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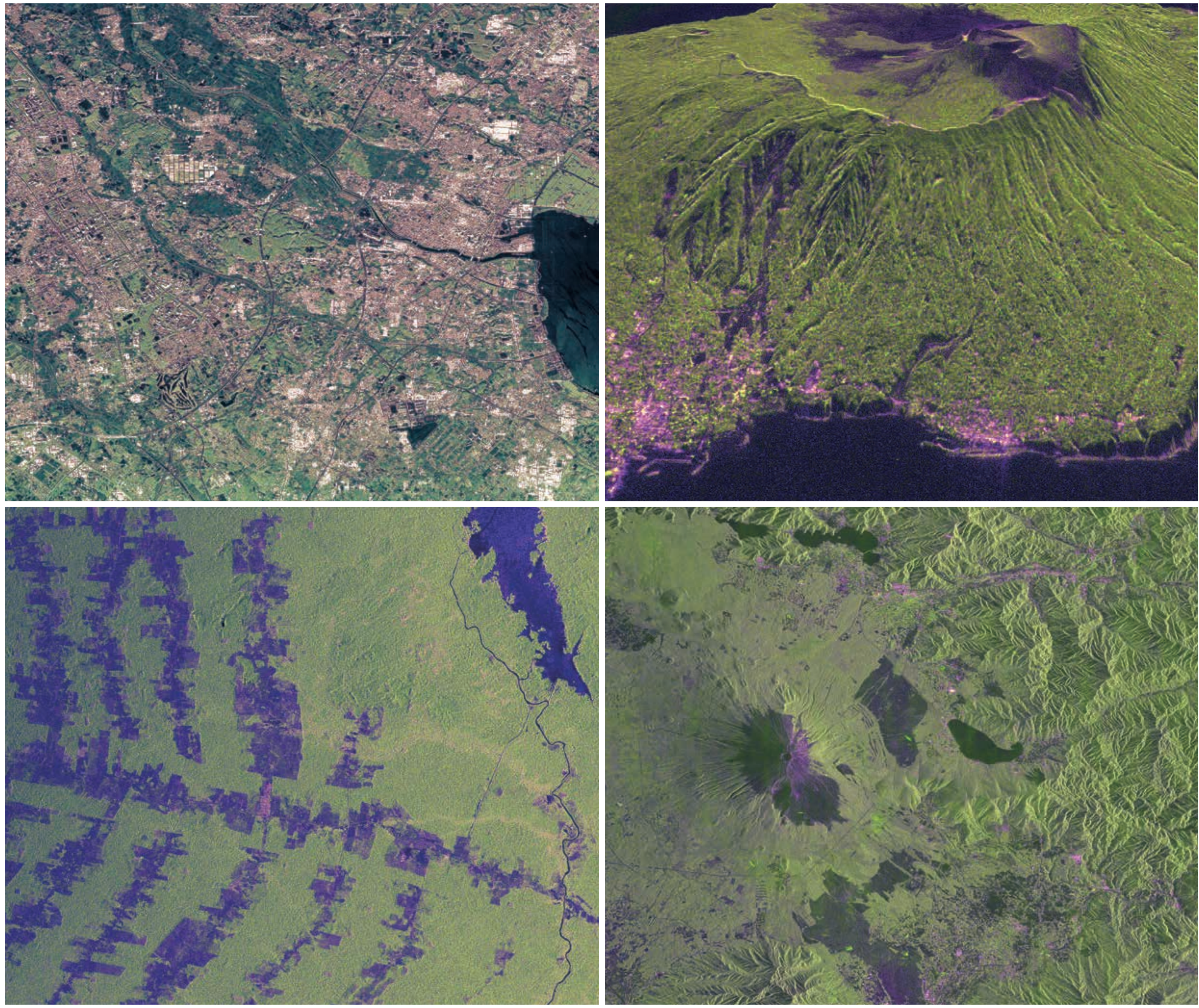
ALOS-2 SOLUTION BOOK

Proposals for “DAICHI 2”
SAR Data Utilization



2nd edition

Japan Aerospace Exploration Agency

JAXA
宇宙航空研究開発機構
Japan Aerospace Exploration Agency

The Earth Needs a Health Check

The Earth is changing in ways that are visible only from space.
Japan's world-class L-band radar satellite keeps its eye on our Earth out for even the slightest symptoms caused by constant changes such as land deformation and environmental destruction.

Introduction

The ALOS-2 (the Advanced Land Observing Satellite-2) "DAICHI-2" is the successor to the ALOS "DAICHI," and it is expected to have multiple applications including disaster monitoring, agriculture and fisheries, ocean observation and resource exploration.

In particular, the L-band Synthetic Aperture Radar (L-band SAR) on board the ALOS-2 is a technology in which Japan leads the world and is expected to contribute to the tackling of challenges in a range of fields.

The Solution Book presents ways of using satellite data and solutions that we hope can be found by ALOS-2 to industry, universities and government. This book has been published in the aim of helping you to analyze data, develop new applications and discover new ways of using satellite data.

Therefore, this book introduces first the special features of ALOS-2, SAR data analysis and the latest research findings, and real-life examples with "Solution Proposal".

ALOS-2 data can be used in combination with the archive of data collected by ALOS. There is unlimited potential in satellite data, as new information waits to be discovered by being combined with other satellite data and ground data, for example.

For all of you reading this book, we sincerely hope that you sense the potential for application of ALOS-2.

And should you come up with an idea for solving a challenge using satellite data, do not hesitate to contact JAXA. Our contact details can be found at the back of this book.

Background photo: Mount Fuji observed by ALOS-2/PALSAR-2

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Bottom right: Mt. Fuji observed by ALOS/PALSAR (refer to p.9)

Background Image: Mt. Fuji (Observed by ALOS/AVNIR-2)

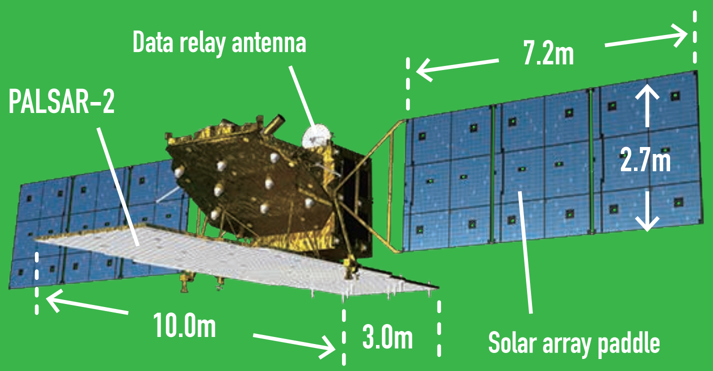
About ALOS-2 and PALSAR-2 (Basic Level)

Overview of ALOS-2

ALOS-2 is the successor to the Advanced Land Observing Satellite (ALOS).

Although ALOS was equipped with both Synthetic Aperture Radar (SAR) and two optical sensors, ALOS-2 is specialized only in SAR. The SAR on ALOS-2 is the Phased Array type L-band Synthetic Aperture Radar (PALSAR-2), which is a state-of-the-art microwave sensor.

The improved wide and high-resolution observation technologies allow more accuracy and prompt information services.

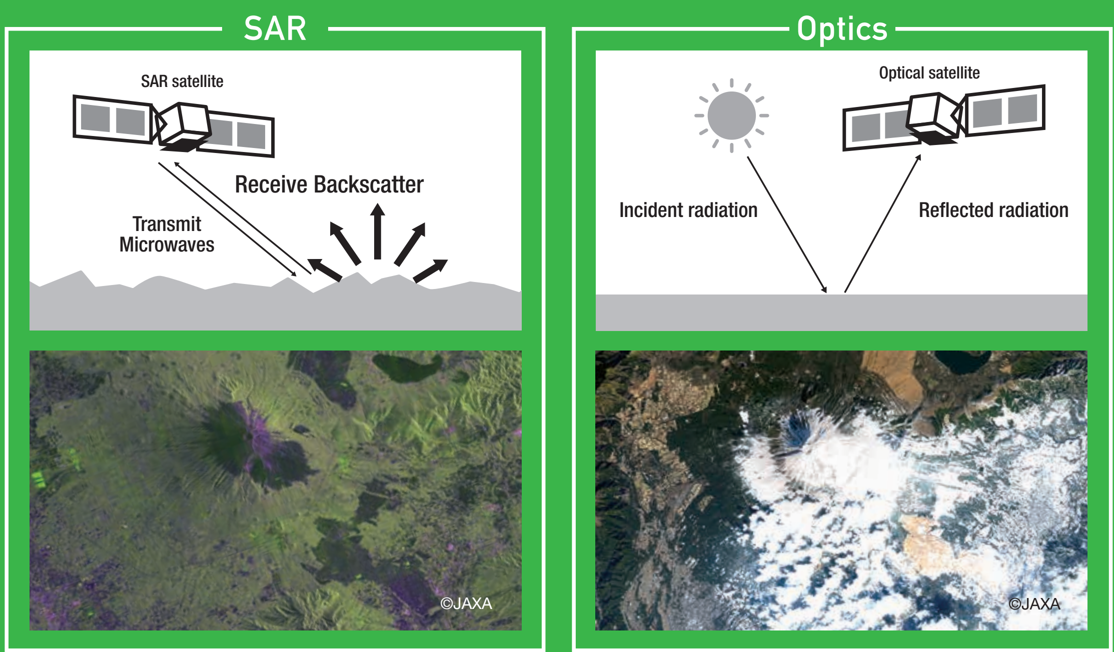


Design life	5 years (target: 7 years)
Launch date	24 May 2014
Launch vehicle	H-IIA launch vehicle No. 24
Launch site	Tanegashima Space Center
Orbit (altitude)	628 km (on the equator)
Orbit period	Approx. 100 min
Repeat cycle	14 days
Satellite mass	Approx. 2,100 kg
Satellite size (on orbit)	Approx. 10.0 m × 16.5 m × 3.7 m
Mission data transmission	Direct transmission, and via data relay satellite
PALSAR-2 (Frequency)	L-band (1.2 GHz band)

ALOS-2 also carries Space-based Automatic Identification System Experiment 2 (SPAISE-2), and Compact Infrared Camera (CIRC) as technology demonstration missions.

Differences Between SAR Images and Optical Images

There are two main types of sensors (observation instrument) in the ALOS series—an optical sensor and Synthetic Aperture Radar (SAR). The optical sensor observes visible light, while the SAR emits microwaves and receives the backscatter of the microwave from the surface of the Earth. A key feature of the SAR is its ability to observe day and night regardless of weather conditions. Hence, because SAR penetrates clouds, the earth surface covered by clouds is captured on the SAR image, even though the same area is covered by clouds on the optical image.



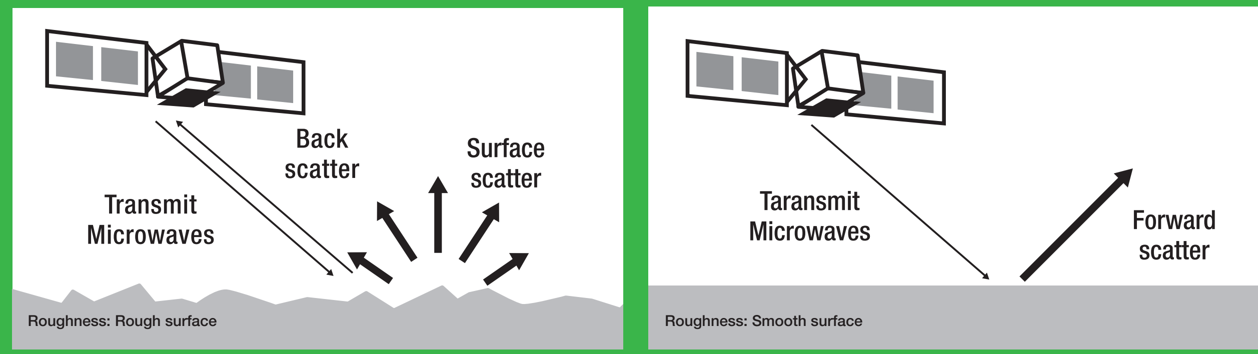
(Top left) Observation Image of SAR satellite
(Bottom left) SAR image
(Top right) Observation Image of optical satellite
(Bottom right) Optical image

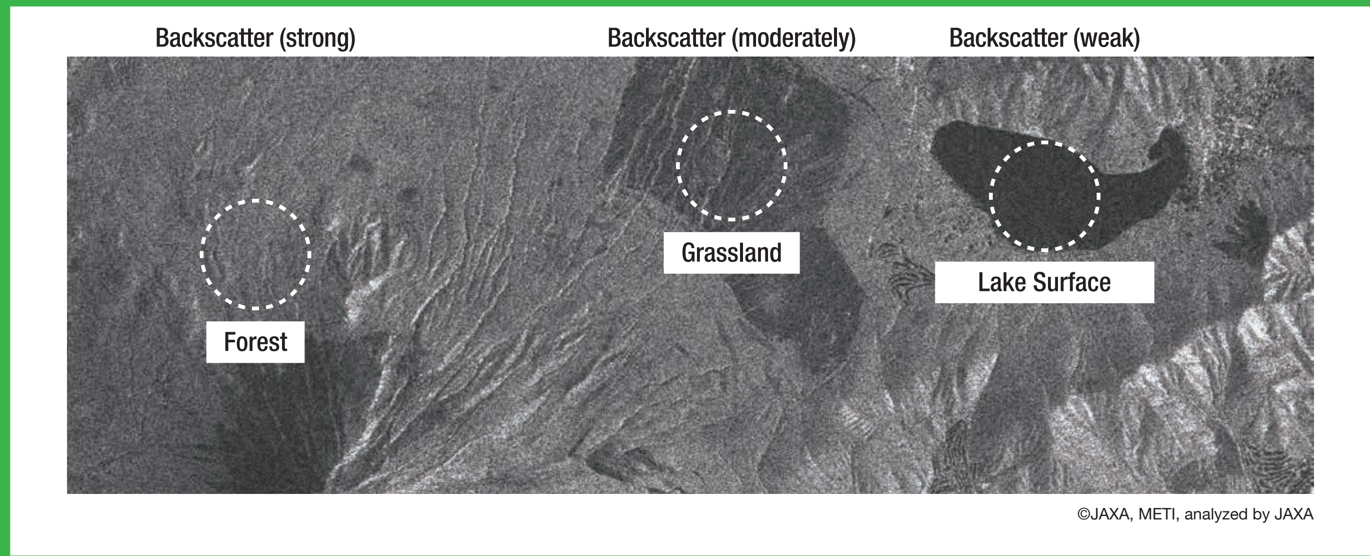
SAR Imaging Principle

SAR transmits the pulse signals to the target, and obtains information about the conditions of the surface depending on the strength of receiving signals. This reflection component is called "backscatter." The target that has strong backscatter appears bright on SAR image.

As shown in the figure, when the pulse signals are transmitted onto a rough surface, it appears bright, because the backscatter is strong by scattering on the surface.

On the other hand, the backscatter is small on a smooth surface such as water surface because most waves are forward scattered. The target appears dark on the image.





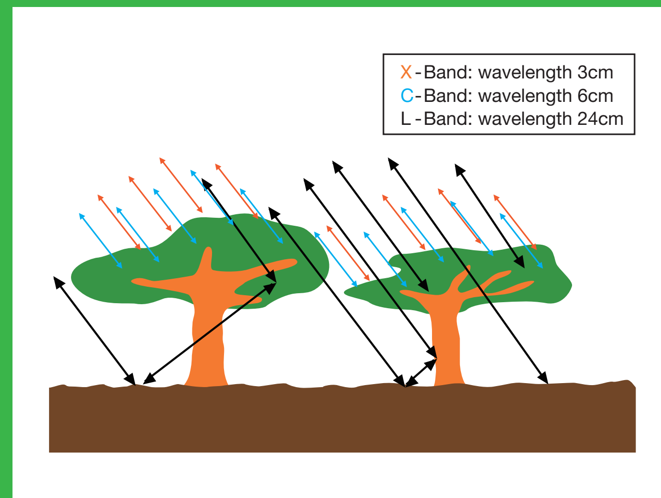
Characteristics of L-Band SAR

Today the three wavelength bands, X-band, C-band, and L-band are used for observations by SAR satellite.

X-band and C-band microwaves with a short wavelength are suitable to observe detailed structures. For example, the signal has the capability to detect slight unevenness on the earth surface, and to be reflected from detailed structures such as ripples on water surfaces and foliage in forests.

On the other hand, L-band microwaves with the a long wavelength penetrate detailed structures. For example, the signal penetrates the foliage of trees easily, and is therefore able to observe the shape of ground surfaces.

L-band SAR is Japanese advanced technology. It is extremely useful for observing surfaces in vegetated area and steep terrain, including Japan.

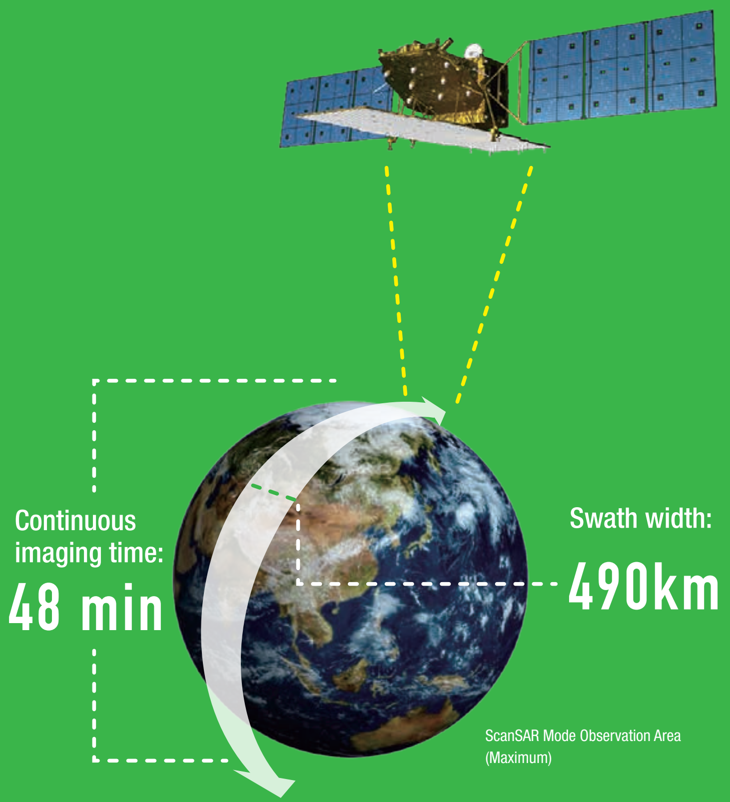


Information Available Regardless of Day or Night, Weather Conditions

Three Characteristics of ALOS-2

Observation of Wide Areas on the Earth

The PALSAR-2 antenna is fixed to the nadir direction of the satellite. Because ALOS-2 satellite body can tilt right and left to observe on both sides, it is possible to expand its observation range to 2,320 km almost three times greater than DAICHI's. ScanSAR Mode was able to achieve 490km swath wider than 350km observed by ALOS/PALSAR. ALOS-2 has another advantage to secure observation time of 48 minutes during approximately 100 minutes to circle the Earth once.



ScanSAR Mode Observation Area (Maximum)

High-resolution Observation Regardless of Day or Night, Weather Conditions

The greatest characteristic of Synthetic Aperture Radar (SAR) is its ability to observe the Earth's surface day and night, regardless of weather conditions. PALSAR-2 also has Spotlight Mode to achieve the resolution of 1m × 3m, allowing it to carry out observations at a higher resolution as compared to ALOS. Another characteristic is its ability to maintain a broader swath width even at high resolution. The swath width is 25km at a resolution of 1m × 3m, and 50km at a resolution of 3m.

