ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

Sistema Nazionale per la Protezione dell'Ambiente

SUMMER SCHOOL WORKSHOP

ACTION 2020-2-21:
COPERNICUS
FOR CULTURAL HERITAGE

Cyprus University of Technology

DLR

Geotechnical engineering for the preservation of cultural heritage and the possible aid of Earth Observation data

Alessandro Flora, Emilio Bilotta, Gianluigi Della Ragione

University of Napoli Federico II, ITALY

13-16.06.2023

PARCO REGIONALE DELL'APPIA ANTICA
Ex Cartiera Latina - Via Appia Antica, 42

Presentation outline

- Geotechnical engineering and the preservation of built heritage: TC301 of ISSMGE
- Geotechnical problems of interest
- Monitoring issues
- Final remarks

Technical Committee TC301 on the Preservation of Monuments and Historic Sites

of ISSMGE (*International Society of Soil Mechanics and Geotechnical Engineering*)

https://tc301-historic-sites.com/

Supported by AGI *(Associazione Geotecnica Italiana)*

PERIOD 2021-2025:

- Chair: A. Flora (Italy)
- Secretary: T. Jitesh (India)
- 42 active members from 20 countries

TERMS OF REFERENCE:

1. Dissemination
2. Guidelines and recommendations
3. Conference assistance
4. Industry links

Technical Committee TC301 on the Preservation of Monuments and Historic Sites

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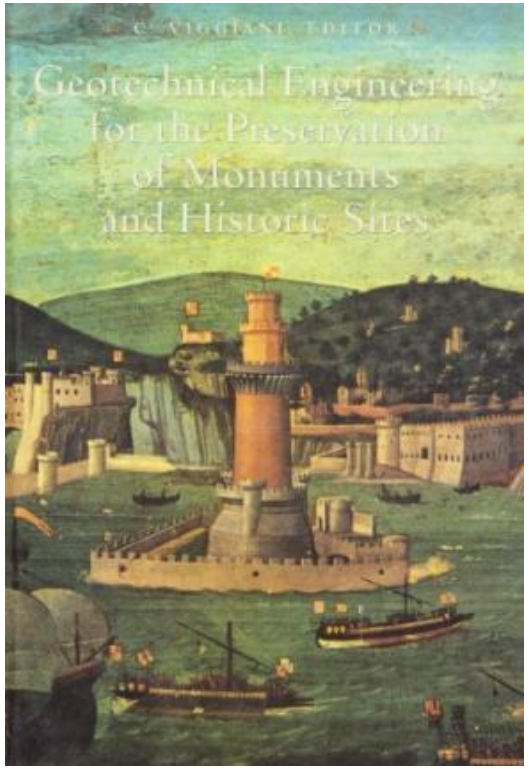
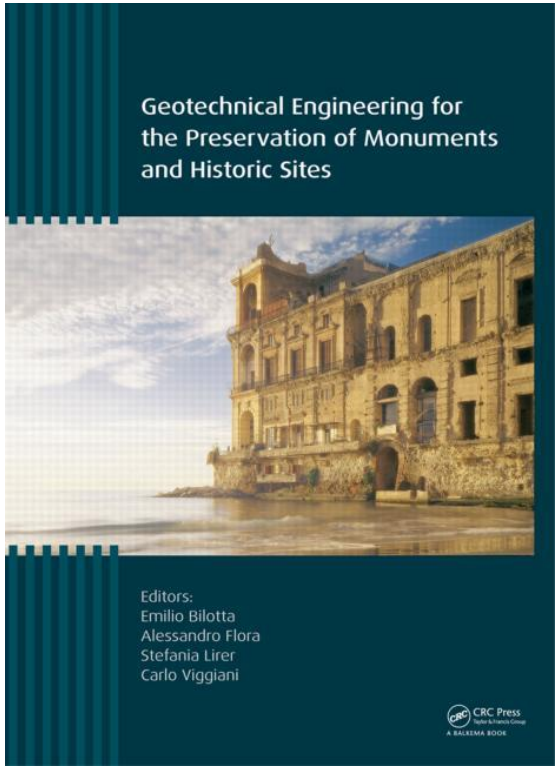
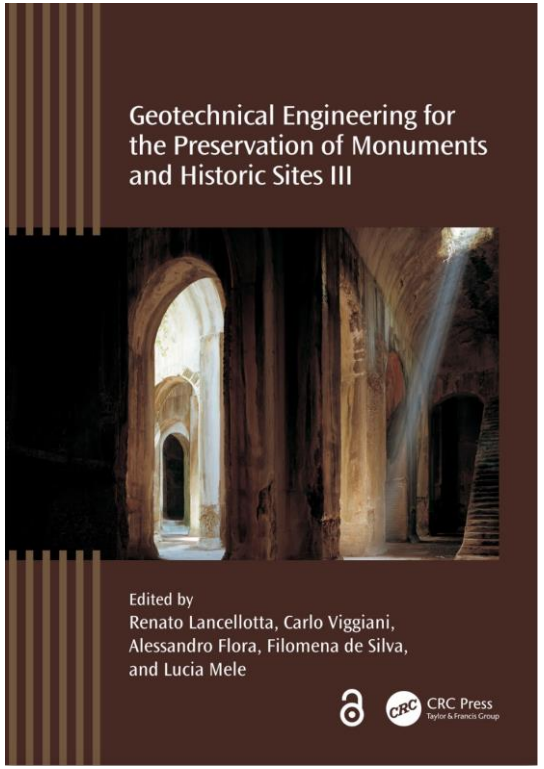
Dissemination (and conference assistance)



