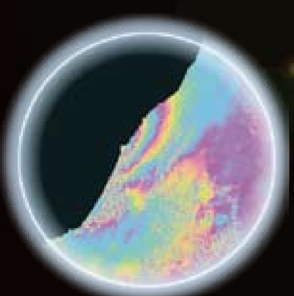
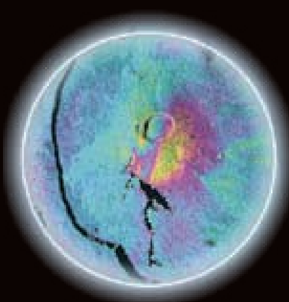
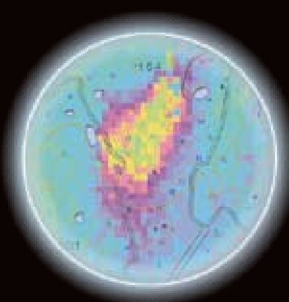
Synthetic Aperture Radar Interferometry

Keep an eye on the Earth Deformation from space



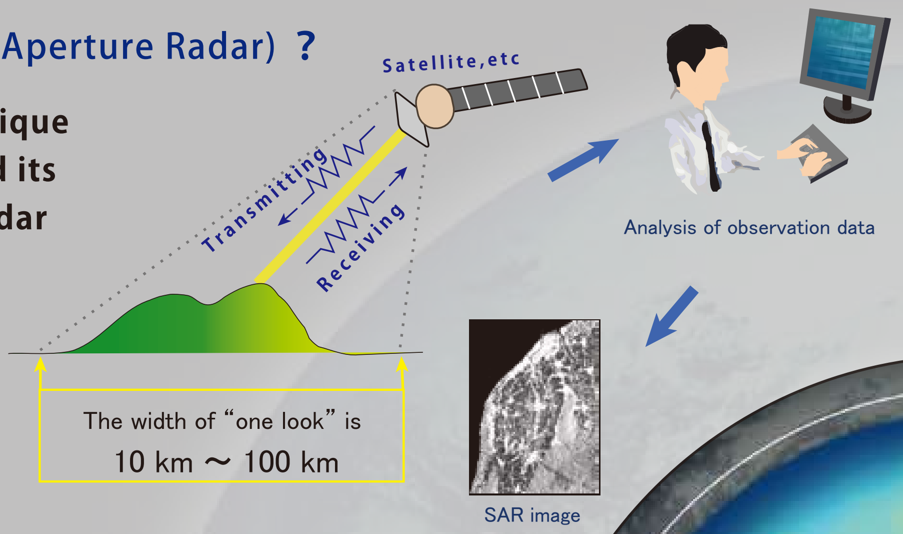



Geographical Survey Institute
Government of Japan

Principle of InSAR

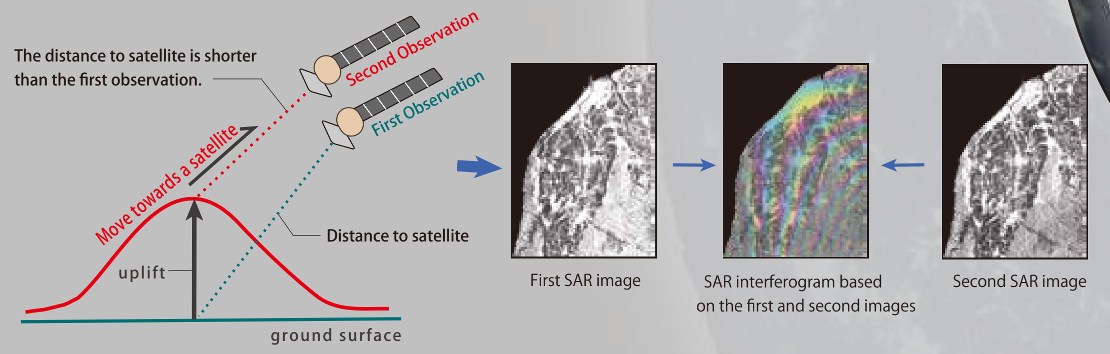
What is SAR (Synthetic Aperture Radar) ?

SAR is a remote sensing technique that can image the terrain and its structure by transmitting a radar wave from a satellite, etc and receiving reflection from the ground.

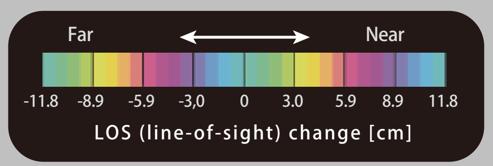


What is InSAR (Interferometric SAR) ?

