Providing Aerial Photographs and Geographic Information of the Disaster Area by the Great East Japan Earthquake

Hiroyuki HASEGAWA, Kanichi SAITO, Hironori TAKAHASHI, Takao SYUDO, Osamu KAI, Mitsunari HIROTA, Mitsuru SHIBAHARA, Yuji HATAKEYAMA, Masami NEMOTO, Hiroyuki OHNO, Takayuki ISHIZEKI

Abstract

As countermeasures for the 2011 off the Pacific coast of Tohoku Earthquake which occurred at 14:46 on March 11, 2011 and the tsunami disaster triggered by this event, the Topographic Department (reorganized as "National Mapping Department" in April of the same year) immediately conducted a series of photograph shooting (color aerial photographs) from the next day (12th) across approximately 6,900 km^2 of affected areas from Misawa City in Aomori Prefecture to Soma City in Fukushima Prefecture, and released the aerial photograph images on the Geospatial Information Authority of Japan (GSI) website.

These aerial photograph images were also converted into "orthoimage data" (hereinafter referred to as "orthoimage" (Note that it was created via a simplified method due to the urgency at the time of the disaster)) to overlap with our map, and then the main map information was laid on top of this orthoimage to create an "orthophoto map (orthoimage data + mapping information)" (hereinafter referred to as "orthophoto map").

While these images and maps were released to the public, efforts were made to compile pre and post-disaster photographs of some of the most affected areas and promptly provide these comparison documents to the associated organizations as information that may contribute to disaster response or restoration.

For the recovery/restoration tasks in the affected areas, we also prepared/provided aerial photographic information and the base map for disaster restoration planning to be shared among all organizations associated with public projects.

This report briefly explains about these efforts.

1. Introduction

In response to the Great East Japan Earthquake, we, at Topographic Department, set up the Topographic Department Disaster Response Team (hereinafter referred to as "Disaster Response Team") immediately after the disasters, based on the Topographic Department's disaster countermeasure procedures.

The Disaster Response Team was established at the same time as the GSI Disaster Response Headquarter (hereinafter referred to as "Disaster Response Headquarter"), and took charge of the initial response which included gathering information on the damages as well as collecting and coordinating information that would relate to the necessity of emergency photographing, while also coordinating responses with the associated departments such as the Planning Department. Also, under the Disaster Response Team, the "Survey Team" was formed which includes a "Photographing Team" assigned for emergency photographing, and the emergency measures were implemented right away.

2. Emergency photographing

2.1 Emergency photographing by agreement with Association of Precise Survey and Applied Technology

In case the GSI's survey aircraft "Kunikaze 3" does not have the capability to handle its tasks or is not available due to certain circumstances when a disaster occurs, GSI has signed the “Agreement on Emergency Photographing at Disaster Occurrence" (hereinafter referred to as the "Agreement") on March 31, 2005 via the Association of Precise Survey and Applied Technology (hereinafter referred to as "APA") with their member companies to receive assistance in order to conduct emergency photographing of affected areas efficiently.

At the time of the disaster on March 11th, "Kunikaze 3" had been under the regular maintenance specified by the Aviation Law (hereinafter referred to as

"regular maintenance") from the previous day, and therefore was not available for emergency photographing for the rest of March. Moreover, as the damages in each region gradually became apparent, it could be assumed that an extremely large area was affected and that emergency photographing based on the Agreement was to be conducted.

Immediately after the earthquake, the Photographing Team started preparation for emergency photographing while also gathering information about the damages mainly along the Pacific Coast in eastern Japan.

The outline of the emergency photographing after the occurrence of Great East Japan Earthquake is as follows:

1) Camera types

Digital aerial camera or film aerial camera

(All captured in color)

2) Photo scale by flight (ground pixel dimension)

In order to quickly assess the whole picture of the disaster as top priority and complete the photographing of the wide affected area within one day, it was decided to basically shoot at a scale of about 1:20,000 (40 cm in ground pixel dimension). Note that, for Sendai and Ishinomaki regions where enormous damages had already been reported at that point, the photographing scale was set to 1:10,000 (20 cm in ground pixel dimension) as more detailed information was required.

