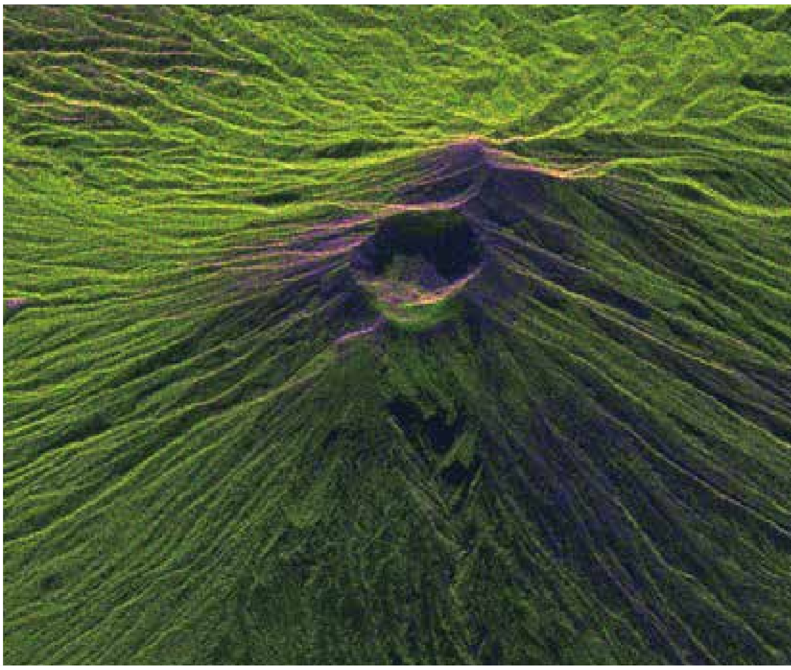
ALOS-2 SOLUTION BOOK

Proposals for “DAICHI 2” SAR Data Utilization



3rd 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 Advanced Land Observing Satellite 2 (ALOS-2, also known as “DAICHI-2”) was launched in May 2014 as the successor satellite to “DAICHI” (ALOS), and is used for a range of purposes including capturing information about disaster conditions, agriculture, forestry and fishery, marine observation, and resource exploration.

In particular, Japan has built up a wealth of technological know-how ahead of the world in the field of the L-band Synthetic Aperture Radar (L-band SAR) mounted on ALOS-2, which is contributing to resolving issues in various sectors.

This book introduces the uses of satellite data to everyone in the industrial, academic, and administrative sectors, with a focus on solutions that are enabled by ALOS-2. It was produced with the objective of facilitating the development of new applications for the analysis and processing of data, as well as the discovery of 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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Top left: Forest fires in Canada (see p.9)
Bottom left: Sea ice in the Sea of Okhotsk (see p.24)
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Bottom right: Volcanic eruption in Bali, Indonesia (see p.8)

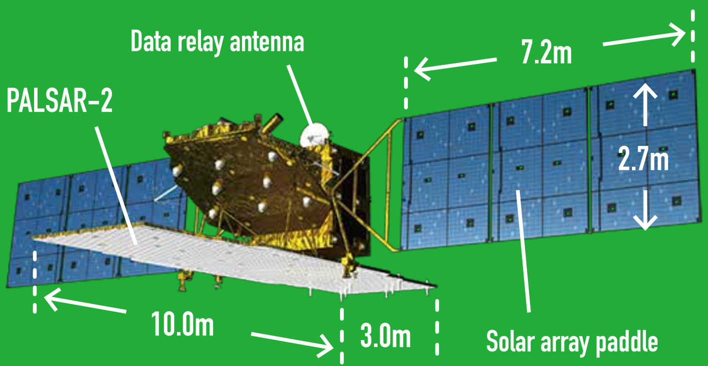
Background Image: Mt. Fuji (Observed by ALOS/AVNIR-2)

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

Overview of ALOS-2

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

The SAR mounted on ALOS-2 is the "Phased Array type L-band Synthetic Aperture Radar" (PALSAR-2), a high-performance microwave sensor. It improves performance in aspects such as resolution and regions that can be observed, and makes it possible to provide information more accurately and swiftly.



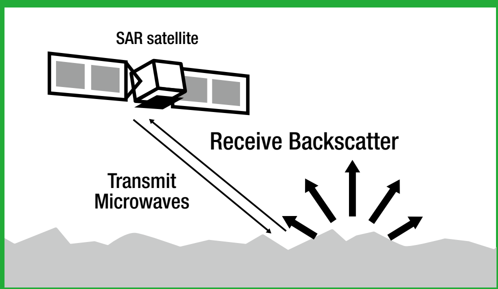
Design life	5 years (target: 7 years)
Launch date	24 May 2014
Launch vehicle	H-IIA launch vehicle No. 24
Launch site	Tanegashima Space Center
Orbit (altitude)	628 km (on the equator)
Orbit period	Approx. 100 min
Repeat cycle	14 days
Satellite mass	Approx. 2,100 kg
Satellite size (on orbit)	Approx. 10.0 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.

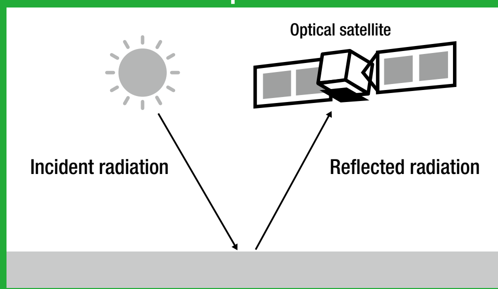
Differences Between SAR Images and Optical Images

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.

SAR



Optics



(Top left) Observation Image of SAR satellite

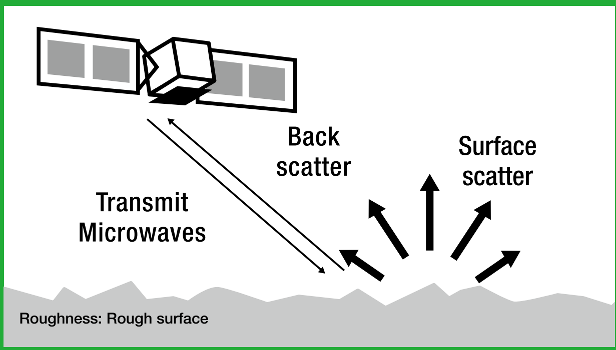
(Bottom left) SAR image

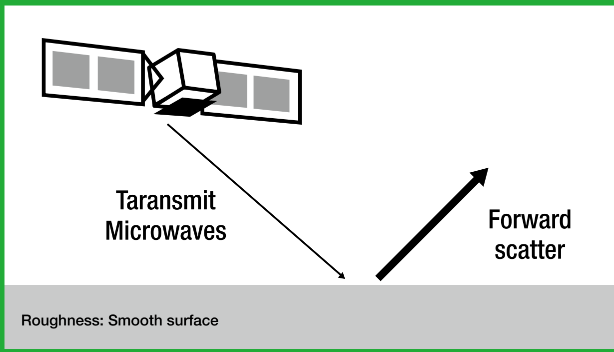
SAR Imaging Principle

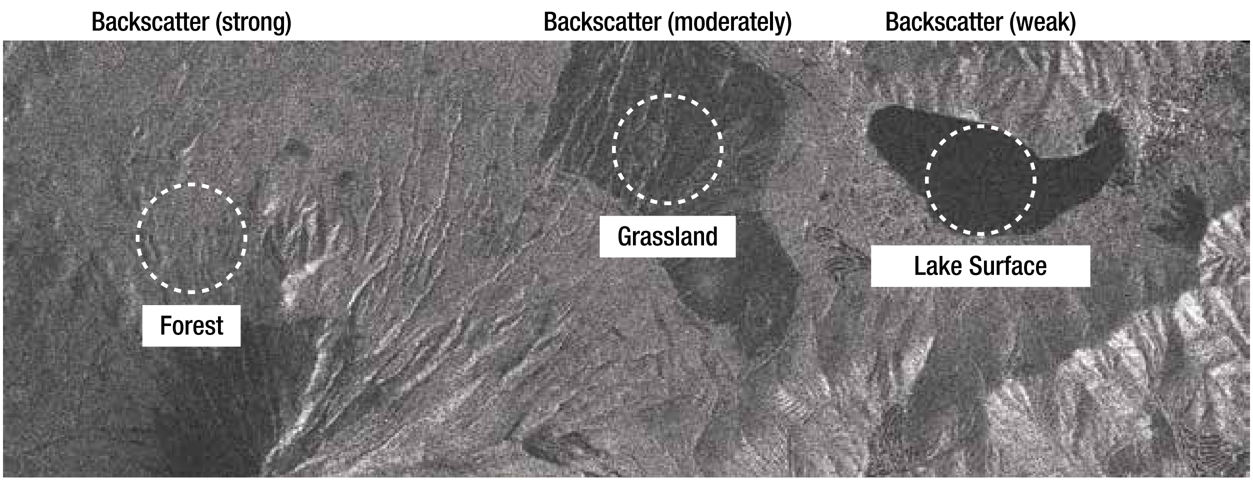
SAR transmits the pulse signals to the target, and obtains information about the conditions of the surface depending on the strength of receiving signals. This reflection component is called “backscatter.” The target that has strong backscatter appears bright on SAR image.

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.







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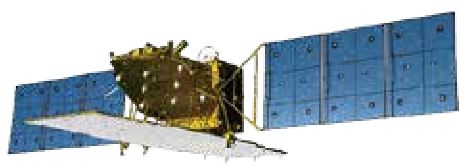
Characteristics of L-Band SAR

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.

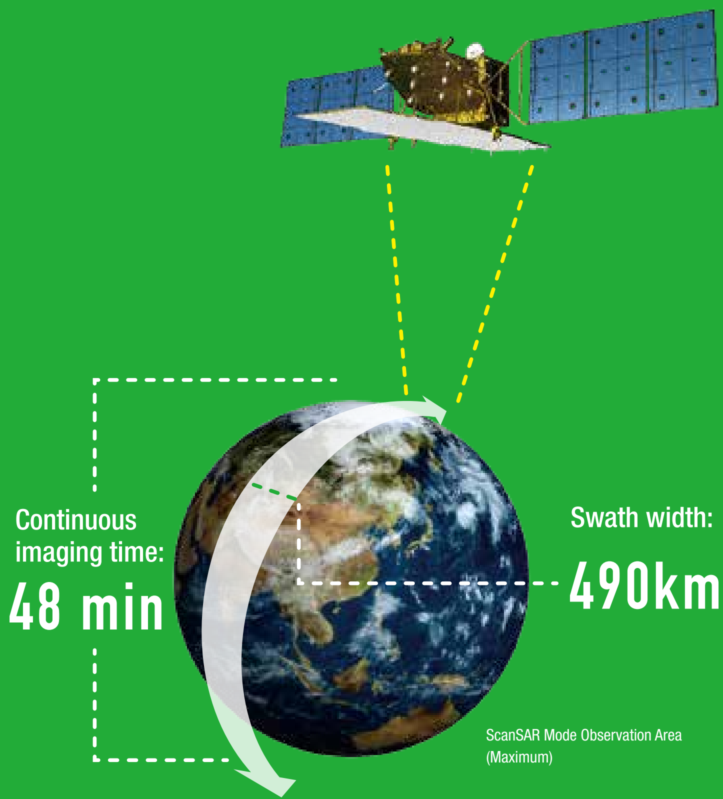


Information Available Regardless of Day or Night, Weather Conditions

››› 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.

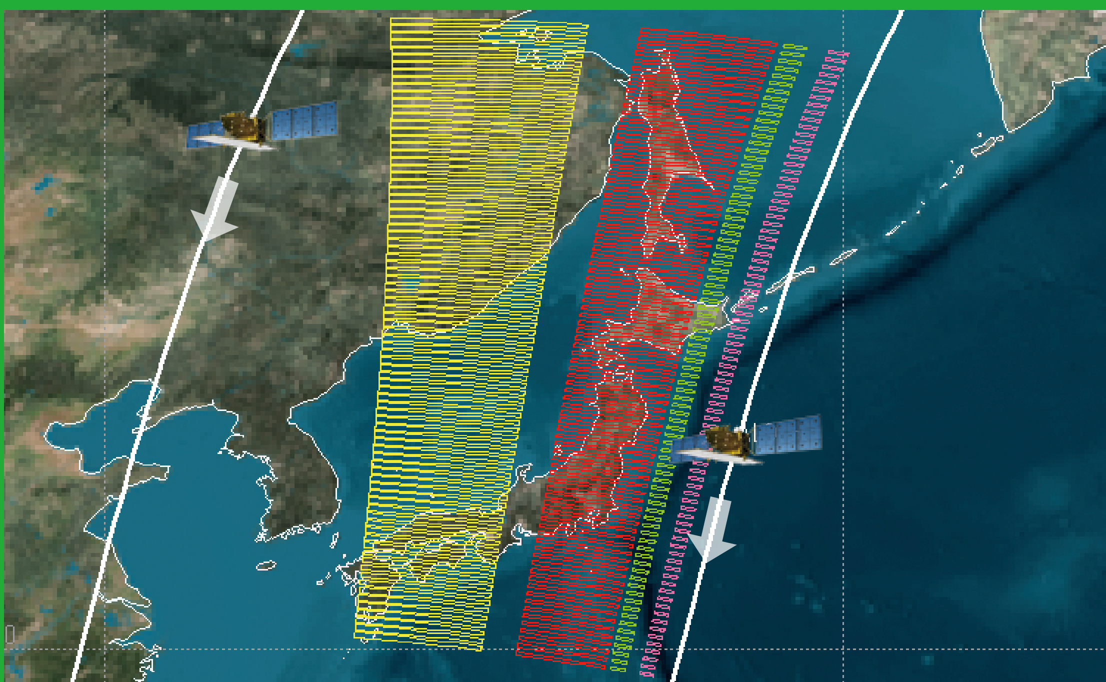


☑ High-resolution Observation Regardless of Day or Night, Weather Conditions

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)

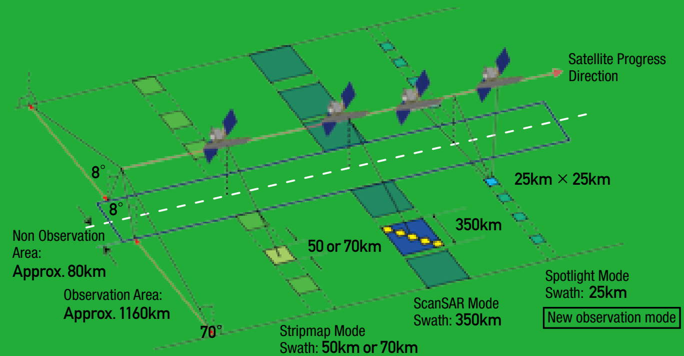
Green band: Stripmap (10m) Mode (Swath width: 70km)

Pink band: Stripmap (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 Stripmap 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)
Stripmap	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)

Stripmap Mode

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

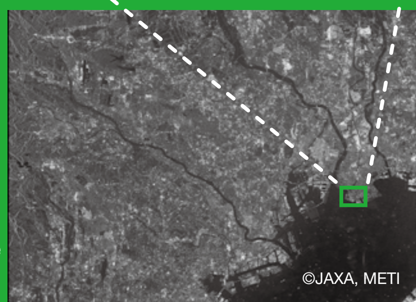


Image captured using Stripmap Mode (Tokyo, Chiba area) (Observation by ALOS/PALSAR)

ScanSAR Mode

It is possible to capture images up to 490 km swath with ALOS-2. Compare d 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.

