Detection of damages due to slow landslide through the three-dimensional Finite Element modeling of DInSAR measurements and in situ surveys

Michele Manunta, Raffaele Castaldo, Vincenzo De Novellis, Piernicola Lollino, Pietro Tizzani

CNR-IREA, Napoli, Italy

CNR-IRPI, Bari, Italy

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The case study: Ivancich landslide

The landslide site has been extensively investigated through in-situ surveys. In particular, deep boreholes and inclinometer measurements are available, providing information on the geological setup and geotechnical properties of the landslide body.
Multi-sensor SBAS approach: key points

The **SBAS** approach allows to produce “long term” deformation times-series by:

- exploiting interferograms characterized by a “**small baseline**” in order to limit the noise (decorrelation) phenomena, thus maximizing the number of investigated pixels;
- using **no a priori or model information** on the investigated deformation signal.
- merging SAR data geometrically compatible but acquired by **different sensors (ERS-ENVISAT)**;

**Achieved accuracies:**

- ≈ 1 - 2 mm/year on the mean deformation velocity
- ≈ 5 - 10 mm on the single displacement
C- and X-Band SAR Datasets

91 Descending ERS-1/2 and 39 ENVISAT (130 scenes) 1992-2010

39 Descending CSK December 2009 – February 2012
1992-2010 ERS-ENVISAT Results
1992-2010 ERS-ENVISAT Results

 LOS Inclinometer

\[ \Delta \text{ LOS SAR} \]

\[ \text{LOS Inclinometer} \]

\[ \sigma = 0.5 \text{ cm} \]
2D Inverse Finite Element Modeling

SS': Longitudinal Section of the Landslide

4 Inclinometers (103, 113, 117, 202) recorded in the 1998-2009 time period

Detailed Geological and Geotechnical Information
FE Modelling Inversion: Flow Chart

FIELD DATA INPUT
- Deformation Time Series

NUMERICAL MODEL INPUT
- Slope geometry

Model

BEST-FIT SOLUTION AND PARAMETERS


Boundary conditions

Legend
- Limestone
- Arenaceous Marl
- Shear band
- Landslide debris

Fixed parameters:
- Fixed parameters
- Fixed parameters
- Fixed parameters
- Fixed parameters

Unknown parameters:
$\alpha_n$

Boundary conditions:
- Newtonian Viscosity
- Creep Rate

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Best-Fit Solution: Model vs. ERS/ENVISAT data
Best-Fit Solution: Model vs. Inclinometric Data

- Inclinometric data
- Newtonian model
- Creep model

Displacement [cm]

Time [yr]

Displacement [cm]

Time [yr]
2D Temporal Behavior

Amplitude Deformation Velocity

Distance [m]

Height [m]

Displacement [cm]

Amplitude

Deformation

Velocity

[cm]

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From 2 to 3 Dimensional Analyses
From 2 to 3 Dimensional Analyses

- limestone
  - Upper Jurassic Cretaceous
- fluvial and lacustrine deposits
  - Pleistocene
- debris deposits
  - Holocene
- pelitic sandstone
  - Miocene
- colluvial deposits
  - Holocene

North [m]
East [m]
0m a.s.l.

From 2 to 3 Dimensional Analyses

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From 2 to 3 Dimensional Analyses
2009-2012 CSK Results
3D FE Model Results

3D Modelled Data

CSK SBAS Results
3D FE Model Results

CSK SBAS Results

SBAS-Model Residuals

LOS mean velocity [cm/yr]

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3D FE Model Results

Velocity [cm/yr]

0  0.5  1  1.5  1  0.25

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3D FE Model Results

Displacement [cm]

Inclinometer 117
3D FE Model Results vs. Geomorphological Analysis
Shear Rate Map
Shear Rate Map and Structure Damages

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Conclusive Remarks

- An approach to integrate, within a Finite Element Model, surface deformation measurements retrieved through the multi-sensor and multi-scale SBAS-DInSAR algorithm with in-situ observations and geological information has been presented.

- The FE model inversion allows finding best-fit solution in an efficient and effective way.

.... and further developments

- Exploitation of long term deformation time series for retrieving the triggering factors of the investigated landslide phenomenon.

- Refinement of the FEM modeling approach for taking into account a large number of physical scenarios and case studies where less information than the Ivancich landslide are available.