Project Number: 101062427

Project Acronym: PALEOSIM

Project Title: PALEOclimate modelling of Small Islands in the Mediterranean and possible impacts on arthropod habitats

TFR1: Technical and Financial Report 1

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December 2023

Technical Overview

This report is divided into two parts, an overview of the technical aspects of the project, PALEOSIM, and an update of the financial plan.

The main objective of PALEOSIM is ***to determine the impacts of climate change on arthropod habitats in the last 21,000 years, and extending to the current global warming projections***. To achieve this goal, PALEOSIM was sectioned into 6 Work Packages (WPs) with their own associated tasks and goals, of which the first 3 WPs contain research goals, and the latter 3 make up transfer of knowledge, dissemination, and management of the project. An overview of each WP is presented in the following sections.

WP1 - Climate Impacts on Arthropod Habitats

The specific research objective of WP1 was **to establish climate links to arthropod habitats with climate data from past studies**. The original concept for obtaining this objective was to use environmental parameters (such as, air temperature and wind speed) to establish a comfort range (or danger) for the habitat a few indicator species (such as, bees as pollinators, beetles as decomposers, oriental hornets as invasive species).

T1.1 - Arthropod Habitats and Climate Links

This task was initiated by researching literature on arthropods and their ecology, and the first training exercise (**TR1: Training for Arthropod Classification & Species of Interest**). This was led by Prof. David Mifsud through early meetings and discussions, as well as directing reading of numerous books, academic publications, and online material. Special attention was given to the acquisition and study of the books listed below:

- The Insects (5th Ed) - Gullan & Cranston
- Insect Ecology (5th Ed) – Schowalter

A crucial result of this training, apart from basic arthropod body plans, was an understanding of the taxonomy of the *phylum* Arthropoda and the main *clades* associated with this group: Chelicerata (e.g. spiders, scorpions, horseshoe crabs), Myriapoda (e.g. centipedes, millipedes), Crustacea (e.g. shrimps, woodlice), Hexapoda (mostly insects). An infographic (Figure 8) was thus designed for outreach activities.

From the activities of TR1, a few **Potential Species of Interest (PSI)** were identified to test the method used throughout the project (Table 1), and their corresponding observations were obtained from the iNaturalist database. As the method was set to be tested on European data, the species chosen were not restricted to the Circum-Sicilian Islands (CSI). The species selected vary in their abundance of observations; this serves as a useful tool to test the applicability of the method. *Apis mellifera* was initially also considered as a PSI, however, it was not deemed ideal for this stage of analysis, since it is a domesticated species and widely distributed across several climate zones.

Table 1. List of PSI used in the primary testing of the PALEOSIM ENM. The list includes the Genus and species, the common name, and the ecological role of the species.

Genus species	**Common name**	**Role/Status**
Ameles decolor	Grey Mantis	predator
Argiope lobata	Lobed Argiope	predator
Brachytrupes megacephalus	*Sand cricket*	herbivore/vulnerable
Polyommatus celina	Austaut's Blue	pollinator
Scarabaeus variolosus	*Dung beetle*	decomposer
Selysiothemis nigra	Black Pennant	predator
Spilostethus pandurus	Indian milkweed bug	herbivore
Xylocopa violacea	Violet Carpenter Bee	pollinator

Several ecological studies describe Ecological Niche Models (ENMs) that use climatological parameters, together with a myriad of other environmental factors. For the purposes of this project, a different method was designed, to consider only climate parameters (to study the direct impacts of climate change), and to enable the direct application of climate model output. This method is based on the following assumption:

A living organism observed at a particular location can be assumed to find the climatology of that location favourable. Hence, the observed locations of the same organism can describe the range of climate conditions necessary for its survival.

The metric developed to describe the climatological component of a species' environment (for this report it will be referred to as **Eco-Climate Index**, or **EI**), is explained below.

Taking a PSI (*Polyommatus celina* [Austaut's Blue]), s, with n sampling locations, and a selection of climate indices, the value of an index at a sample location can be expressed as x_i (where i describes each index, such as mean temperature [*tas*], or annual sum of precipitation [*prsum*]). The corresponding mean index of the population of s can be expressed as μ_i.

The **ideal conditions of a specific climate index, C_i**, for s would occur when x_i approaches the value of μ_i. As x_i deviates from μ_i, the climate index becomes less ideal, until it exceeds a limit, L_i. Thus, C_i can be expressed as Equation (1) below, where σ_i is the standard deviation of i for the population, and d_i is a standardized distance value.

$$(1) \quad C_i = \begin{cases} 1 & , \text{ if } |x_i - \mu_i| = 0\ \sigma_i \\ 1 - \left|{}^{d_i}/_{L_i}\right| & , \text{ if } |x_i - \mu_i| = d_i\sigma_i \\ 0 & , \text{ if } |x_i - \mu_i| = L_i\sigma_i \end{cases}$$

Using Equation (1), the d_i can be defined as $d = \frac{x_i - \mu_i}{\sigma_i}$ and C_i is reduced to Equation (2).

$$(2) \quad C_i = 1 - \left|\frac{x_i - \mu_i}{\sigma_i}\right| \frac{1}{L_i}$$

The limit, L_i, is expressed as Equations (3) and (4), which describe the largest deviation from the maximum or minimum of d_i, after removal of outliers (Carling, 2000; Wilcox, 2022).

$$(3) \quad L_i = \max\left(d_{i,max}, d_{i,min}\right)$$

$$(4) \quad \begin{aligned} d_{i,max} &= \left|\frac{x_{i,max}-\mu_i}{\sigma_i}\right| \\ d_{i,min} &= \left|\frac{x_{i,min}-\mu_i}{\sigma_i}\right| \end{aligned}$$

The different quantities of C_i are combined into $\boldsymbol{EI_s}$ as shown in Equation (5), after which the EI_s is divided by its own maximum, to obtain a scale relative to 1. It is important to note that a value of 1 describes the ideal climate conditions for species s according to its current known locations. It is important to note that a value of 1 does not imply the presence of species s as non-climatological factors (such as human population density, and presence of competing species) are not included in this assessment.

$$(5) \quad \boldsymbol{EI_s} = \boldsymbol{C_{tas}} \times \boldsymbol{C_{prsum}} \times \cdots \times \boldsymbol{C_i}$$

The method was extensively tested and for some time, an additional step was included where all values of C_i would be converted into their principal components using Principal Component Analysis (PCA), however this was not producing reliable results compared to the method presented above, and resulted in substantial delays in the progress of WP1. At this point the PCA is only used to test the co-dependence of the climate indices used.

Several indices of varying complexity were considered (described/used in various studies e.g. (Giorgi *et al.*, 2011; Giorgi, Coppola and Raffaele, 2018; Sylla *et al.*, 2018; Coppola *et al.*, 2021; Schwingshackl *et al.*, 2021) prior to the development of the method. For the purposes of the current tests, 8 climate indices were selected (described in Table 2) which included: 3 temperature-related and 3 precipitation-related indices, that describe average and extreme (upper and lower) conditions; average wind conditions; and elevation. The method is not restricted to 8 indices, and in the upcoming analysis the quantity and selection may differ.

Table 2. A description of the climate indices used to test the calculation of EI.

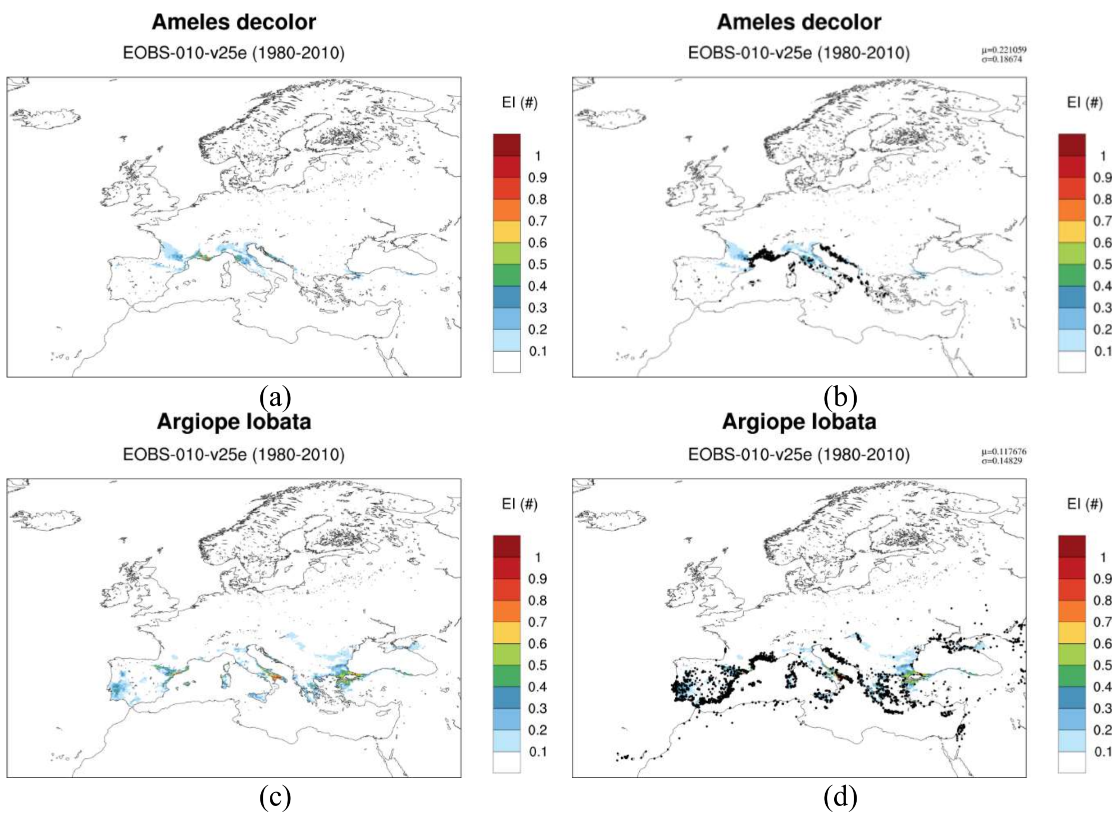
Short Name	**Long Name**	**Units**
tasmean	Annual mean of near-surface air temperature	°C
tasp10	10^{th} Percentile of near-surface air temperature	°C
tasp90	90^{th} Percentile of near-surface air temperature	°C
prsum	Annual total precipitation	mm/yr
cdd	Annual mean of maximum consecutive dry days	days/yr
r99	Annual total precipitation greater than the 99^{th} percentile	mm/yr
windmean	Annual mean of near-surface wind speed	m/s
orog	Surface Altitude	m

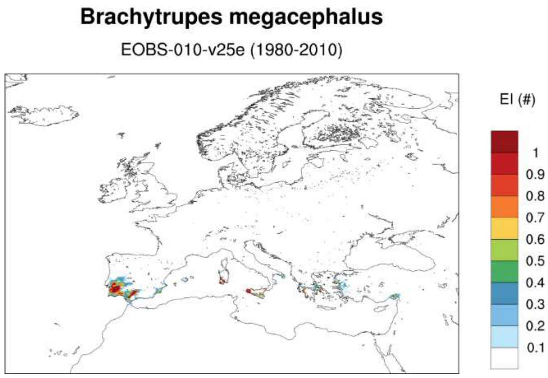
One of the challenges when selecting a PSI for this method, is the number of observations available, n. Some species, such as *B. megacephalus* have a very small number of observations. This is circumvented by a bootstrapping method to artificially inflate the sample size via resampling (with replacement). To keep the sample size consistent between different PSIs, the number of times a single PSI dataset is resampled is chosen so that it brings up the sample size to ~5000 ($5000 = n \times N$). E.g., the number of research grade observations for *B. megacephalus* is n=26, thus N=185 is used (seen in Table 3).

