Revising 1:25,000-Scale Topographic Maps Using ALOS/PRISM Imagery

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Abstract

ALOS (Advanced Land Observing Satellite) was launched in January 2006, and this made it possible for the Geographical Survey Institute (GSI) to acquire high-resolution images (2.5 m) from the satellite's sensor PRISM (Panchromatic Remote-sensing Instrument for Stereo Mapping). It is expected that PRISM will be applied to the mapping and revision of 1:25,000-scale topographic maps. In collaboration with the Japan Aerospace Exploration Agency (JAXA), GSI has finished verifying and demonstrating the feasibility of PRISM images for mapping and revision of 1:25,000-scale topographic maps, and has started using the images in its mapping program. This report describes this feasibility study and details the actual applications of PRISM images for topographic mapping.

1. Introduction

Today, we live on land that has many geospatial features that are subject to frequent change. For example, when a hill is leveled for the development of a housing site, roads leading to the site are constructed at the same time. When new houses are built on the new site, a name is given to the new settlement. The list of such changes in geospatial features is almost endless. Due to this constantly changing nature of geospatial information, it is almost impossible to synchronize all changes that take place throughout the world instantaneously in a map. For this reason, GSI revises its 1:25,000-scale topographic maps by placing a priority on changes to important feature that are to be incorporated into the maps in near real-time, in order to keep them as up to date as possible.

To obtain the latest changes in geospatial information that are to be used in the revision of the 1:25,000 topographic maps, various materials supplied by local authorities, and changes in geospatial information identified through ground verification as well as from conventional information sources—including aerial photographs, are collected. However, it is difficult to take aerial photographs of the entire country at frequent intervals just as to ensure the acquisition of the latest geospatial information. In addition, materials that include the latest topographic changes and that have the accuracy necessary for the revision of these topographic maps do not necessarily exist. At the same time, acquiring all these changes through ground verification far exceeds the current capacity of existing resources at GSI. Furthermore, in the case of remote islands, it is sometimes difficult to take aerial photographs and carry out ground verification due to limited access opportunities, and due also in some cases to political issues. In consideration of these situations, the available means for real-time revision of the 1:25,000-scale topographic maps are limited.

ALOS was launched in January 2006, having as one of its main objectives the mapping and revision of 1:25,000-scale topographic maps. The satellite has an optical sensor called PRISM. Observations made by this sensor enabled us to obtain low-cost stereo images that can be used for the mapping and revision of these 1:25,000-scale topographic maps. Although ALOS/PRISM images do not measure up to aerial photographs in terms of spatial resolution, the satellite has the advantage of being able to provide the latest extensive images of geospatial features and the latest images of remote islands due to its periodical observations on a global basis.

In order to apply the ALOS/PRISM images that have these advantages to the mapping and revision of 1:25,000-scale topographic maps, GSI jointly conducted a study with JAXA on the feasibility of using the images for mapping. Based on the output of the study, we are now actually using ALOS/PRISM images as a means to revise these maps.

In this document, we present the results of this feasibility study, and actual examples of 1:25,000-scale topographic maps that were mapped and revised using ALOS/PRISM images.

2. Specifications of ALOS

One of the main objectives of ALOS is the mapping and revision of 1:25,000-scale topographic maps. In this study, images acquired by one of the sensors onboard ALOS—the optical sensor known as PRISM—are mainly employed.

ALOS is designed in accordance with the specifications shown in Tables 1 and 2. As PRISM has three optical systems that enable it to make observations in three directions simultaneously, we can make stereoscopic measurements on elevations and topographic features. However, stereo pair images can be obtained only 3.5 times a year, while monoscopic images can be obtained more frequently. However, as PRISM is an optical sensor, there are limitations, such as when clouds obscure ground features. Furthermore, in the event of disasters, PRISM's emergency operation mode gives priority to the observation of affected areas. However, even with such limitations, the frequency of satellite observations is still high enough to provide up-to-date geospatial information for the revision of 1:25,000-scale topographic maps.

Table 1 ALOS specifications

Design life		3～5 years
Orbit		Synchronous sub-recurrent orbit
	Repeat cycle	46 days
	Altitude	691.65 km
	Inclination	98.16 degree
Attitude accuracy		2.0×10^{-4} degree or less
Positional accuracy		1 m or less

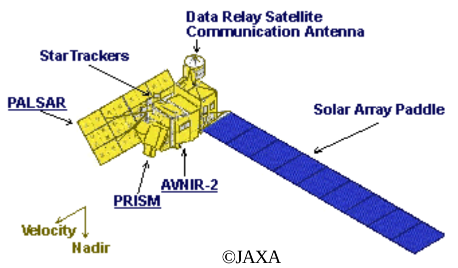

Fig. 1 ALOS overview

3. Verification of ALOS/PRISM imagery for mapping and revision of 1:25,000-scale topographic maps

The results of the verification that 1:25,000-scale topographic maps could be mapped and revised with images obtained by ALOS/PRISM are presented below.

Table 2 PRISM principal specifications

Number of bands	1 (Panchromatic)
Wavelength	0.52 to 0.77 micrometers
Optical system	3 telescopes pointing in different directions (Forward, nadir and backward views)
Base-to-Height ratio	1.0 (Between forward and backward views)
Spatial resolution	2.5 m
Swath width	35 km-width in three directions (in OB1 mode) 70 km-width in nadir view and 35 km-width in backward view (in OB2 mode)
Bit length	8 bits

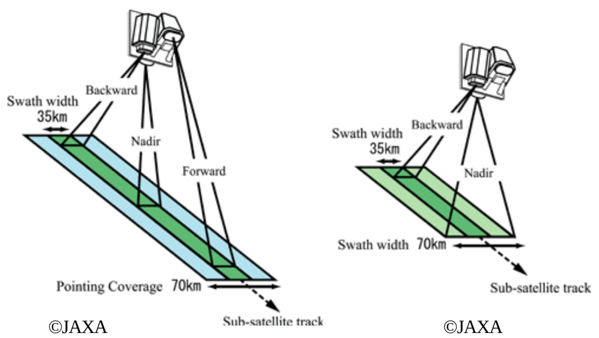

Fig.2 Observation modes
(Left：OB1 mode; Right：OB2 mode)

3.1 Verification of legibility

To map and revise 1:25,000-scale topographic maps using ALOS/PRISM images, it is necessary to collect, map and edit information on the latest geographic changes using various images—in the same way as with aerial photographs. In addition, ground verification must be conducted as needed (Fig. 3).

