HERACLES NEWSLETTER

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HERACLES

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CASE STUDIES

GUBBIO, ITALY:

3. Town Walls
4. Consoli Palace

CRETE, GREECE:

1. Minoan Knossos Palace
2. Venetian coastal fortress of Koules

HERACLES
HEritage Resilience Against CLimate Events on Site

ONGOING ACTIVITIES OF THE GREEK SITES

Within the frame materials documentation and degradation mechanism investigation, UoC has initiated the examination of the primary and secondary gypsum erosion products (accumulations). The external surface of the gypsum architectural elements that was exposed to high temperature (due to the fire that occurred during the destruction of the first palace) was altered and appear white and compact due to dehydration and rehydration process. In contrast the inner layers retain the original translucency and shape of the crystal aggregates. The two different types present substantially different decay behavior under the same environmental conditions. Our preliminary studies based on microscopic examination and m-Raman analyses have shown that among other substantial differences between the recrystallized products of the two gypsum varieties found in Knossos palace, the presence of tubular crystals of anhydrite ($CaSO_4$) as a constituent of the burned gypsum, is indicative of the high temperatures that were developed in close proximity or directly on the surface of the stone. Up to this point and apart from the preparation of the specimens and preliminary micro Raman spectroscopic analysis, X-Ray powder diffraction experiments and Scanning Electron Microscopy examination of the accumulation samples from primary gypsum has been carried out. According to XRD analysis, the predominant crystalline phase of all the samples is gypsum.

XRD patterns indicate the presence of calcite as a medium to trace mineral phase in all samples. Moreover, trace amount of quartz were detected in all samples. Also, the abundance of recrystallized gypsum formations and the presence of calcite as well as of bacterial colonies has been documented by means of Scanning Electron Microscopy. In the case of recrystallized gypsum accumulation in Knossos, the biological formations often play the role of the connecting matrix that holds in place the rest of the accumulation constituents. From the XRD and SEM/EDS analyses on accumulation samples collected from primary gypsum architectural elements, the main crystalline phase of the samples is gypsum ($CaSO_4x2H_2O$). As expected, no traces of anhydrite ($CaSO_4$) have been detected. Calcite occurs in relatively small amounts and as a secondary mineral, which originates from the

dissolution and re-precipitation of gypsum.

In addition to the aforementioned documentation approach, DRMS tests were carried out. The aim of the DRMS measurements performed on mineral gypsum building elements in the site of Knossos, was the evaluation of the degradation extent (depth) below the exposed surface of the stones. Apart from the obvious benefits that will occur as a result of this approach and is the main scope of the deliverable 3.7, useful conclusions were drawn that are being used for the design and customization of the restoration materials.

Moreover, drilling resistance tests were carried out on a building block that was partially burned during the destruction of the first place. This building element is consisted of rehydrated/secondary gypsum with a white/opaque appearance and compact texture as well as primary gypsum that retains its original shape of crystal aggregates. The aim of this approach was to investigate both the depth of alteration, due to dehydration (burning) and consequently the rehydration of basanite ($CaSO_4x^1/_2H_2O$) back to calcium sulfate dihydrate namely gypsum, as well as the hardness of primary comparing to that of the secondary gypsum.

As regards to the Rocca a Mare fortress, UoC has carried out a systematic sampling from the argillaceous limestone outcrops/quarry located in the area of Katsampas near the city of Heraklion. According to the literature as well as relevant petrological studies, the dominant lithotype used in Koules came from this quarry. Given the intensity of the salt efflorescence on the building stones of Koules fort, the application of DRMS was focused mainly on the ability of the system to act as a high precision sampling tool. Based on this property, samples of the drilling residue were collected at interval depths of 5mm. The purpose was to investigate the presence of the salts that appeared as efflorescence, below the surface of the stone, in terms of qualitative as well as quantitative composition. On a second level, through the application of DRMS it was made possible to assess the preservation state of the tested stones in terms of structural degradation. For that purpose, a throughout drill was opened and the drilling data was compared to similar information acquired from pristine/unweathered specimens that were provided by the end user (Heraklion Ephorate of Antiquities).

The samples from Koules fort along with selenite samples from the Knossos site, that were already in the laboratory, were evaluated via the application of drilling resistance measuring system (DRMS) both in terms of mechanical performance of the pristine stone as well as for micro sampling. The results collected from the aforementioned experiments are used as control/baseline data for the evaluation of consolidants performance.

Within the same frame DRMS tests were carried out on the monuments of Gubbio: Town Walls and Consoli Palace. The dominant problem of the stones used in the Gubbio monuments is related to the decay action of water and consequently the freeze – thaw effect. The results of this problem often appear in the general form of spalling or flaking which under certain circumstances, it is a common decay effect especially in limestone. The first step of this approach included the mineralogical examination of the samples from the monuments as well as from samples collected from the nearby historic outcrops. The samples were analyzed by means of X-Ray powder diffraction, Scanning Electron microscopy coupled with elemental and stoichiometric analysis (energy dispersive X-ray spectrometry) and m-Raman spectroscopy. The main effort of the DRMS campaign carried out in Gubbio, was focused on the investigation of the current state of preservation of the monuments stone building elements. DRMS tests were performed and measurements were collected from the dominant lithotypes found in Gubbio that were subject to different environmental conditions (directly exposed to the environmental conditions or protected indoors). The DRMS data collected from pristine stone samples collected from the outcrops were used as reference measurements for the determination of the monuments stone elements decay degree.

In terms of restoration and preservation of the building and ornamental aspects of the ancient monuments, several samples have been collected from the Knossos Palace, to elucidate and verify the supposed degradation mechanism and to investigate the feasibility synthesis study of the new materials and ecoinnovative solutions. Our approach is based on chemical consolidants that possess multi-functional attributes and has been focused on mineral gypsum (structural element in Knossos). One such additive that was tested on gypsum was TESPSA (3-(triethoxysilyl) propylsuccinic anhydride) and APTES (3-Aminopropyl-triethoxysilane). Moreover, synthesis of new metal-phosphonate materials have been implemented, along with their basic physicochemical characterization. Studies are underway to evaluate these innovative consolidants based on metal-phosphonate materials.

Physicochemical and micromechanical (drilling resistance) characterization evaluation demonstrated that some consolidants achieved sufficient penetration, restoring the cohesion of the mineral gypsum aggregates. Moreover preliminary artificial ageing tests have been initiated (Natural stone test methods: Determination of resistance to salt crystallization/EN 12370:1999 E) in order to replicate and evaluate the performance of TESPSA based consolidants under stress conditions. Also, studies are underway to evaluate other innovative consolidants based on metal-phosphonate materials. A multipurpose laboratory analysis of the new combined material systems, to assess their physico-chemical characteristics and their mechanical properties, compared to the state of the art materials, previously identified, has organized.