Table 3. The sample size, n, and resampling number, N, applied to each PSI.

Genus species	***n***	***N***
Ameles decolor	778	6
Argiope lobata	3062	2
Brachytrupes megacephalus	26	185
Polyommatus celina	631	8
Scarabaeus variolosus	143	35
Selysiothemis nigra	529	9
Spilostethus pandurus	5037	1
Xylocopa violacea	5420	1

Finally, a climate data-set is required. These are described in T1.3, but for the purposes of this test, the climate observation data-set, E-OBS (Haylock *et al.*, 2008; Cornes *et al.*, 2018), was used with a 30-year time-period (1980-2010). The species listed Tables Table 1 and Table 3 were applied to the method described above, and the results obtained are presented in Figure 1.




Brachytrupes megacephalus
EOBS-010-v25e (1980-2010)
EI (#)
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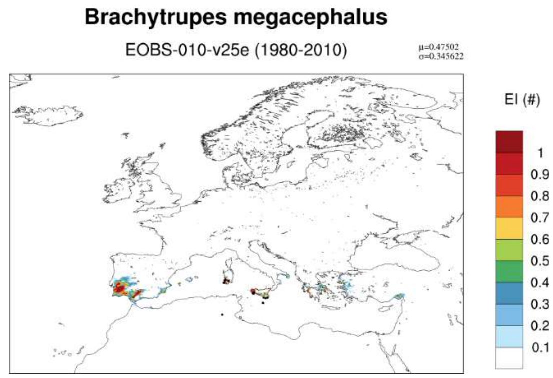
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

(e)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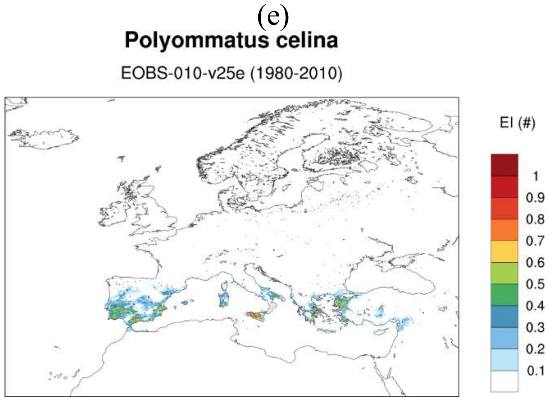
0.2
0.1

(f)


Polyommatus celina
EOBS-010-v25e (1980-2010)
EI (#)
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0.7
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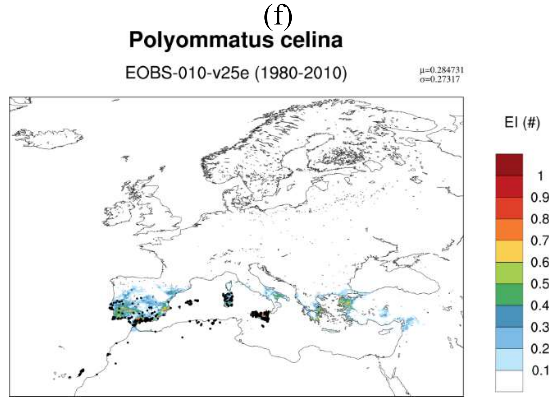
0.4
0.3
0.2
0.1

(g)


Polyommatus celina
EOBS-010-v25e (1980-2010)
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σ=0.27317
EI (#)
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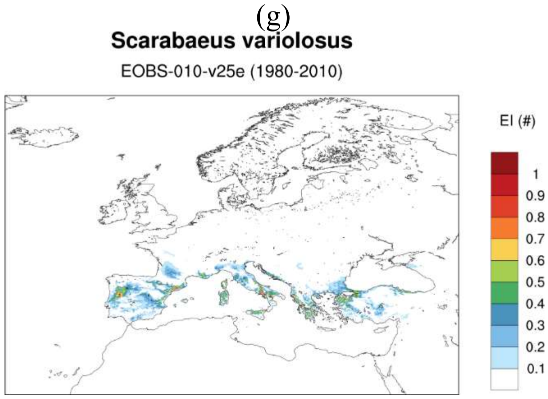
0.7
0.6
0.5
0.4
0.3
0.2
0.1

(h)


Scarabaeus variolosus
EOBS-010-v25e (1980-2010)
EI (#)
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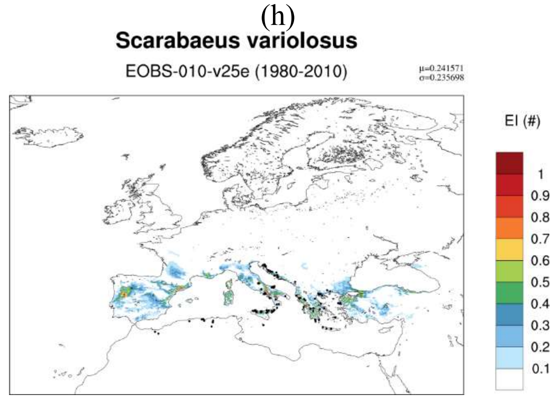
0.7
0.6
0.5
0.4
0.3
0.2
0.1

(i)


Scarabaeus variolosus
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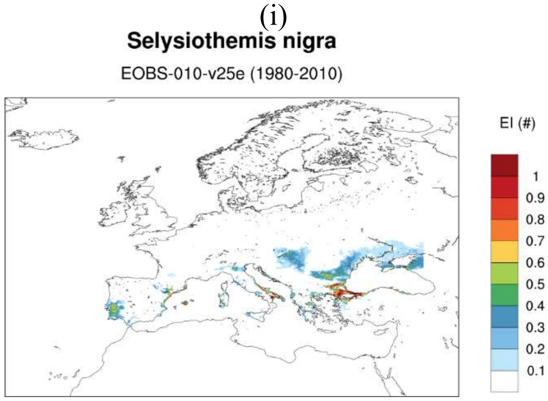
0.4
0.3
0.2
0.1

(j)


Selysiothemis nigra
EOBS-010-v25e (1980-2010)
EI (#)
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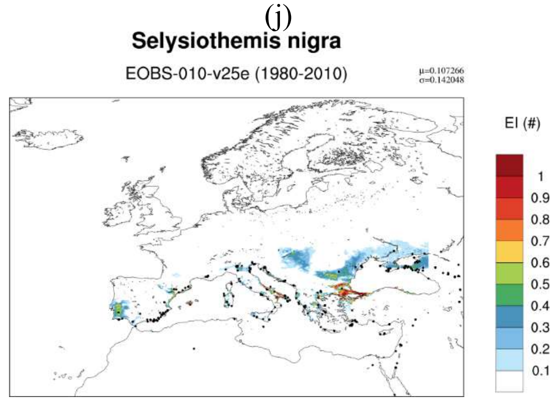
0.7
0.6
0.5
0.4
0.3
0.2
0.1

(k)


Selysiothemis nigra
EOBS-010-v25e (1980-2010)
μ=0.107266
σ=0.142048
EI (#)
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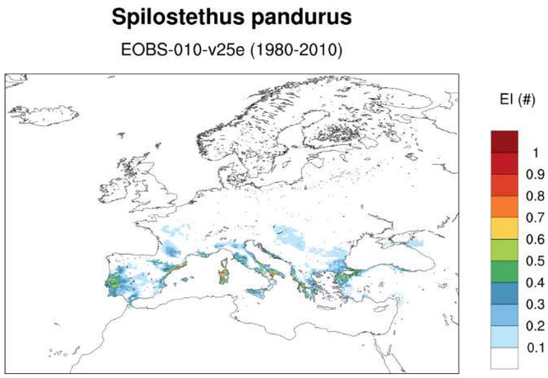
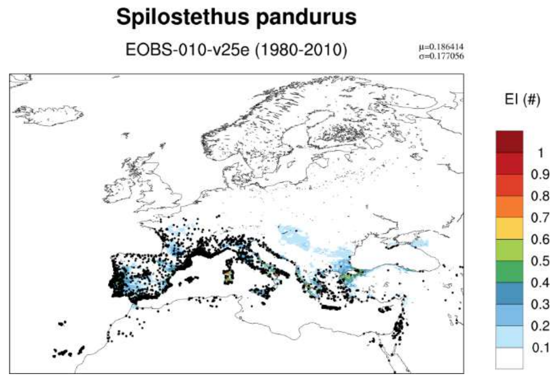
0.7
0.6
0.5
0.4
0.3
0.2
0.1

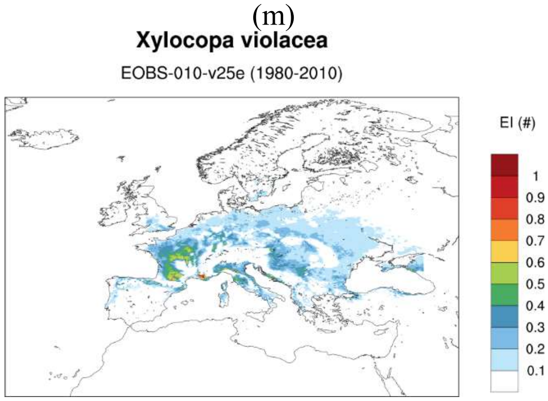
(l)



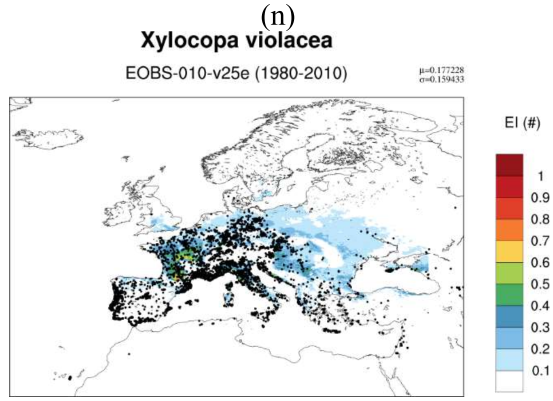
(m)



(n)



(o)



(p)

Figure 1. The EI for 8 species (a-p) described in Tables Table 1 and Table 3. The left shows only the EI, while the right shows the observation locations of the PSI (dots) superimposed on the EI. For the latter, a mean (μ) and standard deviation (σ) for the EI at these locations is included on the top right.