Therefore, we verified how much information on changes in geospatial features, which are required for mapping and revising 1:25,000-scale topographic maps, could be collected and correctly interpreted from ALOS/PRISM images.

The result of the verification revealed that large-scale geospatial features such as expressways, reclaimed land at ports and developed land could be identified without difficulty (Fig. 4). With PRISM's resolution of 2.5 m, point features or small structures such as a lighthouse at a port, a tower on developed land, and a road divider cannot often be interpreted. In addition, legibility tends to decline in a region where features are located with high density on the ground (Fig. 5). Furthermore, it is also difficult to interpret a flat land surface without structures such as vacant land, rice paddies, fields and wasteland due to the lack of clearly identifiable textures and patterns (Fig. 6).

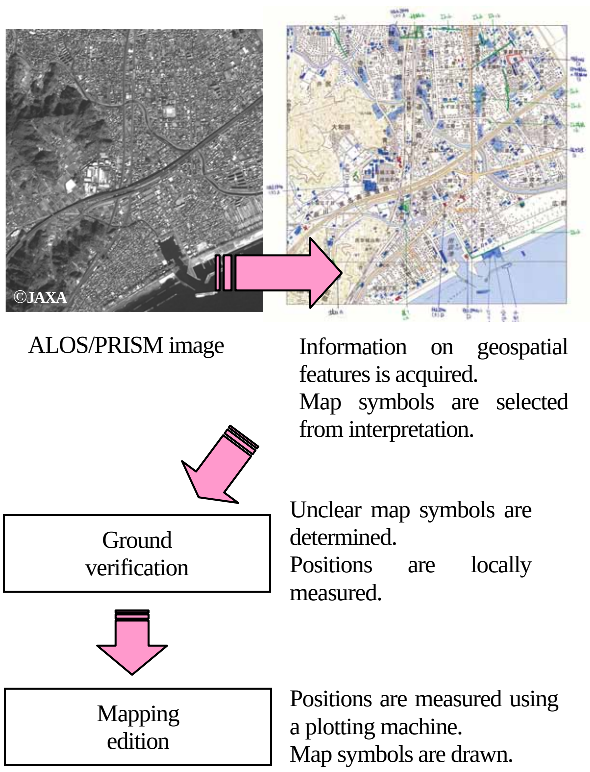

Fig. 3 Flow of preparation and revision of 1:25,000-scale topographic map

The impact on legibility depends heavily on the resolution of the images. Other factors affecting legibility include image quality such as block noise and insufficient radiometric resolution.

Block noise results from JPEG compression, an irreversible compression applied to the observed images when the image data are transferred to the ground. This noise creates a regular 8×8 pixel block pattern on the images and adversely affects legibility (Fig. 7).

Fig. 8 shows an ALOS/PRISM image without radiometric correction (sensor's sensitivity: Gain 2) and its histogram. The entire image is dim and of low-contrast because the quantization bit rate is 8 bits, and the actual radiometric coverage is almost half the entire radiometric range and compressed toward lower range.

Fig. 4 Interpretation of large structures

Fig. 5 Interpretation of a dense residential area

Fig. 6 Interpretation of ground surface

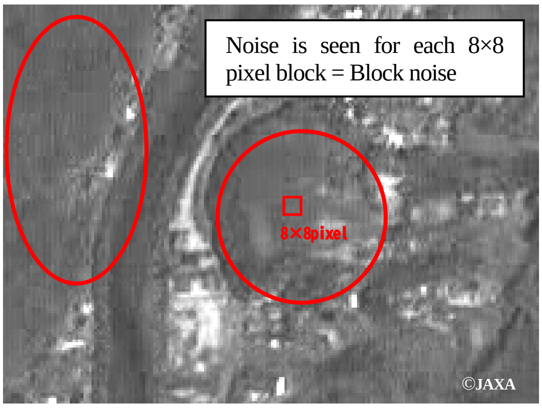

Fig. 7 Block noise

Fig. 8 Image without radiometric correction, inset shows the histogram (Sensor's sensitivity: Gain 2)

The image's resolution is fixed due to the specifications of the sensor, but the image quality could be improved. JAXA has continued to develop and utilize software for the reduction of block nose that employs a method developed by GSI, and to control the sensor's sensitivity based on seasonal changes in light intensity in order to improve the legibility of PRISM images. This has improved the image quality to some extent.

3.2 Verification of positional accuracies

GSI verified the positional accuracies for both orientation and plotting of ALOS/PRISM images (GSI, 2007). This report describes the outline of the GSI verification in Sections 3.2.2 and 3.2.3. This verification evaluates whether it is possible to apply ALOS/PRISM images (Processing level 1B1: Non-geometric corrected image) and RPC (Rational Polynomial Coefficients) data associated with the images to map and revise 1:25,000-scale topographic maps by orienting and plotting these images and data using a digital photogrammetry workstation.

The relationship between the orientation and plotting accuracies can basically be considered as shown in Fig. 9. The orientation error results mainly from an RPC data-inherent error, GCP's (Ground Control Point: High-precision control point obtained from on-site surveys) coordinates error, a measurement error of GCP and tie points (points designating common location among images) on the images and so on. A combination of these factors must satisfy the limits of orientation accuracies specified in the operational regulations for a public survey (draft) (within 12.5 m [at revision] or 7.5 m [at mapping] in the horizontal direction, and within 2.5 m in the vertical direction). Conversely, a plotting error mainly results from an error of stereo measurement. A combination of orientation and plotting errors must meet limits of plotting accuracies (within 17.5 m (RMSE) in the horizontal direction, within 5 m (RMSE) for contour lines, and 3.3 m (RMSE) for spot heights).

The accuracies of 1:25,000-scale topographic maps are also affected, though only partially, by errors introduced by displacement and symbolization of geospatial features. In this report, mapping accuracies specified in the operational regulations for a public survey (draft) are employed as the error limit values for 1:25,000-scale topographic mapping.

For reference, as the error limit values in the regulations (draft) were developed on the assumption of aerial photogrammetry, the direct application of these values to ALOS/PRISM images and other satellite images may not be always appropriate. This issue should be studied in the future.

