ESTABLISHMENT OF LANDSLIDE MONITORING AND HAZARD LEVEL ASSESSMENT SYSTEM BY ALOS, AND ITS APPLICATION

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1. INTRODUCTION

Landslides disaster frequently occurs in many places in every year. Normally, location of landslides hazard area is known. Therefore, we can make landslides monitoring environment easily like volcano monitoring. However, huge amount of budget is necessary because numbers of landslides is quite large. For example, more than 300,000 scattered landslides are existed in Japan [1]. In order to monitor scattered landslides efficiently, remotely sensed technology is expected.

In this research, Differential SAR Interferometry (DInSAR) technique is applied to monitor/detect landslides. And its applicability is evaluated from two test sites of creep-type landslide that has different slope angle. Difficulty of monitoring of landslides due to slope angle, size of landslides, etc., is already known by previous research, therefore, integration to referenced data as ground-based, air-borne, and simulation (numerical model) is expected. In the research, in order to applied numerical model to future landslide slide monitoring system, tool for generating Digital Surface Model (DSM) is developed. DSM is one of the sources for numerical analysis of landslides and it can be generated from stereo pair of ALOS/PRISM. And InSAR can be also generated surface height information as Digital Elevation Model. Moreover, DInSAR can be calculated its change as surface deformation. Thus, InSAR/DInSAR processing tool is developed in this research. On the other hand, DInSAR can’t detect collapsed type landslide. Therefore, landslide recognition and landslide detection tool is developed in this research..

2. DEVELOPMENT OF DATA ANALYSIS TOOLS FOR ALOS

In order to obtain parameters for landslide analysis from ALOS data, PRISM/DSM generating tool was developed. And PALSAR data analysis tool including InSAR/DInSAR processing function were developed. And also landslide detection tool based on face recognition analysis was developed to detect landslide area from ALOS/AVNIR-2 imagery. In this section, development of each tools and its evaluation is discussed.

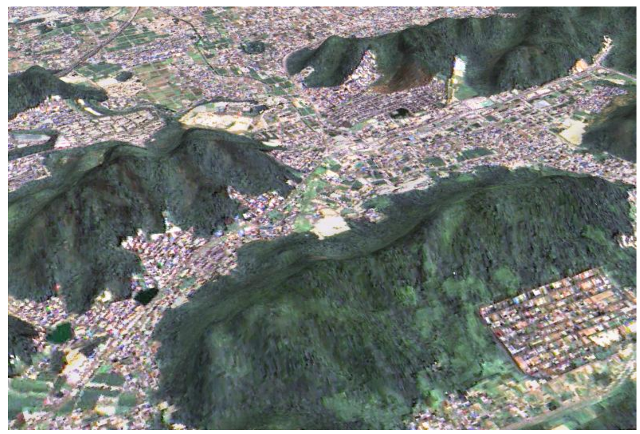


Fig. 2.1-1 3D view of Gifu city. Original DSM was processed by developed tool. And pan-sharpened imagery was superimposed to processed DSM by ArcGIS.

2.1 PRISM/DSM generating tool

In the landslide monitoring, latest surface height is one of the important parameter/information for the simulation and analysis of landslide.

In the developed tool, level 1B1 or level 1B2R data of PRISM are used for input data. And SSDA method is used for image registration and calculation of parallax between nadir and oblique (forward or backward) image. Then calculated parallax is converted to height. In the developed tool, DSM can be calculated not only whole scene but also local scale as landslide site or area. Figure 2.1 shows 3D imagery of Gifu city, Japan. DSM was generated by developed tool and ALOS pan-sharpened imagery is superimposed by ArcGIS. Generated DSM of Gifu city was evaluated by comparison with 50m DEM that provided by Geographical Survey Institute of Japan, GSI. To avoid structural height in comparison of DSM and DEM, bare soil area was used. From comparison, + and – 12m accuracy was confirmed for Gifu city area.