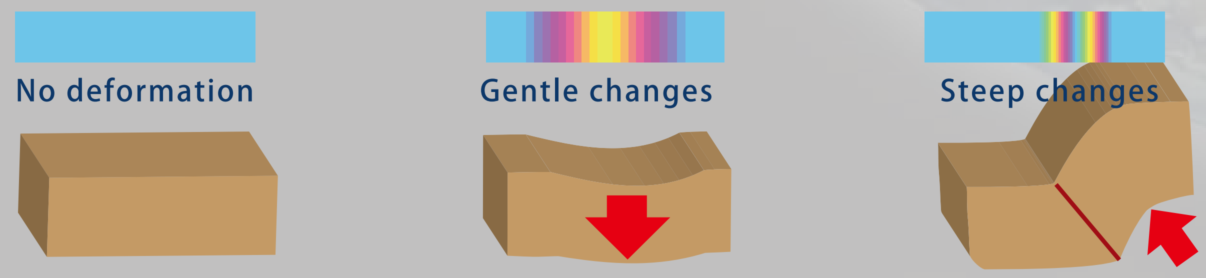
SAR data have information of the distance between a satellite and a ground surface. The deformation on the ground is detected as a change of the distance. Interferometric process requires a pair of SAR data acquired at different times. As a result of the process, we can detect the deformation on the ground occurred during the period.

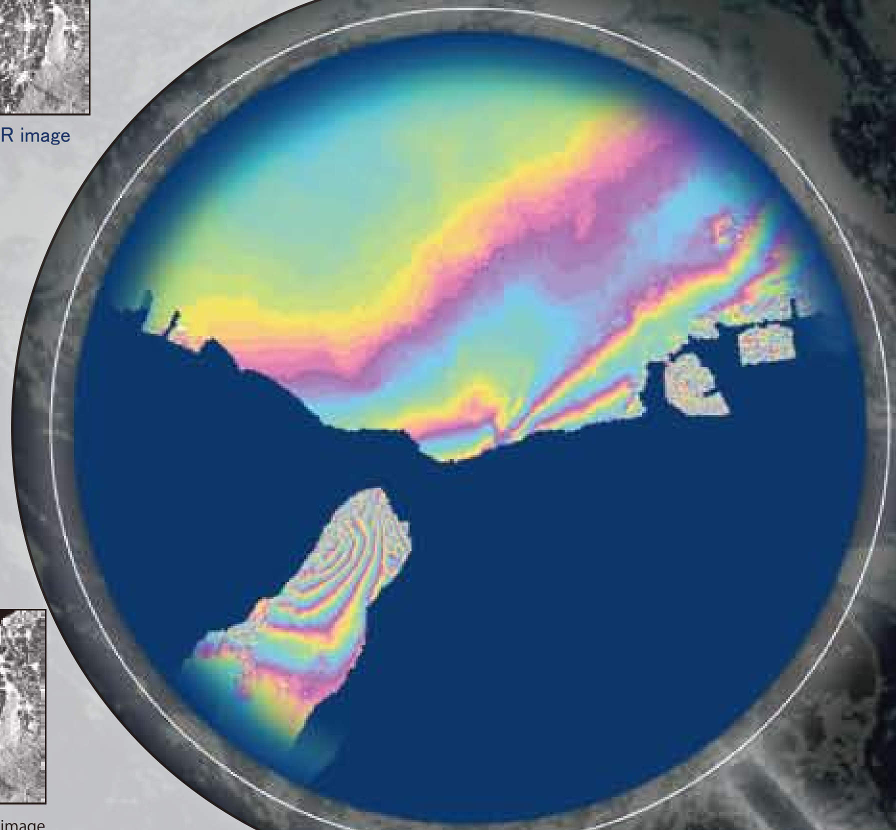


How to understand the SAR interferogram



The SAR interferogram is conventionally expressed in the change of the colors. When there is no deformation on the ground surface, the color does not change. However, when there is any deformation on the ground surface, the color changes as below.





Advantages of InSAR

1. Monitoring wide area

The SAR image covers tens of kilometers with one observation. Therefore, we can catch the detailed movement of the ground surface for a wide area.

2. No survey equipments required on the ground

The SAR can observe the places where people cannot access due to a disaster or rugged topography.

3. All weather observation

SAR uses a radar wave, rather than visible light, which can penetrate the clouds, etc. Therefore, the SAR observation can be made in day and night under any weather condition.

