SAR Image Processing Technologies are Improving Remote Sensing Data

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Abstract

Since the images from SAR data were successfully reproduced for the first time in Japan in 1980, NEC has been advancing R&D into various SAR image processing. High-level processing of SAR data enables acquisition of 3D information on the earth's surface, extraction of its changes and "feature extraction" that is one of SAR advantages for target analysis. This paper introduces the latest SAR image processing technologies including; the polarimetric SAR image analysis software "RSGIS-SAR," ScanSAR/ScanSAR interferometry and bistatic SAR image reproduction.

Keywords

SAR, Synthetic aperture radar, Earth observation, ScanSAR, Bistatic SAR, Interferometry, Polarimetry, RSGIS

1. Introduction

SAR (Synthetic Aperture Radar) is imaging radar installed on aircraft or spacecraft to obtain images of the earth's surface using microwave. Unlike an optical sensor, SAR requires the image reproduction processing of the acquired data via the radar in order to obtain images of the earth's surface. The imaged data may be further subjected to a high-level processing in order to obtain 3D information on the earth's surface, extract its changes and "feature extraction" that is one of SAR advantages for target analysis.

In this paper, we report some results of our recent R&D related to SAR image processing.

2. SAR Image Processing at NEC

We began independent research for the development of SAR processing software in the 1970's and succeeded in the reproduction of images from SAR data for the first time in Japan in 1980 (using observation data from the U.S. satellite SEASAT).

Subsequently, we developed and delivered; NEDIPS dedicated SAR image processing computer for the Remote Sensing Technology Center of Japan (RESTEC) in 1985, the NEDIPS-SAR image processing computer for JERS-1 SAR, Japanese first spaceborne SAR of National Space Development Agency of Japan (currently Japan Aerospace Development Agency, or JAXA) in 1992, and independently developed the image processing software for PALSAR, which was installed on ALOS (DAICHI) and was the latest spaceborne SAR in Japan in 2006.

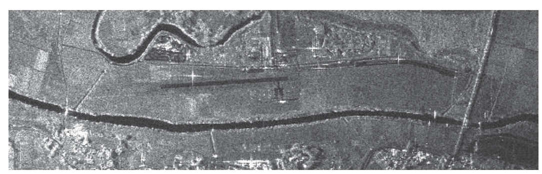


Fig. 1 Observation image of airborne SAR "NEC-SAR".

The image processing of airborne SAR is more complicated than that of the spaceborne SAR due to the motion disturbance of the aircraft, etc. In 1992 which is the same year as JERS-1 SAR was launched, we succeeded in developing SAR image processing software for "NEC-SAR," which is the first Japanese airborne SAR (**Fig. 1**). We subsequently continued to research into SAR processing, which led to the development of an on-board SAR image processing system that can be mounted on aircraft and the image processing software for airborne SAR with a maximum resolution of 30 cm.

The basic SAR image processing technologies such as the motion compensation technology for airborne SAR and the extraneous interference elimination technology, and the high-level processing technologies such as the interferometric SAR processing for generating a 3-dimensional DEM (Digital Elevation Model) (**Fig. 2**) [1], the differential interferometric SAR processing for extracting crustal movements (**Fig. 3**) and the polarimetric processing (multiple polarized wave processing)

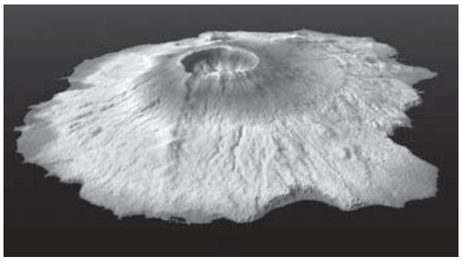


Fig. 2 Example of DEM obtained with interferometric SAR processing.[1)]