2.2 PALSAR data analysis tool

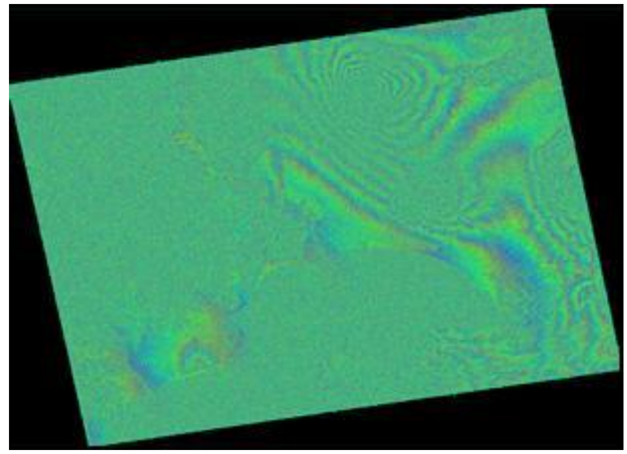
Generally, type of landslide can be categorized to two type as collapse type and creep type. In collapsed type landslide, normally, surface condition is dramatically changed after the landslide occurrence. And in creep type landslide, normally, surface condition is almost stable in before and after landslide. Therefore, different type of analysis should be applied for the each type of landslide. For the detection of collapse type landslide, ordinary image analysis/processing is preferable. And for the detection/monitoring of creep type landslide, DInSAR analysis is preferable. Thus, two types of analysis/processing tool was developed.

Firstly, collapse type landslide detection tool was developed. In the tool, level 1.5 data of PALSAR was used for input data. This tool has functions that geometric correction function, ortho rectification function, conversion to sigma-naught function, subtraction/normalized difference of sigma-naught calculation function, and correlation calculation function. All of results outputted by GeoTIFF format therefore it is easy to install to GIS environment. In the analysis menu, calculation of normalized difference of sigma-naught is adopted. The normalized difference of sigma-naught expressed normalized value of subtraction of sigma-naught value of a pair of imagery. And it can be expressed by equation (1).

$$NDSI = \frac{\sigma_1^0 - \sigma_2^0}{\sigma_1^0 + \sigma_2^0} \qquad (1)$$

Here, σ_i^0 is sigma-naught value of image *i*. According to equation (1), value of calculation result takes a range of value from -1 to +1. Thus, it can be prospect to use for statistical analysis.

Secondly, InSAR/DInSAR processing tool was developed. In the tool, level 1.1 data of PALSAR was used for input data. This tool processes ordinary InSAR/DInSAR analysis for the extraction of latest topography (InSAR/DEM) and its deformation. InSAR and DInSAR processing can be processed at least. However, some kinds of modification still remained. Figure 2.2-1 is an initial result of topographical interferogram that processed by developed tool.



Processed by ©RESTEC, ©JAXA, METI

Fig. 2.2-1 Preliminary result of topographic interferogram processed by developed tool.

2.3 Landslide detection tool for AVNIR-2 imagery

Most of collapsed type landslide shows collapse of horseshoe-shaped pattern at the top of landslide. Based on this phenomenon, pattern matching algorithm like face recognition technique [2] can be applied for the landslide detection. Firstly, horseshoe-shaped imagery as specified pattern is created. Secondly, pattern matching process is applied to band-3 imagery of AVNIR-2 imagery. Finally, collapsed type landslide is recognized like figure 2.3-1. Detected landslide marked by red cell on the AVNIR-2 imagery. It can’t cover whole area of each landslide, however it is possible to identify and interpret landslide area based on the result of this tool.