UoC has initiated designed chemical syntheses that will yield additives/consolidants that will restore the cohesion by strongly bind onto the surface/degraded gypsum aggregates surface and interior to the underlying pristine stone mass. UoC is looking into possibilities that these novel chemical compounds find application to Rocca a Mare fortress (Koules) and Gubbio sites. The test results analysis will represent the guidelines for investigating applicability of those materials. UoC has initiated applicability studies regarding the penetration/absorption performance of the TESPSA based compounds on mineral gypsum specimens. An application protocol is being formatted taking under consideration the different aspects (crystal aggregate size) of the dominant mineral gypsum varieties of Knossos. The applicability studies are focused on mechanical resistance of consolidated gypsum stone (mainly based on micro-drilling). Further experimentation is planned through the application of more traditional methods such as uniaxial stress tests. UoC is also looking into setting-up appropriate experimental studies that will involve accelerated ageing in an environmental chamber, in order to evaluate long-term robustness and performance of the tested consolidating compounds. Our plans for the next 6-month period include the following actions:

- Continuation of our efforts to complete studies regarding TESPSA.
- Test additional consolidants (either commercially-available, but never tested on gypsum, or laboratory-prepared).
- Full physicochemical characterization of newly-synthesized consolidants
- Full documentation on consolidant efficiency
- Microdrilling measurements in order to quantify efficiency in consolidated stone
- Further chemical syntheses of new materials.

DEVELOPING A METHODOLOGY FOR THE ON-SITE LASER ANALYSIS AND MONITORING OF ENVIRONMENTAL SURFACE ALTERATION ON MONUMENTS.

The main objective of the HERACLES project is to design, validate and promote responsive systems and solutions for the effective resilience of Cultural Heritage (CH) monuments against climate change effects. In this respect a highly multidisciplinary approach is followed, which involves different expertise related to systematic inspection and monitoring of selected monuments, the development of analytical methodologies to investigate deteriorations, the synthesis and testing of new protective materials, etc. all inter-connected through a dedicated ICT (information and communication technology) platform.

The Institute of Electronic Structure and Lasers of the Foundation for Research and Technology – Hellas (IESL-FORTH) having outstanding experience on the use and exploitation of lasers in the preservation of CH monuments and being at the fore-front of technology participates to HERACLES with state-of-the-art analytical instruments and methodologies. Specifically, IESL-FORTH within the HERACLES project, is developing a methodology for the in-situ study of alteration products in terms of their chemical composition as well as their distribution and evolution on the monument's surface. This methodology will combine data obtained through the use of advanced, portable, non-contact, laser and optical instruments on the basis of measurements recorded regularly and/or after major events related to Climatic Changes.

Specifically, the multi-technique approach involves the use of micro-Raman spectroscopy, Laser Induced Breakdown Spectroscopy (LIBS) and Multispectral Imaging (MSI). Data obtained through periodic measurements is analysed and cross-correlated in order to produce maps, which indicate evolution trends and possible hazards. Measurements are carried out at two test-beds at Heraklion city: (a) the archaeological site of Knossos Palace and (b) at the historic Venetian sea-fortress of Koules, both affected in different extents by the Climatic Change.

Micro-Raman spectroscopy is a molecular analytical method, which does not necessarily require sampling. It is a non-destructive method, which provides real time measurements.
The detailed Raman analysis leads to a precise chemical classification of the deposits formed on the surfaces of Cultural Heritage monuments. For every deposit, (ex-situ and in-situ), multiple various spots of similar morphology have been analysed in order to derive all the available information concerning the material under-study.

LIBS spectroscopy is an elemental, micro-destructive, analytical technique, which can be easily applied in-situ. LIBS analysis was applied complementarily to the Raman analysis, in order to overcome certain limitations of the Raman technique.

Imaging Spectroscopy is a non-destructive imaging technique which allows materials differentiation and mapping by acquiring images at consecutive narrow bands from UV to NIR. The technique is applied in situ by means of a portable instrument. The acquired data are further processed for the definition of the alteration extent. Periodic measurements enable the study of the alteration evolution.

Data from micro-Raman and LIBS spectroscopy are effectively combined with Imaging Spectroscopy for the holistic investigation of the alteration both in terms of chemical composition and in terms of extent and evolution of the alteration.

The analytical protocol of the developed methodology is presented briefly hereafter:

1

•DETERMINATION OF THE AREAS OF INTEREST

- •Selection of characteristic areas with intense damage or decay.
- •Classification of the selected areas based on the different morphology and colour of the products formed on the surface of the stone (i.e. a. white crusts/salt accumulations, b. black crusts, c. efflorescence salts and d. stalactites).

2

•MATERIAL SAMPLING FOR LABORATORY CHEMICAL ANALYSIS

- •Carefull sampling from the areas of interest; performed by experts.

3

•DEVELOPMENT OF A REFERENCE DATABASE

- •Establishment of a continuously updated, reference database based on the recorded data from the laboratory chemical analysis of the surface alteration products.

4

•ON-SITE CHEMICAL ANALYSIS AT THE AREAS OF INTEREST

- •On-site chemical analysis using portable equipment (i.e. MSI, LIBS, micro-Raman)
- •Validation of the on-site results through the correlation of the laboratory measurments.

5

•MONITORING OF THE SELECTED AREAS OF INTEREST

- •Development of an Imaging Spectroscopy protocol for the on-site monitoring of the evolution of the alteration products over time and upon different environmental conditions.
- •Periodic measurements for the validation of the protocol.

6

•PROCESSING OF RESULTS

- •Cross correlation of the identified alteration products to the original substrates (i.e. limestone, gypsum) in order to determine the deterioration mechanism and estimate its evolution over time.

7

•CORRELATION OF CLIMATIC CHANGES TO THE MONUMENTS MATERIALS

- •Cross correlation of analytical results, with in order to associate the chemical composition and spatial distribution of surface alteration products with climatic conditions over time.

