_DSM can stay within the standard deviation of 10 m in the vertical direction by adopting the bias correction. The orthoimages made from a PRISM nadir image and a created PRISM_DSM can stay within the standard deviation of 5 m in the horizontal direction. The image matching correlation differs depending on the topographical condition of the object area and the quality of the PRISM_DSM is also dependent on that. Providing one GCP for adjustment can stabilize the accuracy of a PRISM_DSM and an orthoimage. And the created PRISM_DSM well represent contours of buildings and small corrugations of mountainous areas. Concerning the second purpose, the created PRISM_DSM was ranked between the 50m mesh DEM, which was made from a 1/25000 topographic map and published from Japanese Geographical Survey Institute (GSI), and the LIDAR data, proving to be useful for tree height estimation and forest type classification in wide areas.

1. INTRODUCTION

Advanced Land Observing Satellite (ALOS) was launched by Japan Aerospace Exploration Agency (JAXA) in January 24, 2006. ALOS is equipped with three types of sensors - Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM), Advance Visible and Near Infrared Radiometer type 2 (AVNIR-2), and Phased Array type L-band Synthetic Aperture Radar (PALSAR).

PRISM has three independent cameras for viewing nadir (N), forward (F) and backward (B) producing triplet images along the satellite track. Forward and backward telescopes are inclined at +24 and -24 degrees from nadir to realize a base-to-height (BH) ratio of 1.0. The PRISM triplet images are expected to be used for generating high-precision stable Digital Surface Models (DSMs).

In this study, we set two purposes. The first purpose is to generate PRISM_DSMs and orthoimages and to make an accuracy assessment of them. The PRISM_DSMs and orthoimages were generated from triplet images. The accuracy assessment was based on the comparison with LIDAR data. Furthermore, the correlation between errors of PRISM_DSMs and topographical / landuse conditions was analyzed.

The second purpose is the examination of the availability of PRISM_DSMs and orthoimages in forestry, in which wide-area dataset are demanded concerning the problem of global warming and sustainable forest management. The tree height estimation and the forest type classification were conducted

based on the created PRISM_DSM and orthoimage. The results were compared with LIDAR data and an air photo to examine the availability of PRISM_DSMs and orthoimages.

2. MATERIAL

2.1 Study Site

Target area was set to forest area of about 11km² including Tama Forest Science Garden which is located in west Tokyo, Japan (Figure 1). Cross section to examine the availability of PRISM_DSMs for the tree height estimation was set in the middle of the target area. Area of tree height estimation was set in the northwest of the target area. Area of forest type classification was set in the east of the target area.

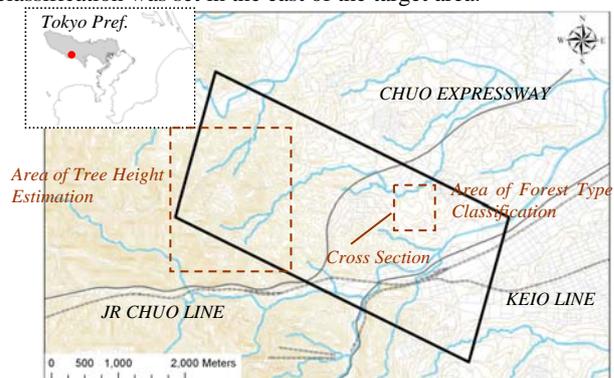


Figure 1. Study site

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2.2 Used Data

In this study, we used ALOS/PRISM level 1B1 data to generate PRISM_DSMs. In order to make orthoimages, we used an ALOS/PRISM level 1B1 nadir image and ALOS/AVNIR-2 level 1B1 data. For validation of PRISM_DSMs, we used LIDAR data acquired by the fixed-wing aircraft. In addition, we used Terra/ASTER level 3A01 (DEM) data and the Digital Map 50m Grid (Elevation) made by Japanese Geographical Survey Institute (GSI) (Table 1).