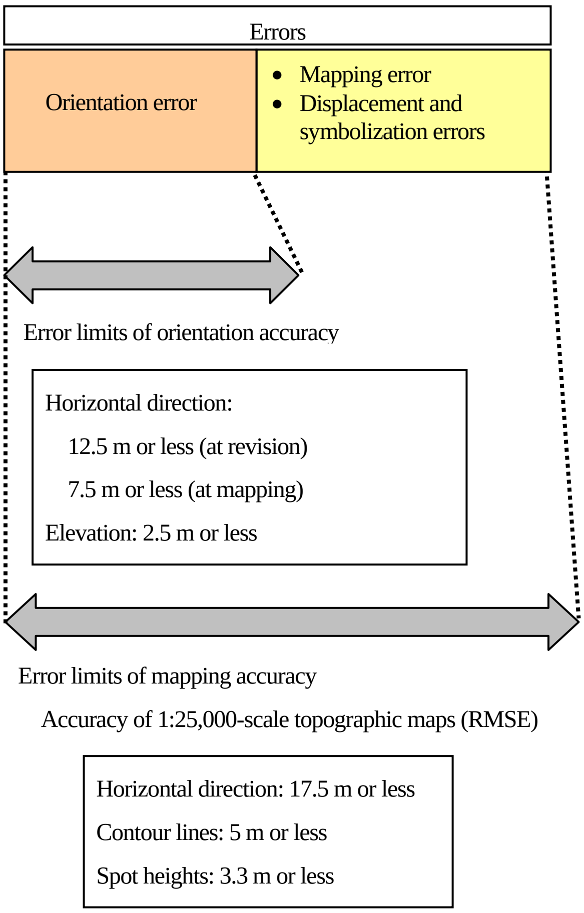

Fig. 9 Relationship between orientation and mapping accuracies of 1:25,000-scale topographic map

3.2.1 RPC model

ALOS/PRISM individual images (processing level of 1B1) have parameter files called RPC data. If these parameters are used for an RPC model expressed as a rational polynomial given in Equation (1), the relation between image and geographic coordinates can be determined with relatively high precision. If coordinates (R_1, C_1, R_2 and C_2) of the same location are measured on at least two different images, the geographic coordinates (B, L and H) of the location can be calculated.

$$R = \frac{N_R(B,L,H)}{D_R(B,L,H)} \qquad \text{(1)}$$

$$C = \frac{N_C(B,L,H)}{D_C(B,L,H)}$$

$$\begin{aligned}N_R(B,L,H) &= a_1 + a_2L + a_3B + a_4H + a_5LB + a_6LH \\ &+ a_7BH + a_8L^2 + a_9B^2 + a_{10}H^2 + a_{11}BLH + a_{12}L^3 \\ &+ a_{13}LB^2 + a_{14}LH^2 + a_{15}L^2B + a_{16}B^3 + a_{17}BH^2 \\ &+ a_{18}L^2H + a_{19}B^2H + a_{20}H^3 \\ D_R(B,L,H) &= b_1 + b_2L + \cdot\cdot\cdot + b_{19}B^2H + b_{20}H^3 \\ N_C(B,L,H) &= c_1 + c_2L + \cdot\cdot\cdot + c_{19}B^2H + c_{20}H^3 \\ D_C(B,L,H) &= d_1 + d_2L + \cdot\cdot\cdot + d_{19}B^2H + d_{20}H^3\end{aligned}$$

R, C : Image coordinates (row, column)

B, L, H : Geographic coordinates (latitude, longitude, ellipsoidal height)

a_i, b_i, c_i, d_i $(i = 1, \ldots, 20)$: Approximate coefficients of RPC model

*Latitude, longitude and ellipsoidal height are converted to projected coordinates and elevations as needed.

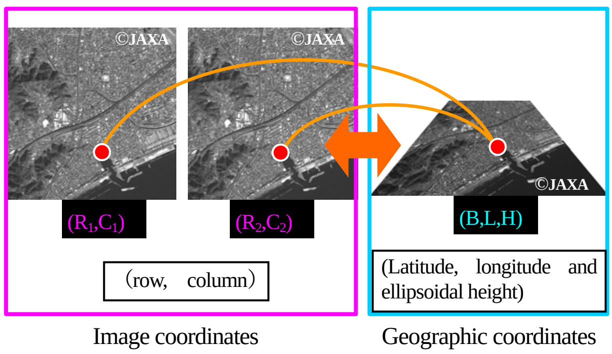

Fig. 10 RPC model

When geographic coordinates are calculated using Equation (1) in the previous section, these coordinates contain errors to some degree (a few meters to a few tens of meters in RMSE). An approximate expression with higher accuracy can be obtained by giving additional parameters to the above equation and determining the coordinates using GCPs. Shift parameters in the row and column directions on each image are added to Equation (2) as an additional factor.

$$R + s_R = \frac{N_R(B,L,H)}{D_R(B,L,H)}$$

$$C + s_C = \frac{N_C(B,L,H)}{D_C(B,L,H)} \quad (2)$$

s_R, s_C : Shift parameters (row and column directions)

When this expression is used, at least one GCP is required to determine the shift parameters.

The following section describes the verification of orientation accuracies using this approximate expression.

3.2.2 Verification of orientation accuracies

In order to verify ALOS/PRISM's orientation accuracies, GCP-based orientation tests were conducted in three regions, Tsukuba, Okazaki and Sakurajima. For each of these verification test sites, the number of GCPs to be used for orientation was varied. Assuming that the coordinates at verification points (points obtained from on-site surveys to verify orientation accuracies and not used for orientation) are true values, residuals of coordinates measured on an oriented image were calculated (Table 3).

Table 3 Orientation accuracies

Unit : m (RMSE)

Number of GCPs		None	1	3	6
Tsukuba	Horizontal direction	18.25	2.34	2.08	2.11
	Vertical direction	11.06	2.51	2.34	2.18
Okazaki	Horizontal direction	3.89	3.85	2.85	2.87
	Vertical direction	4.67	2.51	2.23	2.13
Sakurajima	Horizontal direction	5.69	2.72	2.82	3.06
	Vertical direction	9.07	3.26	2.38	2.43

Due to greater errors and their variations among different test sites for the orientation without GCPs, it can be seen that GCPs are required for orientation when 1:25,000-scale topographic maps are to be mapped and revised using ALOS/PRISM images. Three GCPs or more significantly reduce error variations within a range of about 2-3 m and 2-2.5 m in the horizontal and vertical directions, respectively.

Based on these results of verification as well as the previous findings with photogrammetry, in order to satisfy the operational regulations for a public survey (draft), the orientation must be made as follows (Fig. 11).

-On the assumption of 100% overlap between the images, and the three-point method for aerial photographs, nine tie points are to be selected uniformly on each entire image scene.

