L-band SAR Monitoring River Conditions of the Shimanto River, Shikoku, Japan

By Makoto OMURA1) and Masanobu SHIMADA2)

1) Kochi Women’s University, Kochi, Japan
2) JAXA, Tsukuba, Japan

(Received September 30th, 2009)

Space-borne Synthetic Aperture Radar (SAR) sensors can provide images of vast ground surface under any weather conditions irrespective of day or night. These capabilities greatly contribute to emergency disaster monitoring. JAXA established a Working Group (WG) for flood disasters monitoring by means of SAR sensors. As members of the WG, the authors employed ALOS/PALSAR L-band SAR imagery to monitor the usual condition of the Shimanto River, Shikoku, Japan. In particular, the SAR amplitude images of holms are examined in connection with the water level of the river during the period of January 2007 through December 2008.

Key Words: SAR, L-band, ALOS, PALSAR, River

1. Introduction

Space-borne Synthetic Aperture Radar (SAR) sensors can provide images of ground surface under any weather conditions irrespective of day or night. JAXA established a Working Group (WG) to monitor flood disasters, using SAR sensors. In 2008, the WG and some Local Government Units (LGUs) in Japan held joint demonstration experiments regarding flood disaster monitoring 1) mainly by means of the Japanese L-band Space-borne SAR, ALOS/PALSAR, and semi-real-time distributions of monitored information to disaster-prevention groups in each LGU. The critical issues are detection of the flood and GIS applications for the semi-real-time information distribution. The present study concerned on a preliminary trial for quick detection of the flood.

The Space-borne SAR monitoring of flood disasters has been reported since 1990s in view of major rivers in Japan 2) and in other countries 3). However, it has been pointed out that it is difficult to provide high resolution flood distribution maps at the arbitrary timing those disaster-prevention groups of the LGU are requesting. Space agencies in Japan have employed L-band SAR sensors, JERS-1/SAR and ALOS/PALSAR which operate with an intermission of about 7 years. The authors are making an attempt to improve the methods for flood detection by means of L-band SAR sensors for major rivers in Japan. Rivers in Japan are rather small in space and their water levels change very rapidly when a flood disaster occurs.

The authors analysed ALOS/PALSAR data for the Shimanto River, Shikoku, Japan during the period of January 2007 through December 2008 and discussed on SAR amplitude images of holms in connection with water level of the river in particular.

2. The Shimanto River and ALOS/PALSAR Data

2.1. The Shimanto River

The Shimanto River is well-known for its beautiful natural environment; it shows meanders in the Shikoku Mountains (Fig. 1). Occasionally, a heavy rain fall results in a flood disaster and slope failures along the river. The ALOS/PALSAR sensor has been in use since 2006 to dispatch repeated observations of the Shimanto River.

Fig. 1. The Shikoku Island and the Shimanto River. The west part of the Shikoku Island is shown by the ALOS/PALSAR geo-coded amplitude image (85 km x 100 km), observed on March 7, 2008. The rectangle indicates the downstream region of the Shimanto River, which is enlarged in Fig. 2.

2.2. ALOS/PALSAR data

The ALOS/PALSAR data were collected in order to cover the downstream region of the Shimanto River (Fig. 2) from the ascending orbit during the period of January 1, 2007 through December 31, 2008. They included FBS and FBD data with an off-nadir angle 34.3 degrees (Table 1). The all observations were made at approximately 13:40 (UTC), which was 22:40(JST).
The ALOS/PALSAR geo-coded amplitude image was acquired on March 7, 2008. The circle labeled ‘A’ and the zone ‘B’ are the holms which will be discussed in the following sections. The yellow dots labelled as ‘G’, ‘G2’ and ‘U’ are the gauging stations ‘Gudo’, ‘Gudo-2nd’ and the rain gauging station ‘Uyama’, respectively.

Ownership of ALOS/PALSAR original data is retained by JAXA and METI.

2.3. Water level data at gauging stations along the Shimanto River

The data on the water level at the gauging stations along the major rivers in Japan are archived and distributed through the website of the Water Information System 4), Ministry of Land, Infrastructure and Transport, Japan. Hourly data on the water level at the two gauging stations, Gudo and Gudo-2nd (Gudo-dai-ni) were obtained during the day of PALSAR observation. Fig 2. depicts the locations of the two gauging stations. The arithmetic mean values of the data of 22:00(JST) and that of 23:00 (JST) were adopted as the water level at the time of PALSAR observation. Fig. 3 indicates the water level at the time of each PALSAR acquisition.

Hourly rainfall data have been archived and are distributed through the website of the Water Information System 4). We calculated the total amount of rainfall during the period of 20:00 to 23:00 for each PALSAR observation at Uyama rain gauging station, which stands near to the Gudo gauging station.

According to the water level at Gudo station and the rainfall at Uyama station, there is a little rainfall at 21:00-22:00 for Date 3 (June 7, 2008) and it may introduces water level rise of about 4 cm. So the weather condition can be regarded as the same in the following comparison of the SAR images.