1997



2013



2022

Technical Committee TC301 on the Preservation of Monuments and Historic Sites

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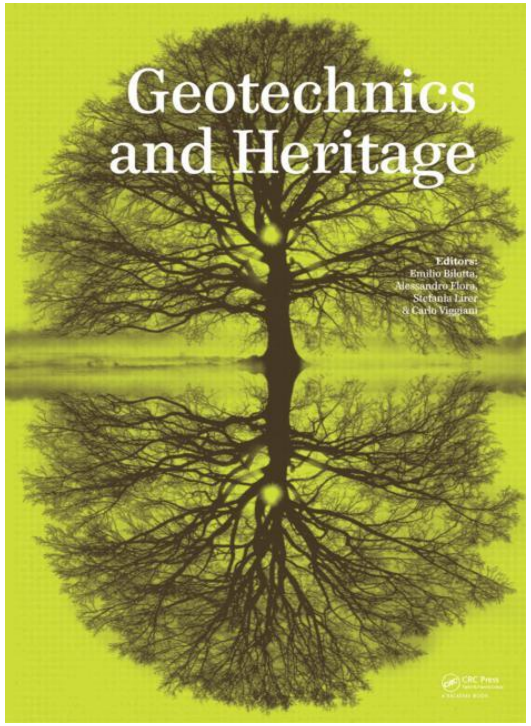
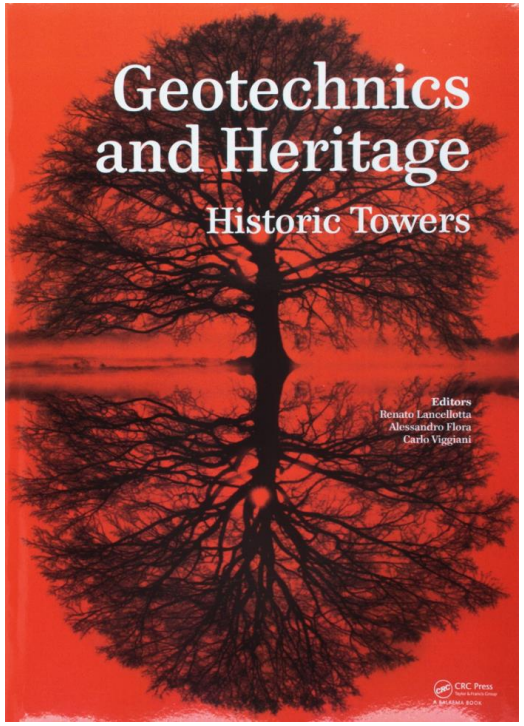
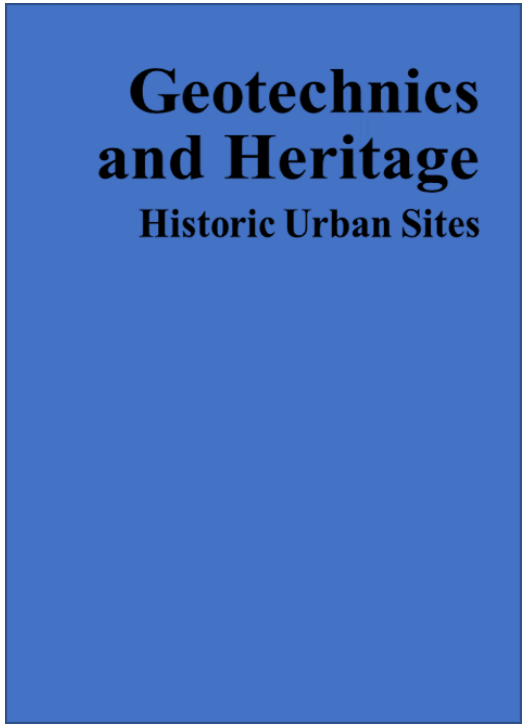
Guidelines an recommendations



