Coastal **S**atellite-**A**ssisted **G**overnance (tools, techniques, models) for **E**rosion

Coastal SAGE

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L-Università ta' Malta

MINISTRY FOR TRANSPORT, INFRASTRUCTURE AND CAPITAL PROJECTS

Xjenza The Malta Council for Science & Technology

Outline

- Introduction and motivation
- Earth Observation (EO) for coastal erosion - why and how
- The Coastal SAGE project outcomes
- Study areas around the Maltese Islands
- Stakeholder engagement and participation

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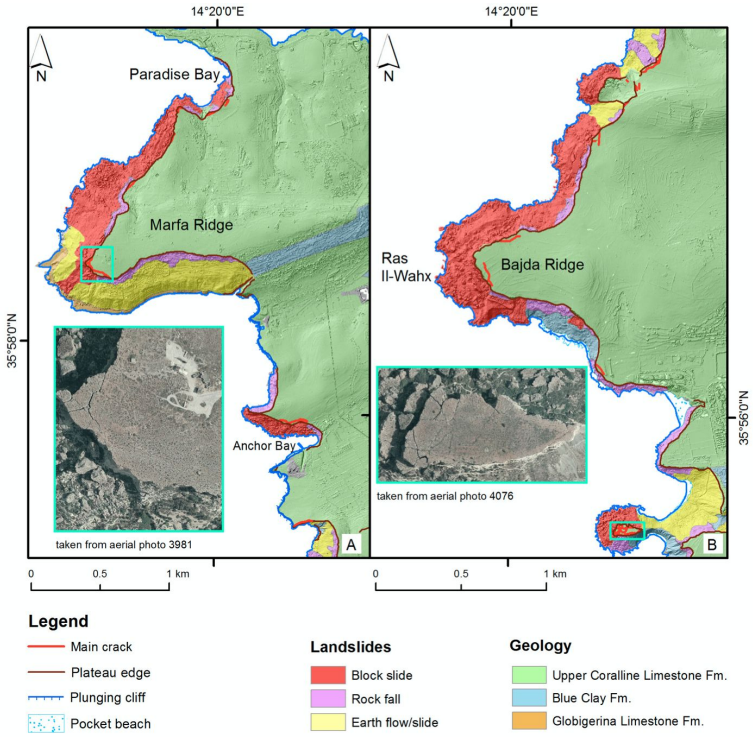
Introduction and motivation

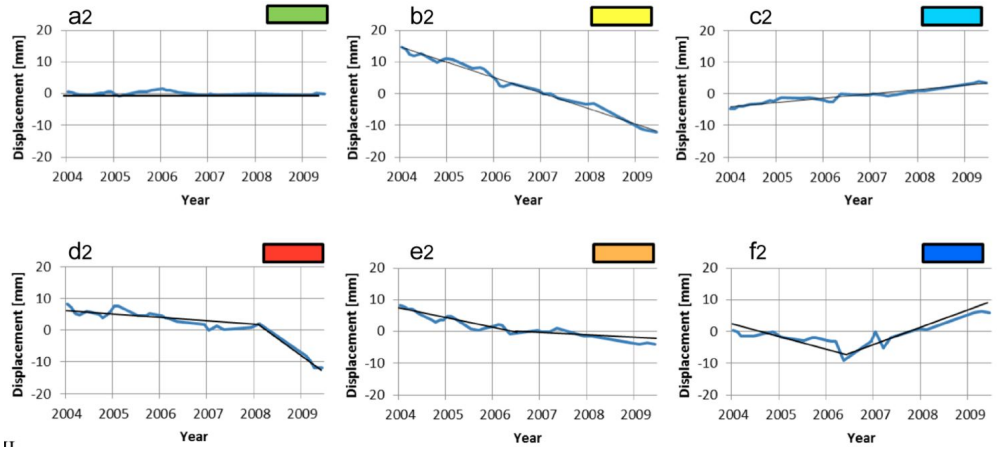
- Coastal erosion is of importance to the Maltese Islands as the coast is one of the most intensely-used and visited areas.
- Erosion along the rocky shoreline poses hazards to life, infrastructure and cultural heritage.
- Current response to this issue is mostly reactive and driven by visual site inspections.
- The Coastal SAGE project will use satellite data and related image processing and AI techniques to better monitor the phenomenon of erosion.

Introduction and motivation



Mantovani et al., Remote Sens. **2016**

- A team from CNR/UNIMORE has already studied slow-moving landslides along the NW coastline using SAR satellite data and Persistent Scatterer Interferometry techniques.
- Collaboration envisaged for the Coastal SAGE project.



