COUPLING TERRESTRIAL AND MARINE DATASETS FOR COASTAL HAZARD ASSESSMENT & RISK REDUCTION IN CHANGING ENVIRONMENTS

COORDINATING CENTRE: ICoD, Malta

PARTNER CENTRES: CERG, France, UNIMORE, Italy

REPORT ON THE RESULTS OBTAINED WITHIN THE COORDINATED PROJECTS FOR 2014

Work-package 1: Integration of terrestrial and marine data sets

In order to outline the geomorphological evolution of the north-western area of the Island of Malta, the geology and morphology of the seafloor are required. The bathymetric survey provided both the morphological data and the backscatter data from the seafloor. The latter was analysed both manually and through the TexAn software (University of Bath, UK) producing a sediment coverage map (Figure 2). Moreover, some geological sections between land and seafloor were made providing a first attempt of geological map of the seabed.

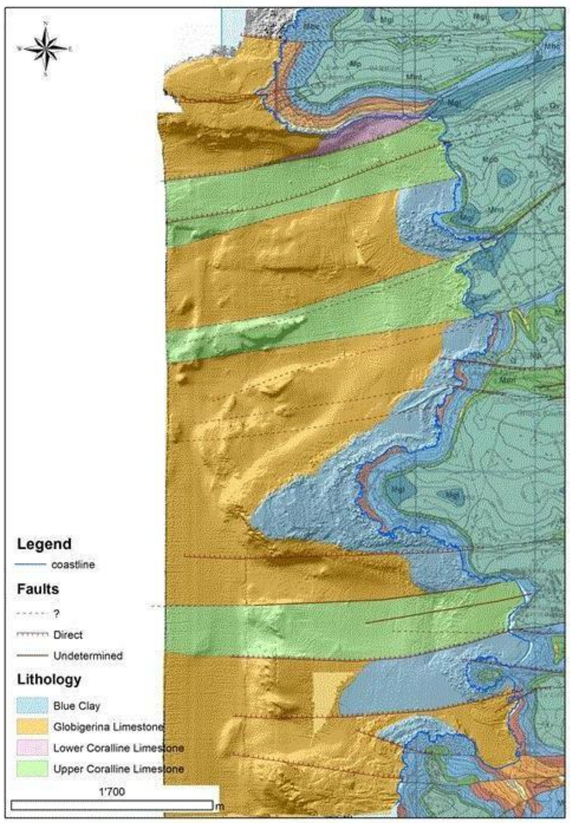


Figure 2. Seafloor geological map of the NW area of Malta. The geology on land is provided by the Geological map by Oil and Exploration Directorate (1993).

Even without a ground-truthing through samples, the two maps (sediment coverage and geology) result to be consistent. Crossing them with the geomorphological interpretation, a geomorphological map of the seafloor was produced (Figure 3).