-Obtain about six GCPs in consideration of redundancy to ensure the orientation accuracies specified by the regulations

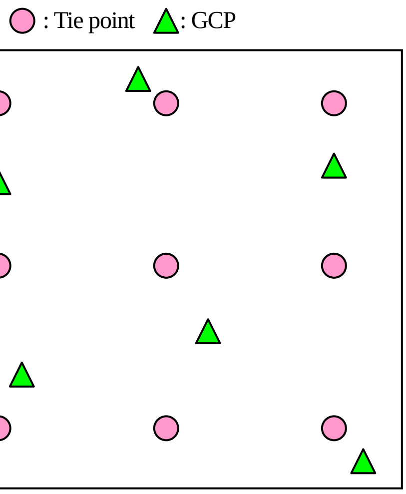

Fig. 11 Configuration of tie points and GCPs

3.2.3 Verification of plotting accuracies

Under the following three types of verification, plotting accuracies of ALOS/PRISM images oriented using RPC data were measured.

1) Horizontal accuracy of plotting

Roads, rivers and buildings in two regions, Okazaki and Mikawawan, were stereoscopically plotted. Next, the horizontal accuracy was calculated on the assumption that plotted data using 1:20,000-scale aerial photographs are true to verify the accuracy of the plotted data using ALOS/PRISM images (Table 4). For the comparison of plotted data, the coordinates of road centers, road ends, river centers, shorelines, building corners and so on were measured.

In Table 4, it can be seen that plotting errors (RMSE) in roads, rivers and buildings satisfy the plotting accuracy limit (within 17.5 m in the horizontal direction in RMSE).

Table 4 Plotting accuracy (horizontal direction)

		Residual (m)	
		Okazaki region	Mikawawan region
Road	SD	2.03	4.39
	RMSE	4.14	7.38
	max.	8.18	18.64
River	SD	1.97	2.61
	RMSE	4.92	9.67
	max.	7.56	15.67
Building	SD	1.28	0.56
	RMSE	4.77	5.91
	max.	7.52	6.45

SD: Standard Deviation

2) Vertical accuracy by plotting

Errors in the vertical direction were calculated by comparing the spot height values that were measured by stereo plotting of the ALOS/PRISM images with the elevation values measured on 1:20,000-scale digital aerial photographs (Table 5). This verification was conducted in the Mikawawan region. In addition, for the measurement of spot heights, centers of white cross lines drawn in road intersections, where elevations are easily measured, were used.

From Table 5, it is seen that errors of spot heights (RMSE) reach 4.62 m in forward-nadir views and 3.12 m in forward-backward views, and the plotting errors substantially exceed the limit of elevations in the forward-nadir views (within 3.3 m at RMSE). Consequently, it was decided that it was not suitable to acquire spot heights by stereo plotting of ALOS/PRISM images.

Contour lines can be plotted because their errors meet the accuracy limit (within 5 m at RMSE), but it is necessary to plot the lines carefully due to their fairly large errors. The closest attention must be paid when contour lines are drawn with stereo pair images of forward (or backward)-nadir views that have a smaller B/H ratio (B/H ratio=0.5) than forward-backward views (B/H ratio=1.0) because it was confirmed that the errors became larger with smaller B/H ratio.

Table 5 Mapping accuracy (vertical direction)

		Residual (m)	
		Forward - Nadir	Forward - Backward
Spot height values	SD	2.45	1.83
	RMSE	4.62	3.12
	max.	8.56	5.99

3) Quality of topographic features represented by contour lines

Fig. 12 shows a combination of two sets of contour lines from the Mikawawan region drawn by stereo-plotting of ALOS/PRISM images and aerial photographs. By making a comparison between these contour lines, the quality of the topographic features represented by the contour lines plotted with ALOS/PRISM images was qualitatively verified.

The contour lines plotted with ALOS/PRISM images could not depict minute topographic features—unlike those plotted with aerial photographs. However, the ALOS/PRISM contour lines by and large depict topographic features required for the mapping of 1:25,000-scale topographic maps.

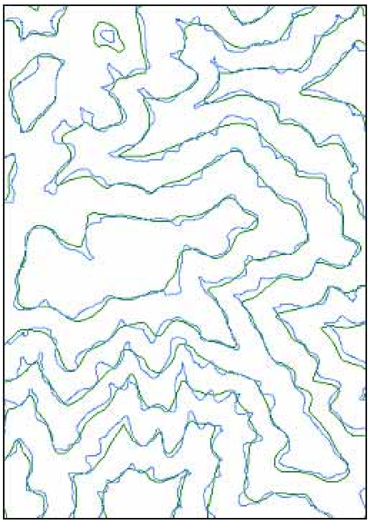

Fig. 12 Comparison of plotted contour lines (Only index contour lines in the Mikawawan region)

※ Blue and green lines represent contour lines plotted from 1:20,000-scale aerial photographs and ALOS/PRISM images, respectively.

4. Demonstration for revision of 1:25,000-scale topographic maps

The verification in Section 3 revealed that

1:25,000-scale topographic maps could be mapped and revised using ALOS/PRISM images, but with partially conditional legibility and positional accuracies.

However, it is necessary to review the adequacy of legibility and positional accuracies meeting the requirements of the operational regulations for a public survey (draft), and also the efficiency and performance of actual works, in order to actually use them on a full scale. Therefore, the following demonstration activities were implemented.

4.1 Consideration on orientation method suitable for actual operations

The result of the verification in Section 3.2.2 is that the number of tie points required was nine, and that the number of GCPs required was six.

It does not take a lot of time and labor to measure nine tie points with a digital photogrammetry workstation. But the orientation of one image scene with spare points requires that more than six GCPs should be measured on the ground. In light of the extent of one full scene (35 x 35 km) and the distance required to travel in the area, this requires significant time and labor. For this reason, an orientation method that minimizes ground measurements and provides a practical workload was developed.

From Table 3, it is seen that the orientation with one GCP in the horizontal direction sufficiently meets the limits of the regulations (draft). Because the limit for the vertical direction is more rigorous than that for a horizontal direction, however, methods must be devised to constantly ensure sufficient vertical accuracy.

Hence, assuming that only one GCP is available from the ground measurement, we examined a method for using elevation information on a 1:25,000-scale topographic map to ensure vertical accuracy. It is easy to find appropriate elevation values on 1:25,000-scale maps for an area as large as an ALOS/PRISM scene, which reduces the workload of GCP acquisition on the ground.

Fig. 13 represents a graphic plot of coordinate residuals that were measured on the image rectified with the use of one GCP and a number of spot heights (varying from one to 10 points) and with coordinates at verification points as true values. The result shows that sufficient vertical accuracy could be achieved with three or more spot heights measured on the topographic maps. Also in consideration of the results in Section 3, the following orientation method could be employed to ensure the orientation accuracies specified in the regulations (draft) and enable operational mapping activities (Fig. 14).