2013



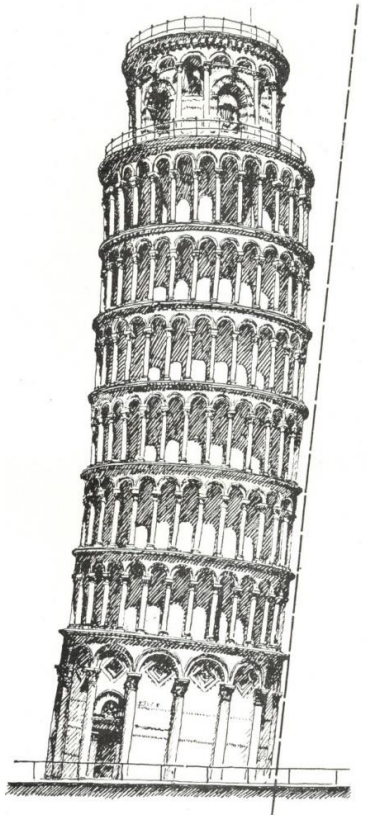
2018



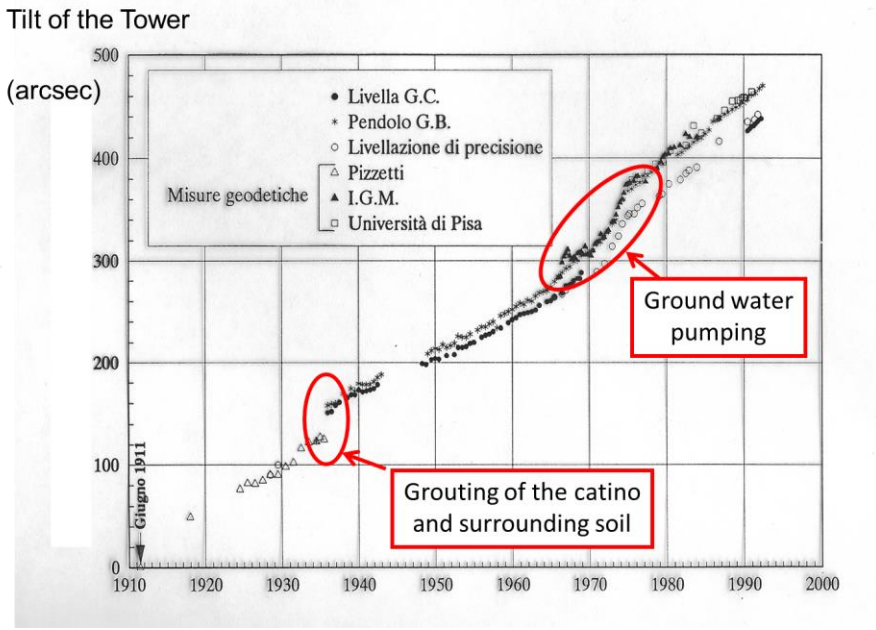
2024

Geotechnical problems of interest

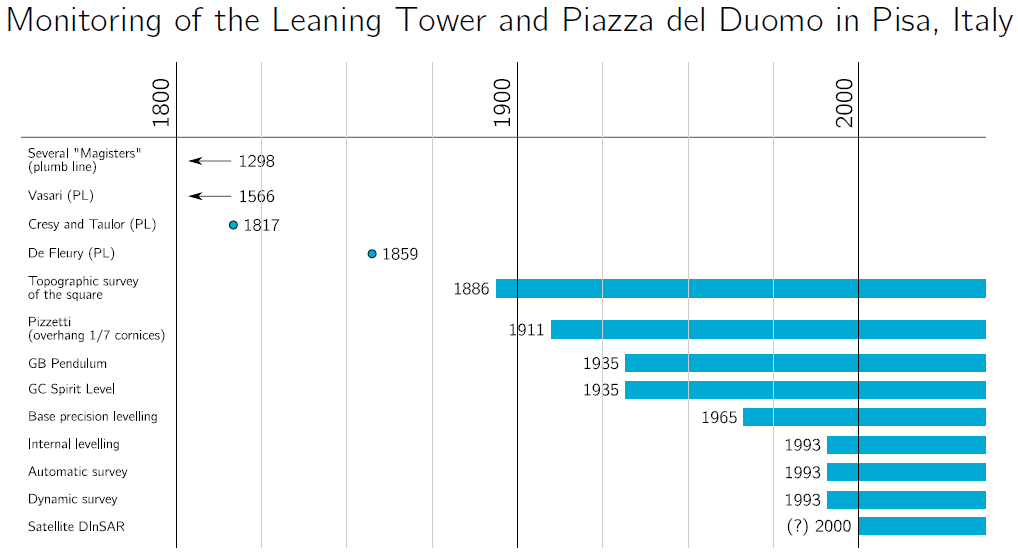
At the scale of the single structure: rotation of foundations



Pisa Tower (Italy)



Viggiani et al., 2011

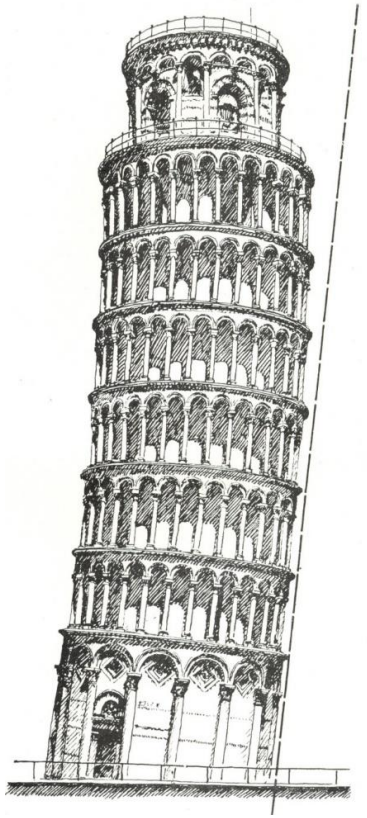


De Falco et al., 2022

slow (but accelerated, before underexcavation in the 1990's) mechanism

Geotechnical problems of interest

At the scale of the single structure: rotation of foundations



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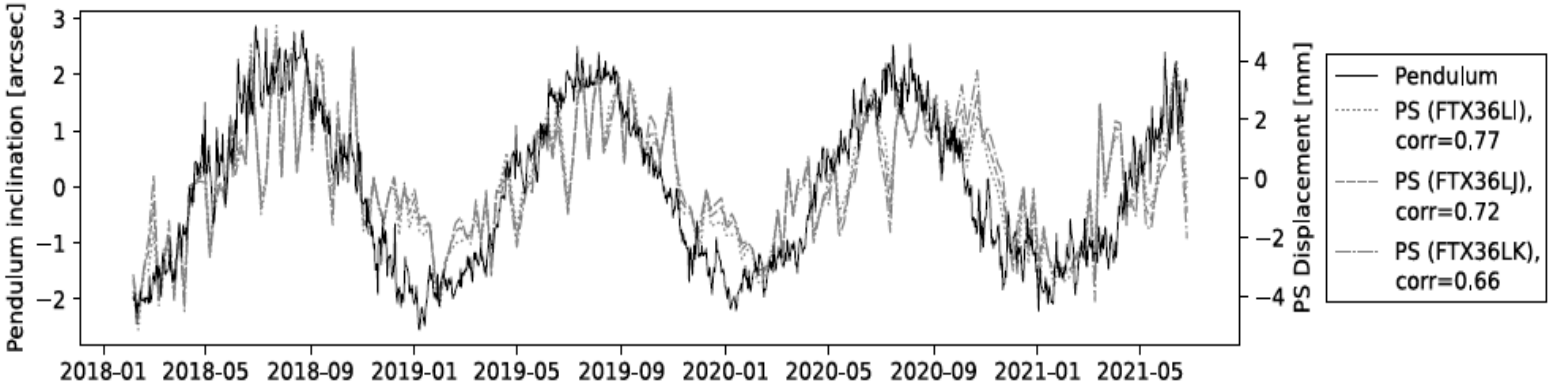


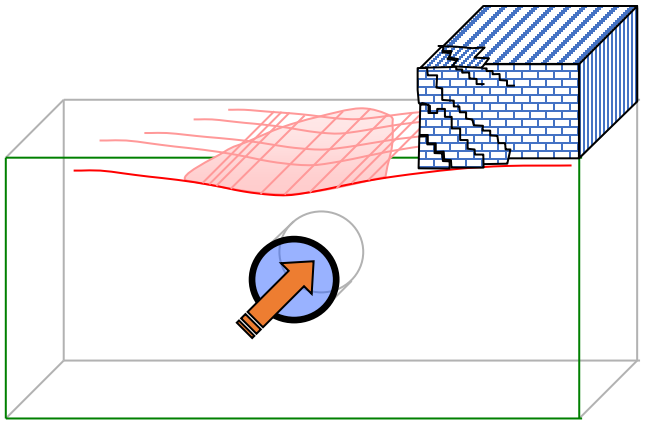
Comparison of the seasonal components of traditional (pendulum measured via telecoordinometer) and satellite (PS FTX36LI, -LJ and -LK) monitoring data for the Leaning Tower.