Japanese SAR satellites

Launch date	Jan. 24, 2006
Orbital altitude	About 700km
Total weight	About 4tons
Recurrence cycle	46-day
Size of Antenna	Width : 3.1m Length : 8.9m
Wavelength	L-band（23.6cm）
Resolution	7 ～ 44m
Off-nadir angle	8 ～ 60°
Scanning width	40 ～ 70km

Advanced Land Observation Satellite
「ALOS：“Daichi”」

（Feb.1992 - Oct.1998）

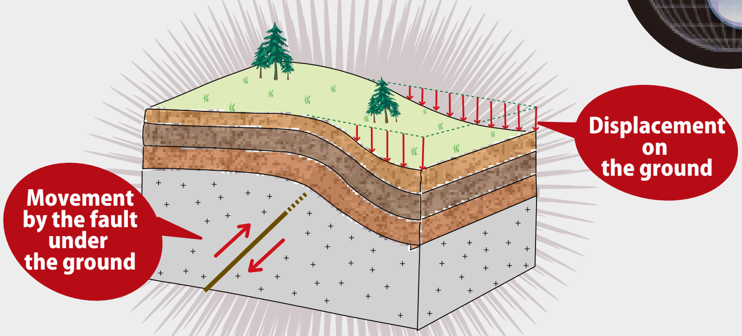
Japanese Earth Resources Satellite 1
「JERS-1」

「ALOS」and「JERS-1」 adopt L-band sensor that uses the radar with about 24cm wavelength. This sensor has a property to penetrate leaves and branches of trees. Therefore, we can recognize movements of the ground surface covered largely with plants. The L-band sensor is effective for an area with forests or vegetations like in Japan.

Earthquake

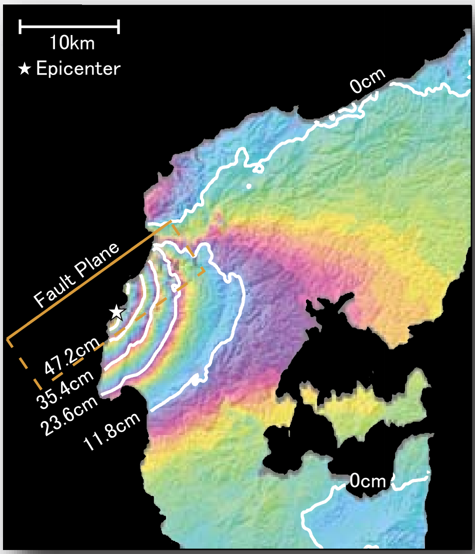
Earthquake occurs when the strain accumulated under the ground is released and the rock slips along the fault plane.

An inland earthquake occurs at the depth between a few to twenty kilometers. In that case, the ground surface around the epicenter is deformed according to the movement of the fault.



Noto Hanto Earthquake

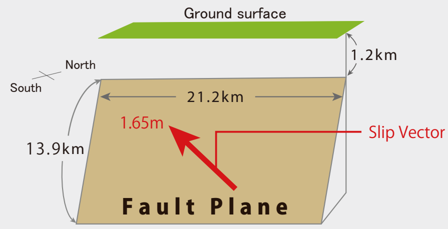
March 25, 2007 (M6.9)



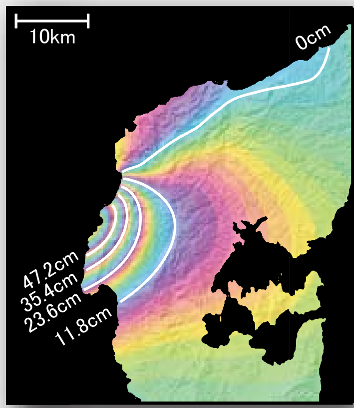
SAR interferogram 2007.2 ~ 2007.4 (ALOS)

The active fault on the ground was not exposed in this earthquake, because the most part of the earthquake fault was under the sea area.

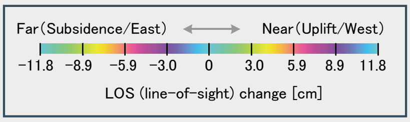
From the results of SAR interferogram and GPS, the western region of Noto peninsula moved at most 50cm. The results indicate the fault model as below.



The estimated fault model

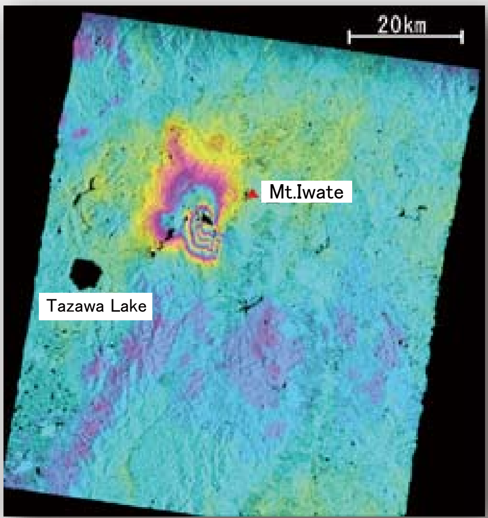


Simulated interferogram from the estimated fault model



Northern Iwate earthquake

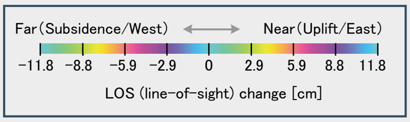
September 3, 1998 (M6.2)