- On the assumption of a thee-point method for aerial photographs, nine tie points must be obtained uniformly on the entire scene based on almost 100% overlapping.
- The orientation must be made with at least one GCP, and at least five spot heights on 1:25,000 topographic maps.
- One GCP can be placed on any position of the image, but the GCP and spots heights must be uniformly configured through the image scene.

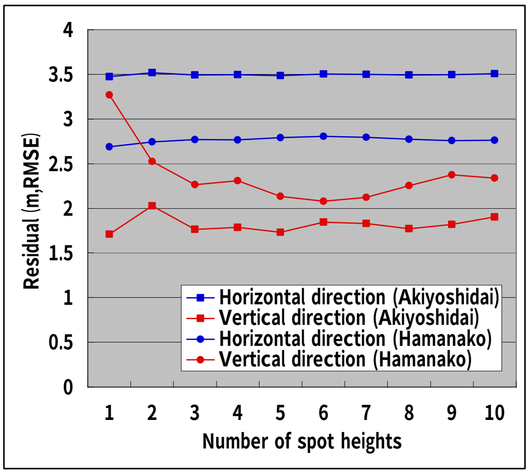

Fig. 13 Residuals of orientation with a number of spot heights

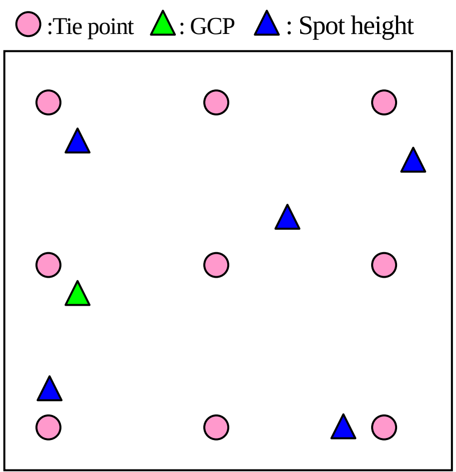

Fig. 14 Configuration of tie points and spot heights for operational mapping

4.2 Consideration as to work efficiency and performance

In the verification of legibility in Section 3.1, it was concluded that small structures and other minute geospatial features could not be interpreted in ALOS/PRISM images due to the limitation of spatial resolution of 2.5 m and the effects of systematic noise on image quality, but it was found that changes of large geospatial features can be identified with decent interpretation.

Here, in order to review the efficiency and performance of the work required for the revision of a 1:25,000-scale topographic map, ALOS/PRISM images in the area of Yamato, Sendai, were rectified, and initial change detection (extraction of changes in geospatial features and interpretation of the images), ground verification and plotting were conducted using the same process as in actual map revision procedures. For comparison, the same procedures were taken for 1:20,000-scale color aerial photographs.

If aerial photographs, as one of the main traditional means of map revision, and ALOS/PRISM images are separately used for the work, and the aerial photographs-based result is compared with the ALOS/PRISM-based result, the efficiency and performance of work using ALOS/PRISM images can be evaluated.

The result of initial change detection, as described in the results on the verification of legibility, indicated that while some types of features, depending on their size or conditions, were difficult to interpret in the images, large geospatial features could be identified almost without problems (Fig. 15), and the initial change detection procedure was successfully completed. Due to the fact that the images have more hard-to-interpret features than the aerial photographs, the time required to organize and summarize the results of the change detection shown in Fig. 15 is slightly increased. However, this factor is not considered to greatly affect the efficiency and performance.

Next, in order to review the efficiency of ground verification, hard-to-interpret features were checked in the field to compare the number of the locations with travel distances and times during the ground verification (Table 6). The ALOS/PRISM images had many locations that needed to be checked in the field, but the total travel distances to these locations were almost the same for both cases. For this reason, the time required for ground verification of the ALOS/PRISM images was not greatly different from that of the aerial photographs, resulting in the same work efficiency and the same output as aerial photographs. However, those areas with many hard-to-interpret features due to crowded features in residential areas required a lot of time for ground verification, and were found to be inappropriate for the work using ALOS/PRISM images.

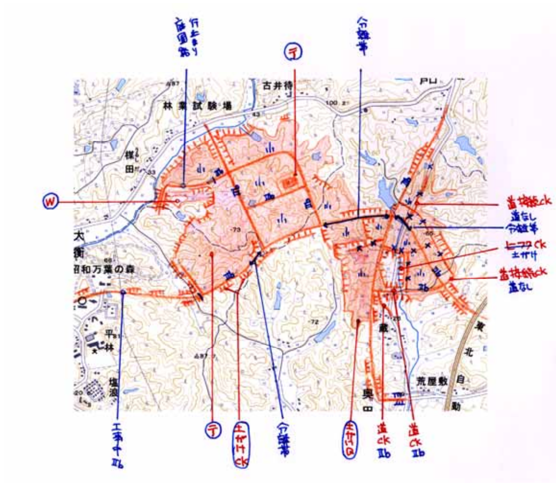

Fig. 15 Results of initial change detection and ground verification with ALOS/PRISM images (Red:Initial change detection; Blue: Ground verification)

Table 6 Comparison of efficiencies of ground verification

ALOS/PRISM images	Aerial photographs
Hard-to-interpret features: 27	Hard-to-interpret features : 15
Travel distance : 11 km	Travel distance : 11 km
On-foot investigation time : 25 min.	On-foot investigation time : 20 min.
Time required for ground verification : 72 min.	Time required for ground verification : 61 min.

When the plotting result from ALOS/PRISM images were compared with that from aerial photographs (Fig. 16), it was found that the ALOS/PRISM images could not provide the exact shapes of changes such as the minute geometries of buildings, and the absence or presence of small steep soil slopes as much as the aerial photographs, but it was also demonstrated that features with a size required for revision of a 1:25,000-scale topographic map could be identified and plotted without much difficulty. However, features that cannot be clearly identified require some time for evaluation, and potentially additional ground verification, which would reduce work efficiency. Before plotting, it is necessary to ensure thorough ground verification and collection of references, and establish map symbols to be drawn.