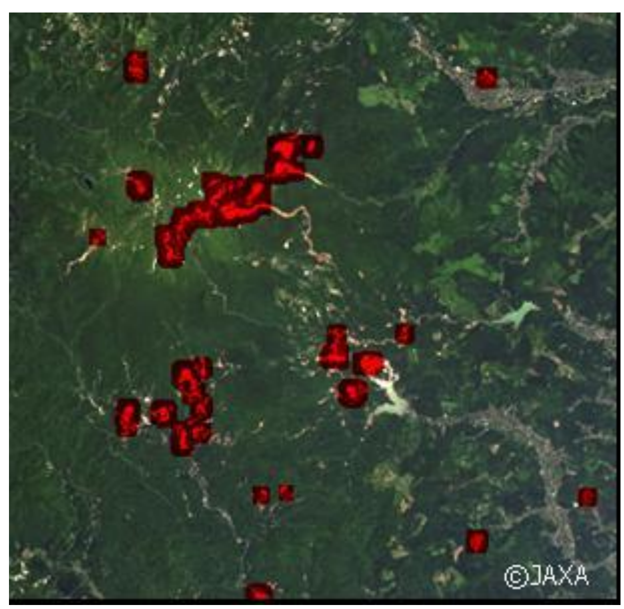


Fig. 2.3-1 Result of landslide recognition by AVNIR-2 imagery. Detected area marked by red cell(s).

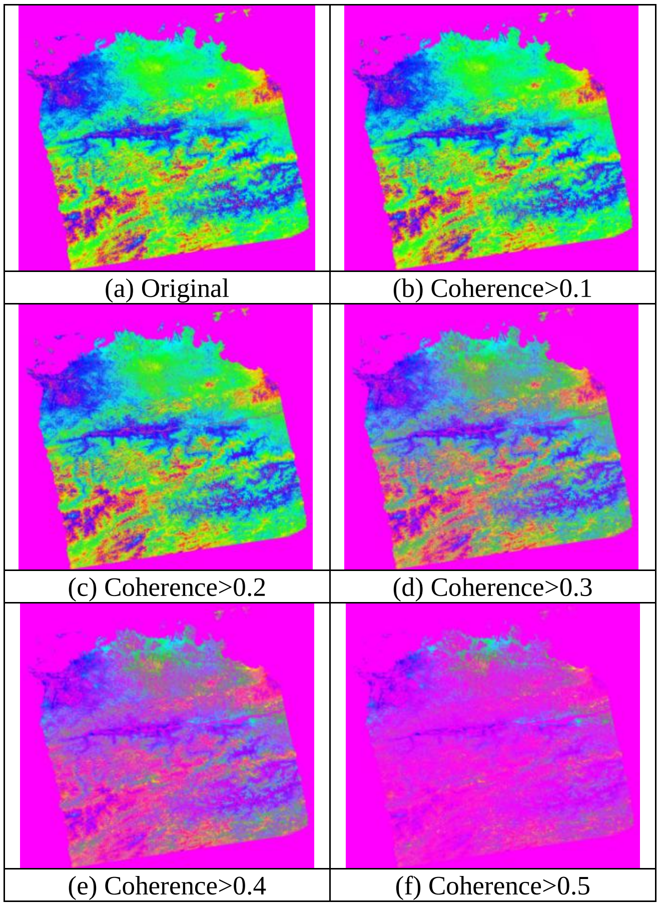


Fig. 3.1 Effect of mask process based on the coherence value.

3. CASE STUDY OF LANDSLIDE MEASUREMENT BY ALOS/PALSAR DInSAR

In order to understand applicability of DInSAR analysis for landslide measurement in Japan, ALOS/PALSAR DInSAR is applied to three kinds of test sites in Japan. Each test site has different characteristic of landslide in slope inclination, size, geology/geomaterial, and location. Before the DInSAR analysis, noise reduction technique is considered. Then, DInSAR analysis was applied to landslide detection.

All of DInSAR analysis was processed by ©SIGMA-SAR software [3]. And post-process was processed by original software.