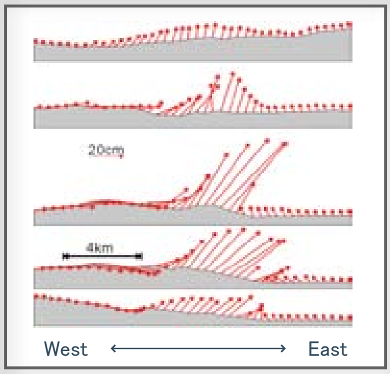


SAR interferogram 1997.11 ~ 1998.9 (JERS-1)

This earthquake was accompanied by the volcanic activities in Mt. Iwate.

The most remarkable displacement is located along the known fault. Moreover, the deformation pattern on the ground corresponds to the topographic features. The results indicate that the fault had been activated repeatedly and formulated the present topographic feature.





2D displacement vectors by InSAR

2-dimensional displacement information can be revealed by combining two InSAR images observed from different orbit paths.

※ gray : Topography profiles

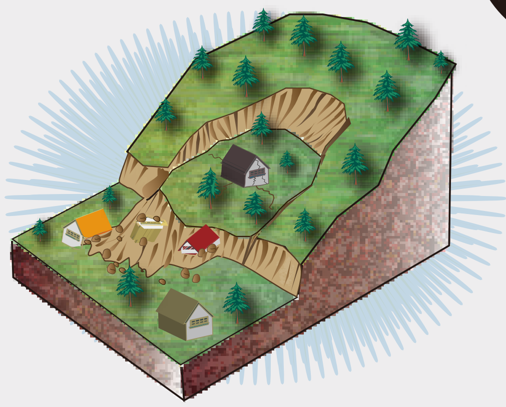
※ red arrow : 2D displacement vectors

By InSAR, we are able to understand the fault system that causes an earthquake, even if the fault does not reach the surface. To know the fault movement under the ground is important to predict the occurrence of the aftershocks or simulate the seismic damage from potential earthquakes.

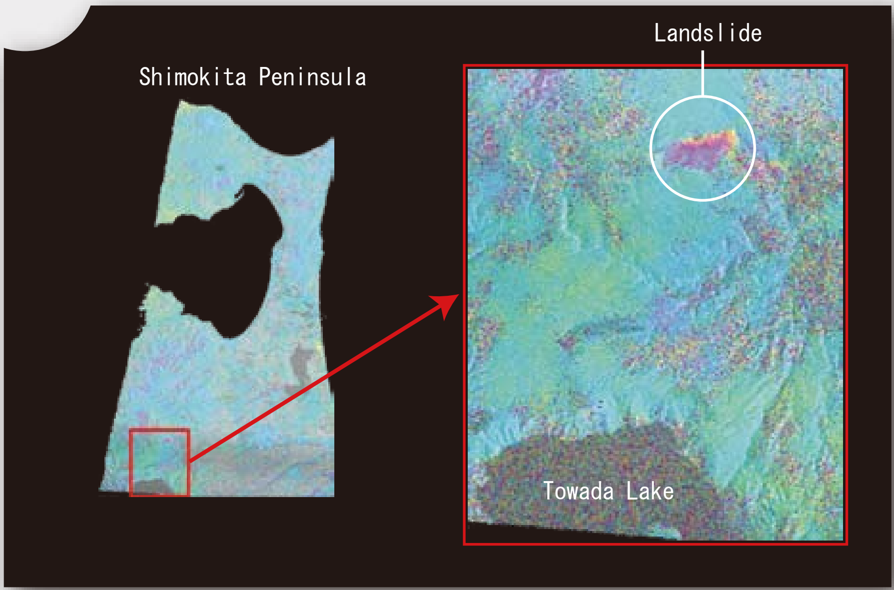
Landslide

Landslide is a phenomenon that subsurface layer or mass on mountainside slides down, triggered by an increase in groundwater from heavy rains.

When a slope moves greatly by a landslide, it appears as a "visible" surface deformation like a collapse of buildings. However, when a slope moves slightly and slowly, it is sometimes hard to detect the deformation because it appears as "invisible" one.