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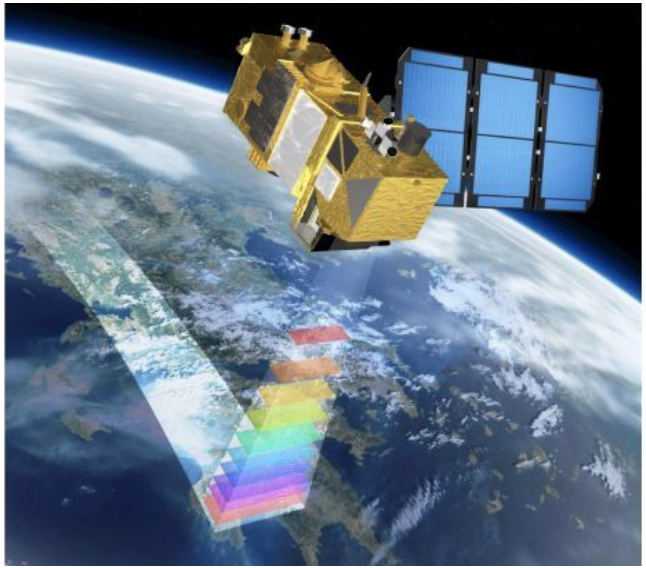
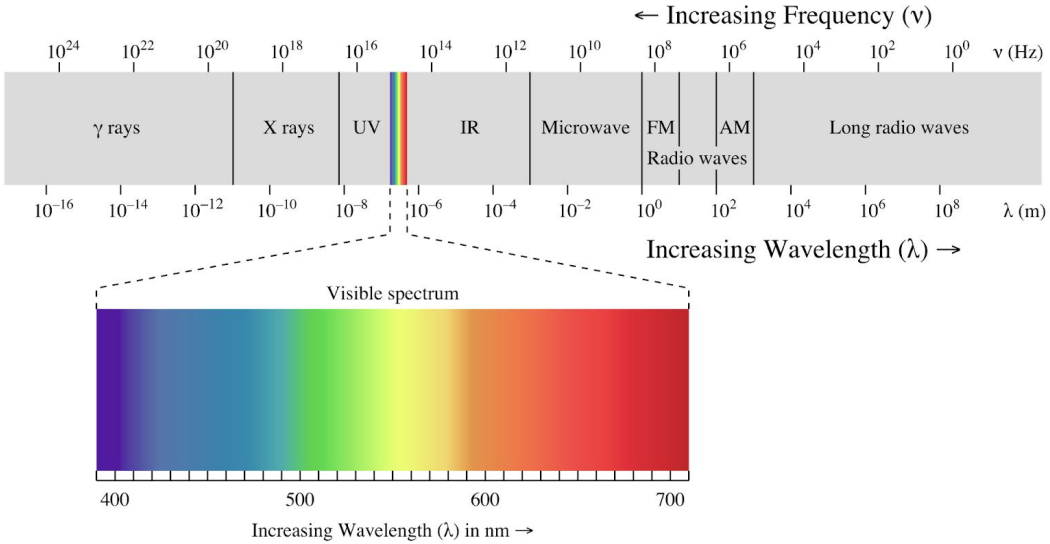
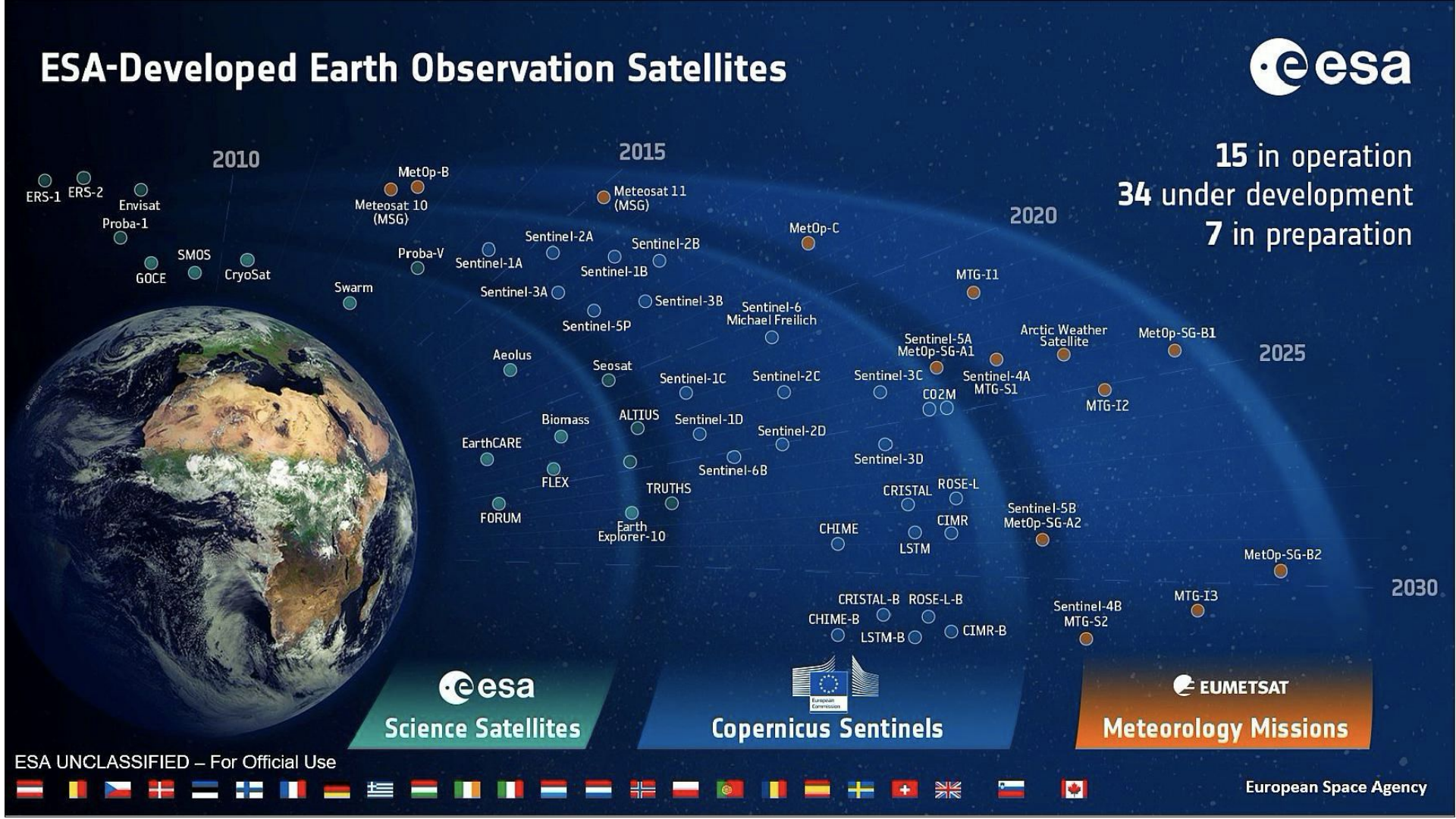
Earth Observation - a primer