Disaster Response by Emergency Observation

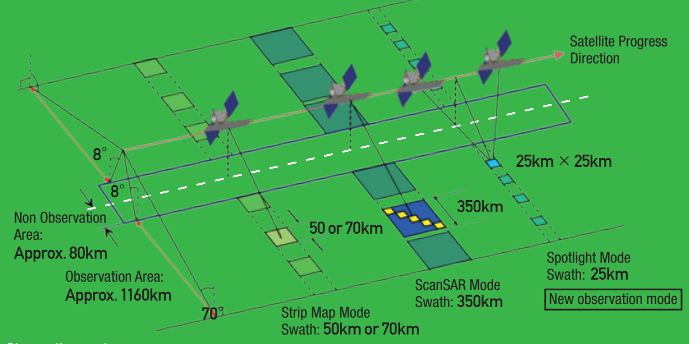
When natural disasters occur, immediate response is required. ALOS-2 realizes emergency observation by left-and-right looking capability, the significant reduction in revisit time (to target quickly on the location to be observed) and improved data transmission ability. In the case that the emergency observation for natural disaster is required in Japan, images of the disaster area can be obtained in as little as two hours or in 12 hours at the longest.

Yellow band: ScanSAR Mode (Swath width: 490km)
Red band: ScanSAR Mode (Swath width: 350km)
Green band: Strip Map (10m) Mode (Swath width: 70km)
Pink band: Strip Map (3m/6m) Mode (Swath width: 50km)

The Observation Mode and Each Resolution/Observation Swath

ALOS-2 has three observation modes.

We can choose Spotlight Mode with the resolution of 1m × 3m for the most detailed observation. And also Strip Map Mode with the resolution of 3 – 10m (swath width of 50 – 70km), and ScanSAR Mode to cover a wide area in just one observation (resolution of 60 – 100m, swath width of 350 – 490km) are operated. It is possible to realize the optimal observation by selecting the most appropriate observation mode that corresponds with your objectives.



Observation mode and range

Observation mode	Resolution	Swath
Spotlight	1m (Az) × 3m (Rg)	25km (Az) × 25km (Rg)
Strip Map	3m	50km
	6m	50km
	10m	70km
ScanSAR	100m	350km
	60m	490km

*"Az" means azimuth direction (Satellite progress direction). "Rg" means range direction (radio wave irradiation).

Spotlight Mode

Spotlight Mode, which was not available on ALOS, was added as a new function. This mode makes it possible to obtain better quality images at the high resolution of 1m × 3m. Spotlight Mode enables to increase the illumination time with electronic beam steering in the direction of the azimuth away from nadir. As a result, it is now possible to capture the Earth's surface in more detail.

Image captured using Spotlight Mode (around Maihama Station) (Observation by ALOS-2/PALSAR-2)

Strip Map Mode

Incorporating the dual-beam system into PALSAR-2 makes it possible to maintain a high resolution and wide swath width in Strip Map Mode. While realizing the resolution of 3m – 10m, it also ensures a wide swath width extending from 50 – 70km.

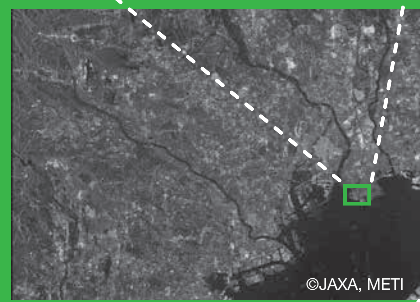


Image captured using Strip Map Mode (Tokyo, Chiba area) (Observation by ALOS/PALSAR)

ScanSAR Mode

It is possible to capture images up to 490 km swath with ALOS-2. Compared to other Earth observation satellites, it can capture images over an extremely wide area.

In addition, it can carry out continuous observations up to 48 minutes, going about halfway around the Earth in a single observation. Improved instruments allow continuous monitoring and greatly expanding the observable range.

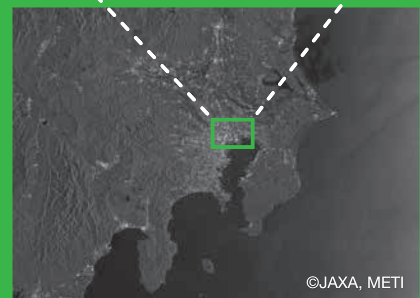


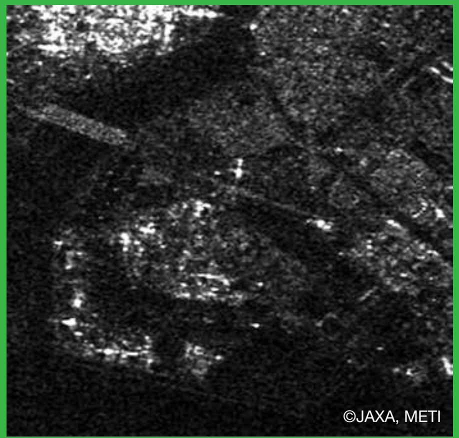
Image captured using ScanSAR Mode (Kanto region) (Observation by ALOS/PALSAR)

First Images Obtained by ALOS-2

This section features the observation images obtained between 19 through 21 June 2014 through the test waves emitted by the Phased Array type L-band Synthetic Aperture Radar (PALSAR-2) mounted on ALOS-2.

Comparison with Previous SAR Images

The figures show SAR images of the area near Urayasu City in Chiba Prefecture. The PALSAR-2 image obtained by ALOS-2 (right) is compared to images obtained by the ALOS (center) and by the Japanese Earth Resources Satellite (JERS-1)(left). A higher resolution is archived by ALOS-2 than the other previous satellites, and we have high expectations for its ability to capture detailed information about the situation when a disaster strikes.



JERS-1/SAR 18m resolution (21 April 1992)

ALOS/PALSAR 10m resolution (27 April 2006)

ALOS-2/PALSAR-2 3m resolution (19 June 2014)

Comparison of satellite images obtained by PALSAR-2 mounted on ALOS-2 with previous satellite images

Landslides on Izu-Oshima

The left figure shows SAR imagery of Izu-Oshima obtained by PALSAR-2 mounted on ALOS-2. The right figure shows the same location, but is a bird's-eye view presentation that uses elevation data obtained by ALOS PRISM. Here, we can still see the scars of the large-scale landslides caused by heavy rains of Typhoon No. 26 in October 2013, even though about eight months have passed. The vegetation has not recovered there yet.

By incorporating false coloring through the use of polarized wave information, we can generally see that green indicates vegetation, bright purple or yellow-green indicates the town areas, while dark purple indicates bare land.

Observation image of Izu-Oshima obtained by PALSAR-2 mounted on ALOS-2 (3m resolution) on 19 June 2014

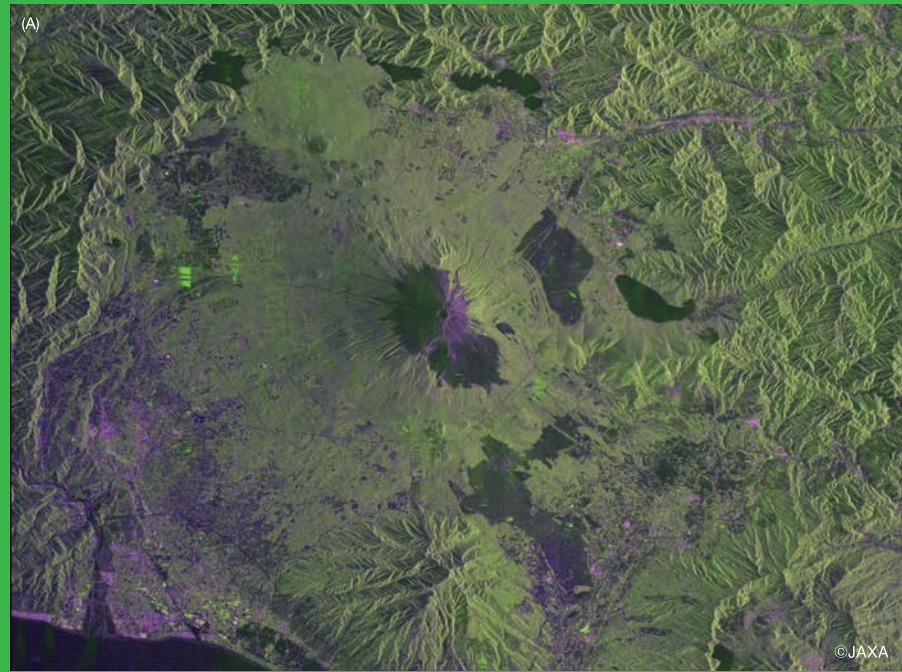
*Polarization color composite image with HH, HV, HH/HV polarized waves assigned to each image as red, green, and blue, respectively.

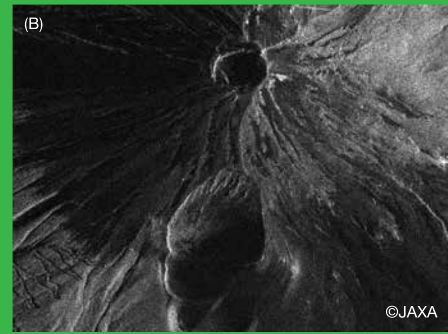
Mount Fuji

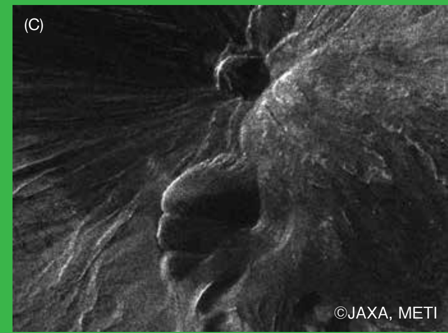
Figure (A) shows an image of the area around Mount Fuji, obtained using the Strip Map Mode (resolution of 3m) by PALSAR-2 mounted on ALOS-2.

The image was colored spuriously using polarization data acquired through the observation in order to understand the land cover classification more precisely. Roughly speaking, green indicates vegetation, light purple and yellowish green are urban areas, and dark purple is barren areas.

Figure (B) is an enlarged view of the area near the peak of Mount Fuji. Comparing this to Figure (C), an image obtained through PALSAR mounted on ALOS, we can see a dramatic improvement in visibility and clarity. It allows us to gain an understanding the crater conditions and the roads leading to the top of Mount Fuji.







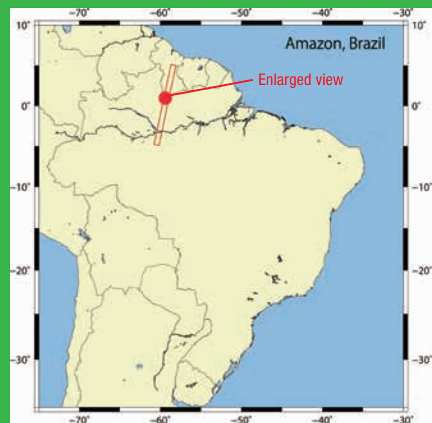
The image of the area around Mount Fuji obtained by PALSAR-2 mounted on ALOS-2 (3m resolution) on 20 June 2014

*Polarization color composite image with HH, HV, HH/HV polarized waves assigned to each image as red, green, and blue, respectively.

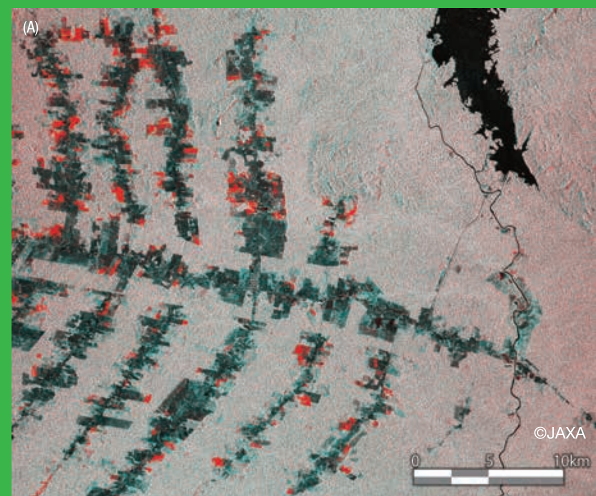
Deforestation in Amazon

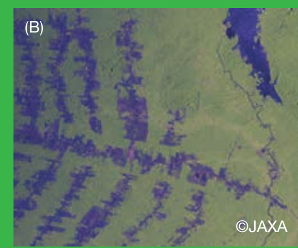
Figure (A) shows the deforestation in the eastern part of Roraima in Brazil. This image is a color composite image that combines image (B) taken on 21 June 2014 by ALOS-2/PALSAR-2, with image (C) taken in 2009 by ALOS/PALSAR. The light blue color indicates non-forested areas, gray indicates forested areas, while red shows the forest areas that have decreased over five years. On this image, we can find approximately 25km² deforestation.

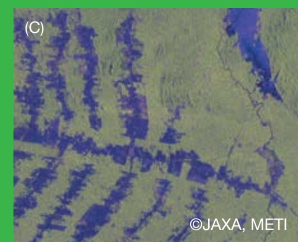
L-band SAR is suitable for forest observation, and ALOS-2/PALSAR-2 has made it possible to observe forests on a global scale. Hence, it is expected to contribute to the estimation of forest biomass, which is closely tied in with forest management and climate change.



Observation range







Deforestation in Amazon captured by PALSAR-2 mounted on ALOS-2 (3m resolution) on 21 June 2014

SOLUTION » Disasters

Understanding the Situation to Speed Up the Reconstruction Process

Earth observation satellites providing a bird's-eye view of the overall situation demonstrate their true value when grasping the situation of wide disaster hit areas immediately.
Because ALOS-2 can carry out observations even in rainy weather and at night, ALOS-2 can be used as a means for understanding the situation in the event of a disaster.

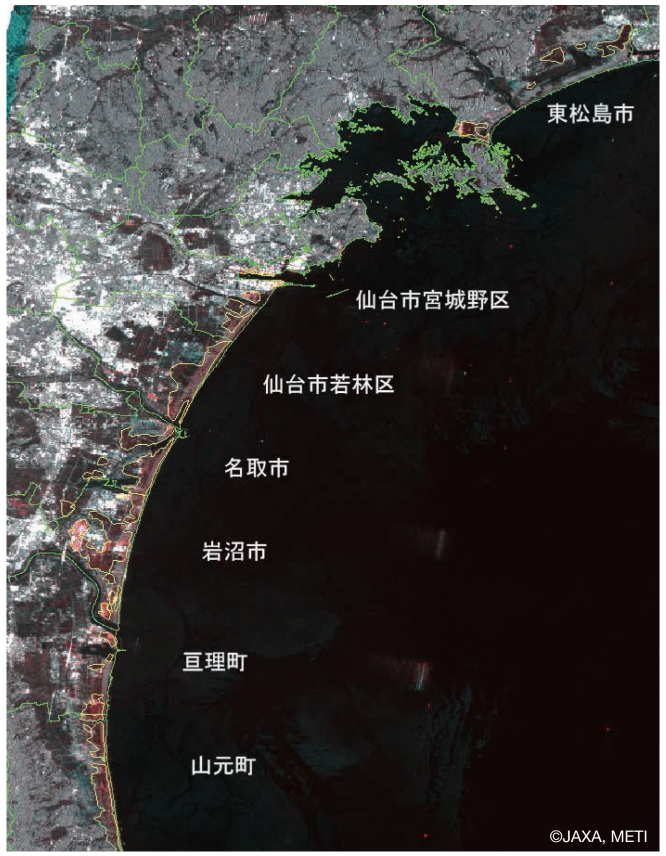
» Understanding the Situation of Tsunami Damage to Formulate a Recovery Plan

It is possible to identify the areas affected by a tsunami using SAR data. The intensity of microwaves reflected on water surfaces and marshlands is lower, these surfaces appear darker on an image. In a contrasting situation, land surfaces appear brighter. Using this characteristic, it is possible to extract areas inundated by tsunami and flood waters.

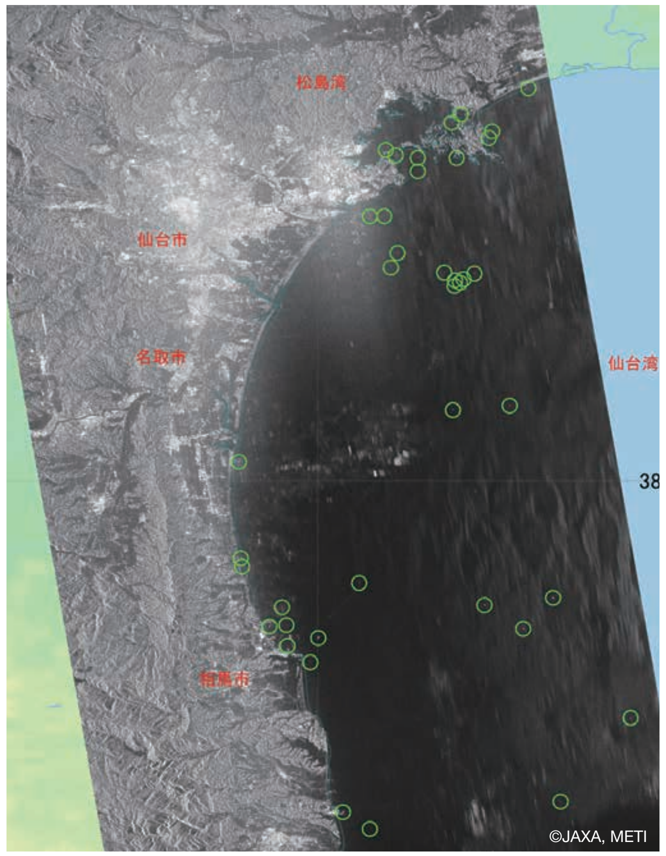
Images obtained by emergency observation for natural disasters are first used for emergency response, such as rescue efforts and identification of isolated areas. In particular, PALSAR-2's ScanSAR Mode is suitable for a wide area disaster.

In the Great East Japan Earthquake on 11 March 2011, ALOS PALSAR carried out emergency observations. Information about the widespread region inundated by the tsunami was provided to the Prime Minister's Office, disaster prevention administrative agencies, and the press. These observation data continued to be used to the formulation of recovery plans for the inundated areas after that. Furthermore, as floating objects such as rubble floating on the sea surfaces showed up brightly on the images, they could be distinguished from the surface of the sea. These data were useful in estimating the total amount of floating objects on the sea.

Observation data of disaster situation is transmitted in one hour only by ALOS-2. This is immensely useful in helping to capture information about the situation over a wide area, and during the night when helicopters and airplanes are unable to fly. We oftern hear it said that the response in the first 72 hours after a disaster is critical to save lives. Observation data is valuable for such initial response.

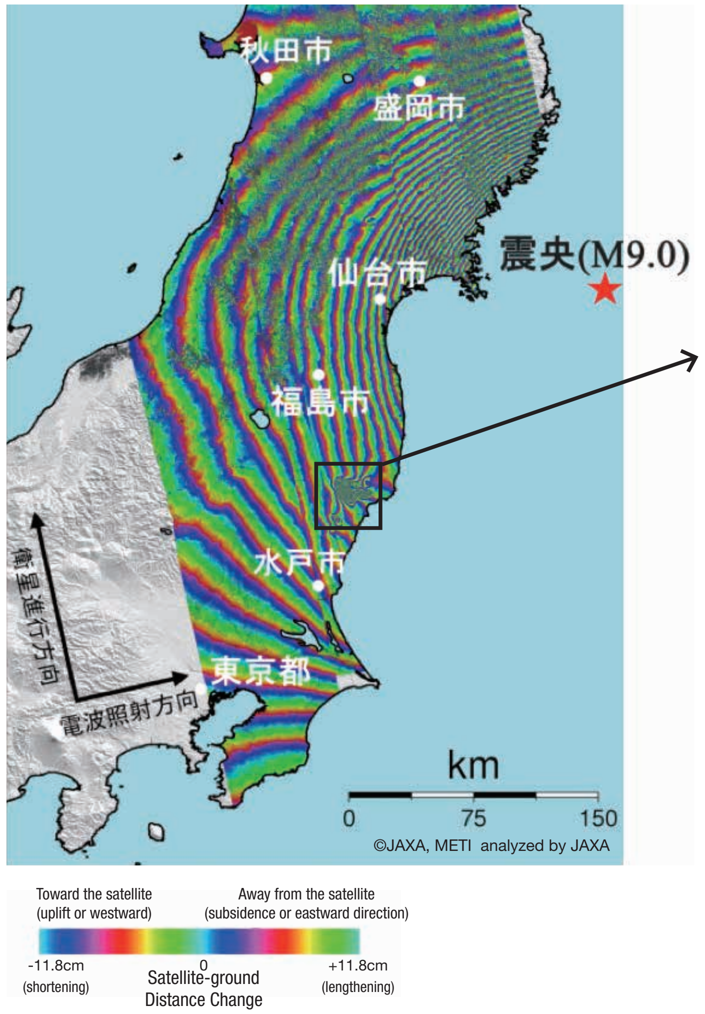


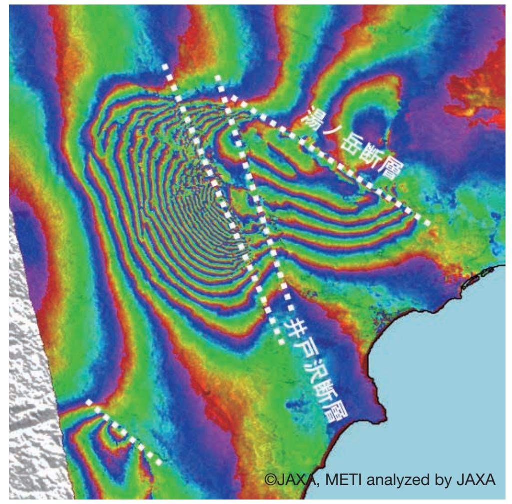
Extraction of inundated areas (the areas lying within the yellow polygon are inundated)
Analysis of observation images taken from March to April 2011
(Observation by ALOS/PALSAR)



Extraction of floating objects on the sea surfaces (the green area shows objects floating on the sea)
Analysis of observation images taken on 13 March 2011
(Observation by ALOS/PALSAR)

» Estimating Earthquake Damage Based on Land Deformation





Crustal movements in the Great East Japan Earthquake
(Observation by ALOS/PALSAR in 2011)

The method to measure distances or movements on the Earth's surface by interfering with two SAR images taken of the same location is referred to as "Interferometry". The figures show images of the crustal movements by the Great East Japan Earthquake, before the earthquake (3 March 2011) and after the earthquake (18 April 2011), detected using the PALSAR mounted onto ALOS. The rainbow-colored stripes show the changes in distance between the satellite and the Earth's surface. Each cycle of color changes, from blue to green, yellow, red, then back to blue, shows the Earth's surface moving closer to the satellite (uplift) by 11.8cm. The localized interference stripes in the right figure are considered to show the crustal movements occurred by M7.0 Earthquake in Hamadori region of Fukushima Prefecture on 11 April 2011.

