

2.1.4 Cooperation with from overseas institutions

JAXA asked Sentinel Asia and, on behalf of the Cabinet Office, the Disaster Charter to carry out emergency observations immediately after the earthquake struck at 14:46 on March 11 2011 for (request time: 15:24).

2.1.4.1 Response by the Disaster Charter and others

In response to the request made to the Disaster Charter for emergency observations, earth observation satellites managed by space-related institutions worldwide observed more than 5,000 images and provided them to Japan. Table 2.1-5 shows a list of satellites and contributing institutions that conducted observations at the disaster areas as members of the Disaster Charter and others (except Daichi). In addition, footprints (observation areas) monitored by the Disaster Charter are also listed in Figure 2.1-29.

Table 2.1-5 Satellites used for observations by members of the Disaster Charter and others
(except Daichi)

Sensor type	Satellite name	Organization name	Country
SAR data	TerraSAR-X	(Deutsches Zentrum für Luft- und Raumfahrt : DLR)	Germany
	RADARSAT-1, 2	(Canadian Space Agency : CSA)	Canada
	ENVISAT	(European Space Agency : ESA)	EU
	COSMO-SkyMed ※Provided by non-Charter member	(Agenzia Spaziale Italiana : ASI)	Italy
Optical sensor data	IKONOS-2	(U.S. Geological Survey : USGS)	USA
	GeoEye-1	USGS	USA
	QuickBird-2	USGS	USA
	WorldView-1, 2	USGS	USA
	SPOT-4, 5	(Centre National d'Etudes Spatiales : CNES)	France
	Kompsat-2	(Korea Aerospace Research Institute : KARI)	South Korea
	RapidEye	DLR	Germany
	HJ	(China National Space Administration : CNSA)	China
	LANDSAT-5, 7	USGS	USA
	EO-1	USGS	USA
	Cartosat	(Indian Space Research Organization : ISRO)	India
	Dubaisat ※Provided by non-Charter member	EIAST(Emirates Institution for Advanced Science and Technology)	UAE

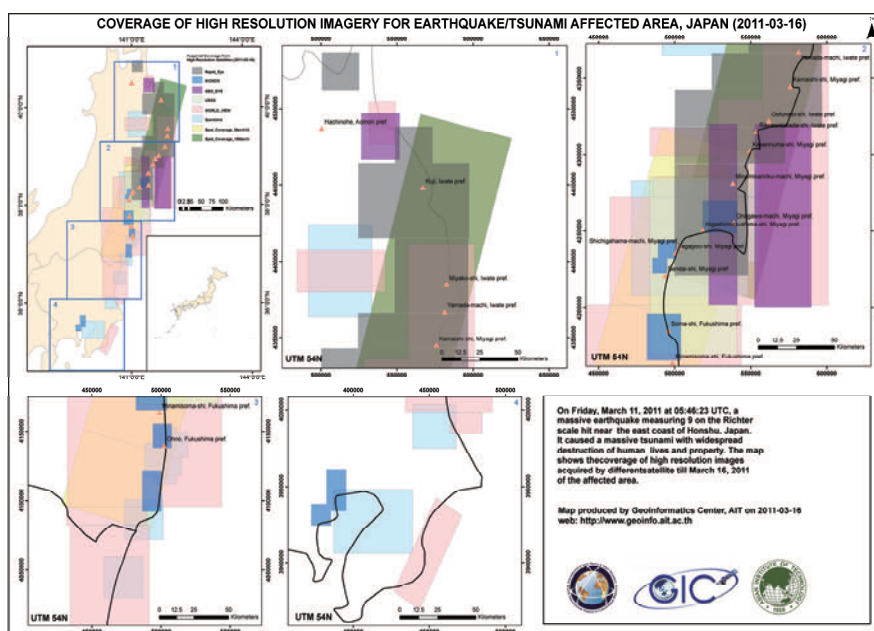


Figure 2.1-29 Overview of observations by Disaster Charter members

The images of the disaster areas provided by the Disaster Charter were processed and analyzed by JAXA, the Asian Institute of Technology (AIT), and other institutions across the world that were approved by the Disaster Charter. These organizations produced over 90 useful data sets and created related analysis products, which were made available to the public on the Disaster Charter website (Figure 2.1-30).



Figure 2.1-30 Image analysis products released on the Disaster Charter website

(<http://www.disasterscharter.org/web/charter/home>)

The institutes produce analysis products for the disaster-area images are listed in Table 2.1-6, and examples of products themselves are shown in Figures 2.1-31 to 2.1-41.