3.1 Consideration of extraction of appropriate information from DInSAR result

In the interferogram, distinguishing of noise and actual deformation is difficult. Distinguishing of noise and actual deformation is very important for the detection of local scale deformation like land subsidence and landslide. In order to extract appropriate information from interferogram, interferogram was masked based on the coherence value. Coherence value with 0 to 0.5 was applied to interferogram shown in figure 3.1-1. Effect of coherence mask was shown in the case of coherence value from 0.3 to 0.5. In the case of both coherence value with 0.3 and 0.4, noise due to atmospheric effect is still remained. However, in the case of coherence value with 0.5, both noise and noise due to atmospheric effect is reduced. Thus, coherence value with 0.5 is adopted to post processing of DInSAR analysis in this research.

3.2 Description of test sites

3.2.1 Takisaka landslide, Fukushima, Japan

Takisaka landslide is one of the large size and active landslide in Japan. It located in North-West part of Fukushima prefecture. Size of landslide is approximately 2.1km (NS) x 1.3km (EW). And slope angle is approximately 10 degrees. In the landslide, some GPS station, slope movement measurement instruments, and weather station is installed. Figure 3.2.1-1 shows location map and map of Takisaka landslide.

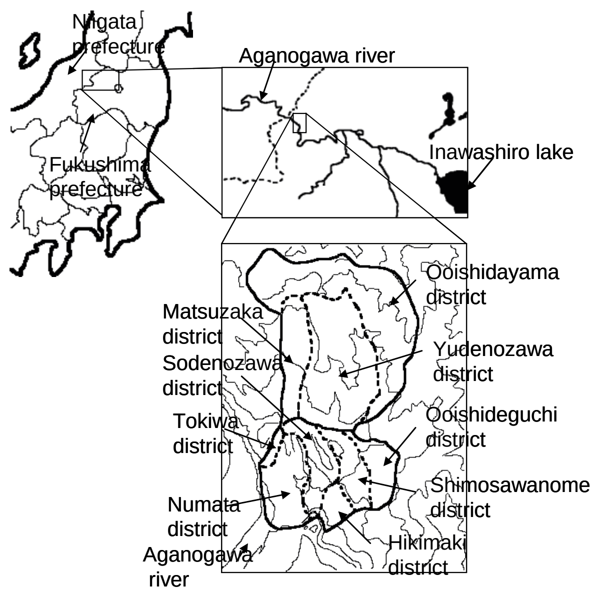


Fig. 3.2.1-1 location map of Takisaka landslide [4]

3.2.2 Zentoku landslide, Tokushima, Japan

Zentoku landslide is also one of the large size and active landslide in Japan. It located in West part of Tokushima prefecture. Size of landslide is approximately 2.0km (NS) x 0.9km (EW). And slope angle is approximately 30 degrees. Therefore, it can compare to Takisaka landslide as comparison of gentle slope landslide and steep slope landslide. In the landslide, some GPS station, slope movement measurement instruments, and weather station

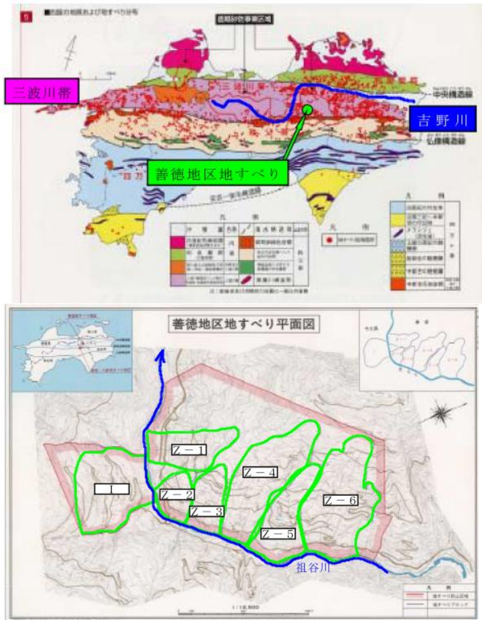


Fig. 3.2.2-1 location map of Zentoku landslide [5]

is installed. Figure 3.2.2-1 shows location map and map of Zentoku landslide.