Even if an earthquake occurs, ALOS-2 is able to obtain data everywhere around the world within two days. SAR pair images are able to be provided within 14 days at the latest. If we are able to capture the situation of crustal movements early, we can use these data to estimate the scale of damage and formulate recovery and reconstruction plans.

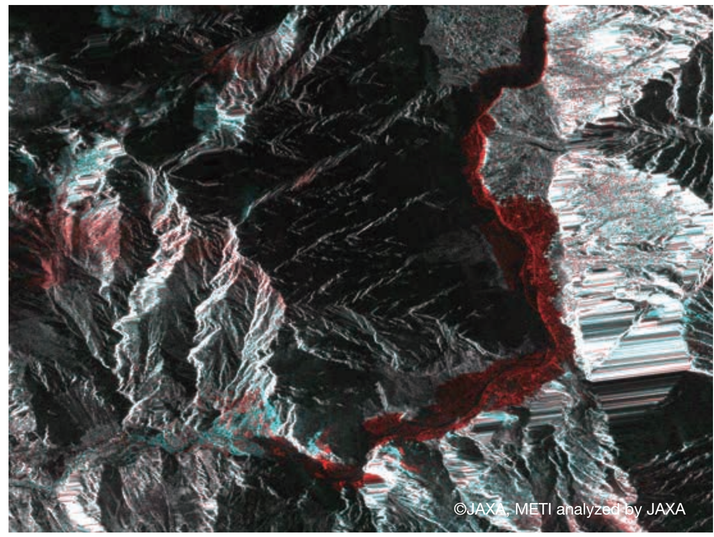
» Understanding Landslides and Floods

The monitoring of changes on the Earth's surface allows us to gain an understanding of the damage by landslides and floods.

The figure shows a natural dam lake formed by the large-scale landslide occurred in the Hunza Valley in Pakistan in January 2010, captured by ALOS/PALSAR. The landslide dammed up the river and a natural dam lake was formed.

Red was assigned to the image before the disaster, while green and blue were assigned to the image after the disaster. Hence, red indicates the flooded areas, while blue indicates the areas where the landslides occurred.

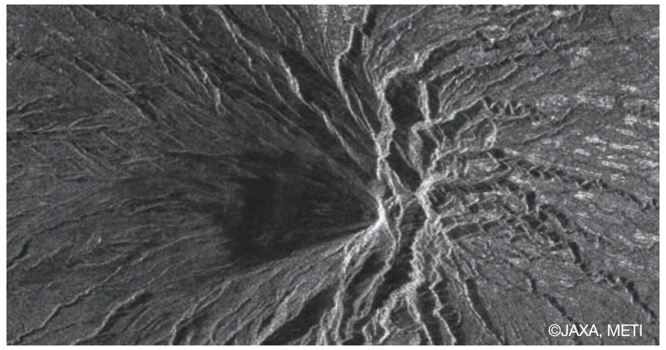
The image was provided to the local government and was used to make decisions about issuing instructions for evacuation. Through such image analysis, it is possible to gain an understanding of the situation early, and apply the knowledge in drawing up countermeasures against landslide disasters.

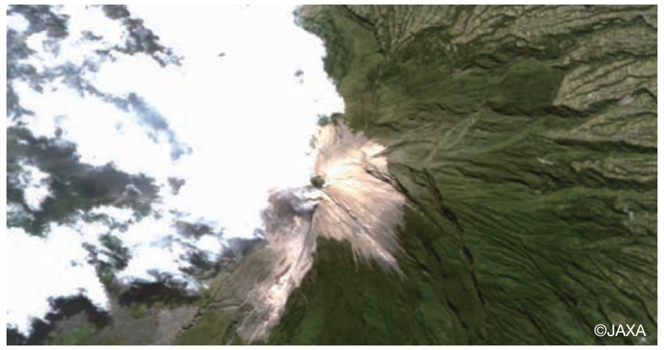


Dam lake produced in the Hunza Valley in Pakistan (Observation by ALOS/PALSAR)
Before the disaster: 17 May 2006, After the disaster: 29 May 2010

Observing Volcanoes through Smoke and Ashes

The figures below show the eruption of Mount Merapi in Indonesia. According to the Directorate of Volcanology and Geological Hazard Mitigation, Indonesia (DVGHM) , the volcano crater cracked, and volcanic fumes were rising about 100 meters high from the crater. ALOS/AVNIR-2 observes volcanic fumes clearly, and it is also possible to see volcanic ash spreading from the crater to the mountainside (right). Even in PALSAR observation image (left) also clearly shows the undulating geographical character as radar reflection spreading radially from the crater to the foot of the mountain . As SAR is able to pass through the volcanic fumes to capture the situation on the Earth’s surface, it is suitable for monitoring dangerous area such as volcanoes.



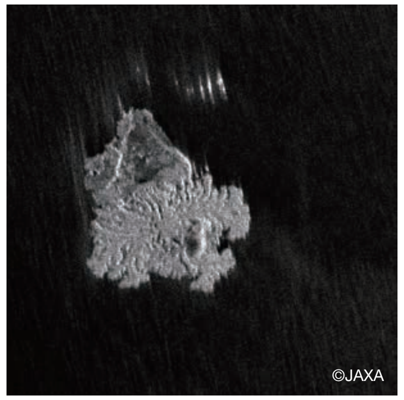


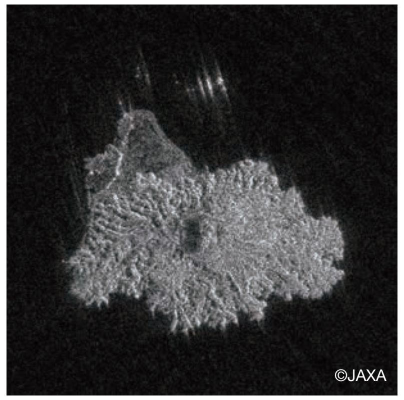
Eruption of Mount Merapi, Indonesia, observed on 26 April 2006 (Left) SAR image (observation by ALOS/PALSAR) ©JAXA, METI (Right) Optical image (observation by ALOS/AVNIR-2) ©JAXA

Understanding Volcanic Activity Even Over a Wide Area

At about 16:00 on 20 November 2013, a new island was born in the sea near Nishinoshima of the Ogasawara Islands. The center image shows the area around Nishinoshima, obtained by Strip Map Mode (resolution of about 3m) of PALSAR-2 mounted on ALOS-2 on 20 June 2014. The left image was taken by L-band SAR (Pi-SAR-L2) mounted on an airplane on 4 February 2014. We can find that the island has expanded in these four months, comparing these images. The expanded area is estimated approximately 0.67km^2. SAR is sensitive to the Earth’s surface roughness, and we can see that it has captured in detail the appearance of the island surface that has just been born.

The right image is an aerial photograph obtained at the same time at about 400m - 500m altitude, and shows volcanic fumes rising from two locations. Hence, SAR is able to pass through volcanic fumes to capture images of the Earth’s surfaces, making it possible to continuously monitor volcanic activity in remote locations using PALSAR-2.





Eruption of Nishinoshima, Tokyo
(Left) Observation by SAR mounted on an airplane on 4 February 2014
(Center) Observation by ALOS-2/PALSAR-2 on 20 June 2014
(Right) Photograph taken using an optical camera on 4 February 2014

*Pi-SAR-L2 (Polarimetric Interferometric Synthetic Aperture Radar L-band 2): JAXA's radar mounted in an aircraft. It is able to take photographs at about the same resolution as images captured using ALOS-2.
http://www.eorc.jaxa.jp/ALOS/Pi-SAR-L2/

SOLUTION PROPOSAL

- **Disaster Mitigation**
  ALOS Data can be used in mitigation activities of the impact of disasters by providing a bird’s-eye view of the overall situation from space promptly.
- **Drawing Up and Distributing Disaster Hazard Maps**
  ALOS Data can be used for planning disaster prevention by local governments and other organizations ordinary times.

Providing Information About Disasters Around the World Through International Cooperation

When disaster occurs, it is important to obtain observation images of affected areas as quickly as possible. However, the observation satellite of the affected country may not necessarily be orbiting above the affected areas in a timely. Hence, an international cooperation framework has been established in which countries work together during a disaster to provide one another with observation data obtained from their respective satellites. The largest such framework is “the International Charter on Space and Major Disasters”. Approximately 300 cases of large-scale disasters, such as earthquakes, floods, and typhoons, which call for emergency response, occur around the world every year. For example, the International Charter on Space and Major Disasters worked for 40 cases in 2012. More than 20 countries and organizations, including Europe, the United States, China, South Korea, and Russia, are members of the Charter, and Japan also participated in the initiative after the launch of ALOS.

Sentinel-Asia can be described as the Asian version to this Charter. This initiative is led by Japan, with the participation of countries including India, Thailand, and Taiwan. JAXA has also concluded separate cooperative agreements with Italy and Canada to exchange satellite data during disasters. Since ALOS operation was completed in 2011, Japan has become unable to provide data. However, Japan’s renewed activity in this field is highly anticipated after the launch of ALOS-2.

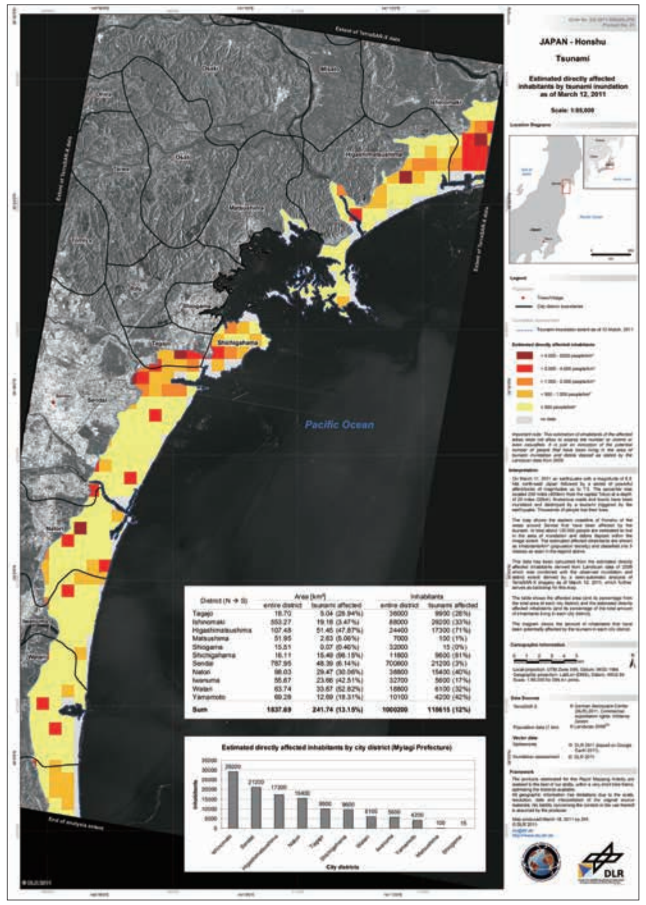


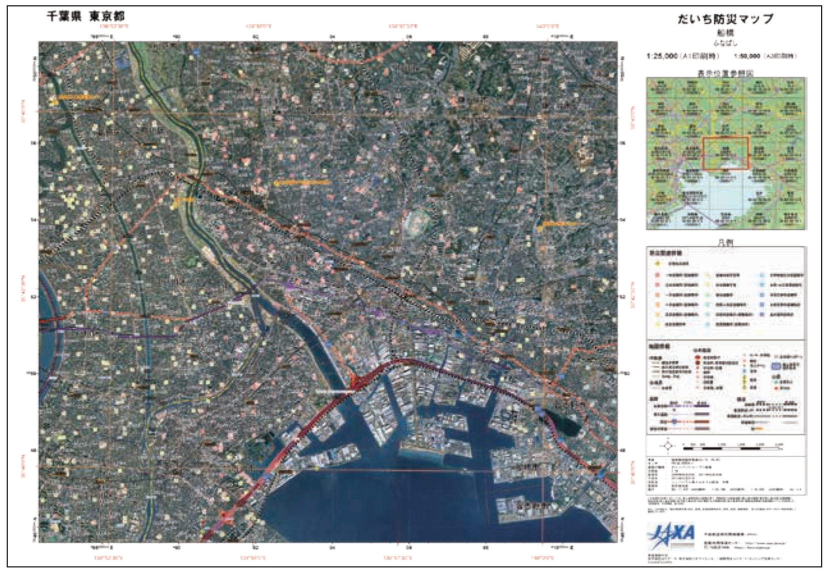
Image of the areas affected by the tsunami in the Great East Japan Earthquake, provided by German Aerospace Center (DLR) through the International Charter on Space and Major Disasters. The image is a superimposition of SAR image (TerraSAR-X) with population density data.

Using Satellite Images in Local Governments’ Disaster Prevention Plans

If we predict potential hazards such as earthquakes and tsunamis, volcanic eruptions, landslides, and floods, to formulate evacuation plans beforehand, the preparation can facilitate smooth response for actual disasters and may save as many lives as possible.

Until now, JAXA has provided disaster prevention authorities and agencies as well as local governments with “DAICHI Disaster Prevention Map”. This is a topographic map that has been superimposed with road information and detailed optical image data captured using ALOS. The combination use with disaster data obtained by ALOS-2 immediately is expected to contribute more than before toward the formulation of disaster prevention plans by the national government and local governments in the future.

Satellite data hold great potential for disaster prevention and countermeasures like this.



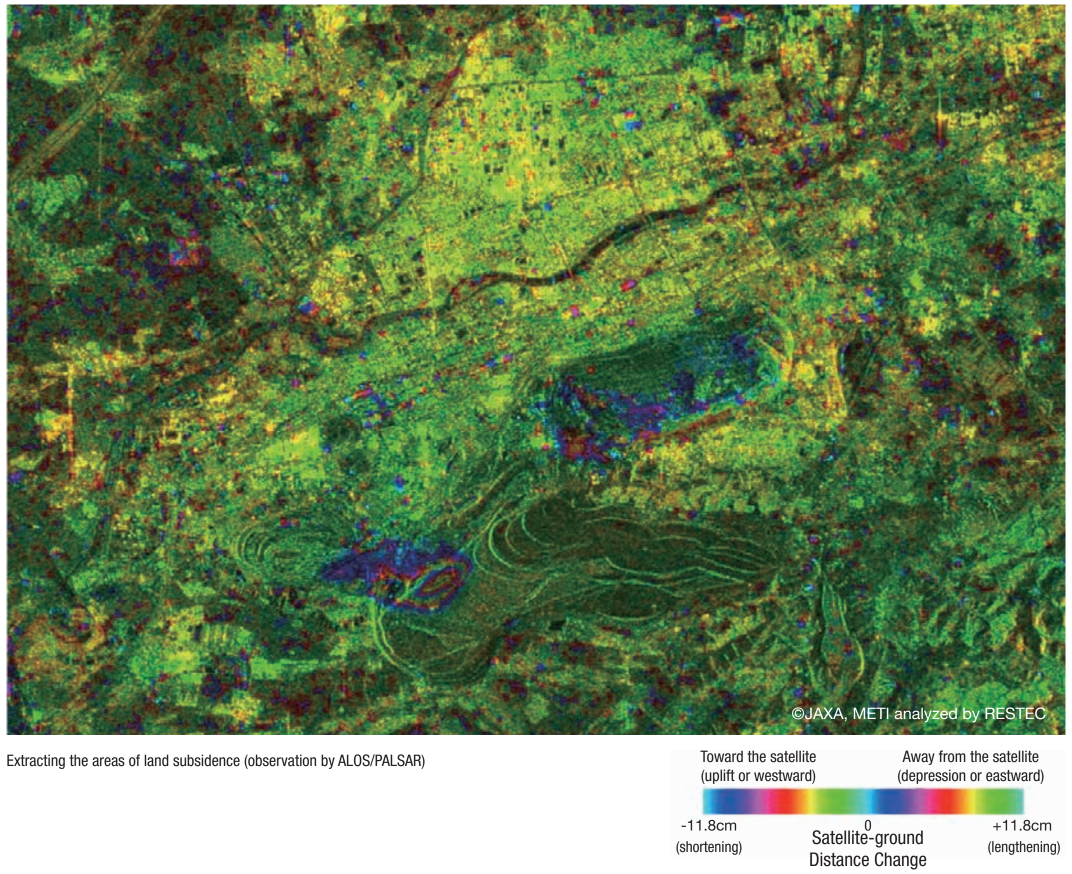
DAICHI Disaster Prevention Map

SOLUTION ››› Civil Engineering

Protecting Cities from Land Deformation

ALOS-2 is able to capture deformation of the Earth's surface with an accuracy of a few centimeters.
By capturing invisible deformation, the information can be used as fundamental materials for countermeasures to prevent land subsidence and to maintain infrastructure.

››› Capturing the Trends of Land Subsidence



Extracting the areas of land subsidence (observation by ALOS/PALSAR)

Land deformation such as land subsidence or crustal movements, can be found by measuring the distance from the satellite to the Earth's surface and comparing two difference sets of data of the same location obtained at different dates and times (interferometry).

Land deformation is also measured by electronic reference points, but the deformation is captured based on the moving points only. On the other hand, it is possible to capture land subsidence in millimeters or centimeters from the satellite.

This method has the advantage of enabling observations of changes across a wide area along a time axis, and various analytical methods have been developed.

The figure shows an image that captures land subsidence at a coal mine, by interferometric processing on an image obtained by ALOS/PALSAR. The Earth's surface is predicted to have become deformed in the two elliptical locations shown in blue. The ellipse on the right is the coal mine, and land subsidence as well as landslides have actually occurred. The ellipse on the left was a venue for supplying water used for chilling when drilling the coal mine. It seems that massive use of underground water caused the land subsidence here.