Table 2.1-6 Overseas institutions creating image analysis products for the Disaster Charter

Origin	Institution providing product	Satellite using data	Example of product
United Nations (UN)	United Nations Institute for Training and Research (UNITAR) / UNITAR's Operational Satellite Application Programme (UNOSAT)	RADARSAT-1 RADARSAT-2	Figure 2.1-31
USA	Clark Labs, Clark University	GeoEye-1, WorldView	Figure 2.1-32
	Earthquake Data Enhanced Cyber-Infrastructure for Disaster Evaluation and Response (E-DECIDER)	WorldView, QuickBird-2	Figure 2.1-33
	Rochester Institute of Technology (RIT)	GeoEye-1, WorldView	Figure 2.1-34
	USGS	WorldView-1	Figure 2.1-35
	George Mason University	WorldView-2	Figure 2.1-36
	GISCorps, Auburn University	WorldView-1	Figure 2.1-37
	ImageCat inc.	GeoEye-1	Figure 2.1-38
	Pennsylvania State University	WorldView-2	Figure 2.1-39
Germany	DLR / Center for Satellite Based Crisis Information (ZKI)	RapidEye TerraSAR-X	Figure 2.1-40
France	Regional Service of Image Treatment and Remote Sensing (SERTIT)	WorldView-1, 2 IKONOS-2 SPOT-5 Landsat-7	Figure 2.1-41

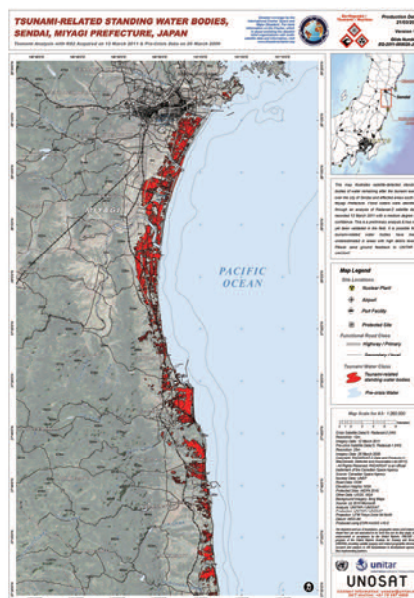


Figure 2.1-31 Example of image analysis products produced by overseas institutions (United Nations Institute for Training and Research (UNITAR) / UNITAR's Operational Satellite Application Programme (UNOSAT)) Identification of tsunami-hit areas from Sendai to southern Miyagi using pre- and post-disaster SAR images Images used: RADARSAT-1 (observation after disaster on March 12, 2011), RADARSAT-2 (observation before disaster on March 26, 2006)

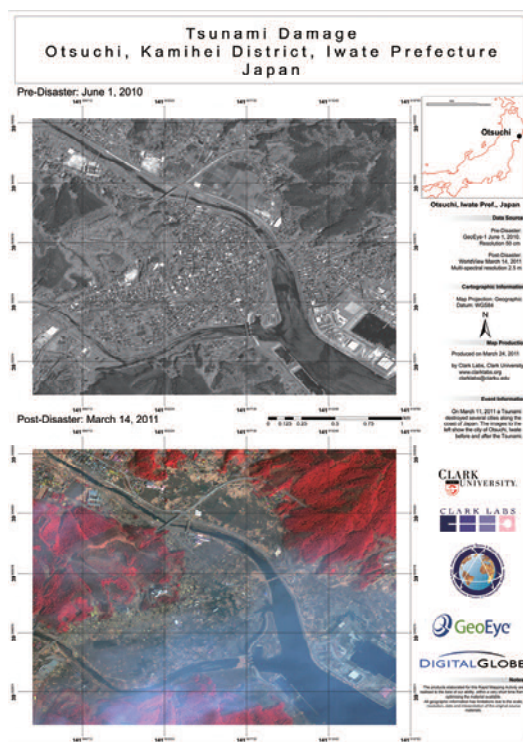


Figure 2.1-32 Example of image analysis products produced by overseas institutions
 (Clark Labs, Clark University.)