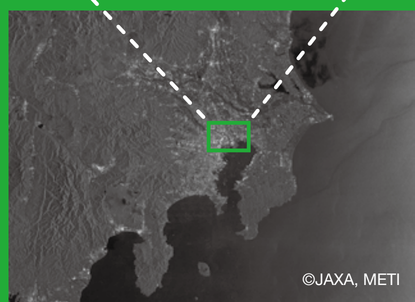


Image captured using ScanSAR Mode (Kanto region) (Observation by ALOS/PALSAR)

Case Studies of Recent ALOS-2 Observations, and Future Potential

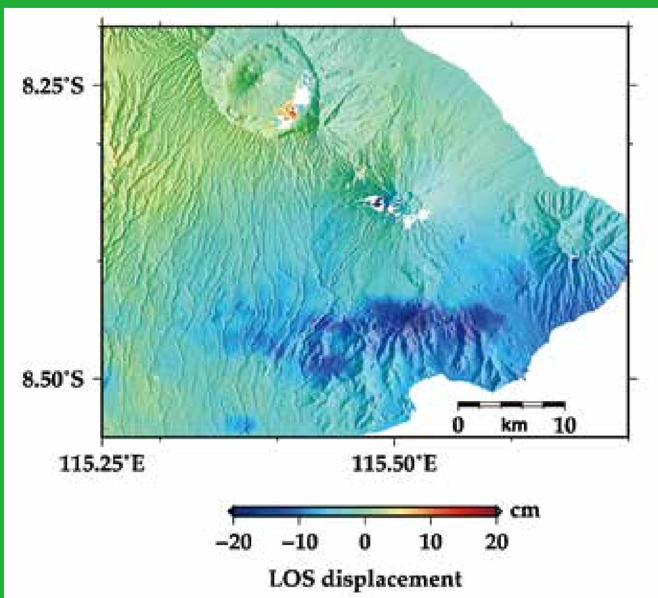
Following on from its predecessor ALOS, ALOS-2, launched in May 2014, provides data as well as emergency observation services accompanying disaster monitoring in Japan and countries around the world. There are also plans to launch its successor satellite, ALOS-4, in 2020. Here, we will feature some of the exceptional case studies from among the recent observations carried out by ALOS-2 (as of November 2017). We hope that these case studies will help you learn more about some of the observation results that can be obtained only through the use of an L-band synthetic aperture radar (PALSAR-2), and that you will use these as hints for problem-solving and business development going forward.

››› Observation carried out on 1 December 2017 Results of the observation of Mount Agung, Indonesia

On 21 November 2017, Mount Agung on the island of Bali, Indonesia, erupted for the first time in 54 years. JAXA conducted an observation through the L-band synthetic aperture radar (PALSAR-2) mounted on ALOS-2 on 1 December at 1:38 a.m. (Japan time), and obtained images of the emergence of lava from the crater of the volcano.

Through an interference SAR analysis (interferometry), it was found that although crustal deformation was not observed around Mount Agung, surface change had occurred on the south side of the crater, including the deposition of volcanic ash and ejecta. Through Sentinel Asia, information was provided to the relevant institutions and authorities at the local site. This is an example where the ability of ALOS-2 to observe ground surfaces even during night time or under cloudy conditions or fumes was utilized.

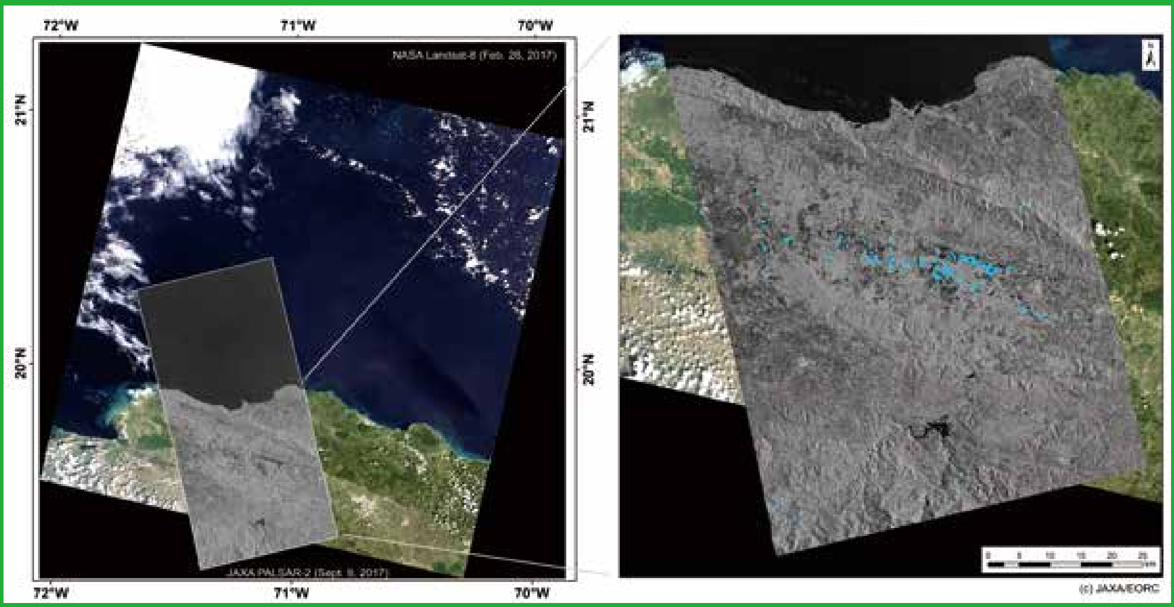
The figure above shows the PALSAR-2 observation area on 1 December 2017 (Red triangle on the top right of the figure: Location of Mount Agung; Black frame: Observation range). The color composition is as follows: HH polarization data observed through the ALOS-2 Stripmap 10m mode (dual polarization) in red, HV polarization in green, and HH polarization/HV polarization ratio in blue. The areas in blue and black show water and bare ground respectively, areas in green denote vegetation, and the localized areas in bright green and purple show town and urban areas.



The figure above is a differential interference image obtained by subjecting ALOS-2 image data for two periods, before and after the eruption of Mount Agung, to interference processing (interferometry). Through interference processing, it is possible to obtain the degree of variation in cases where crustal deformation (uplift or subsidence, etc.) has occurred alongside the eruption. In this observation, no significant variations exceeding the detection limit of interference processing were observed, and the event did not result in a serious disaster.

Observation carried out from 8-12 September 2017
Results of the observation of hurricane damage along the Caribbean Coast

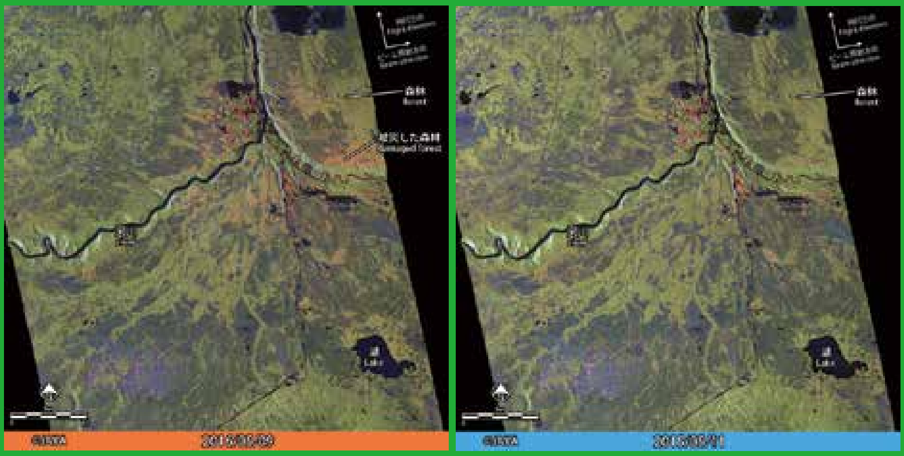
A number of hurricanes passed by the Caribbean Coast from the end of August 2017, and caused serious damage to the region. ALOS-2 carried out emergency observations, and provided the data to the relevant organizations. Observation images dated 8 September detected a location in the Dominican Republic that was very likely to be flooded. Based on observation images dated 12 September, locations on the west coast of Florida, the United States were identified as places that were very likely to be flooded.



The figures above show data of observations carried out on the northern part of the Dominican Republic on 8 September 2017, using Stripmap mode (Resolution: 10m; Observation width: 70km). Based on image processing, the area in blue is inferred to be a flooded region. Through this observation, we can see that much flood damage has been incurred along the inland areas, rather than along the coastal regions.

Observation carried out on 9 May 2016 Results of the observation of wildfires in Canada

With regard to the wildfire that occurred near Fort McMurray in Alberta, Canada, on 1 May 2016, JAXA carried out an observation through ALOS-2 on 9 May 2016 at the request of the International Disasters Charter. Using the 4 polarization mode (full polarimetry), which is capable of analyzing changes in the situation of the ground surface, the observation was able to capture the majority of the areas affected by the wildfire.



Source: ALOS Research and Application Project of EORC, JAXA website

While forests usually appear in green, the areas affected by this wildfire have changed to a reddish or orange color. This indicates that the branches and leaves of the trees have been destroyed by the fire, leaving only the trunks. It is possible to infer that this is because the dominant reflection from the leaves and branches (green) has become a dominant reflection from the trunks (red).

The smooth ground surfaces (water surfaces) such as rivers, lakes, and runways are presented in black, while towns and urban areas are shown in bright pink or yellow-green.

Observation carried out on 10 September 2015
Results of the observation of torrential rains caused by Typhoon No. 18 in Ibaraki Prefecture

From 9 to 10 September 2015, torrential rains occurred due to Typhoon No. 18, and river flooding as well as landslides and other sediment-related disasters struck various regions, particularly in Tochigi and Ibaraki Prefectures.

At the request of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), JAXA carried out an emergency observation through PALSAR-2 mounted on ALOS-2 at 11:43 a.m. on 10 September. The data from this observation was provided to organizations involved in disaster prevention, including MLIT. The observation allowed to clarify multiple regions that were considered to be flooded regions.

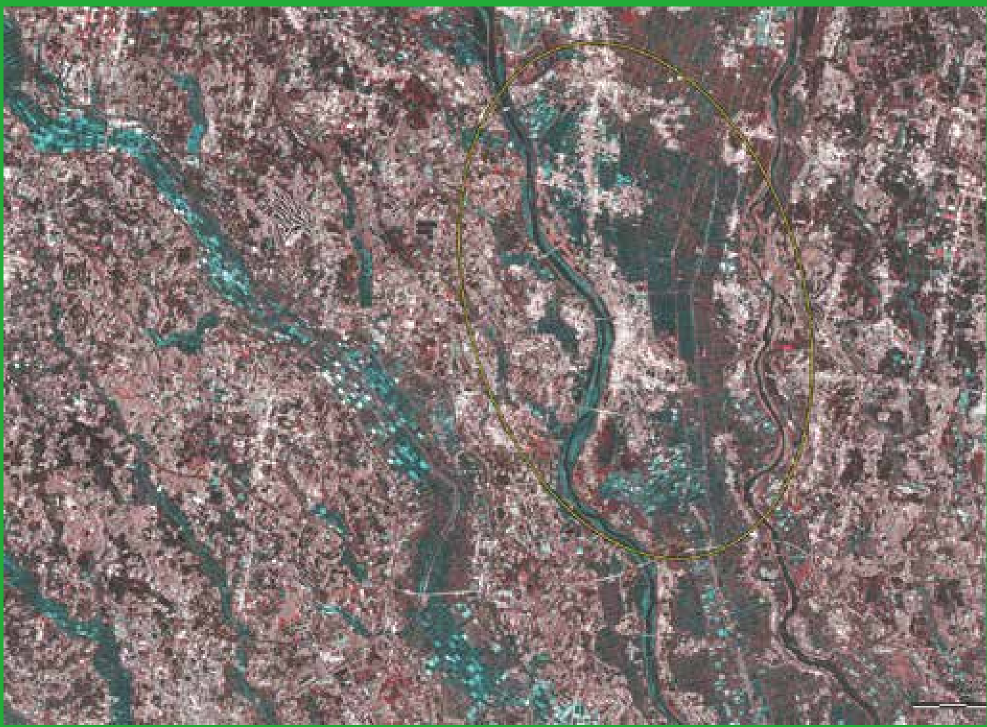


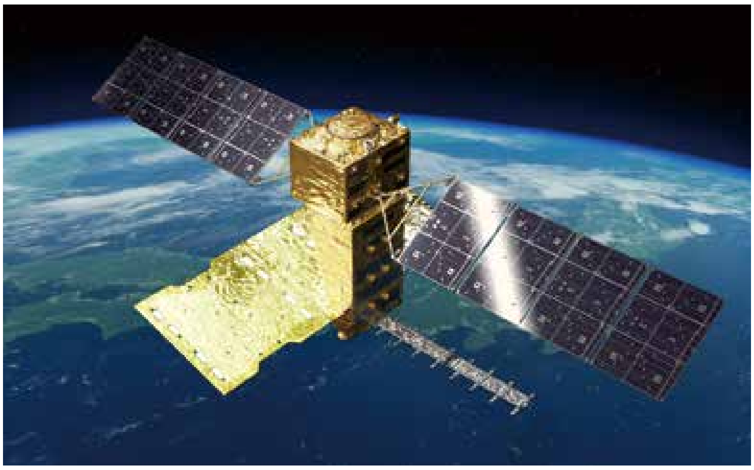
Figure 1: Observation image of the area near Joso City

Figure 2: Observation image of the area near Chikusei City

Figure 1 shows an observation image of the area near Joso City. Kinugawa River flows near the center of the image, and the section where the river width has expanded is shown in dark blue along the river. The area in even darker blue east of the river is highly likely to be flooded (area within the yellow circle in the figure). Figure 2 is an image of the area near Chikusei City. The area shown in dark blue in the yellow-framed section is likely to be a flooded region.