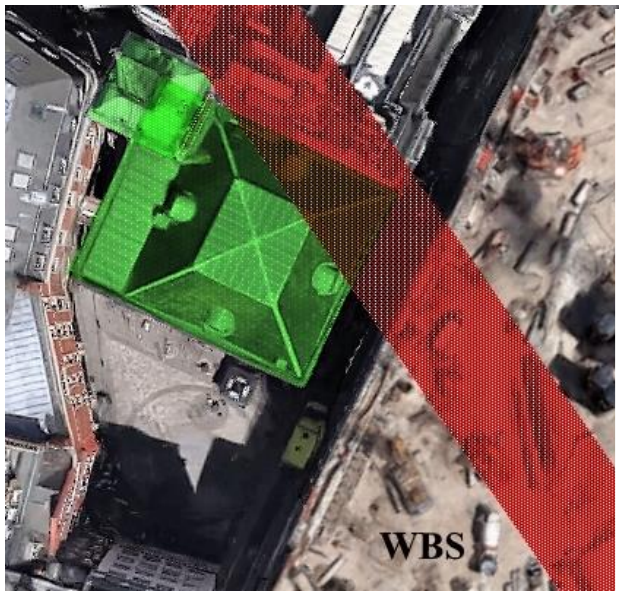
De Falco et al.,2022

Excellent agreement on tower's inclination measurements

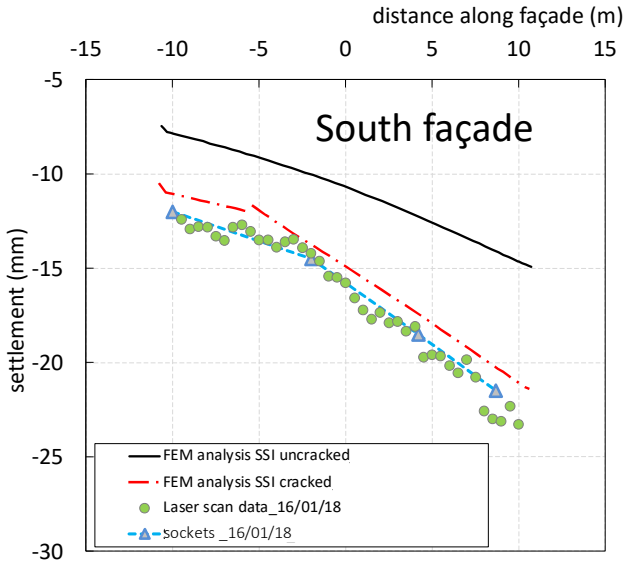
Geotechnical problems of interest

At the scale of the single structure: settlements caused by underground excavation





St. Mary's Abchurch (London, UK)

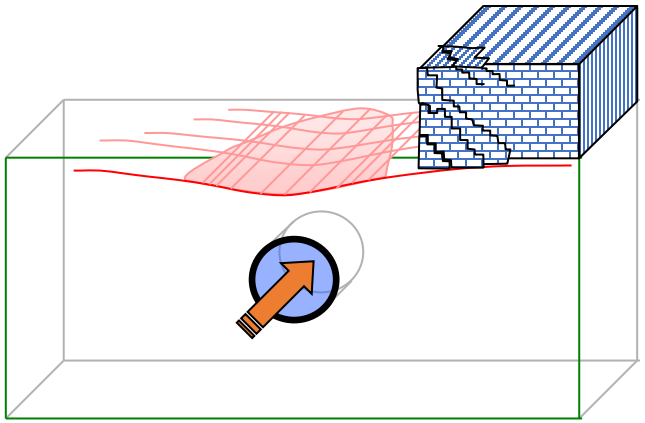


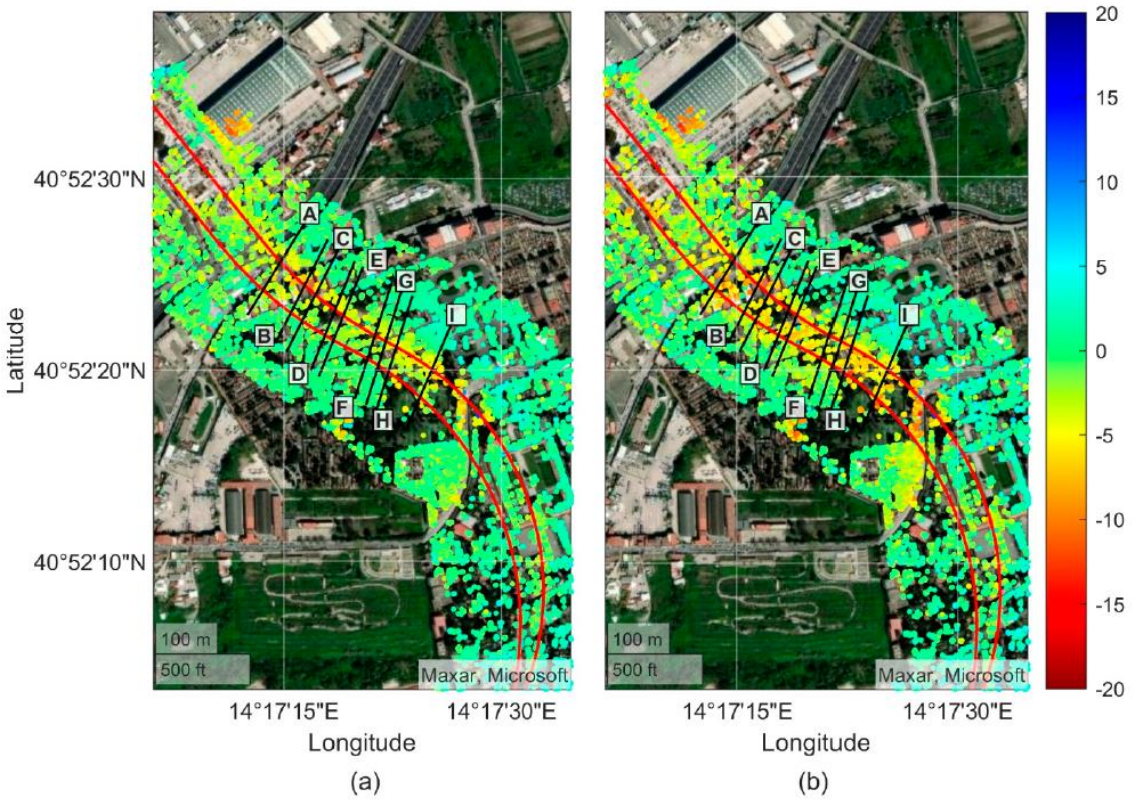
Pascariello et al. 2023

Usually slow mechanism

Geotechnical problems of interest

At the scale of the single structure: settlements caused by underground excavation