Pre- and post-disaster images of Otsuchi Town, Iwate, taken using a high-resolution optical sensor
 Images used: top: GeoEye-1 (observation before disaster on June 1, 2010); bottom: WorldView (observation after disaster on March 14, 2011)

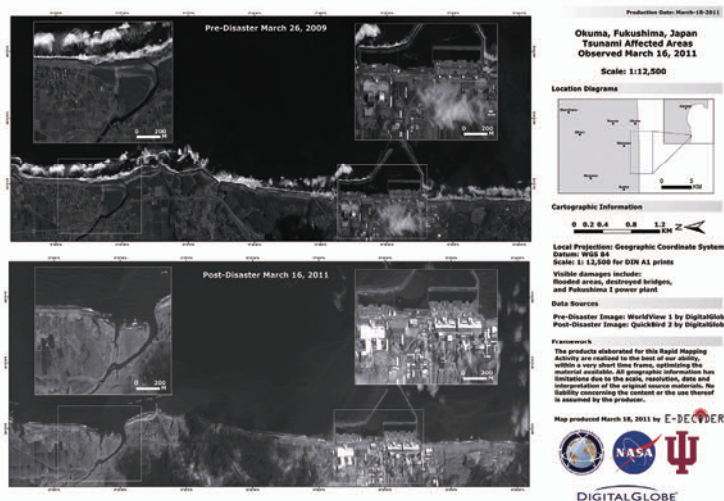


Figure 2.1-33 Example of image analysis products produced by overseas institutions (Earth quake
 Date Enhanced Cyber-Infrastructure for Disaster Evaluation and Response(E-DECIDER))

Pre- and post-disaster images of the Fukushima Dai-ichi Nuclear Power Station taken using a high-resolution optical sensor
 Images used: top: WorldView-1 (observation before disaster on March 26, 2009): bottom: QuickBird-2 (observation after disaster on March 16, 2011)

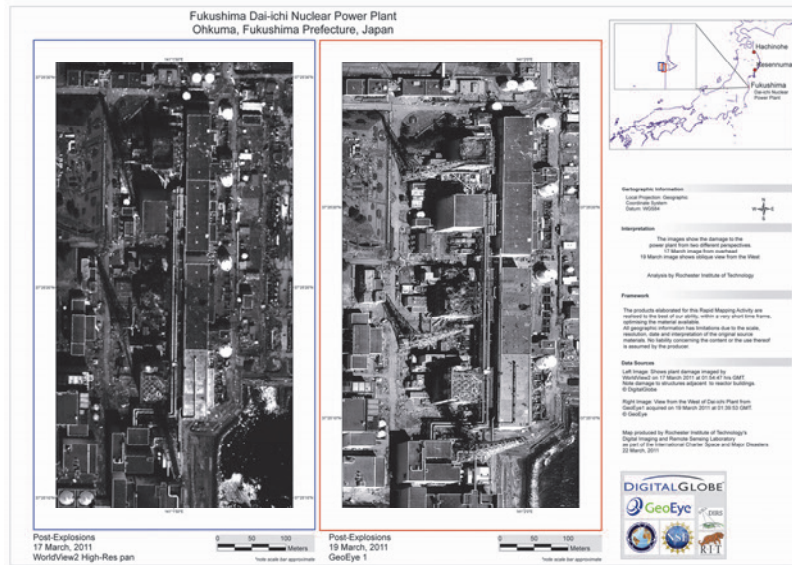


Figure 2.1-34 Example of image analysis products produced by overseas institutions Rochester Institute of Technology (RIT)

Post-disaster images of the Fukushima Dai-ichi Nuclear Power Station taken using a high-resolution optical sensor after the hydrogen explosion
 Images used: left: WorldView-2 (observation on March 17, 2011); right: GeoEye-1 (observation on March 19, 2011)