Type	Name	Level	S.R	Date
Satellite Image	ALOS/PRISM	1B1	2.5m	2007/5/8
	ALOS/AVNIR-2	1B1	10m	2007/5/8
LIDAR	RAMS	DSM DEM	2m	2005/10/14
Marketed DEM data	Terra/ASTER	DEM(3A01)	15m	2002/8/10
	Digital Map 50m Grid (Elevation)		50m	
Geoid Data	Digital Data 2km Grid (Geoidal Height)		2km	
Air Photo	RC-30	Orthoimage	0.3m	2000/12/5
Digital Map	Digital Map 25000 (Spatial Data Framework)			
	Forest Compartment Map			

S.R: Spatial resolution

PRISM SceneID F: ALPSMF054262825, N: ALPSMN054262880

B: ALPSMB054262935

AVNIR-2 SceneID : ALAV2A054262880

Table 1. Data used for this study

3. METHODS

The flow of this study is shown in Figure 2.

3.1 Generation of PRISM_DSMs

A PRISM_DSM can possibly be generated by either of two methods - the triplet matching method that uses all of three images and the stereo matching method that uses stereo pair images. Since triplet matching is redundant, it can generate a DSM with less noise than stereo matching. A PRISM sensor model is being incorporated into commercial three-dimensional measuring systems for stereo matching, and some of such systems support an RPC model. Meanwhile, the triplet matching technique has not yet been mounted in commercial systems, and the systems have not shown much progress on supporting PRISM.

Under such circumstances, NEC and Kokusai Kogyo Co., Ltd. (KKC) are promoting the development of “RSGIS PRISM-DEM”, a system equipped with the triplet matching method for PRISM. The triplet matching of “RSGIS PRISM-DEM” uses triplet redundancy to reduce matching error (Maruya and Ohyama, 2007a; Maruya and Ohyama, 2007b). F-N matching, B-N matching and F-B matching are performed independently, and only a portion of results which coincide with each other are adopted (Figure 3). Therefore, the matching method of “RSGIS PRISM-DEM” can be called “the technique which utilizes the triplet redundancy and which has a constraint condition of the error of forward intersection being small”. When making a DSM, adjustment is necessary, in general, by manually giving tie points or GCPs. However, PRISM was designed aiming at high orbit accuracy, and no significant error is considered to occur even if image matching processing is done without an adjustment process. The advantage of creating DSMs and orthoimages without the help of GCPs is considered to produce

an effect especially in a forest area with few GCPs. “RSGIS PRISM-DEM” is a prototype of an automatic DSM making system that uses such features.

In this study, we set the matching window size to 13×13 pixels and the outputting PRISM_DSM mesh size to 10 m, and we made 2 kinds of PRISM_DSMs. One was generated without using GCPs (hereinafter called “PRISM_DSM(No GCP)”), and another was generated by using 1 point GCP (hereinafter called “PRISM_DSM(1 GCP)”). Since the output Z-value is correspondent to the ellipsoid height, PRISM_DSM (No GCP) was corrected to sea surface altitude using Digital Data 2km Grid (Geoidal Height) made by GSI.

3.2 Generation of a LIDAR_DSM

Conducting equalization by using the Triangulated Irregular Network (TIN), we made the 10 m grid data (LIDAR_DSM) from LIDAR data formed as 2 m interval point clouds.

3.3 Accuracy Assessment of PRISM_DSMs

We evaluated the difference between the PRISM_DSMs and the LIDAR_DSM, and calculated error statistics such as standard deviation and mean error. In addition, we conducted relevance analysis between the errors of both DSMs and the image matching correlation, the slope azimuth and the slope angle to examine the tendency and cause of the errors.