Both Figures 1 and 2 were obtained using Stripmap mode (3m resolution) of ALOS-2 at the time of the disaster. These were superimposed with images obtained under the same conditions on 13 August of the same year, before the flood, subjected to color synthesis, and analyzed. (These changes include changes in the agricultural land as a result of the harvesting of rice and other factors, and it is important to note that not all the changes are related to the disaster.)

ALOS-4



From Capturing Information after the Event, to the Early Detection of Abnormalities

The launch of ALOS-4, positioned as the successor to ALOS-2, has been scheduled for FY2020 (*). This successor satellite is mounted with an L-band synthetic aperture radar like the ALOS-2, and also maintains the orbital altitude (628km) and recurrent period (14 days) of the ALOS-2. By retaining these features, it is able to maintain data continuity while development is ongoing, providing users with even greater convenience than before.

The greatest change from ALOS-2 is the significant increase in observation width.

For example, in Stripmap mode, the observation width at a resolution of 3m increases from 50km for ALOS-2 to 200km for ALOS-4. Until now, observation of the entire land mass of Japan by ALOS-2 using the same mode could only be carried out about four times a year; with the ALOS-4, however, it can now be carried out about 20 times a year. This significant increase in observation frequency makes it possible to carry out long-term observation of crustal deformation and other phenomena at greater precision, and is expected to contribute to the early detection of abnormalities and the formulation of countermeasures.

To bring about the realization of the expansion in observation width, digital beamforming (DBF) technology will be introduced into the ALOS-4. This technology enables an increase in observation width without incurring any decline in sensitivity. While this technology is already being used in fields such as mobile phone communication, Japan has taken a step ahead of the world in applying this technology to observation satellites.

In other aspects, the ship Automatic Identification Systems (AIS) receiver also performs better than the one mounted on the ALOS-2, and is expected to produce an improvement in ship detection rate over waters that are overcrowded with ships. By carrying out observation in tandem with the synthetic aperture radar, it is expected to contribute further to marine monitoring.

ALOS-2, which continues to carry out observations smoothly at present, should also continue to play an important role going forward. ALOS-4 will get off to a flying start as an even more reliable satellite, even as it inherits the track record and capabilities of its predecessor.

*An observation satellite mounted with optical sensors is scheduled to be launched in FY2020 as ALOS-3.

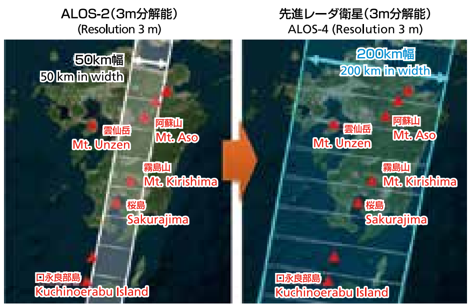
観測幅の比較　Comparing observation swath

	ALOS-2	先進レーダ衛星 ALOS-4
高分解能モード(分解能3m、6m、10m) Stripmap mode (Resolution 3 m, 6 m, 10 m)	50km, 70km	➡ 100km-200km
広域観測モード(分解能25m) ScanSAR mode (Resolution 25 m)	350km, 490km	➡ 700km
スポットライトモード(分解能1m×3m) Spotlight mode (Resolution 1 m x 3 m)	25km× 25km	➡ 35km× 35km

日本の観測頻度の比較　Comparison of observation frequency in Japan

	ALOS-2	先進レーダ衛星 ALOS-4
高分解能モード(分解能3m) Stripmap mode (Resolution 3 m)	年4回 Four times a year	年20回(2週に1回) 20 times a year (once every two weeks)

Comparison of the observation width of ALOS-2 and ALOS-4. It is extended by close to 4 times.



The range expands significantly with one observation in Stripmap mode.

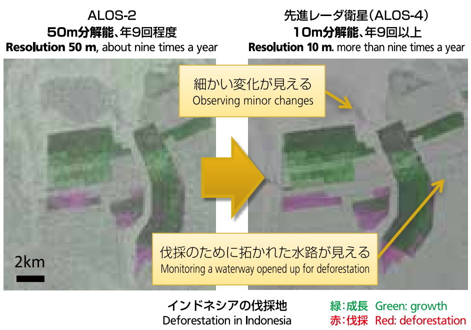


Image of improved forest monitoring. It is possible to capture changes in greater detail.

SOLUTION ››› Disasters

Capturing information about the situation to speed up disaster measures

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.

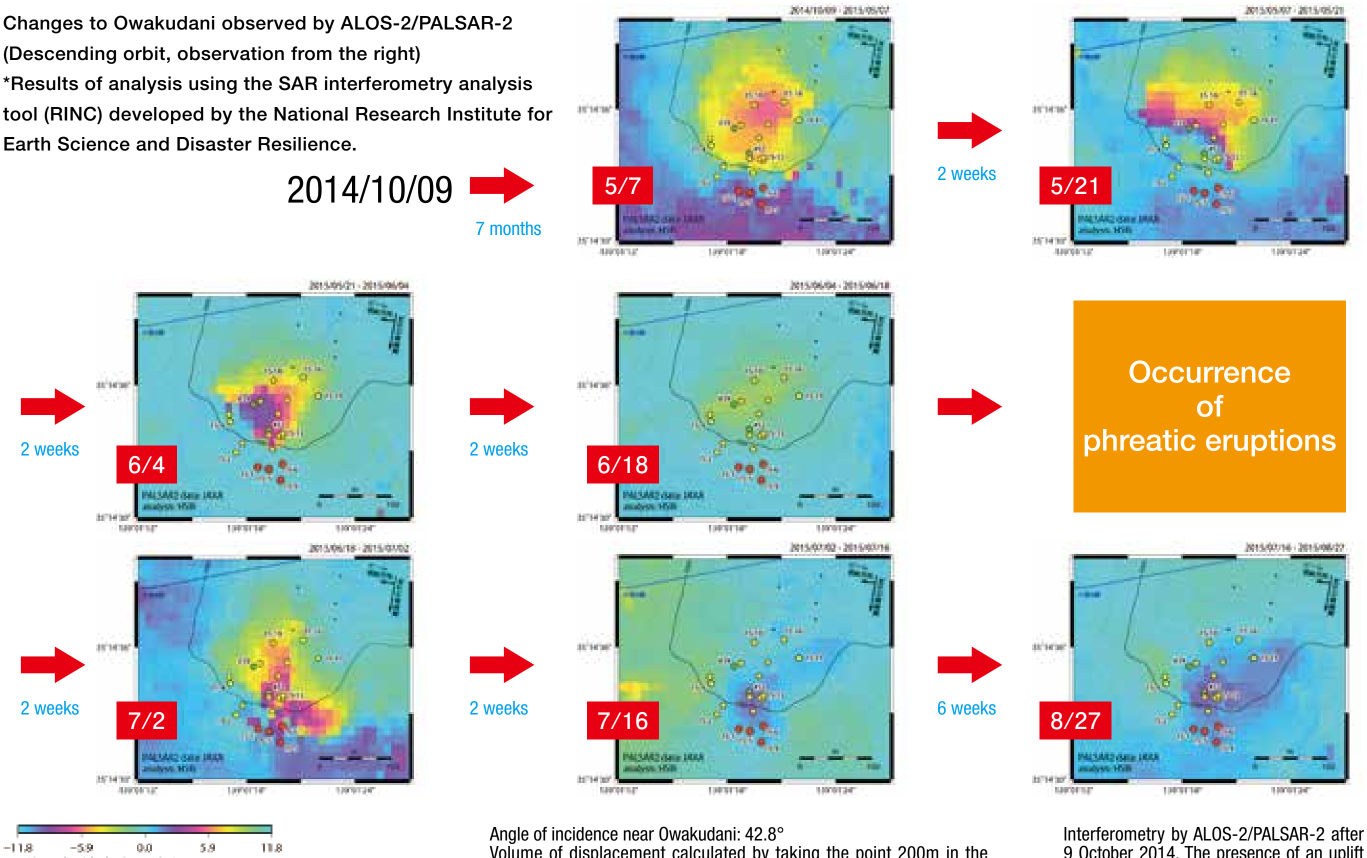
››› Capturing Displacement Information Just Before a Volcanic Eruption And Using it for Decision-Making on Safety Measures

In June 2015, Mt. Hakone in Kanagawa Prefecture erupted for the first time in the history of its observation. The signs of a potential eruption began to emerge in around April the same year, when it was confirmed that the mountain itself had begun expanding marginally. Eruption activity intensified at the start of May, and a part of the Owakudani area, which is visited by many tourists, had to be closed off. Earthquake activity dampened after peaking on 15 May, but crustal deformation continued thereafter. On 29 June, the situation escalated into a steam eruption, although it was a very small-scale one. After a magma eruption about 3,000 years ago, Mt. Hakone has not had any records of eruptions in recent history except for signs of a steam eruption around the 12th to 13th century, which were revealed through a geological survey.

SAR images observed by ALOS-2 were used to obtain information about the situation leading up to this eruption. On 6 May, the Japan Meteorological Agency announced a level 2 volcanic alert for Mt. Hakone. In response, an emergency observation was carried out by ALOS-2 the next day, on 7 May. Using the SAR images obtained in that observation, as well as SAR images obtained in observations carried out in October 2014 before the occurrence of this event, an interferometry (refer to p.31) was conducted, and it was found that an uplift was emerging within an approximately 200m-diameter range centered around Owakudani. This location corresponded perfectly with the location of a hot spring supply facility where abnormal fumarole activity had been confirmed four days before the emergency observation. Based on these results, a decision was made to shut off Owakudani completely with effect from the afternoon of 8 May, making it off-limits even to local personnel. At the end of June, a steam eruption occurred very close to the area of uplift observed by ALOS-2.

The capturing of the displacement at the location where the steam eruption occurred immediately prior to the eruption, through a satellite observation, is considered to be the first such case in the world. ALOS-2 had demonstrated how significant a role SAR images can play in volcano monitoring.

Changes to Owakudani observed by ALOS-2/PALSAR-2 (Descending orbit, observation from the right)
***Results of analysis using the SAR interferometry analysis tool (RINC) developed by the National Research Institute for Earth Science and Disaster Resilience.**



Volume of displacement in the direction of the satellite's line of sight

Angle of incidence near Owakudani: 42.8°
Volume of displacement calculated by taking the point 200m in the N60E direction from the area near No. 39 I as the stationary point

Interferometry by ALOS-2/PALSAR-2 after 9 October 2014. The presence of an uplift about 6cm high, at maximum, was verified.

Capturing Changes in a Volcano Through Interferometry using ALOS-2 Data

During the volcanic eruption at Mt. Hakone in Kanagawa Prefecture that struck in June 2015, SAR images from ALOS-2 successfully observed the unusual events that occurred beforehand. How did it succeed in doing that, and what possibilities for ALOS-2 did it present? We spoke to the researcher who carried out the data analysis.

USER INTERVIEW

Dr.Ryosuke Doke

Hot Springs Research Institute of Kanagawa Prefecture

—— Could you give us an overview of the Hot Springs Research Institute of Kanagawa Prefecture?

The Hot Springs Research Institute of Kanagawa Prefecture is a research institute that conducts research in fields such as hot springs, groundwater, geology, earthquakes, and volcanoes. The primary aim of conducting research on hot springs and groundwater is to conserve and protect resources, while that of research on earthquakes and volcanoes is to ensure the safety and security of the citizens of the prefecture. From that perspective, Mt. Hakone is an important research subject for the institute.

—— How is the observation of Mt. Hakone usually carried out?

There are multiple GPS observation points at Mt. Hakone and its surroundings. If any unusual events occur underground, the ground will move, and based on that change in positional information, we will be able to know what the crustal displacement is. However, due to the distribution of the observation points, what we learn through the GPS are changes at a relatively deep depth of about 7 – 10km. As such, an inclinometer is also used to detect changes in the shallow areas. Measuring the incline of the ground using an inclinometer allows us to learn if the ground near the surface has swelled, or if any cracks have emerged.

After the launch of ALOS-2 in 2014, we began using SAR images in addition to these methods. Coincidentally, an eruption occurred the year after that, and SAR images began to play an important role in the aftermath of that eruption.

—— During this eruption, an emergency observation was carried out by ALOS-2 immediately before the eruption. Could you tell us the flow of events that led up to that?

Around the beginning of April, observations showed that the distance between the GPS observation points positioned on either side of the volcano was growing. This presented the possibility that the magma chamber deep underground could be swelling. However, due to GPS observation errors, it was only at the end of April, when earthquake activity began, when we could say for certain that this had happened. After that, abnormal fumarole activity occurred at one of the hot spring supply facilities in Owakudani on 3 May. Then, in response to the announcement of a level 2 volcanic alert issued by the Japan Meteorological agency on 6 May, an emergency observation was carried out by ALOS-2 the next day, on 7 May. Thereafter, we continued to carry out observation activities under the same conditions once every two weeks.

—— How were observations by ALOS-2 utilized?