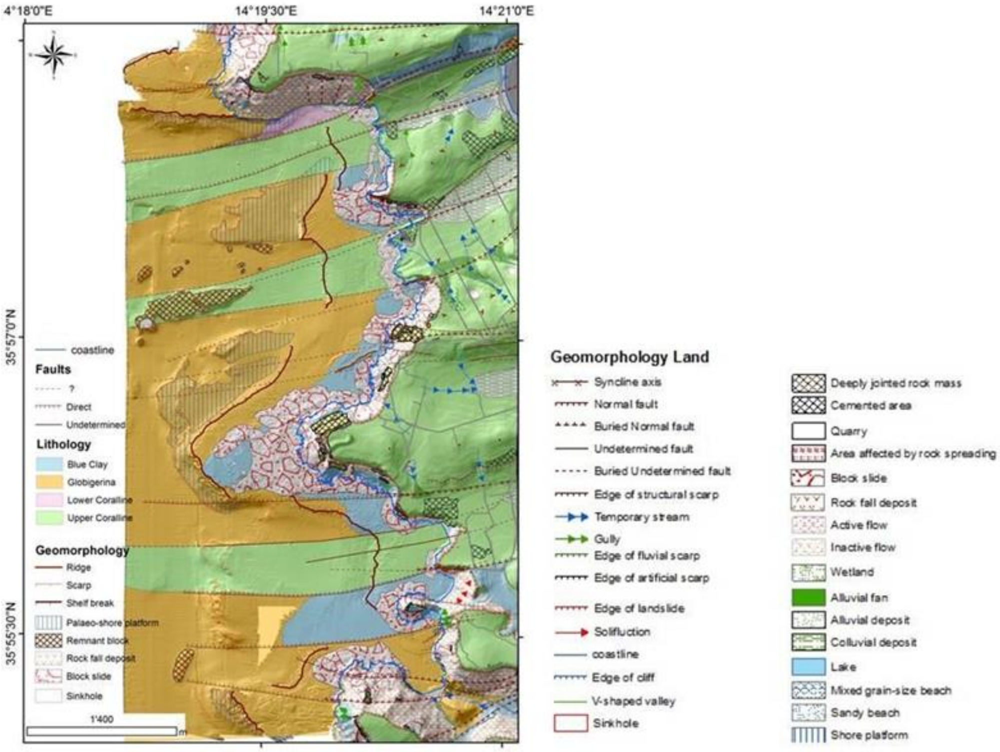


Figure 3. Geomorphological map of the North Western Maltese coastal sea floor.

Work-package 2: Workshop to identify a procedure for the development of hazard maps, integrating sea level rise and the anthropic impacts for both rocky coast environments and sandy beaches.

The project coordinator opened the meeting by thanking Prof Mauro Soldati for kindly offering to host and organize the logistics of this meeting.

Following several presentations by each of the project partners and intense discussion, the group agreed that the best way forward in the generation of hazard maps is to adopt a stepped approach that allows a larger geographic area to be addressed in a shorter time frame. This route to hazard mapping is via the development of 'susceptibility maps' that also consider cost-benefit issues of the number of people at risk, which can highlight priority action areas via the more in-depth hazard and subsequent risk maps (where a vulnerable element has been identified) and where development is being considered.

Susceptibility maps reflect the probability of spatial occurrence of an instability event. These maps combine different spatial factors predisposing to a certain phenomenon/process, and outline areas more prone to the occurrence of a phenomenon/event. For example, a landslide susceptibility analysis combines factors such as slope, geology, rainfall, vegetation, aspect, etc. to produce a map showing where landslides are more likely to occur. No time factor is associated with a susceptibility map (unlike hazard maps which reflect the probability of occurrence in a specified period and within a given area of potentially damaging hazard of a given magnitude). Hazard maps therefore include a time frame/likelihood reference.

In this context, one can see the sequence and sense of first preparing susceptibility maps for a given hazard prior to developing more complex hazard and subsequently, risk maps for areas either prioritised by the susceptibility maps e.g. where a vulnerable element is present, or where development is being considered. The subsequent risk maps will indicate the consequences of an event with a likelihood scale. For example, a 500-year flood hazard map may be used to develop a risk map with the 500-year flood indicating the number of buildings per km2 in a damaged state.

Work package 3: Coastal monitoring

A multipronged evaluation of beach sediment transport patterns has been launched at Ramla Bay on Gozo, Malta, via:

- A series of 10 shore perpendicular beach profiles, (Figure 7).
- A series of 9 sand-traps (four transects) installed to capture aeolian beach sediment transport over the beach, sand- dune and back-shore areas, (Figure 8).
- An extension of the shore profiles to cover the underwater nearshore seabed, (Figure 9).
- A study of beach sediment granulometry and pebble / cobble distribution/movement patterns, (Figure 10).

Results, data analysis and interpretation will be available towards the end of 2015 when the above measurements will be reproduced, thus allowing an annual / seasonal comparison of trends.