The results reveal a reliable consistence between the area of EI and the regions with most concentrated PSI observations. The corresponding values of EI vary significantly at this point, but they suggest that EI values above 0.2 are sufficient for the PSI, however additional analysis is required to determine any form of 'threshold' that describes different 'grades' of the habitat. This result marks the achievement of the milestone **M1.1 (Impact assessment results for first data-set)**.

At the current stage of testing, some species cannot be applied reliably to the method. *Apis mellifera* (Western Honey Bee), is a domesticated species that has spread through a large variety of climate zones, thus the Ci values obtained for *A. mellifera* would be too broad. An interesting alternative could be to observe subspecies, such as *A. mellifera ruttneri* (Maltese Honey Bee), however the iNaturalist database only provides a sample size of *n*=3. Additional observations could be potentially added from other datasets, or the Citizen-science Observation Program (COP; described below). Alternatively, the climate of all grid points of the Maltese Islands could be used as standard and applied to the method; this would only be relevant with for a storyline approach following the completed simulations of WP2 and WP3.

T1.2 - Arthropod Observations

The objective of this task was to provide training through field-work and provide new observations pertinent to the CSIs. This was initiated with **TR2 (Field-work training)**, which began with a safety protocol to be used in all field-work activities. This safety protocol was also associated with the Citizen-science Observation Program (COP), described with WP5, and included on the website as follows:

> Your safety (and that of others) is more important than any image or entry. You are encouraged to be vigilant and stay safe at all times. Here are some helpful suggestions that you can follow whilst doing your own field-observations.
>
> - Do not enter private property;
> - Be careful of your footing and your surroundings;
> - Avoiding dangerous terrain;
> - Carry a first-aid kit with you;
> - Have a travel-partner, especially in unfamiliar places;
> - Inform a friend or family member of where you intend to be, and stay in contact.
>
> You can also consider taking a first-aid course (or a refresher course).

The Epicollect5 app, a citizen-science tool commonly used in biology-related studies, was selected as a data-collection tool, particularly to be associated with COP, but also for TR2 and all field-work excursions, and random observations (any kind of observation taken during and outside working hours, during regular day-to-day activities).

The TR2 was conducted by Prof. David Mifsud, which took the form of preparatory discussions, guided field-work, and suggestions for additional field-work locations (the locations included/planned are listed in Table 4). A summarized list of the lessons learnt during this training follows:

- expect different species observed depending on seasonality and the diurnal cycle;
- water pools attract all sorts of animals (especially dragonflies)
- nocturnal animals avoid the sun, e.g. Tenebrioid beetles commonly found under sand
- various species hide under rocks to stay in moist environments and for shelter;
- leave a place undisturbed (as much as possible) – replace any turned stones;
- the app should include the possibility of inputting multiple images for better species identification;
- some areas show evidence of human influence:
    - beach erosion and salt rich environment – due to position of breakwater
    - damaged plants and reduced dunes – due to proximity to human presence

A Bioblitz (a training activity for new citizen-science volunteers) was held in Janurary 2023 to train and encourage people to join the COP and expand the data-set, and to get feedback to improve the PALEOSIM data-collection in the app. An upcoming 2024 trip to the Aegean islands is currently being planned, together with the possibility of additional field-work in the Maltese islands.

Table 4. Date and locations of field-work excursions conducted for PALEOSIM.

Date	Location	Island	Companions
07/09/2022	*Il-Ballut ta Marsaxlokk*	Malta	D. Mifsud, A. Lamoliere
07/01/2023	Buskett Gardens	Malta	*Bioblitz*
22/04/2023	*Valle d'Agira*	Sicily	G. Sabella, D. Mifsud, A. Lamoliere
22/04/2023	*Ponte dei Saraceni*	Sicily	G. Sabella, D. Mifsud, A. Lamoliere
23/04/2023	*Bosco di Malabotta*	Sicily	G. Sabella, D. Mifsud, A. Lamoliere
24/04/2023	Eastern Lampedusa	Lampedusa	D. Mifsud, A. Lamoliere
25/04/2023	Western Lampedusa	Lampedusa	D. Mifsud, A. Lamoliere
04/06/2023	Binġemma Valley	Malta	G. Galea, C. Galea
17/06/2023	Għajn Tuffieħa	Malta	S. Mifsud
11/11/2023	Comino	Comino	A. Agius
Spring 2024	Aegean Isles	Aegean Isles	*T.B.D.*

The data collection effort has provided a more cohesive understanding of the habitats, a promising means of choosing more PSI, and a possibility to add new data points to exisiting PSI observation data-sets (especially for PSIs with a small *n*).

T1.3 - Past Models and Reference data preparation

The method developed in T1.1 is currently being tested with the use of climate data from past studies. Four types of data-sets had been considered for use in this project, one of which is still under consideration.

Direct observation data-sets (station data) serve two purposes: (a) a climate assessment of the CSI, which is currently in preparation potentially in the form of a publication; and (b) a reference tool for the simulations associated with WP2 and WP3. Currently two data-sets have been acquired: a weather station from the Giordan Lighthouse in Gozo (hourly data, 1997-2022), and 8 weather stations from the Met Office of the Malta International Airport (daily data, 2007-2022; monthly data, 1922-2022). Acquisition of a third data-set, SCIA (*sistema nazionale per la raccolta, elaborazione e diffusione di dati climatici* – managed by ISPRA; http://www.scia.isprambiente.it/wwwrootscia/scia.html), is still under-way due to technical problems with the online systems (communication with technical staff is still ongoing to resolve these issues, and acquire the data).

The gridded (~10 km horizontal resolution) reference data-set, E-OBS, is currently being used to test the ENM described in T1.1. This has been selected due to the selection of atmospheric parameters available, providing enough climate input to test the ENM. This data-set is also being used in conjunction with others [MSWEP (Schneider *et al.*, 2013), CPC (Xie *et al.*, 2007; Chen *et al.*, 2008), GPCC (Elke *et al.*, 2022), CRU (Harris *et al.*, 2020), CARPAT (Szalai *et al.*, 2013), ENG-REGR (Perry, Hollis and Elms, 2009), SWEDEN (Johansson, 2002), SPAIN02 (Herrera, Fernández and Gutiérrez, 2016), NORWAY-METNO (Mohr, 2009), EURO4M (Isotta *et al.*, 2014), RADKLIM (Anon, 2019), COMEPHORE (Tabary *et al.*, 2012), RdisaggH (Wüest *et al.*, 2010), GRIPHO (Fantini, 2019)] to evaluate the new simulations from the historical experiments described in WP2 and WP3.

The testing of the ENM method is being extended to the 12 km EURO-CORDEX (Jacob *et al.*, 2014, 2020) simulations available on the Earth System Grid Federation (ESGF). This Regional Climate Model (RCM) data is made up of 7 simulations (described in Table 5) driven by the ECWMF-ERAINT reanalysis (Dee *et al.*, 2011) and evaluated in past studies (Vautard *et al.*, 2013; Kotlarski *et al.*, 2014; Casanueva *et al.*, 2016; Prein *et al.*, 2016; Fantini *et al.*, 2018). More such evaluation simulations exist; however, these did not have the required time-period (1980-2010) for a direct comparison, or are missing some metrological parameters. This data has been processed and is currently being analysed for T1.4.

Table 5. RCMs driven by ECMWF-ERAINT used for WP1.

Institute & RCM	**Reference**
CLMcom-ETH-COSMO-crCLIM-v1-1	(Sørland *et al.*, 2021)
CNRM-ALADIN63	(Nabat *et al.*, 2020)
GERICS-REMO2015	(Jacob, 2001; Jacob *et al.*, 2012)
ICTP-RegCM4-6	(Giorgi *et al.*, 2014)
KNMI-RACMO22E	(van Meijgaard *et al.*, 2012)
RMIB-UGent-ALARO-0	(Giot *et al.*, 2016)
SMHI-RCA4	(Kupiainen *et al.*, 2011)

The 3km European Climate Prediction system (EUCP) (Ban *et al.*, 2021; Pichelli *et al.*, 2021) evaluation simulations are still being considered for the analysis of T1.4. A total of 14 simulations may be available; however, this data-set does not include the CSIs, and given the progress of the simulations in WP2, this part of the analysis might not be necessary.

T1.4 - Climate Impact Assessment

This task brings together the work completed in the previous WP1 tasks: the ENM developed for T1.1, and the climate data described in T1.3. The observation locations for the PSI have been obtained from the iNaturalist data-set instead of the COP and T1.2 (this data will be used directly in the final publication of the project); however, this was instrumental in determining the PSIs to consider for this analysis.

The results of this task are being compiled and prepared for publication (the **WP1 deliverable D1.1**). Submission is envisioned for the end of December 2023 (delays from the proposed submission date were due to the PCA tests described in T1.1), to the journal ‘Open Access Europe’ (instead of ‘npj Climate and Atmospheric Science’ considered in the proposal – the journals associated with the publications for WP1-3 have been reconsidered due to their high open-access fees).

WP2 - Modern-day Climate Assessment

The specific research objective of WP2 was **to configure Convection Permitting (CP)-model and simulate historical and future climate and arthropod habitats**. The purpose of this WP is to obtain high-resolution simulations for a 20-year ‘historical’ experiment (1995-2015), to be followed up by future simulations of different Global Warming Levels (GWLs).

Notable Risk and Mitigation

A significant model bug, which produced anomalously high summer temperatures, was identified after 5 months of progress in T2.3. The error was in the pre-processing of the parent simulations, which meant that that all simulations (except the evaluation run) had to be discarded and restarted. This is resulting in significant delays in WP2 (which may influence the waiting time of WP3 simulations). To mitigate this problem, priority is being given to one GCM (notably MPI-ESM1-2-HR) to ensure that an analysis could still be completed by the end of the project. All effort to complete the other simulations will still take place.