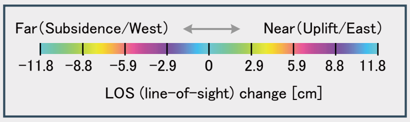
Detecting landslide areas



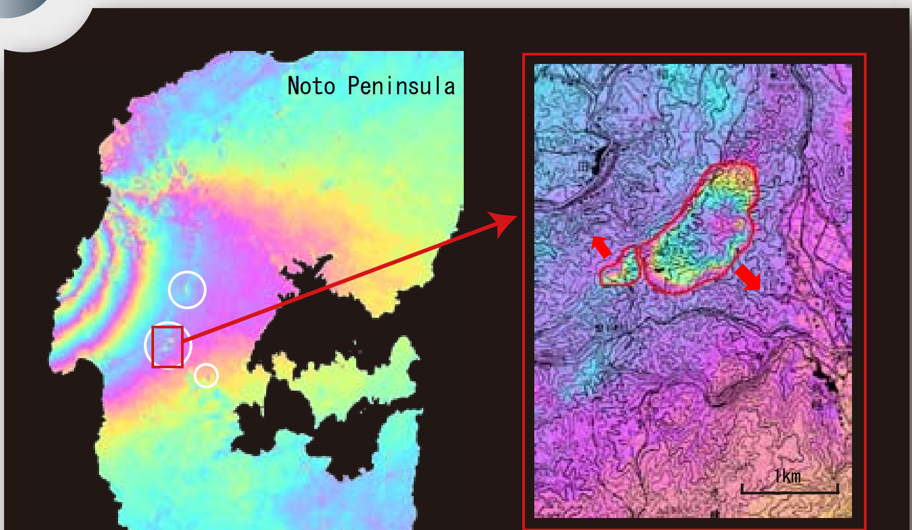
SAR interferogram 1992.10 ～ 1998.4 (JERS-1)

The enlarged InSAR image shows a landslide that occurred in a mountain region of Aomori Prefecture.

InSAR can catch the "invisible" and slight surface deformation. It enables us to assess the area and risk of a landslide before it brings us the hazardous situation.



The landslide occurred by an earthquake

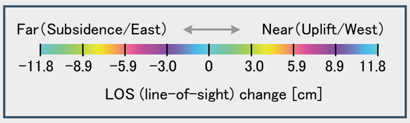


The red arrow shows the direction of landslide.

SAR interferogram 2007.2 ～ 2007.4 (ALOS)

The left image shows the ground deformation triggered by the Noto Hanto Earthquake in 2007.

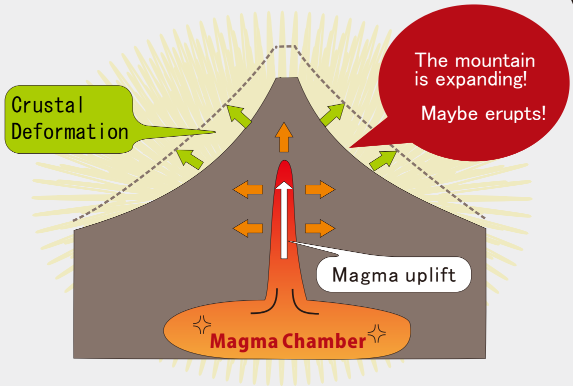
Most of the fringes in the image are deformation caused by the earthquake, but the pattern of fringes in circled areas are different from others. We concluded these changes are landslides by considering the topographical and geological information.



InSAR can detect an "invisible" and slight surface deformation. Therefore it is effective for discovery and monitoring of landslides. We can assess the area and risk of landslides with InSAR immediately after a disaster or in areas that can not be easily accessed.

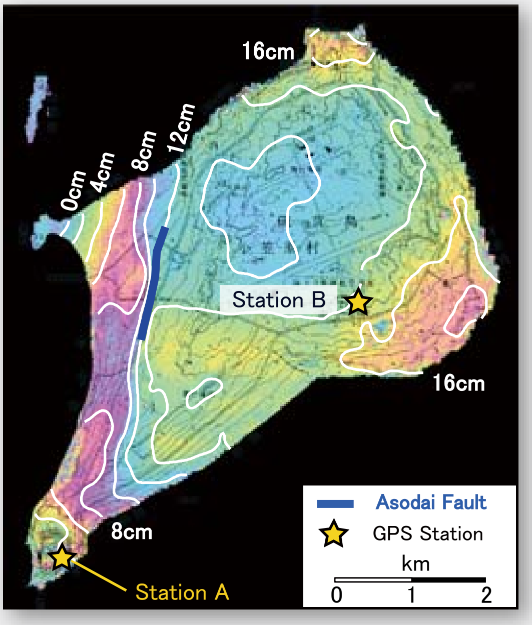
A volcano erupts when magma and/or gas components are uplifted toward the shallow area.