3) Allocation of photographed districts

Out of the six companies who responded to APA on March 11th to offer help for emergency photographing, we allocated the four companies with digital aerial camera to the coastal area devastated by the tsunami, and the two companies with film aerial camera to the mountainous area. After that, we added one company from the 10 companies who responded to APA on the 13th for the emergency photographing of areas that were not initially included such as the Sanriku coastal area. (The companies whom we request emergency photographing by the Agreement are hereinafter referred to as the "Agreement partners.")

2.2 Emergency photographing by Kunikaze 3

Photographing was conducted in accordance with the Agreement under fine weather conditions on March 12/13/19th, and also from April 1st, "Kunikaze 3", on which the regular maintenance had been completed, was directly assigned for complementary photographing in regions that had not been photographed.

2.3 Status and area of emergency photographingions

The status of implementation of the emergency photographing, conducted either directly or by the Agreement during the period between March 12th and April 5th, is shown in Table 1, and the photographed area is shown in Figure 1.

3. Provision of aerial photograph images and creation of GSI website data

Aerial photographic images were organized and duplicated for the associated organizations, while image data of the coastal areas devastated by tsunami were created for public release on the GSI website.

As for aerial photographs and orthoimages, another website offering high resolution images for the associated organizations was created separately from the public website.

4. Utilizing private aerial photographs

For the Ibaraki coastal area where emergency photographing was not initially conducted, we found out later that there were aerial photographs taken right after the disaster, and GSI purchased the relevant photographs including the copyrights. From these aerial photograph images, each survey team created orthoimages and orthophoto map and released on the website. (See Table 2.)

Table 1 Status of emergency photographing

Region	Area (km^2)	Date	Scale	No. of strips/ photographs	Web release	Company/ Organization	Camera type
North Sanriku ∗1	818	March 13th	1:20,000	11 / 196	March 15th 10:00	Asia Air Survey Co., Ltd.	Digital aerial camera
South Sanriku ∗1	1,044	March 13th (Recaptured)	1:20,000	17 / 245	March 13th 16:00	Kokusai Kogyo Co., Ltd.	Digital aerial camera
Sendai/ Ishinomaki ∗1	529	March 12th March 13th	1:10,000	Sendai: 15 / 645 Ishinomaki: 5 / 233	March 13th 16:00	PASCO Corporation	Digital aerial camera
Sendai Bay ∗1	663	March 12th	1:20,000	11 / 563	March 13th 16:00	Aero Asahi Corporation	Digital aerial camera
Sanriku Coast ∗1	964	March 19th	1:20,000	15 / 171	March 20th 8:00	Nakanihon Air Service Co., Ltd.	Digital aerial camera
Sanriku Coast 2 ∗2	2,082	April 1st April 5th	1:20,000	25 / 514	April 2nd 8:00 April 6th 8:00	GSI	Digital aerial camera
East Kurikomayama ∗1	517	March 13th	1:20,000	5 / 114	—	A-TEC Co., Ltd.	Film aerial camera
West Kurikomayama ∗1	285	March 13th	1:20,000	5 / 78	—	Hasshu Co., Ltd.	Film aerial camera
Total	6,902	—	—	109 / 2,759	—		

∗1: Photographed in accordance with the Agreement ∗2: Photographed on Kunikaze 3 by GSI