- EO satellites have special ‘cameras’ onboard which can take ‘pictures’ of the Earth’s surface
- Resolution: tens of cm per pixel up to kilometres per pixel
- Revisit time of ~1 day to a couple of weeks





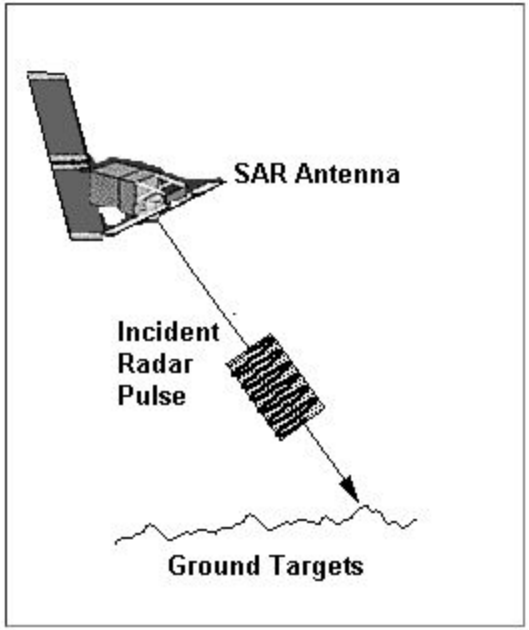
ESA-Developed Earth Observation Satellites



15 in operation
34 under development
7 in preparation

European Space Agency

Earth Observation - a primer to SAR

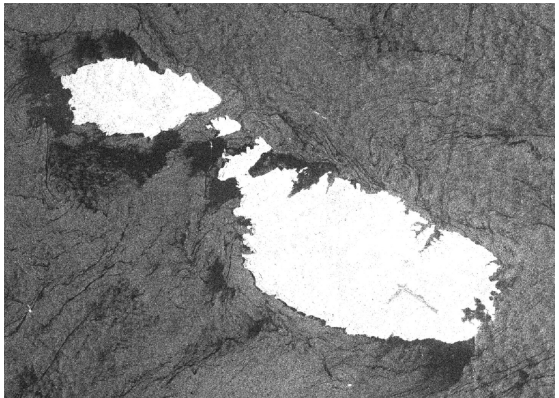


Principles of Synthetic Aperture Radar (SAR)