T2.1 - Land-Use Map Updates

The need for high-resolution simulations of the CSIs requires updated land-use maps for the new simulations. Since the new simulations will be part of the Coupled Model Intercomparison Project Phase 6 (CMIP6)(Eyring *et al.*, 2016) downscaling for EURO-CORDEX, all WP2 simulation will CORDEX Flagship Pilot Studies (FPS) Land Use and Climate Across Scales (LUCAS)(Davin *et al.*, 2020) protocols and use annual land use land cover maps from LUCAS LUC V1.1 based on Land-Use Harmonization 2 (LUH2)(Reinhart *et al.*, 2022; Hoffmann *et al.*, 2023). This dynamical land-use interacts with the RegCM through the Land Surface Model (LSM) selected for these simulations is the Community Land Model version 4.5 (CLM4.5)(Oleson *et al.*, 2013). The implementation of this data would not have been possible without Graziano Giulian from the ICTP; his collaboration was vital to the success of this task.

T2.2 - Model Configuration

Following the successful publication of Giorgi et al. (2023), the newest version of the model RegCM5 was selected for the simulations of WP2 and WP3. Most of the work associated with this task was conducted during the **1st secondment at the ICTP (15 Jan-16 Mar; SC1)**. The decision regarding the configuration were made through a series of tests, and meeting with Dr Erika Coppola.

During these meetings the standard resolution ratio in downscaling (100 km > 30 km [not often used] > 12 km > 3km) was discussed, which clearly shows the necessity of a 12 km intermediate simulation between the driving General Circulation Models (GCMs) and the target 3km simulation. The EURO-CORDEX domain (EUR-11) was thus ideal as an intermediate simulation, and since the downscaling goals of PALEOSIM coincide with the new EUR-11 downscaling objectives, three GCMs with high, medium, and low Equilibrium Climate Sensitivity (ECS) selected for EUR-11 (shown in Table 6) were also chosen for PALEOSIM.

Table 6. The driving GCMs and ensemble members used in WP2, together with the corresponding ECS according to Scafetta (2022).

Abbreviation	GCM	Member	ECS
MPI	MPI-ESM1-2-HR	r1i1p1f1	2.98
NorESM	NorESM2-MM	r1i1p1f1	2.5
EcEarth	EC-Earth3-Veg	r1i1p1f1	4.31

A series of tests of the EUR-11 domain were run, starting with the configurations used by (Giorgi *et al.*, 2023). The simulations were driven by the ECMWF-ERA5 reanalysis (ERA5)(Hersbach *et al.*, 2020) as an evaluation experiment, and using the microphysics schemes: NoTo (Nogherotto *et al.*, 2016), and WSM5 from the WRF modeling system (Hong, Dudhia and Chen, 2004). Figure 2 and Figure 3 show a comparison between these two test-simulations, which reveals that the WSM5 is drier and warm than NoTo, hence the latter was selected.

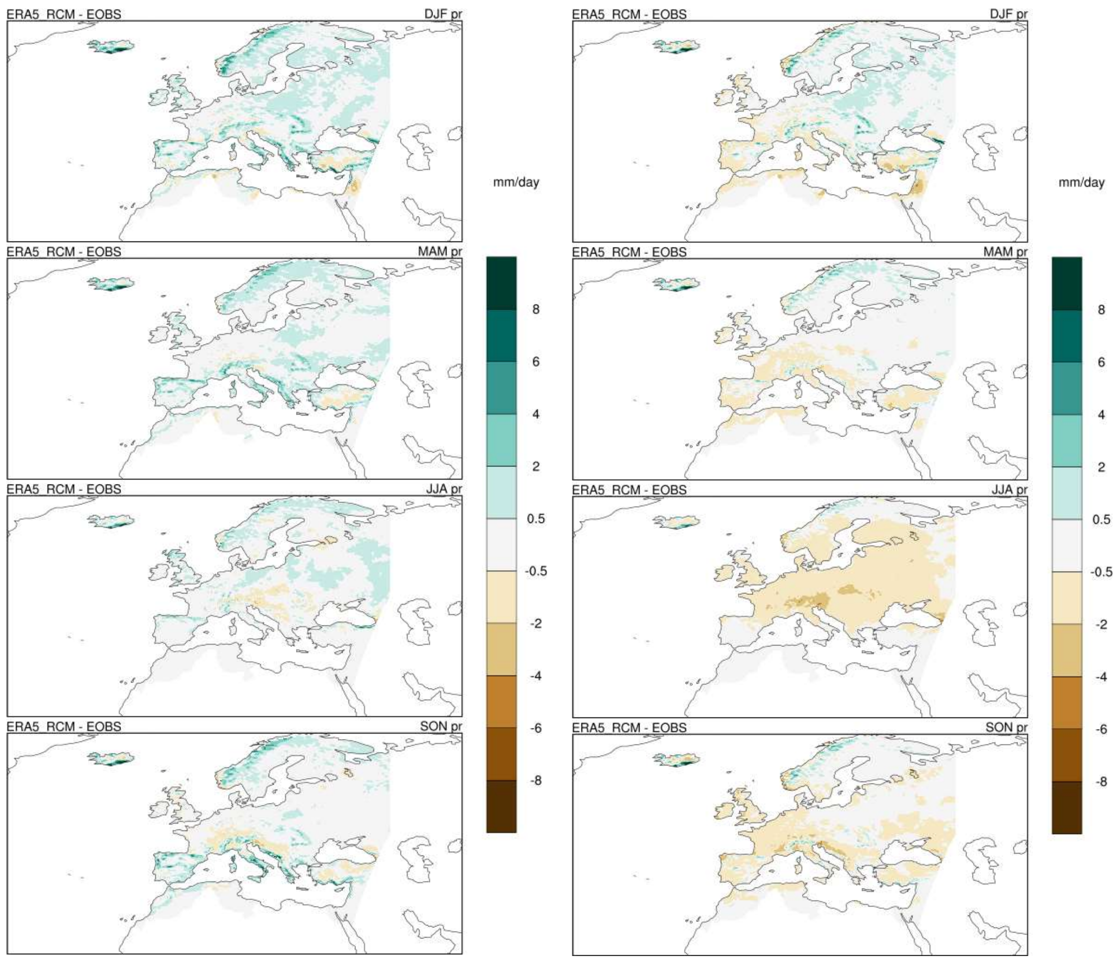


Figure 2. Seasonal precipitation bias (mm/day) compared to E-OBS for RegCM5 test simulations of 2000-2004 driven by ERA5 using NoTo (left) and WSM5 (right) microphysics schemes.

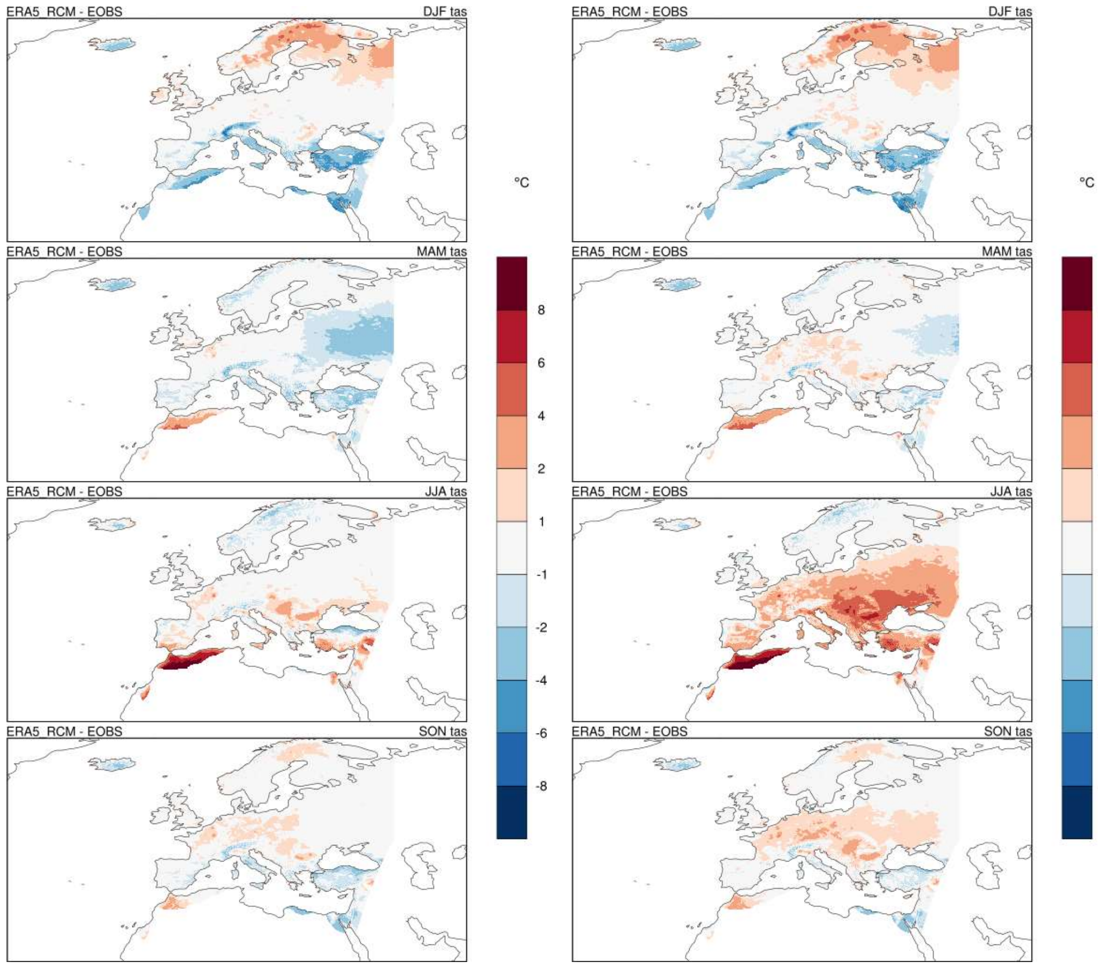


Figure 3. Seasonal near-surface air temperature bias (°C) compared to E-OBS for RegCM5 test simulations of 2000-2004 driven by ERA5 using NoTo (left) and WSM5 (right).

The proposed suggested that the CP simulations could be run at 2 km horizontal resolution. Given the uncertainty of model stability and reliable results at this resolution, an analysis of the number of grid points that constitute the CSI under these two resolutions was made (see Table 7). The number of grid points gained by choosing 2 km over 3 km was minimal and thus, a horizontal resolution of 3 km was the optimal choice for the simulations.

Table 7. Number of grid cells making up the archipelagos of the CSIs in 3 & 2 km resolutions.

Islands	**# Grid Cells**	
	3km	**2km**
Maltese	132	210
Linosa	6	10
Lampedusa	25	41
Pantelleria	63	83
Egadi	73	94
Ustica	21	28
Aeolian	222	300

For the CP simulations, 5 domains were tested with a special attention to the quality of results obtained for the CSIs. A minimal-spatial coverage domain (CSI-03) was found to be too small, and had a very strong influence from the border throughout the domain. A larger domain from the EUCP project, South East Europe (SEE-03), placed the CSI too close to the western border of the domain and produced similar problems to the CSI-03. Promising results were obtained from two domains, the Mediterranean (MED-03) and the Western Mediterranean (WMD-03), but the smaller WMD-03 domain was found to be very wet close to the western border. Due to the large size of the MED-03, the WMD-03 domain (seen in Figure 4) was chosen, with the possibility of excluding the western border from the impact analysis.