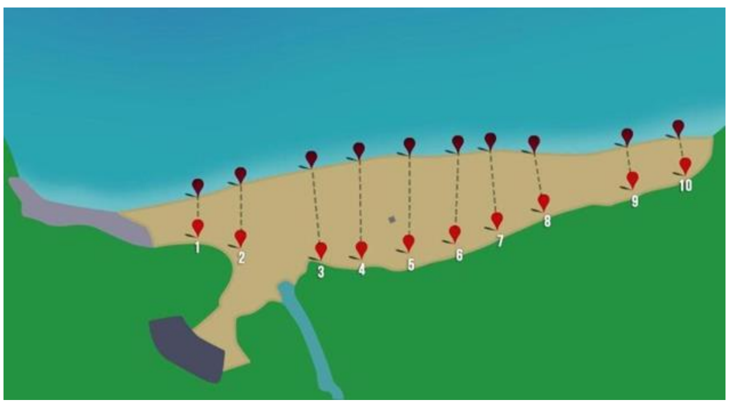


Figure 7: Ten shore perpendicular beach profiles

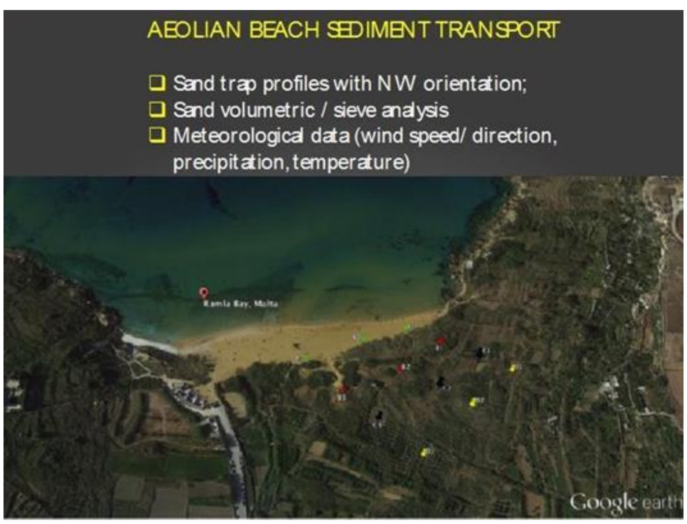


Figure 8. Beach sediment traps established to capture Aeolian sediment transport.

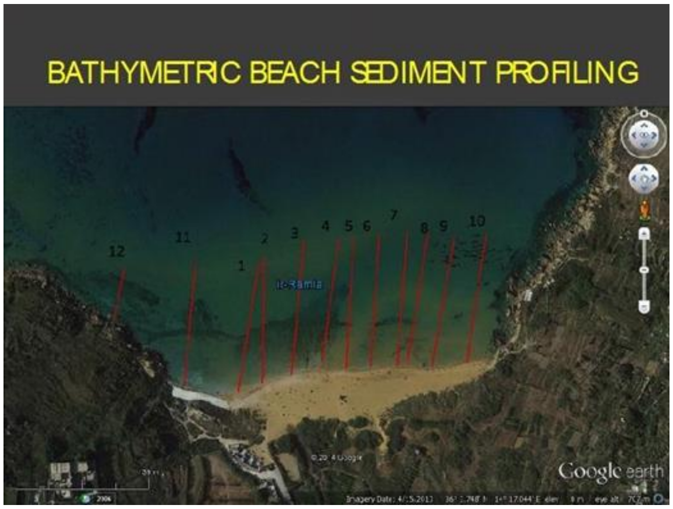


Figure 9: extension of the shore profiles to cover the near-shore seabed.

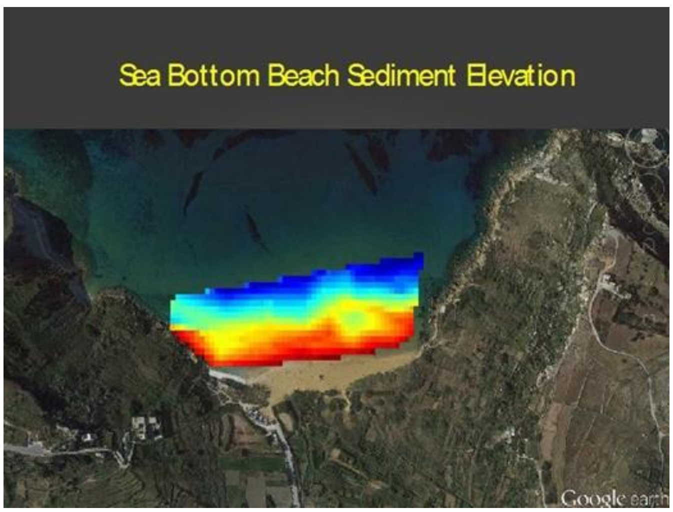


Figure 10: Bathymetric elevation obtained from nearshore sediment profiles.