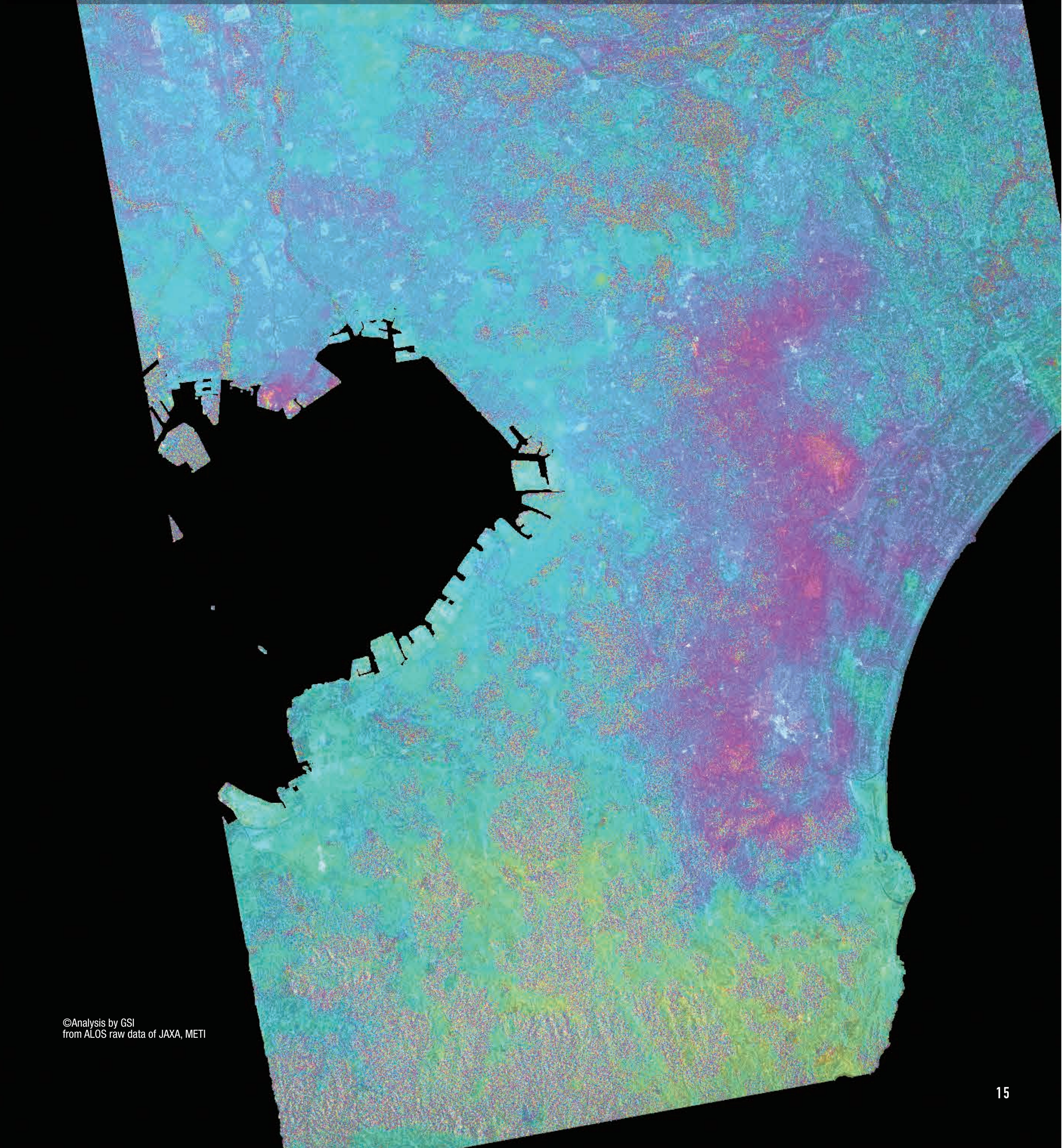
Land subsidence and landslides have a major effect on our lives. If we use SAR images to identify land deformation, we can apply these to making decisions about disaster prevention policies.

››› Capturing Information on Long-Term Crustal Movements to Contribute to Earthquake Prediction Research

Crustal movements is the movement of the Earth' crust from a few millimeters to a few centimeters per year in the long term. This movement brings the phenomenon on the Earth's surface such as earthquakes, volcanoes. Japan lies over four tectonic plates. The movement of plates deep below the surface of the Earth and fault is thought to be closely tied to volcanoes and earthquakes. Hence, monitoring crustal movements over the long-term can contribute to elucidating the mechanism of earthquakes and volcanic activity.

The Geospatial Information Authority of Japan has attempted to measure crustal movements over the long-term by using methods such as leveling, triangulation, and GPS. Now, they are willing to incorporate the new method of using the perspective from space.

This image of the Chiba and Tokyo area was captured using the ALOS PALSAR, and processed using interferometry. The areas in red show the locations where the Earth's surface has become depressed and is therefore further away from the satellite. In particular, it has succeeded in capturing land subsidence in a large part of the Kujukuri Plains.

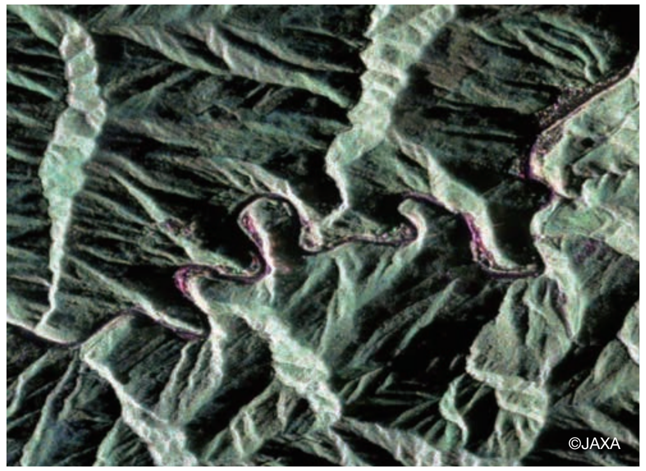


Utilizing for Maintenance, Inspection, and Management of Roads and Rails

In Japan, it is not uncommon to see roads and rails surrounded by impenetrable mountains.

The right figure is the SAR image of Tenkawa Village, Yoshino-gun, Nara Prefecture, taken by the Pi-SAR-L2. The river flowing among mountains is indicated dark on the image. With a resolution of about 3m by ALOS-2, it is possible to identify rivers.

For locations where it is difficult to monitor from the ground, it is possible to gain an understanding of the situation of river flooding and cliff collapse by comparing SAR images that are taken at regular intervals. It is also possible to assess priorities for checkout and repair work for roads and rails in mountains and near rivers.



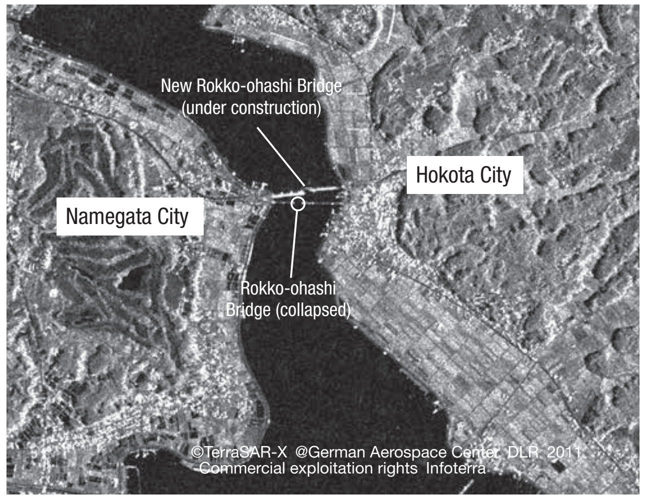
Roads in Tenkawa Village, Yoshino-gun, Nara Prefecture
(Observation by SAR mounted on an airplane on 18 June 2012)

Utilizing for the Management of Bridges

SAR is also able to capture the appearance of bridge over a wide river.

The figure shows a TerraSAR-X image of Rokko-ohashi Bridge, which connects Namegata City and Hokota City in Ibaraki Prefecture. As a part of the Rokko-ohashi Bridge collapsed in the Great East Japan Earthquake, the line is cut off on the image. The new, large-scale Rokko-ohashi Bridge on the north side is also shown imperfectly-shaped, but this is because this new bridge is still under construction. This image was provided to the Cabinet Office, disaster prevention authorities and agencies, and local governments after the earthquake.

The periodic observation by ALOS-2 leads to grasp the situation of roads and bridges.



Rokko-ohashi Bridge collapsed by the Great East Japan Earthquake
Provided through the International Charter on Space and Major Disasters
(Observation by TerraSAR-X on 13 March 2011)

Managing Huge Structures

Huge structures may cause land subsidence by their own weight. It is necessary to conduct periodic inspections to avoid the danger including structure collapse.

The two images below shows Tokyo Dome (the big baseball stadium in Japan) and its surroundings. The right is an optical image, and the left is SAR image (photographed from SAR mounted on an airplane).

As PALSAR-2 on ALOS-2 is also able to obtain images under the same resolution condition as SAR on the airplane, conducting periodic observations of massive structures such as Tokyo Dome using SAR can help us to capture land movements that cannot be shown by the optical images.

SAR image (observation by SAR mounted on an airplane on 18 April 2012)
The red areas show HH polarization, while the green areas show HV polarization.

Optical image (observation by ALOS/AVNIR-2)

Formulating Plans for Recovery from Flood Damage

Gaining promptly the details of damage from flooded river due to typhoons and heavy rains, or tsunamis, leads to contribute to the formulation of recovery plans and plans for preventing secondary disasters.

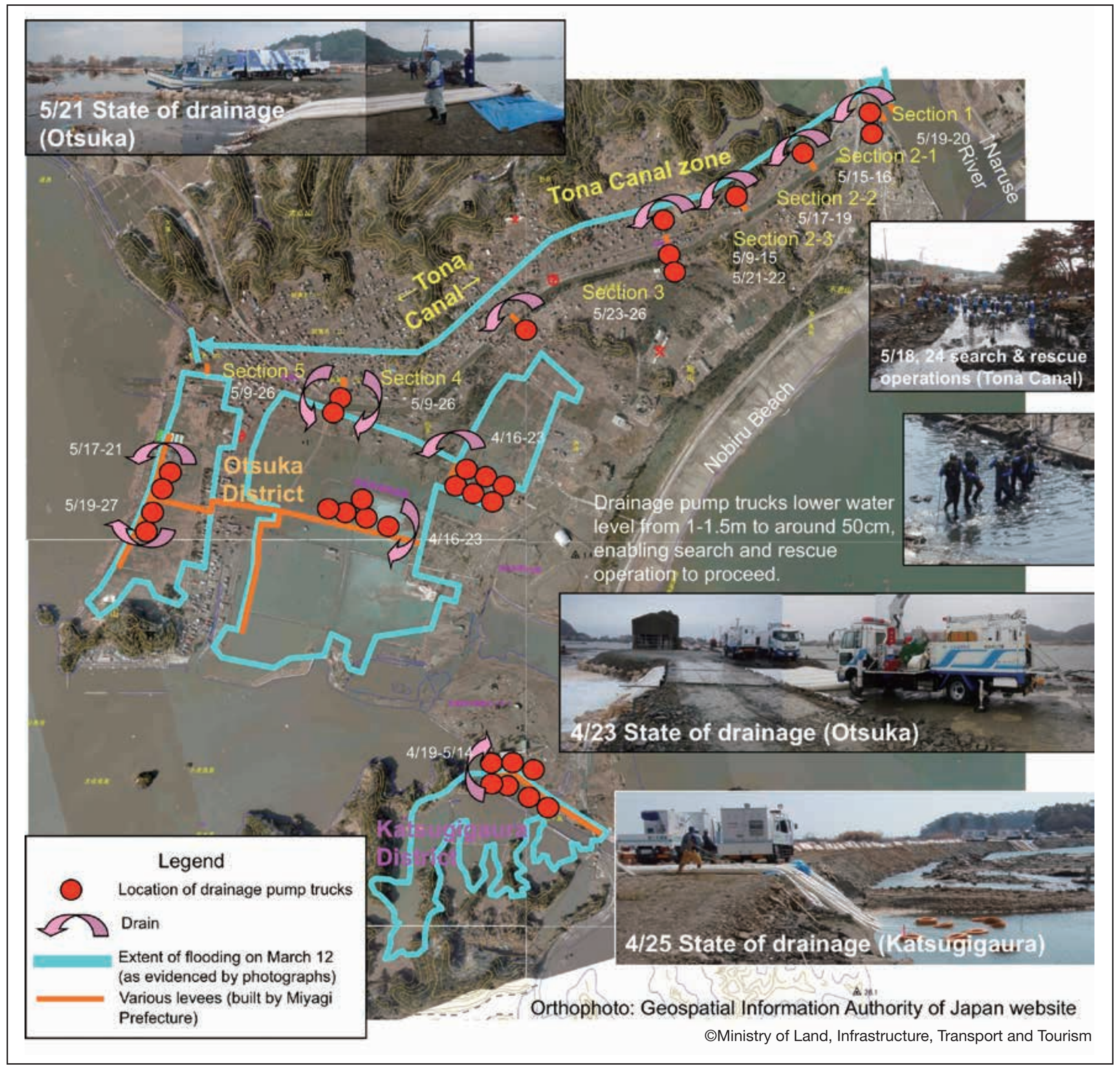
The figure shows a recovery plan for areas inundated by the tsunami after the Great East Japan Earthquake, and is visualized the satellite use verification. This background photograph was taken using optical cameras mounted onto an airplane. By superimposing SAR images before and after the disaster on it, the inundated regions are determined.

In the scenario of ALOS-2 data utilization, the analysis results of SAR data by the Geospatial Information Authority of Japan are provided to the Ministry of Land, Infrastructure, Transport and Tourism, as well as to local governments, for use for disaster recovery plans.

In formulating recovery plans and drainage plans, it is necessary not only to identify the inundated areas, but also to obtain data about altitude. Hence, by superimposing the digital 3D topographical data generated by ALOS (ALOS World 3D) onto images, it is possible to carry out studies on how to drain water from the inundated areas and make the land usable once again.

ALOS and ALOS-2 data can be used for “Disaster prevention”, “Disaster mitigation” and “Recovery”.

Satellite Use Verification Ministry of Land, Infrastructure, Transport and Tourism



SOLUTION PROPOSAL

- **Utilization for urban planning**
  ALOS-2 data helps us to understand land subsidence trends early, and the data can be used as fundamental material to improve land safety.
- **Protecting huge infrastructure from crustal movements**
  ALOS-2 data helps us to estimate the damage to infrastructure by continuously monitoring the effect of crustal movements.

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Remote Sensing Unit
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Kenichi Honda
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Manager
Remote Sensing Unit
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Monitoring infrastructure from space

USER INTERVIEW

**KOKUSAI KOGYO Co., Ltd. has used ALOS/PALSAR to monitor subsidence of dam.
What does this company at the frontier of geospatial information technology, expect from ALOS-2?
We asked the staff from the Remote Sensing Group.**

—— Could you explain your job?

Imai: In my team, the Remote Sensing Unit, we deal with images taken by overhead remote-sensing instruments such as SAR satellite, optical satellite and aircraft, and provide secondary processing images as required to serve our customers' needs.

—— How do you make use of SAR data?

Imai: KOKUSAI KOGYO offers so-called "Shamen-net" 24 hours monitoring service. We observe movements on a dam and slope with small and low cost GPS sensors installed on many observation points, that we developed uniquely. The service is provided to clients which manage road and railway and which own and manage buildings, to monitor nearby slopes. We are experimenting with using SAR for this service.

—— So, you need to identify slopes at risk of landslide?

Imai: Yes. GPS is perfectly adequate for monitoring of structures and other designated targets. While still a future prospect, we also hope to harness the potential for wide area screening to determine which dams or slopes might be dangerous - because what satellites can do better than any other method is viewing over a wide area. Rather than using it in our existing businesses, we are at the stage now of trying SAR in a range of applications in areas that we hope to expand into in the future.

Honda: The advantage of a satellite – if it goes over a certain location – is the ability to compare the past with the present. When subsidence became an issue in the redevelopment of Italian cities, for example, instead of having to install GPS sensors, they used SAR data from Cosmo-SkyMed to prove there was a problem by checking previous displacement.

—— What are your hopes for ALOS-2?

Mushiake: That it will have higher resolution. Our company has confirmed changes in the shape of rock-fill dams using the ALOS PALSAR, but if the resolution were three times better, it could also be used for dams that are one-third of the size. It would greatly broaden the scope of the technology's application.

Honda: The shorter the period between observations in monitoring is, the more precise it is. So the fact that ALOS-2 will be overhead every 14 days, three times more frequent than ALOS, is of tremendous significance.

Imai: In addition, we are assisting JICA and other organizations to establish a developing country forest resource monitoring system as a measure related to combating climate change. This uses SAR imagery, so it would be very convenient to have increased resolution to enable more detailed observation of forests.

—— I see. Finally, what are your views and hopes concerning satellite operations in the future?

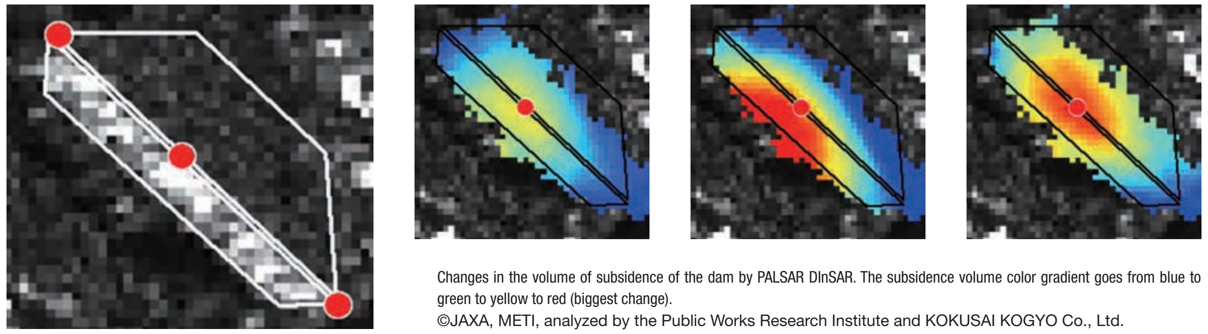
Imai: To date in our remote sensing business, we have done a lot of work through a process beginning with data, using our specialist technology as our weapon. Most of our contracts have been for the public sector, but I feel it is time to expand our services to the private sector. What is important to private sector clients is not the process but the quality of the results and information. Therefore, it will be difficult to really bring remote sensing to the private sector on a large scale if we do not take advantage of all data sources, not just satellite data, to offer businesses the results and information they require.

Honda: When actually looking at a dam, the scale is too small for us to judge displacement by SAR, but we got the idea from the Public Works Research Institute, our research partners on shamen-net when they commented, "We hear that the SAR satellite can measure displacement. Could you also look at dams?"

Mushiake: We gave it a try, thinking that such a small target would suffer from phase difference, but we were able to analyze it perfectly well. I do not believe we would have come up with that idea by ourselves. Since then we have continued by a process of trial and error in collaboration with the Public Works Research Institute.

Imai: Sometimes, casual suggestions from people outside of our field can result in new solutions. That is one reason why fresh developments are more likely to come from end users – not just data specialists like us – being able to come into contact with broader data, not just data points.

Photographed 12/6/2006 Photographed 12/9/2007 Photographed 12/11/2008 Photographed 12/14/2009



Changes in the volume of subsidence of the dam by PALSAR DInSAR. The subsidence volume color gradient goes from blue to green to yellow to red (biggest change).
©JAXA, METI, analyzed by the Public Works Research Institute and KOKUSAI KOGYO Co., Ltd.