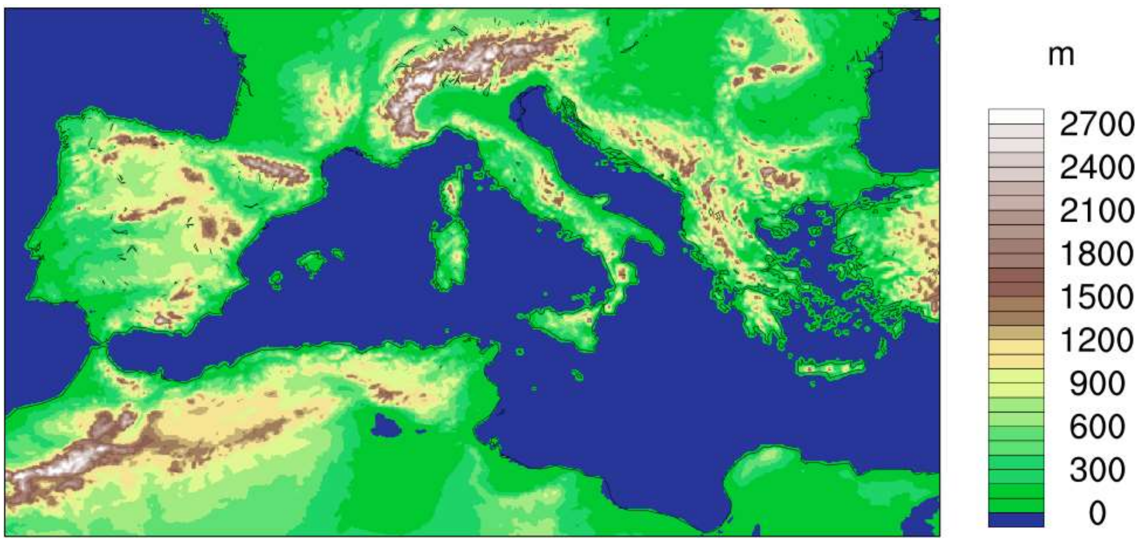


Figure 4. The 3km horizontal resolution domain, named Western Mediterranean (WMD-03), selected for the simulations of WP2 and WP3.

Finally, both the EUR-11 and WMD-03 simulations will require substantial storage. The pycordexer tool of RegCM enables fast post-processing of numerous variables. The EUR-11 processed data is stored at the CINECA facilities and is associate with other projects. The storage of WMD-03 is however, relevant to WP2 of PALEOSIM. Currently, post-processing is following the protocols established in the CORDEX FPS-Convection (Coppola *et al.*, 2020)(using the fpsconv-x2yn2 – meaning nest and parent have different configurations [x2], increased level of difference [y], one intermediate nest [n2]). Table 8 shows that the current storage plan should occupy approximately 361 TB, due to limited storage availability a reduced plan is being considered which would occupy 194 TB (not including the requirements of WP3). *It is also possible that this data will not be able to stored at the CINECA facilities, and thus external hard drives will be required, which may require a more reduced storage plan*.

Table 8. Current and partial storage plans for WP2 simulation output and the associated size capacity. The output is represented according to the variables and their associated frequency.

Frequency	**Variables**
Current (803 GB/simulation year, Total for all simulation = 361 TB)	
1hr	clt evspsbl evspsblpot hfls hfss hurs huss mrro mrros mrsol pr ps psl rlds rlus rsds rsus sfcWind snm snw sund tas tauu tauv ts ua100m uas va100m vas zmla zo
3hr	clt evspsbl evspsblpot hfls hfss hurs huss pr ps psl rlds rlus rsds rsus sfcWind sund tas zo
6hr	clh clivi cll clm clwvi hus1000 hus200 hus300 hus400 hus500 hus700 hus850 hus925 mrro mrros prw rlut rsdt rsut snm snw ta1000 ta200 ta300 ta400 ta500 ta700 ta850 ta925 tauu tauv ts ua200 ua300 ua400 ua500 ua600 ua700 ua850 ua925 uas va200 va300 va400 va500 va600 va700 va850 va925 vas wa1000 wa200 wa300 wa400 wa500 wa700 wa850 wa925 zg200 zg300 zg400 zg500 zg600 zg700 zg850 zg925 zmla
day	clh clivi cll clm clt clwvi evspsbl evspsblpot hfls hfss hurs hus1000 hus200 hus300 hus400 hus500 hus700 hus850 hus925 huss mrro mrros mrsol pr prw ps psl rlds rlus rlut rsds rsdt rsus rsut sfcWind sfcWindmax snm snw sund ta1000 ta200 ta300 ta400 ta500 ta700 ta850 ta925 tas tasmax tasmin tauu tauv ts ua100m ua200 ua300 ua400 ua500 ua600 ua700 ua850 ua925 uas va100m va200 va300 va400 va500 va600 va700 va850 va925 vas wa1000 wa200 wa300 wa400 wa500 wa700 wa850 wa925 zg200 zg300 zg400 zg500 zg600 zg700 zg850 zg925 zmla zo
fx	areacella orog sftlf
Partial (433 GB/simulation year, Total for all simulation = 194 TB)	
1hr 1.9T	tas ts pr uas ua100m vas va100m huss rsds rlds hfls hfss rsus rlus evspsbl evspsblpot clt mrro mrros
3hr 51G	ps psl
6hr 838G	hus1000 hus200 hus300 hus400 hus500 hus700 hus850 hus925 ta1000 ta200 ta300 ta400 ta500 ta700 ta850 ta925 ua200 ua300 ua400 ua500 ua600 ua700 ua850 ua925 va200 va300 va400 va500 va600 va700 va850 va925 wa1000 wa200 wa300 wa400 wa500 wa700 wa850 wa925 zg200 zg300 zg400 zg500 zg600 zg700 zg850 zg925
day 507G	clh clivi cll clm clt clwvi evspsbl evspsblpot hfls hfss hurs hus1000 hus200 hus300 hus400 hus500 hus700 hus850 hus925 huss mrro mrros mrsol pr prw ps psl rlds rlus rlut rsds rsdt rsus rsut sfcWind sfcWindmax snm snw sund ta1000 ta200 ta300 ta400 ta500 ta700 ta850 ta925 tas tasmax tasmin tauu tauv ts ua100m ua200 ua300 ua400 ua500 ua600 ua700 ua850 ua925 uas va100m va200 va300 va400 va500 va600 va700 va850 va925 vas wa1000 wa200 wa300 wa400 wa500 wa700 wa850 wa925 zg200 zg300 zg400 zg500 zg600 zg700 zg850 zg925 zmla zo
fx 8.5M	areacella orog sftlf

The completion of this preparatory process marked the achievement of the milestone **M2.1 (Successful configuration of RCM in CP-mode)**.

T2.3 - Historical and Future Simulations

This task was associated with the 'historical' and 'future' experiments of the CP simulations. To achieve this, and provide a reliable assessment of the results, an 'evaluation' experiment driven by ERA5 was included. The progress and estimated completion time (ECT) of these simulations is shown in Table 9. The SSP370 scenario is used for future simulations (following the current EURO-CORDEX protocols), where 20-year time periods will be downscaled from the EUR-11 to the WMD-03 that correspond to the Global Warming Levels (GWLs) associated with the parent GCM. *Note that the progress on these simulations has been impacted by a bug (as mentioned at the beginning of this section) and thus ERA5 and MPI have been given priority to ensure reliable results from the project.* The remaining simulations will be started/continued once 80% of the priority simulations have completed.

Once all the ERA5 and MPI CP-simulations reach the target date, the milestone **M2.2 (Completion of CP Simulations)** would be achieved.

Table 9. Current state of planned simulations as of 01/12/2023. Priority simulation that will contribute towards M2.2 have been marked in bold.

Driver	**Start**	**Current**	**Target**	**ECT**
EUR-11 simulation (running rate: 1.613 hr/sim.mon)				
ERA5	**1970/01**	**2019/12**	**2019/12**	**Complete**
MPI	**1970/01**	**2010/02**	**2099/12**	**Feb 2024**
NorESM	1970/01	1986/05	2099/12	Mar 2024
EcEarth	1970/01	1992/02	2099/12	Feb 2024
WMD-03 simulation (running rate: 7.618 hr/sim.mon)				
ERA5	**1995/01**	**2002/09**	**2014/12**	**Jan 2024**
MPI: historical	**1995/01**	**1996/08**	**2014/12**	**Fen 2024**
MPI: GWL1.5	**2001/01**	**(1996/08)**	**2020/12**	**Mar 2024**
MPI: GWL2	**2041/01**	**-**	**2060/12**	**77 days from start**
MPI: GWL3	**2072/01**	**-**	**2091/12**	**77 days from start**
NorESM: historical	1995/01	-	2014/12	77 days from start
NorESM: GWL1.5	2037/01	-	2056/12	77 days from start
NorESM: GWL2	2053/01	-	2072/12	77 days from start
NorESM: GWL3	2081/01	-	2100/12	77 days from start
EcEarth: historical	1995/01	-	2014/12	77 days from start
EcEarth: GWL1.5	2002/01	-	2021/12	77 days from start
EcEarth: GWL2	2023/01	-	2042/12	77 days from start
EcEarth: GWL3	2048/01	-	2067/12	77 days from start

T2.4 - CP-Simulation Evaluation and Impact Assessment

The progress of the simulations is being monitored at regular intervals (every 10 years for EUR-11; first year and every 5 years for WMD-03). Figure 5 and Figure 6 show the current evaluation of the ERA5-driven CP simulations. Although additional plots and variables were prepared for this evaluation, this report only showcases seasonal biases and Probability Distribution Functions for precipitation and near-surface air temperature.