CASE STUDY: THE CHEMICAL CHARACTERIZATION AND MONITORING OF THE EVOLUTION OF EFFLORESCENT SALTS

The sea-fortress of Koules shows intense salt efflorescence, which is usually observed on the internal surfaces of its 16th century limestone walls. A series of chemical analyses have been performed in the laboratory as well as on-site using Raman and LIBS spectroscopy (Figure **1b**, **1c**), following the methodology protocol described above.
The laboratory results were compared and found to be in good agreement with the ones obtained from the on-site analytical campaigns; this validation stage is a prerequisite in order to obtain reliable data.
The Raman signal detected from efflorescence samples was notably weak and no Raman bands were identified. LIBS spectroscopy, on the other hand, identified strong emission signal of Sodium (Na) (Figure **2**) thus indicating the presence of NaCl, supported also by the morphology of the sample (Figure **1a**). This result is in agreement with the close proximity of the monument to the sea.

(a) (b) (c)

Figure **1**. (a) Stereoscopic image from efflorescence salts sample.
(b) On-site Raman and (c) LIBS measurements of salt efflorescence extracts at Koules monument, by FORTH-IESL team.

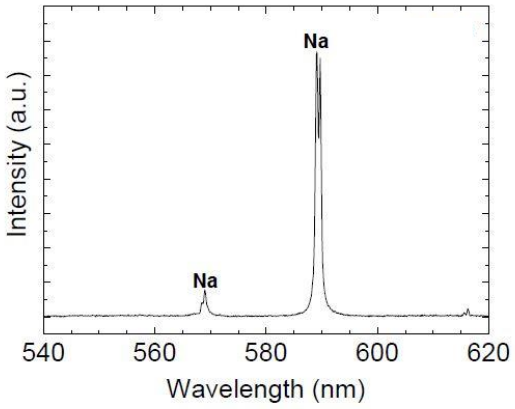


Figure **2**. LIBS emission lines from in-situ analysis of salt efflorescence formed on 16th century limestone wall, corresponding to Na.

Furthermore, the selected area of interest showing salt efflorescence, is periodically examined by **Imaging Spectroscopy** in order to define their possible evolution or mitigation. In Figure **3** an example of the efflorescence mapping in two different seasons, summer and autumn of 2017, is presented.

Figure **3**. The Multispectral imaging setup for measurement of the efflorescence extent.

Observing the extent of salt efflorescence in the area of interest between two different seasons (summer and autumn 2017) it was found that during autumn is significantly reduced (occupying only 5.92% of the area of interest) in comparison to the measurement recorded during summer (43.81%) (Figure **4a,4b, 4c, 4d).**

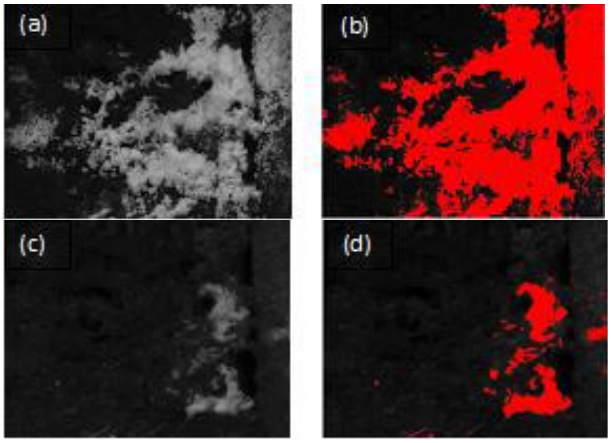


Figure **4**. (a) The spectral image acquired during summer 2017; (b) The corresponding pseudo-colour image highlighting the efflorescence extent; (c) the spectral image acquired during autumn 2017; (d) the corresponding pseudo-colour image highlighting the efflorescence extent.

CORRELATION OF CLIMATIC MODELING RESULTS AND WAVE IMPACT

The main objective of the HERACLES project is to design, validate and promote responsive systems and solutions for the effective resilience of Cultural Heritage (CH) monuments against climate change effects. In this respect a highly multidisciplinary approach is followed, which involves different expertise related to systematic inspection and monitoring of selected monuments, the development of methodologies to correlate climate change and extreme weather conditions modelling and inter-connect through a dedicated ICT (information and communication technology) platform.

The Institute of Applied and Computational Mathematics (IACM) of FORTH specializes in research on numerical simulation and monitoring of environmental, engineering and physiological processes. The research activities of IACM are focused on the integrated study of the coastal environment (atmospheric, terrestrial and marine), with the aspiration to develop state-of-art scientific contributions in the areas of

(i) risk assessment and prevention related to the impact of climatic change on the coastal zone, (ii) coupling of coastal air-sea-land interaction related processes, (iii) instrumentation/ field measurements for coastal zone survey and (iv) coupling of data sets and models towards more effective and realistic simulations and forecasting.

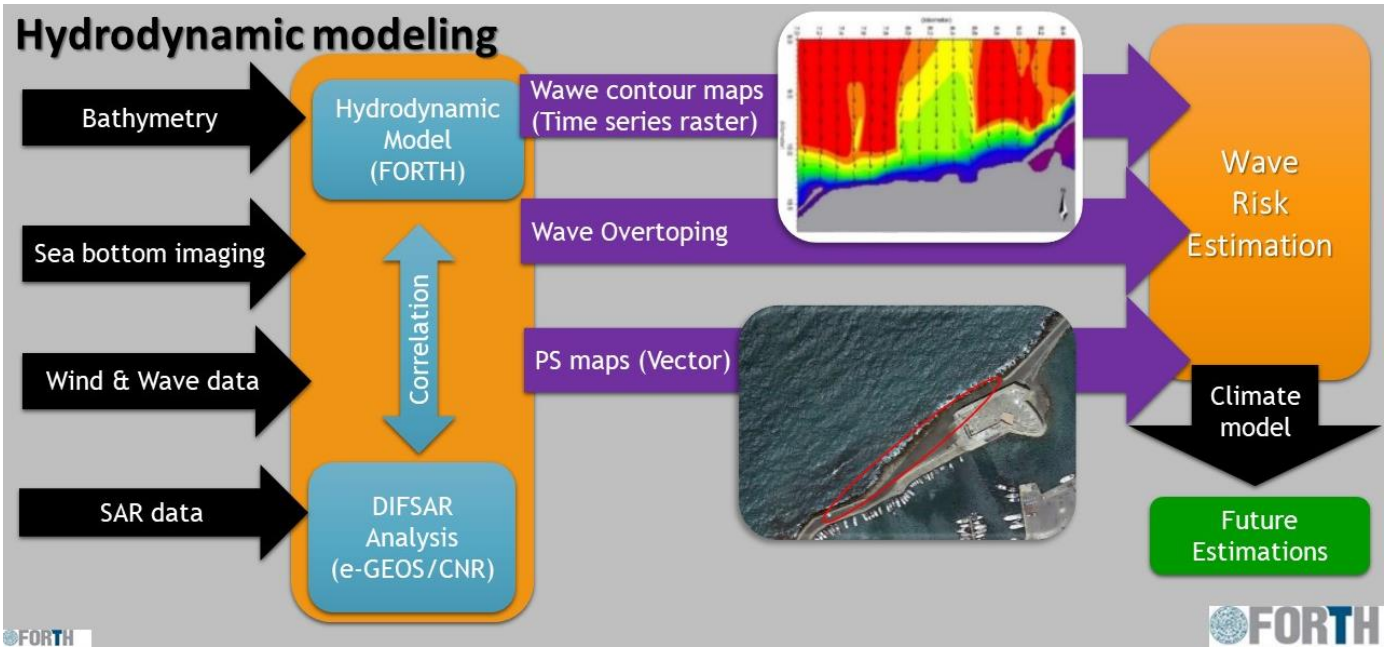


Figure 1: Workflow for the correlation of climatic data and wave modeling..