The body of the mountain inflates as the magma moves upward and pushes the mountain from inside. From the crustal deformation detected by InSAR, we can estimate the volume of the magma and its movement under the ground.



Monitoring volcanoes in domestic area

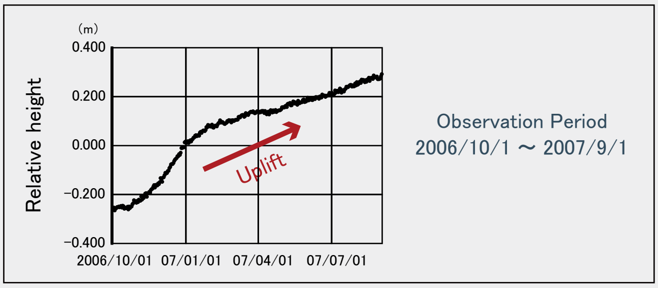
～ Io To (Iwo-jima) ～



SAR interferogram 2006.11 ～ 2006.12 (ALOS)

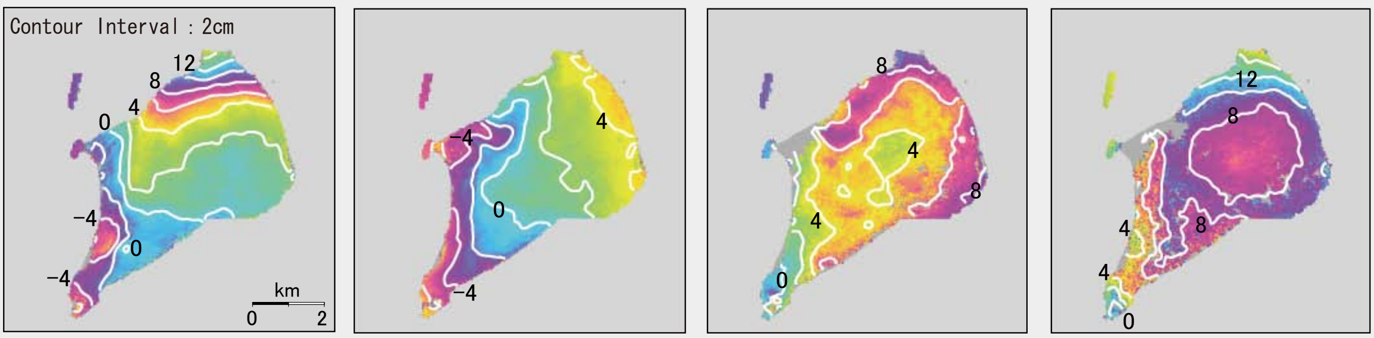
Io To (Iwo-jima) is the volcanic island in the Ogasawara Islands. There have been repeated volcanic activities. Therefore it has been monitoring by GPS continuously. The GPS graph below shows Station B has been uplifted greatly with respect to Station A since Oct. 2006.

The left InSAR image shows the crustal deformation patterns. It reveals the deformation along the Asodai Fault which cannot be detected by GPS.



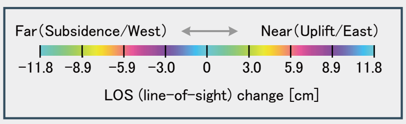
Height change on GPS station B
(Reference : GPS station A)

SAR interferograms



2006.12 ～ 2007.2 | 2007.2 ～ 2007.4 | 2007.4 ～ 2007.5 | 2007.5 ～ 2007.8

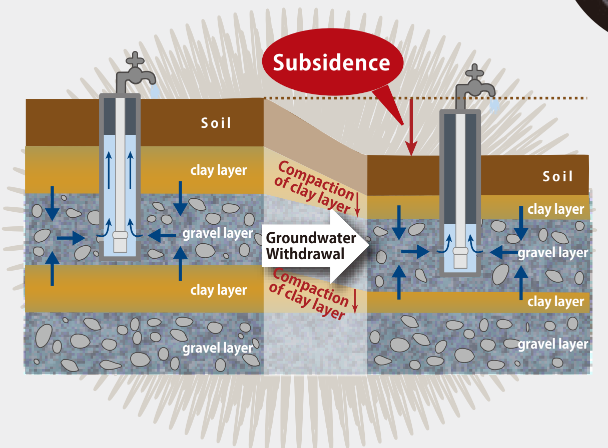
The above four InSAR images represent the time-series changes of the crustal deformation patterns in Io To since Dec. 2006. These show that the uplift on the east coast is continuing slowly.



InSAR can catch by large-scale monitoring the signal of volcanic activity which has not been detected so far. SAR is one of the most promising methods for volcano monitoring as it can observe the unreachable areas by people because of gases and heat from volcanic activity.