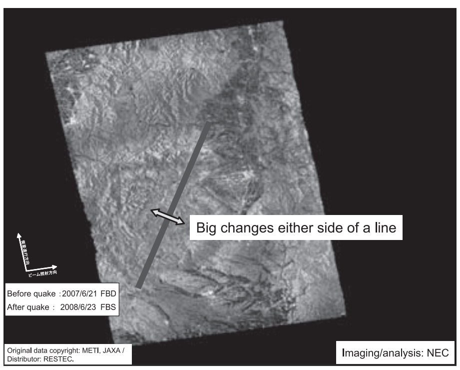


Fig. 3 Example of the extraction of the crustal movement with interferometric SAR processing (2008 Miyagi Earthquake, Japan).

for various types of analyses of the targets, are developed up to the present.

3. Latest Developments of SAR Image Processing Technologies

This section shows the following three technologies that are the latest SAR image processing technologies.

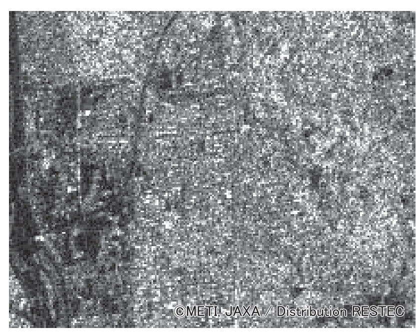
- Polarimetric SAR image analysis software “RSGIS-SAR”
- ScanSAR/ScanSAR interferometry
- Bistatic SAR image processing

3.1 Polarimetric SAR Image Analysis Software “RSGIS-SAR”

SAR equipped with full polarimeric observation, such as Pi-SAR and PALSAR, is called a polarimetric SAR and the number of polarimetric SARs has been increasing recently. In full polarimetric observation mode, SAR transmits two linear-polarized signals (horizontal and vertical) by turns, receives two linear-polarized reflection waves (horizontal and vertical) and gives full (quad) polarimetric data (HH, HV, VH, and VV) for polarimetric radar applications. It is capable of extracting and analyzing the feature of target information that cannot be extracted with a single polarimetirc data.

NEC developed RSGIS-SAR, which is the software for the analysis of polametric SAR. This software features the following two functions.

The first one is the virtual change of the polarized directions used in the transmission/reception of SAR. With SAR images in general, the reflection intensities of the radio waves from the target vary depending on the polarized directions of the radio waves used in transmission/reception and the view of the target after the imaging also varies accordingly. On the other hand RSGIS-SAR virtically modifies the polarized directions of the radio waves used in transmission/reception and outputs images by calculating the reflection intensities that would be observed with the modified polarized wave



(a) Vertical polarized wave transmission/Horizontally-polarized wave reception

(b) Transmission with a polarized wave obtained by 60° rotation of vertical polarized wave/ Reception with a polarized wave obtained by 60° rotation of horizontal polarized wave

Fig. 4 SAR observation image with modified polarization direction.

directions.

Fig. 4 shows a PALSAR image obtained by modifying the polarized wave directions. Image (a) is obtained via transmission using the vertically-polarized wave for transmission and the horizontally-polarized wave for reception. Image (b) is obtained when the directions of the polarized waves used in both transmission and reception are rotated by 60 degrees. The received signal hidden in image (a) becomes identifiable when the polarized directions are modified in image (b). This function can be used to select the polarization angles that provide clear target recognition.

The second function is the calculation and display of graphs of the relationship between the types of polarized waves used in transmission and reception (polarization signature diagrams) of each pixel based on the quad polarization data observed via the polarimetric SAR. The polarization signature diagram depends on the shape of the target reflecting the radio waves and this function can be used to define the target shape.