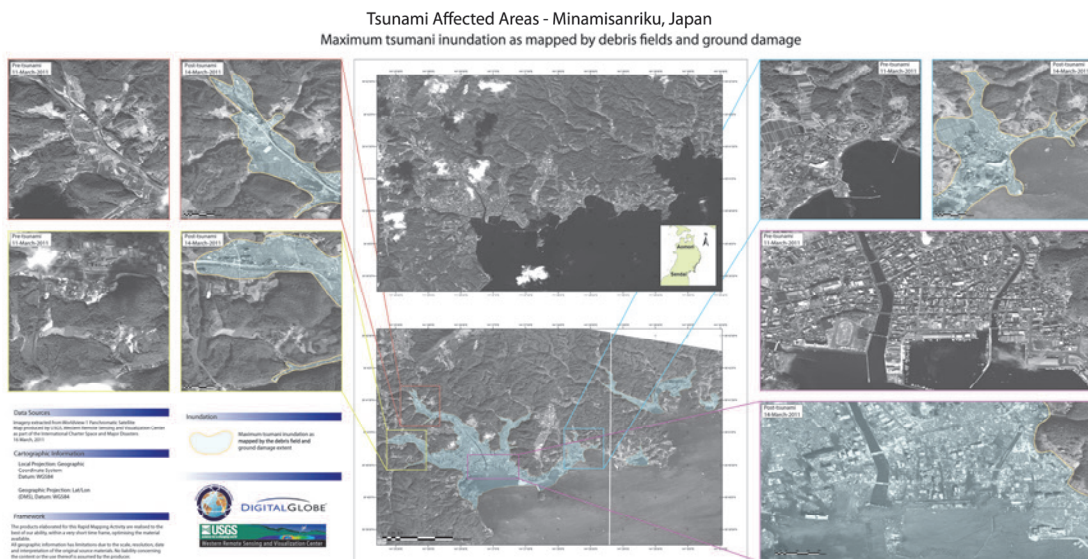


Figure 2.1-35 Example of image analysis products produced by overseas institutions United States Geological Survey (USGS)

Pre- and post-disaster images of tsunami-affected areas in Minamisanriku Town, Miyagi, taken using a high-resolution optical sensor
 Images used: Worldview-1 (observation before disaster on March 11, 2011; observation after disaster on March 14, 2011)



Figure 2.1-36 Example of image analysis products produced by overseas institutions (George Mason University.)
Pre- and post-disaster images of tsunami-affected areas in Tagajo City, Miyagi, taken using a high-resolution optical sensor
Images used: Worldview-2 (top: observation before disaster on August 4, 2010; below: observation after disaster on March 14, 2011)

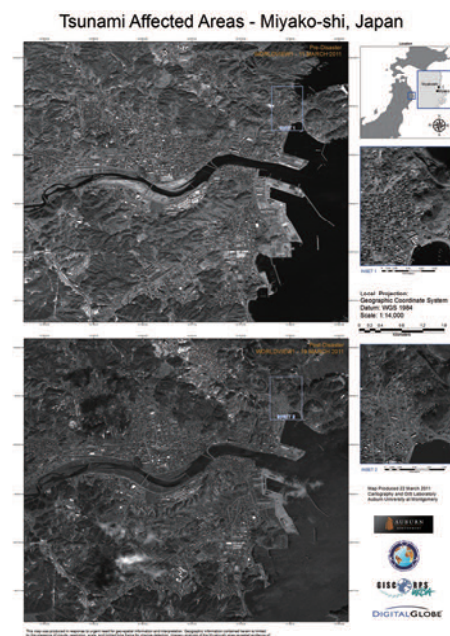


Figure 2.1-37 Example of image analysis products produced by overseas institutions (GISCorps, Auburn University.)
Pre- and post-disaster images of tsunami-affected areas in Miyako City, Iwate, taken using a high-resolution optical sensor
Images used: Worldview-1 (top: observation before disaster on March 11, 2011; bottom: observation after disaster on March 19, 2011)

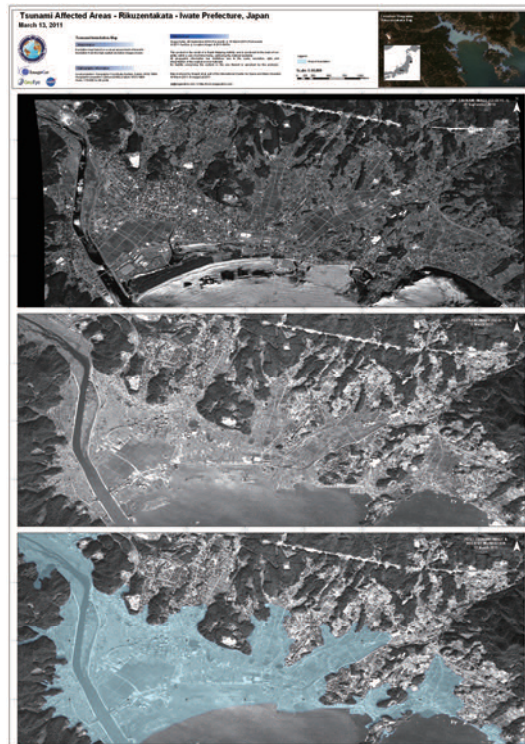


Figure 2.1-38 Example of image analysis products produced by overseas institutions (Image Cat Inc.) Pre- and post-disaster images of tsunami-affected areas in Rikuzentakata City, Iwate, taken using a high-resolution optical sensor
 Images used: GeoEye-1 (top: observation before disaster on September 29, 2010; center: observation after disaster on March 13, 2011; bottom: post-disaster image of tsunami-affected areas)