Once SAR images of the observation carried out on 7 May were available, we used these images, as well as SAR images observed in October 2014 prior to the eruption, to carry out an interferometry immediately. As a result, it was confirmed that an uplift was emerging at a range of about 200m centered around Owakudani, and we also found out that its core corresponded with the location of the hot spring supply facility where abnormal fumarole activity occurred on 3 May.

Based on these results, we were able to ascertain that the abnormal fumarole activity was related to the ground displacement, and a decision was made to shut off Owakudani completely with effect from the afternoon of 8 May, making it off-limits even to the parties concerned. At a meeting held on 11 May, it was decided that the complete prohibition of entry would be returned to a status of allowing conditional entry. In making that decision, the analysis results of the observation carried out from the skies in the west on 10 May (a different observation from the emergency observation carried out on 7 May from the skies in the east) were also taken into consideration in the review.

—— The unique advantages offered by SAR images became clear in this event, didn't they?

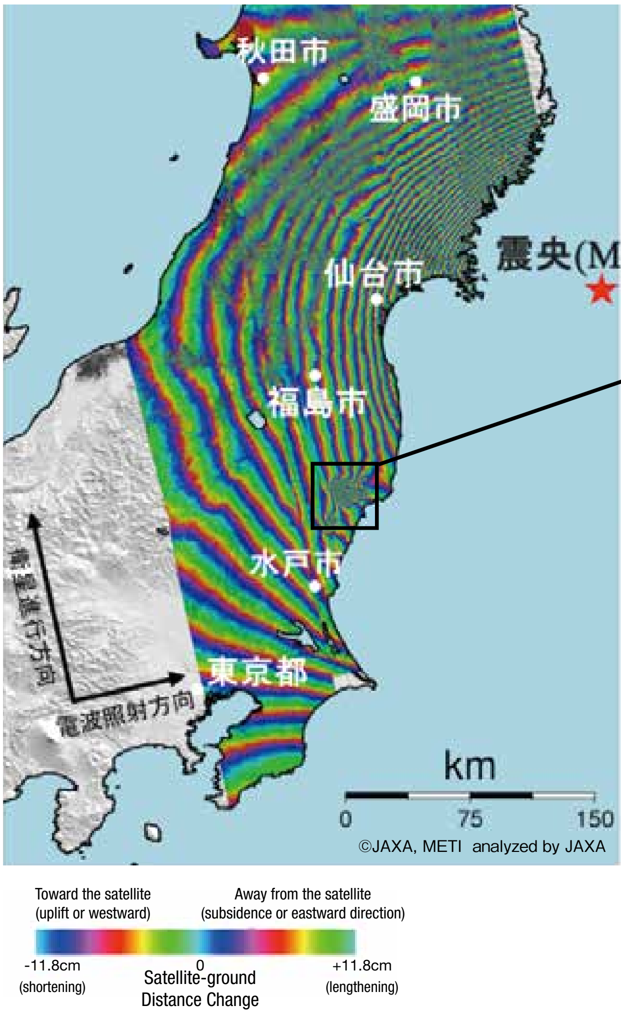
This time, we learned that information obtained through interferometry of SAR images is highly effective in capturing ground movement. Even for phenomena that we can actually observe, such as abnormal fumarole activity, it is not possible to find out what changes are actually occurring under the ground based on the observation of that phenomenon alone. SAR images were the only information source that provided quantitative indication of ground movement at Owakudani. I believe we would not have been able to make the decision to restrict entry on 8 May without the SAR images observed by ALOS-2.

—— Will SAR images also be used in volcano monitoring when there are no eruptions?

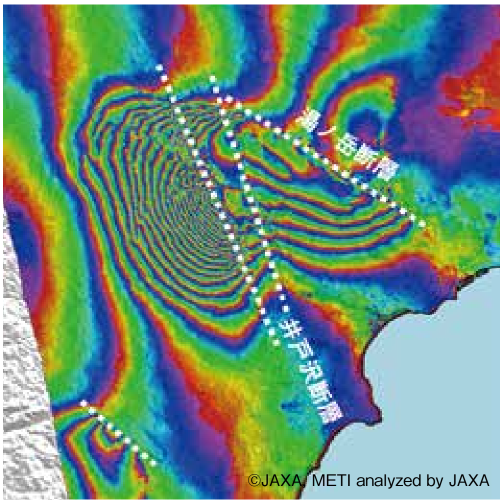
Even now, observation data of Mt. Hakone by ALOS-2 is continuously accumulated at a frequency of once every few months. Using the large volume of data collected in this way to conduct a time-series analysis can help us to understand how the region has changed over a long period of time. Going forward, I understand that there are plans to launch a successor satellite offering improvements in observation frequency. By continuing to build up this wealth of data, I hope that we will gain an ever more precise understanding of the events that are actually occurring in a volcano, and continue to monitor such volcanic activity.

Hot Springs Research Institute of Kanagawa Prefecture
WEB: http://www.onken.odawara.kanagawa.jp/ (Japanese Only)

»» 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.

»» 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.

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, After the launch of ALOS-2, Japan has been providing much data.

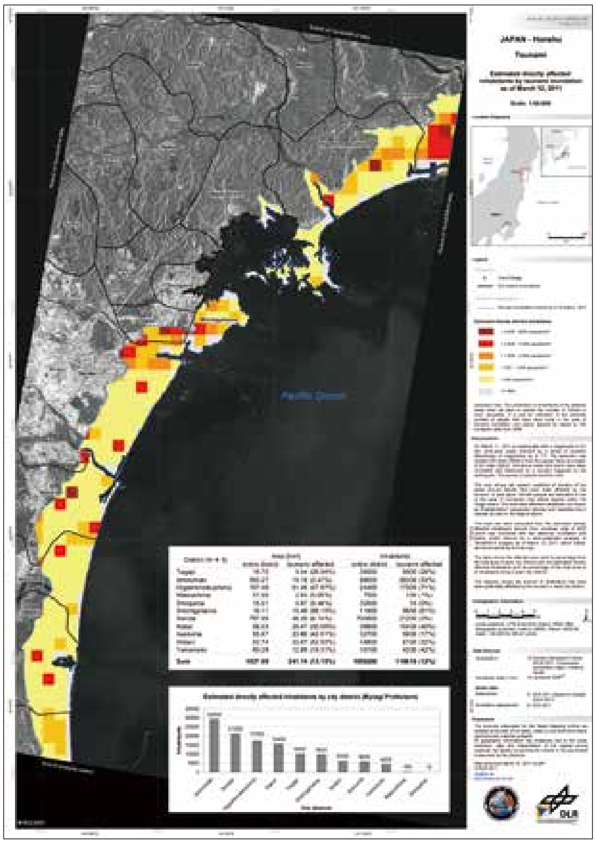


Image of the areas affected by the tsunami in the Great East Japan Earthquake, provided by German Aerospace Center (DLR) through the International Charter on Space and Major Disasters. The image is a superimposition of SAR image (TerraSAR-X) with population density data.

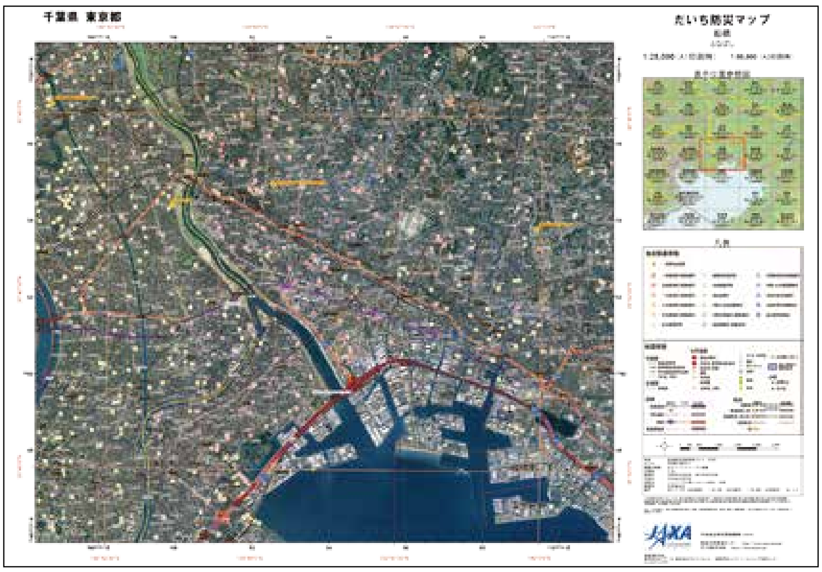
Using Satellite Images in Local Governments' Disaster Prevention Plans

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.

Disaster report data obtained through ALOS-2 is currently used in conjunction with other information sources, and is contributing to the formulation of disaster readiness plans by the national and local governments more than ever before.

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.

››› Land Subsidence Monitoring Work With Greater Precision, and at Lower Costs

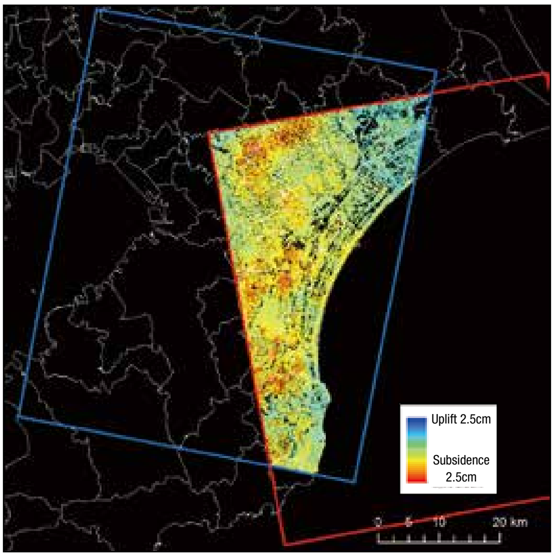
Since around the Taisho era, Japan has been drawing up groundwater for use as industrial water. As a result, land subsidence has advanced over the long years of such activity, particularly in metropolitan areas. The collection of groundwater has been regulated, and there has been a trend toward the abatement of land subsidence in recent years. However, there are regions where land subsidence is still ongoing even today, and monitoring and observation, as well as countermeasures to counter land subsidence, continue to be an important part of the work of administrative organizations.

The Ministry of the Environment published the Guidelines for Monitoring Ground Subsidence in 2005,which sets out the technological guidelines and methods for monitoring land subsidence. These guidelines are based on technologies such as leveling and groundwater level observation. However, new measuring technologies that harness aircraft and satellite have emerged in recent years, and interference analysis (interferometry) through the use of SAR images from ALOS/ALOS-2 has become a useful technological means for measuring land subsidence. The methods of utilizing this technology and examples of actual analysis conducted have been summarized for practitioners from local public organizations, and published in May 2017 as the Guidebook for the Utilization of Satellites in Monitoring Ground Subsidence.

While it had only been possible to carry out observations of land subsidence in places where benchmarks are located, the use of SAR images enables planar observation across wide areas. By using SAR images, it is possible to reduce the number of leveling surveys conducted, and as a result of that, reduce the cost of such monitoring work by 30% - 40% depending on the conditions, according to estimates drawn up by the Ministry of the Environment.

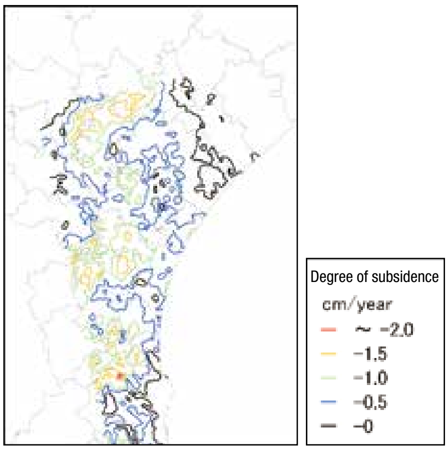
Going forward, by widely disseminating information about this manual, we hope that land subsidence monitoring operations in the respective regions can be carried out with greater precision, and at lower costs.

* Measuring the distance from the satellite to the ground surface, and comparing two sets of data obtained for the same location on different dates and times.



Drawn up based on the Guidebook for the Utilization of Satellites in Monitoring Ground Subsidence

The image shows the result of a time-series analysis. It is possible to reduce measurement errors, and to assess uplifts and subsidence based on the color tones.



Original Data ©JAXA

Land subsidence distribution map of the Kujukuri Plain observed by ALOS-2

Source: Guidebook for the Use of Satellites in Monitoring Ground Subsidence

Reducing Cost and Labor in Leveling Work Through the Use of SAR Images Observed by ALOS-2

"ALOS-2 data is useful in the observation of land subsidence."—The Ministry of the Environment has drawn up a manual summarizing the methods and benefits of using ALOS-2 data. We spoke to the officer-in-charge about the objectives and outlook for this technology.

USER INTERVIEW

Masatoshi Yamaguchi (left)
Office for Groundwater and Ground Environment
Environmental Management Bureau
Ministry of the Environment

Kazuhiko Ito (right)
Deputy Director

—— In May 2017, the Ministry of the Environment published the Guidebook for the Utilization of Satellites in Monitoring Ground Subsidence. Could you tell us about the background leading to the publication of this manual?

Having drawn up groundwater for use as industrial water, various parts of Japan, particularly in metropolitan areas such as Tokyo, Osaka, and Nagoya, have experienced significant land subsidence for many years. While cases of subsidence are now gradually declining, there are still regions experiencing advancing land subsidence, for example when groundwater is drawn up at the same time as the mining of natural gas, or when groundwater is used to melt snow.

The Ministry of the Environment published the Guidelines for Monitoring Ground Subsidence in 2005,which sets out the guidelines and methods for monitoring land subsidence through technologies such as leveling and groundwater level observation. Thereafter, amidst reviews on the possibility of using new measuring technologies, we learned that interferometry (refer to p.31) based on SAR images is useful in the measurement of land subsidence. This Guidebook for Monitoring Ground Subsidence summarizes information about how to use this technology as well as examples of analysis. The objective is to help practitioners of local governments who are engaged in the work of monitoring land subsidence gain an understanding of the usefulness of SAR images, and to promote the use of this technology.

—— Could you tell us some of the specific ways in which SAR images observed by ALOS-2 can be used?