A rock-fill dam in Okinawa Prefecture

KOKUSAI KOGYO Co., Ltd.
Provides technology services focused on spatial information technology. Experienced in mapmaking and building of disaster prevention infrastructure. Currently researching dam deformation measurement using ALOS/PALSAR.
WEB: http://www.kkc.co.jp/

SOLUTION ⟫ Forests

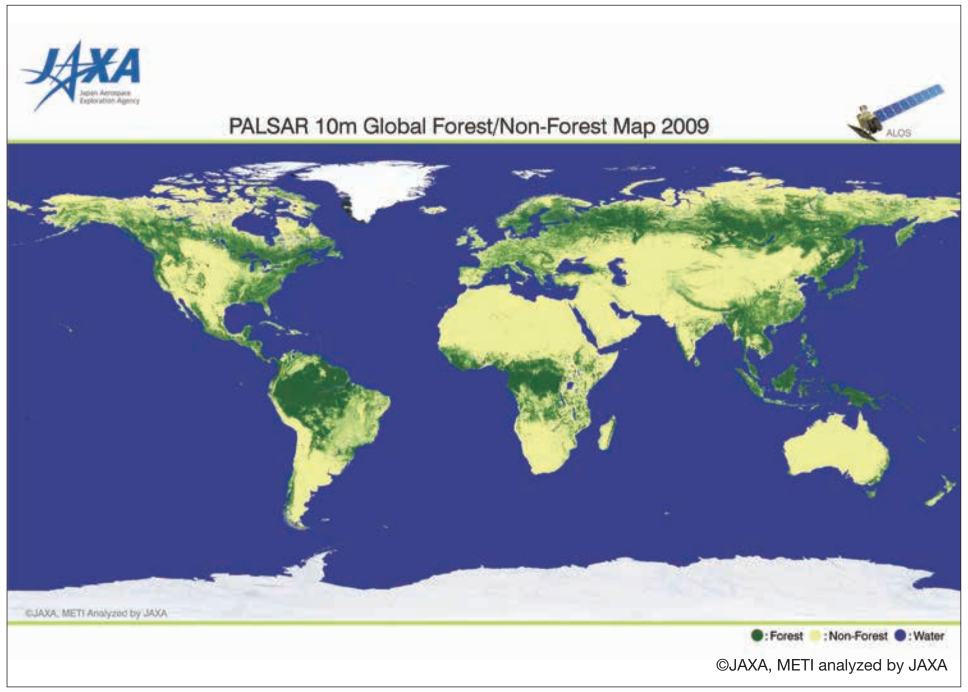
Monitoring 4 Bha is Our Responsibility to Future Generations

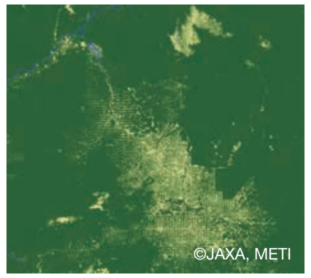
It is very difficult to grasp changes over vast areas of land from the ground, caused by illegal logging, drought and desertification. SAR satellites are able to observe cloud-shrouded mountains and equatorial regions without being affected by weather, regardless of day and night.

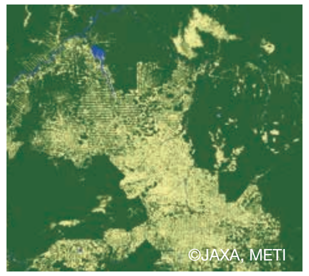
⟫ Observing Forests for Optimum Thinning

L-Band SAR has the feature to look though cloud and vegetation. It therefore enables to observe tropical rainforests often covered with cloud. Japan has continuously observed forests using L-band SAR. Japan has obtained observation data for over 11 years, even if including a blank period by JERS-1 (Fuyo No.1) launched in 1992 and ALOS which completed its operations in 2011.

ALOS-2 can obtain more information as types of microwaves for observation increased (see p.28). For example, ALOS-2 has potential to identify kinds of trees and its height, and it is expected that we can get information on tree classification and its distribution for afforestation and thinning projects. As it is likely that this will enable very precise calculation of the amount of carbon on the planet and the absorption of CO_2 by forests, it is also expected that such information leads to global monitoring of logging and the decision-making process in countries and international organizations toward prevention of climate change.







Left: Whole Earth Forest Map (observed by ALOS/PALSAR in 2009)
Right: Logging in Rondonia State, Brazil (Top: observation by JERS-1/SAR in 2009, below: observation by ALOS/PALSAR in 1996)

SOLUTION PROPOSAL

- **Use for forest monitoring in forest industry**
  ALOS-2 helps regular monitoring of tree growth and planning of planting, thinning and harvesting.
- **Use for forest monitoring to prevent desertification**
  ALOS-2 contributes to the formation of policy to stop desertification by monitoring vegetation in desert regions.

30 Years of SAR Research: Promising Future

Dr. Masanobu Shimada, who has been researching SAR data for decades, comes up with ways to use SAR and puts them into practice in the course of his daily work of analysing SAR data and investigating the characteristics of different sensors. No wonder he is so enthusiastic about the launch of the ALOS-2. He shares his thoughts with us.

His hobbies are SAR and music. He extremely loves Bach and Mozart, and is enraptured by the music between his many research studies.

RESEARCHER INTERVIEW

Dr. Masanobu Shimada
Earth Observation Research Center
Satellite Applications Mission Directorate I JAXA

—— What are your hopes for ALOS-2?

Upgrade for ALOS-2 is not only improved resolution. Overall sensitivity will be better than ALOS due to the advances in the digital hardware itself. And with improved ability to maintain a consistent orbit, I am also hoping that it will provide more precise monitoring.

One of the analysis techniques is SAR interferometry. By bringing more precision to this technology, we will be able to discover deformations in built structures. It promises to help prevent future accidents, for example by aiding the discovery of weaknesses in the ageing Tokyo expressway network.

—— The scope of application should expand when it comes to disaster monitoring too.

In the transition from ALOS to ALOS-2, I would highlight the addition of high resolution polarimetry mode as a major upgrade of function and precision. This is a method of observation that combines multiple microwaves of different oscillation directions (see p.31). We know that this mode of observation allows us to clearly see the difference between forests and bare land. I hope that the technology will demonstrate its value in helping search and rescue during earthquake and typhoon disasters by allowing for us to distinguish large-scale landslides in steep, mountainous areas more clearly.

—— What kinds of possibilities do you see in terms of business development?

To return to search and rescue operations during disasters, if the public and private sectors collaborate, this would be a viable business. We can also see business related to forest conservation. For example, REDD+ is an initiative that has grabbed worldwide attention. It is a framework that provides economic incentives to developing countries in return for conservation, that is, to stop logging and the destruction of forests. For this to function well, reliable data on forests is vital.

Another use would be in selection of locations with the strongest ocean winds for building offshore wind farms (see p.24).

Business applications will be promoted by the fact that the cost per unit of data is less than for ALOS, and that data can be obtained in a short time.

—— The launch is keenly anticipated.

While we are already researching the same kind of sensor as found on ALOS-2 mounted in aircraft (Pi-SAR-L2), I believe we will learn a lot from looking at the data sent to us after the satellite is launched. It might help us to better understand movements in the Earth's crust, which could be of interest to solid earth geophysics research for example. From a scientific point of view, this is a tremendously interesting and hopeful prospect.

JAXA Earth Observation Research Center
Conducts development of Earth observing satellite sensors for ALOS-2, principally research on the process of obtaining data from Earth observing satellites, processing the data and putting it to use.
WEB: http://www.eorc.jaxa.jp/

SOLUTION ››› Oceans

Observing Boundless Oceans from Boundless Space

It is essential for a marine nation, Japan to secure the safety of maritime transport.
It is expected that SAR data can be utilized in the term of maritime applications such as safety confirmation of shipping routes and new energy developments.

››› Observing the Northern Sea Route for Shipping Industry

Arctic sea ice shrinking by global warming is opening up the way for new shipping routes that link Asia, Europe and the East Coast of the United States. In particular, Northeast Passage along Russian coastline where its shrinking level is high is used particularly as a shipping route.

In the case of the route from Japan to Europe, the Arctic Ocean route is 40% shorter distance than the route via the Suez Canal. Pirate attacks occurs often along the Suez route, so the Arctic route raises expectations for safety as well. It is also predicted that this route will be used to carry resources such as natural gas as well as cargo from Siberia and Northern Russia to Japan.

While the AMSR2 equipped with GCOM-W observes broad area including ice sea (upper left figure), ALOS/PALSAR observes detail and localized sea ice (lower right figure). ALOS-2 will be able to observe at higher resolution. Combination of ALOS-2 imagery and shipping signal data obtained by the signal receiver for Automatic Identification System (AIS), equipped on ALOS-2, allows us to track the route taken by any ship. This enables to offer more detailed sea ice information and a safe shipping route to vessels crossing the Arctic Ocean.

* AIS receiver……The Automatic Identification System that all large ships over 300t must carry.
The system operates on a VHF signal, automatically transmitting and receiving information about ships' identification number, type, position, route, speed, navigation status and other safety matters.

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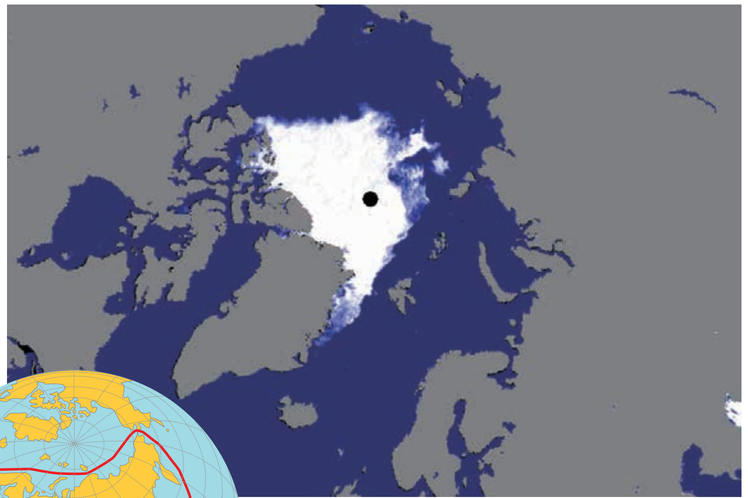
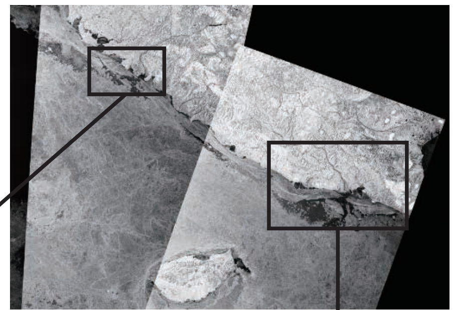


Upper left: Sea ice in the Arctic Ocean (the smallest extent in observation history)
From GCOM-W/AMSR2, 16 September, 2012
Lower left: The Arctic Ocean shipping route.
The red line indicates the Arctic route (Northeast Passage), the blue line indicates the route via the Suez Canal.
Right: Sea ice along the coast of eastern Siberia, Arctic Ocean.
Observed by ALOS/PALSAR in 2010



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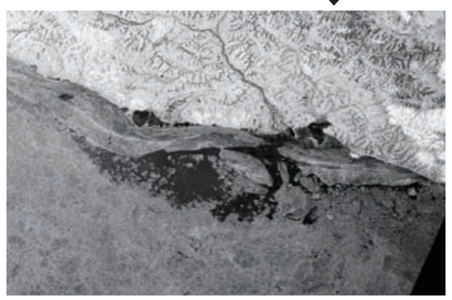

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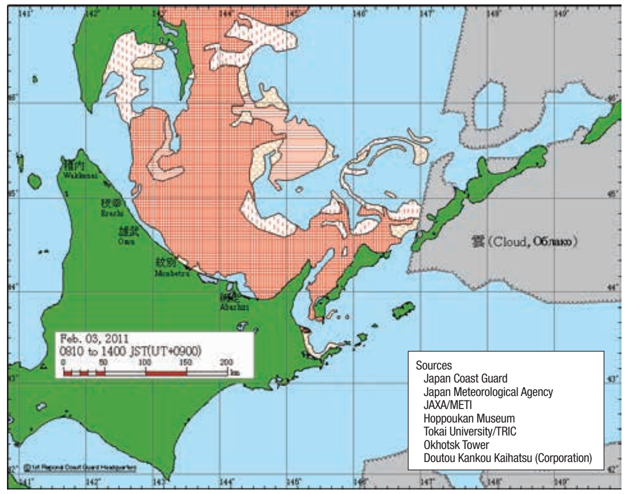
››› Monitoring Sea Ice to Provide Support for the Safe Travel of Ships

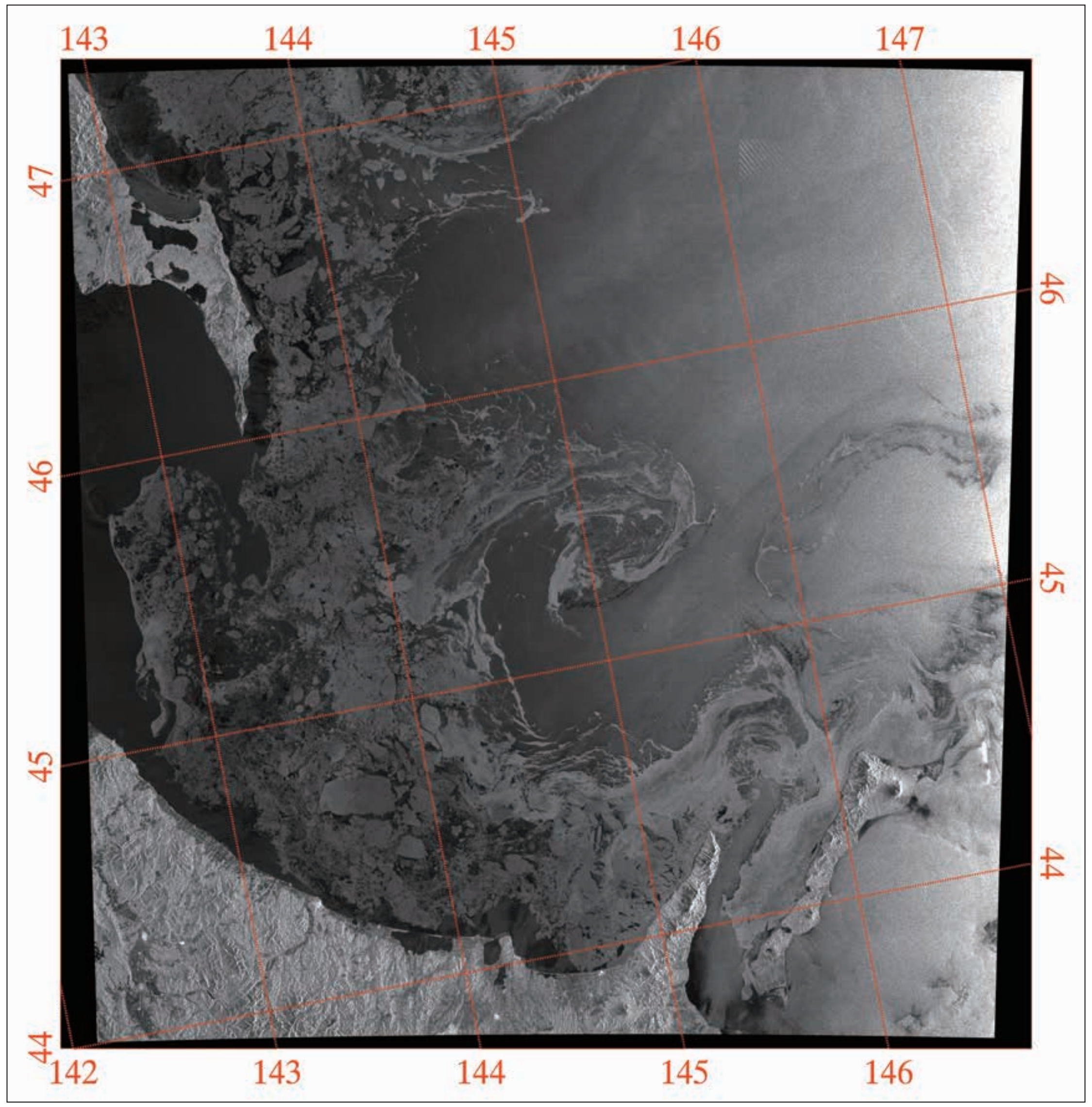
The Okhotsk Sea is the only maritime region of Japan where sea ice forms and is now touted as the gateway to the Arctic Ocean shipping route. The Ice Information Center, run by the 1st Regional Coast Guard Headquarters, transmits sea ice information daily during the winter season, based on data from multiple organizations.

JAXA also provides sea ice data on a regular basis every year from December to May, using observations from the ALOS/PALSAR wide area observation mode. In particular, the Okhotsk Sea suffers from a large number of stormy days in winter and is clouded over almost every day, so SAR imagery without any effect by clouds makes it very effective. However, due to the fixed angle of the sensor, it was our question that the frequency of observations was not sufficient.

ALOS-2 can observe more frequently because it takes images on both sides of satellite body, and it is possible to provide the Japan Coast Guard with sea ice information almost every day. Moreover, it is expected to be able to make observations by HV polarization using the wide area observation mode, which will allow us to provide more information about sea ice.



Upper: Sea ice report created from analysis of multiple data sources, 3 February, 2011
©Ice Information Center, 1st Regional Coast Guard Headquarters
Lower: Sea ice in the Okhotsk Sea (observed by ALOS/PALSAR, 3 February, 2011)



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Using Observations of Ocean Wind for Optimum Location for Wind Farms

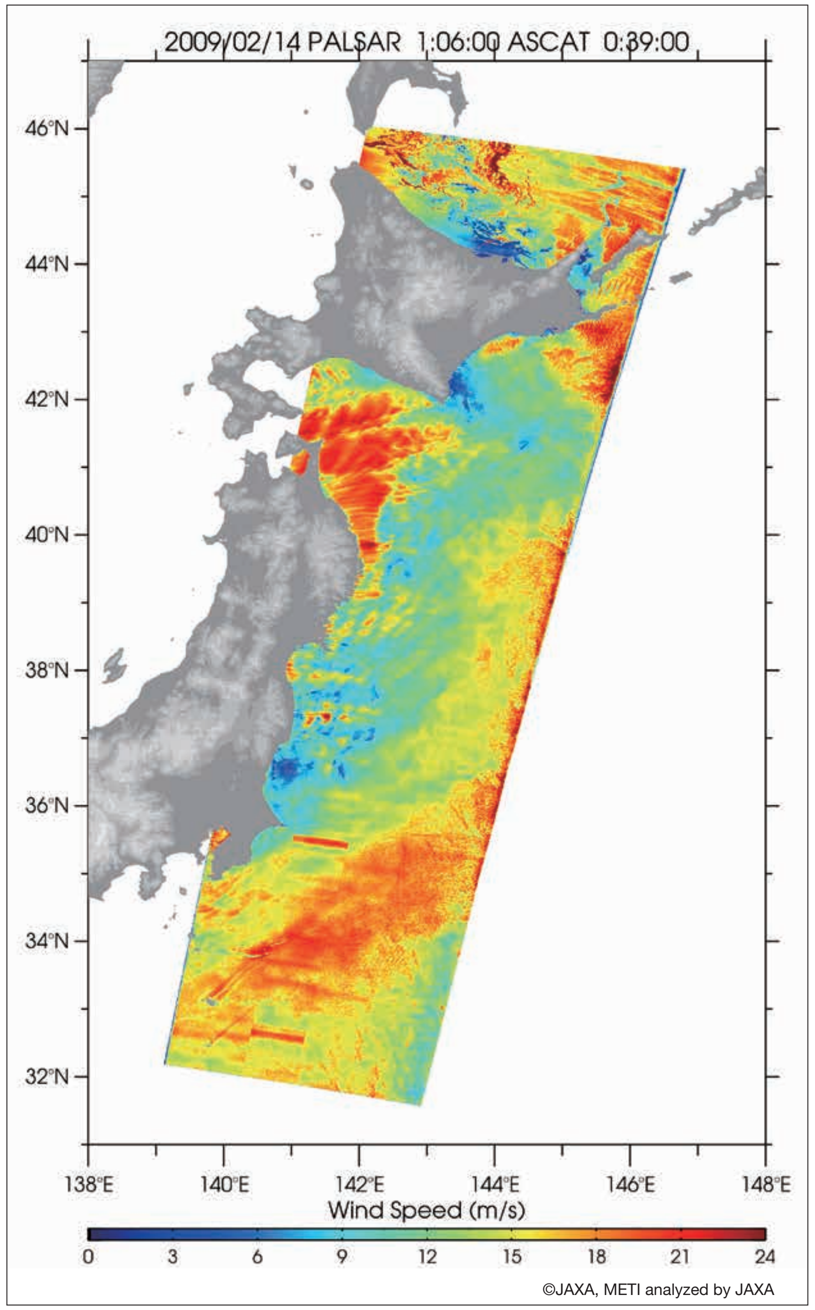
Wind power is now a vital sustainable energy source. Increasingly, we are looking to the sea for wind farm locations, where the wind blows stronger than on land. This means a more stable supply of energy, and it also reduces the noise and landscape impacts of wind turbines.