Subway line 1 (Naples, Italy)

Della Ragione et al. 2023

Usually slow mechanism

Geotechnical problems of interest

At the scale of the single structure: seismically induced structural inertial damages

Walls of Constantinople (Turkey)

T19: North side

T19: South side

Flora, 2022

seismic soil-structure interaction: fast mechanism

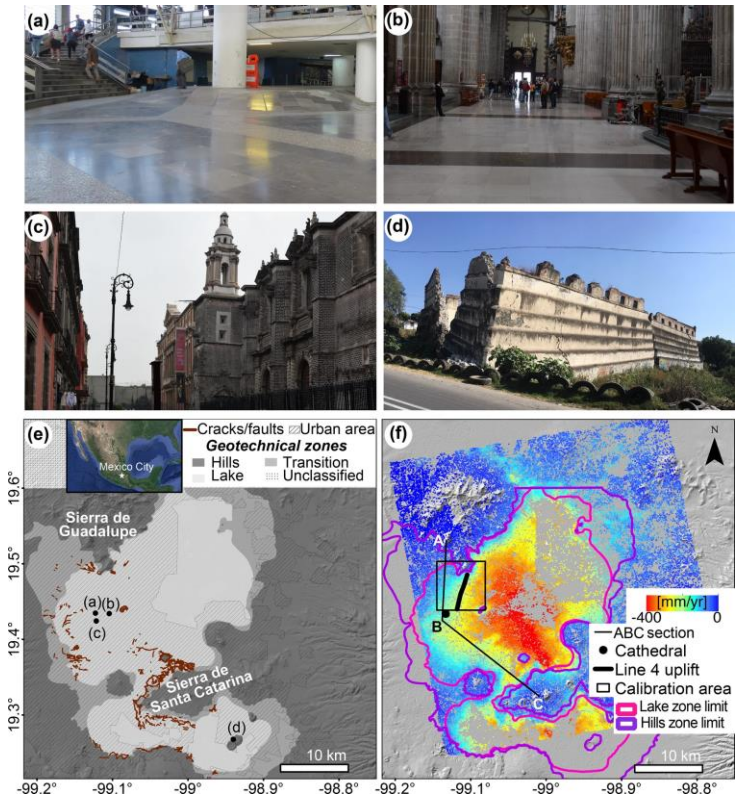
Geotechnical problems of interest

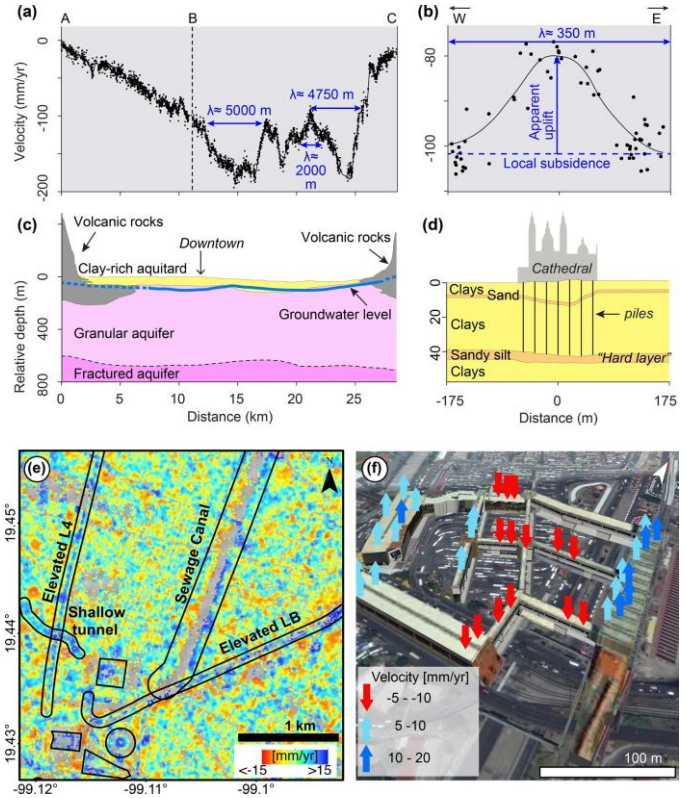
At the scale of the single structure: seismically induced lack of bearing capacity of the foundations

soil seismic liquefaction: fast mechanism

Geotechnical problems of interest

Problems at urban scale: subsidence





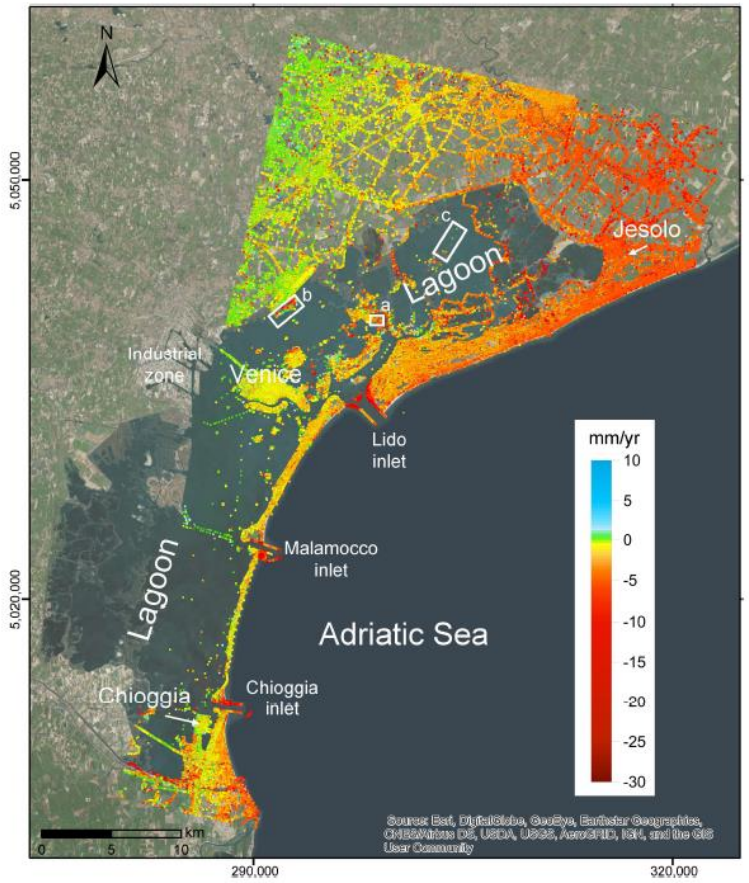
Mexico city (Mexico)