An analysis of the expected changes in a future climate have been performed in order to simulate current and future climate. The statistical analysis of the meteorological data focuses on two different time-scales. First the data from the long-term analysis are evaluated based the results provided by ARIA using the output from the EURO-CORDEX project that provides regional climate projections for Europe at 12.5km resolution. The provided data for the two future periods (near future: 2036 – 2065, far future: 2071 - 2100) are used to extract the near and far future wind time-series output in order to be introduced to the wave model analysis software. This way the significant wave height and period can be estimated for the coastal front of Heraklion and the impact on Koules monument can be addressed for the near and far future.

Examining figures 2 and 3 for the Heraklion coastal area, there is an obvious wind speed shift to higher values over the near and far future distributions. The wind-rose diagram and Table 1 shows that the prevailing wind direction remains the NW (315deg.) throughout the two forecasting periods (near and far future periods) with the mean wind speed increasing by 0.15m/s in the near future and by 0.24m/s for the far future with respect to the reference period. The secondary wind direction is the Western direction (270deg.)

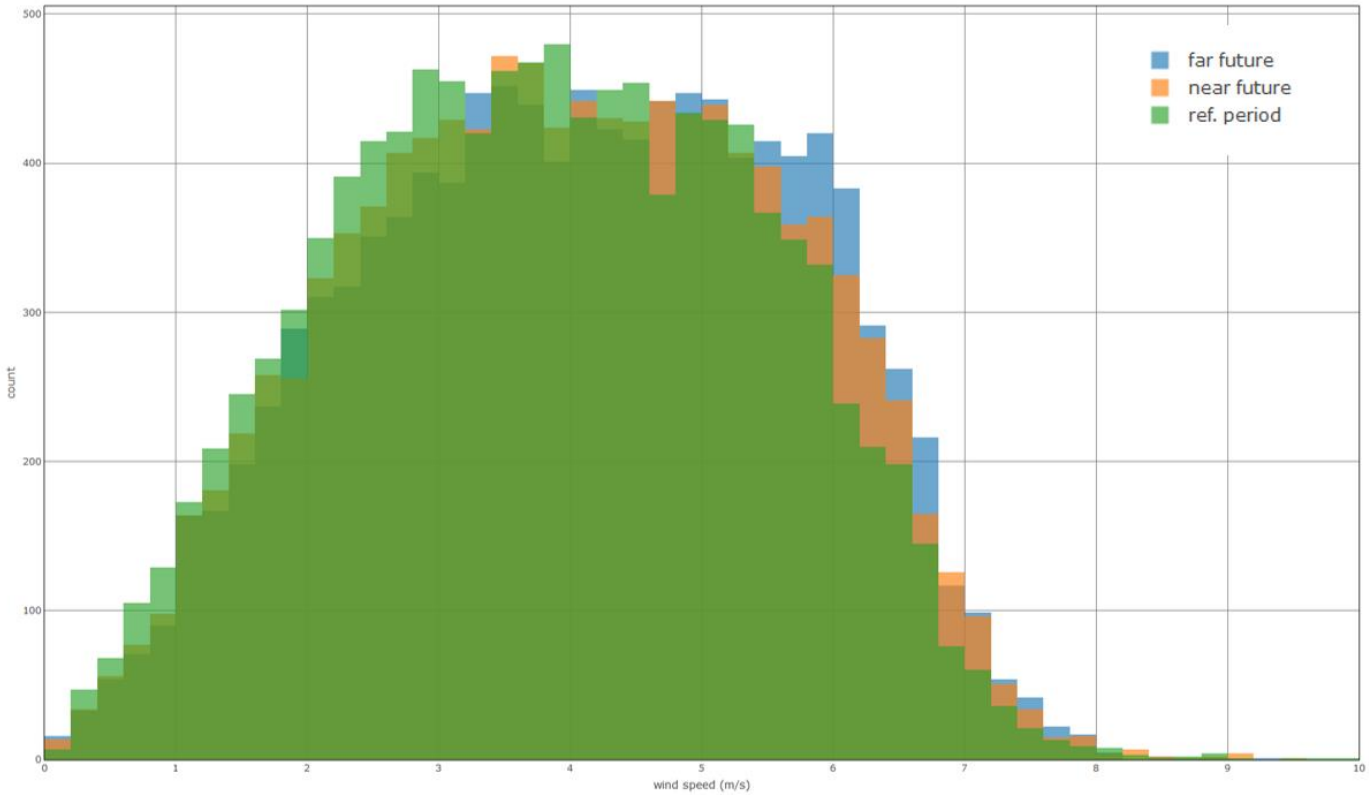


Figure 2: Wind speed distribution for the reference period and the two forecasting periods.

