Ontake Volcano Observed by Airborne SAR (Pi-SAR2) Craters under the Volcanic Smoke are Found by the Radar Images

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The eruption of Mt. Ontake on September 27, 2014, overwhelmed many climbers and hikers, and 56 lives were lost in the area around the summit. The volcano has become much more active, and it has not been possible to discern conditions surrounding the crater due to smoke and clouds.

Synthetic Aperture Radar (SAR), which is able to reveal terrestrial conditions at night and during poor weather conditions, is particularly useful for determining conditions during disaster. In 1998, NICT developed an aircraft-mounted SAR (Pi-SAR) with resolution of 1.5 m. Pi-SAR is equipped with a polarimetry function, which uses polarization to discriminate details, and an interferometry function, which measures the altitude of the surface using two antennas simultaneously for stereo imaging. For the two volcanic eruptions occurring in 2000 (Mt. Usu in Hokkaido and Miyake-jima), airborne SAR was used for the first time, one week after the eruptions, as a means to determine the state of, and any changes in, the eruption. This also showed the general public, for the first time, how useful SAR observations could be in times of disaster. In these two volcanic eruptions, the ground rose or subsided by from tens to hundreds of meters in some areas due to the volcanic activity. The Pi-SAR interferometry function was able to show such topological changes in 3D. The polarimetry function was able to identify areas that had been blanketed in volcanic ash.

However, for the 2004 earthquake with epicenter in the Nakaetsu region of Niigata Prefecture, Pi-SAR did not have ability to identify the many, but small landslides occurring in the mountainous region. It also took considerable time to get the data to the site, where it was needed most. There is some urgency with a volcanic eruption, but for an earthquake, real-time knowledge of the state of the disaster can be very helpful. With this in mind, NICT began developing the new, Pi-SAR2, in 2006, with the objectives of being able to discern small-scale landslides and to share the data rapidly. Pi-SAR2 has 30 cm resolution, five-times that of Pi-SAR, and like Pi-SAR, has both polarimetry and interferometry functions.

In February, 2011, after performance testing of Pi-SAR2 was completed and full-operational testing had begun, Mt. Kirishima-Shinmoedake in Kagoshima Prefecture erupted, causing great damage to the surrounding region due to the intermittent volcanic ash. Then, in March, 20,000 lives were lost in the Great East Japan Earthquake and Tsunami.

After the Great East Japan Earthquake, preparation for observations began immediately, and the next morning, aircraft and equipment, which were at Nagoya airport, took off and made observations over a wide range centered on the Pacific coastline, from the Tohoku region to the Kanto region. Pi-SAR2 is able to record data continuously for approximately 50 km over a width of approximately 7 km. There are gaps in the data along the coastline due to course changes, but continuous observations of approximately half of the coastline were made. Observation data was partially processed on the aircraft, and after downloading, was sent to Koganei and published the same day. All data was brought back to the laboratory at NICT headquarters in Koganei, where additional processing was done. The ability to handle such a large-scale disaster rapidly shows that the overall objectives of developing Pi-SAR2 had been achieved.

However, through this experience, we realized that there were still outstanding technical issues with using Pi-SAR2 during disasters. Data was processed on the aircraft so that it could be provided rapidly, but the damaged area was larger than imagined and there was only time to process a small amount of the data, and it was difficult to process monochrome imagery (converting only one of the four data combinations obtained through polarimetry to images) in the aircraft. Processing data for this large of an area had not been anticipated in the laboratory, much less on the aircraft, and imagery was not produced till several days after the disaster. Further, the simple increase in resolution resulted in larger image files, so manual effort was needed to find a way to transmit the data, adding to the time required.

For the eruption at Mt. Shinmoedake, the risk of landslides due to the accumulation of volcanic dust had been identified, and there was a need to evaluate the accumulation (the depth) of volcanic dust. Comparing surface altitude measurements using interferometry could be useful for this problem. However, due to the overload of processing for the Tohoku Earthquake, it was not possible to analyze the data in a timely manner.

To resolve these issues and be able to process large volumes of data after an earthquake, NICT increased the speed of processing equipment. These improvements yielded the capability to process more than ten-times previous volumes. These results were applied to the airborne equipment as well. As a result, all polarimetry data from 3 km in all directions can be processed within 15 minutes using on-board processing. This is about the time required for aircraft to make course corrections, so equipment resources can be allocated to processing data during this time, while observations are not being made. We have also made other improvements and tested them, such as adding a function to transmit

from the aircraft to the ground using a commercial satellite (INMARSAT).

NICT conducted Pi-SAR2 observations on October 2, 2014; five days after the Mt. Ontake eruptions began. From 12:45 to 14:30 on that day, Pi-SAR2 took observations along nine courses in various directions surrounding the Mt. Ontake summit, which was billowing smoke and hidden by clouds. The aircraft was at an altitude of approximately 13,000 m, but could obtain imaging resolution of 30 cm, even at this height.

Most of the nine observation paths were along North, South, East or West directions, and after each observation, data was processed into images on the aircraft. All images in a 3 km square centered on the summit were output as color images synthesized from the polarimetry to a resolution of 30 cm. Pixel decimation and data compression was then done to reduce file size, and images were transmitted to earth, via commercial satellite, to the Coordinating Committee for Prediction of Volcanic Eruption (Japan Meteorological Agency office). They were also sent to related agencies through the Ministry of Internal Affairs and Communications.