By superimposing two SAR images of the same location on different dates and times, capturing the differences and processing the data appropriately, it is possible to obtain the displacement, which indicates the extent to which the ground moved during that period of time. This method is known as interferometry. Furthermore, by correcting this data, it is then possible to find out the length of movement in the vertical direction, or in other words, the magnitude of land subsidence. While measurement through the leveling method can only shed light on the displacement of locations where benchmarks are present, this method offers the advantage of making it possible to obtain displacement information for a wide surface area.

—— With the availability of SAR images observed by ALOS-2, does this mean that leveling will no longer be necessary?

Under current circumstances, that is not the case. The displacement information obtained through SAR images is ultimately relative values; hence, to find the actual height of the ground, it is still necessary to carry out leveling. However, if displacement data obtained through SAR images is available, it would be possible to obtain more precise information about the overall trend with a smaller number of leveling surveys than before. For this reason, it can help to reduce the labor required in measuring work, and, in turn, reduce the cost involved.

—— To what extent can the actual cost be reduced?

The use of SAR images incurs costs related to purchasing data and hiring a contractor to carry out the analytical work. However, as it can reduce the amount of leveling work in the process, depending on the conditions, it can reduce overall costs by 30% - 40% as compared to current processes where only leveling is used.

—— Are there any points to note in adopting this technology?

It may be necessary to purchase a large number of images at the start, so initial costs may be somewhat high. However, from the long-term perspective, this method should help in cost-cutting. Moreover, as it is possible to capture land subsidence conditions more accurately across wide areas, we hope that it will become more widely used in the future.

—— Going forward, there are also plans to launch successor satellites for the ALOS-2. What can we look forward to in the future?

The observation of an even wider area at any one time is expected to become possible. As a result, the number of images that users need to purchase will be reduced, so we anticipate a possible further reduction in cost. In addition, as the observation frequency of the same location will also increase, we believe it will be easier for users to procure the images they need. We hope that the publication of this manual will prompt more widespread knowledge about the benefits offered by SAR images in the observation of land subsidence, and we look forward to the utilization of successor satellites in a wide variety of sectors.

Ministry of the Environment
http://www.env.go.jp/en/

Guidebook for the Utilization of Satellites in Monitoring Ground Subsidence
http://www.env.go.jp/press/104084.html (Japanese Only)

Reducing the cost of river maintenance and management through SAR images and analysis

In Japan, which experiences many floods due to typhoons and other factors, structures around rivers nationwide, such as embankments and sluice pipes (a covered conduit built for the purposes of drawing water/ draining water from rivers, such as water for agricultural uses), are inspected each year before and after periods when the rivers tend to rise. The current method used is to have inspectors walk along all the rivers to visually observe and study the conditions; however, this method requires a great deal of labor and cost to implement. With economizing on manpower as the top priority, Nippon Koei Co., Ltd. is working in cooperation with JAXA to build an inspection system that can efficiently carry out inspections by using SAR images observed by ALOS-2.

The basic method involves checking for any variations in the embankment by carrying out an interferometric analysis (refer to p.31) of SAR images of rivers. Once variations are detected, it would then be possible to make inferences on the probability that some form of deformation could have occurred on the embankment nearby. Inspectors would then be dispatched to these areas only to verify the situation in person. The aim is to establish this process as the method of inspection.

However, embankments have different ground conditions, such as places with people and vehicular traffic and places with slopes extending downward, and any vegetation growing on the slopes become “noise” in the images; for these reasons, it takes skills to conduct an accurate analysis. For example, in interferometric analysis, effort is constantly made to find the most suitable analysis method, such as the use of time series analysis that superimposes as many as 15 SAR images in order to minimize this “noise.”

Furthermore, the potential for applying SAR images to the purpose of learning about the conditions of trees growing in the inner regions of rivers, is also being explored. For all of these applications, reviews are underway to investigate if SAR images can be used to carry out the overall maintenance and management of rivers.

Currently, the maintenance and management of rivers imposes a heavy cost burden on local governments. There are hopes that ALOS-2 can demonstrate its capabilities and offer a solution to this problem.

Results of analysis of embankment deformation volume based on ALOS-2 data

[Estimation of the amount of topographical change using SAR Interferometry (InSAR) time series analysis]

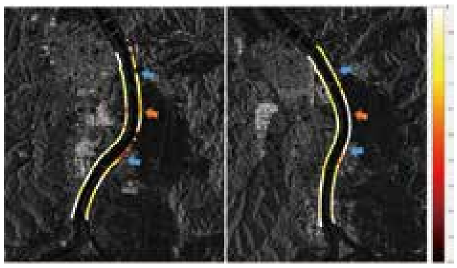
- Using observation data from ALOS-2, an intensity analysis and Differential SAR Interferometry (DInSAR) analysis were carried out and compared with LP data.
- Based on the results of the observation, as shown in the tables below, the trend for uplifts and subsidence had a validity of above 80%, with the exclusion of areas below 11.5km on the left bank. The margin of error was below 1.5cm, which means it was kept within a targeted level of about 5cm.

Specifications of measuring instruments from the satellite

Observation frequency	L band (1.2GHz band)
Spatial resolution (m)	3 (ALOS-2)
Observation width (km)	50 (ALOS-2)

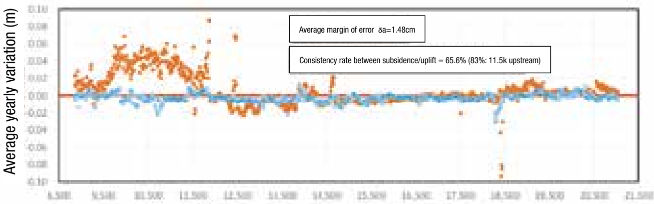
Specifications of measuring instruments from the satellite

Orbit		
Direction of observation	West-north-west from east-south-east	East-north-east from west-south-west
Date of observation	February 13, 2015	September 15, 2014
	August 14, 2015	February 16, 2015
	September 25, 2015	June 22, 2015
	December 4, 2015	October 12, 2015
	March 11, 2016	December 7, 2015
	June 17, 2016	March 14, 2016
	July 29, 2016	May 9, 2016
	August 26, 2016	June 20, 2016
	November 18, 2016	November 21, 2016

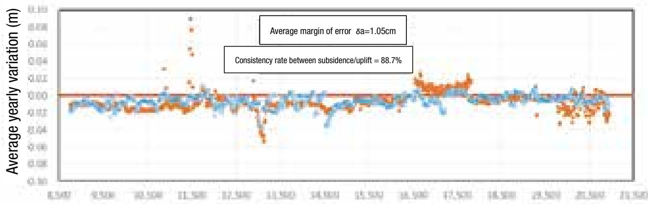


Example of the result of InSAR time series analysis: Result of estimation of amount of subsidence 0(Left: Ascending, Right: Descending)

Comparison of embankment deformation volume on the left bank of Maruyama River (LP and ALOS-2)



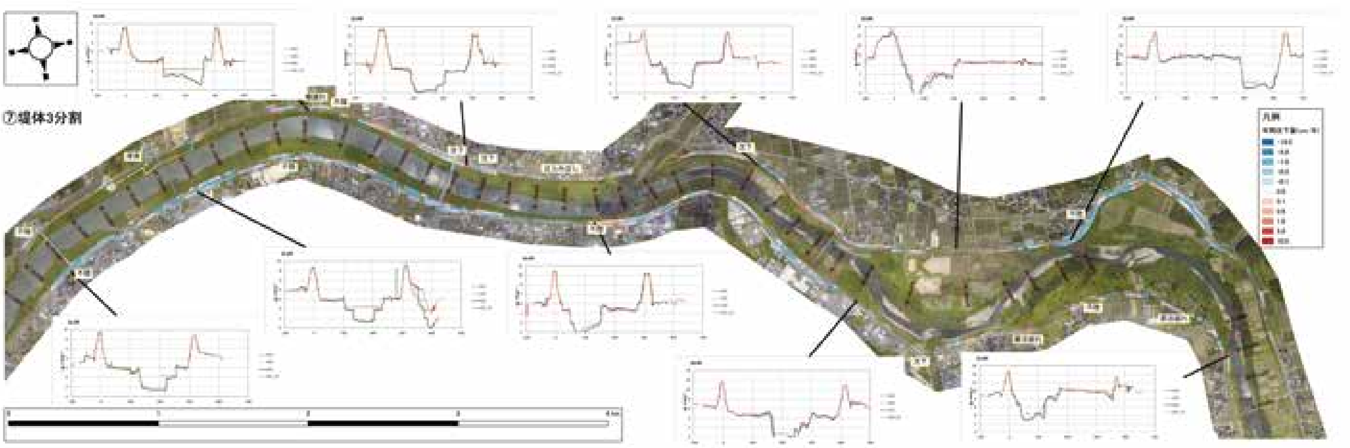
Comparison of embankment deformation volume on the right bank of Maruyama River (LP and ALOS-2)



● Average yearly variation during the observation period ● ALOS-2 variation

● Average yearly variation during the observation period ● ALOS-2 variation

After carrying out differential interferometric analysis using ALOS-2 observation data, and comparing the data with airborne laser scanning data (LP data), the results had a correct answer rate of above 80%, and margin of error below 1.5cm.



Embankment deformation detected through the analysis. The areas colored in red show the subsidence, while the areas colored in blue show the uplifts.

Source: Toyooka Office of River and National Highway, Kinki Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism

Toward building an embankment maintenance and management system

To prevent flooding in the event of typhoons or torrential rains, it is vital to monitor rivers.
There are plans to apply ALOS-2 to the maintenance and management of embankments, which is a central part of river monitoring. We speak to the person-in-charge at the company that is responsible for building this system.

USER INTERVIEW

Kentaro Kageyama

Deputy General Manager
River Basin & Urban Infrastructure Division
River & Hydraulic Engineering Dept
NIPPON KOEI CO.,LTD.

—— Could you give us an overview of the business of Nippon Koei Co., Ltd., and of your work, Mr. Kageyama?

Nippon Koei Co., Ltd. was founded in 1946, and is mainly engaged in the business of consultancy work related to infrastructure in Japan and abroad. In Japan, its work includes conducting basic surveys in the design and planning stages of infrastructural construction carried out by the Ministry of Land, Infrastructure, Transport and Tourism and local governments, and assessing the condition of existing structures. Since I am in charge of river structures, my work involves the design as well as maintenance and management of embankments among the various types of infrastructure. Recently, Japan has suffered much damage from the rising and flooding of rivers due to factors such as typhoons and torrential rains. In that sense, it is very important to monitor the conditions of embankments and ensure that appropriate maintenance and management is carried out.

—— What is the background behind the plans to apply ALOS-2 to the maintenance and management of embankments?

The rivers of Japan span a distance of close to 8,700 km (embankments spanning 13,000 km) when considering only those managed by the Government of Japan. Currently, the maintenance and management of embankments is carried out by having engineers walk along the sites periodically to conduct visual inspections. This incurs enormous costs. This method also poses other problems such as a decline in the number of engineers, and dependence on the competence of individual engineers. Hence, reviews were undertaken to see if maintenance and management can be carried out efficiently and accurately through the use of satellite data. Among the various methods considered, interferometric analysis using SAR images turned out to be the most effective method for capturing the deformation of embankments, and the decision was made to build a maintenance and management system for embankments using SAR images observed by ALOS-2.

——Could you tell us the concrete ways in which SAR images are used?

Basically, variations in the embankment are identified by carrying out interferometric analysis (refer to p. 31) using a range of data observed at different periods of time. Once any variations are detected, we consider it probable that some form of deformation has occurred such as the development of cracks in the embankment nearby. In this way, it is possible to identify the areas that are possibly problematic from among all the embankments in Japan, and dispatch engineers only to these areas to conduct a detailed check. If this could be achieved, we should be able to save a considerable amount of labor as compared to the current method of conducting visual inspections on all embankments. We are now engaged in development work with the aim of building such a system.

—— The scheduled completion of the system is around 2018. What are some of the challenges faced by the team?

Embankments are shaped like trapezoids, and the conditions differ depending on the section with the highest horizontal plane (levee crown) and the slope that extends downward from that plane (slope of the embankment). In addition, the slope of the embankment is usually covered in vegetation, which can also cause “noise” in the observation images; hence, it is not an easy task to carry out an accurate analysis using SAR images. Interferometric analysis is usually carried out using two SAR images. However, in the case of embankment observation, it is not possible to obtain an adequate degree of precision with just two images. For this reason, we use 15 images and apply the “time series analysis” method. By coming up with various schemes like that, we aim to establish an algorithm which observations based on the actual situation and the satellite match with an adequate degree of accuracy. However, we still have to conduct a number of investigations and reviews moving forward.

—— Even though the system is still under development, the system can apparently realize significant cost savings once it is launched.

Even after it has been completed, the current method will continue to be used for some time, so costs may not fall dramatically at once. However, as such systems are definitely necessary from the long-term perspective, we feel that the development of this system holds great significance.

Separately from embankments, it is also necessary to capture and manage the situation of trees growing in rivers, as they can cause the cross-sectional area of a river to contract. We are also currently reviewing the methods for assessing this using SAR images. In this way, we aim to eventually reach a point where it is possible to use this system to carry out overall maintenance and management for rivers, and not just embankments.

I understand that the successor satellite, ALOS-4, offers improvements in the frequency of recording images. If that is the case, we hope that it will be able to capture river conditions more quickly during disasters and other times.

NIPPON KOEI CO.,LTD.
https://www.n-koei.co.jp/english/

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.

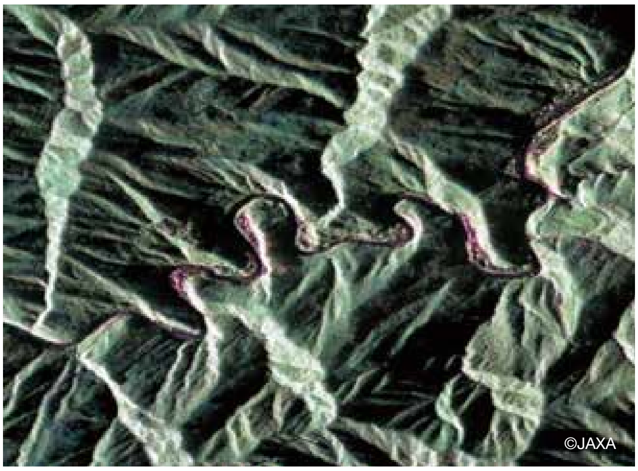
©Analysis by GSI
from ALOS raw data of JAXA, METI

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.