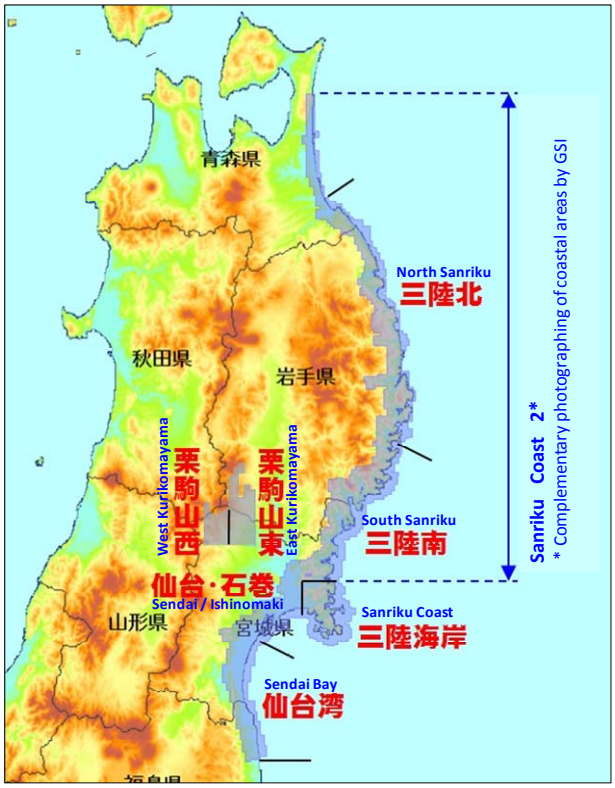


Fig.1 Area of emergency photographing

Table 2 Status of use of private aerial photographs

Region	Date	Scale	Strip No. Photographs	Web release
Ibaraki Coast*	March 12th March 27th	1:9,000	C1-C16 378	April 21st 18:00

∗ Photographed by Eiwa Development Survey Co., Ltd.

5. Creation of orthoimage and orthophoto map

An orthoimage of the whole area was first created for each photographed region, then mechanically divided by the borders of the national base map of Japan which is 2 km (west-east) by 1.5 km (north-south) on a scale of 1:2,500.

Additionally, roads, railways, shorelines, administrative boundaries, building symbols, notes from the Digital Japan Basic map (map information) were laid over orthoimages to create an orthophoto map to be uploaded on the website, in order to make it possible to understand how the villages and infrastructures were located before the disaster. The status of orthoimages and orthophoto maps created are shown below in Table 3.

Table 3 Status of orthoimage and orthophoto map creation

Region	Orthoimage data (orthoimage)		Orthophoto map (orthoimage data + map information)	
	Date, ground resolution, sheets (1/2,500 National base map borders)	Web release	Date, sheets (1/2,500 National base map borders)	Web release
North Sanriku	March 18th High resolution: 40 cm, Low resolution: 80 cm (481 sheets each)	March 18th (18:30)	March 18th to 19th (481 sheets each)	March 20th (12:00)
South Sanriku	March 17th High resolution: 40 cm, Low resolution: 80 cm (617 sheets each)	March 18th (18:30)	March 18th to 19th (617 sheets each)	March 20th (12:00)
Sendai/ Ishinomaki	March 15th High resolution: 20cm, Low resolution: 80 cm (321 sheets each)	March 17th (17:15)	March 17th to 18th Sendai: 221 sheets Ishinomaki: 100 sheets	March 18th(22:30)
Sendai Bay	March 18th High resolution: 40 cm, Low resolution: 80 cm (393 sheets each)	March 19th (17:15)	March 19th (164 sheets each)	March 20th (12:00)
Sanriku Coast	March 22nd High resolution: 40 cm, Low resolution: 80 cm (717 sheets each)	March 23rd (11:10)	March 23rd (717 sheets each)	March 23rd (17:05)
Sanriku Coast 2	April 2nd High resolution: 40 cm, Low resolution: 80 cm (469 sheets each) April 6th High resolution: 40cm, Low resolution: 80 cm (678 sheets each)	April 2nd (19:20) April 7th (18:30)	April 2nd (480 sheets each) April 6th to 7th (496 sheets each)	April 4th (11:00) April 7th (18:30)
Ibaraki Coast	April 14th High resolution: 20 cm, Low resolution: 80 cm (322 sheets each)	April 18th (17:00)	April 13th to 15th (304 sheets each)	April 18th (17:00)

6. Creating a 1:50,000 scale map for earthquake response

GSI received a request from the Road Bureau of Ministry of Land, Infrastructure, Transport and Tourism to provide 1:50,000 topographic maps (publicized map), and existing 1:50,000 topographic maps were provided from the Geospatial Information Department for the time being. However, a problem arose where several names of municipalities and main roads did not match the present state because the map had not been updated. The 1:50,000 map for earthquake response, designed to tackle this problem, has been created by using the auto 1:50,000 map creation technology that was being developed at the Topographic R&D Office (reorganized as "Geospatial Technology Development Office" on April 1, 2011).