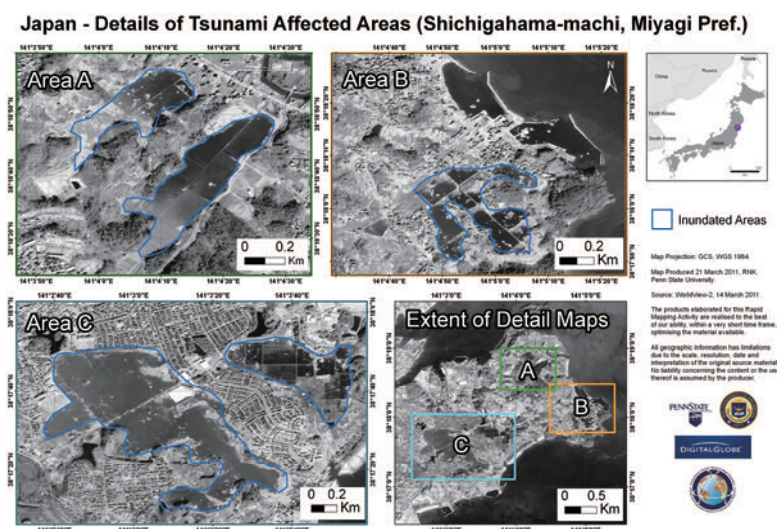


Figure 2.1-39 Example of image analysis products produced by overseas institutions (Pennsylvania State University.)

Post-disaster images of tsunami-affected areas in Shichigahama Town, Miyagi, taken using a high-resolution optical sensor
 Images used: Worldview-2 (observation after disaster on March 14, 2011)

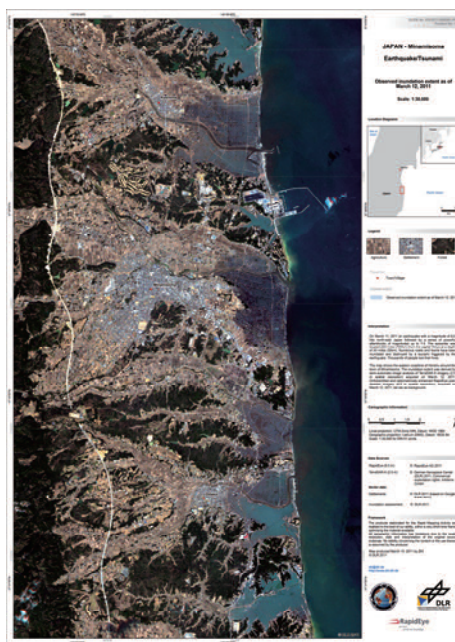


Figure 2.1-40 Example of image analysis products produced by overseas institutions (Deutsches Zentrum für Luft-und Raumfahrt (DLR) / Center for Satellite Based Crisis Information (ZKI))
Superimposition of a SAR image showing tsunami-affected areas in Minamisoma City, Fukushima, onto one taken using a high-resolution optical sensor
Images used: SAR/Terra SAR-X (observation after disaster on March 12, 2011), optics/RapidEye (observation after disaster on March 12, 2011)

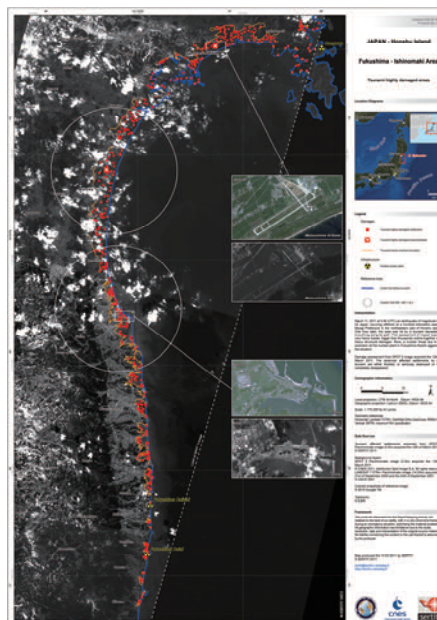


Figure 2.1-41 Example of image analysis products produced by overseas institutions (Service Régional de Traitement d'Image et de Télédétection (SERTIT))
Superimposition of pre-disaster wide-range images of the area encompassing Ishinomaki City, Miyagi, and Okuma Town, Fukushima, taken using an optical sensor, onto an image of the tsunami-affected areas, and post-tsunami enlarged images taken using a high-resolution optical sensor
Images used: broad-swath images/Landsat-7 (observations before disaster on September 21, 2000 and September 24, 2001), enlarged images/SPOT-5 (observation after disaster on March 12, 2011)