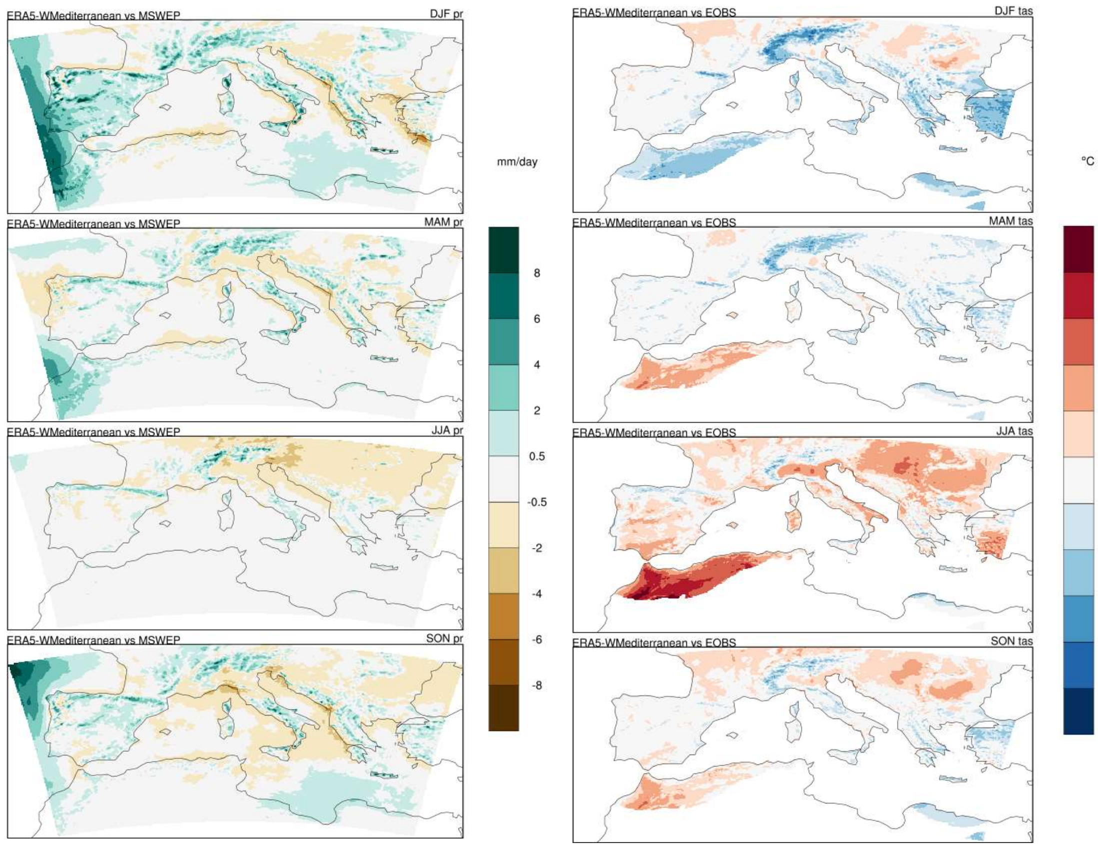


Figure 5. Seasonal precipitation (mm/day; left) and near-surface air temperature (°C; right) bias for ERA5 (1995-1999) driven CP simulation of the WMD-03 domain. Reference data is MSWEP and E-OBS for precipitation and temperature respectively.

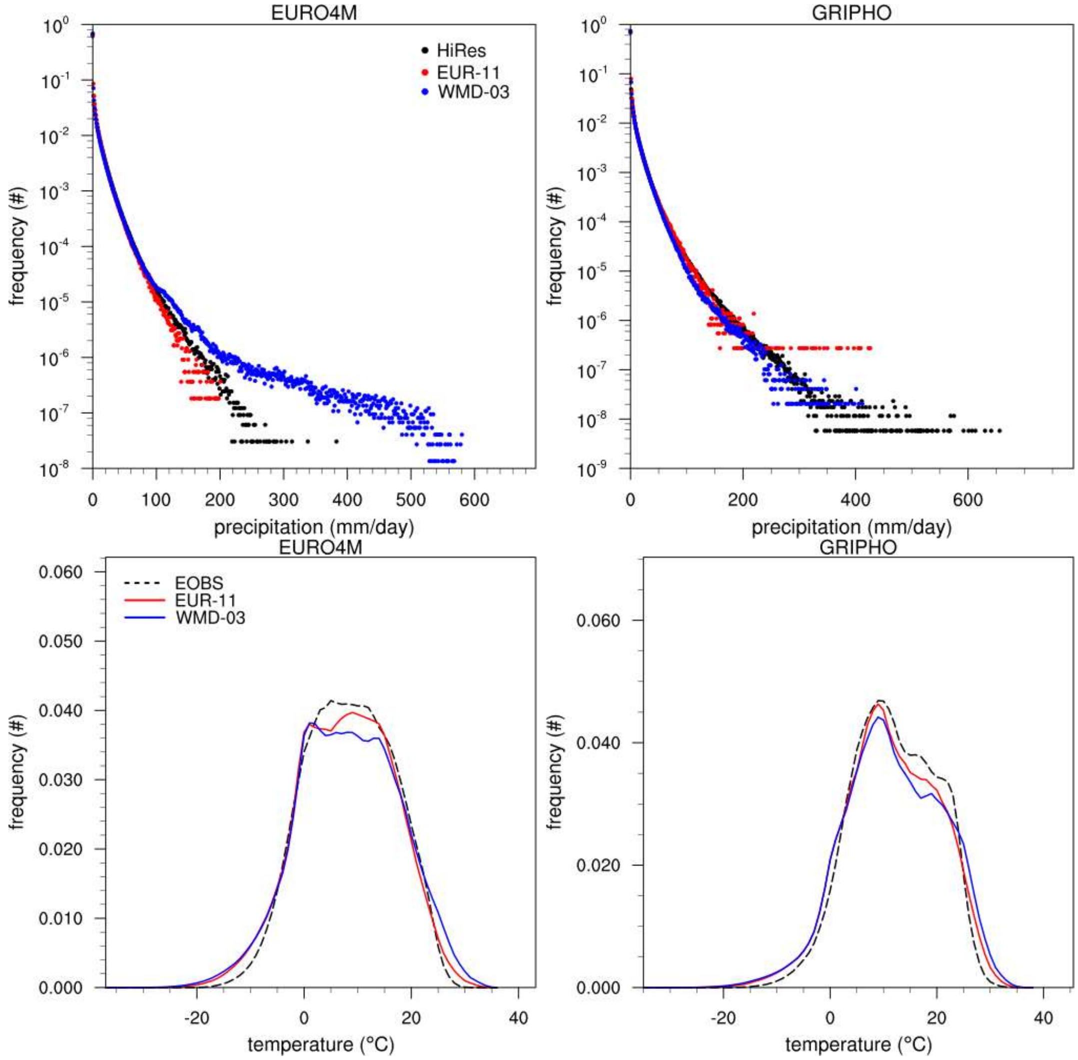


Figure 6. Precipitation (mm/day; top) and near-surface air temperature (°C; bottom) PDFs for ERA5 (1995-1999) driven CP simulation of the WMD-03 domain. Reference data is E-OBS and masked for regions corresponding to EURO4M and GRIPHO datasets.

Once the milestone M2.2 has been completed, the complete assessment of the simulations will be compiled into a publication to be submitted to 'Journal of Advances in Modelling Earth Systems' as **Deliverable D2.1**.

Following this, the ENM developed in WP1 will be applied to the 'historical' experiments and extrapolated with the GWL simulation data. This data will be included in the analysis and publication of D3.

WP3 - Paleoclimatic Changes to the Central Mediterranean

The specific research objective of WP3 was **to run paleoclimate model and assess the impact on arthropod habitats from the Last Glacial Maximum (LGM) to future GWL scenarios**. The purpose of this WP is to obtain high-resolution simulations for a 20-year time-periods that according occur prior to the 'historical' experiment time-periods defined for CMIP6.

T3.1 - Paleoclimate and Palaeontology review

Research into the paleoclimate conditions of the past 21,000 years was necessary to confirm the time-periods considered for the project, and their relevance to each other. The Last Glacial Maximum (LGM; ~21,000 years ago) represents a time when many of today's CSIs were connected directly to Europe via land-bridges. The mid-Holocene (~6,000 years ago) was a period of relative climate stability with close-to-present-day topography. The Medieval Period (particularly ~1000 CE) is a time with low human population and close-to-present-day topography. The Pre-Industrial period (~1850 CE) is also important due to its small LUC and serves as a starting point to the current climate crisis.

An assessment of PSIs from fossil records is still underway. These may come from extant species and add information relative to existing populations, or from extinct species/populations that may be relevant to the results in T3.5.

T3.2 - Simulation Setup: Paleoclimate Adjustments

Paleoclimate simulations are very similar in principle to future-simulations, like the ones in WP2, however, a few variations in paleoclimate conditions require adjustments to the model and the experiments. Most of the work associated with this task was conducted during the **2nd secondment at the ICTP (14 Sep-22 Oct; SC2)**.

The RCM used in WP2, RegCM5, included the mechanisms to run paleoclimate simulations, and hence is ideal for this WP and connect the results. The driving GCMs from WP2 however, do not have a corresponding Paleoclimate Modeling Intercomparison Project (PMIP4) experiments [LGM (Kageyama *et al.*, 2017), mid-Holocene (Otto-Bliesner *et al.*, 2017), Medieval and Pre-Industrial Period (Jungclaus *et al.*, 2017)]. Thus, different GCMs were needed for WP3, that had either the LGM or mid-Holocene experiments available, and had the following data:

- fixed frequency: orography (orog)
- daily or monthly: sea surface temperature (tos)
- 6 hourly: surface pressure (ps), humidity (hus), air temperature (ta), u- and v-winds (ua, va respectively)
  - hus, ta, ua, va required a high vertical-resolution starting from close-to-surface and all the troposphere (EC-Earth3-LR was not selected because the data had only 7 vertical-levels)
  - files needed the inclusion of the formula and parameters to extrapolate the atmospheric pressure from ps (e.g., $p = a\,p_0 + b$ ps)

The GCMs chosen for WP3, also with high, medium, and low ECS, are presented in Table 10. MPI and IPSL data was available from the ESGF database, while the MIROC data was kindly provided by Dr Akitomo Yamamoto (from Japan Agency for Marine-Earth Science Technology). Since these GCMs are not the same as the ones used in WP2, an additional 'historical' experiment is needed to perform an evaluation of the model performance.

Table 10. The driving GCMs and ensemble members used in WP3, together with the corresponding ECS according to Scafetta (2022).

Abbreviation	GCM	Member	ECS	# v. levels
MPI	MPI-ESM1-2-LR	r1i1p1f1	3	47
MIROC	MIROC-ES2L	r1i1p1f2	2.68	40
IPSL	IPSL-CM6A-LR	r1i1p1f1	4.56	79

From these 3 GCMs only MIROC has a horizontal resolution of 100 km; the MPI and IPSL have a horizontal resolution of 250 km, and thus will require another intermediate simulation prior to the EUR-11, covering a larger area at 50 km (hereafter referred to as Extra-Europe; XEUR-44).