This automated 1:50,000 map was created by automatically scaling down the data from 1:25,000 maps such as the Digital Japan Basic Map to a 1:50,000 level so it appears like a topographic map, and the major roads are indicated with different colors to make them more noticeable. A sample is shown in Figure 2.

The work was started on March 17th, and 67 maps that cover the coastal areas from Aomori to Ibaraki Prefecture had been created and released on the GSI website from 18th.

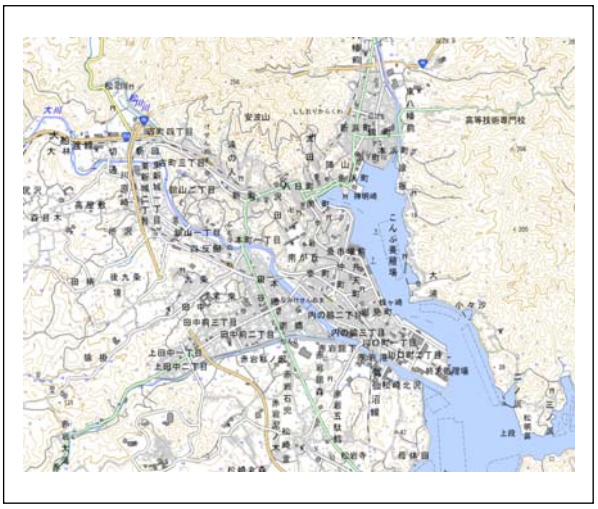
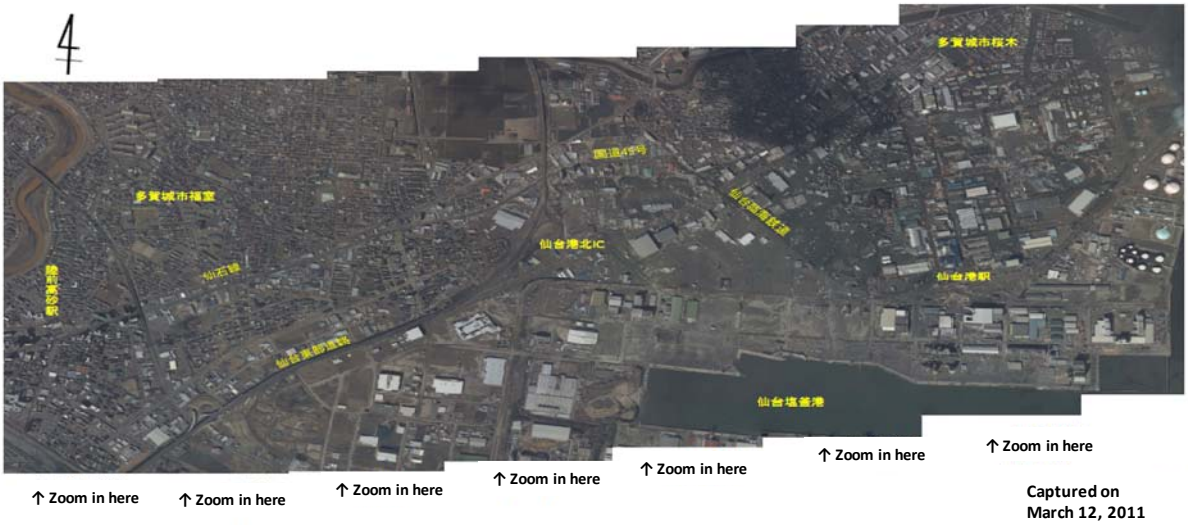


Fig.2 1:50,000 scale map for earthquake response (part of "Kesennuma") Major regional roads in green, ordinary prefectural roads in yellow

7. Creation of photo mosaics

Since one aerial photo only covers a small area and does not contain information such as annotations, it is difficult for people who are unfamiliar with the area to understand where the photograph was captured.

If sufficient amount of time was given, this problem could have been solved by orthorectifying the photo images then overlaying the map information to create an orthophoto map. However, this process would require several days which was too slow considering the urgency at the initial response stage during March. As an alternative measure until the completion of orthoimages and orthophoto maps, we combined photographs then added notes on some major features and geographical names to create photo mosaics and released them on the GSI website to inform people of what was occurring at which location.