3.2.3 Tokuyama Dam, Gifu, Japan

Tokuyama Dam construction was end in 2006 and water logging was started just after the construction. Water logging activity is affected to ground water pressure at the surrounding slope of the dam lake. In order to evaluate the stability of slope that surrounding of dam lake, DInSAR analysis was applied. Figure 3.2.3-1 shows location map of Tokuyama Dam.

Fig. 3.2.1-1 location map of Tokuyama Dam [6]

3.3 Results and Discussions

3.3.1 Takisaka landslide, Fukushima, Japan

ALOS/PALSAR data was used in this case as shown in table 3.3.1-1. And DInSAR analysis is applied to understand the current status/stability of Takisaka landslide.

Takisaka landslide is located in the center part of each map of figure 3.3.1-1. In the Takisaka landslide, countermeasure work is already done. However, small deformation was detected from previous analysis by JERS-1/SAR DInSAR [4]. In the previous case, small deformation was detected in the term of heavy rain with 400mm/month. In figure 3.3.1-1, definite deformation was not confirmed. This result might be shown effectiveness of countermeasure work.

Table 3.3.1-1 List of utilized ALOS/PALSAR data

<table>
<tr><th>Obs. date</th><th>Obs. mode</th><th>A/D</th><th colspan="3">Case</th></tr>
<tr><td>2009/07/01</td><td>FBD</td><td>Asc.</td><td rowspan="2">1</td><td></td><td rowspan="2"></td></tr>
<tr><td>2009/10/01</td><td>FBD</td><td>Asc.</td><td rowspan="2">2</td></tr>
<tr><td>2010/05/19</td><td>FBD</td><td>Asc.</td><td rowspan="2"></td><td rowspan="2">3</td></tr>
<tr><td>2010/07/04</td><td>FBD</td><td>Asc.</td><td></td></tr>
</table>

3.3.2 Zentoku landslide, Tokushima, Japan

ALOS/PALSAR data was used in this case as shown in table 3.3.2-1. And DInSAR analysis is applied to understand the current status/stability of Zentoku landslide.

Zentoku landslide is located in the center part of each map of figure 3.3.2-1. In figure 3.3.2-1(a) and (c), almost hole landslide area masked out by coherence mask due to low coherency. However, definite deformation is detected in figure 3.3.2-1(c). Deformation with approximately 5cm is detected in the middle part of landslide block. And also it is possible to see deformation at the bottom part of landslide. However, signal is very small and it is difficult to distinguish to noise. This result is coincided to field measurement is confirmed.

Table 3.3.2-1 List of utilized ALOS/PALSAR data

<table>
<tr><th>Obs. date</th><th>Obs. mode</th><th>A/D</th><th colspan="3">Case</th></tr>
<tr><td>2009/03/05</td><td>FBS</td><td>Asc.</td><td rowspan="2">1</td><td></td><td rowspan="2"></td></tr>
<tr><td>2009/07/21</td><td>FBD</td><td>Asc.</td><td rowspan="2">2</td></tr>
<tr><td>2010/04/23</td><td>FBS</td><td>Asc.</td><td rowspan="2"></td><td rowspan="2">3</td></tr>
<tr><td>2010/07/24</td><td>FBS</td><td>Asc.</td><td></td></tr>
</table>

3.3.3 Tokuyama Dam, Gifu, Japan

ALOS/PALSAR data was used in this case as shown in table 3.3.3-1. And DInSAR analysis is applied to understand the effect of water logging to landslide stability.

In the case of Tokuyama Dam, definite deformation was detected at the center part of figure 3.3.3-1. It is coincide to South-East part of Tokuyama Dam Lake. The maximum deformation with approximately 9cm is detected in this case. And slope was is deformed to west direction is confirmed. This direction is coincide to direction of slope. Therefore, detected movement might be definite movement as landslide. The results might be shown the possibility of change of ground water pressure around Dam Lake and slope instability.