In order to build wind farms offshore, it is first necessary to find locations with strong winds and to find out how powerful they are. This is where SAR data comes into its own.

Wind on the surface of the ocean causes friction and this generates waves. They start as small waves (ripples) and develop into big waves as the wind strengthens. In other words, when the wind blows and waves form on the surface of the water, the water loses its smoothness. We can estimate the strength of the wind by observing the "roughness" of the water surface. With SAR imagery, smooth surfaces are dark, while rough, wavy surfaces look bright. Since ALOS-2 has higher sensitivity than ALOS, we will be able to see the dark areas more clearly and it will be possible to estimate the strength of winds with increased accuracy.

The original name of ALOS-2 being "DAICHI-2" (daichi means "earth" in Japanese), the main target of observation remains land, but the observation plan includes areas out to 200km from the coast. Therefore, it will be able to forecast ocean wind strengths in coastal waters around the world.

Currently, all countries are debating their future electricity and energy plans. The ability to forecast ocean wind strengths anywhere in the world is likely to be an extremely valuable business.



Left: Offshore wind farm, Kitakyushu
Organization (NEDO)
Right: Analysis of ocean winds off eastern Japan
(observed by ALOS/PALSAR, 14 February, 2009)

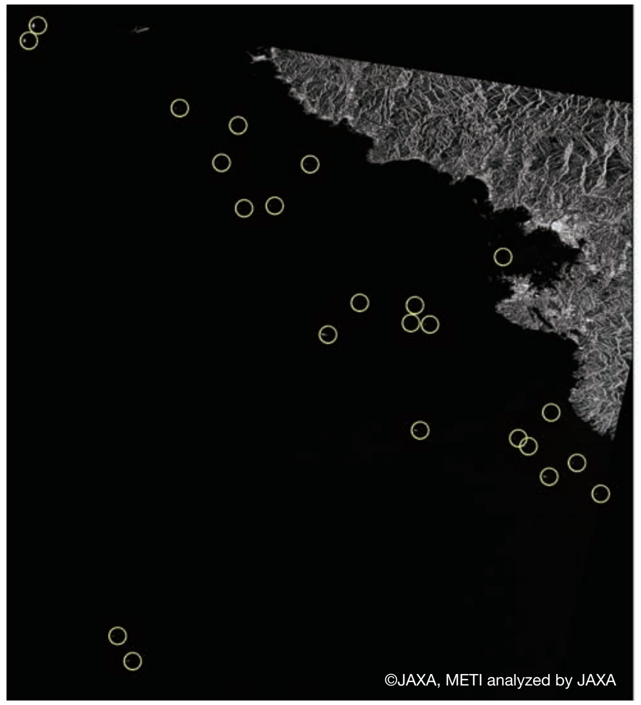
The right figure shows ocean wind speeds as calculated from an observation spanning from Hokkaido to the coast of east Japan using the PALSAR wide area observation mode (350km wide) on 14 February, 2009. Warm colors signify strong wind zones. At the time of observation, a trough is centered over Hokkaido, with westerlies blowing over the south end of the island and easterlies to the north. Coastal winds are strongly influenced by the adjacent topography, and here we see a zone of strong westerly winds between the Tsugaru Strait and the seas off the Sanriku Coast. Also visible is a pattern of oscillation in the strong wind zone probably caused by mountain waves. Coastal zones are also affected by atmospheric stratification, but SAR is able to render ocean wind distribution in high resolution.

Providing Navigation Services, and Safety and Security for the Fishery Industry

Shipping movements can be monitored for the purposes of safe shipping, or to discover illegal fishing or suspicious vessels.

The right figure, taken by the ALOS/PALSAR, is of the coast of the Kansai region. This is plotted overlapping data obtained by AIS data of the coastal authorities around same time. The ALOS/PALSAR enabled to capture ships of 2–3 times the size of PALSAR's resolution. ALOS-2 is the first satellite in the world to be equipped with both an SAR and an AIS receiver. SAR imagery will be able to determine the position of ships, but even more detailed information about shipping will be generated in combination with the AIS data.

Combining SAR imagery and AIS data in this way would be useful for combating illegal fishing or investigating ships leaking oil, and could even be used to monitor shipping around marine installations such as offshore wind farms or oil rigs. Shipping companies could also confirm shipping traffic on their planned route and whether small craft are present.

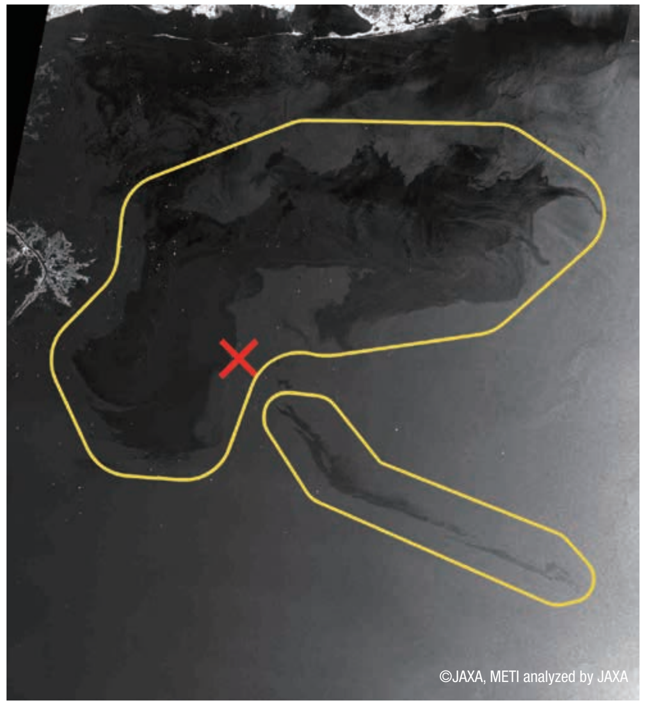


Shipping off the coast of the Kinki region, also known as the Kansai region. AIS data (from the AIS coastal authority) is imposed on an SAR image.
(observed by ALOS/PALSAR in 2010)

Understanding Marine Pollution, and Formulating Countermeasures

On 20 April, 2010, a offshore oil rig in the Gulf of Mexico exploded, leading to an enormous oil spill. The spill continued for months, releasing crude oil over hundreds of square kilometers of ocean. The right figure is SAR imagery taken by ALOS/PALSAR after explosion. Released oil covers the surface and forms oil slicks. As the oil slick is smoother than the normal sea surface and its part shows dark on SAR imagery, it is easy to distinguish oil slicks.

Such observation is also used for exploring for undersea resources. While an accident such as oil slick in the Gulf of Mexico is observed temporary, an oozing oil from underwater oil field is observed constantly.



The oil spill in the Gulf of Mexico (the affected areas are within the yellow circles)
(observed by ALOS/PALSAR in 2010)

SOLUTION PROPOSAL

- **Ensuring shipping safety**
  ALOS-2 assists fishing and shipping firms to check on the safety of ships at sea.
- **Site selection for renewable energy generation**
  ALOS-2 provides information about the location of offshore wind farms in Japan and overseas.

SOLUTION ⟫ Energy

Exploring Energy Resources

SAR data can be used for not only visible targets on the surface. It can also be used to explore for fossil fuels, minerals and other energy resources under ground.

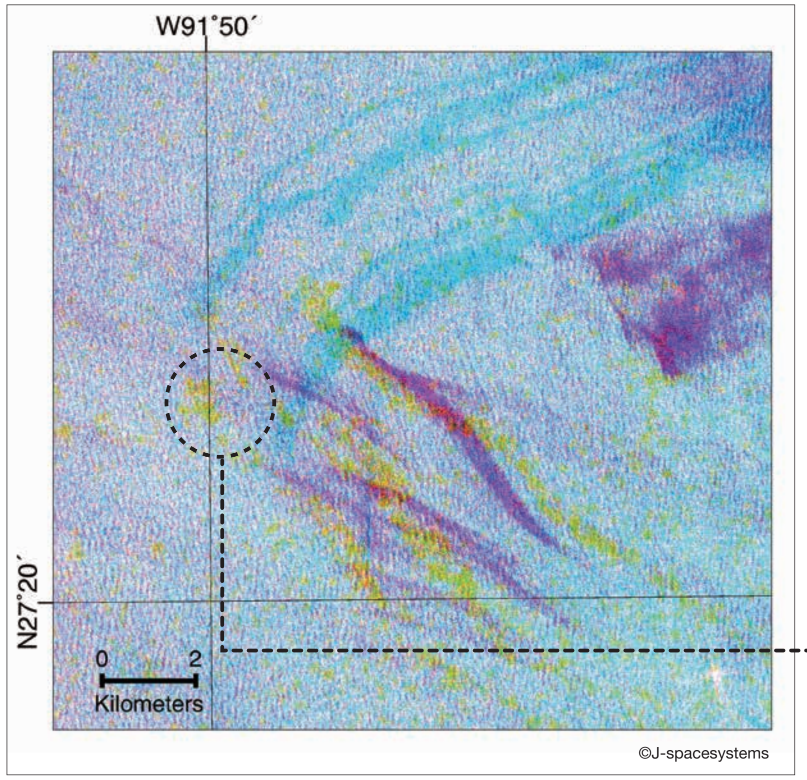
⟫ Tracking Down Clues of Undersea Resources

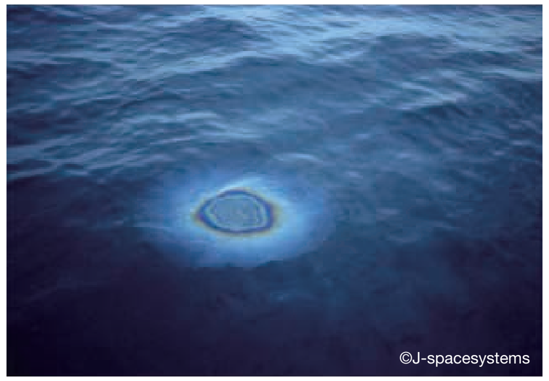
In underwater oil field areas, oozing oil float on the sea surface and might form belt-like oil slicks by oceanic currents and winds.

Oil slicks appear darker than water in SAR imagery. We can find the possibility of oozing oil from the ocean floor by targeting constant oil slicks and comparing some SAR images observed at different times.

The left figure is a color composition of observation data at three different times by ALOS/PALSAR for the Gulf of Mexico, off the coast of Louisiana, USA. It is possible to estimate the point where oil oozes using this composition image that appears flowing oil from the target point.

SAR data can also be used for land-based exploration for mineral resources. Essentially, mineral deposits are formed though the process that chemical components dissolved in hot water underground rise up along fractures and faults in soil, and they get cool and hard near the surface. Outcrops of minerals (deposits on the surface) are good indications that a large amount of the mineral is present. It is likely that we can find them using the SAR. L-band SAR in particular would be suitable for exploration of mineral deposits in forested areas, because it can observe Earth surfaces through vegetation cover.





Left: Color composition of oil slicks observed at three different times by PALSAR
Yellow: 25 June, 2006
Red: 13 June, 2006
Blue: 20 May, 2006
Right: Marine oil slick soon after oil surfacing (photographed by optical camera)

*There is a high chance that this is a seabed oil seepage

SOLUTION PROPOSAL

- **Subsea oil exploration**
  ALOS-2 observes oil slicks to find underwater oil field.
- **Mineral resource exploration**
  ALOS-2 observes surface mineral deposits to find minerals.

Asking Remote Sensing Specialist What is the ALOS-2 Features?

The Yokoyama Geo-Spatial Information Laboratory carries out projects using various types of remote sensing data. We asked Dr. Ryuzo Yokoyama, who has been engaged in remote sensing since the 1970s, what kinds of developments are on the horizon with the launch of the ALOS-2.

Dr. Ryuzo Yokoyama
Professor Emeritus, Iwate University
President, Yokoyama Geo-Spatial Information Laboratory Co., Ltd.

USER INTERVIEW

—— I heard you visited companies and local governments around Japan to conduct hearings regarding the ALOS-2.

Yes, I visited 12 organizations to find new users and to hear from them about potential uses they see for the ALOS-2.

—— How do organizations use SAR data now?

Traditionally, SAR imagery has been used in the resource exploration field. It has been used for finding fissures in the Earth's surface which may point to subterranean resources. In recent years SAR images have been used to find slicks of oil on the sea surface in the hunt for subsea oil fields. We can expect even more activity as the observation scope of ALOS-2 will be three times the size of the original ALOS and the resolution of the PALSAR-2 will be around 3m.

—— What did you learn from the hearings?

The fact that the SAR observes the surface regardless of clouds and others was of great interest to organizations researching land slips and electric utilities, for example.

—— How would power companies use the surface data?

Basically they have two requirements. One is in the field of geothermal power. Geothermal power is generated by hot water pumped out from deep underground, but it is not the case that hot water can be extracted from the earth in an unlimited way for power generation. In New Zealand we have seen reports of subsidence as a result of extracting too much hot water.

If it were possible to understand the geothermal profile of an area using surface movement information extracted from SAR data, we could use it to run geothermal power plants more efficiently. Another point is that land slips cause power lines and water pipelines to bend and twist, and currently the issue is dealt with after the event. Yet if the inside surface of pipes could be regularly monitored using SAR data, we would know how often work was needed and areas of ground stability where the pipe could be rebuilt.

—— As a result of the hearings, do you have any requests for the ALOS-2?

Local governments also showed a lot of interest because satellite SAR can observe data in disasters through clouds even if bad weather is ongoing, and before aircraft can fly over a disaster zone. But for this kind of data to be of use, the satellite would have to be orbiting over that area continuously. So I would like more satellites with the same features as ALOS-2 to be launched.

If this were done, I am sure many more organizations would need the PALSAR-2 data.

Yokoyama Geo-Spatial Information Laboratory Co., Ltd.
Engaged in projects using remote sensing data to develop various products and analytical processing.
WEB: http://www.yg-space.jp/

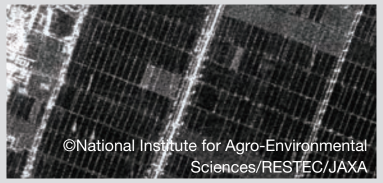
SOLUTION »» Agriculture

Securing Food Sources in the Future

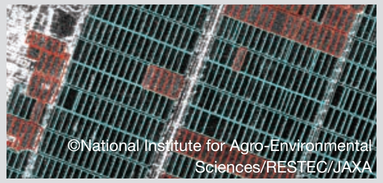
Addressing the issues associated with the global population explosion is our major preoccupation.
It is also necessary to accurately grasp the state of agriculture for the food problem, because an imbalance between supply and demand is predicted.

»» Monitoring Rice-Paddy Acreage with High Accuracy

Planting season



To obtain the imagery of rice paddies in planting season (observed from aircraft-mounted SAR, 10 June, 2013)

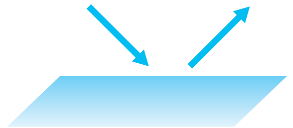


To extract water surfaces from imagery
The blue rectangles are water surfaces, the red rectangles are not water surfaces.

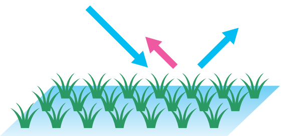
Growing season

To obtain the imagery of rice paddies in growing season (observed from aircraft-mounted SAR, 8 August, 2013)

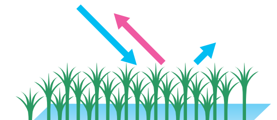
To extract water surfaces. To estimate rice cropping by growing condition of rice paddy extracted in growing season (blue rectangles)



A paddy before planting acts as a mirror, deflecting incoming microwaves in a different direction. Therefore the microwaves do not return to the satellite meaning paddy field looks very dark on SAR imagery.



Similarly, just after planting, the backscatter from paddy field is weak and the paddy field looks dark on SAR imagery.



With the growth of rice plants, the backscatter of microwave from rice paddy field is strong. The paddy field looks bright on SAR imagery.

In order to address the food problem, we first need to grasp accurately the cropping state of agricultural crops. In particular, Asian countries need accurate and detailed data about rice paddy production, since rice is the staple in Asia. However, current surveys do not have a high level of reliability. This is where L-band SAR is useful.

Before paddy rice is planted, a paddy field needs to be flooded with water, so at first they look dark on SAR imagery. As the rice sprouts and grows to hide the water, paddies look lighter. In other words, by comparing SAR images observed at different time intervals, we can estimate that the area changing brighter has been planted with rice.

A pilot using ALOS/PALSAR data in Thailand has already been validated, and we are in transition to practical utilization stage using ALOS-2 data. While ALOS only allowed small areas to be covered, it is expected that detailed data on a broad area taken from ALOS-2 will be able to be used as basic data for food security over wide regions including prefectures in whole of Japan. The data is set to be used in Viet Nam, Indonesia and other countries in addition to Thailand.

L-band SAR has a potential to distinguish other relatively large crops such as corn and sugarcane besides rice, and its adaptation is also being considered for those crops.

There is always a need to know about cropping because farmers frequently leave paddies or fields fallow or change the crops being planted. Agriculture can be managed more efficiently if SAR can be used to know at once what is being planted over a wide range.

SOLUTION PROPOSAL

- **Grasping condition of various types of food crops**
  ALOS-2 provides information leading to local food shortages domestically or globally in order to decide investment or policy.
- **Basic data in business development**
  ALOS-2 provides Data about planting and crop growth domestically and globally for business development or investment.

USER INTERVIEW

Working toward Practical Use of Satellite Imagery for Agriculture

Dr. Ishitsuka has been researching the application of SAR data to farming since the late 1990s.
The reason he started the research was because he wanted to observe farmland at any time regardless of cloud cover.
We talk to Dr. Ishitsuka about his relationship with the SAR and ALOS-2.

National Institute for Agro-Environmental Sciences
Dr. Naoki Ishitsuka

—— What topics do you research?

I am studying ways of applying SAR data to the agricultural sector. For example, satellite data can be used to find out the volume of crop production.

In Japan, production adjustment (rice acreage reduction) has been used since 1970 as a policy to balance rice production and consumption. This system relies on statistics such as the area planted with rice. Currently, people directly check on farms at 38,000 sites around Japan, but research has been continuing for many years on methods of doing this more efficiently using satellite data. This is not yet reality due to the need for more precision, but if the high-resolution ALOS-2 data could be used in this task, practical applications would suddenly be much closer.

—— How is SAR data used in the agriculture sector?

SAR data is being used on a trial basis in a range of ways, using its strengths of being able to see through clouds and distinguish water surfaces such as flooded rice paddies. For example, the Ministry of Agriculture, Forestry and Fisheries has used it in the creation of maps charting the concentration of cesium in soil since the Great East Japan Earthquake Disaster. When measuring radiation, whether the site is covered by water or not is relevant information, and SAR data allows us to distinguish whether this was the case.

—— When did you start to study SAR data?

As a graduate student, I studied underground water pollution. At the time I was also working part-time at the Forestry and Forest Products Research Institute, which is where I had the opportunity to engage with satellite data for the first time. The first time I used SAR data was when I started work for the National Institute for Agro-Environmental Sciences. Back then, SAR was not widely used yet but its advantage of being able to monitor through cloud cover was gaining attention and research was gradually starting.

—— What are you expecting of ALOS-2?

I anticipate that ALOS-2 will be much more applicable to small-scale farming as found in Japan due to its higher resolution. For example, it will probably be able to tell us how much land has been planted with corn for animal feed and how much has been harvested. I hope that the power of the satellite can be felt in this area, at a time when we are hearing about the importance of self-sufficiency in feed stock but at the same time, publication of feed stock statistics by municipality has stopped.

—— How do you see the future of SAR?

There are things that only SAR can do, and I hope that it will be more widely used. But there is a tendency to consider it harder to understand than optical sensor. I believe it is my job to act as a bridge to data users. It is my mission as a national institute scientist to develop technologies that really can be useful in national policies and down on the farm.

National Institute for Agro-Environmental Sciences
Conducts a wide range of research and technology development related to environmental issues in agriculture, including science at the interface of global environmental change and farming.
WEB: http://www.niaes.affrc.go.jp/

Learn About Image Analysis (Advanced Level)

So far we have explained what is possible by utilizing the special characteristics of SAR sensors.
Here we present in simple terms the principles and some examples of how analysis is performed.

What is a Polarized Wave?