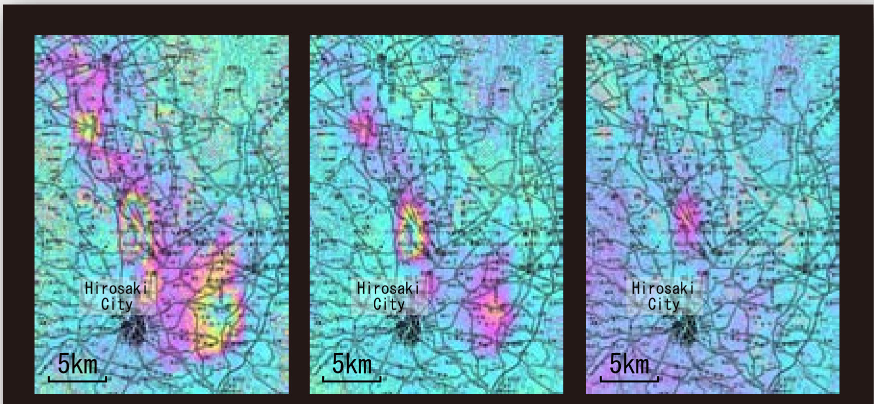
The cause of subsidence is closely related to human activities such as excessive groundwater withdrawal and housing development on soft grounds. As subsidence affects the structures such as buildings and roads, monitoring is needed on a regular basis.

The leveling is often used for subsidence monitoring. It can measure with very high precision, but only provides us the data at limited numbers of spots.



Monitoring subsidence regularly

～ The Tsugaru Plain ～

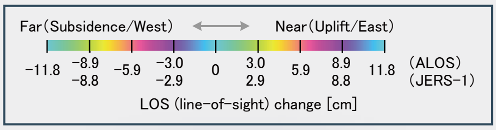


1992.10 ～ 1998.5 (JERS-1) 1995.4 ～ 1998.9 (JERS-1) 2006.4 ～ 2007.4 (ALOS)

SAR interferogram

The left three InSAR images focus on subsidences that occurred in the Tsugaru Plain, Aomori Prefecture.

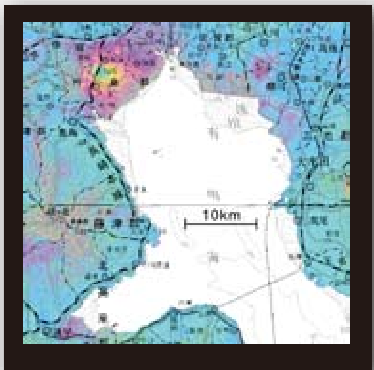
Recently the area has not been monitored by the leveling, but InSAR shows that subsidence has been continuing.



ALOS (wavelength:23.6cm) and JERS-1 (wavelength:23.5cm) use L-band. However, due to the marginal difference in wavelength, the figure on the ALOS and JERS-1 color bar are not exactly the same.

Example of subsidence

～ Ariake Sea ～

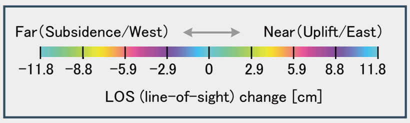


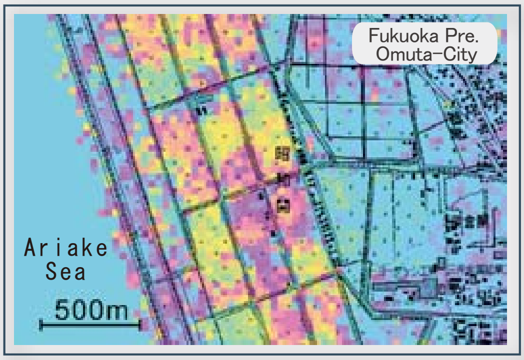
SAR interferogram
1993.10 ～ 1996.4 (JERS-1)

The land around Ariake Sea has been expanded by reclamation for several decades.

The left InSAR image shows us the subsidence image around Ariake Sea.

This was probably occurred by the influence of the great drought in 1994.





SAR interferogram 1993.9 ～ 1993.10 (JERS-1)

The above image represents the subsidence that occurred in the drained land along Ariake Sea.