Water = flat & smooth => appear dark as radiation is mirrored away from the radar
Urban areas = bright due to high backscatter

Earth Observation - a primer to SAR

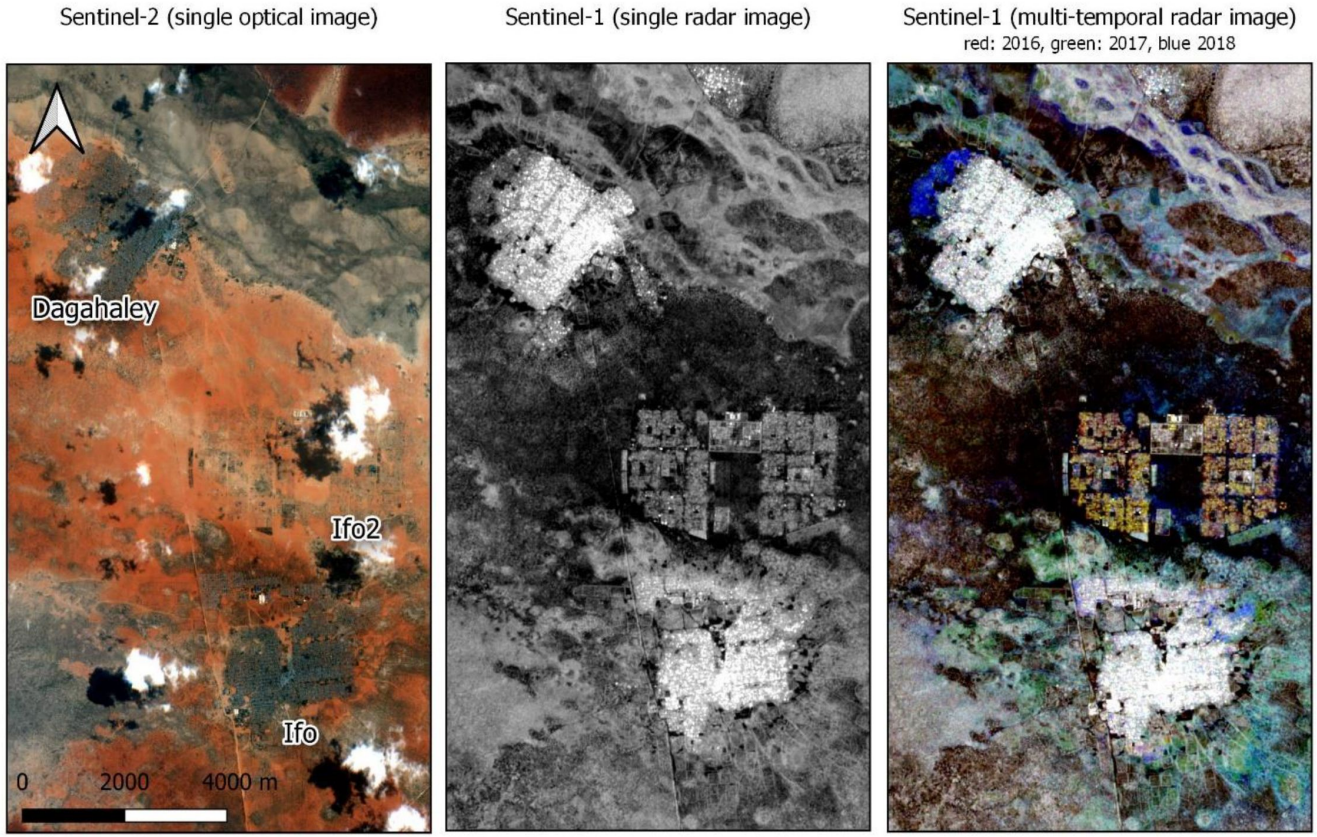
- The European Space Agency's Sentinel-1 satellites were launched in 2014-2016.
- Their Synthetic Aperture Radar (SAR) instrument monitors changes on Earth with millimetric precision.
- Spatial resolution: 5 x 20 metres
- **Applications:** land surface deformation, urbanization, agriculture, forestry, oceanography and glaciology.



