Satellite Remote Sensing: monitoring ground surface movement & application on tailings dams

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Oulu, 21.09.2017
Norut (Northern Research Institute)

- Norut Tromsø
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- Biotechnology
- Information and Communication Technology
- Earth Observation
- Social science Research

Remote sensing, satellites and unmanned aircrafts systems

Sentinel-1 (ESA)  
Gamma GPRI  
Norut UAS
Ground deformation measurements

In situ monitoring

From traditional measurement methods ...

Continuous DGPS

Bolts network for Total Station surveying

Satellite SAR

UAS

MDA Corp.

... to new remote sensing technologies

Spaceborne & Airborne methods
RADAR
Radio Detection and Ranging

SAR
Synthetic Aperture Radar
### SAR satellites:
Various resolutions, coverages, frequencies, repeat periods, prices, etc.

<table>
<thead>
<tr>
<th>SAR på satellitt</th>
<th>resolution x,y</th>
<th>Life span</th>
<th>Repeat period</th>
<th>Scene size</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERS-1/ERS-2</td>
<td>50 m</td>
<td>1992 - 2001</td>
<td>35 days</td>
<td>100 x 100 km</td>
</tr>
<tr>
<td>Envisat</td>
<td>50 m</td>
<td>2003 - 2010</td>
<td>35 days</td>
<td>100 x 100 km</td>
</tr>
<tr>
<td>Radarsat-1</td>
<td>25 m</td>
<td>1995 -</td>
<td>24 days</td>
<td>50 x 50 km</td>
</tr>
<tr>
<td>Radarsat-2</td>
<td>Ultrafine: 2.1-4.6 x 2.8 m Fine: 7-10 x 8 m Standard: 17-27 x 25 m</td>
<td>2007 -</td>
<td>24 days</td>
<td>Ultrafine: 20 x 20 km Fine: 50 x 50 km Standard: 100 x 100 km</td>
</tr>
<tr>
<td>TerraSAR-X</td>
<td>1.2 x 1-4 m 3 x 3-6 m 16 x 16 m</td>
<td>2007 -</td>
<td>11 days</td>
<td>5-10 x 10 km 30 x 30-50 km 100 x 100 km</td>
</tr>
<tr>
<td>CosmoSkyMed - 4 satellitter</td>
<td>1 m 3-15 m 100 m</td>
<td>2007 -</td>
<td>1-7 days *</td>
<td>10 x 10 km 40 x 40 km 200 x 200 km</td>
</tr>
<tr>
<td>Sentinel-1A/1B</td>
<td>IW: 5 x 20 m</td>
<td>2014 – 2015</td>
<td>12 days 6 days **</td>
<td>IW: 250 x 250 km</td>
</tr>
<tr>
<td>TerraSAR-X NG</td>
<td>1.2 x 1-4 m 3 x 3-6 m 16 x 16 m</td>
<td>2016 -</td>
<td>6 days**</td>
<td>5-10 x 10 km 30 x 30-50 km 100 x 100 km</td>
</tr>
<tr>
<td>Radarsat CM – 3 satellitter</td>
<td>3 m 5 m 30 m 50 m 100 m</td>
<td>2018 -</td>
<td>4 days ***</td>
<td>20 x 20 km 30 x 30 km 125 x 125 km 350 x 350 km 500 x 500 km</td>
</tr>
<tr>
<td>Cosmo-Skymed SG – CSG satellitter</td>
<td>1 m 3 m 20 m 40 m</td>
<td>2015 -</td>
<td>8 days **</td>
<td>10 x 10 km 40 x 40 km 100 x 100 km 200 x 200 km</td>
</tr>
</tbody>
</table>
Ground deformation measurements: Why SAR?

- Remote sensing → info about hard-to-access areas
- Large coverage → from punctual info to several km² coverage

Sentinel-1:

Repeat-pass interval: 12d (6d for constellation)

Coverage: 250 km (interferometric wide swath)

Resolution: 20m (azimuth) x 5m (range)

Remote sensing → info about hard-to-access areas
Large coverage → from punctual info to several km² coverage
Ground deformation measurements: Why SAR?

→ Independency to illumination & weather conditions

S1 IW 2014.09.20 16:16 (R,G,B)=(VV,VH,VV)

LS-8 2014.09.23 12:00
SAR Interferometry (InSAR)

InSAR studies phase difference between two SAR images

Two main applications:

- 2 acquisitions from 2 different locations: Generate Digital Elevation Model (DEM)
- 2 acquisitions at 2 different times: Measure millimetric deformation along the line of sight (LOS)
Examples of InSAR results

Subsidence from reservoir infilling

Geohazards

Subsidence in Oslo

ERS track 380:
SBAS 1993-2000
- Reference point
- Time serie location
Mean velocity (mm/year) along the LOS
- 6 mm/year
- -6 mm/year
InSAR on dams

Demo: maps.globesar.com
Combination of SAR geometries for retrieval of 2D deformation
InSAR on dams: Boliden’s Aitik copper mine and tailings dam
InSAR with TerraSAR-X 2016 datasets
Summer images between June and October
TerraSAR-X 2016 InSAR results

Mvel along LOS
-80 mm/yr
+80

29.97 deg

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TerraSAR-X InSAR results

X-band (3,1 cm wavelength). Repeat-pass: 11 d. Final resolution: 10 m
Sentinel-1 InSAR results

C-band (5.55 cm wavelength). Repeat-pass: 12(6) d. Final resolution: 40 m
Comparison time series TSX-S1

Note:
Not corrected for difference in LOS orientation;
Not corrected for different time reference
InSAR - Aitik: Conclusion and Further work

• Promising InSAR results confirming the value of InSAR for monitoring of dam stability
• Good match of TerraSAR-X and Sentinel-1 results

Next steps:
• Combination of ascending & descending geometries: 2DInSAR for retrieval of vertical/horizontal components
• Comparison with other deformation info
  In situ measurements / info about areas under construction during the measurement period, etc.
• Processing of 2017 SAR images
Thanks for your attention!
Kiitos huomiostanne!

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