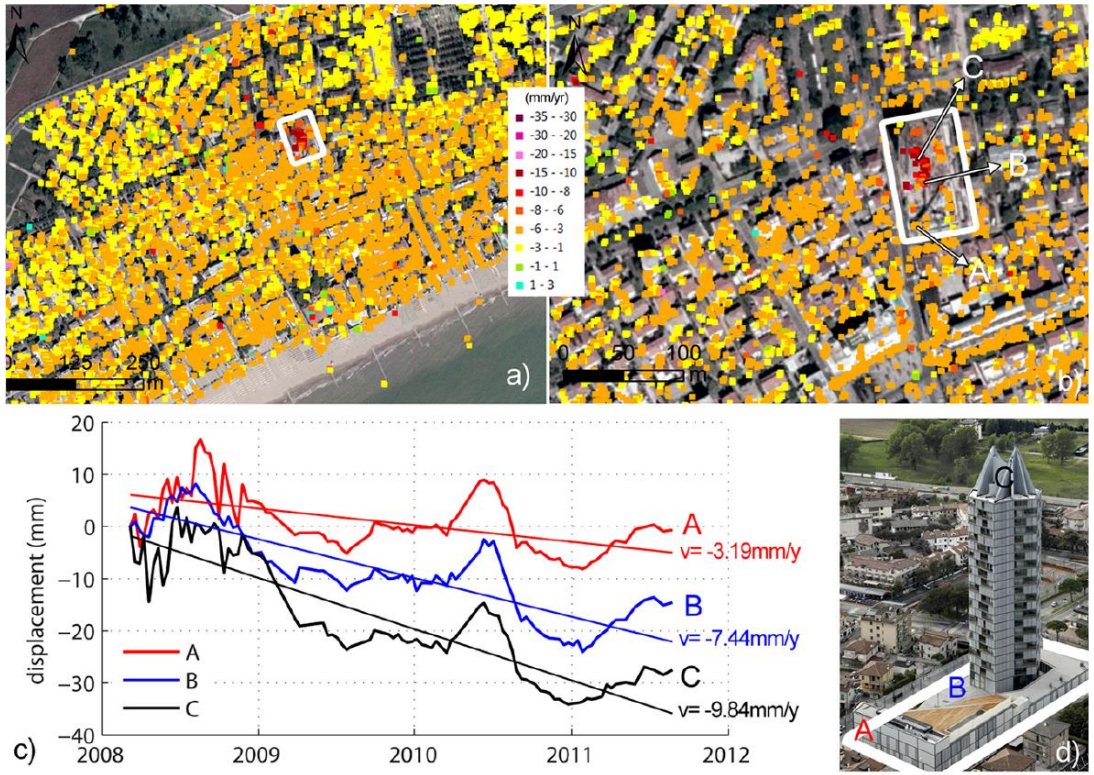
Solano-Rijas et al., 2020

detecting settlement velocities at different scales

Geotechnical problems of interest

Problems at urban and regional scale: subsidence





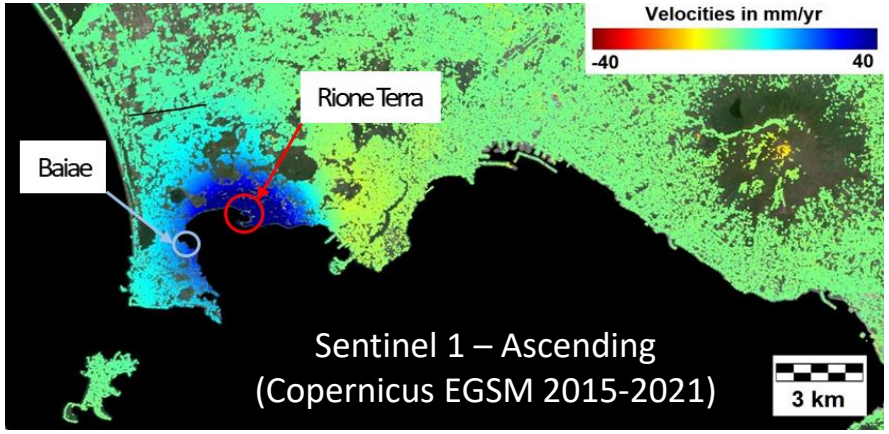
Tosi et al., 2018

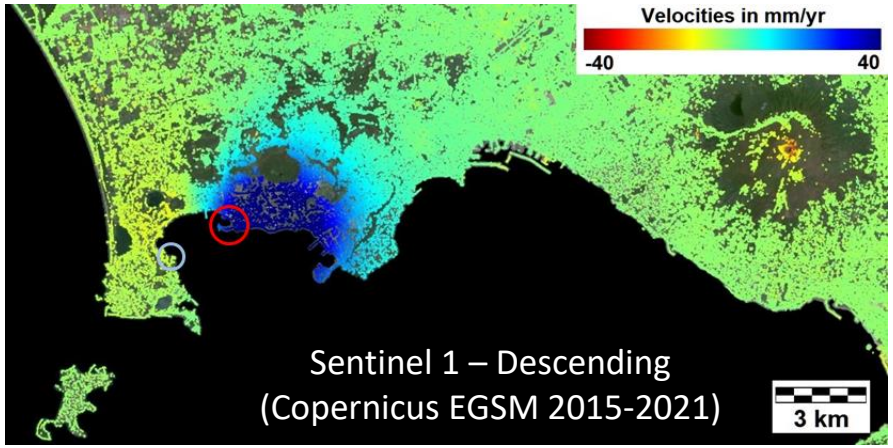
Venice (Italy)

detecting settlement velocities at different scales

Geotechnical problems of interest

Problems at urban and regional scale: bradisism





Phlegrean Fields (Napoli, Italy)

Castle of Baiae (NA)
(XV century A.D.)