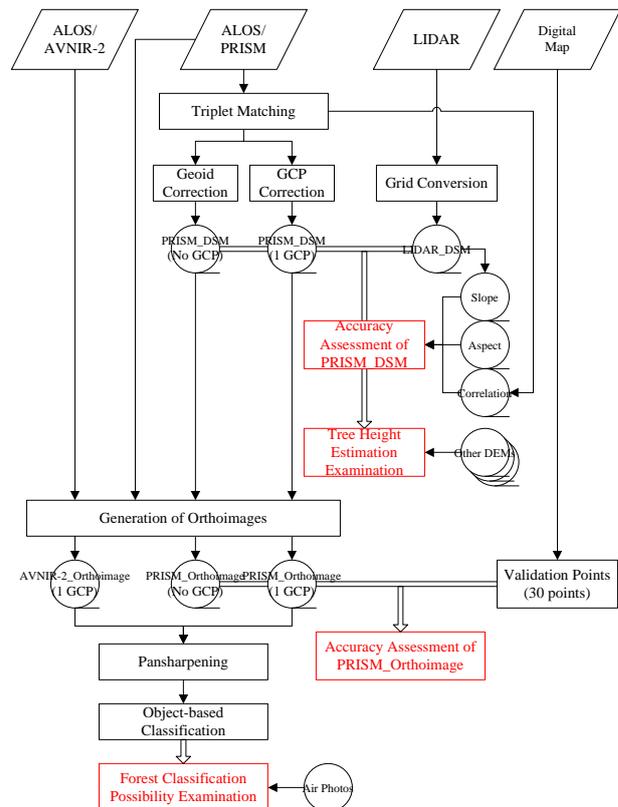


Figure 2. Flowchart of this study

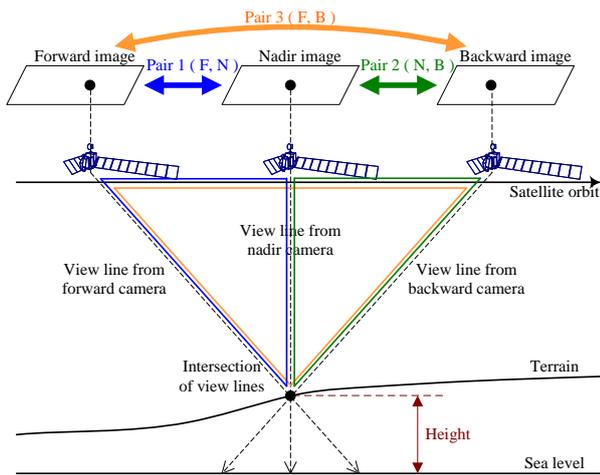


Figure 3. Algorithm of "RSGIS PRISM-DEM"

3.4 Accuracy Assessment of Orthoimages

We made orthoimages using PRISM_DSMs and a PRISM nadir image. Next, we selected 30 validation points from the road intersection points using Digital Map 25000 (Spatial Data Framework) made by GSI. And we calculated the level error of PRISM orthoimages.

3.5 Tree Height Estimation using PRISM_DSMs

At first, we compared the cross sections of PRISM_DSM, LIDAR_DSM and LIDAR_DEM in order to know which height PRISM_DSM is catching. The cross sections of ASTER_DEM and Digital Map 50m Grid (Elevation) were also examined. Next, respective average tree heights of the forest compartment were obtained by the calculation of the difference between PRISM_DSM and LIDAR_DEM, and the difference between LIDAR_DSM and LIDAR_DEM. Then, the possibility of tree height estimation using PRISM_DSMs was examined by comparing these.

3.6 Forest Classification using Orthoimages

At first, we made a PRISM orthoimage and an AVNIR-2 orthoimage using a PRISM_DSM, and a colored orthoimage of the 2.5m resolution was made by pansharpening of these orthoimages. The software used for pansharpening was ERDAS IMAGINE ver.9.1, and the HPF method was applied. Next, the forest type classification was carried out by means of the object-based classification using Definiens ver.5. Then, the possibility of forest type classification based on PRISM orthoimages and AVNIR-2 orthoimages was examined by comparing the result with the air photo.

4. RESULTS AND CONSIDERATION

4.1 Accuracy of PRISM_DSMs and Their Characteristics

Vertical error calculated from the difference result between the PRISM_DSM and the LIDAR_DSM is shown in Table 2. The mean errors were 2.65m in PRISM_DSM (No GCP) and 4.81m in PRISM_DSM (1 GCP). Though the difference result between the PRISM_DSMs and the LIDAR_DSM basically shows the normal distribution, the mode is shifting to the plus side, and some biases seem to have been applied. Then, the bias

correction was carried out using median value of the histogram, and the relative error was recalculated.

The difference between the PRISM_DSMs and the LIDAR_DSM after the bias correction is shown in Figure 4. Most of the errors were positioned within +/- 2m on the flat land, showing a high degree of coincidence. The mean errors after the bias correction were -0.36m (No GCP) and -1.07m (1 GCP). Standard deviations of the errors were 9.71m (No GCP) and 7.54m (1 GCP).