2.1.4.2 Response by Sentinel Asia

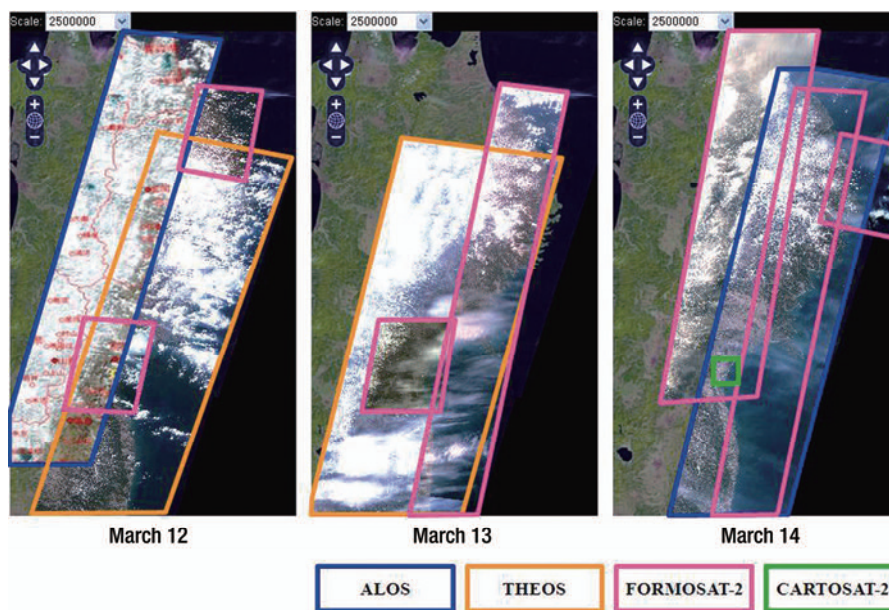
JAXA asked Sentinel Asia observations along the Tohoku coast to supplement the observation areas of Daichi on March 11, because PRISM and AVNIR-2 observations using Daichi were scheduled for inland Tohoku on the day after the earthquake (March 12) and the tsunami was thought to have affected a wide area.

In response, Taiwan's National Space Organization (NSPO) of the National Applied Research Laboratory (NARL) and Thailand's Geo-Informatics and Space Technology Development Agency (GISTDA) conducted observations along the coast using FORMOSAT-2 and THEOS on March 12. The activities were continued on March 13, and the Indian Space Research Organization (ISRO) also observed the Sendai area using CARTOSAT-2 on March 14 after the FORMOSAT-2 survey.

FORMOSAT-2 has the particular characteristic of following the same orbit every day and making three observations of Japan with each flight over the country by shifting the pitch of its axis from north to south. It continuously observed the disaster areas between March 12 and 24 every day.

Table 2.1-7 Emergency observations by Sentinel Asia satellites (except Daichi)

Date	Time	Major events
March 11	14:46	Earthquake occurrence
	15:24	Emergency observation requested
March 12	Approx. 9:12	Observation by FORMOSAT-2
	Approx. 10:07	Observation by THEOS
	Approx. 13:00	FORMOSAT-2 data provided (observation on March 12)
March 13	Approx. 9:12	Observation by FORMOSAT-2
	Approx. 9:47	Observation by THEOS
	Approx. 15:00	FORMOSAT-2 data provided (observation on March 13)
March 14	Approx. 9:12	Observation by FORMOSAT-2
	Approx. 10:30	Observation by CARTOSAT-2
	Approx. 15:00	FORMOSAT-2 data provided (observation on March 14)
	Approx. 17:09	THEOS data provided (observation on March 12)
	Approx. 23:04	THEOS data provided (observation on March 13)
March 15	Approx. 9:12	Observation by FORMOSAT-2
	Approx. 15:00	FORMOSAT-2 data provided (observation on March 15)
March 16	Approx. 9:12	Observation by FORMOSAT-2
	Approx. 15:00	FORMOSAT-2 data provided (observation on March 16) CARTOSAT-2 data provided (observation on March 14)
March 17 – 24	Approx. 9:12	Observation by FORMOSAT-2
	Approx. 15:00	FORMOSAT-2 data provided (observation on the day)



*FORMOSAT-2 observed the same area between March 14 and 24 every day.
 Background images: acquired by LANDSAT, NASA

Figure 2.1-42 Observation areas covered by each satellite

(1) Quick gathering of data on the affected areas

Satellite images covering all the affected areas, including inland regions, had been taken on March 12 (the day after the earthquake) through cooperation with Sentinel Asia using the FORMOSAT-2, THEOS and CARTOSAT-2 satellites in combination with observations made by Daichi. By March 14, cloud-free images had been obtained for almost all coastal areas, including zones where local conditions could not be determined from images obtained on March 12 due to the presence of clouds.