SAR amplitude image of the Maltese Islands

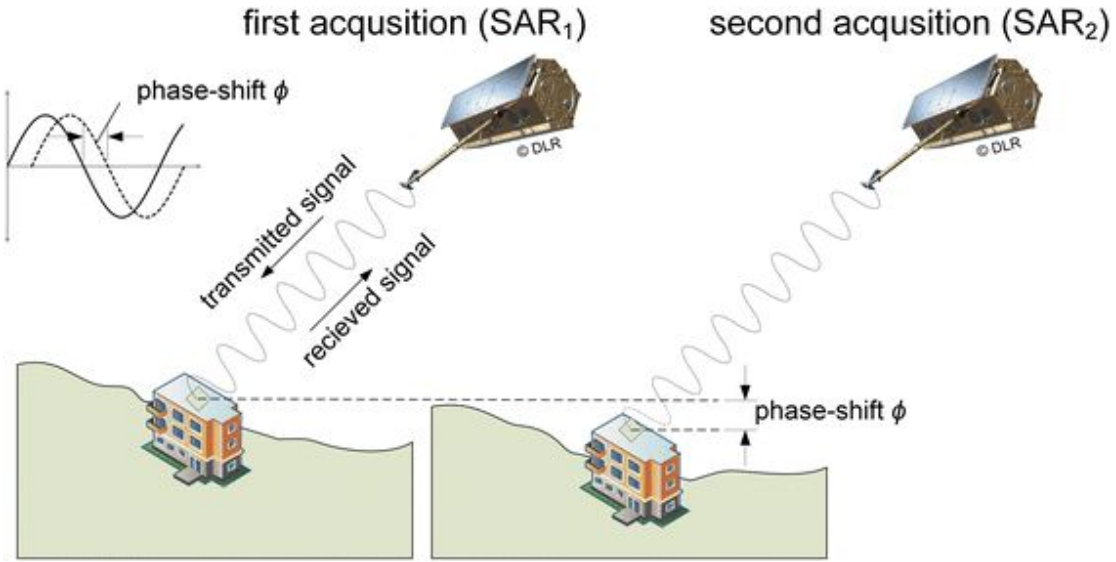
Earth Observation - a primer to SAR

Refugee camps in Kenya

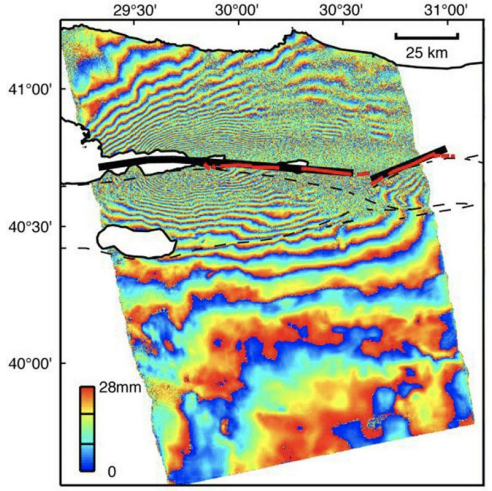


Interferometric SAR

- So far we have looked at images representing the **amplitude** of the backscattered radar.
- To measure **change**, we look at the **change in phase** of the received signal **over time**.