The RegCM5 code includes the possibility of modifying orbital parameters and gas concentrations through the namelist-file. To adjust for orbital parameters (eccentricity, obliquity, precession), a 'year offset' [from 1950] is applied (-21000 for LGM, -6000 for mid-Holocene, -950 for the year 1000, and -100 for the year 1850) which is currently applicable only up to -1,000,000. The gas concentrations of Greenhouse Gasses (GHGs; specifically, carbon dioxide [CO_2], methane [CH_4], nitrous oxide [N_2O], and Chlorofluorocarbons [CFC11 & CFC12]) are modified by applying a multiplication factor to the prescribed concentrations in the model. The concentrations for each experiment (described in Table 11) were set according to the PMIP4 protocols (https://pmip4.lsce.ipsl.fr/doku.php/exp_design:index).

Table 11. GHG concentrations used for experiments in WP3 following PMIP4 protocols.

Experiment	CO_2 (ppm)	CH_4 (ppb)	N_2O (ppb)	CFC11 (ppt)	CFC12 (ppt)
1950 CE	310.70	1147.50	290.00	0.00	0.00
1850 CE	285.79	825.71	274.20	0.00	0.00
1000 CE	279.66	698.18	273.65	0.00	0.00
-6 ka	264.40	597.00	262.00	0.00	0.00
-21 ka	190.00	375.00	200.00	0.00	0.00

To adjust for changes in elevation differences such as sea-level and isostatic depression, elevation difference data from ICE7G (Roy and Peltier, 2018) was applied to the 30s-resolution topography and bathymetry dataset of RegCM (after distance-weighted interpolation is applied). Furthermore, an upscaling to 1 degree is applied to the area within the glacial mass (ref to paper that used this method) to account for the smoother surface of a glacier. As most volcanoes have been around for a long time or have been dormant or unchanged in the last 21ka, no change in volcanic height was made.

Unlike the simulations in WP2, a simpler LSM, the Biosphere-atmosphere Transfer Scheme (BATS)(Dickinson, Henderson-Sellers and Kennedy, 1993), was selected for these simulations due to the high-degree of uncertainty in determining these starting conditions of these time-periods. The land-use maps were generated from Köppen-Geiger (KG) climate classification (Peel, Finlayson and McMahon, 2007) masks, calculated from the daily temperature and precipitation data of the driving GCMs. Table 12 shows which climate classifications were assigned to the BATS categories, following an assessment of geographical locations of these vegetation types (Wagle *et al.*, 2016; Luo and Yu, 2017) and the corresponding KG classification (note that changes in rivers are not applicable when using BATS). This land-use setup was applied to the LGM, mid-Holocene, and year 1000 experiments, while it was unchanged for the year 1850 experiment. For the historical experiment, the LUCAS v1.1 (used in T2.1) for the years 2010 to 2015 was used to provide more reliable urban categories. All grid cells with Plat Function Type 15 (PFT15 - Urban) above 0.4 were assigned as urban, while those between 0.1 and 0.4 were assigned as suburban. The standard soil categories were used for all experiments, with any “new land” (terrain exposed above sea level due to changes applied to elevation) set to ‘bedrock’.

Table 12. The KG classifications assigned to the BATS categories (Cat.) for the paleoclimate simulations. Urban and Sub-Urban are only assigned for the historical experiment. *mask* – represents the ICE7G glacier mask; *r.u.c.* – remaining unassigned cells.

Cat.	**Description**	**Assigned Category**
1	Crop/mixed farming	-
2	Short grass	Bsh, Bsk
3	Evergreen needleleaf tree	Csc
4	Deciduous needleleaf tree	Dwc, Dwd, Dsc, Dsd, Dfc, Dfd
5	Deciduous broadleaf tree	Am, Dwa, Dwb, Dsa, Dsb, Dfa, Dfb
6	Evergreen broadleaf tree	Af
7	Tall grass	Aw
8	Desert	Bwh
9	Tundra	ET
10	Irrigated Crop	-
11	Semi-desert	Bwk
12	Ice cap/glacier	EF, *mask*
13	Bog or marsh	-
14	Inland water (rivers and lakes)	-
15	Ocean	-
16	Evergreen shrub	Cwa, Cfa
17	Deciduous shrub	Csa, Csb
18	Mixed Woodland	Cwb, Cwc, Cfb, Cfc, *r.u.c.*
19	Forest/Field mosaic	-
20	Water and Land moisture	-
21	Urban	PFT15<0.4
22	Sub-Urban	0.1<PFT15<0.4

The completion of this preparatory process marked the achievement of the milestone **M3.1 (Integration of paleoclimate model terrain)**.

The implementation of all the data associated with this task would not have been possible without Graziano Giulian from the ICTP; his collaboration was vital to the success of T3.2.

T3.3 - Paleoclimate Simulations

The purpose of this task is to run (and perform analysis) of 4 20-year paleoclimate experiments, and an additional historical experiment, necessary to evaluate the model performance. As the simulations in WP2, once-started, 20-year Europe simulation should run for ~16 days, and the CP simulations would require ~77 days. These are:

- LGM (21,000 years ago; *experiment not available for IPSL*)
- Mid-Holocene (6,000 years ago)
- Medieval (1000 CE; *experiment not available for IPSL*)
- Pre-Industrial (1850 CE)
- Present day ('historical'; 1995-2015 CE)

<u>*Notable Risk and Mitigation*</u>

The simulations are not currently running. A request has been made for the final modifications and compilation of the RegCM code to be able to recognise the new GCM inputs. This delay is partly a side-effect of the delays in WP1 and WP2, and a similar mitigation to WP2 is currently envisaged. Priority will be given to one GCM (notably MPI-ESM1-2-LR) to ensure that an analysis could still be completed by the end of the project. All effort to complete the other simulations will still take place. An alternative solution can be to run 10-year simulations instead of 20-year.

Once all the MPI CP-simulations reach the target date, the milestone **M3.2 (Completion of Paleoclimate Simulations)** would be achieved.

T3.4 - Climate Proxy Data Preparation

This task is intended for the preparation of proxy data to evaluate the paleoclimate simulations of T3.3. Training **TR3 (proxy conversion)** was associated with this task and took the form of discussions with Prof. Aaron Micallef followed by directed reading. This provided a first experience into the parameters and methods used to associate these readings with climate parameters; mainly with numerous case studies that link each proxy measurement (mostly core samples) with atmospheric parameters, often through a correlation assessment.

For the purposes of this WP, data was accessed from the PAst Global changES 2k Network (PAGES2k; https://pastglobalchanges.org/science/wg/2k-network/intro), for 49 datasets that include coral, documents, lake & marine sediments, speleothem, and tree data.

T3.5 - Paleo-Simulation Evaluation and Impacts

Once completed the following evaluation will take place: for the historical experiments, a similar evaluation to T2.4 will be conducted; and the paleoclimate experiments will be compared to the proxy data collected from T3.4 and will serve as a support for the historical evaluation.

Following the evaluation, the ENM developed through WP1 will be used to assess various PSI within the historical experiments. This will serve as a baseline to establish the "current" conditions associated with known habitats, and then applied to the paleoclimate experiments.

When combined with the results obtained in WP2, a storyline analysis of each chosen PSI will be compiled into a publication, serving as Deliverable D3.1 (potentially submitted to 'npj Climate and Atmospheric Science' instead of 'Nature Climate Change' considered in the proposal - the journals associated with the publications for WP1-3 have been reconsidered due to their high open-access fees).

WP4 – Training and Transfer of Knowledge

This WP covers all training and transfer of knowledge pertaining to PALEOSIM. The training tasks, TR1, TR2, and TR3 are associated with T1.1, T1.2, and T3.4 respectively, while the secondments SC1 and SC2 are associated with T2.2 and T3.2 respectively. All the above-mentioned activities have been completed marking the achievement of the milestone **M4.1 (Completion of Training and Secondment)**. The **deliverable D4.1** (Training and Secondment Report - TSR) will be compiled in the coming months.

Discussions with the University of Malta and Esplora are currently underway to come up with an agreement and concept of the objectives of the upcoming **Placement (P; Display preparation) taking place between 1st August 2024 and 31st January 2025**, which will mark the achievement of milestone **M4.2 (Design plan of display for Esplora)**.

The display can make use of photos collected during the COP to highlight the species needing conservation, and showcase the storyline developed for D3.1 through T3.5 – with a selection of PSIs and the final corresponding ENM result in different time periods. Geographical and climatological information of the CSI can also accompany these results to help provide context of the environment. This is all subject to change following discussions with Esplora, and their expertise especially regarding their audience. The final Museum Display will serve as **deliverable D4.2**.

WP5 – Communication, Dissemination, and Exploitation

The project outreach is covered within WP5 and takes the form of a list of seminars, public engagement activities, and the Citizen-science Observation Program (COP). The first **deliverable D5.1 (Dissemination and Communication Plan; DCP)** was prepared at an early stage of the project [October 2022], the information presented below details the current progress of this plan.

To support any form of outreach associated with this WP, a project image was prepared (to serve as a logo where necessary) as well as an infographic defining arthropods.

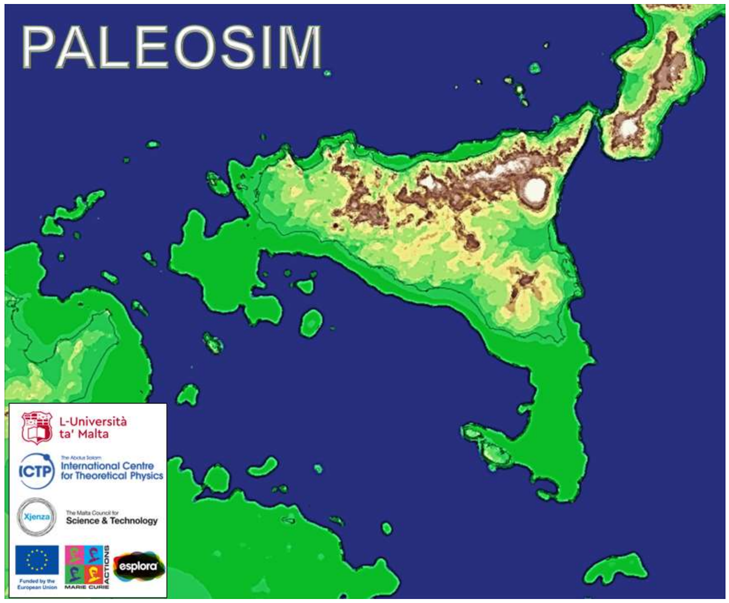


Figure 7. Project promotional image also serving as logo where necessary.

