CONNECTING LAND SUBSIDENCE MONITORING RESULTS BY MULTI-TEMPORAL DINSAR USING ALOS1 AND ALOS2 DATA

Putu Edi Yastika
Norikazu Shimizu
Tasuku Tanaka
Masanobu Shimada
Subsidence is a serious problem for some big cities in the world including in Indonesia.

Requires a continuous monitoring system and accurate subsidence maps for the purpose of risk management.

DInSAR is one of the powerful techniques to overcome such issues.

Requires a continuous SAR data from satellites.

Lifespan of SAR satellites is limited. There are periods where no SAR satellites in services.

Launch date: 24 January 2006
Deactivated: 12 May 2011

Launch date: 24 May 2014

ALOS
ALOS-2
3 years

How to connect these two separated results?

Use Hyperbolic method
Outlines

✓ Introduction

✓ Outline of DInSAR and Multi-Temporal DInSAR

✓ Application of Proposed Multi-Temporal DInSAR to Land Subsidence Monitoring

✓ Connecting the Results of ALOS with the results of ALOS-2, using Hyperbolic method.

✓ Conclusions
Outlines of DInSAR

Principle of DInSAR works

1. Focusing
2. Images registration & Interferogram generation
3. Removing Topography phase component
4. Differential Phase Unwrapping
5. Phase to displacement conversion and Geocoding

Standard Procedure of DInSAR

Processing stages to obtain Line of Sight (LOS) displacement by using DInSAR technique
How about long term monitoring?

In order to long term monitoring of land surface deformation by DInSAR, several methods and processing strategies are available:

1. A set of consecutive interferometric pairs
2. A set of interferometric pairs which is the reference master image is the first available scene
3. Some sets of small baseline interferometric pairs
4. A proposed method, which is considering the interferograms quality in the time series
APPLICATION OF PROPOSED MULTI-TEMPORAL DINSAR TO LAND SUBSIDENCE MONITORING AND CONECTING THE RESULTS OF ALOS1 AND ALOS2

(Semarang Case)
The study area is Semarang city, located on the north of Java Island. Geographically, Semarang city lies on $6^\circ 58' S 110^\circ 25' E$. With an area of 373.70 square kilometers and a population of approximately 2 million people.
Data Collection and Interferograms Selection

• Data Collections

**PRIMARY DATA**
- **23 Scenes** of ALOS PALSAR (ascending)
- **4 Scenes** of ALOS-2 PALSAR-2 (ascending)
- **SRTM 3** DEM data

**SECONDARY DATA**
- GPS data observation by Geodesy research group ITB
- Perpendicular and baseline table for Interferogram selection of ALOS-2

• Interferogram Selection for Proposed Multi-Temporal DInSAR (ALOS)

(Images of graphs showing interferogram selection and baselines from 2007 to 2011, and from 2015 to 2016.)
Results and Interferograms selection of ALOS

There are 253 interferograms
Results and Discussion of ALOS

Comparison of subsidence by DInSAR (proposed methods) and GPS from 2009 to 2010. Both results agree on each other.
Results and Discussion of ALOS

Landsat 7 image (gap-filled, slc-off, bands 4/R, 5/G, 7/B) taken on September 17, 2006 showing the investigation area (dashed frame) and simplified geological section AB (not to scale) (Kuehn, et al 2009)
Results and Discussion of ALOS

The subsidence pattern in the time series of some points. Three groups of subsidence pattern were found.
Hyperbolic method

Prediction of Subsidence Using Hyperbolic method

In order to predict the final subsidence, the hyperbolic method (Tan, et al 1991) is adopted in this study. The subsidence “St” is assumed to be represented by the following equation:

\[ S_t = \frac{t}{\alpha + \beta t} \]

Whereas \( \alpha + \beta t \) is the linear regression equation of the curve of period divided by its measured subsidence data, \( (t/S_t) \)

When “t” goes to infinity, the final subsidence value can be predicted by the following equation

\[ S_f = \frac{1}{\beta} \]

The time to reach “k” percent of the final subsidence \( (t_k) \) also can be predicted by using the following equation:

\[ t_k = \frac{\alpha}{\beta\left(\frac{100}{k} - 1\right)} = \left(\frac{k}{100 - k}\right)\frac{\alpha}{\beta} \quad \text{In this research} \quad k=90\% \text{ was used} \]
By Using Multi temporal DInSAR, the evolution of Semarang’s subsidence in space and time can be provided.

Black thick line is smoothed curve by applying hyperbolic method

Start Date:
21 January 2007

End Date:
1 February 2011
Hyperbolic method results

Hyperbolic method applied for all observation points. Its results on the several points shown in the table below.

6 points shown as an example

<table>
<thead>
<tr>
<th>Observation points</th>
<th>α</th>
<th>β</th>
<th>$S_f$</th>
<th>$t_{90}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1124</td>
<td>1.4016</td>
<td>0.0427</td>
<td>23.4</td>
<td>24.6</td>
</tr>
<tr>
<td>SMG3</td>
<td>1.1993</td>
<td>0.0202</td>
<td>49.5</td>
<td>44.5</td>
</tr>
<tr>
<td>SMG5</td>
<td>0.9274</td>
<td>0.0196</td>
<td>51.0</td>
<td>35.5</td>
</tr>
<tr>
<td>RMPA</td>
<td>1.1852</td>
<td>0.0121</td>
<td>82.7</td>
<td>73.5</td>
</tr>
<tr>
<td>K370</td>
<td>0.0319</td>
<td>1.1297</td>
<td>31.3</td>
<td>26.6</td>
</tr>
<tr>
<td>QBLT</td>
<td>2.0843</td>
<td>0.0462</td>
<td>21.7</td>
<td>33.8</td>
</tr>
</tbody>
</table>
The parallel fringes clearly are seen on the interferograms. However, the proposed multi-temporal DInSAR could not be applied because the number of Interferogram is too small.

2015/1/30 (T=0)  2015/7/3 (T=154 days)  2015/9/11 (224 days)  2016/1/29 (364 days)
Connecting the results of ALOS-1 with the results of ALOS-2

There are no ALOS satellite data during this periods.

Lack of Satellite’s data, and land subsidence estimated by Hyperbolic method

ALOS end of observations period

ALOS-2 starting observation time

ALOS-1

Sub est

ALOS-2

K370

DATES

2007/1/1 2008/1/1 2009/1/1 2010/1/1 2011/1/1 2012/1/1 2013/1/1 2014/1/1 2015/1/1 2016/1/1

SUBSIDENCE (cm)
Connecting the results of ALOS-1 with the results of ALOS-2

Hyperbolic method have an ability to connecting the results of ALOS and ALOS-2. It shows good estimation results compare to the result of ALOS-2 (blue circle)
Connecting the results of ALOS-1 with the results of ALOS-2

The hyperbolic method applied on the large subsidence area, it also can provide good estimation results, but needs further study to ensure its reliability.
4. Conclusions

• Comparing the monitoring results of DInSAR and GPS, it was found that the proposed method can provide displacements measurement which agree well with those of GPS.

• According to the results by the proposed method, the northeast area and the coastal area have large subsidence of 20-32 cm over 4 years or an average rate of 5-8 cm/year. The distributions of subsidence trends in space, coincide with the ground conditions.

• Future subsidence can be estimated by applying the hyperbolic method to the results obtained by the proposed method.

• The ability of the hyperbolic method to connecting the results of ALOS and ALOS-2 has been shown, and its need the further study to ensure its reliability.
THANK YOU FOR LISTENING

Any questions and comments appreciated!