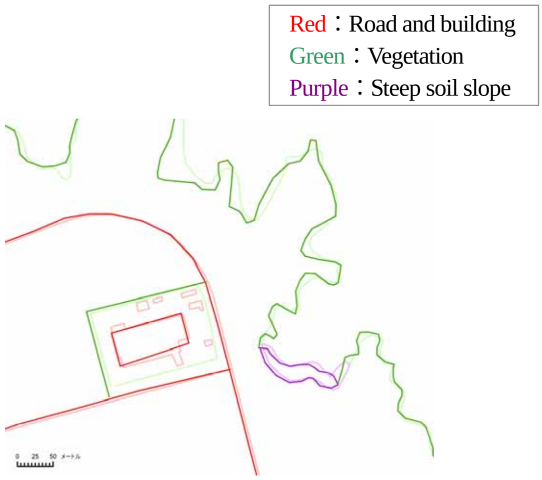

Fig. 16 Comparison of plotted results
(Deep color : ALOS/PRISM image; Light color: Aerial photo)

If ground verification of areas with non-dense structures is correctly made with a focus on large-scale features with ALOS/PRISM images in a series of revision process of initial change detection, ground verification and plotting, the 1:25,000-scale topographic maps can be revised with almost the same efficiency and performance as with aerial photographs.

5. Applications of ALOS/PRISM images

GSI introduced a digital photogrammetry workstation that employs the RPC model in March 2008 to support the more efficient development and revision of 1:25,000-scale topographic maps, and started full-scale use of ALOS/PRISM images.

We reviewed advantages of ALOS/PRISM images that can serve as a means for more effective and efficient revisions of 1:25,000-scale topographic maps, in comparison with various other methods such as aerial photographs, reference maps and on-site surveys (Table 7).

Table 7 Applications of ALOS/PRISM images

Applications \ Preparation and revision methods			ALOS/PRISM's images: Single image mapping	ALOS/PRISM's images: Stereo mapping	Aerial photographs	References, site surveys, etc.
Available new aerial photos			×	×	○	×
Unavailable new aerial photographs	Processing of contour lines (Large developed land, cut-and-fill road, etc.)		×	○	—	△
	Non-processing of contour lines (Port reclamation, river repair, etc.)	Many large changes	△	○	—	△
		Few small changes	○	△	—	△
	Locations where aerial photographs are hard to take and on-site surveys are hard to conduct		△	○	—	×

○ : Acceptable
△ : Approved (Partially approved)
× : Unacceptable, not approved
※ It should be noted that the criteria are not absolute.

When there are new aerial photographs available, they should be used as they have a higher resolution and greater versatility than ALOS/PRISM images and are easily processed. On the other hand, when contour line processing is needed, the contour lines are not often represented in reference maps and may not be easily obtained even through on-site surveys. In addition, sometimes a great deal of large changes cannot be supported by reference maps and on-site surveys. When changes of ground features are relatively small, no reference maps exist in most cases. In these cases, the map can be revised in an effective manner by using ALOS/PRISM images. In cases where it is difficult to take aerial photographs from an airplane, and where an inaccessible and isolated land is being investigated, ALOS/PRISM images and other satellite images are effective in revising maps.

6. Examples of application for revision of 1:25,000-scale topographic map

6.1 Example of collection of changes of geographic information

As the information in 1:25,000-scale topographic maps becomes outdated over time, it is necessary to revise changed features. For the revision of a map, as shown in Fig. 17, these changed features are extracted, while the features are interpreted to find out what have changed. Because of the wide-area coverage of ALOS/PRISM images that are frequently acquired at regular intervals, it is possible to effectively collect the changes of features for the revision of the 1:25,000-scale topographic maps.

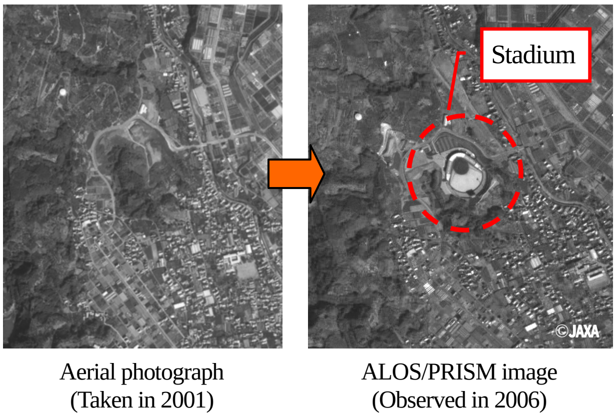

Fig. 17 Example of change detection with ALOS/PRISM imagery

6.2 Example of revision of 1:25,000-scale topographic map

If changed features are collected from ALOS/PRISM images, and map symbols for the changed features are determined from ground verification and reference maps, the map symbols are drawn at proper positions to complete the revision of a 1:25,000-scale topographic map. Some examples of map revision with ALOS/PRISM images are given below.

6.2.1 Example of map revision using a single ALOS/PRISM image

When the changed features are located on relatively flat ground, one ALOS/PRISM image is enough to revise a map based on the changed features by overlaying the map on top of the image with a map-compilation software application and tracing the changed features. Figs. 18 and 19 show a large building and a road that were detected as changes using a single ALOS/PRISM image and used to revise 1:25,000-scale topographic maps. ALOS/PRISM images have the advantage of making map revision easier and simpler than aerial photographs, which require a digital photogrammetry workstation for orientation and stereo plotting.

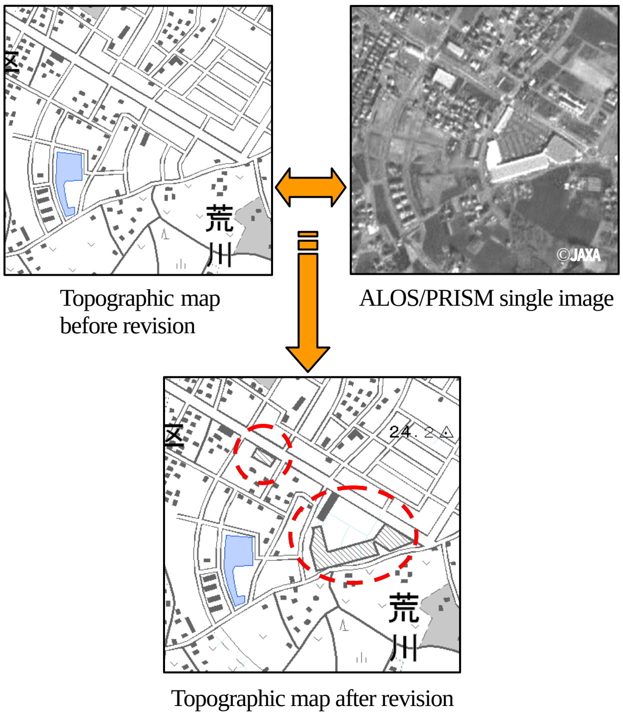

Fig. 18 Map revision of a large building using a single image (1:25,000-scale topographic map “Tsuchiura”)

6.2.2 Example of revision using ALOS/PRISM stereo image pair

Fig. 20 shows an example where an ALOS/PRISM stereo image pair is oriented using a digital photogrammetry workstation that can employ the RPC model, and a 1:25,000-scale topographic map is revised by stereo plotting. Because stereo plotting enables the acquisition of contour lines, it is possible to revise developed land with changed geospatial features and a large cut-and-fill road. Furthermore, due to the improvement in legibility due to the stereoscopic view of the image pair, complicated revision of the map can be done with high precision, and the number of hard-to-interpret locations can be reduced, resulting in a reduction of the time required for ground verification and reference data collection.