Table 3.3.3-1 List of utilized ALOS/PALSAR data

<table>
<tr><td>Obs. date</td><td>Obs. mode</td><td>A/D</td><td colspan="3">Case</td></tr>
<tr><td>2007/06/07</td><td>FBD</td><td>Asc.</td><td rowspan="2">1</td><td></td><td rowspan="2"></td></tr>
<tr><td>2009/09/12</td><td>FBD</td><td>Asc.</td><td rowspan="2">2</td></tr>
<tr><td>2010/04/30</td><td>FBD</td><td>Asc.</td><td rowspan="2"></td><td rowspan="2">3</td></tr>
<tr><td>2010/09/15</td><td>FBD</td><td>Asc.</td><td></td></tr>
</table>

4. CONCLUSIONS

Through the research opportunity, several analysis tools for ALOS data were developed. However, currently, each tool works on single environment. In order to develop the system of landslide monitoring, integration of each tool is necessary. In near future, after the finalization of development of InSAR/DInSAR function, each tool will be integrated. Then we will propose landslide monitoring system.

On the other hand, DInSAR analysis for landslide measurement was applied to landslide area of Japan. Results were shown difficulty of application for landslide on steep slope. However, it was shown good result for landslide on gentle slope. It means that we have to re-organize the criteria of applicability of DInSAR for landslide based on slope inclination and clarify an applicability of DInSAR for landslide measurement is necessary. We will organize the criteria for application of DInSAR for landslide based on the comparison of slope inclination and DInSAR result in the next research.

5. REFERENCES

[1] http://www.mlit.go.jp/river/sabo/link20.htm

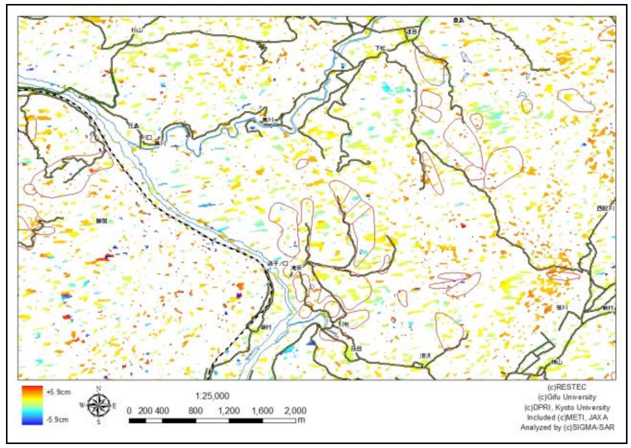
[2] W.Y. Zhao, R. Chellappa, "Image-based Face Recognition: Issues and Methods", Image Recognition and Classification , Ed. B. Javidi, M. Dekker, pp. 375-402, 2002.

[3] M. Shimada, "Verification processor for SAR calibration and interferometry," *Advanced Space Research*, Vol. 23, No.8, pp. 1477-1486, 1999.

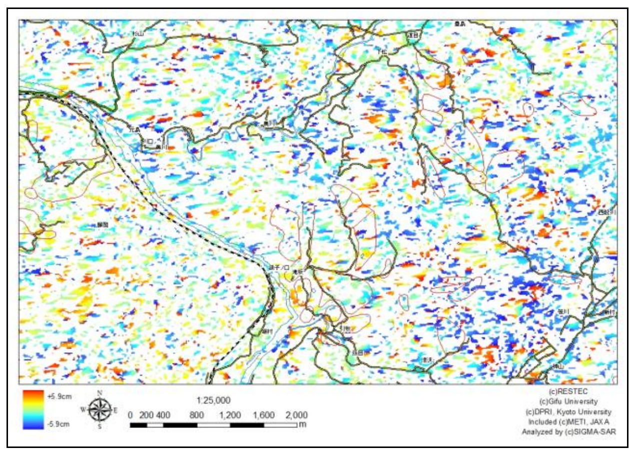
[4] Furuta, R., Shimada, M., Tadono, T. and Watanabe, M., "Applicability of Synthetic Aperture Radar Differential Interferometry to Observation of Takisaka Landslide (in Japanese)," *Proceedings of the 31th Remote Sensing Symposium*, pp. 23-26, 2006.