Immediately after observation, FORMOSAT-2 data were initially sent to Taiwan due to the geographical situation of the receiving station. The observation data were made available on the afternoon of the same day. The images taken on March 12 were provided at around 13:00 together with those taken on March 11 before the earthquake struck. On the following day (March 13), the results of image analysis were also provided to enable comparison of conditions before and after the disaster (Figures 2.1-43 and 2.1-44), and proved helpful in promptly determining the extent of the damage.



Figure 2.1-43 FORMOSAT-2 images (Watari Town and surrounding areas, Miyagi)

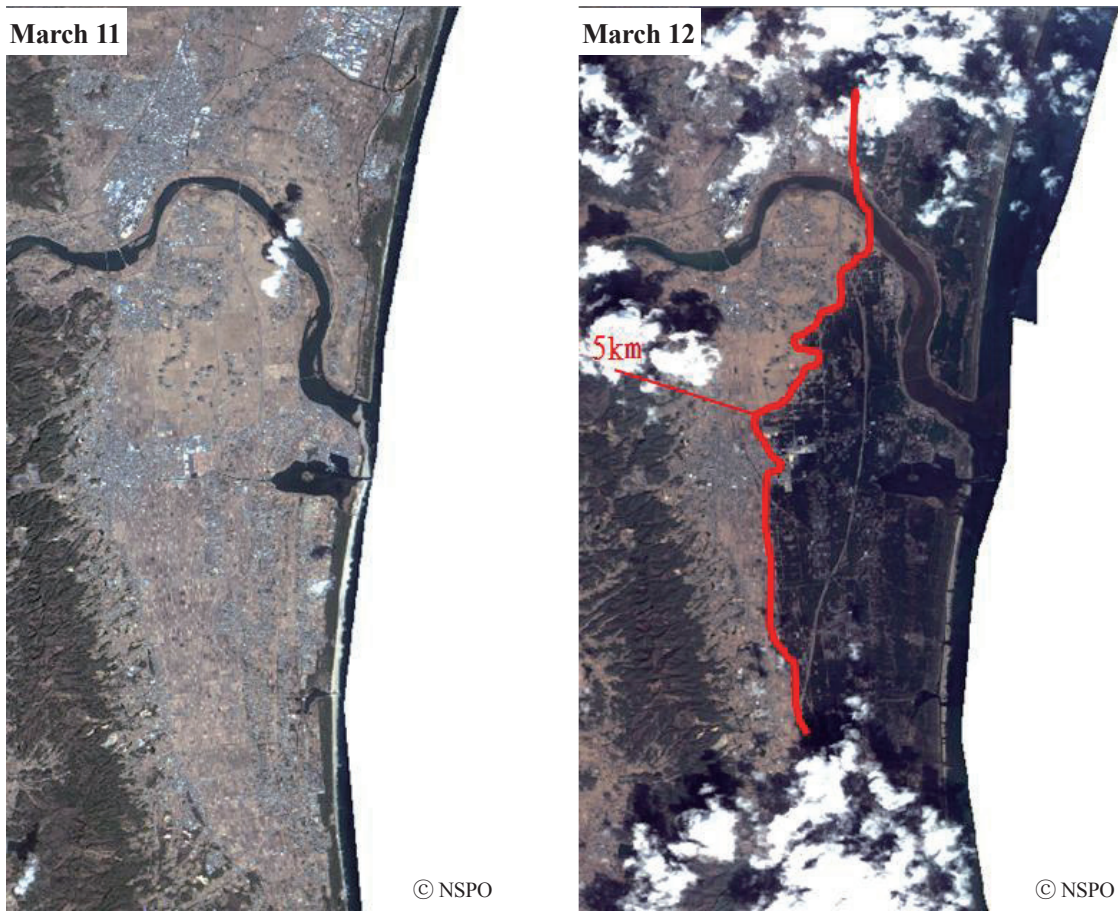


Figure 2.1-44 FORMOSAT-2 images (Watari Town and surrounding areas, Iwanuma City, Miyagi)



Figure 2.1-45 FORMOSAT-2 image (Miyagino Ward and surrounding areas, Sendai, Miyagi)



Figure 2.1-46 THEOS image (Higashimatsushima City and surrounding areas, Miyagi)



Figure 2.1-47 CARTOSAT-2 image (Shiogama Port and surrounding areas, Sendai)

(2) Continuous observation for determination of changes in the affected areas

Sentinel Asia continuously observed all the affected areas immediately after the earthquake and for a period of two weeks in collaboration with FORMOSAT-2.