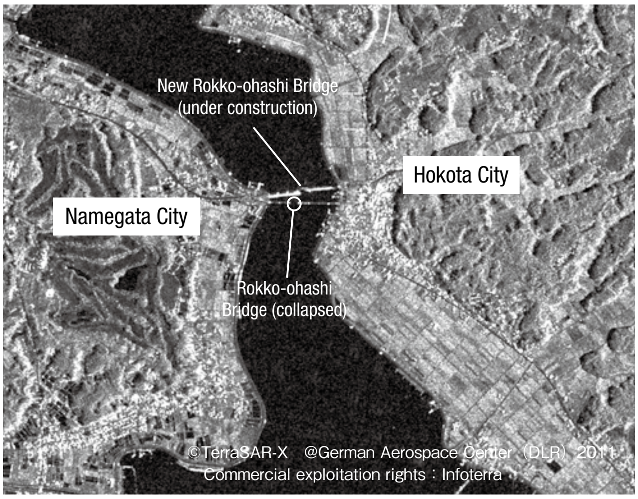
Roads in Tenkawa Village, Yoshino-gun, Nara Prefecture
(Observation by SAR mounted on an airplane on 18 June 2012)

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)

SOLUTION ››› Forests

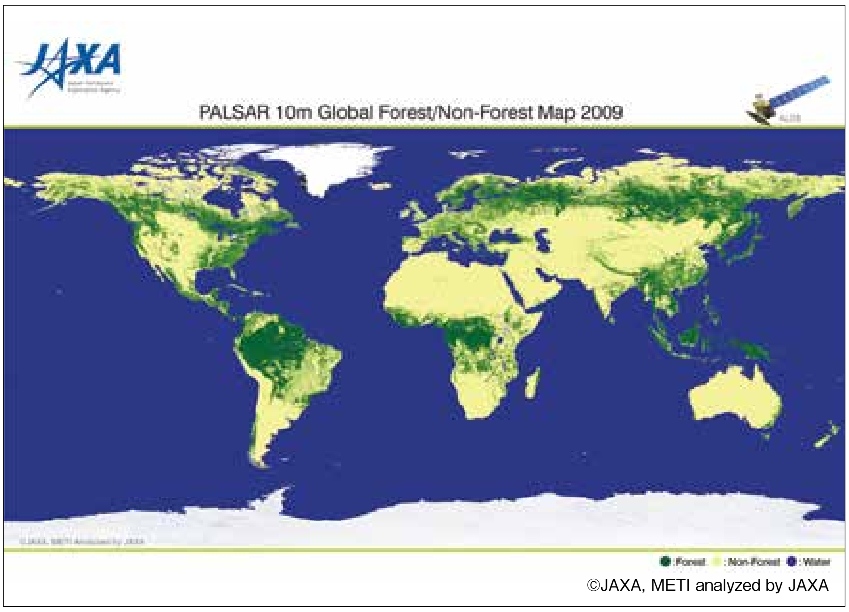
Forests are Our Responsibility to Future Generations

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-1) launched in 1992 and ALOS which completed its operations in 2011.

The types of radio waves that can be used for observation on ALOS-2, launched in 2014, have increased, making it possible to obtain even more information than before (refer to P.30).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 CO2 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)

The Potential of JJ-FAST A New Forest Monitoring System that Uses ALOS-2

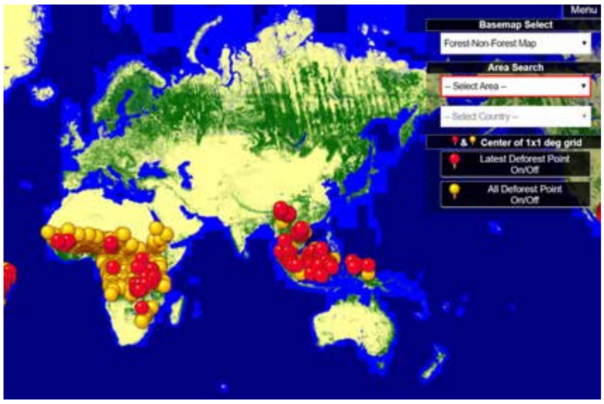
Until now, Japan has continued to carry out forest monitoring using L-band SAR. Starting with the JERS-1 (FUYO-1) launched in 1992, then developing and transitioning to ALOS and ALOS-2, the history of forest monitoring spans as many as 25 years. The data obtained over this long period of time has also been used in policymaking by various countries and international organizations. For example, in Brazil's project to monitor illegal logging activities in forests, this data contributed to the detection of deforestation in 1,000 locations as well as illegal logging activities in 150 locations during the period from 2010 to 2011.

Based on these accumulated results, the new forest monitoring system that uses ALOS-2 was established in 2016 by the Japan International Cooperation Agency (JICA) and JAXA. This new system is known as JJ-FAST, an acronym for JICA-JAXA Forest Early Warning System in the Tropics. It carries out observation of forests in 77 countries and regions of the world, which covers virtually all the tropical forests of the world, every 1.5 months (ScanSAR mode, resolution 50m), and is a system that can be freely accessed from any location in the world.

Through the JJ-FAST website, users can verify the situation of forest decline for the world's tropical forests from April 2016 to the present day on the map of the world. Clicking on the areas of forest decline enlarges the map and draws up information such as the name of that region, its surface area, and its location. It is also possible to input detailed feedback from the local site. In addition, GIS data that indicates the areas where logging activities have been detected is also available for download.

In the SAR images, areas with many trees appear bright, while areas with few trees appear dark. The basic principle is that this property makes it possible to infer that deforestation activities have been carried out when an area that used to be bright becomes darker. Going forward, we aim to further improve detection precision, make it possible to also identify small tracts of logging areas (currently, such areas can be identified up to 5ha), and achieve full automation of the system. To that end, efforts are ongoing to improve the system and there are high expectations for this system to play an important role in countries and regions where forest monitoring is a pressing issue.

JJ-FAST was unveiled to the world during the 22nd session of the Conference of the Parties (COP22) to the United Nations Framework Convention on Climate Change held in November 2016.



JJ-FAST user screen. Effort has been made to reduce data volume as far as possible, so that the data can also be viewed in areas where high networks speeds are not fully guaranteed, such as in developing countries.

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.

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.

››› Improving Observation Frequency with ALOS-2 Monitoring Sea Ice to Prevent Accidents at Sea

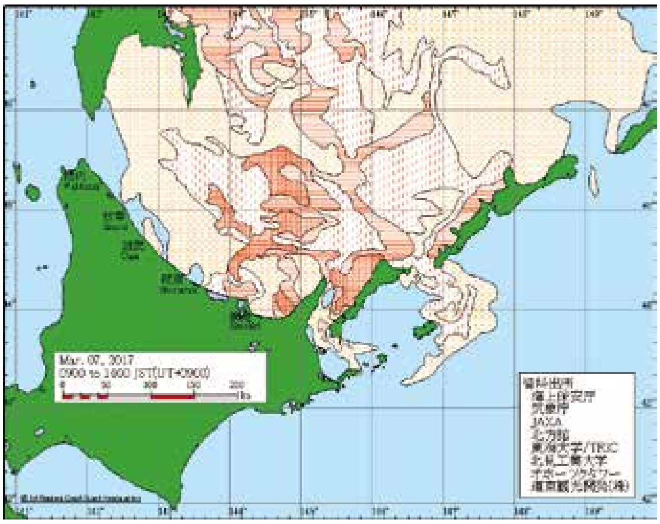
The Sea of Okhotsk is a treasure-trove of fishery resources, but is also known as the only waters near Japan where sea ice is present.

Visually, sea ice may evoke a beautiful and poetic winter scene; however, it poses an obstacle to the navigation of ships, and is sometimes the cause of accidents. With the primary objective of preventing such accidents at sea, the Ice Information Center under the 1st Regional Coast Guard Headquarters of the Japan Coast Guard disseminates navigational warnings and the sea ice condition chart, containing information such as the status on the distribution of sea ice. It draws up the data based on information obtained from multiple organizations, and the sea ice condition chart is updated every day during the sea ice season (from the end of December to early May). After 2003, when the sea ice condition chart issued by the Center became available on the Internet, the number of accidents at sea has declined.

This sea ice condition chart utilizes data observed by ScanSAR Mode of ALOS-2. During the winter season, the Sea of Okhotsk experiences many days of stormy weather, and the skies above are often obscured by clouds. As such, SAR images observed by ALOS-2, which is not impacted by clouds, serve as a valuable source of information. In recognition of these contributions, JAXA was presented an award in September 2017 by the Commandant of the Japan Coast Guard.

ALOS-2, which replaced ALOS, increased the frequency of observation by significantly reducing the recurrent period and expanding the observation width. Nevertheless, as it is impacted by factors such as the observation conditions, its data utilization for the sea ice condition chart is currently limited to about once every three to four days.

The successor satellite for ALOS-2, which is currently being developed, is aimed at producing greater improvements in observation frequency by further increasing the observation width. For that reason, SAR images are expected to play an even greater role than presently in the field of sea ice observation.



Sea ice condition chart drawn up based on an analysis of information from multiple sources (dated 7 March, 2017). This was the day during the sea ice season when the greatest spread of sea ice was recorded in the Sea of Okhotsk.

Image of sea ice in the Sea of Okhotsk, observed by ALOS-2. Date and time of observation: 11:25 a.m., 13 February, 2017 (JST). Images can be observed without being affected by the time of day (day/night) and weather conditions.

With ALOS-2— Possible to Observe Sea Ice without Being Affected by Weather Conditions

To prevent shipping accidents caused by sea ice, the Ice Information Center of the Japan Coast Guard monitors sea ice and disseminates such information. In doing so, how does it utilize data observed by ALOS-2? We find out the answer to this question from someone on the frontlines of sea ice monitoring.

USER INTERVIEW

Akira Furuta

Director
Hydrographic and Oceanographic Department
1st Regional Coast Guard Headquarters
Japan Coast Guard

—— Could you tell us about the role of the Ice Information Center, and about your work?

The Ice Information Center, established under the Japan Coast Guard, fulfills the primary role of capturing and disseminating information about sea ice distribution and trends, with the aim of preventing accidents at sea caused by sea ice. Specifically, we analyze and organize data obtained through observations carried out by aircraft, patrol boats, and coast guard offices along the coast, as well as sea ice observation information obtained by other cooperative organizations and satellite observation data. Based on this, we provide information about the status of the distribution of sea ice every day through the sea ice condition chart, and provide navigational warnings to ships as and when necessary, with information about sea ice that poses a high degree of risk to navigational safety.

—— How, and at what frequency, is the sea ice condition chart drawn up?

Using GIS (geographical information system) software, the observation information collected is superimposed and displayed. The person-in-charge checks this information visually, and at the same time, sketches the distribution of sea ice and its concentration (the value that indicates the percentage of sea surface covered by ice), as well as the distribution of cloud, onto the map to create a chart. This work is carried out every day from about 20 December when the sea ice emerges around Hokkaido, to around the beginning of May the following year, and the sea ice condition chart is updated daily at about 5:00 p.m. It can be viewed by anyone on the center's website.

—— It must be difficult for someone to draw up the condition chart manually every day. What are the points that you pay particular attention to in drawing up the charts?

In truth, it is very difficult (laughs). The production of the sea ice condition charts is a job that spans a long period of time, including days off, and is drawn up by the staff in the office working in rotating shifts. Hence, the quality differs depending on the individual, but we take care to try and make it as uniform as possible. Data is collected from about 1:00 p.m., and it takes the person-in-charge until about 5:00 p.m. to analyze and review all that data, and to draw up the map. After that, it is checked by all the staff, corrections are added if necessary, and the condition chart is thus completed. We of course pay careful attention to accuracy, but of particular importance are situations where sea ice emerges in areas where there is typically no sea ice, and the edges of the sea ice areas. That is because these are areas where accidents occur easily.

—— In drawing up the sea ice condition charts based on observation information from multiple sources, what role do images obtained from ALOS-2 play?

In drawing up the condition charts, we place the greatest importance on visual information obtained from sources such as aircraft. However, as aircraft can only fly about once a week, data obtained from satellites is also valuable to us. If the weather is fine, we can see the sea ice more clearly on images taken by optical satellites; when it is very cloudy, images observed by ALOS-2 are very useful due to its ability to observe sea ice across a wide area without being affected by weather conditions. When observing sea ice from aircraft during periods of consecutive cloudy days, we try to carry out the observation while taking reference from ALOS-2 images so as to obtain information as efficiently as possible. In that sense, ALOS-2 images are also used to determine the flight paths. Incidentally, we used 43 ALOS-2 images in the winter season from 2016 – 2017, and estimate that we will use 78 images for the winter season from 2017 – 2018.

—— In September 2017, JAXA received an award from the Commandant of the Japan Coast Guard for the provision of sea ice observation data over many years. What aspects of this activity was it commended for?

JAXA made adjustments to the data area and carried out its own data processing to enable our Center to promptly utilize the images obtained from satellites such as ALOS-2. The accumulation of such activities contributed greatly to preventing the occurrence of sea ice accidents, and we value it highly.

—— The launch of a successor satellite for ALOS-2 has been planned for the future. From the perspective of sea ice monitoring, what are your expectations for its launch?

I understand that the successor satellite will be able to obtain images more frequently as a result of an expansion in observation width. Furthermore, through improvements in spatial resolution capabilities, it will also be able to identify areas of thin ice and small-scale sea ice, which we look forward to. On the other hand, image capacity will increase significantly, so the transmission of images is expected to take more time than before. As time is a decisive factor in the drawing up of sea ice condition charts, we hope that measures can be taken to improve matters on that point.