CERG

Survey and monitoring of rocky coastal erosion using Laser techniques Dieppe coastal cliffs, Normandy

Context: The aim of the Project "Coupling terrestrial and marine datasets for coastal hazards assessment and risk reduction in changing environments" of the EUROPA Major Hazards Agreement is the risk reduction in coastal areas thanks to the development of coastal hazards mapping procedures including the impact of sea level rise on coastal processes as a useful basis for multi-hazard assessment. One of the work packages of the project is devoted to extension of current monitoring programme of coastal processes in the context of related erosion and landslide hazards.

The collection of data on a long time span is crucial to better understand coastal processes (erosion vs landslides), distinguish between short term (seasonal) and longer-term trends and produce hazard and related maps.

Also, during the project, we have verified the contribution and interest of different complementary Laser techniques (ALS, TLS & MLS –aerial, terrestrial and mobile-) to survey and assess the rate of retreat, rhythm and modality of retreat, in order to quantify the chalk cliff evolution and the role of the involved processes. The pilot area is located in Upper Normandy along the hard rock cliff subjected to landslides (cliff falls, debris fall and boulder and rock falls) in each part of Dieppe harbour from Cap d'Ailly (Varengeville) at the western part to Puys at the eastern part of the study site.

Laser scanning principles

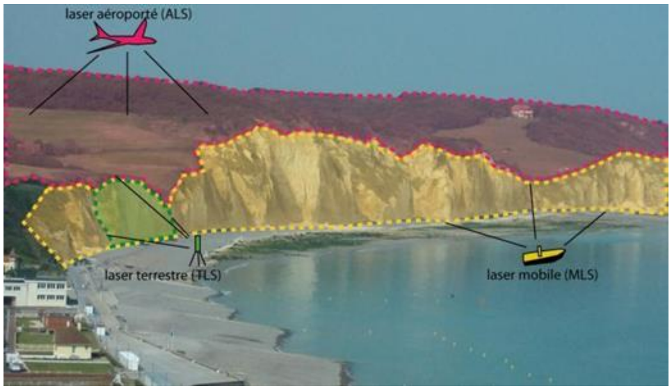
Laser scanning and 3D point clouds are currently widely used since 15 years for studying and monitoring different mountainous and coastal environments.

Principle: The remote detection by laser or LIDAR (Light Detection And Ranging), is a technology based on the analysis of the properties of a beam sent back towards its transmitter. Unlike the radar based on a similar principle, the LiDAR uses some visible or infrared light instead of radio waves.

The distance is given by the measure of time delay between the impulse and the detection of the return signal.

LiDAR quickly produces a high density of georeferenced 3D points clouds which allow to determine the topography of a zone (called topography in terrestrial zone and bathymetry in immerged zone).

A digital terrain model (DTM) could be generated from the 3D points clouds. DTM is a 3D representation of the topography (altimetry and/or bathymetry) of a zone under an adapted format to its use.



Different platforms and spatial resolutions:

Studying the coast requires acquiring data at the same time on terrestrial and submarine area, in spatial and time scales extremely varied. Tools to be implemented will be thus different to cover these various needs. Each LiDAR has its appropriate characteristics and limits. Platforms which carry these sensors can also be very different: satellites, planes, drones, kites, boats, ground measures…

In this project, we have mainly used TLS (Terrestrial Laser Scanning) and MLS (Boat-based Mobile Laser Scanning) in addition of ALS (Aerial Laser Scanning).

Lidar techniques	ALS	TLS	MLS
Point of view	vertical (top of the cliff)	horizontal (front of the cliff)	horizontal (front of the cliff)
Spatial extension	≈ 10 to 100 km²	≈ 300 m (width)	≈ 40 km per day
Accuracy	± 0,15 m	± 0,03 m	± 0,10 m
Information	Rate retreat, rhythms of retreat of the top of cliff (coastline).	Ablation rate, modality of retreat, agents and processes	Ablation rate, modality of retreat, agents and processes

Topographic Aerial Laser Scanning

Topographic Aerial Laser Scanning (ALS) provides to cover large areas (~ 50 km²/day) and get field data of high accuracy. The set of points obtained (several points/m2) has a decimeter precision (depending on the altitude of the plane) in latitude, longitude and altitude.