Click "Zoom in here" to view an enlarged image

Fig.3 Photo mosaic
Created to mainly help information assessment during initial response

Photo mosaics were prepared for 4 locations in Aomori, 56 locations in Iwate, 84 locations in Miyagi, 64 locations in Fukushima, and additional 26 locations in Miyagi taken on March 19th, and were uploaded on the GSI website from 14:00 on March 14th. A sample of photo mosaic is shown in Figure 3.

8. Comparison document of pre and post-disaster aerial photographs

On areas with catastrophic damages by tsunami etc, we released a comparison of aerial photographs before and after the disaster on the GSI website. An example of Kesennuma City is shown in Figure 4.

The pre-disaster (left) photograph is an image from the Land Vicissitude Archive, and the

Pre-disaster (Kesennuma City) **Post-disaster (Kesennuma City)**

Fig.4 Comparison document of pre and post-disaster aerial photographs

Table 4 Status of capturing and releasing oblique photographs

Date	Photographs	Photographed coastal regions	Web release
May 18th	133	Soma City (Fukushima), Yamamoto Town to Minamisanriku Town (Miyagi)	May 20th
May 25th	321	Shinchi Town (Fukushima) to Ofunato City (Iwate)	May 26th
June 7th	176	Hashikami Town to Rokkasho Village (Aomori)	June 10th
June 8th	288	Kesennuma City (Miyagi) to Hirono Town (Iwate)	June 10th
July 11th	458	Asahi City (Chiba) to Iwaki City (Fukushima)	July 14th
July 12th	165	Asahi City (Chiba) to Iwaki City (Fukushima)	July 14th
Sep. 16th	132	Kesennuma City (Miyagi) to Miyako City (Iwate)	Sep. 28th
Nov. 9th	94	Iwaki City, Minamisoma City, Soma City (Fukushima)	Nov. 16th

post-disaster (right) photograph is an image taken from the emergency photographing. (Note that these include documents prepared by the Topographic Department.)

9. Capturing/release of oblique photographs

In order to understand the details of the latest situation of the affected areas, we began shooting oblique photographs from above on "Kunikaze 3" on May 18th which were released on the GSI website from the 20th. The status of photographing and public release of these photographs is shown in Table 4.

Upon releasing these photographs on the website, icons indicating the location and direction were inserted to make the target more noticeable. (Figure 5, 6, 7)

After selecting the regions devastated by the tsunami (coastal area from Rokkasho Village in Aomori Prefecture to Asahi City in Chiba Prefecture) as the target areas, the survey aircraft flew parallel to but about 2 km away from the shoreline while lowering the altitude to 2,000 ft (approx. 700 m) from the normal 7,500 ft (approx. 2,300 m), in order to obtain more detailed photographs of the scene.

10. Providing aerial photographs from the emergency photographing

From March 13th, materials such as aerial photographs from the emergency photographing were provided to each bureau in Ministry of Land, Infrastructure, Transport and Tourism, Cabinet

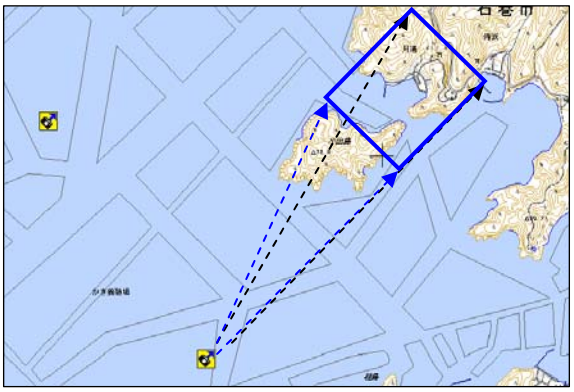


Fig.5 Oblique photograph from GSI website (Tsukinoura, Ishinomaki City)

Fig.6 Oblique photograph of the area in blue frame from the above figure (Tsukinoura, Ishinomaki City)

Fig.7 Zoom-in photograph of the area in red frame from the above figure

Secretary, Cabinet Office, Regional Development Bureau, and Self-Defense Force, as well as the on-site government task force and associated organizations of the prefectures/municipalities in the affected areas. These information are being utilized for various disaster response works such as rescue operations on site, understanding the damage situation on key transportation infrastructure (roads, railways, airports, etc), disaster assessment, survey of tsunami damage on farmlands, and issuing damage reports on buildings.