In existing study, relative error values of 5.8m (Tadono et al., 2006), 6.1m and 13.0m (Mizuta et al., 2007) and 5.5 - 6.6m (Gruen et al., 2007) are reported. The result of this study was almost equivalent to these.

Next, the relevance between the errors of PRISM_DSMs and the condition of matching and topography was analyzed in order to examine the tendency of the errors. The parameters of the relevance analysis are the image matching correlation, the slope azimuth and the slope angle. As a result, it was proven that the image matching correlation is rather worse in mountain areas than in flat areas, corresponding to the quality of a PRISM_DSM. There was a big difference between a PRISM_DSM (No GCP) and a PRISM_DSM (1 GCP) in terms of the error relevant to the slope azimuth, and it was proven that providing one GCP for adjustment can stabilize the accuracy of a PRISM_DSM.

	No Correction		Bias Correction	
	No GCP	1 GCP	No GCP	1 GCP
N	110,629	110,629	110,629	110,629
M.E	2.65	4.81	-0.36	-1.07
S.D	9.71	7.54	9.71	7.54

N: Number of grids, M.E : mean error (m), S.D : standard deviation (m)

Table 2. Validation result of PRISM_DSMs

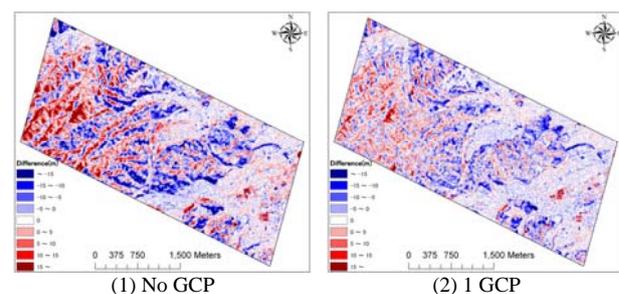


Figure 4. Difference between PRISM_DSMs and LIDAR_DSM

4.2 Accuracy of PRISM Orthoimages and Their Characteristics

Horizontal errors in 30 validation points are shown in Table 3. The mean error of a PRISM orthoimage (No GCP) was 26.60m (X: 18.14m, Y: 19.10m), and the mean error of a PRISM orthoimage (1 GCP) was 4.57m (X: -2.46m, Y: -0.12m). The standard deviation of the error of a PRISM orthoimage (No GCP) was 3.15m (X: 3.04m, Y: 3.78m), and the standard deviation of the error of a PRISM orthoimage (1 GCP) was 2.34m (X: 2.60m, Y: 3.68m). In case of a PRISM orthoimage (No GCP), there are systematic position aberrations to the

northeast direction, which lead to a large error. However, the systematic position aberrations were reduced and the accuracy of a PRISM orthoimage was stabilized when one point GCP was provided (Figure 5).

	No GCP			1 GCP		
	X	Y	Total	X	Y	Total
N	30	30	30	30	30	30
M.E	18.14	19.10	26.60	-2.46	-0.12	4.57
S.D	3.04	3.78	3.15	2.60	3.68	2.34

N: Number of points, M.E : mean error (m), S.D : standard deviation (m)

Table 3. Validation result of PRISM orthoimages

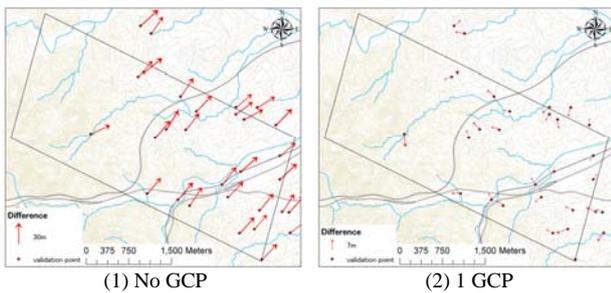


Figure 5. Residual vector map of PRISM orthoimages

4.3 The Possibility of the Tree Height Estimation based on PRISM_DSMS

PRISM_DSM, LIDAR_DSM, LIDAR_DEM, ASTER_DEM and Digital Map 50m Grid (Elevation) were compared in the cross section shown in Figure 1 (Figure 6).