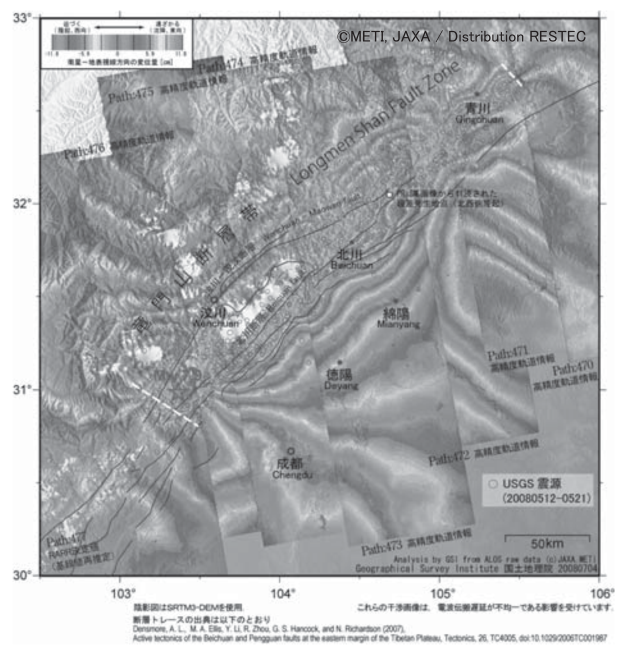
3.2 ScanSAR/Scan SAR interferometry

As described above in section 2, the high-level processing technologies for SAR include differential interferometric SAR processing. This image processing technology extracts crustal movements by observing the same location on two or more occasions, thereby allowing the observed data to mutually interfere and to thus obtain differences from the DEM (Digital Elevation model).

Recent spaceborne SARs such as PALSAR often have a wide area observation mode called ScanSAR in addition to a traditional stripmap SAR mode. ScanSAR switches the observation direction based on a time division so that it can observe a few times wider area than the stripmap SAR with a single observation path. The time-division switching of the observation direction of the ScanSAR posed the problem of difficulty in matching the switching timings of the two observation pathes to be interfered with the interferometric SAR. However we overcame this difficulty and achieved a world first in succeeding in differential interferometric SAR processing between data obtained in the wide area observation modes (ScanSAR) of PALSAR.

Fig. 5 shows the result of differential interferometric SAR analysis in the high-resolution mode (stripmap SAR) of PALSAR of the data before and after the 2008 Sichuan Earthquake in China (result of analysis by the Geospatial Information Authority of Japan, or GSI [2]). To observe the effects over a wide area, the image connects several differential interferometric SAR images obtained from observations of different areas before and after the quake.

Crustal Changes Following the 2008 Sichuan Earthquake – Composition of SAR Interferometric Images



The interferometric image makes it possible to determine the approximate locations of the two extremities of the quake source fault (indicated by white broken lines).
The length of the quake source fault may be about 285 ±5 km.
The zone in which crustal changes are concentrated extends along the Longmenshan fault zone.

Fig. 5 Results of differential interferometric SAR analysis using multiple images captured at 2008 Sichuan Earthquake, China.[2]

Fig. 6 shows the image reproduced by NEC as the result of differential interferometric SAR (ScanSAR/ScanSAR interferometry) processing in the wide area observation mode (ScanSAR) [3]. With an observation width of 350 km, we succeeded in extracting the crustal movements of before and after the quake over a very wide area, from only one set of observation data.

3.3 Bistatic SAR Image Processing

In the case of the generally-used SAR, an antenna is shared by both radio wave transmission and reception. Such SAR with which the transmission and reception antennas are in the same location is referred to as the "monostatic SAR," while SAR that separates the transmission and reception antennas and installs