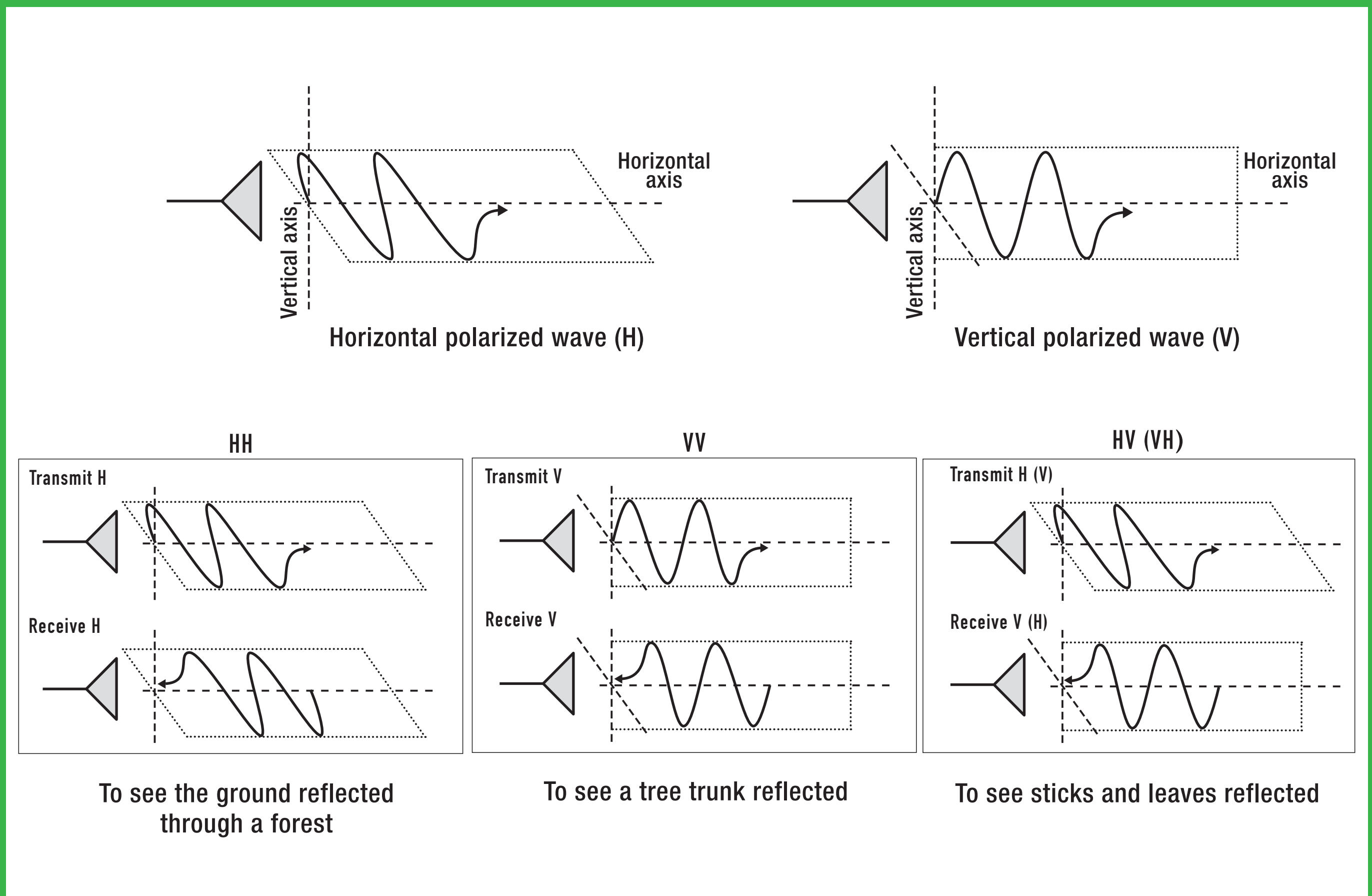
Even for radio waves of the same frequency emitted by a radar, there are two wave types: linear horizontal to the ground (H) and linear vertical to the ground (V). These are called "polarized waves." The waves transmitted by SAR are also either of these H or V types, and the waves received also are of these types. In combination, therefore, there are four types of polarized waves: HH, HV, VH and VV.

Each type of polarized wave has differing features and information. For example, HH waves are highly penetrative, able to reach the ground even in areas covered by forest for example. Using this property, HH waves can detect movements on the Earth as a result of earthquakes or subsidence. On the other hand, VV and HV waves are able to detect whether a location is bare or forested during observation of forests. HV and VH are essentially similar in their properties.

One strength of SAR is that the distinct features of each polarized wave, synthesized by a range of methods, enable very diverse analysis.

Yet, it is not always possible to obtain imagery using all four polarized waves. The number of polarized waves depends on the observation mode used. The highest resolution mode is only using single polarized wave type (HH, VV or HV), while the mode for observing a wider area while losing some resolution uses two or full polarized waves, and it is also possible to obtain several images.

The ALOS-2 boasts more modes able to observe with multiple polarized waves, broadening the scope of analysis. We now present examples of key analysis methods that will be possible.



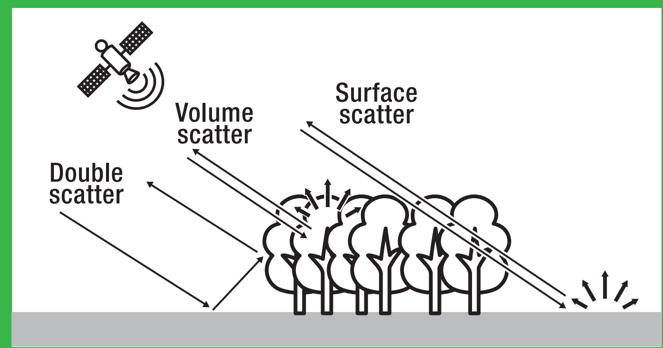
PolSAR (Polarimetric Decomposition)

This is a method of extracting information (more than can be learned from single polarized wave types) from data obtained from synthesis of full polarized wave types by re-disassembly. When the full polarized waves are analyzed, we can disassemble them by whether the waves hit the object and were reflected once only (single scatter), twice (double scatter) or if the reflection was more complicated (volume scattering, surface scattering). The observed object can be further explored by investigating the ratio of each type of returning wave in the backscatter.

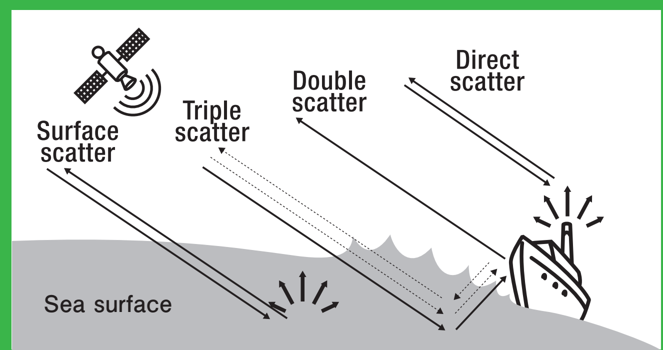
When using multiple wave types, we can calculate the amount of entropy. Entropy is the physical measure of "messiness" (generally, entropy is greater with increased mess).

For example, when trying to distinguish sea ice, calculating the entropy gives us a more precise picture of the ice (with ALOS, entropy could not be calculated in wide area observation mode, the mode commonly used for sea ice observations, because only one wave type was transmitted. This will be possible with ALOS-2.). This can also be used to distinguish land slips, as entropy is reduced when earth is laid bare after a landslide.

››› Practical examples of use: obtaining information about the density of forests, ocean winds or sea ice



Radio wave scattering over a forested region



Radio wave scattering over sea

D-InSAR (Differential Interferometric SAR)

While SAR interferometry is the comparison of two overlaid images (InSAR), D-InSAR is a way to find information on geological changes. This method is used to observe changes in the Earth's crust such as subsidence and upthrust.

››› Practical examples of use: Geomorphic changes, forecasting of volcanic eruptions, visualization of subsidence

SBAS-InSAR (Small Baseline Subset Interferometric SAR)

This is a method of SAR interferometry time series analysis and is an extended version of interferometry. Interferometry is the comparison of two datasets taken at the same location at different times, and SBAS-InSAR is the comparison of datasets taken at the same location multiple times and analyzed together.

In the case of gradual subsidence, two datasets are not enough to gain an accurate picture of the movement. But comparing further time series datasets allows the observation of minute movements.

››› Practical examples of use: Observation of movement in millimeters per year such as volcanic activity, landslips and ageing structures

PS-InSAR (Permanent Scatters Interferometric SAR)

In imagery, many points change gradually in brightness. But among them, there are points that always maintain the same brightness, called persistent scatters (PS). Large built structures are obvious PS. This technique involves running interferometry on PS only. Selecting only points of stable brightness are more reliable than dark points. By looking only at PS, it is possible to pick up extremely detailed changes on the Earth's surface over a wide area.

As L-band SAR shows more PS than C-band or X-band, this is a method that is suited to the technology.

››› Practical example of use: Observation of subsidence in urban areas

PolInSAR (Multi-Polarization Interferometric SAR)

This is a combination of polarimetric decomposition and interferometry (the technique of observing changes in data by observing the same location twice or more; also known as SAR interferometry or InSAR). Data from four wave types is taken in the same location twice, and the two datasets are analyzed by interferometry.

››› Practical example of use: Obtaining more detailed information about vegetation such as forest height or biomass volume, obtaining more precise land cover information

New Analysis Methods and Products

A range of satellite imagery analysis techniques already exist, but researchers are also developing new methods. One example is SAR "colorizing technology." We will also present new products.

From Monochrome to Color: Bringing the Earth's Expressions Back to Life

As SAR imagery is black and white, it often gives bigginer users the impression of being difficult to deal with. To solve this problem, the Remote Sensing Technology Center of Japan (RESTEC) has developed the technology to turn monochrome SAR images into color images.

In simple terms, the observed surfaces (rough or smooth) on SAR imagery are expressed by difference of brightness. This is because different surfaces and forms cause the radio waves to reflect in different ways. As a result, the SAR imagery shows water as dark, vegetation as light-dark, and urban areas as bright.

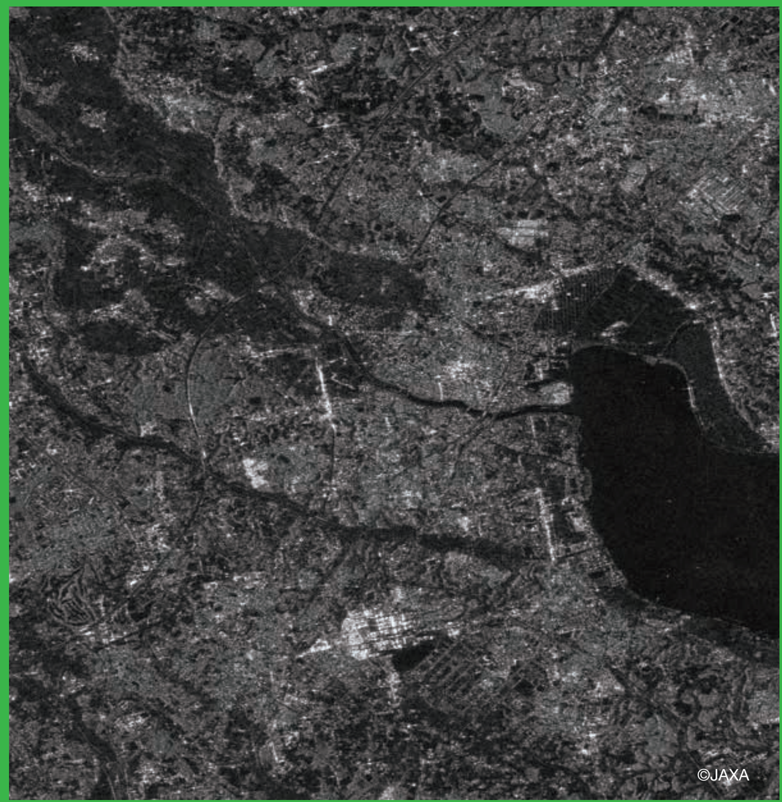
The features of observation data (roughness, smoothness, distinction from surroundings, color differences, etc.) are analyzed for each pixel in the process of this coloration technology. And its respective features are given numerical values, and then its values are transposed to RGB colors. As a result, the colorized imagery similar to optical imagery is formed.

While not being same as all aspects of the optical image because this technology is not able to distinguish different objects with the same surface conditions, (for example, a green car and a red car would appear the same color because their surrounds and surfaces are the same), the colorized image below is closer to a photograph at first glance.

This technology allows us to be easy to understand intuitively SAR image and to change its negative impression, and the aim of the technology is to be recognized by more people that SAR is easy to use.

One of expected applications of this technology is land cover classification mapping. It opens the possibility that such map is created using SAR imagery though it has been created only by optical images.

We hope that the coloration technology will increase the number of user and expand its utilizations.



Tsukuba Space Center and surrounds
Upper: Aircraft SAR (Pi-SAR-L2) image
Lower: Colorized aircraft SAR (Pi-SAR-L2) image

Image processing products

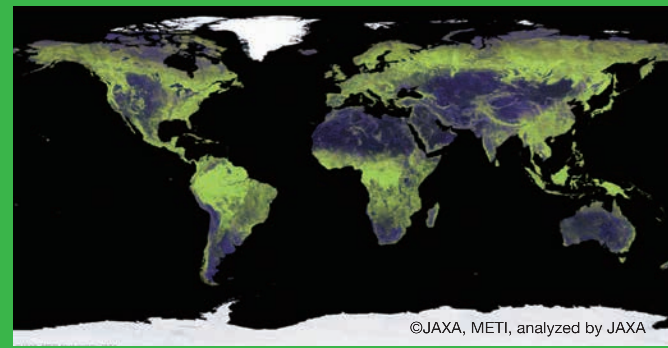
Comparing Past and Present Conditions Using Archival Images Accumulated by ALOS

Using ALOS/PALSAR images, JAXA holds PALSAR mosaic datasets for the whole planet at 10m or 25m resolution. This data has been orthorectified, gradient corrected and mosaicked, making it easy to impose on maps. Images have also been prepared using mosaic data to capture forested and unforested areas.

These images allow monitoring of changes over the years in forestry and land, as PALSAR is not subject to the vagaries of the weather. They can also be used in Japan or abroad to manage forests and land management projects.

It is expected that ALOS-2 will renew these datasets with the same kinds of observation, as it will observe the Earth over the same timespan (June to October) under the same conditions. The continuous observation by ALOS-2 will enable to grasp changes in forest land use over time, and it will allow us to identify land-based factors in global warming and promote the REDD+ (Reducing Emissions from Deforestation and Forest Degradation plus) campaign.

The PALSAR earthwide orthomosaic dataset with 10m resolution (color synthesized)



Processing Level Definitions for PALSAR-2 Standard Products

Level	Definition	Format
Level 1.1	This is complex number data on the slant range following compression of the range and azimuth. As one-look data, it includes phase information and will be the basis for later processing. In wide-area mode, image files are created for each scan.	CEOS SAR/GeoTIFF
Level 1.5	This is multi-look data on the slant range from map projection amplitude data, with range and azimuth compressed.	CEOS SAR/GeoTIFF
Level 2.1	Geometrically corrected (orthorectified) data using the digital elevation data from Level 1.1.	CEOS SAR/GeoTIFF
Level 3.1	Image quality-corrected (noise removed, dynamic range compressed) data from Level 1.5.	CEOS SAR/GeoTIFF

*Level……more information on P.38 Q6

List of Data Sizes for Each Product (Gigabyte)

Observation mode	Spotlight	High resolution			Full polarimetry		Wide-area observation					
							350Km				490Km	
		3m	6m	10m	6m	10m	Mode (1)		Mode (2)		Mode (1)	Mode (2)
Frequency range	84MHz	84MHz	42MHz	28MHz	42MHz	28MHz	14MHz	28MHz	14MHz	28MHz	14MHz	14MHz
Pixel spacing	0.625m	2.5m	3.125m	6.25m	3.125	6.25m	25m					
L1.1 (georeferencing) *1	4.3	5.2	2.4	1.0	5.5	2.1	3.5	6.9	27.1	54.1	6.0	46.8
L1.5/L2.1/L3.1 (Georeferencing)	3.1	1.2	0.8	0.2	0.7	0.1	0.4				0.5	
L2.1 (Geo-coded) *2	6.1	2.4	1.5	0.5	5.7	0.9	0.7				1.1	

- Georeferencing: Map projection based on the direction of the satellite orbit
- Geo-coded: Map projection based on direction of map

*1. Except full polarimetry, each figure indicates the size of a single polarized wave. In the case of two polarized waves, these figures double.
*2. Data size of representative off-nadir/scan number
*3. Expected largest data size

- Mode (1) (Burst mode)
Range compression and one-look azimuth compression are performed for each burst. Signal data is created for each burst, but data with the same scan and radio wave is stored in the same image file in chronological order.
- Mode (2) (Full aperture mode)
Range compressed and one-look azimuth compressed, with zero padding between bursts (analysis by scan and by radio wave).

I Want to View and Use SAR Images!

There are various software offerings available, free and paying, but in this book we introduce free software for handling ALOS/PALSAR data standard products. ALOS-2 data will also be released in GeoTIFF format, making it easier to see than ALOS data.

» NEST (Next ESA SAR Toolbox)

Software for analyzing SAR imagery.

- Developed by ESA (European Space Agency).
- Can be downloaded from the ESA website: https://earth.esa.int/web/nest/home
- Level 1.1 and 1.5 georeference data are available in ALOS standard products.

» PolSAR-Pro

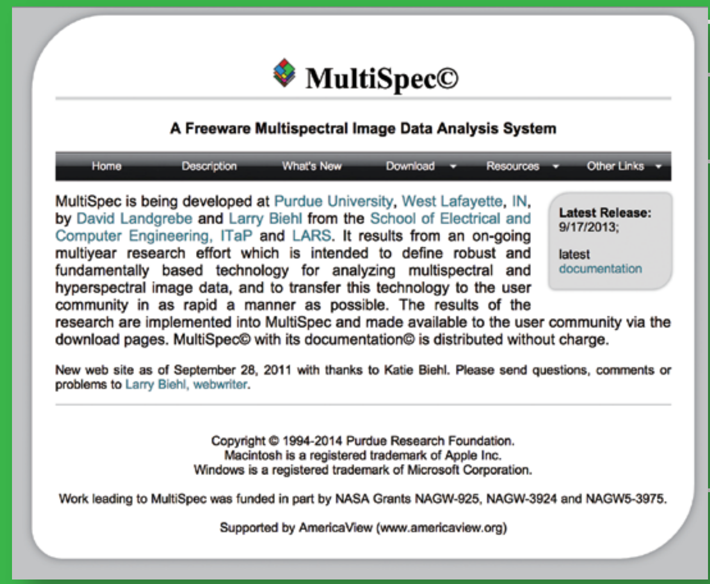
Software for performing polarmetric analysis on SAR imagery (see P.31).

- Developed by ESA (European Space Agency).
- Can be downloaded from the ESA website: http://earth.eo.esa.int/polsarpro/install.html
- E-mail address and other information will be required before downloading.
- Has versions for Windows, Mac OS, Linux and Unix-Solaris.
- Level 1.1 data is available in ALOS standard products for purpose of polarimetric analysis.

» ASF MapReady

Software for geometric correction of SAR imagery (giving correct geographical coordinates using standard points aligned with a map).

- Can be downloaded from the Alaska Satellite Facility website.
- User registration is required in advance.
- Has versions for Windows and Linux.
- The latest version is the 3.2.1 (beta) version.
- Levels 1.1 and 1.5 georeference data are available in ALOS standard products.