The Z-value of PRISM_DSM is higher than that of LIDAR_DEM and close to that of LIDAR_DSM. However, it shows less small height changes compared to LIDAR_DSM, with a gentle change pattern in the whole. Therefore, though PRISM_DSM is considered to receive the effect of trees, it is difficult to catch individual tree and a forest gap like LIDAR_DSM, catching only an average tree crown altitude. In case of the valley, it is difficult to catch the altitude of the root, and the valley tends to be filled.

Like PRISM_DSM, ASTER_DEM is generated by image matching technique. However, the Z-value of ASTER_DEM is further averaged, since the spatial resolution of ASTER is 15m, which is 6 times lower than that of PRISM. Therefore, ASTER_DEM is catching little or no shape of the valley in some cases.

Digital Map 50m Grid (Elevation) traces the height which is approximate to that of LIDAR_DEM because it is made from the topographic map. However, the landform is shown in a staircase pattern due to the large mesh size, and the micro topography is hardly reflected.

Based on these results, it was confirmed that the PRISM_DSM is ranked between the 50m mesh DEM, made from a 1/25000 topographic map, and the LIDAR data.

Next, the tree height distribution was estimated by calculating the difference between PRISM_DSM and LIDAR_DEM in the

tree height estimation area shown in Figure 1. Then, it was compared with the estimated tree height distribution based on the difference between LIDAR_DSM and LIDAR_DEM (Figure 7). It was proven that the relative difference between every forest compartment was well expressed even in the tree height estimation result using PRISM_DSM, where the forest compartment boundaries were repeatedly shown. Average tree heights based on PRISM_DSM and LIDAR_DSM respectively were well correspondent, when calculated for every forest compartment (Figure 8).

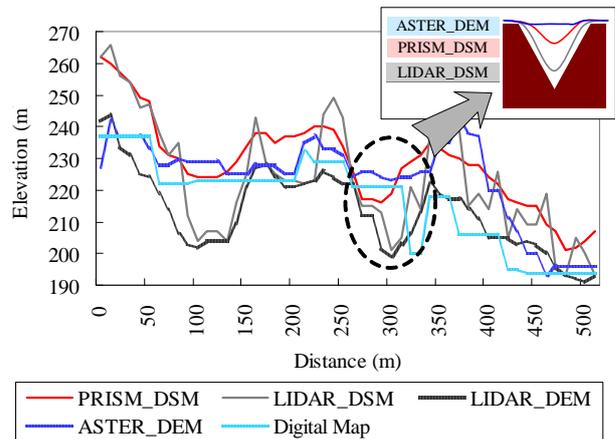


Figure 6. The sectional view of various DSMs and DEMs

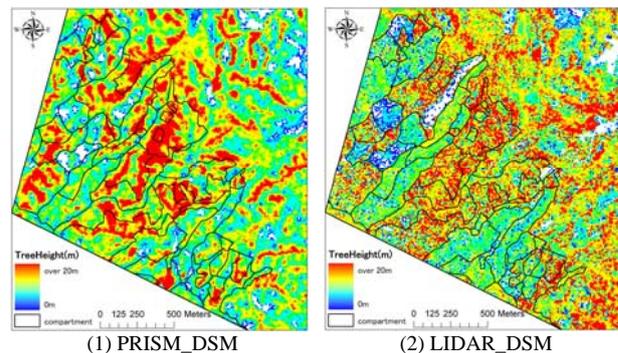


Figure 7. Tree height estimation result by PRISM_DSM and LIDAR_DSM

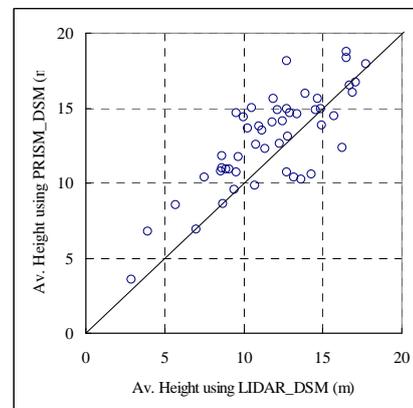


Figure 8. Comparison of average forest heights by using PRISM_DSM and LIDAR_DSM

Thus, it was indicated that PRISM_DSMs are effective for wide-area tree height estimation per forest compartment.