Japan Coast Guard

http://www.kaiho.mlit.go.jp/ (Japanese Only)

Sea ice breaking news site

http://www1.kaiho.mlit.go.jp/KAN1/1center.html (Japanese Only)

»» Using Observations of Ocean Wind for Optimum Location for Wind Farms

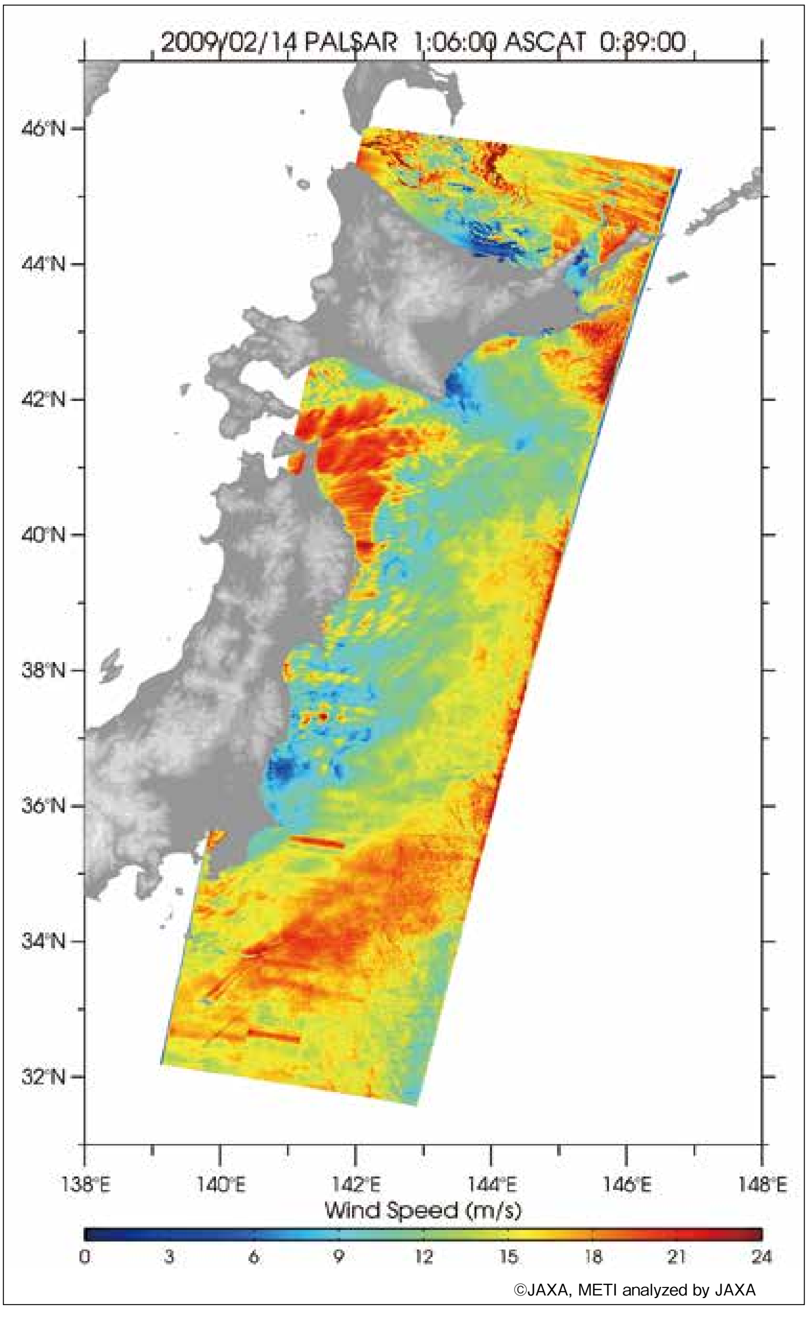
Wind power is now a vital sustainable energy source. Increasingly, we are looking to the sea for wind farm locations, where the wind blows stronger than on land. This means a more stable supply of energy, and it also reduces the noise and landscape impacts of wind turbines.

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)

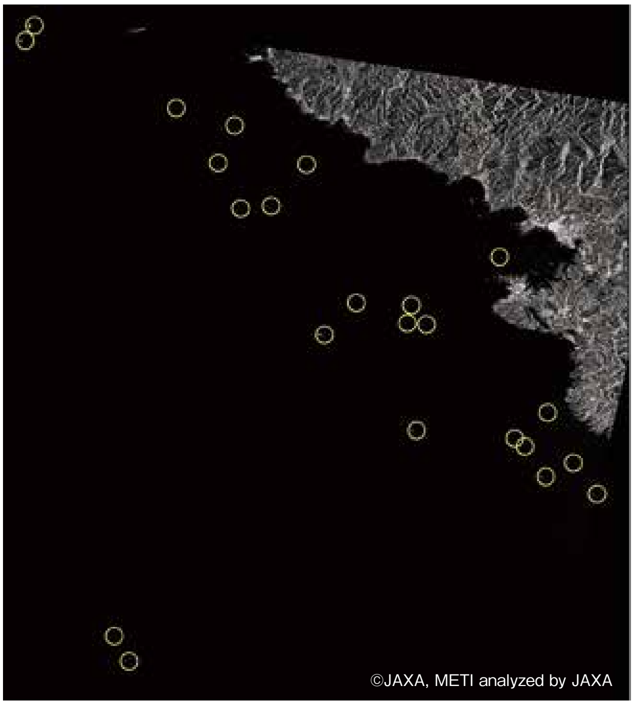
The right figure shows ocean wind speeds as calculated from an observation spanning from Hokkaido to the coast of east Japan using the PALSAR wide area observation mode (350km wide) on 14 February, 2009. Warm colors signify strong wind zones. At the time of observation, a trough is centered over Hokkaido, 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.

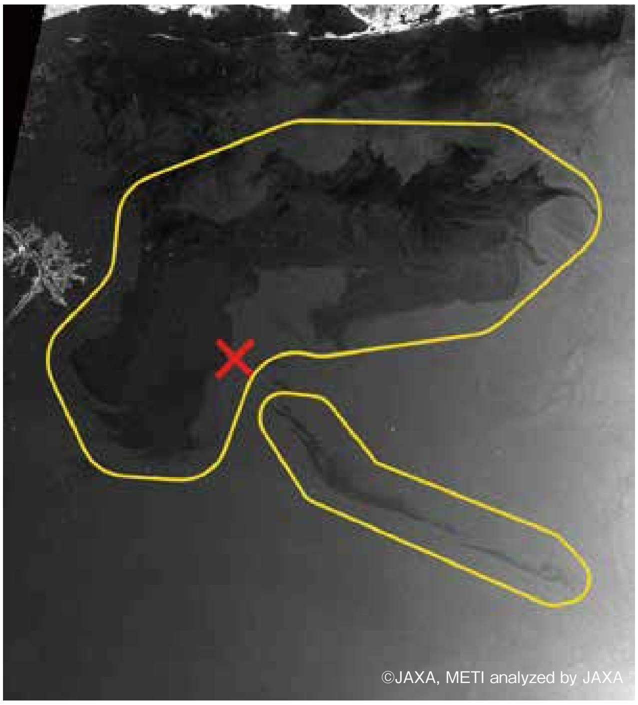


Shipping off the coast of the Kinki region, also known as the Kansai region. AIS data (from the AIS coastal authority) is imposed on an SAR image.
(observed by ALOS/PALSAR in 2010)

»» 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.

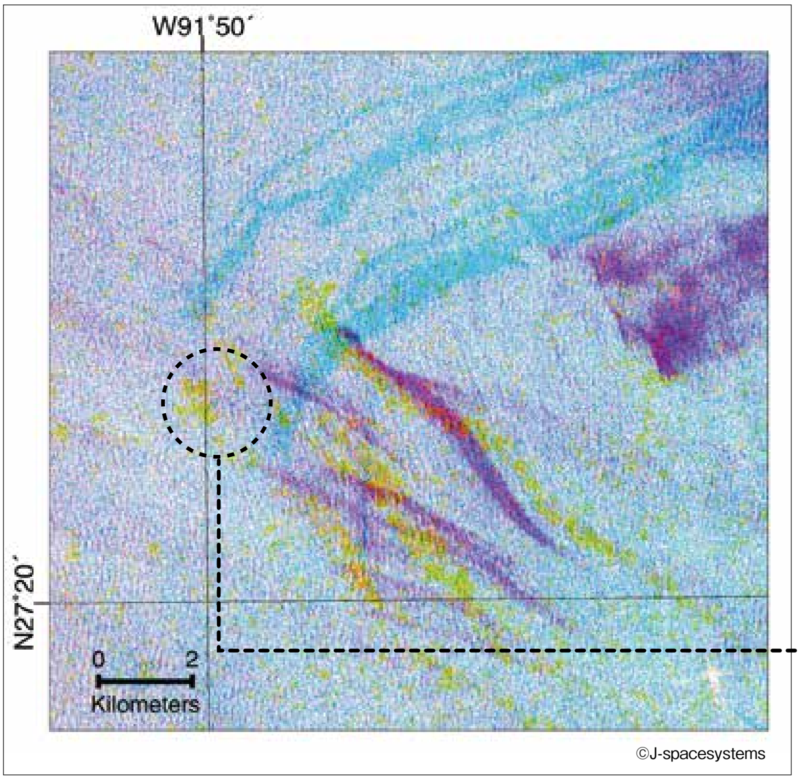
››› Tracking Down Clues of Undersea Resources

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.

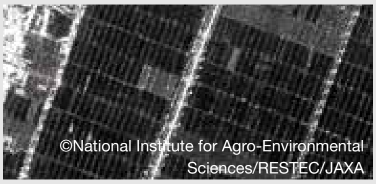
SOLUTION ⟫ Agriculture

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

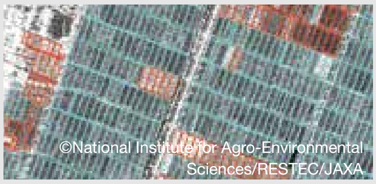


To obtain the imagery of rice paddies in planting season (observed from aircraft-mounted SAR, 10 June, 2013)

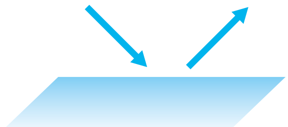
To extract water surfaces from imagery
The blue rectangles are water surfaces, the red rectangles are not water surfaces.

Growing season

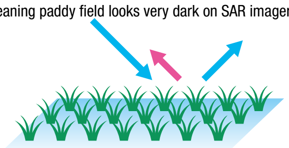
To obtain the imagery of rice paddies in growing season (observed from aircraft-mounted SAR, 8 August, 2013)



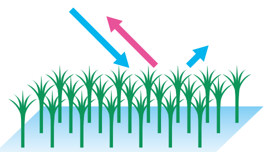
To extract water surfaces. To estimate rice cropping by growing condition of rice paddy extracted in growing season (blue rectangles)



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.

In Thailand, the validation of using PALSAR data from ALOS in this way has already been concluded. Currently, research is underway toward practical application, through the utilization of 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.

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?

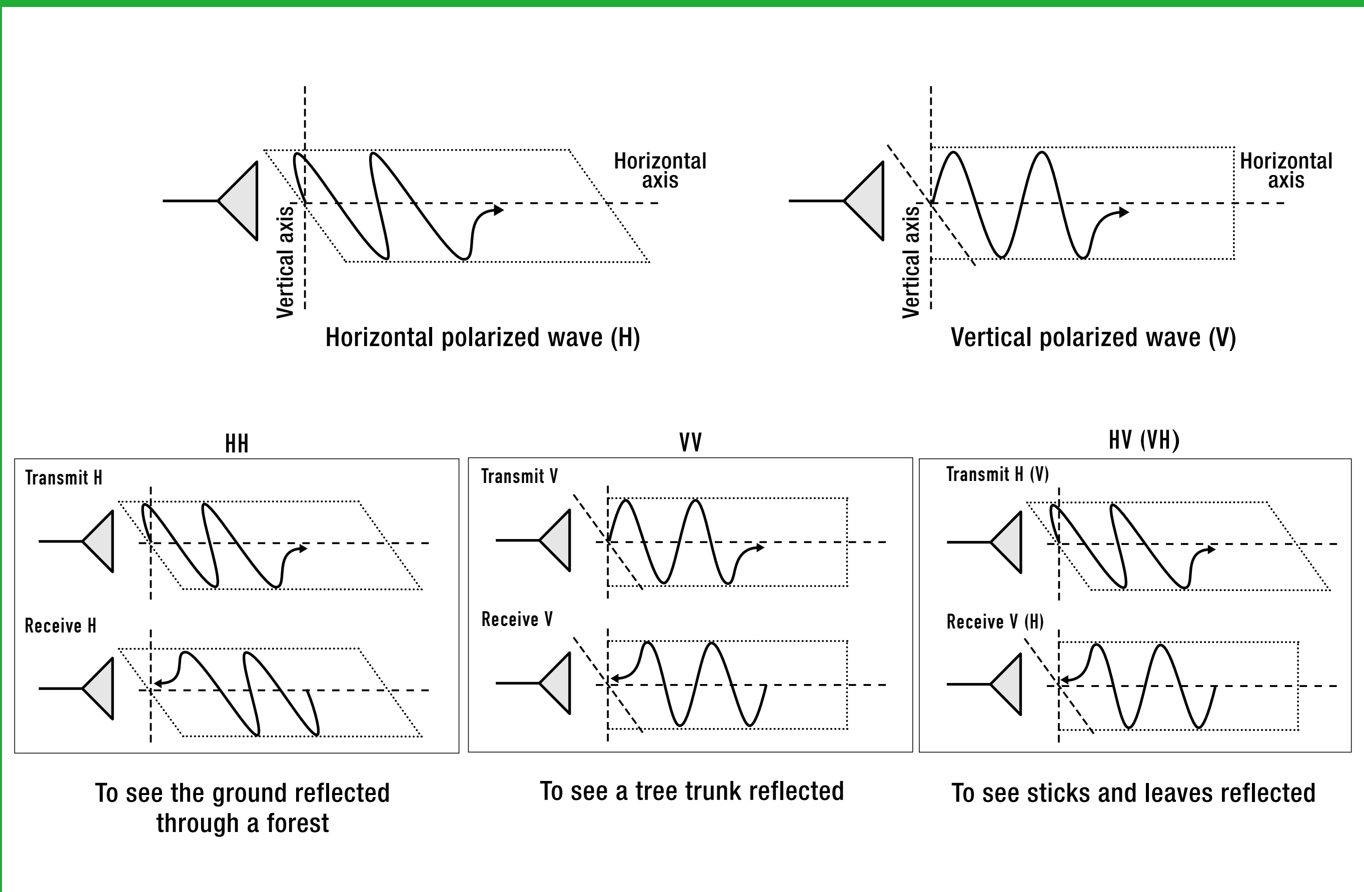
Even for radio waves of the same frequency emitted by a radar, there are two wave types: linear horizontal to the ground (H) and linear vertical to the ground (V). These are called “polarized waves.” The waves transmitted by SAR are also either of these H or V types, and the waves received also are of 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.