10.1 Distribution of aerial photographs to associated organizations

For the three regions (South Sanriku, Sendai/Ishinomaki, Sendai Bay) that we managed to capture photographs on the day after the earthquake, March 12th, a series of work was performed by the Agreement partners all night from digital image processing, index map creation, to saving photograph images to hard disks and printing the images. The completed portion of the photographs were sent to the GSI Tokyo suboffice within the Ministry of Land, Infrastructure, Transport and Tourism at 9:00 in the next morning as flash reports, and then distributed to related bureaus immediately.

Also, on March 13th, photographing was conducted in four regions (North Sanriku, Sendai/Ishinomaki, East Kurikomayama, West Kurikomayama) as well as recapturing of one region (South Sanriku) due to the cloudy weather on the previous day, and these photographs were processed by the Agreement partners in the same manner as the day before. As a result, the whole set including the ones from the 12th was sent to the GSI Tokyo suboffice at 14:00 on 14th the next day (22:00 for North Sanriku), and then distributed to related bureaus within the ministry immediately.

After that, on March 19th, the remaining part of Sanriku coastal area was photographed then the result was sent to the GSI Tokyo suboffice at 3:00 on 20th the next day.

Additionally, on April 1st and 5th, two districts of Sanriku coast were photographed by "Kunikaze 3" (on which the regular maintenance had been completed), and the photograph image data was sent to the GSI Tokyo suboffice the next day.

10.2 Data storage and delivery to affected municipalities

All the information prepared such as the aerial photograph images, orthoimages and orthophoto maps, were saved to hard disk including the output samples,

and we requested the Self-Defense Force and other teams heading to the affected areas from Tokyo in an effort to deliver them to the Response Headquarters of each region as soon as possible.

After contacting the Geospatial Intelligence Unit (hereinafter referred to as "GIU") of the Ground Self-Defense Force in Tachikawa City, Tokyo to organize the delivery, GSI employees carried the hard disks from Tsukuba City, Ibaraki to the GIU office in Tachikawa first so the data can be delivered to the affected areas.

11. Creating a basic map for disaster restoration plan

It was decided in the National Mapping Department to organize and provide high precision aerial photographic information and the base map for disaster restoration planning (hereinafter referred to as the "restoration map") that can be shared among public project organizations within 2011 (FY) for the purpose of recovery/restoration operations such as reconstruction plans of the areas affected by the Great East Japan Earthquake. (Figure 8, 9)

Fig.8 Aerial photograph for restoration map

Fig.9 Restoration map (rapid survey map) of above photograph

11.1 Capturing aerial photographs and providing images for the restoration map

In order to create high precision restoration maps (1:2500 scale) of regions with catastrophic damage from the tsunamis etc, aerial photographs at a scale of 1:8,000 were taken on mainly the coastal areas between Hachinohe City in Aomori Prefecture to Soma City in Fukushima Prefecture from May, creating orthoimages at the same time. The regions covered are shown in Figure