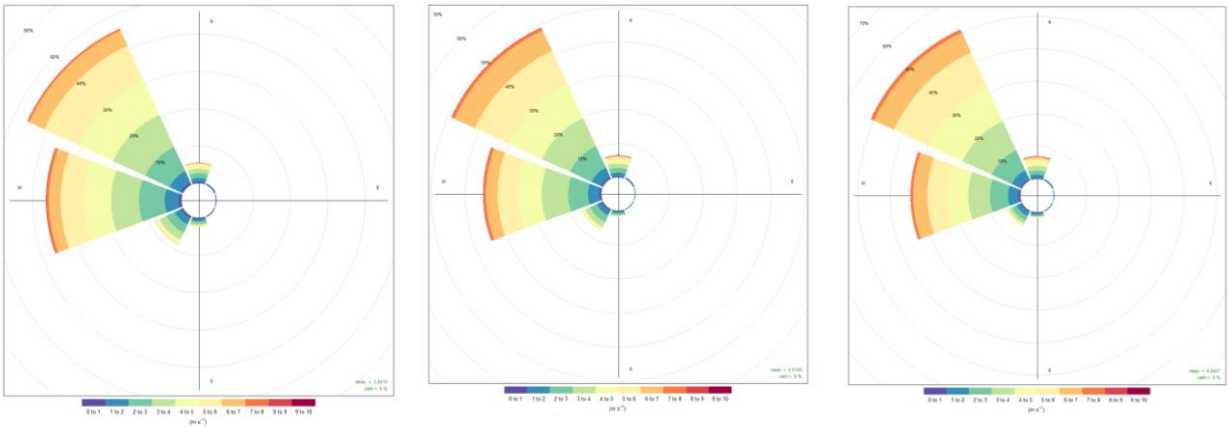


Figure 3: Heraklion Coastal Area Windrose distribution for the reference period (left) the near future (middle) and the far future (right).

Table 1: Number of Counts of Wind Direction Sector for the Reference Period and the Near and Far Future.

%	45°	90°	135°	180°	225°	270°	315°	360°
Ref.	0,49	0,24	0,37	2,53	8,33	36,39	46,10	5,55
Near	0,50	0,26	0,30	1,85	6,77	34,75	49,07	6,50
Far	0,54	0,26	0,38	1,68	5,18	33,77	**51,16**	**7,03**

Coastal hydrodynamics are estimated mainly on the bases of significant wave height, (Hs) estimations. Hs is defined as the mean of the highest one-third of the waves present in the sea and the maximum wave height, (Hm) is the maximum vertical distance between the highest crest to the lowest trough; Tm is the wave period corresponding to Hm, and Tz is the mean zero-up crossing period of the wave field. The calculation was carried out for wind waves from 5 directions (N, NW, NE, E, and W). The wind blowing length (fetch), used in the above forecasting equations, is determined in a straight line along each wind direction. For stretches limited by irregular coastlines it is recommended to measure the length of the stretch at nine points (along the direction of the wind direction and four points per 2° on each side) and the use of the average of the measurements for the waveform calculations (CERC, 1984).

The maximum expected wave characteristics generated by the above winds in the area are given in Table 2. The spectral significant wave height and spectral period calculated are the maximum values that can be derived for the maximum wind speed. The minimum required breathing duration for the winds affecting the area is within the range observed in the wider area and therefore the assumption is that the maximum wave growth is limited only by wind blowing.

The coastal zone of the area is mainly affected by wind waves of N, NE and NW origin, while wind waves W and E originally affect the coastal zone after diffraction and intense refraction. To study the distribution of wave energy along the coast in the area, wave refraction diagrams were constructed using numerical models. For each wave direction affecting the coastal zone, refraction diagrams for waves with higher wavelengths were constructed, as well as the usual peak values for the area calculated on a weighted average basis for the incidence. The data of these waves are shown in Table 2.4.

Table 2: Wave characteristics.

		U_a(m/sec)	H_s(m)	T_s (sec)	h_c(m)	L_o(m)	H_b(m)	d_b(m)
N	**Mean**	21,27	4,09	8,69	7,77	117,81	4,53	5,24
	Max	33,91	6,80	10,28	12,45	164,84	7,27	8,72
NE	**Mean**	18.00	2.64	4.69	1.73	76,92	3,18	3,75
	Max	33.91	4.98	8.37	8.88	109,24	5,22	6,39
NW	**Mean**	20.62	4.6	9.36	14.6	136,62	5,12	5,90
	Max	33.91	7,57	11.03	13.97	189,76	8,15	9,70
E	**Mean**	21,26	3.15	7.22	5.86	81,26	3,41	4,04
	Max	33.91	5.03	8.42	8.97	110,58	5,27	6,45
W	**Mean**	19.94	0.81	3.01	1.34	20,06	1,33	1,77
	Max	33.91	1.34	3.59	2.11	14,13	0,81	1,04

key: U_a wind speed, T_p wave period, H_s significant wave height h_c closure depth ; L_o wave length; H_b breaking wave heightand d_b breaking wave depth.

The waves originating from the north and northeast and maximum intensity waves approach the coastline nearly parallel to the coastal front, with an average wave height of between 4.5m and 5m. For normal north origin waves, the wave height is in the range of 3m - 3.5m. Near the coastline, the wave height is smaller, up to about 2.5m, due to the shallow bathymetry. This is because the breaking zone

begins at a distance of about 500m for the north waves, and about 450m for the Northeast Waves (Figure 4). Waves coming from northwest are approaching the coastline after refraction at the Cape Panagia. The average wave height of normal waves is 2-2.5m, while for normal maximum observed waves it is between 2.5m and 3m. The breaking zone is even wider, and about 600m from the coast. The east origin waves approach the coastline with average wave height of ranging between 1.5m and 2.5m, while for the corresponding average maximum waves observed between 3m and 3.5m. For the waves coming from the west, the wave height appears to be in the range of 0.5-1m for normal waves, and 1-2m for the maximum. From the analysis of the refraction diagrams, it appears that the waves that affect the wider area are those originating from N, NE, NW and E. West origins waves arrive at the shoreline after refraction and diffraction, causing greatly weakening of the wave energy in the nearshore.