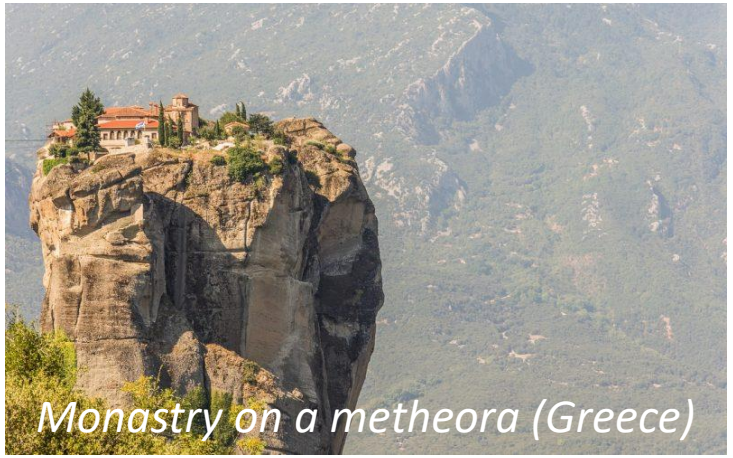
Rione Terra, Pozzuoli (NA)
(II century B.C.)

Thermal baths of Baiae
(NA) - (I century B.C.)

large upwards displacements

Geotechnical problems of interest

Problems at local and urban scale: rock landslides or rock falls



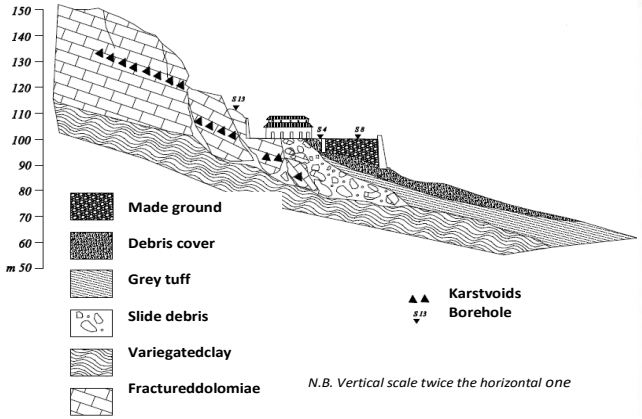
Historic sites on rocky outcrops

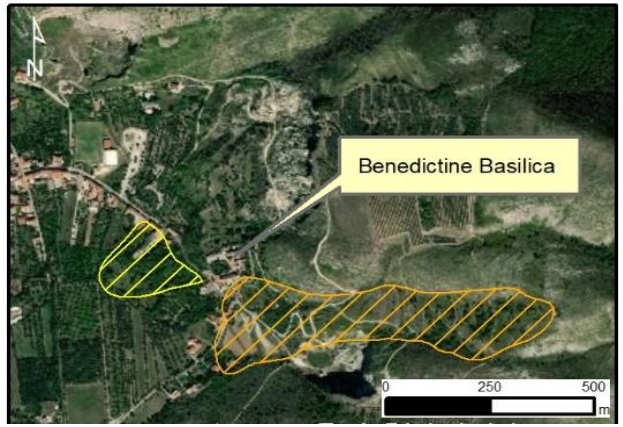
Slow or (most often) fast rock collapse mechanisms

Geotechnical problems of interest

Problems at local or large scale: landslides

Sant'Angelo in Formis (Italy)

