Monitoring Fast Motion of Guobu Slope near Laxiwa Hydropower Station by Point-like Targets SBAS Offset Tracking

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Outline

1. Study Area
2. Datasets
3. InSAR Results
4. Pixel Offset Tracking Results
5. Conclusions
1. Study Area
Laxiwa Hydropower Station

• Located in Qinghai Province
• **Largest** one on the Yellow River
• Elevation difference $>700$ m
• Constructed since 2001
• Impoundment started in 2009
Guobu Slope

highly weathered granite

fragile
The water level raised >200m after impoundment, staying around 2450m.

The scarp is more clear.
Displacement history (Envisat ASAR)

5 years 20031203 - 20090904
1 year 20090904 - 20100924

How about the current state of Guobu slope?

before impoundment  acceleration  after impoundment

2. Datasets

DEM data: WorldDEM (12m spatial resolution)
## Basic parameters of SAR data

<table>
<thead>
<tr>
<th></th>
<th>TSX HS1</th>
<th>TSX HS2</th>
<th>ALOS-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbit Direction</td>
<td>descending</td>
<td>descending</td>
<td>descending</td>
</tr>
<tr>
<td>Heading (°)</td>
<td>189.67</td>
<td>191.00</td>
<td>195</td>
</tr>
<tr>
<td>Look Angle(°)</td>
<td>41.1</td>
<td>23.9</td>
<td>31.4</td>
</tr>
<tr>
<td>Spacing (Az * Rg)</td>
<td>0.86m*0.45m</td>
<td>0.87m*0.45m</td>
<td>3.1m*4.3m</td>
</tr>
<tr>
<td>Temporal Coverage</td>
<td>09/2015 - 04/2017</td>
<td>12/2015 - 04/2017</td>
<td>13/03/2016-08/05/2016</td>
</tr>
<tr>
<td>Number of Images</td>
<td>18</td>
<td>16</td>
<td>2</td>
</tr>
</tbody>
</table>
3. InSAR Results
Result from TerraSAR-X SBAS Analysis

Accumulative displacements in LOS

Phase based method
- ifgs formed with Bt <67 days
- Very few points on the slope
- Maximum displacement ~8cm

Sep. 2015 to Apr. 2017
Coherence of Interferograms

**TSX HS1** (66 days)
- 20160404 - 20160609
- Look angle: **41.1°**
- Perpendicular baseline < 80m

**TSX HS2** (66 days)
- 20160307 - 20160512
- Look angle: **23.9°**

**ALOS-2** (56 days)
- 20160313 - 20160508
- Look angle: **31.4°**
D-InSAR Result of ALOS-2

20160313 - 20160508 (56 days)

- Clear boundary of landslide
- Maximum displacement in LOS ~10cm
- TSX SBAS analysis underestimates the displacements on the slope.

Look angle: 31.4°
4. Pixel offset tracking results
Point-like Targets Offset Tracking (PTOT)

- Make use of point targets with high amplitude values
- Avoid unreliable measurements in rural areas
- Suitable for measuring large displacement
- Based on SAR image matching at subpixel-level accuracy
- Without phase unwrapping

The achievable accuracy: 1/10 – 1/20 of the pixel size

Corresponding to 5 cm – 2.5 cm for TSX HS data
Error Sources of PTOT

**Stereoscopic effects:** The range offset due to topographic relief
(\(\text{Range}\))

\[
\Delta y_{\text{off}} = \frac{B_\perp}{H \tan \theta} \Delta h
\]

For TerraSAR-X

- Orbit height \(-\text{H}=514\text{km}\)
- if: Perpendicular baseline \(B_\perp=200\text{m}\)
- height \(-\text{\(\Delta h=100\text{m}\)}\)

<table>
<thead>
<tr>
<th>Look angle</th>
<th>Range offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.9°</td>
<td>8.8cm</td>
</tr>
<tr>
<td>41.1°</td>
<td>4.5cm</td>
</tr>
</tbody>
</table>

**Random Error:** Atmosphere effect, residual orbital error, coregistration error

(\(\text{Rang \& Azimuth}\))
Workflow of SBAS PT-offset Tracking

Key steps:

- PTs selected from mean amplitude
- Image pairs formed with small $B_{\perp}$
- Cross correlation: extract displacements in pairs
- Time series displacements retrieved with SVD

Shi X, et al., ISPRS Journal, 2015
Spatial-temporal Baselines

TSX HS1

20150919 - 20170413
Look angle: 41.1°

TSX HS2

20151221 - 20170418
Look angle: 23.9°
Displacements from Sep. 2015 to Apr. 2017

Look angle: 41.1°  Slope: 43°  
Range direction: NW290°  
Slope direction: NW285°

Los ~ slope direction

Different displacements pattern on each side of the scarp.
The whole landslide block moved >30cm in 20 months
Maximum displacement in slope direction is ~1.2m

Back scarp

TSX HS1  20150919
Accumulative Displacements in Range

TSX HS1
Look angle: **41.1°**

TSX HS2
Look angle: **23.9°**

20151216 - 20170413

20151221 - 20170418
Accumulative Displacements in Azimuth

TSX HS1

Look angle: **41.1°**

20151216 - 20170413

TSX HS2

Look angle: **23.9°**

20151221 - 20170418
Time series displacements in range

TSX HS2  20151221 - 20170418

SBAS-PTOT  Single Master PTOT
Displacement Pattern Comparison

TSX HS1 20151216 - 20170413

Look angle: 41.1°

Assumption: linear displacement
Converted to displacement in 16 months

ALOS-2 Look angle: 31.4°
3D Displacement Inversion

- **Match in temporal:**
  20151216 - 20170413
  20151221 - 20170418
  Same time span & 5 days gap

- **Match in spatial:**
  Calculate correlation between the mean amplitude images of two datasets

- Invert 3D displacement on pixels with correlation > 0.5 & distance < 5m
- Remove pixels which are moving upward and eastward
5. Conclusions

• SBAS-PTOT was used to extract time series displacements of Guobu slope.
• The displacement rate of Guobu slope slow down.
• Displacements measured by TSX agree well with D-InSAR result of ALOS-2.
• 3D displacements could be derived from two SAR datasets of descending orbits with different look angles.
Thank you for your attention!

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