[5] MLIT/Shikoku Regional Development Bureau, Re-evaluation of direct control landslide relief work of Zentoku area, pp. 1-3, 2003.

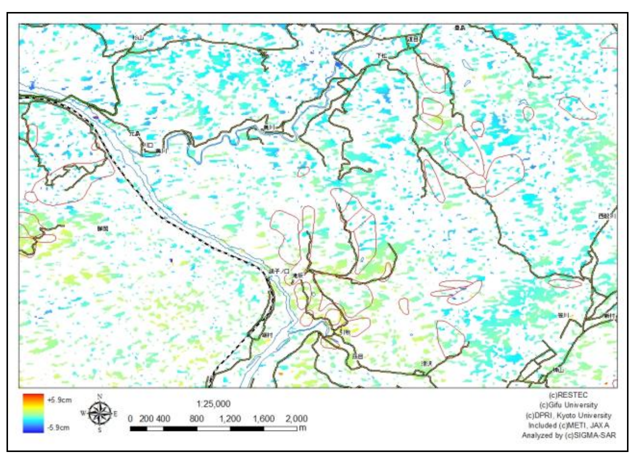
[6] http://www.water.go.jp/chubu/tokuyama/pamphlet/pdf/pamphlet.pdf



(a) Case-1 (2009/07/01-2009/10/01)

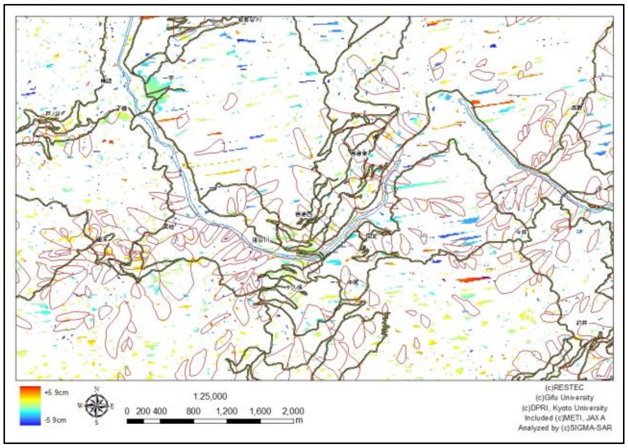


(b) Case-2 (2009/10/01-2010/05/19)



(c) Case-1 (2010/05/19-2010/07/04)