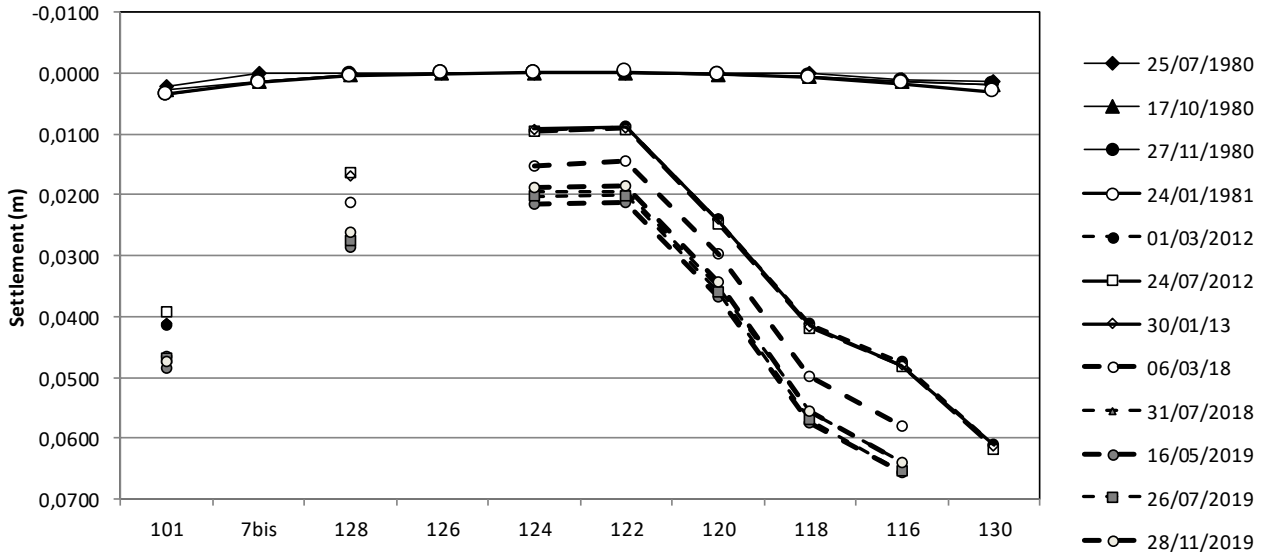




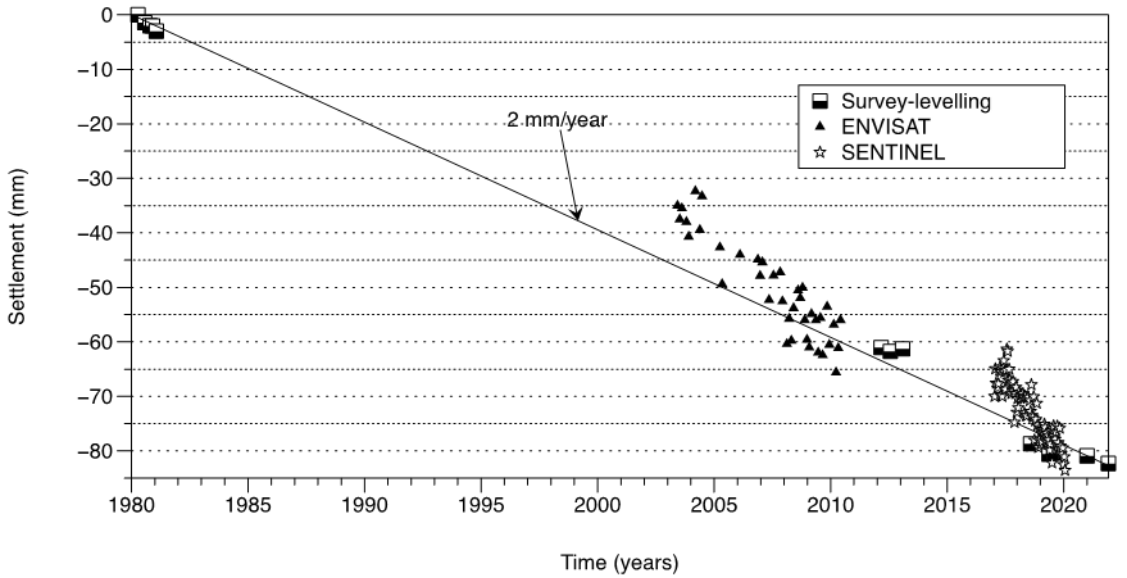
Russo, 2022

Geotechnical problems of interest

Problems at local or large scale: landslides



Sant'Angelo in Formis (Italy)



Russo, 2022

Large hogging deformation of the church floor – link with slow (and complex) slope displacements

Monitoring issues

Monitoring golden questions:

- What is the problem my site/structure is facing?
- Do we have a clear understanding of the causes of the problem, or do we just see the effects?

- What physical quantities are we interested in monitoring? What is their expected order of magnitude?
- What is the final goal of the monitoring activity (understanding an event, early-warning, etc.)?

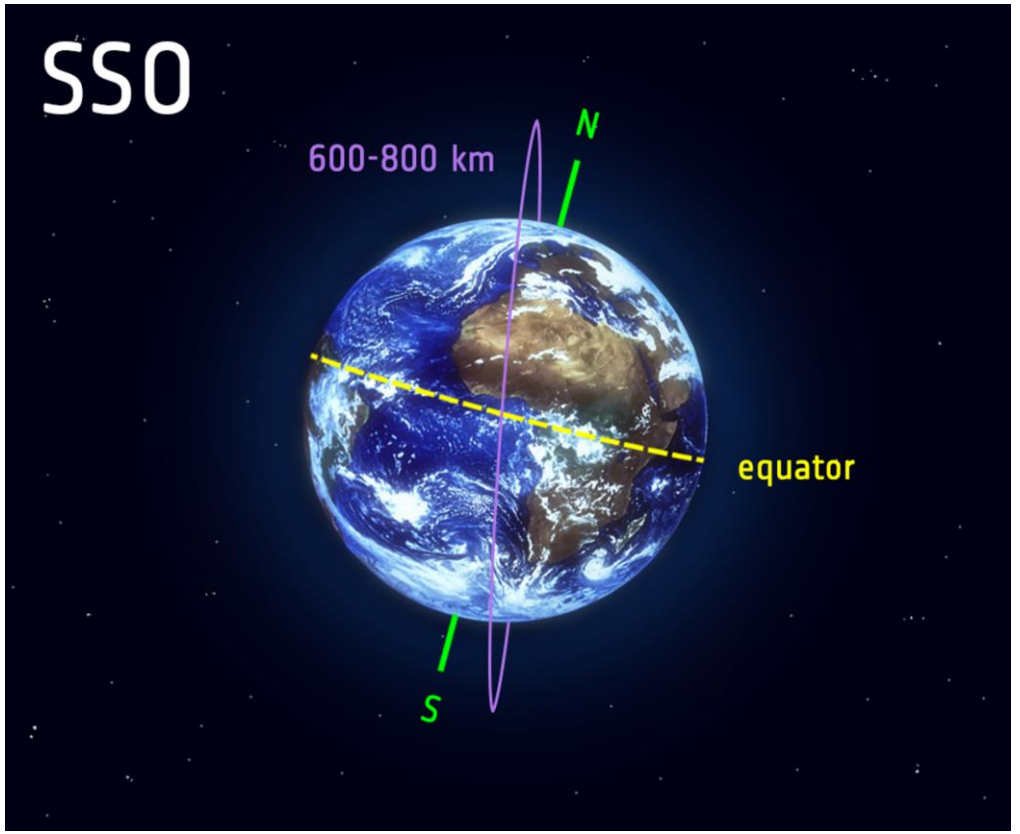
→ choice of the best suited monitoring approach

Monitoring is an answer, which is meaningless if there is no clear question

Monitoring issues

Satellites' Earth Observation

North-South (roughly) displacement components cannot be detected



Monitoring issues

Scale of the problem under investigation

single structure

local/urban

urban/regional

hazard	time span	displacements	velocity	possible aid of EO data	limitations of EO data
Uneven foundation behaviour	variable	centimeters	variable	limited	spatial resolution; urban density
Slow landslides	years	centimeters	cm/year	triggering and evolution	vegetation
Fast landslides	minutes	meters	m/s	limited (effects)	mechanism velocity; vegetation
Rock falls	seconds	meters	m/s	limited (effects)	mechanism velocity
Earthquakes	seconds	variable	m/s	limited (effects)	mechanism velocity
Subsidence/bradisism	years	decimeters	mm/year	evolution	-

Final remarks

- The complexity and variety of geotechnical problems of interest for heritage preservation indicate that satellite monitoring can be of great help

- Satellite monitoring seems not always suited for geotechnical issues (main limitations: scale, velocity, direction)

- Most relevant advantages of satellite monitoring for built heritage preservation:
  - ✓ possibility of travelling back in time (unique aid for understanding mechanisms and carrying out predictions)
  - ✓ quickly detect damages after big and widespread events (e.g. earthquakes)
  - ✓ monitor non-monitored sites
  - ✓ integrate traditional measurements (beneficial redundancy in data)