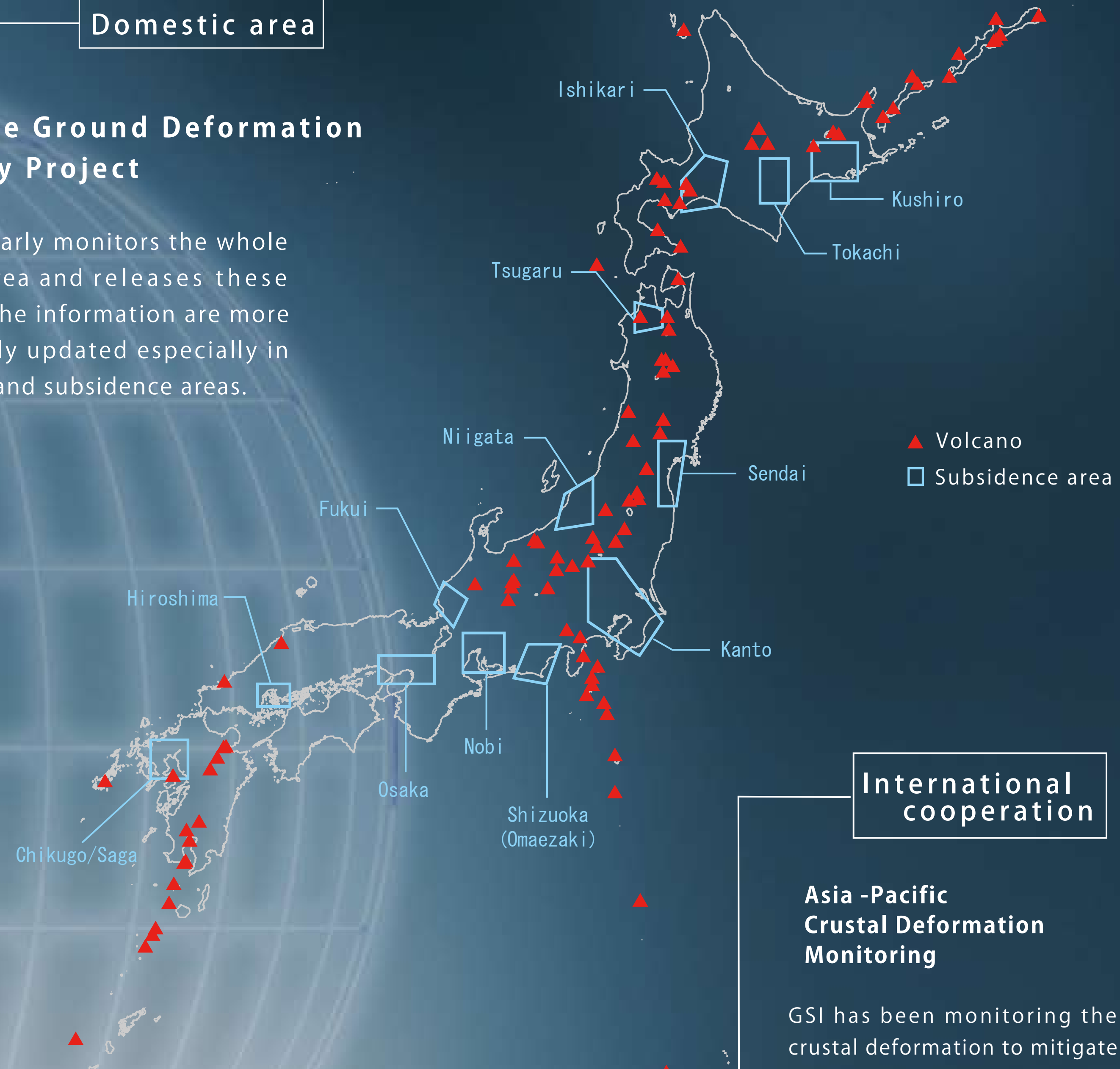
It shows that paddies have subsided during the rice reaping period due to the change in the water content of the soil.

InSAR provides the surface deformation patterns of the subsidence in various horizontal scales. It is an efficient tool for monitoring ground subsidence, as well as detecting an uncharted one.

Domestic area

Precise Ground Deformation Survey Project

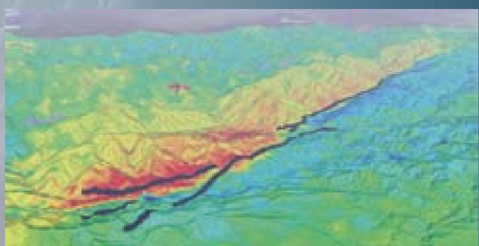
GSI regularly monitors the whole nation area and releases these results. The information are more frequently updated especially in volcanic and subsidence areas.



International cooperation

Asia -Pacific Crustal Deformation Monitoring

GSI has been monitoring the crustal deformation to mitigate the hazard of natural disaster in cooperation with countries in the Asia-Pacific region.
GSI provides InSAR results to this project.



Original ENVISAT data (c)ESA
Observation Period 17 September ～ 22 Octorber, 2005

Crustal deformation occurred by the 2005 Northern Pakistan Earthquake.

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GSI InSAR Analysis HomePage
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