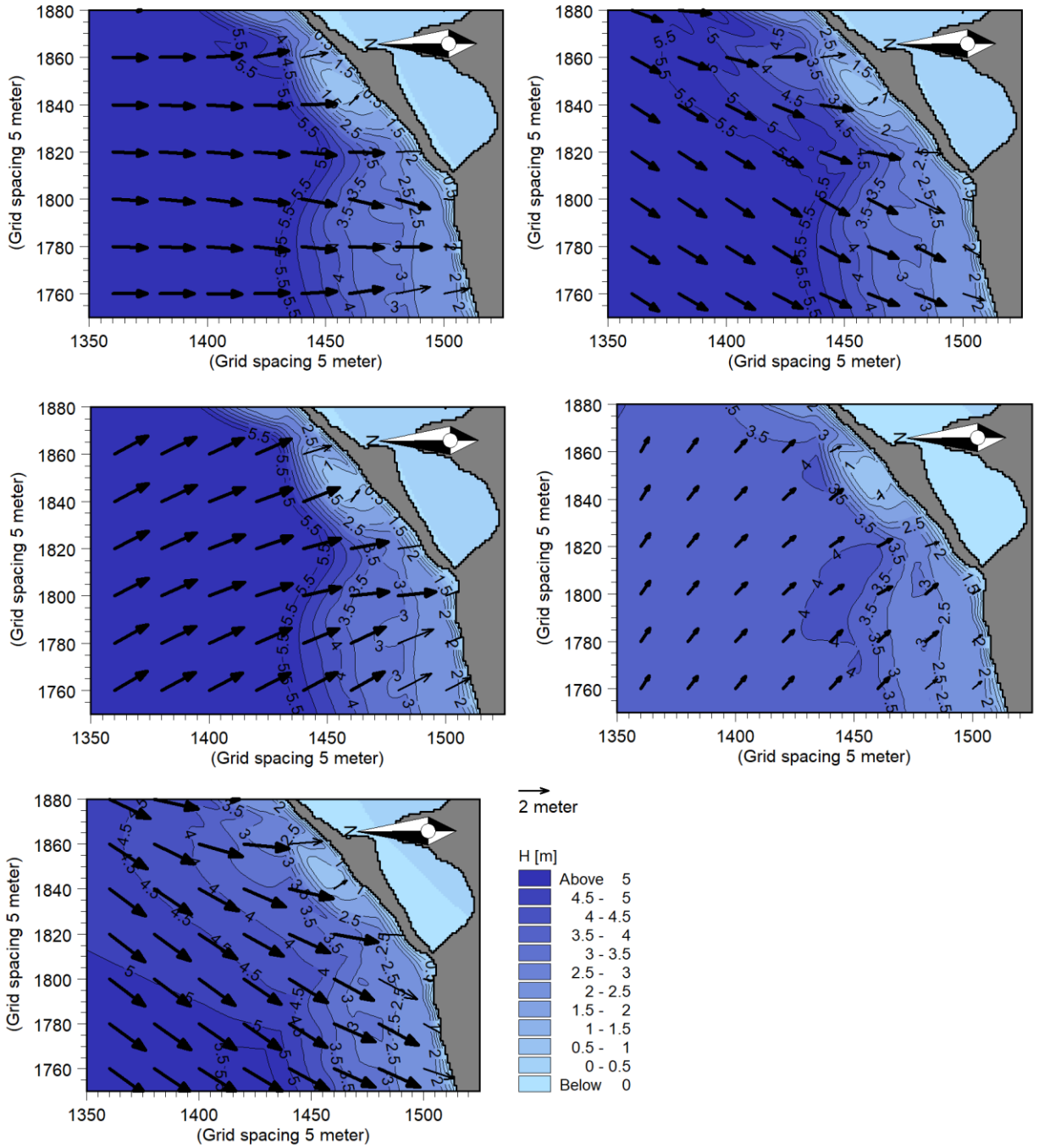


Figure 4: Wave propagation of N (Hs: 6,80m και Ts: 10,28s), NE (Hs: 4,98m και Ts: 8,37s); NW (Hs: 7,57m και Ts: 11,03s); W (Hs: 1,34m και Ts: 3,59s) and E waves (Hs: 5,03m και Ts: 8,42s)

Wave overtopping was estimated by using the wave run-up height MASE'S (1989). This is the wave run-up level, measured vertically from the still water line, which is exceeded by 2% of the number of incident waves. The number of waves exceeding this level is hereby related to the number of incoming waves and not to the number that run-up. The wave run-up level on smooth slopes is determined by the level at which the water tongue becomes less than 2 cm thick. Thin layers blown onto the slope are not seen as wave run-up. Run-up is relevant for smooth slopes and embankments and sometimes for rough slopes armoured with rock or concrete armour. The percentage or number of overtopping waves, however, is relevant for each type of structure.

Wave overtopping is the mean discharge per linear meter of width, q, for example in $m^3/s/m$ or in l/s/m. The methods described in this manual calculate all overtopping discharges in $m^3/s/m$ unless otherwise stated; it is, however, often more convenient to multiply by 1000 and quote the discharge in l/s/m.

The process of wave overtopping is very random in time and volume. The highest waves will push a large amount of water over the crest in a short period of time, less than a wave period. Lower waves will not produce any overtopping. Still a mean overtopping discharge is widely used as it can easily be measured and also classified:

q < 0.1 l/s per m: Insignificant with respect to strength of crest and rear of structure.

q = 1 l/s per m: On crest and inner slopes grass and/or clay may start to erode.

q = 10 l/s per m: Significant overtopping for dikes and embankments. Some overtopping for rubble mound breakwaters.

q = 100 l/s per m: Crest and inner slopes of dikes have to be protected by asphalt or concrete; for rubble mound breakwaters transmitted waves may be generated.

Wave overtopping volumes

The volume of water, V, which comes over the crest of a structure is given in m^3 per wave per m width. Generally, most of the overtopping waves are fairly small, but a small number gives significantly larger overtopping volumes. The maximum volume overtopped in a sea state depends on the mean discharge q, on the storm duration and the percentage of overtopping waves. A longer storm duration gives more overtopping waves, but statistically, also a larger maximum volume. Many small overtopping waves may create the same mean overtopping discharge as a few large waves for rough sea. Research studies with field observations suggest that danger to people or vehicles might be related to peak overtopping volumes, with "safe" limits for people covering:

Vmax = 1000 to 2000 l/m for trained and safety-equipped staff in pulsating flows on a wide-crested dike;

Vmax = 750 l/m for untrained people in pulsating flows along a promenade;

Vmax = 100 l/m for overtopping at a vertical wall;

Vmax = 50 l/m where overtopping could unbalance an individual by striking their upper body without warning.

The mean overtopping discharge, q, is the main parameter in the overtopping process. The overtopping discharge is given in m^3/s per m width and in practical applications often in litres/s per m width. Although it is given as a discharge, the actual process of wave overtopping is much more dynamic. Only large waves will reach the crest of the structure and will overtop with a lot of water in a few seconds. This wave by wave overtopping is more difficult to measure in a laboratory than the mean overtopping discharge. As the mean overtopping discharge is quite easy to measure many physical model tests have been performed all over the world, both for scientific (idealised) structures and real applications or designs. The structures considered in HERACLES that refer to Koules Fortress in Heraklion are rubble mound structures such as breakwaters and rock slopes.

PRESENTATION OF THE PROJECT

1. EGU GA 2018 (VIENNA, AT – 8-13 APRIL 2018)

EGU-GA (European Geosciences Union - General Assembly) 2018 covers special scientific and interdisciplinary events as well as oral and poster sessions on disciplinary and interdisciplinary topics covering the full spectrum of the geosciences and the space and planetary sciences. Furthermore, medal lectures, great debates, short courses, townhall meetings, and splinter meetings complete the overall programme.