4.4 The Possibility of Forest Type Classification based on PRISM Orthoimages and AVNIR-2 Orthoimages

A colored orthoimage of 2.5m resolution made by pansharpening of a PRISM orthoimage and an AVNIR-2 orthoimage using a PRISM_DSM is shown in Figure 9. Observed in winter, shade and shadow is strong in the image. However, it can be found that the grassland and deciduous forest show the reddish brown due to the low plant vigor.

Figure 10 shows the comparison between the forest type classification result, obtained by the object-based classification in the forest type classification area shown in Figure 1, and the air photo. Coniferous forest, broadleaf forest and grassland were classified almost properly, and it was indicated that PRISM orthoimages and AVNIR-2 orthoimages are effective for wide-area forest type classification.

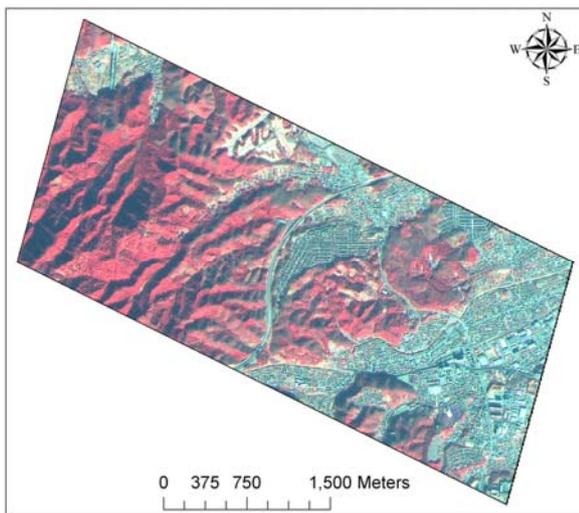


Figure 9. Pansharpen image (False color)

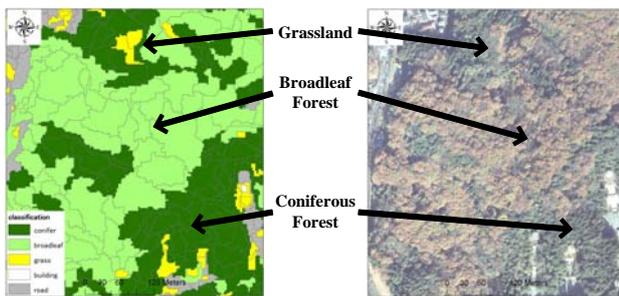


Figure 10. Forest type classification result

5. CONCLUSIONS

In this study, DSMs were generated from ALOS/PRISM images by the triplet matching method of "RSGIS PRISM-DEM", and the accuracy assessment of the PRISM_DSMs was carried out by comparison with a LIDAR_DSM. In addition, the accuracy

assessment of the orthoimages generated from the PRISM_DSMs was also carried out.

The following results were obtained.

- The vertical errors of PRISM_DSMs fall within the standard deviation of 10m by adopting the bias correction.
- The horizontal errors of PRISM orthoimages fall within the standard deviation of 5m.
- Providing one GCP for adjustment can stabilize the accuracy of a PRISM_DSM and an orthoimage.

Furthermore, the tree height estimation and the forest type classification were conducted based on the created PRISM_DSM and orthoimage. The results were compared with LIDAR data and an air photo to examine the availability of PRISM_DSMs and orthoimages in the forest area.

The following results were obtained.

- The created PRISM_DSM was ranked between the 50m mesh DEM, made from a 1/25000 topographic map, and the LIDAR data.
- PRISM_DSMs are considered effective for wide-area tree height estimation per forest compartment.
- PRISM_DSMs and orthoimages are considered effective for wide-area forest type classification.

In the future, we want to upgrade the quality of PRISM_DSMs by improvement of algorithms and post-processing. And we want to examine the possibility of mapping by incorporating the PRISM processing technology into mapping systems. In addition, we plan to promote actual utilization in various fields.

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