Information is then transformed into Digital Terrain Model. If multiple surveys are realized, it will be able to compare the DTM, especially track over time the same geomorphological object (like the toe of the dune, the vegetation limit, the top of the cliff …), providing a quantification of changes of the coastline.

For study the dynamics of the Upper Normandy coast, ALS allows to well observe and compare the position of the top of the chalk cliff, and define a cliff retreat rates. But the incidence angle is the key factor for point cloud density and accuracy (Michoud et al., 2014).

ALS data have then high inaccuracy and lack of information on vertical areas due to unfavourable high incident angles. It is not possible to observe and quantify the evolution of the toe of the cliffs, or even the whole of the cliff face.

Therefore, for vertical rocky coasts, ALS has to be associated with measurements made in ALS and MLS.

Ablation rate of the front of cliff by Terrestrial Laser Scanning

TLS provides a fine quantification (precision ~ 1-3 cm) of ablation rate, it's to say all chalk debris fallen from the cliff face (scree or mass movement). These production of debris, are observed with difficulties by ALS, because the top of the cliff are not always and immediately affected even if mass movement is important. These ALS measures show also the spatial distribution of material departures, and propose information about the processes responsible of these movements. In Upper Normandy a diachronic survey by TLS was conducted between 2010 and 2013 every 4-5 months. This study is conducted on two sites, with close lithostratigraphic characteristics, but differently exposed to marine actions. Then, abandoned cliffs recede slower (6-8 cm/y) than active cliffs (24 cm/y, i.e. 3-4 times slower) confirming the high influence of marine actions on the regressive dynamics of the chalk cliffs. In the context of active cliff, scree movements represent 25% of the total retreat of chalk cliff over the studied period. This quantification is very fine but only representative of pilot site (200-300 meters). ALS and TLS measures have to be combined to a new method, boatbased mobile Laser Scanning.

Landslides detection and monitoring Capability of Boat-based Mobile Laser Scanning

A boat-based mobile LiDAR capability by scanning 3D point clouds of the unstable coastal cliffs has been tested in the pilot area. Methodology and development are given by Michoud et al., 2014.

Three acquisition campaigns were performed in September 2012, 2013 and 2014, scanning (1) a 80-km- long shoreline and (2) the same test cliffs in different environmental conditions and device settings.

By scanning during favourable meteorological and marine conditions and close to the coast, mobile LiDAR devices are able to quickly scan a long shoreline (40 km/day) with median point spacing up to 10cm.

The acquired data are then sufficiently detailed to map geomorphological features smaller than 0.5m2. Furthermore, our capability to detect rockfalls and erosion deposits (>m3) is confirmed.

Problems and further enhancements

Following spatial and temporal scale adopted, laser techniques (ALS, TLS & MLS) allows to quantify the dynamic of the rocky coast (erosion and landslides). MLS survey appears like a reliable and rapid technique for regularly monitor the cliff dynamic. But at the high spatial and temporal scale, the processes have to be observing with the TLS (Terrestrial Laser Scan).

At larger scales, ALS and MLS might thus be used as complementary techniques along long coastlines with successions of gentler and steeper topographies more adapted to resp. ALS and MLS devices (Michoud et al., 2014).

MLS capabilities for accurate change detection and mass balance monitoring along subvertical coastlines at low costs (compared to ALS devices and flights) could really support: Bathymetric Aerial Laser Scanning

- Cliff retreat rates assessments for different sectors, by automatically extracting surfaces affected by rockfalls, compared to the entire surface of kilometre-long scanned cliffs (Michoud et al., 2014);

- Landslide modelling and to manage risks dealing with affected infrastructures and inhabitants. Further actions:

For MLS, additional acquisitions should be performed in the North of the study area along gentler slopes to experiment the potential inputs of using both techniques.

For the bathymetry, prospection with multibeam sounder is not always possible due to low deep of water, presence of dangerous blocks…

Also, the new bathymetric Aerial laser Scanning devices could be providing continuous terrestrial and submarine datasets. A test is planned in 2015.

UNIMORE

Work package 3: Coastal monitoring

The monitoring activity at Anchor Bay and Il-Qarraba is continuing and the most interesting results are from the Anchor Bay site, where GPS benchmarks, fissurimeters and tape-extensometers are installed.