During the European Geosciences Union-EGU GA 2018 conference a HERACLES session was organised.

The HERACLES session, co-sponsored by JpGU, was entitled "*Cultural Heritage Resilience against Climate events and other risks: Modelling, Remote and in-situ sensing, Material characterization and ICT tools*". The convener was Giuseppina Padeletti, and the Co-Conveners were Francesco Soldovieri, Jürgen Moßgraber, George Alexandrakis, Gianfranco Fornaro, Antonella Curulli, Gaelle Lortal, Cecilia Sciarretta, Francesco Calabro, and Paraskevi Pouli.

Among all the presentations, 13 presentations were related to the HERACLES activities:

4a. An oral presentation by Jürgen Mossgraber, G. Lortal, F. Calabrò, M. Corsi (Fraunhofer, Thales, Leonardo, E-geos) entitled "*An ICT Platform to support Decision Makers with Cultural Heritage Protection against Climate Events*"

4b. An oral presentation by M. Costantini, Nicola Cavalagli, Francesco Trillo, and Filippo Ubertini (E-geos, UniPG) entitled "*Towards an effective fusion of satellite InSAR and in-situ data for structural assessment and monitoring of heritage buildings: first experiences in Gubbio and Heraklion*"

4c. An oral presentation by G. Alexandrakis, C. Manasakis, G. Kozyrakis, F. Tosti, E. Kavoulaki, N. Kampanis (FORTH, Gubbio, Ephorate) entitled "*Socio Economic impact of natural and climate change hazards on cultural heritage sites*."

4d. An oral presentation by A. Curulli, J. P. Veiga, K. Demadis, J. Grammatikakis, G. Montesperelli, M. Menichetti, G. Padeletti (CNR, UNINOVA, UOC, INSTM, CVR) entitled "*Methodology for the characterization of Cultural Heritage materials and their degradation state, using ex-situ laboratory analysis and microscopies: the HERACLES project approach*."

4e. A poster presentation by K. Watson, S. Kunz, H. van der Schaaf, F. Ubertini (Fraunhofer, UniPG) entitled "*Analysis of sensor signals for monitoring of heritage buildings*"

4f. A poster presentation by J. Mossgraber, P. Pouli, G. Padeletti (Fraunhofer, FORTH, CNR) entitled "*An ontology for protecting Cultural Heritage against Climate Change*"

4g. A poster presentation by N. Cavalagli, I. Pigliautile, A. L. Pisello, F. Ubertini (UniPG) entitled "*A multidisciplinary approach for assessing structural damage and material degradation of heritage buildings: application to Palazzo dei Consoli*"

4h. A poster presentation by E. Kavoulaki, A. Dokoumetzidi, E. Kanaki, E. Katsaveli, E. Politaki, A. Psaroudaki, V. Sythiakaki, G. Tsimpoukis (Ephorate) entitled "*The Palace of Knossos and the Venetian Fortress «Rocca a Mare» (Koules) in Heraklion, Crete, Greece. How the HERACLES activities and platform will contribute to their protection and resilience against climatic events*."

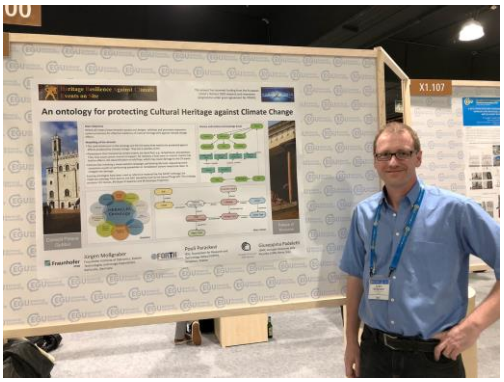
4i. A poster presentation by P. Pouli, A. Philippidis, E. Kalokairinou, K. Melessanaki, O. Kokkinaki, P. Siozos, K. Hatzigiannakis, E. Kavoulaki, E. Politaki, A. Psaroudaki (Forth, Ephorate) entitled "*A methodology for the in-situ chemical analysis and monitoring of environmental and climatic deterioration products on monuments using advanced, non-contact, laser-based technologies*."

4j. A poster presentation by G. Alexandrakis, N. Rempis, G. Kozyrakis, N. Kampanis (FORTH) entitled "*Cultural heritage resilience and socioeconomics benefits*."

4k. A poster presentation by I. Catapano, G. Ludeno, F. Soldovieri, F. Tosti, G. Padeletti (CNR) entitled "*Microwave tomography enhanced GPR surveys in Consoli Palace of Gubbio (Italy).*"

4l. A poster presentation by I. Catapano, G. Ludeno, F. Soldovieri, I. Capozzoli, G. De Martino, E. Rizzo (CNR) entitled "*Integrated Ground Penetrating Radar and Electric Resistivity Tomography Surveys at Gubbio Town Walls: session Data fusion, integration, correlation and advances of non-destructive testing methods and numerical developmentes for engineering and geosciences applications*."

4m. A poster presentation by G. Fornaro, A. Paciullo, D. Reale, S. Verde (CNR) entitled "*Application of advanced SAR interferometric approaches to the Monitoring of Cultural Heritage*."



During EGU GA 2018 conference, some contributions were highlighed and the authors were interviewed by Dagmar Roehrlich from German public radio-station Deutschlandfunk and the web-journal Planeterde.de; among them, the followings, related to HERACLES, were:

4n. An interview to G. Alexandrakis (FORTH) about "Soco Economic impact of natural and climate change hazards on cultural heritage sites."

4o. An interview to J. Mossgraber (FRAU-IOSB), about the importance of ICT tools for CH.

4p. An interview to G. Padeletti and F. Soldovieri (CNR), about the impact of the HERACLES project on CH protection from CC.

2. ISCRAM – ICMT WORKSHOP (ROCHESTER, NY (USA) – 20 JUNE 2018

The ISCRAM – ICMT Workshop is a premier international venue for the dissemination of peer-reviewed research and lessons learned from all aspects of information systems for crisis response and management. Topics of interest include, but are not limited to: crisis informatics, geographic information systems (GIS), human-computer interaction, humanitarian information management, situation awareness, visual analytics, social media, serious games and more.

An oral presentation was made by Jürgen Mossgraber (Fraunhofer) entitled "Keynote - Architecture of Early Warning and Decision Support Systems"

3. E-MRS 2018 SPRING MEETING (STRASBOURG, FR – 18-22 JUNE 2018)

The EMRS Spring Meeting-2018 consisted of 29 parallel symposia with invited speakers, oral and poster presentations and a plenary session to provide an international forum for discussing recent advances in the field of materials science. This conference is improved by a big exhibition of scientific products and services for research & development field.