An example of the transmitted images is shown in Figure 1. Zooming in on the image to 30 cm resolution (Figure 2), the hollow left by the eruption can be seen in detail, following a continuous line. This was only vaguely visible with earlier sensors. The nine sets of observation data, including these reported images, are available to anyone through the NICT Web site*.

NICT is continuing to advance development of technologies that will be useful in times of disaster.

Finally, we sincerely pray that those who were lost in these eruptions may rest in peace.

Figure 1: A Pi-SAR2 image of a 3 km x 3 km area around the summit of Mt. Ontake

The path of the aircraft is from right to left in the figure, and the direction of the radar sweep is from top to bottom. The arrow in the upper left of the figure indicates North. This is a pseudo-color image created using the polarimetry function, with parts shown in green indicating vegetation.

Scene Name	Pos1B
OBS Date (GPS time)	2014/10/2
OBS Time (GPS time)	3:43:07
OBS No.	2014100201
Sensor	NICT-SAR
Polarization Red	RX2-HHm
Polarization Green	RX1-HVm
Polarization Blue	RX1-VVm
Rg Resolution[m]	0.4
Az Resolution[m]	0.3
Range [km]	Rg 2.0 Az 2.0
Early Near (Lat,Long)	+035:53:58.69 +137:28:05.53
Early Far (Lat,Long)	+035:53:47.30 +137:29:24.05
Late Near (Lat,Long)	+035:52:54.81 +137:27:51.52
Late Far (Lat,Long)	+035:52:43.42 +137:29:10.04
Inc.Angle Near[deg]	54.2
Inc.Angle Center[deg]	56.0
Inc.Angle Far[deg]	57.6
Altitude[m]	13145
Flight Speed[m/s]	185
Flight Direction[deg]	190.1
Scene Direction[deg]	280.1

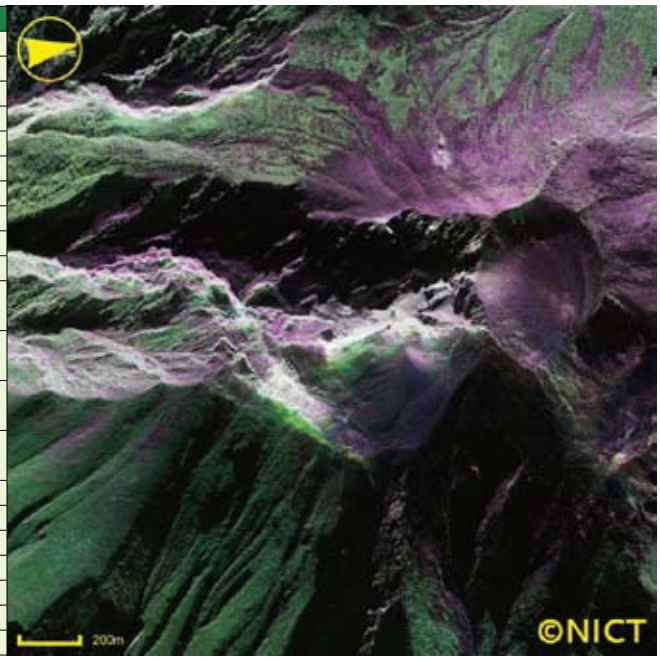
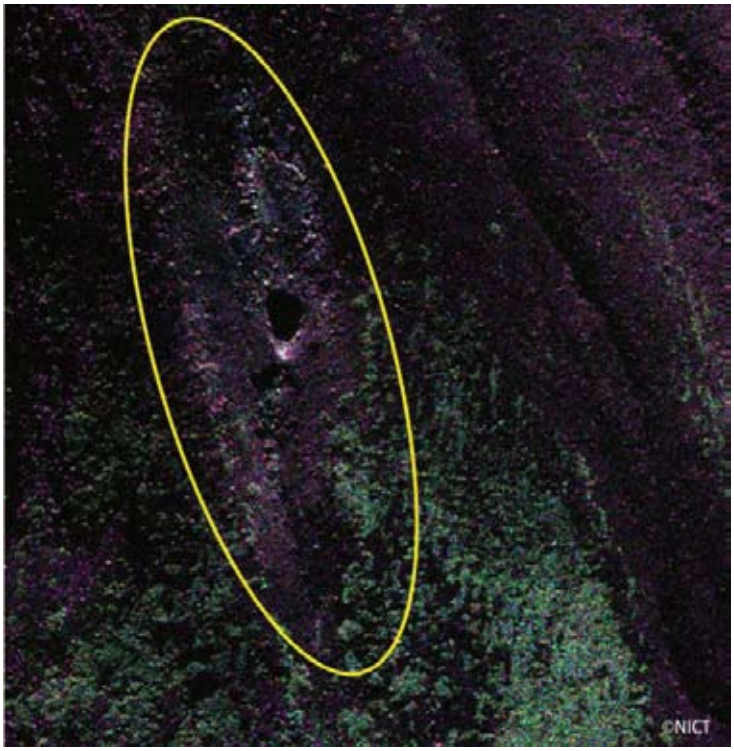


Figure 2: A Pi-SAR2 image of the summit of Mt. Ontake at approximately 12:51 on October 2, 2014

It is a magnification (300 m x 300 m) of part of Figure 1. The condition of the crater, which could not be seen in detail because it was hidden by smoke, can be distinguished clearly (part surrounded by the yellow oval).



* URL: http://www2.nict.go.jp/aeri/rrs/pisar2-ontake/index.html