The GPS data elaborated so far indicates that the lateral spreading phenomena at Il-Prajjet site continue to be active and give deformation rates more significant than the other instruments. GPS results showed significant movements with a rate of displacement that can be considered with a good approximation quasi-constant. New benchmarks 109 and 110, installed in May 2013, recorded rates of planar displacement consistent with those registered previously by the monitoring network, although no significant height variation were measured so far. The displacements recorded are summarized by Figures 5 and 6 below.

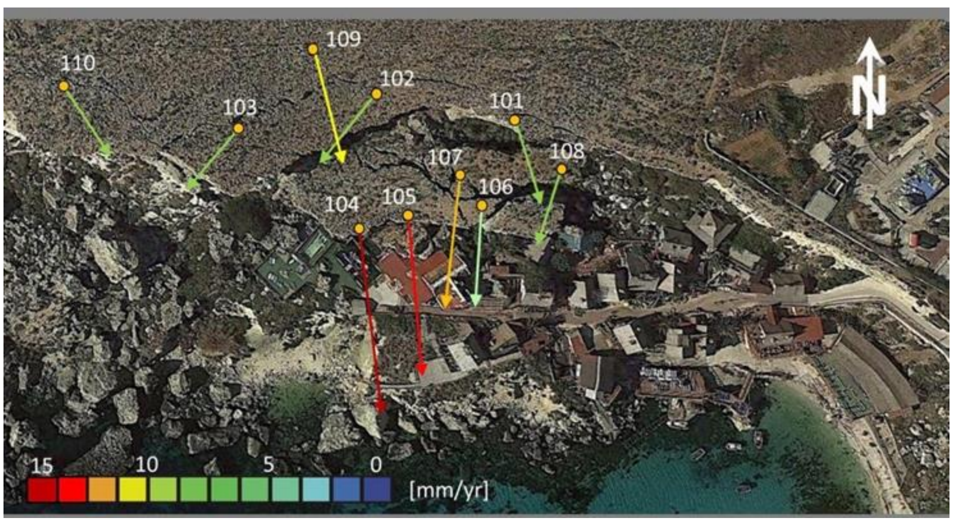


Figure 5: Location of the GPS benchmarks. The arrows represent the direction of the planar deformations and their length and colour the displacement rate. Benchmark 106 has been calculated till last available measurement of November 2012.

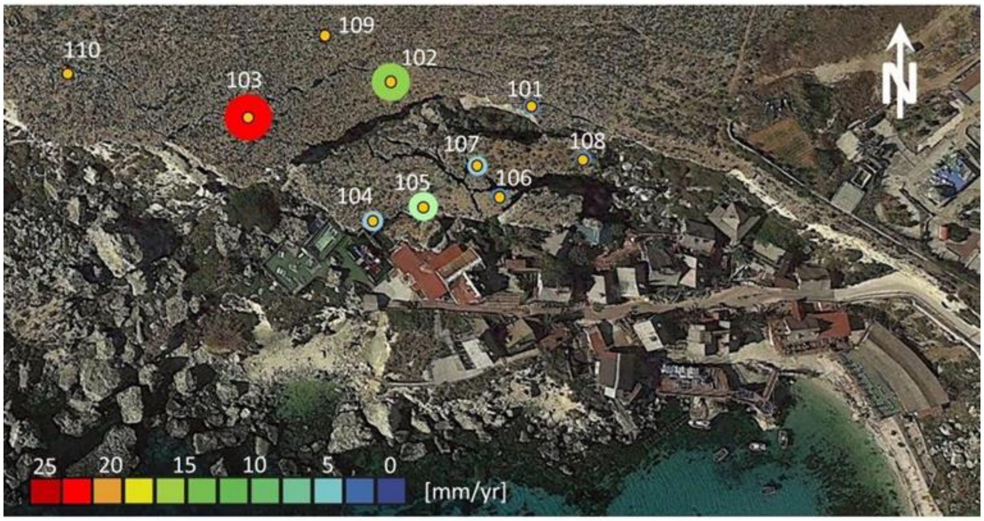


Figure 6: Location of the GPS benchmarks. The size and colour of the circles represent the rate of the vertical deformation. Benchmark 106 has been calculated till the last available measurement of November 2012.