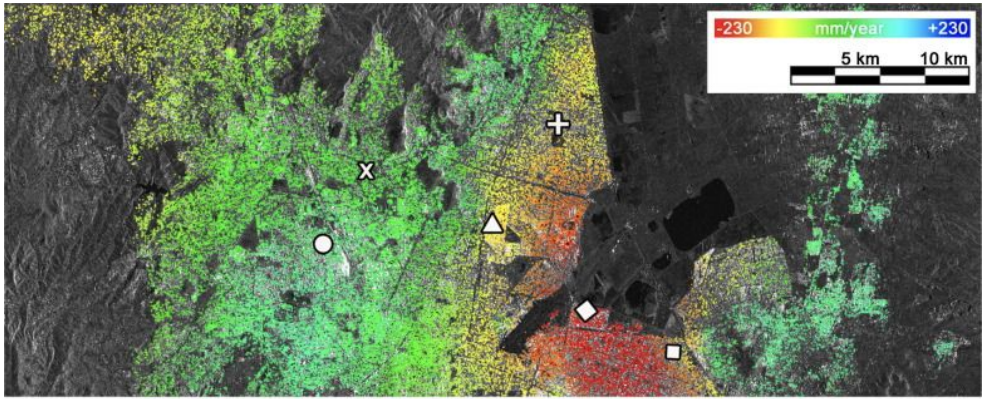


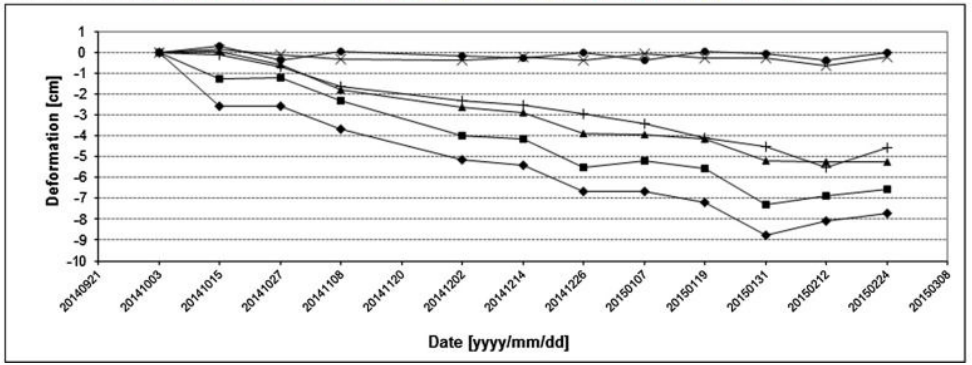
Interferogram showing land deformation in Izmit (Turkey) after earthquake.
Red lines = location of fault



Persistent Scatterer Interferometry

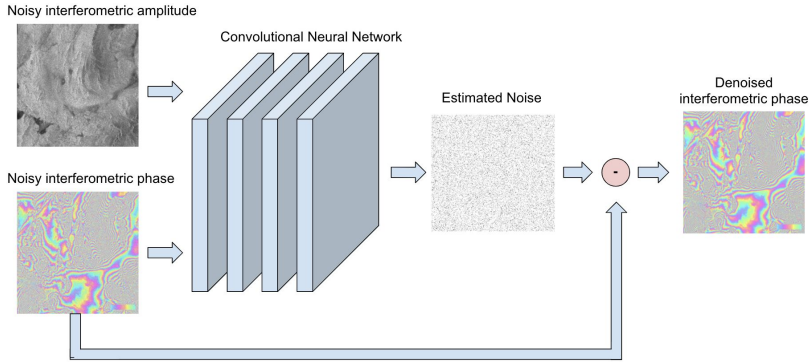
- Certain pixels in a scene may be coherent over a sequence of interferograms.
  - i.e. they reflect the signal roughly in the same way each time the satellite passes over.
- These pixels are known as **persistent scatterers.**
- Therefore, they are very useful in estimating slow deformation over time with high precision (mm).





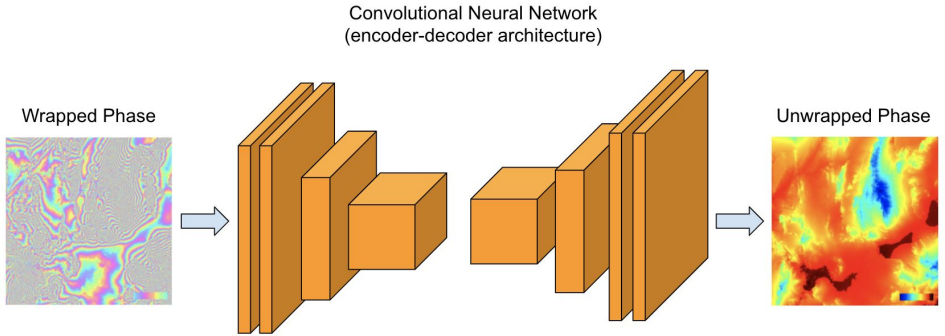
Persistent Scatterer Interferometry

Our planned research contribution is to use **Artificial Intelligence (AI)** techniques to improve the PSI pipeline:



- Improved SAR interferometric phase denoising:

- Improve the phase unwrapping procedure:



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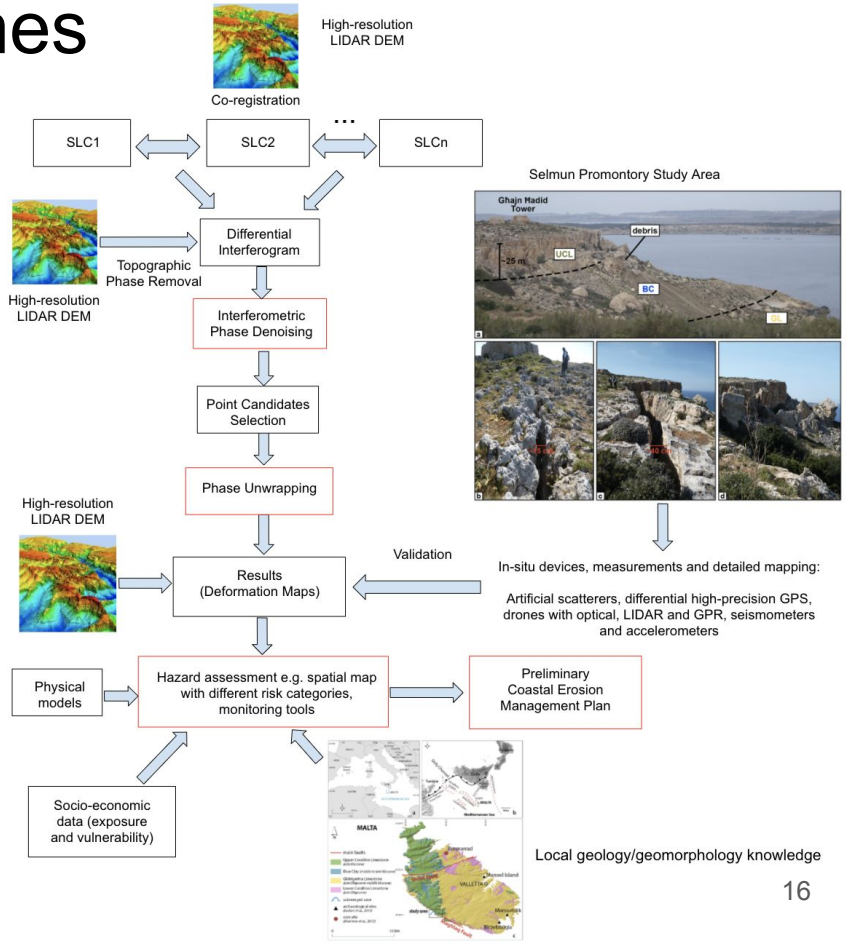
Coastal SAGE project outcomes

- Project outcomes:
  - Improving the EO data processing pipeline
  - Development of a risk assessment and monitoring tool
  - Capacity building
  - Stakeholder engagement and participation
  - Preliminary Coastal Erosion Management Plan



Coastal SAGE: project team

L-Università ta' Malta

MINISTRY FOR TRANSPORT, INFRASTRUCTURE AND CAPITAL PROJECTS

- Department of Communications and Computer Engineering
  - Dr Ing. Gianluca Valentino (PI)
  - Prof Johann A. Briffa (co-investigator)
  - Dr Ing Reuben Farrugia (co-investigator)
  - Dr Qiang Wang (Research Support Officer)
- Department of Geosciences
  - Dr Sebastiano D'Amico (co-investigator)
  - *Research Support Officer to be recruited*
- Public Works Department
  - Dr Perit George Buhagiar (co-investigator)
  - Mr Christopher Gauci (geologist)
  - Mr Sean Dimech (scientific officer)
  - Mr Daniel Fenech (GIS manager)
  - Mr Michael Cini (dissemination)

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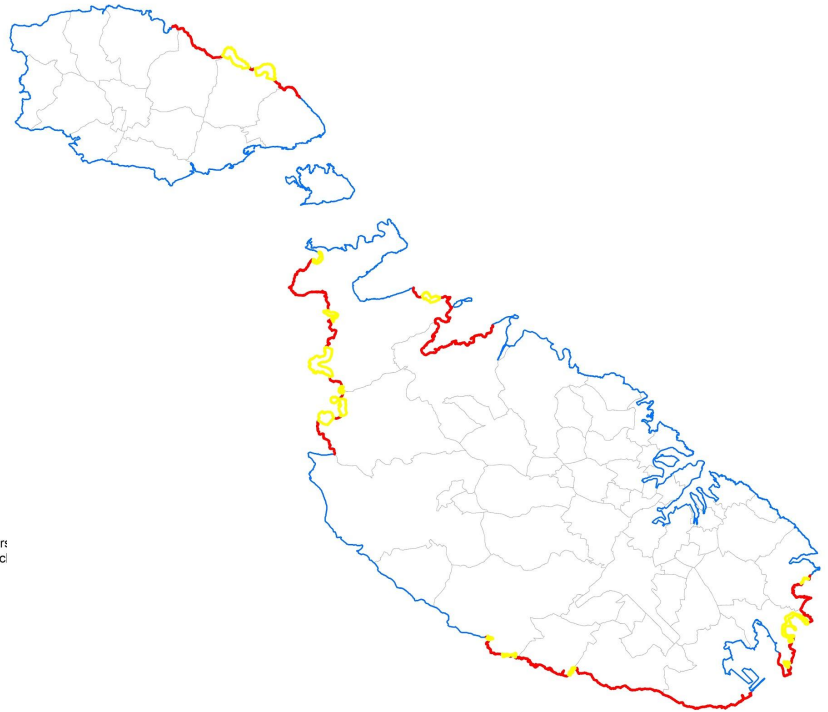
Study Areas around the Maltese Islands