» MultiSpec

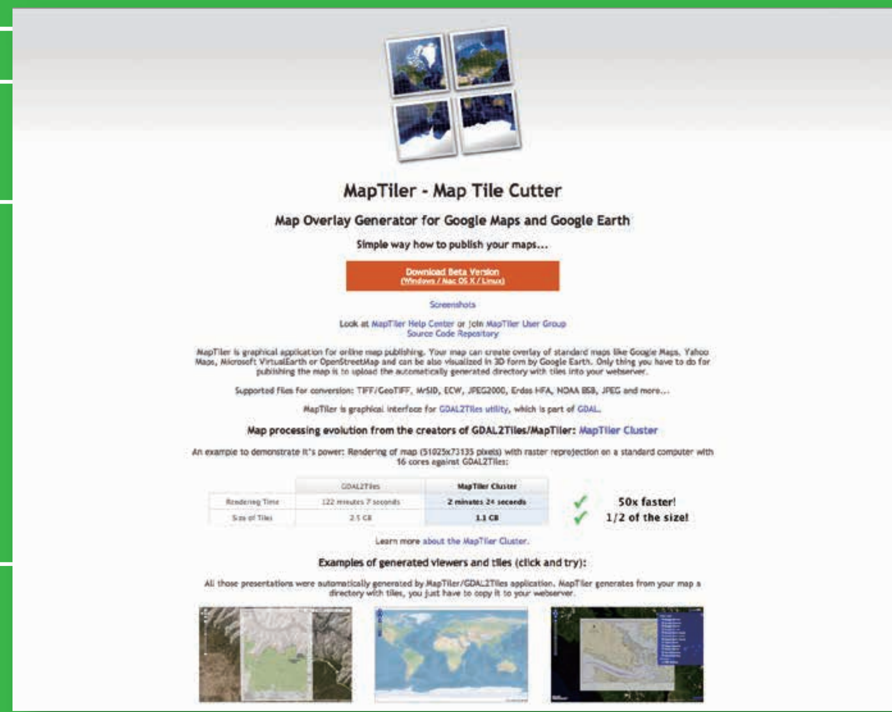
Software for classifying satellite data.

- Can be downloaded from the website “A Freeware Multispectral Image Data Analysis System”: https://engineering.purdue.edu/~biehl/MultiSpec/
- E-mail address and other information will be required before downloading.
- Has versions for Windows and Macintosh.
- The latest version for Windows is the 3.3 version.
- Cannot read ALOS standard products directly, but is able to read them in GeoTIFF format.

» MapTiler

Software for transforming images with geographic information into Google Earth and others.

- Can be downloaded from the MapTiler website: http://www.maptiler.org/
- Beta version can be downloaded free of charge.
- Has versions for Windows, Mac OS and Linux.
- The latest version is the 3.2.1 (beta) version.
- Cannot read ALOS standard products directly, but is able to read them in GeoTIFF format.



» JAXA Let's SAR (coming soon)

A software package for geographic data including PALSAR mosaic image, which can be used to classify forestry, identify deforestation, discover disasters, search for ships, and more.

- JAXA Let's SAR package can be downloaded free of charge from the JAXA/EORC website (Windows 64-bit version). http://www.eorc.jaxa.jp/ALOS/en/index.htm
- The following two software packages currently have analytical functions related to forestry only, but functions related to disasters and shipping will be rolled out in stages going forward.

■LUC
Land cover classification software equipped with object directional classification engine. It enables to classify local survey data with location information as teacher data.

■γ_0 Change
It enables to detect deforestation and forest degradation by detecting change volume of γ_0 in PALSAR mosaic data observed at two different times.

Ground systems and observation operations

Ground system and observation operation

The ground system for DAICHI-2 consists of the following four major systems: “Spacecraft Control and Mission Operation system,” “Earth Intelligence Collection and Sharing System,” “Tracking Network System,” and “Data Analysis System.” They are at Tsukuba Space Center.”

1 Receiving requests, compiling observation requests

2 Operation planning

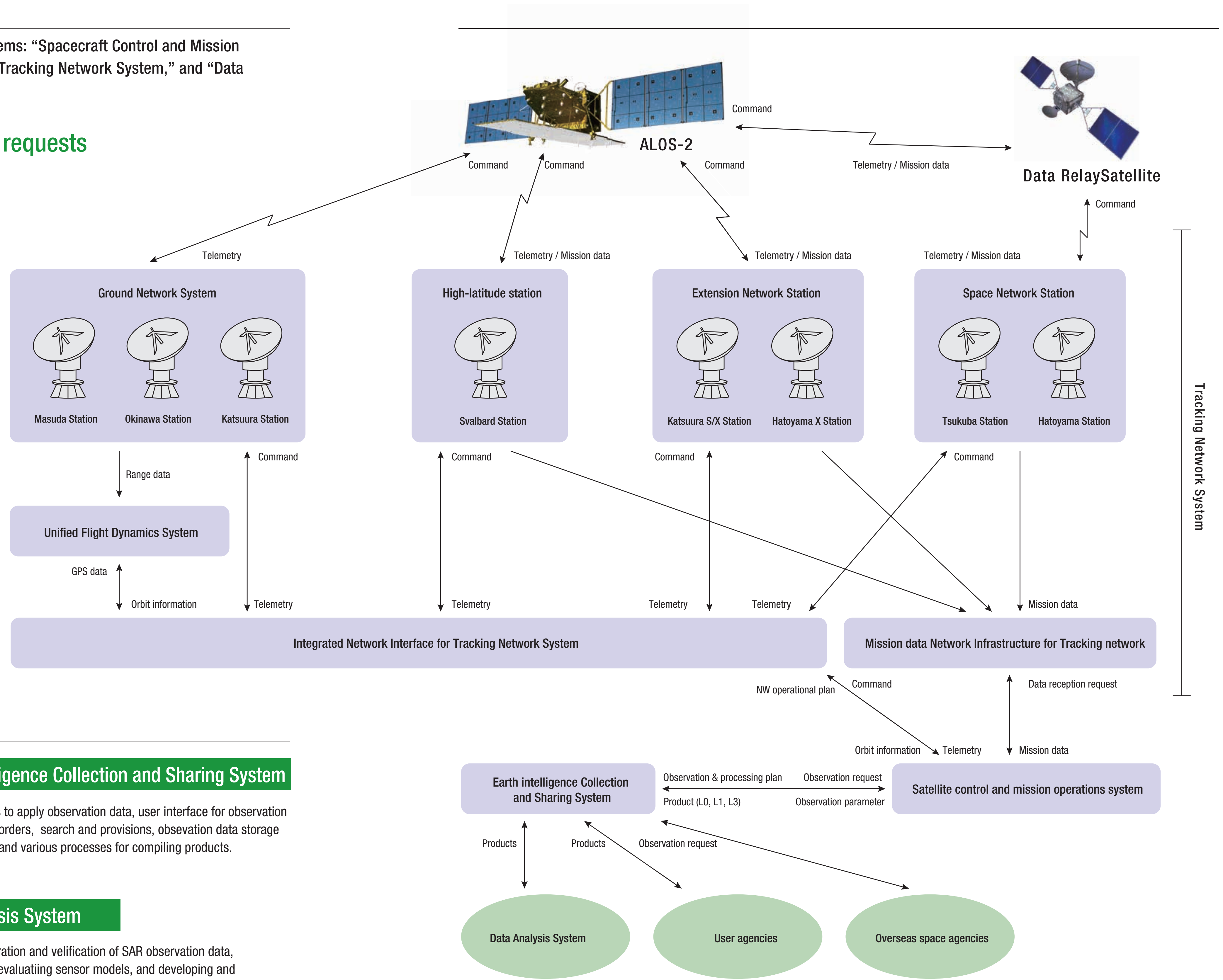
3 Satellite control and tracking network operation

4 Observations

5 Observation data reception

6 Observation data processing

7 Observation data delivery



*The distribution of ALOS-2 data is scheduled to commence at the end of November 2014. Sale of data will be carried out through the distributors. Please inquire with the Satellite Applications and Promotion Center of Japan Aerospace Exploration Agency.

Space Control and Mission Operation System

A system for compiling an observation plan, generating a command, monitoring and controlling satellite conditions, transmitting observation data of the mission instrument and processing them with the Level 0 process, and processing emergency observation data with the Level 1 process.

Earth Intelligence Collection and Sharing System

A system for users to apply observation data, user interface for observation requests, product orders, search and provisions, observation data storage and management and various processes for compiling products.

Tracking Network System

A system for compiling the network operation plan for satellite control operations, orbit determination, monitoring and contorolling ground stations and monitoring and control of ground stations for observation data receiving operations.

Data Analysis System

A system for calibration and velification of SAR observation data, construction and evaluatiing sensor models, and developing and evaluating higher-order processing software.

FAQ

Q1. What kinds of sensors do Earth observing satellites carry?

The main types of Earth observing satellite sensors are as follows:

(1) Optical sensor……Measures the reflections and radiation of sunlight. Able to take color images of the surface like a digital camera.

(2) Active microwave sensor……Emits microwaves from the sensor and gauges the microwaves reflected back from the subject. Effectively it is a radar. ALOS-2 has this type of sensor. It can observe the Earth's surface regardless of conditions, whether the weather is poor or night has fallen.

(3) Passive microwave sensor……Gauges the microwaves emitted by the subject.

Q2. Where can I search and order satellite images?

JAXA satellite images can be searched and ordered from the website below. A website offering ALOS-2 data is expected to go live around six months after the rocket launch.

- G-Portal (Earth observation satellite data provision system): Providing images and data from JAXA satellites and sensors.
  https://www.gportal.jaxa.jp/gp/top.html
- E-Saerch (an online Earth observation satellite data website search system): Available to search across all JAXA websites offering all kinds of data.
  http://www.sapc.jaxa.jp/e-search/ (Japanese only)
- DAICHI Image Gallery: Uploading images observed from all ALOS sensors and practical examples of analysis.
  http://www.sapc.jaxa.jp/gallery/ (Japanese only)
- JAXA Digital Archives: Available to search images and footage from a range of JAXA projects.
  http://jda.jaxa.jp/en/

* If you wish to use images from the JAXA website, please read "How to use" on the website and send your application if needed. Application is available on the website. For details, please read "Conditions for material usage" on the website.

Q3. What kind of format are the satellite images provided in?

The images are provided as electronic data, at an image size that is equivalent to the "scene" (the sensor's instantaneous field of view), which is defined for each satellite.

There are two major types of products, Digital Products offered by scene, and Value Added with mosaicing (multiple images overlaid) or color composition.

Q4. When can I start using ALOS-2 data?

ALOS-2 data will be available to the public about six months after its launch.

Q5. Who should I enquire to regarding use of ALOS-2 data?

Once ALOS-2 goes into operation, data will be available from JAXA or a data provision agent, depending on your intended purpose. Please contact the JAXA Satellite Applications and Promotion Center in the first instance.

Q6. What will be the level of processing for ALOS-2 images?

Observation data is provided as Level 1.1 or Level 1.5 products, with range and azimuth compressed. For details, please see p.33.

As data from satellite observation cannot be used without analysis or interpretation, standard processing is applied as appropriate for purpose. The information retained by the data depends on the level of processing.

For example, Level 1.1 includes information required to conduct interferometry analysis for crustal movement and others, but this level is not processed as an image and therefore a high level of technology is required.

Level 1.5 is processed as an imagery (regeneration treatment) and thus can be used to view images or perform analysis of the numerical values embedded in images. However, it is not appropriate for overlay on maps as the altitude data of images is uncorrected.

Q7. What is the radiometric resolution of ALOS-2 images?

16-bit.

Q8. How accurate will ALOS-2 images be?

Radiometric accuracy (common for all the off-nadir angles)

Absolute accuracy		1dB (1σ) : Corner reflector
Noise equivalent sigma-naught		-29dB or below
Amplitude ratio of VV/HH (PLR)		Within 5%
Phase difference of VV and HH (PLR)		Under 5 degrees
Cross talk (PLR)		-30dB or below
Resolution	Single look in azimuth	3m/5m
	In range	1.8m (84MHz) 3.6m (42MHz) 5.4m (28MHz) 10.8m (14MHz)
Sidelobe	In azimuth	-14dB or below
	In range	-14dB or below

Data used: Corner reflectors (CR) (calibration sites) and PALSAR-2 images from observation of the Amazon rainforest.

Evaluation method: The root mean square error (RMSE) of GRS80 ellipsoid projection corner reflector (calibration sites) location (calculated by GPS) and location measured by SAR imagery, using the 572 CR points worldwide.

*These are values used in development and will change after launch.

Ambiguity

In range	22dB or more
In azimuth	35dB or more

Geometric accuracy (common for all the off-nadir angles)

20 m	Spotlight, Strip
70 m	ScanSAR

Q9. How do I convert it to physical measurements?

The standard deliverable is expressed in the surface reflection function (the backscatter coefficient, to be precise). Using the digital number (DN) contained in the data, it can be converted by the equation Sigma-zero=10xlog10<DN^2>+CF. CF stands for "calibration function," and this will be set by JAXA during its initial calibration after launch.

Q10. What is orthorectification?

As images taken from satellites and aircraft appear distorted, for example for observations made at an angle or elevated land forms and structures, these cannot be directly imposed on a map. Rectifying these distortions using orthogonal projection in order to fit an image to a map is called "orthorectification."

Q11. What is the difference between "Georeference" and "Geocoded?"

■ Georeference

Projection of data on an image using the map projection method established by the processing parameters.

The orbital direction of a satellite is the top and bottom of an image.

■ Geocoded

A georeferenced image that has been turned so that the top of the image is facing north.

- Map North: North using the map projection method established by the processing parameters.
- True North: actual north (direction of the North Pole)

Q12. What is the pixel spacing used for each mode of PALSAR-2?

Spotlight mode: 0.625 m
High resolution mode (3m resolution): 2.5 m
High resolution mode (6 m resolution): 3.125 m
High resolution mode (10 m resolution): 6.25 m
Wide-area observation mode (350km instantaneous field of view): 25 m
Wide-area observation mode (490 km instantaneous field of view): 25 m

SOLUTION ››› Design and art

Satellite Imagery in These Wonderful Products!

Satellite images are also used in design, art and education.
Optical images have a wide range of applications, but so do images and data observed by SAR.

››› Design

©font co., ltd.

1 Fashion

Lines inspired by ALOS include a down jacket utilizing the contrasting blues and greens of an image of the Galapagos Islands, T-shirts and more.

2 Furniture

A sofa patterned using data of circular farms in Saudi Arabia
© Idée

3 iPhone Case

iPhone cases using ALOS images are on the market.
©GAS AS INTERNATIONAL/YOOSHIRO TTEN

4 T-shirts

Colorful images of the Earth's surface cut out and used in T-shirt designs. ©Village Vanguard

5 Earth-colored crayons

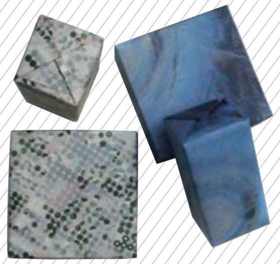
Crayons in assorted colors well-selected from satellite images of all parts of Japan.
©Granma + minna

6 iPad app

"Coasting" is an app enabling you to follow the coast on screen while enjoying music from each place.
©Qosmo

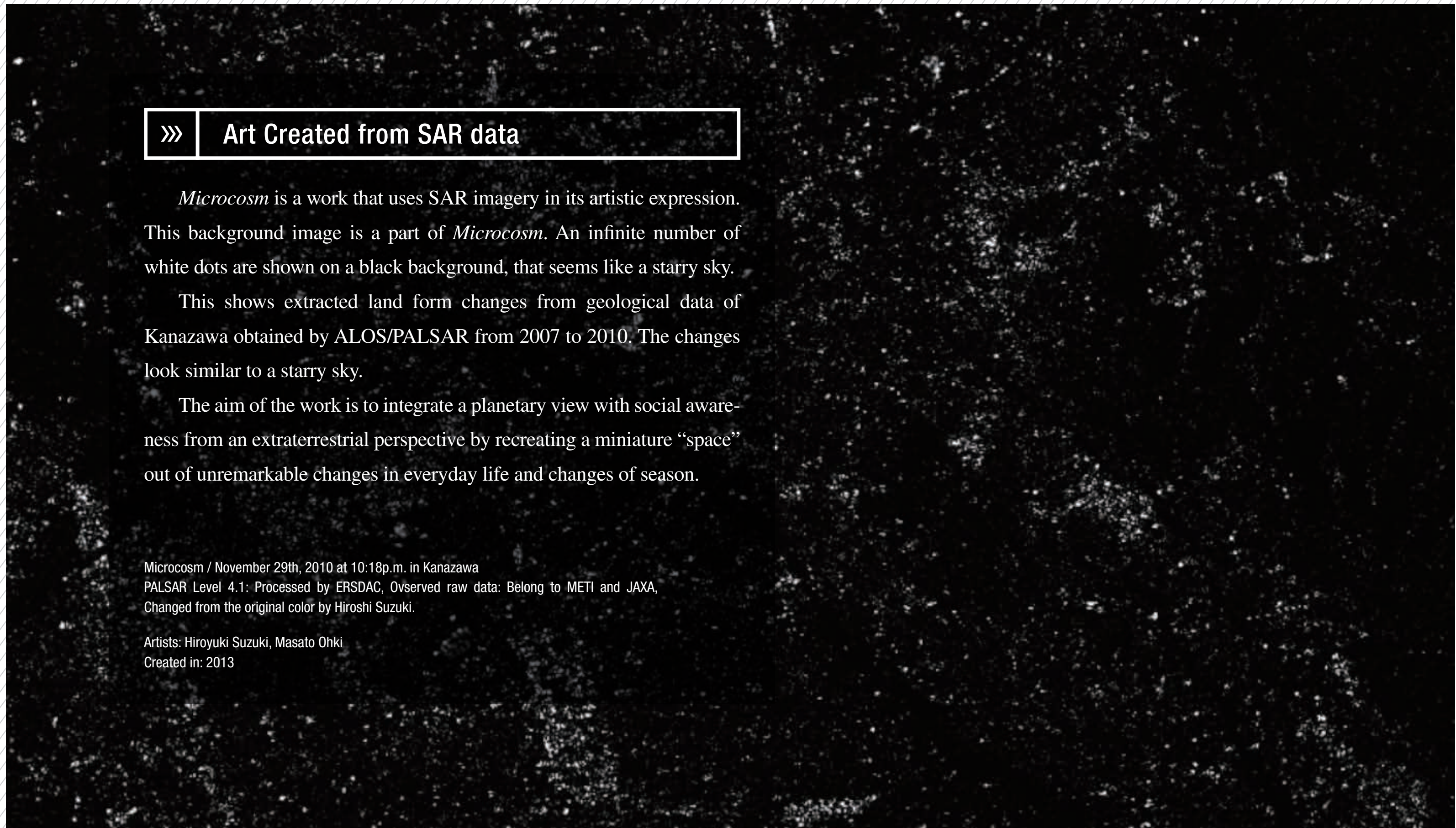
7 High-definition CG silk print

By a fusion of high-definition CG silk print technology through Yuzen process, high-definition data from ALOS is faithfully and artistically rendered on kimonos.
©Japan Style System http://jss-kyoto.jp



8 Origami

Images of the circular Richat Structure in the Sahara Desert and the circular farms of the An Nafud desert have been used as patterns for origami and wrapping paper.
©K&K



››› Art Created from SAR data

Microcosm is a work that uses SAR imagery in its artistic expression. This background image is a part of *Microcosm*. An infinite number of white dots are shown on a black background, that seems like a starry sky.

This shows extracted land form changes from geological data of Kanazawa obtained by ALOS/PALSAR from 2007 to 2010. The changes look similar to a starry sky.

The aim of the work is to integrate a planetary view with social awareness from an extraterrestrial perspective by recreating a miniature "space" out of unremarkable changes in everyday life and changes of season.

Microcosm / November 29th, 2010 at 10:18p.m. in Kanazawa
PALSAR Level 4.1: Processed by ERSDAC, Ovserved raw data: Belong to METI and JAXA, Changed from the original color by Hiroshi Suzuki.

Artists: Hiroyuki Suzuki, Masato Ohki
Created in: 2013

Experiment on a farm near Kanazawa
(14 October, 2010)

Postscript

In this book, we have explained a number of possible solutions that ALOS-2 can offer. Some may feel that SAR is a little difficult. But with a basic understanding of the characteristics of SAR, surely others will now have a sense of the possibilities it offers in a wide range of fields and occasions.

We hope that the attributes of ALOS-2 are not simply seen as "space infrastructure" for use in disasters, but as tools for application in business, society, civil life and international contributions. We would be truly delighted if ALOS-2 is made full use, leading the world as a Japanese technology in the SAR field.

(Editorial committee)

If you would like to use ALOS-2, please contact JAXA Satellite Applications and Promotion Center (Tokyo office) by e-mail: SAPC-INFO@jaxa.jp.

Editorial assistance from: Remote Sensing Technology Center of Japan/Cross Media Marketing
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