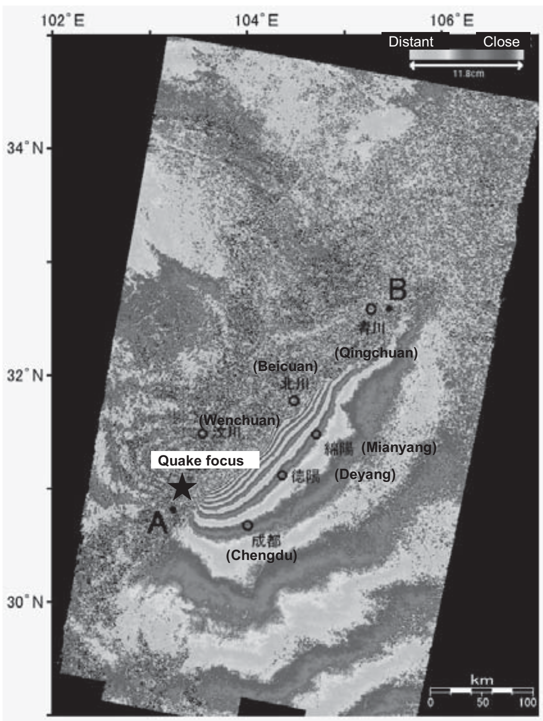


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Fig. 6 Result of differential interferometric SAR analysis with ScanSAR/ScanSAR interferometry at 2008 Sichuan Earthquake, China.

them in different locations is referred to as "bistatic SAR." The observation information and images of the monostatic and bistatic SARs are different because their radio wave reflection directions on the ground surface are different. There are for example cases in which an object that cannot be observed with monostatic SAR is observable with the bistatic SAR. However, the different locations of the transmission antenna/transmitter and reception antenna/receiver of bistatic SAR tends to pose a problem in the synchronization of shared timings.

In a bistatic SAR experiment of spaceborne and airborne SARs commissioned by JAXA, we succeeded in imaging bistatic SAR observation data by solving the issue of the timing synchronization by means of image processing of the observation data, without installing a special function for bistatic SAR in the SAR hardware. The algorithm applied in the image processing is shown in **Fig. 7** . The bistatic SAR image processing is achieved by performing the timing synchronization in the "Synchronization" step during ground-based

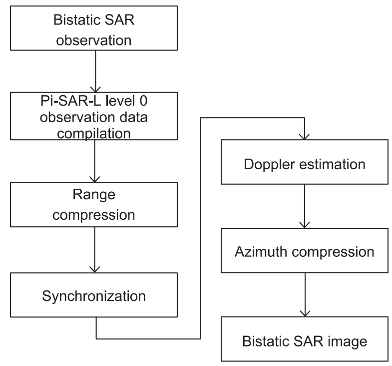
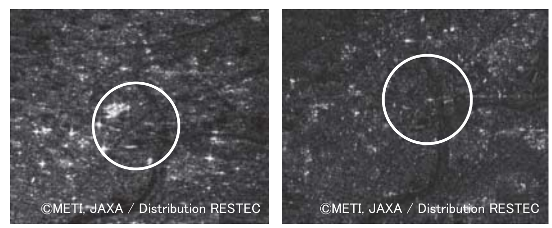


Fig. 7 Bistatic SAR image processing.



(a) PALSAR/Pi-SAR-L bistatic SAR observation image

(b) PALSAR monostatic SAR observation image

Fig. 8 PALSAR monostatic SAR observation image.[4)]

processing of the data after observation and the motion compensation and Doppler frequency estimation for bistatic SAR in the subsequent "Doppler estimation" step. **Fig. 8** (a) shows the bistatic SAR observation image obtained by the above method.

Compared to the monostatic SAR observation image in (b), the difference in the views of the two images such as the different reflection intensities depending on the objects on the ground surface allows us to confirm the effectiveness of the bistatic SAR between the spaceborne and airborne SARs [4)] .

4. Conclusion

NEC has been advancing R&D into SAR image processing continuously since the 1970's, achieving new results in SAR image reproduction and higher-level processing such as SAR image analysis software "RSGIS-SAR," ScanSAR/ScanSAR interferometry and bi-static SAR. In the future, too, it is our intension to continue development of practical and useful technologies by enhancing the remote sensing data including the SAR data and by improving its image identification capability.

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