Landslide Displacement Monitoring by InSAR Analyses with Persistent and Distributed Scatterers: A Case Study of Danba County, China

Jie Dong, Lu Zhang, Mingsheng Liao, Jianya Gong

LIESMARS, Wuhan University, China

Email: dongjie@whu.edu.cn
Outline

- Study Area and Data
- Method: DSI
- Results
  - Evaluation of DSI
  - Wide-area landslides detection
- Conclusions
Outline

- **Study Area and Data**
- **Method:** DSI
- **Results**
  - Evaluation of DSI
  - Wide-area landslides detection
- **Conclusions**
Study Area

- The zone of first step extending to second step of the China's three ladders
- The upper reach of Dadu River in Danba County, West of China
  - Steep and forested terrains
  - Active tectonic movements
  - Frequent geological hazards
Jiaju Village

- A well-known Tibetan style village
- One of the most beautiful villages in China
Study Area - Jiaju landslide

- Two parts: northern and southern parts
- Road S211 and Dajinchuan River

- Northern part
- Southern part

- Crack
- River erosion

- Two landslides
- Road S211

[Map and images showing the study area with northern and southern parts, road S211, Dajinchuan River, crack, and river erosion.]
Data

**SAR images:**
- L-band ALOS PALSAR: Ascending, 19 images, Dec-2006 - Jan-2011

**GPS observations for Jiaju landslide:**
- 20 monitoring + 2 reference stations
- Trimble 5700 GPS receivers
- Aug-2006 – Dec-2013
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Challenges of conventional time series InSAR

In rural areas, very few PS points are available. SBAS uses more points but still underestimates large deformation gradient results in phase unwrapping errors. Increase points density to mitigate these issues.

According to the GPS measurements.
**Method - DSI**

**DSI method:**

Persistent Scatterers (PS) + Distributed Scatterers (DS)

(1) **PS preprocessing:**
StaMPS/PSInSAR

(2) **DS preprocessing**

(3) **Combination analysis of PS and DS**
Standard time series analysis

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Ferretti et al, 2011, IEEE TGRS
Pariizzi, 2011, IEEE GRSL
Monti Guarnieri et al, 2008, IEEE TGRS
DS preprocessing

- **Identify SHP pixels**
  - **KS**
    - Kolmogorov-Smirnov Test
  - **AD**
    - Anderson-Darling Test
  - **KL**
    - Kullback-Leibler Divergence
  - **GLR**
    - Generalized Likelihood Ratio Test

- **Estimate optimal phases**
  - **Maximum Coherence-based-Weighted Sum of Residual Phasors**
  - **Eigendecomposition-Based Phase Estimator**
  - **Least Squares Phase Estimator**
  - **Maximum-likelihood Phase Estimator (Phase Linking)**

Ferretti et al, 2011, TGRS
Pariizzi, 2011, IEEE GRSL

Ferretti et al, 2011, TGRS
Cao et al, 2015, IEEE GRSL
Monti Guarnieri et al, 2008, TGRS
Method - DSI

Example for DS preprocessing

LostHills Oil Field, ENVISAT ASAR, 37 SLC images

Noisy

Spatially adaptive filtering

Temporal filtering
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LOS Deformation rate

PALSAR

ASAR

SBAS

DSI

Jiaju landslide

<table>
<thead>
<tr>
<th>Method</th>
<th>Spatial density (MPs/km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSI</td>
<td>323</td>
</tr>
<tr>
<td>SBAS</td>
<td>498</td>
</tr>
<tr>
<td>DSI</td>
<td>4,973</td>
</tr>
<tr>
<td></td>
<td>1,093</td>
</tr>
</tbody>
</table>

PSI & SBAS: StaMPS
Jiaju landslide

Jiaju landslide (PALSAR dataset)
Correlations of different methods: PALSAR and ASAR

- **PALSAR**
  - PSI vs. SBAS: $R=0.919$
    - Mean: 3.88 mm/yr
    - STD: 6.03 mm/yr
  - DSI vs. SBAS: $R=0.926$
    - Mean: 4.26 mm/yr
    - STD: 6.15 mm/yr

- **ASAR**
  - PSI vs. SBAS: $R=0.913$
    - Mean: 4.33 mm/yr
    - STD: 3.88 mm/yr
  - DSI vs. SBAS: $R=0.963$
    - Mean: 6.04 mm/yr
    - STD: 3.72 mm/yr

- All the correlations are above 0.90.
- For PALSAR, the STD values are less than 7.0 mm/yr.
- For ASAR, the STD values are less than 4.0 mm/yr.

**Evaluation of DSI**
Correlation of PALSAR and ASAR on DSI results

- The correlation is 0.79
- The mean difference is -3.49 mm/yr
- The STD of the differences is 9.72 mm/yr

Reasons for the discrepancy:
- Different look angles
- Different time spans of acquisitions
- Different spatial locations of points
Validation with GPS measurements

- The northern part (120 mm/yr) moved much faster than the southern part.
- The foot moved faster than the head.
- InSAR results agree well with GPS results.

Evaluation of DSI

DSI-derived PALSAR rate

GPS rate
Evaluation of DSI

Validation with GPS measurements

- The correlation between DSI-derived PALSAR rate and GPS rate on the GPS stations is 0.96
- The mean difference is -2.7 mm/yr
- The STD of the differences is 10.9 mm/yr
Evaluation of DSI

Validation with GPS measurements

- **G4** ($\Delta = 6.12$ mm/yr)
- **G8** ($\Delta = -0.537$ mm/yr)
- **G10** ($\Delta = -9.95$ mm/yr)
- **G17** ($\Delta = -13.1$ mm/yr)
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Wide-area landslides detection

LOS deformation rate map derived by DSI from PALSAR (2006-2011)

- More than 4,000,000 measurement points (MPs) identified over an area of 1,000 km²
- A spatial density of over 4,000 MPs/km²
- 16 landslides detected along the Dadu River

field survey
Results – Suopo landslide

scarp

2-3 m

Δ +8.0 to -8.0 cm/yr
Results – Gezong landslide

- Gezong landslide

+10.0 cm/yr
Results – Zegong landslide

+6.3 cm/yr

Landslide Sign

Scarp

Road S211
Results – Wulipai landslide

- Wulipai landslide

Results - Wulipai landslide

N +4.4 - 4.4 cm/yr
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Conclusions

- DSI can detect wide-area landslides and monitor local-scale landslides with high precision.

- More points are detected by DSI than PSI and SBAS.

- DSI and L-band SAR data are more suitable for landslide monitoring in vegetated terrains.

Thursday, 9:40am - 10:00am, Menghua Li, Monitoring Fast Motion of Guobu Slope by Point-like Targets SBAS Offset Tracking. Location: Juhlasali
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THANK YOU
Results

SHP pixels

N=4  N=6  N=8  N=10  N=12  N=14  N=16

KS test

GLR test

TerraSAR-X stripmap images
Results

Current activity state of Jiaju landslide: **slow moving**

- **X-band TerraSAR-X**
  - 20170302-20170324
  - Bt: 22d, Bp: 50m

- **C-band Sentinel-1**
  - 20161231-20170217
  - Bt: 48d, Bp: 16m

- **L-band ALOS-2 PALSAR-2**
  - 20160226-20161216
  - Bt: 294d, Bp: 240m
Results – Jiaju landslide

Animation: Jiaju landslide