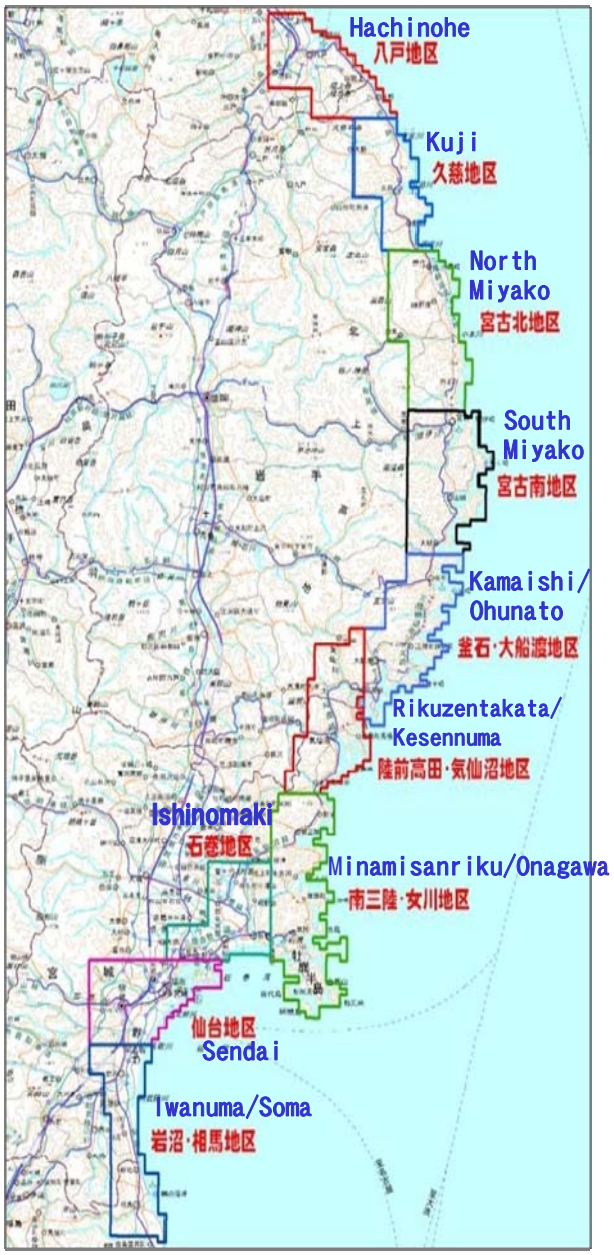


Fig.10 Areas where aerial photographs were taken for restoration map (10 regions from the initial plan)

Table 5 Status of capturing aerial photographs and creating orthoimages for restoration map

Region	Related municipalities	Area (km^2)	Period	Scale	Strips/ Photographs	No. of orthoimages (1/2,500 National base map borders)
Hachinohe	Hachinohe City, Hashikami Town, Hirono Town	575	5/19 to 10/17	1:8,000	40 / 1,393	191 sheets
Kuji	Kuji City, Fudai Village, Noda Village, Hirono Town	492	5/11 to 8/15	1:8,000	27 / 1,041	168 sheets
North Miyako	Miyako City, Iwaizumi Town, Tanohata Village, Fudai Village , Noda Village	741	5/18 to 11/1	1:8,000	76 / 3,277	253 sheets
South Miyako	Miyako City, Kamaishi City, Otsuchi Town, Yamada Town	749	5/19 to 8/15	1:8,000	39 / 2,372	253 sheets
Kamaishi/ Ofunato	Ofunato City, Rikuzentakata City, Kamaishi City	702	5/12 to 8/9	1:8,000	37 / 1,580	237 sheets
Rikuzentakata/ Kesennuma	Rikuzentakata City , Kesennuma City	647	5/18 to 8/2	1:8,000	33 / 1,623	217 sheets
Minamisanriku/ Onagawa	Ishinomaki City , Kesennuma City , Onagawa Town, Minamisanriku Town	869	5/19 to 9/12	1:8,000	39 / 1,242	303 sheets
Ishinomaki	Ishinomaki City, Higashimatsushima City, Matsushima Town	549	5/12 to 8/9	1:8,000	25 / 958	183 sheets
Sendai	Sendai City, Shiogama City, Natori City, Tagajo City, Higashimatsushima City, Matsushima Town, Shichigahama Town, Rifu Town	642	5/18 to 8/29	1:8,000	23 / 1,152	215 sheets
Iwanuma/Soma	Natori City, Iwanuma City, Watari Town, Yamamoto Town,Soma City, Shinchi Town	612	5/18 to 8/8	1:8,000	37 / 1,017	215 sheets
Total	—	6,578	—	—	376 / 15,655	2,235 sheets

10 which are 10 regions with a total area of 6,578 km^2. Also, the status of capturing aerial photographs and creating orthoimages is shown in Table 5.

In addition, out of the region from Soma City to Iwaki City in Fukushima Prefecture which was initially not included in the restoration map but later added in October, photographs with the scale of 1:8,000 were taken on three regions shown in Figure 11 which are Minami-Soma (68 km^2), Iwaki 2 (173 km^2) and Iwaki (387 km^2).

