Use of space-borne DInSAR data to optimize landslide numerical models: the example of an ancient landslide in El Portalet, Central Pyrenees, Spain

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DInSAR for (slow-moving) landslides

→ Identify unknown instable slopes
→ Build up/update landslide maps
→ Monitor the evolution of landslides over space and time

DInSAR limitation: measurements along LOS, but for landslides 3D surface deformation is important...
Landslides 3-D deformation: Why?

→ Understanding driving processes
→ Better assess hazard potential
→ Build interpretative models & scenarios

Physically based models can help in determining the 3D surface deformation field in instable slope areas
Tena Valley, Central Pyrenees

Famous place for ski resorts, but...
ERS-ENVISAT Results: 1993-2008

El Portalet landslide
Linear evolution of the surface displacements over the 15-years observation period

DInSAR retrieves surface displacements along satellite LOS only

Additional information is necessary for a more accurate assessment of the landslide behavior
Standard modeling approach

Geomorphology
Geophysics
Borehole logging → Model geometry

Geophysics and/or laboratory tests → Material parameters

Displacement results

DInSAR data ← LOS projection
Our modeling approach

Geomorphology → Geophysics → Borehole logging → Model geometry

DInSAR data → LOS projection → FEM optimization (GA) → Displacement results

↑ GA iterations

FEM model solution
best fit of DInSAR data

Manconi et al. 2009
First step: 2D FEM optimization

Geometry defined from field and geomorphological analyses

Shear band position and width from borehole inclinometric surveys

Poro-elastic FE model

<table>
<thead>
<tr>
<th></th>
<th>Young’s Modulus (Pa)</th>
<th>Poisson’s ratio</th>
<th>Porosity</th>
<th>Permeability (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower bound</td>
<td>$1e8$</td>
<td>0.2</td>
<td>0.01</td>
<td>$1e-19$</td>
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<tr>
<td>Upper bound</td>
<td>$1e10$</td>
<td>0.4</td>
<td>0.5</td>
<td>$1e-14$</td>
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</table>
2D FEM modeling results

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<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Colluvium</td>
<td>1.48e9 – 2.87e9</td>
<td>0.32 – 0.39</td>
<td>0.37 – 0.41</td>
<td>1.4e-15 – 6.3e-15</td>
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<tr>
<td>Shear band</td>
<td>3.4e9 – 9.32e9</td>
<td>0.20 – 0.37</td>
<td>0.3 – 0.44</td>
<td>4.0e16 – 9.5e-15</td>
</tr>
</tbody>
</table>

Away from the satellite LOS (however, not visible in the InSAR dataset)

Towards the satellite LOS
2-3 mm/year

LOS displacement

-3 < mm/year < 3
2D FEM modeling results

Modeling results allow exploiting 2D deformation field, and thus better interpreting the landslide behavior.
Additional field constraints

Seismic tomography to constrain the position of the sliding surface
We build up a 3D geometry by considering the high resolution DEM of the area and the 3D sliding surface derived from geophysical data.
Starting from 1D surface deformation measured by DInSAR we retrieve the 3D components of the surface deformation field.
3D Numerical Modeling: results

3D surface displacements

Vertical displacement

-1 < cm/year < 1
Summary

→ DInSAR is a powerful remote sensing technique to measure surface deformation over instable slopes, however 3D surface displacements can be rarely retrieved from DInSAR only analyses.

→ Numerical Models can be a convenient tool to combine remote sensing, field data, and other available information, to better assess surface deformation.

→ We have successfully applied FEM optimization approach to the El Portalet landslide in order to retrieve 3D surface deformation maps.
AIS monitoring @ El Portalet, Spain

Continuous monitoring since August 2014, main sliding surface in agreement with previous information from inclinometric surveys (13m depth)
AIS displacements vs. rainfall data
Thanks for your attention!

http://www.lampre-project.eu/