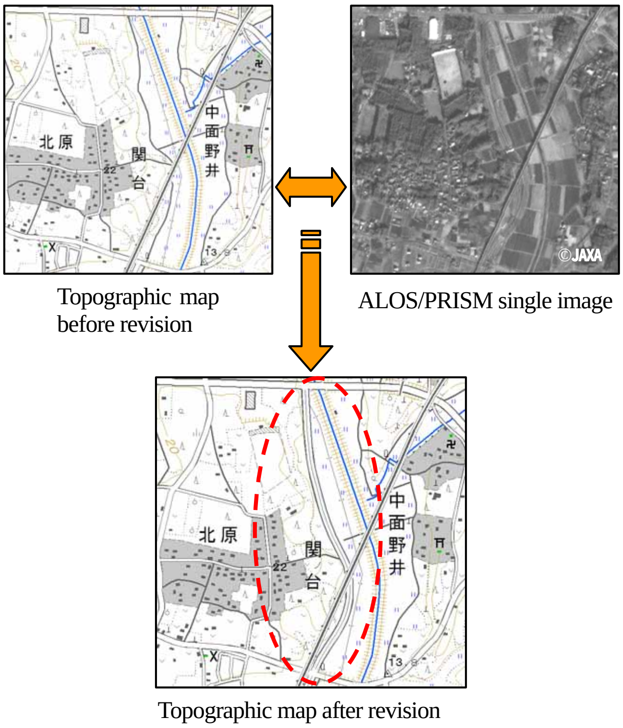

Fig. 19 Map revision of a road using a single image (1:25,000-scale topographic map "Yatabe")

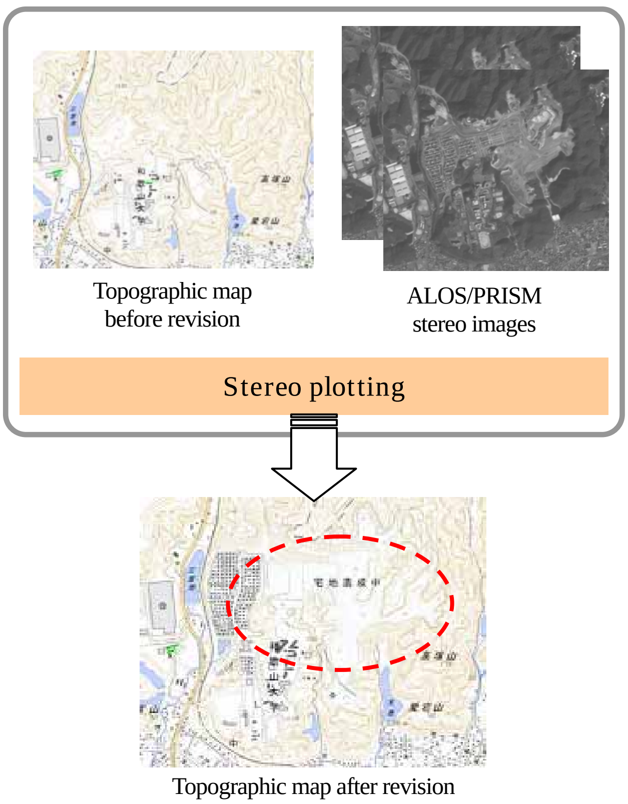

Fig. 20 Map revision of developed land for housing by stereo plotting（1:25,000-scale topographic map "Tannowa"）

6.2.3 Notable example I—Map revision for Io To Island

1:25,000-scale topographic maps are prepared based on consistent specifications for all parts of the country, even for remote islands that are located far away from the mainland. As it is difficult to take aerial photographs of these remote islands, ALOS/PRISM images, which can be provided for any place on the Earth regardless of the location, can be used effectively as a means for revising topographic maps.

A 1:25,000-scale topographic map for Io To Island, which was first issued in 1982, was revised for the first time in 25 years and reissued on September 1, 2007. This was the first case in which ALOS/PRISM images were used for the revision and issuance of a 1:25,000-scale topographic map.

In this example, after the images were imported into map-compilation software, changed features including an airport, roads, buildings (Fig. 23) and coastline (Fig. 24) were revised using the results of ground verification and on-site surveys. Other high-resolution satellite images were also used as needed.

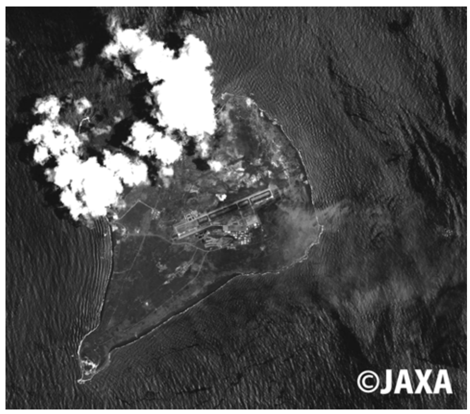

Fig. 21 ALOS/PRISM image used for revision of Io To Island

Fig. 22 ALOS/PRISM image used for revision of Io To Island (partial enlargement)

Part of outdated topographic map (issued on March 30, 1982)

Part of revised topographic map (issued on September 1, 2007)

Fig. 23 Map revision for Io To Island (1)

(1:25,000-scale topographic map “Io To”)

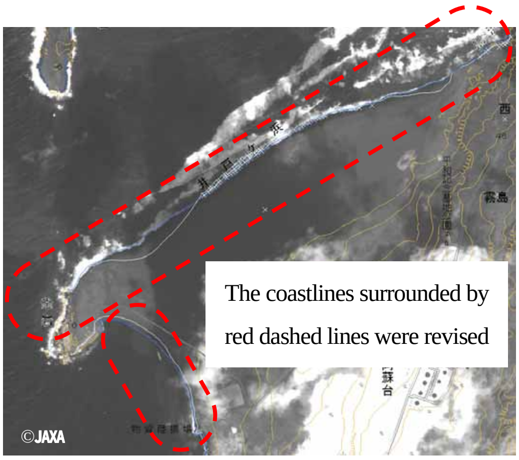

Fig. 24 Map revision for Io To Island (2)

6.2.4 Notable example II—Mapping of Takeshima

In places such as Takeshima, where it is difficult to take aerial photographs and access in person to carry out ground verification and on-site surveys, ALOS/PRISM images and other satellite images are the only option available for the development of 1:25,000-scale topographic maps. Therefore, ALOS/PRISM and other satellite images were employed when a topographic map of Takashima was prepared for the first time as an inset map for the 1:25,000-scale topographic map of “Nishimura,” issued on December 1, 2007 (Fig. 25).