Comparison of daily data observed under the same conditions enabled identification of developments in the affected areas, such as changes in flood areas, fire outbreaks, fire control, snowfall and other weather considerations.

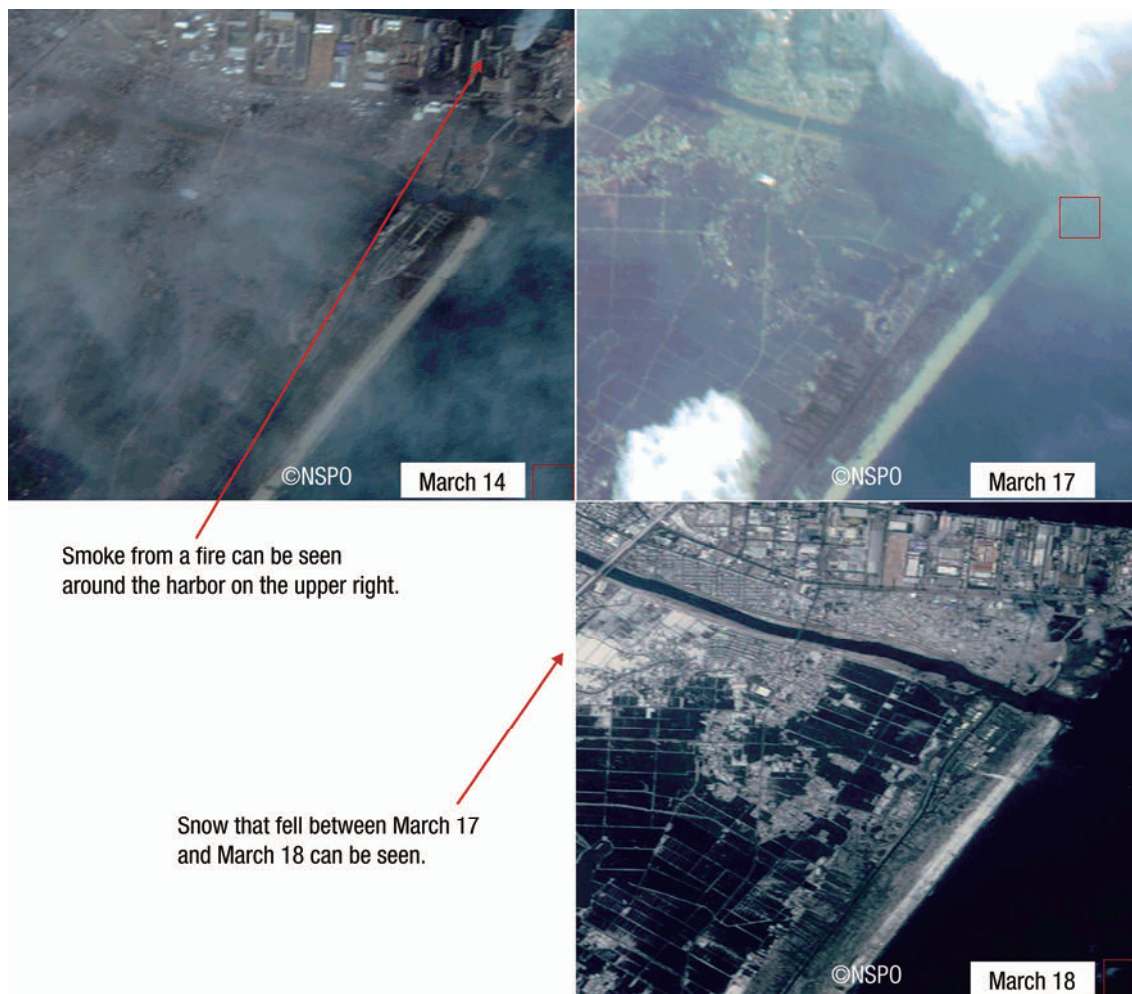


Figure 2.1-48 FORMOSAT-2 images (Shiogama Port area, Sendai)

(3) Provision of satellite data to organizations in Japan

Satellite data from Sentinel Asia which can be used for analysis is usually provided exclusively to member organizations operating as Data Provider Nodes and Data Analysis Nodes. However, it was decided to distribute the data freely to organizations in Japan in response to the Great East Japan Earthquake in conjunction with the National Applied Research Laboratory (NARL) and the National Space Organization (NSPO).

As a result, FORMOSAT-2 data were provided to six universities and one private company on request, and were utilized by a variety of organizations in activities to support the affected areas.