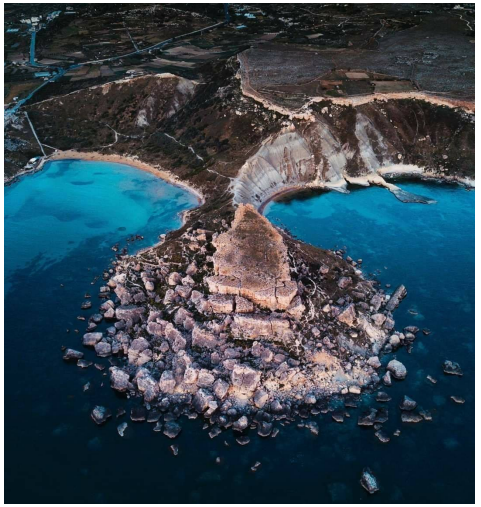
Study Area	Length of study area (km)	% of total coastline
Nadur	4.2	1.6
Northwest Malta	9.2	3.5
Selmun	1.2	0.4
Delimara	4.5	1.7
Ghar Lapsi	1.4	0.5
Blue Grotto	0.7	0.3
Total	**21.9**	**8.1**

Study Area #1 - Nadur

- Edges from the plateau are fracturing causing rock toppling/sliding on top of Blue Clay.
- As waves remove sediments from the coastline, Blue Clay seeps out to replace eroded material, causing pieces from the plateau to topple due to the remaining empty space.
- Plateaus overlook two frequented beaches at the end of the valleys (Ramla and San Blas).

Study Area #2 - North-West coastline

- Similar geological features to Nadur.
- Highly frequented due to beaches in the area
- Previously studied by CNR/University of Modena team



Study Area #3 - Selmun promontory

- Similar geology and geomorphology to Nadur and NW coastline.
- Beach area is small and directly underneath the promontory.

Study Area #4 - Delimara promontory

- Dominant geology is Globigerina Limestone.
- More susceptible to erosion, even due to wind forces.
- Areas e.g. Hofriet, St. Peter’s Pool are constantly frequented by people

Study Area #5 - Għar Lapsi

- Cut off in terms of geology due to the Maghlaq Fault, the area of Ghar Lapsi consists of Upper Coralline Limestone.
- Well frequented by bathers and boat owners.
- Presence of infrastructure (boathouses, restaurants).

Study Area #6 - Blue Grotto

- The Lower Coralline Limestone arch in the Blue Grotto area is constantly visited by tourists.
- The presence of several faults in the area create a weak spot for waves to increase the risk of erosion.

In-situ measurements

- In each of the above 6 Study areas, we will conduct in-situ measurement campaigns in specific test sites:
  - UAV missions will be flown to obtain LIDAR cloud points to construct Digital Elevation Models
  - Differential high-precision GPS for topographic campaigns
  - Fixed GPS sensors for long-term monitoring
  - Tiltmeters
  - Accelerometers
  - Artificial scatterers deployed to improve the SAR response.

Risk assessment and monitoring tool

- Gather socio-economic data
  - E.g. bathing frequency, maritime traffic, presence of infrastructure
- Develop a risk assessment matrix
  - Hazard = geologically induced situations estimated through PSI techniques
  - Exposure = socio-economic aspects
- Using the risk assessment tool, potential mitigation strategies for areas deemed to be at high risk will be postulated
  - Managerial e.g. use-zonation
  - Engineered e.g. reducing flow velocity at cliff faces
- **End result:** preliminary Coastal Erosion Management Plan

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Proposed Plan for stakeholders meetings

- Stakeholders meeting #1 (today)
  - Over 50 attendees from 20 entities present
  - Contributions by three entities (local council, climbing club, heritage entity)
  - Objectives:
    - Present the project and its goals
    - Listen to feedback, experience, needs and wants

- Stakeholders meeting #2 (mid-project ~October 2021)
  - Present interim results
  - Additional presentations from stakeholders

- Stakeholders meeting #3 (end of project ~May 2022)
  - Present final project results + developed risk assessment tool

Conclusions

- The Coastal SAGE project kicked-off in September 2020 with the aim of providing the Maltese authorities with an EO data-driven solution to develop a proactive response to the problem of coastal erosion.

- First site visits and in-situ data gathering have already begun (Ghar Lapsi, Nadur)

- Main project goals:
  - Improving the EO data processing pipeline
  - Development of a risk assessment and monitoring tool
  - Capacity building
  - Stakeholder engagement and participation
  - Preliminary Coastal Erosion Management Plan

- For further updates throughout the project: https://www.um.edu.mt/projects/coastal-sage/index.html

11th ESA Training Course in Earth Observation

Registration deadline: 31st January 2021

Acknowledgements

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