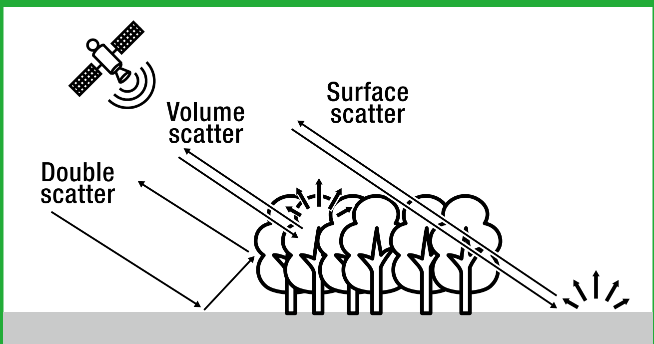
⟫ PolSAR (Polarimetric Decomposition)

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.

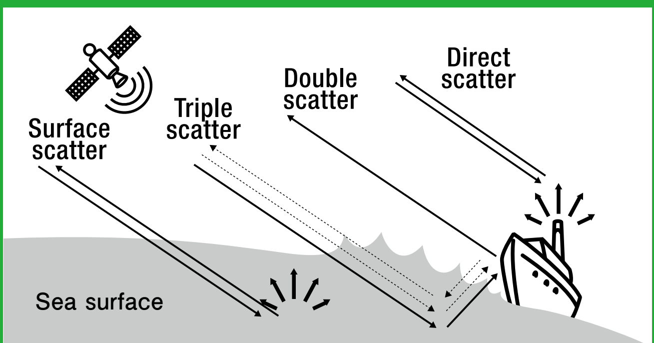
When using multiple wave types, we can calculate the amount of entropy. Entropy is the physical measure of "messiness" (generally, entropy is greater with increased mess).

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

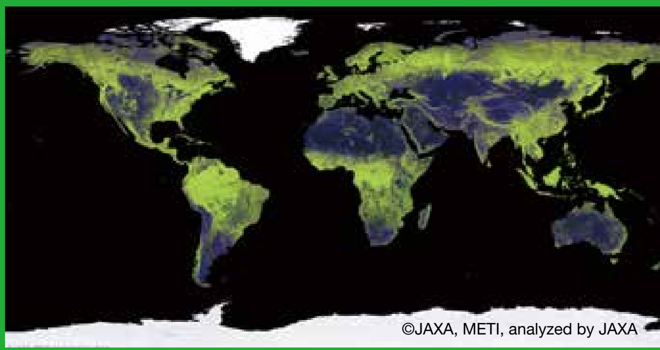
Comparing Past and Present Conditions Using Archival Images Accumulated by ALOS

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. As ALOS-2 data can also be provided in the form of GeoTIFF data, it can be displayed more easily than ALOS data.

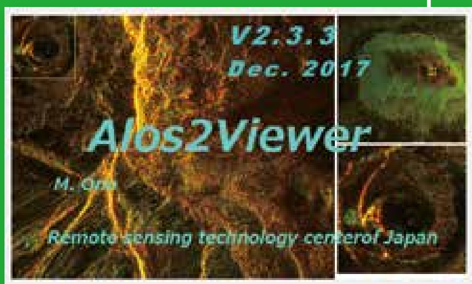
››› JAXA Let's SAR

A software package for geographic data including PALSAR mosaic image, which can be used to classify forestry, identify deforestation,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 two types of software featured below currently come with forest-related processing functions.
  - ■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.

››› ALOS2 Viewer

This is a multifunctional program that can process and display images from the synthetic aperture radar (PALSAR-2) mounted in ALOS-2.



- Developed by the Remote Sensing Technology Center of Japan (RESTEC).
- Available for download, free of charge, from RESTEC's website.
  https://www.restec.or.jp/en/knowledge/alos2-viewer-software
- Users need to input their information, such as name, affiliation, and e-mail address.
- System requirements: OS: Windows 7 or later (32bit, 64bit), CPU: 2.2GHz or higher, Memory: 2GB or more, Display resolution: 1024×768 or higher
- Tiling of large image files from ALOS-2/PALSAR-2 to optimize them for display.
- Automatic generation and display of tiles for color display of ALOS-2/PALSAR-2 polarization synthesis.
- Automatic generation and display of tiles for display and superimposition of ALOS-2/PALSAR-2 images from two different periods of time.

-Execution and display of interferometry processing through complex ALOS-2/PALSAR-2 of two different periods of time.

-Orthorectification and output of all tiled images, and the generation of text files in KML format (can be displayed on Google Earth).

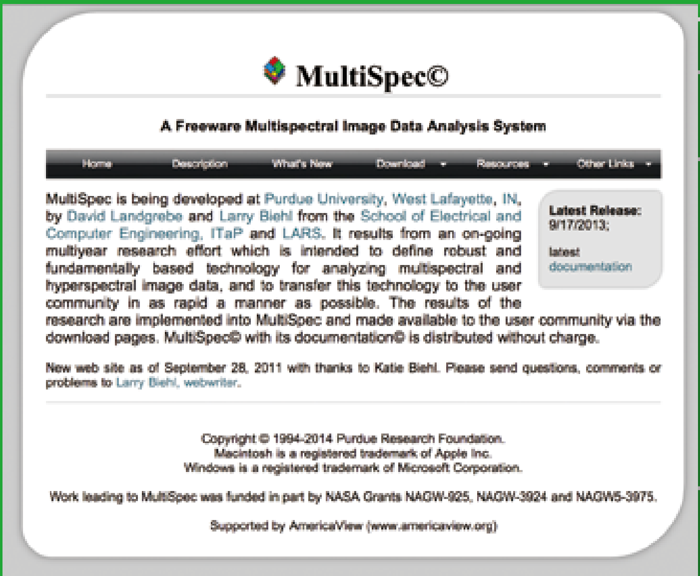
-Generation of differential interferogram, and generation and KML output of coherence images.

-Statistical processing of radar reflection coefficient in multiple polygons, produced manually in the images, as well as output of files in CSV format. The polygon is output in KML format.

››› 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.



»» 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.

»» 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.

»» 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.

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

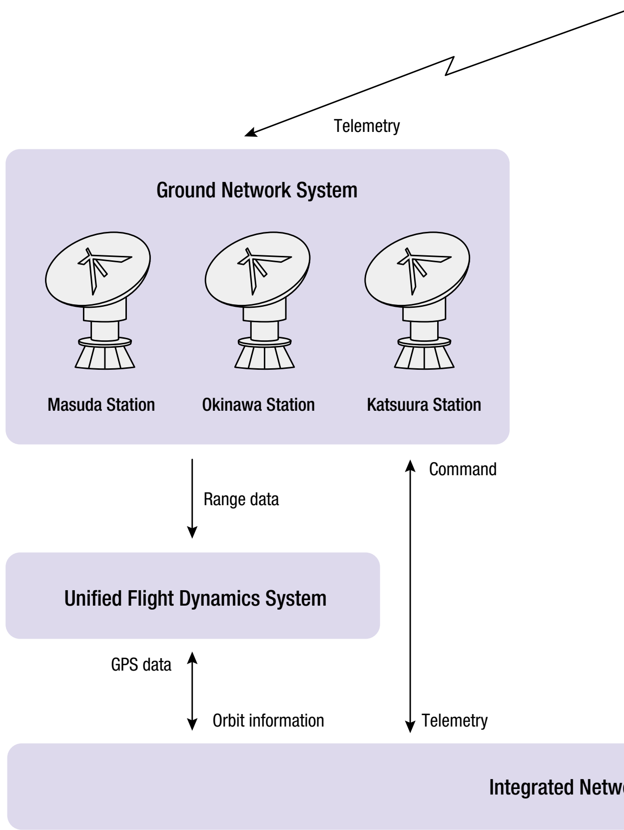
3 Satellite control and tracking network operation

4 Observations

5 Observation data reception

6 Observation data processing

7 Observation data delivery



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

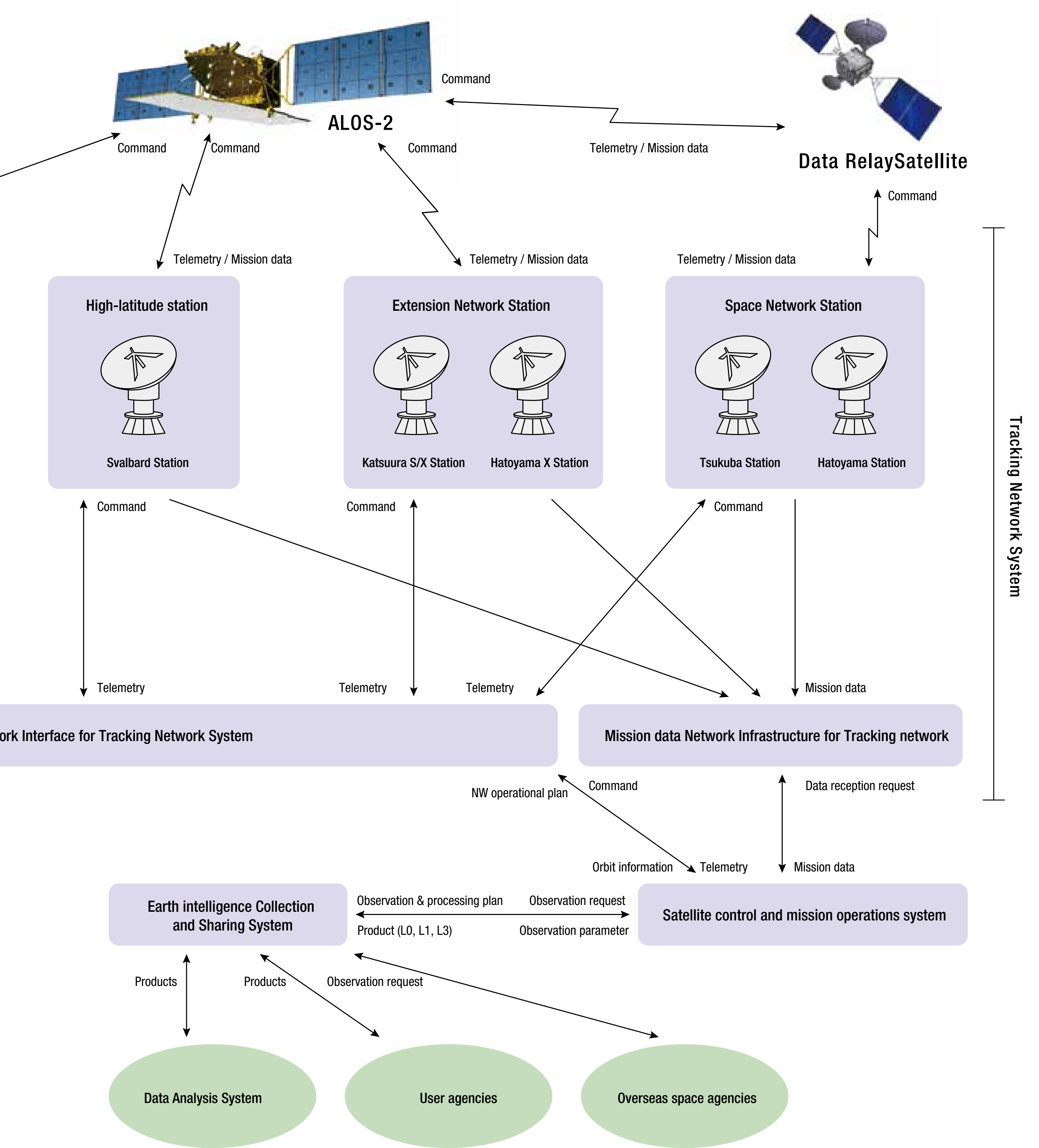
A system for users to apply observation data, user interface for observation requests, product orders, search and provisions, obsevation data storage and management and various processes for compiling products.

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.



*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.

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. Please refer to the following for websites that supply ALOS-2 data.
-You can search for ALOS-2 data.
https://auig2.jaxa.jp/ips/home
- 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. Who should I enquire to regarding use of ALOS-2 data?

Data can be obtained from JAXA or data distribution companies, corresponding to the purposes of use. Please contact the JAXA Satellite Applications and Promotion Center in the first instance.

Q5. 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.

Q6. What is the radiometric resolution of ALOS-2 images?

16-bit.

Q7. 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.

Ambiguity

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

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

20 m	Spotlight, Stripmap
70 m	ScanSAR

Q8. 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.

Q9. 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."

Q10. 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)

Q11. What is the pixel spacing used for each mode of PALSAR-2?

Spotlight mode: 0.625 m
Stripmap mode (3m resolution): 2.5 m
Stripmap mode (6m resolution): 3.125 m
Stripmap mode (10m resolution): 6.25 m
ScanSAR mode (350km instantaneous field of view): 25 m
ScanSAR mode (490km 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

© 有限会社 ファント

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 Astronomical telescope

The popular astronomical telescope retailed by Vixen Co., Ltd. wrapped in satellite images.

3 T-shirts,iPhoneCase

Freely customize satellite images of your favorite locations, and create and purchase merchandise such as fully-printed T-shirts and smartphone cases.

4 iPad app

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

5 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

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 Operations Center (Tokyo office) by e-mail: SAPC-INFO@jaxa.jp.

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