Fig. 3.3.1-1 Result of DInSAR of Takisaka landslide



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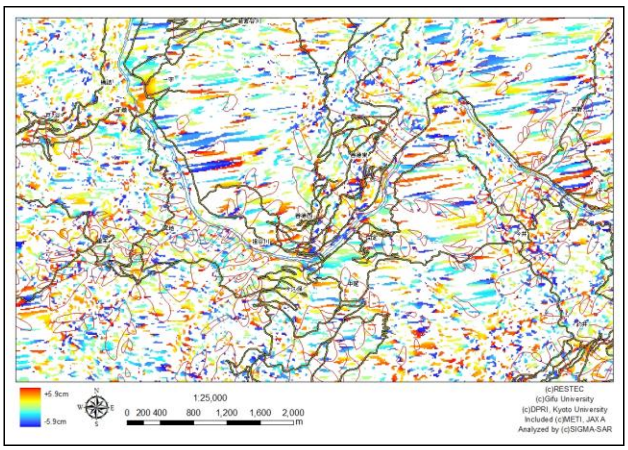
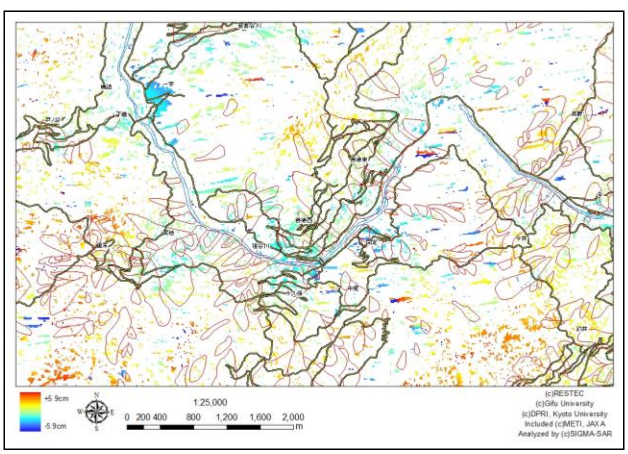
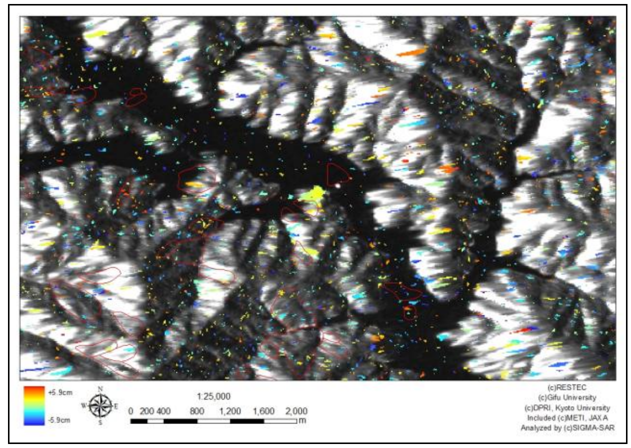


(b) Case-1 (2009/07/21-2010/04/23)

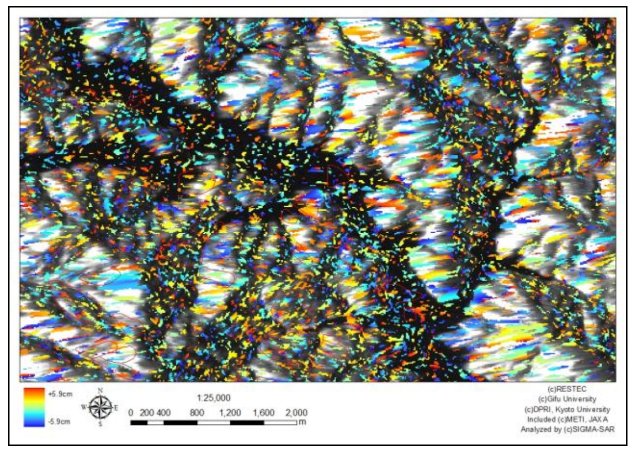


(c) Case-1 (2010/04/23-2010/07/24)

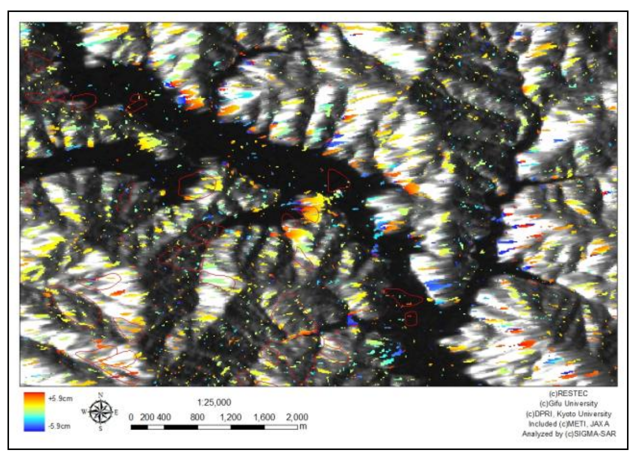
Fig. 3.3.2-1 Result of DInSAR of Zentoku landslide



(a) Case-1 (2007/06/07-2010/09/12)



(b) Case-2 (2009/09/12-2010/04/30)



(c) Case-3 (2010/04/30-2010/09/15)

Fig. 3.3.3-1 DInSAR result of Tokuyama Dam lake