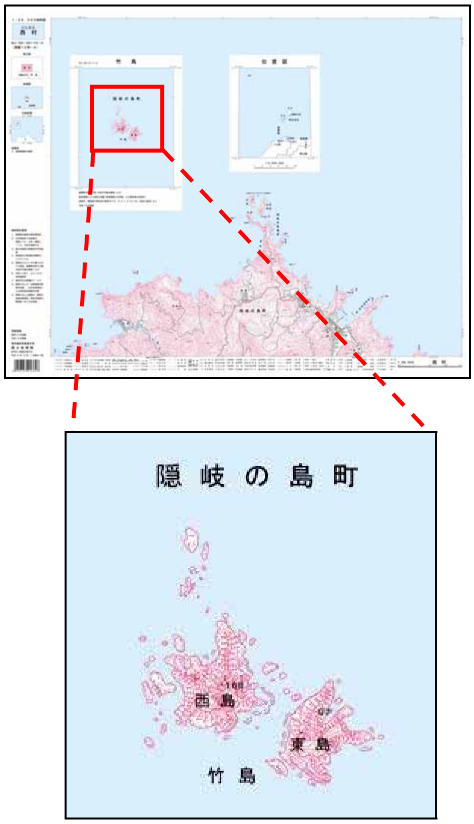

Fig. 25 Preparation of 1:25,000-scale topographic map of Takeshima

(1:25,000 topographic map “Nishimura”)

Before ALOS/PRISM images became available, high-resolution satellite images from other sources could have been used to draw the geometries and topographic features of islands and interpret them in detail. But due to the difficulty in accessing Takashima, GCPs were not available, and locations on satellite images could not be determined with high precision.

Geographic coordinates of Takeshima can be determined with RPC data when ALOS/PRISM images are employed, but the positional accuracies could contain large errors due to the unavailability of GCPs. Therefore, the following special method was developed to determine the geographic coordinates of the island with higher accuracy.

ALOS/PRISM is an optical sensor with three systems comprising forward, nadir and backward views. A positional relationship between the sensor's three axes and the body of ALOS is decided by calibration/verification (Fig.

26). In addition, as GCPs can be obtained within images for Yamaguchi and Kagoshima, the attitude and position of ALOS can be calculated with high accuracy when the satellite observes the images of Yamaguchi and Kgoshima. Furthermore, the forward view for Yamaguchi and the nadir view for Takeshima are simultaneously observed, while the forward view for Kagoshima, the nadir view for Yamaguchi and the backward view for Takeshima are observed at the same time. Consequently, the attitude and position of the satellite when the satellite observes Takeshima are the same as those when it observes Yamaguchi and Kgoshima. As mentioned above, as the positional relationship between ALOS/PRISM's three-direction sensor and the body of ALOS is fixed, the sensor's viewing direction toward Takeshima is determined once the other viewing directions are fixed. Based on the above consideration, geographic coordinates of Takeshima can be determined with high precision by stereo measurements using the images of Takeshima observed from two directions. The same method was applied to a pair images observed in different periods, and the difference between the geographic coordinates measured from these two image pairs for Takeshima was a few meters. Additionally, the same method was applied to measure geographic coordinates of other known areas, the result proved the viability of the method. Therefore, this method was adopted to determined the location of Takeshima (Figs.26, 27).

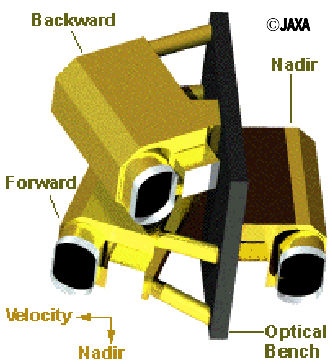

Fig. 26 Configuration of ALOS/PRISM

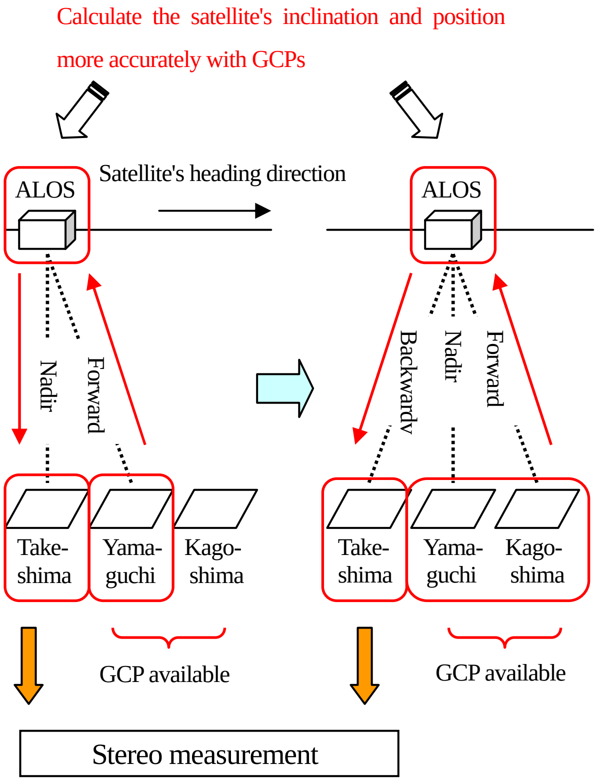

Fig. 27 Method for measurement of geographic coordinates of Takeshima

7. Conclusion

GSI and JAXA have completed a series of joint studies to verify and demonstrate the applications of ALOS/PRISM images for mapping applications. Based on the results of these studies, GSI has started full-scale use of ALOS/PRISM images for revising 1:25,000-scale topographic maps as shown in the above examples. Recently, it has become more common to continuously revise maps for changes of major features and immediately release them via the Internet. Consequently, GSI plans to make further use of ALOS/PRISM images for the extraction of changed features and for the revision of 1:25,000-scale topographic maps, maximizing the benefits of the images that can be acquired for anywhere and with high frequency.

Acknowledgments

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