3. ALOS/PALSAR Data Processing

3.1. Amplitude images

The present study employed the SIGMA-SAR software 5). Amplitude images show the backscatter intensity from the ground surface. The smooth water surface was detected as a portion of the very low intensity. In order to keep the resolution of the image, we produced them in radar coordinate. The pixel resolution for the FBS and FBD images was set at 4.7 m and 9.4 m in range, respectively. The pixel resolution for azimuth was set at 9 m for both FBS and FBD images by 2-Looks processing.

Table 2 shows the river conditions at the date of the local maximum of water level, when the PALSAR observe the region. Image comparisons were made on the basis of the river condition on Jan. 1st, 2007. In addition, Table 2 is equipped with the labels of the dates.

Ownership of ALOS/PALSAR original data is retained by JAXA and METI.

<table>
<thead>
<tr>
<th>Path-Frame</th>
<th>Scene Shift</th>
<th>Mode</th>
<th>No. of Scenes</th>
<th>Off-nadir</th>
</tr>
</thead>
<tbody>
<tr>
<td>419-659</td>
<td>-1</td>
<td>FBS</td>
<td>6</td>
<td>34.3 Degrees</td>
</tr>
<tr>
<td>420-659</td>
<td>-3</td>
<td>FBS</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>FBD</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. River condition and PALSAR observation.

<table>
<thead>
<tr>
<th>Date, Path, Mode</th>
<th>Water Level (m)</th>
<th>Rain fall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>G2</td>
<td>20:00-23:00</td>
</tr>
<tr>
<td>0 Jan. 1, 2007 419 FBS</td>
<td>-0.90</td>
<td>2.43</td>
</tr>
<tr>
<td>1 July 4, 2007 419 FBD</td>
<td>1.82</td>
<td>5.31</td>
</tr>
<tr>
<td>2 Jan. 21, 2008 420 FBS</td>
<td>-0.57</td>
<td>3.08</td>
</tr>
<tr>
<td>3 June 7, 2008 420 FBD</td>
<td>0.10</td>
<td>3.54</td>
</tr>
<tr>
<td>4 Oct. 6, 2008 419 FBD</td>
<td>0.54</td>
<td>4.05</td>
</tr>
</tbody>
</table>
The amplitude images for Date 1 to 4 were co-registered on the image of Date 0, by applying affine transform of the 1st order. The 6 GCPs along the river were used. After the co-registration, RGB composite images (Fig. 4) were generated by assigning RGB color as R: image Date 0 (Jan. 1, 2007) with the lowest water level, G and B: another date with a higher water level. The area covered in water at the date of a high water level is shown in red color, with its RGB color intensities having been adjusted.

Fig. 4. The change in the water coverage between Date 0 (Jan. 1st, 2007) and Date 1 (July 4, 2007) when the water became higher about 2.8 m. The large portion of the holms A and B are shown in red colour. The western part of the holm B (forest canopies) is above 2.8 m over the usual water level.

4. Discussion

In the present study, the preliminary time-series analysis of changes in the amplitude images of the Shimanto River and its water level was conducted for the times of local maximums of the water level.

The detailed inspection of the time-series images for holms A (Fig. 5) and B (Fig. 6) has found that the shape of holms has some relationship with the relative water level (WL). There are some similarities in the shape of the holms.

For both holms A and B, the shape stays similar in the interval of WL, which is less than 0.5 m, with an interval of 0.5 m - 1.5 m and more than 2 m. Yet, the detection of water covered holms by using the simple SAR image processing is difficult at the present stage.

We examine the case for holm A (Fig. 5). It is likely that one of the difficulties we had in monitoring the shape of the holm comes from the spatial pattern of the small streams on the holm. The scale of the spatial pattern is a few meters (Fig. 7). Then the pixel resolution of about 10 m turned out to be insufficient to discriminate the surface condition.
Furthermore, the effect of waves on the surface of the river water is important to consider for the better detection of the holms. Isoguchi and Shimada proposed an L-Band Ocean Geophysical Model based on the PALSAR data and in-situ wind data which were synchronously observed \(^6\). However, there are no in-situ wind data and the surface topography of the Shimanto River. Before the detailed discussion, we need the new method to measure the height of the water surface in the night.

5. Concluding Remarks

The present study has shown that the L-band ALOS/PALSAR Space-borne SAR sensor successfully monitored the changes in the river condition of the Shimanto River, Shikoku, Japan in the night. No optical sensor can provide time-series images during the night time. The comparison of the amplitude images revealed the relationship between the images of the Shimanto River and the changes in its water level. The result obtained from the present analysis suggests that SAR amplitude images address a strong potential in monitoring the topographic information of the holms. Finally, we show that the SAR sensors with higher resolution (a few meters or more) will be required to detect the detailed shape of the holms. It is important to study the effect of the waves on the water surface of the river in the future.

Acknowledgments

The authors are grateful for the members of JAXA Working Group for the flood disasters monitoring by using SAR sensors for their valuable advice and encouragement. The PALSAR data were provided for the activities of the WG. We thank for Ms Asami Nakakuki of Kochi Women’s University for her much help in the image processing.

Ownership of ALOS/PALSAR original data is retained by JAXA and METI.
References