During the EMRS Spring Meeting several events related to HERACLES project occurred:

- a Symposium dedicated to CH, and linked with the 2018 EYCH, was organised: Symp CC "*Cultural heritage materials, techniques and knowledge perspectives on a common identity*"
- during Symp CC, a session dedicated to European project funded by EC was created: Special Symp CC Session - "*European Commission Funded Projects to Face Climate Change and Natural Hazards Effects on CH*"
    - HERACLES project was presented by the coordinator G. Padeletti: "*HERACLES Project - Heritage Resilience Against Climate Events on Site*"
- Within the Symp. CC programme, the following contributions presented results from the HERACLES activities:
    - **7a**. An oral presentation by G. Alexandrakis, N. Kampanis, P. Pouli (Forth) and A. Psaroudaki (Ephorate) entitled "*Climate changes impact, Risk management and mitigation of Costal Cultural heritage sites*."
    - **7b**. An oral presentation by Jürgen Mossgraber (Fraunhofer) entitled "*Modelling the domain of Cultural heritage-materials in relation to climate change*"
    - **7c**. An oral presentation by Nicola Cavalagli (UniPG) entitled "*Structural damage and material degradation assessment of Palazzo dei Consoli in Gubbio, Italy*"
    - **7d**. An oral presentation by K. Demadis, I. Grammatikakis, E. Armakola (UOC) entitled "*Surface coordination chemistry as a mechanistic tool for evaluating calcium-binding consolidants: Application on gypsum stones*"
    - **7e**. An oral presentation by I. Grammatikakis, E. Armakola, K. Demadis (UOC) entitled "*Evaluation of consolidant efficiency on sulfate stones: A case study of the mineral gypsum from the Minoan Palace of Knossos*"
    - **7f**. An oral presentation by A. Philippidis, E. Kalokairinou, K. Melessanaki, K. Hatzigiannakis, O. Kokkinaki, P. Siozos, P. Pouli, E. Kavoulaki, E. Politaki, A. Psaroudaki (FORTH, Ephorate) entitled "*In-situ analysis and monitoring of environmental deterioration products on stone monuments using advanced laser-based technologies*."
    - **7g**. An oral presentation by I. Catapano, G. Ludeno, F. Soldovieri, F. Tosti, G. Padeletti (CNR, Gubbio) entitled "*GPR surveys for Cultural Heritage assets: the case study of Consoli Palace at Gubbio – Italy*"
    - **7h**. A poster presentation by F. Carvalho, G. Padeletti, A. Curulli, G. Montesperelli, M. M. Lima, A. Lopes, T. P. da Silva, J. P. Veiga (CENIMAT/I3N, UNINOVA, CNR, INSTM, LNEG) entitled by "*The case study of the Medieval Town Wall of Gubbio in Italy. First results on the characterization of mortars and binders*"

- Within the EMRS Spring Conference 2018, the satellite event "Europe in Motion - EUMAT joint session " was organised. HERACLES project was presented at this event:
    - An oral presentation of the project by G. Padeletti (CNR) ***HERACLES, Heritage Resilience Against Climate Events On Site***

- In the EMRS Spring 2018 Conference Exhibition area, the HERACLES Exhibition STAND was set up In the stand a monitor showing in continuous the HERACLES concept and results achieved was present.
  Explanation were provided to the public, and HERACLES flyers and USB keys were distributed.

4. 5TH AND 6TH HERACLES VIRTUAL COURSES

The fifth virtual course was organised by e-Geos and CNR from Naples, IT on April 5th, and was entitled "Satellite and airborne techniques for surveillance and monitoring at territory and site scales". This course was presented by Gianfranco Fornario and Gabriele Murchio.

It concerned synthetic Aperture Radar (SAR), with techniques known as persistent scatterer intereformetry (PSI) and tomography, and photogrammetry, that are valuable tools reconstruction and monitoring of territories and structures as well as detailed 3D reconstruction. The talk aimed at reviewing the fundaments of these technologies and discussing their advantages in the frame of cultural heritage preservation, with specific focus on the medieval Gubbio town.

See http://www.heracles-project.eu/virtual-course-satellite-and-airborne-sensing-techniques-surveillance-monitoring-territory-and-site

The sixth virtual course was organised by CNR from Naples, IT on April 5th, and was entitled "In-situ sensing techniques for subsoil and structure diagnostics". This course was presented by Ilaria Catapano.

It concerned Ground penetrating radar (GPR), this well-assessed technology widely used for subsoil and structure characterization, whose performance benefit of the use of model-based data processing approaches. The talk summarized the GPR working principles and the key concepts of linear microwave tomography. In addition, results of a measurement campaign performed at the Condoli Palace of the Gubbio town were presented.

See http://www.heracles-project.eu/virtual-course-situ-sensing-techniques-subsoil-and-structure-diagnostics

FUTURE EVENTS

1. OPTO-CH 2018 - HERACLES SUMMER COURSE (HERAKLION, EL – 2-4 JULY 2018)

HERACLES will be the subject of this year OPTO-CH 2018 summer courses is to introduce participants to applications of advanced laser-based technologies in Cultural Heritage (CH) science, diagnostics and conservation, and to inform them on the latest developments of the project research as regards the effective resilience of Heritage monuments against climate events. Lectures from experts on modern laser diagnostic and analytical techniques, as well as on laser cleaning methodologies will be combined with practical demonstrations and laboratory hands-on sessions. In parallel, experts researching on advancing the level of heritage monuments resilience (analysis and understanding of materials' degradation mechanisms, synthesis of new protective materials, in-situ diagnosis and monitoring as well as ICT technologies) will present the HERACLES concept.

Four presentations wil be made:

2a. An oral presentation was made by Tobias Hellmund (Fraunhofer), entitled "Introduction and Demonstration of the HERACLES ICT platform."

2b. An oral presentation was made by Elisa Kavoulaki and Elpida Politaki (Ephorate), entitled "Conservation and restoration works in the Palace of Knossos: The previous interventions and the recent strategies within HERACLES."

2c. An oral presentation was made by V. Sythiakaki, E. Georgali and K. Patedakis (Ephorate), entitled "The Venetian Sea Fortress (Rocca a Mare or Koules). Building and restoration history."

2d. An oral presentation was made by Angeliki Psaroudaki (Ephorate), entitled "Degradation problems and risks/hazards at the Venetian Sea Fortress of Koules.".