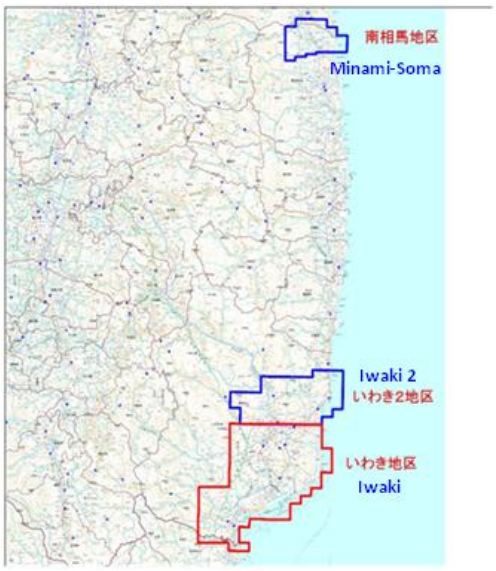


Fig.11 Areas where aerial photographs were taken (additional 3 regions)

11.2 Use of satellite images

For the coastal region of Fukushima (433.62 km^2) where flying restrictions were imposed due to the accident at the Fukushima Daiichi nuclear power plant, satellite image data was used alternatively to prepare the restoration map with the scale of 1:5,000.

This region (Fukushima coastal district) is shown in Figure 12. Sources of the satellite images used are shown in Table 6.

Fig.12 Development area by satellite images (Fukushima coastal region)

Table 6 Sources of satellite images for Fukushima coastal region

Satellite name	**WorldView-2** (DigitalGlobe, Inc. of USA)	**GeoEye-1** (Space Imaging, Inc. of USA)
Image type	Stereo Pair	Ortho Basic
Date	4/3/2011	3/29/2011
Product type	4-band bundle (Panchromatic + 4-band multispectral)	Color pan-sharpened (4-band color)
Image quality	16bit	8bit
Resolution	50 cm worth	50 cm worth
Target area	654 km^2	789 km^2

11.3 Preparing/providing the restoration map

Originally, in an attempt to promote the recovery/restoration operations of regions devastated by the tsunamis, it was considered a top priority to recreate a high precision map information that includes fundamental geospatial data items (this data is the standard to determine the positioning on digital map, and full set of the data includes 13 items ordered by the Ministry of Land, Infrastructure, Transport and Tourism) and prepare the restoration map.

Consequently, for the area from Hachinohe in Aomori to Soma in Fukushima where high precision photographing had been conducted since May, we started providing the pre-completion data as "rapid survey maps" from August, and the provision of the entire initial improvement area (approx. 4,200 km^2) was completed by November.

Furthermore, it was decided to additionally create a restoration map by October for an area of approximately 900 km^2 from Soma to Iwaki in Fukushima that was not initially included in the restoration map even though the region had been greatlyaffected by the tsunami. It was also decided that a restoration map was needed by December for an area of approximately 100 km^2 of inland Sendai City where many districts were experiencing severe landslides from the great earthquake and aftershocks, despite the fact that the area had not been affected by tsunami. Areas covered in the final version of the restoration map are shown in Figure 13.

12.Conclusion

This document summarizes our work on disaster response at the National Mapping Department from March to December 2011, such as the emergency photographing of areas affected by the Great East Japan Earthquake.

In response to the Great East Japan Earthquake, we immediately focused on speedily organizing necessary information based on our past experiences with disaster response and enhancing/strengthening the cooperation with associated organizations, and every effort was made to provide information such as aerial photographs required for assessing damages of the affected areas as soon as possible.

From now on, we, as the Disaster Response

Fig.13 Areas covered in Restoration map

Team, plan to discuss the issues/problems in our disaster response to this event and address the points for improvement, and take these results further to speed up disaster responses and to strengthen preparation for the future.

Finally, we would like to express our foremost desire that the information that we prepared/provided will be of any assistance for disaster response operations carried out in each region and associated organizations, as well as for supporting the reconstruction assistance of the affected areas.