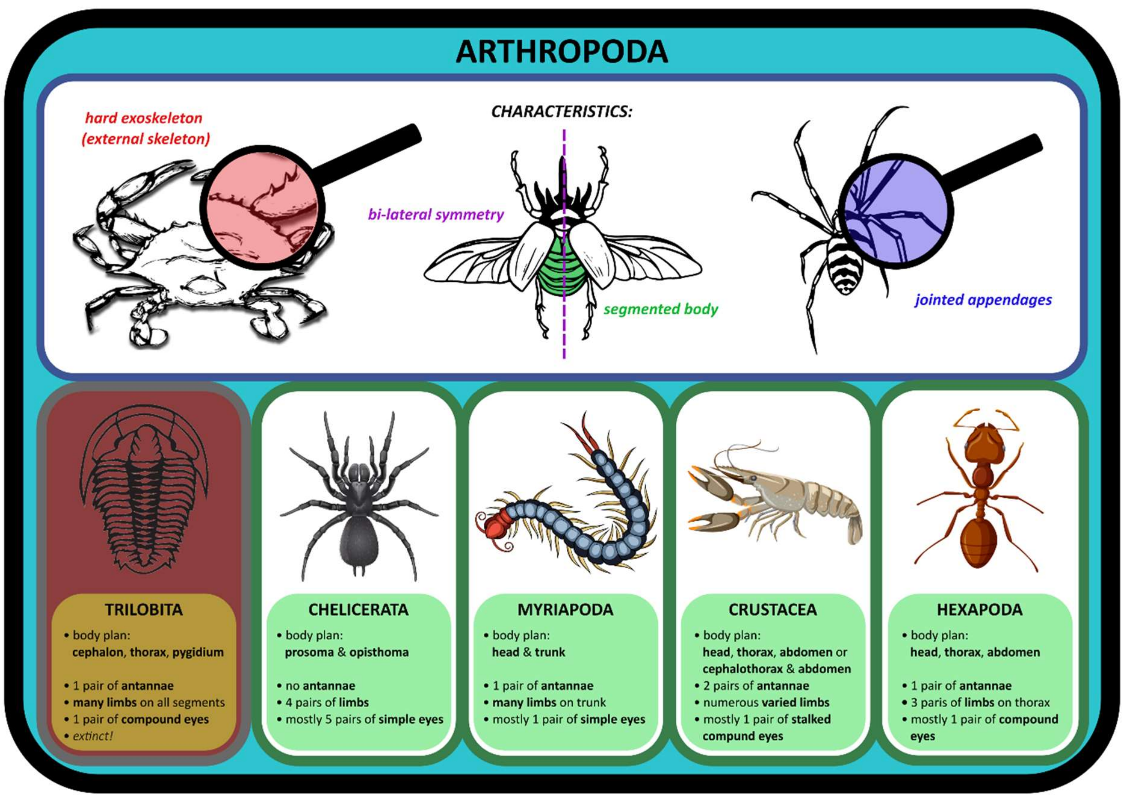


Figure 8. Arthropod infographic designed for outreach events.

The first two public seminars have been done:

- Seminar S1 at UM entitled '*Climate Impacts on Insect Habitats: PALEOSIM - A Marie Curie Project*' took place on 15 November 2022;
- Seminar S2 at ICTP entitled '*Ecological niche modelling for arthropod habitats in the Circum-Sicilian islands: - A PALEOSIM component*' took place on 7 March 2023.

Given the challenges encountered in the research WPs, S3 and S4 will be combined in one seminar (S3/4) that will take place in July or August 2024 at UM. A final seminar (S5) will mark the conclusion of the project and launch of the public display; this may take place at Esplora, possibly in January of 2025.

Figure 9. Dr James Ciarlo` presenting the Seminars S1 at UM (left) and S2 at ICTP (right).

On 17 May 2023, PALEOSIM was also featured at the UM Research Expo, the first activity of its kind at the UM, which brought together several local researchers for networking.

Figure 10. Dr James Ciarlo` presenting at the UM Research Expo.

Three research conferences were planned for the project; however, two additional international activities took place in Trieste at the same time as the SC2, and were pertinent to the project activities. At the International Conference on Regional Climate-CORDEX 2023 (ICRC-CORDEX 2023; C0) in Trieste [25-29 September 2023], a poster was presented entitled '*An*

Ecological Index for Arthropod Habitats in the Circum-Sicilian islands using Convection Permitting data' which showcased the use of climate models for ENMs. This was followed by the 11th Workshop on the Theory and Use of Regional Climate Models (W0) also in Trieste [2-6 October 2023], where a presentation was given '*Paleoclimate experiments using RegCM5*' showcasing the ability of RegCM5 to use for paleoclimate experiments. Following these, a detailed presentation of the ENM and the use of climate models was given to the Entomological community at the XII European Congress of Entomology (C1) in Heraklion [16-20 October 2023] entitled '*An ecological index for arthropod habitats using climate model data applied to the Circum-Sicilian islands*'. Currently, preparations have been made for a presentation at the American Geophysical Union (AGU) Fall Meeting 2023 (C2) in San Francisco [11-15 December], and an abstract is currently being prepared for the European Geosciences Union (EGU) General Assembly 2024 (C3) in Vienna [14-19 April 2024].

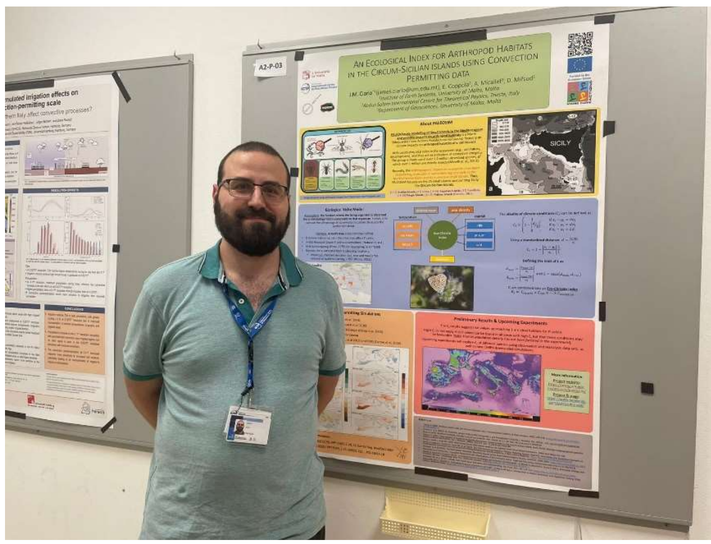


Figure 11. Dr James Ciarlo` presenting at the C0 in Trieste.

For a broader public engagement, a website, and a social media page (WS) were set up. The website [https://www.um.edu.mt/projects/paleosim/] is part of the UM website, where useful information about the project is presented, together with project updates. Initially, the Facebook page of the Institute of Earth Systems was used to disseminate information about project-related events, however, due to the limited efficiency and collaboration on the matter, an independent page was set up [https://www.facebook.com/paleosim.msca], where semi-regular updates are posted with a few ads to encourage people to follow the page and contribute to the citizen-science campaign (detailed below).

The original proposal mentioned Public talks in Malta (PM) and Local school presentations (LS) – these were adjusted to fit ongoing activities. The PM activities, were fit into public appearances at Esplora events, namely World Children's Day 2022, Halloween Event 2023, 7 years of Esplora, which also served as LS activities, since several schools brought their classes to these events.

Figure 12. Dr James Ciarlo` participating in Esplora public activities World Children's Day 2022 (left), Halloween Event 2023 (middle), 7 years of Esplora (right).

A public talk in Sicily (PS) took place on [21 April 2023] entitled '*Modellazione ecologica degli insetti nelle isole circumsiciliane dall'ultima era glaciale ad oggi*' at the Zooligical Museum of University of Catania, prior to the field-work activities in Sicily.

Figure 13. Photo taken after public talk PS, in Sicily, with Prof. David Mifsud, Prof. Giorgio Sabella, Dr Fabio Vigilianisi, and Prof. Christian Mulder.

Participation in the European Researcher's Night (ERN) was also planned. One ERN in Malta (EM) took place on [30 September 2023], which showcased early concepts of the project. Unfortunately, a planned ERN in Sicily (ES) in 2023 could not take place as it clashed with other activities (namely SC2 and C0). Plans are currently underway for the 2024 ERN in Malta.

Figure 14. PALEOSIM stand at the ERN 2022 in Valletta, Malta.

News items (N) were also an important part of the proposal, and so far, several local and Italian articles featured PALEOSIM. In preparation for the PS activity in Sicily, an article was published on the UNICT Magazine[1], which was later picked up by several Italian media outlets. Following the PS and field-work activity in Sicily and Lampedusa, another article was published on the UM Newspoint[2]. The MSCA-Net also featured an 'inspirational story'[3], and most recently, Times of Malta with the collaboration of the Malta Chamber of Scientists, published a story about PALEOSIM[4].

A Citizen-science Observation Program (COP) was also set-up to attract local volunteers to document arthropod observations around the CSIs. The Epicollect5 app was used due to its user-friendly layout and lack of unsolicited data-collection. The app was launched on [October 2022] marking the achievement of **milestone M5.1 (Launch of COP)**. This was supported with a Bioblitz activity (which consisted of a short briefing on the project and the app, and followed by fieldwork to test the use of the app) in Buskett, Malta on 7 January 2023, which

[1] https://www.unictmagazine.unict.it/dagli-insetti-le-risposte-sugli-effetti-dei-cambiamenti-climatici
[2] https://www.um.edu.mt/newspoint/news/features/2023/06/the-first-climate-and-ecology-research-trip-to-the-circum-sicilian-islands
[3] https://msca-net.eu/wp-content/uploads/2023/05/Widening-countries-inspirational-stories_PF_PALEOSIM.pdf
[4] https://timesofmalta.com/articles/view/does-manmade-climate-change-affect-maltese-insect-population.1068225

saw the participation and training of new volunteers, as well as improvements on the app questionnaire.

Between the field-work and volunteer input, >400 observations have been logged into the app, mainly from the Maltese Islands, with some input from Sicily and Lampedusa (Figure 15). The PALEOSIM Citizen Science Program would not be possible without the contribution of numerous volunteers who upload their observations through the Epicollect5 app. The images below show the extent of observations uploaded by our volunteers. Special thanks should also be given to these individuals, who made this Citizen Science Program successful.

- **Preparation and support with Epicollect5:** *Simone Cutajar*, *Arthur Lamoliere*
- **Participation in PALEOSIM field-work:** *Adrian Agius*, *Michelle Ciarlo`, Gareth Galea*, *Claire Galea*, *Arthur Lamoliere*, *David Mifsud*, *Giorgio Sabella*, *Stephen Vella*
- **Identification of observations:** *Godwin DeGabriele*, *Matthew Calleja*, *Simone Cutajar*, *David Mifsud*, *A Gjonova, L F Cassar, E de Lillo*

The COP is set to run until April 2024, after which, the results will be published marking the achievement of the **milestone M5.2 (online publication of field-work/COP results)**.

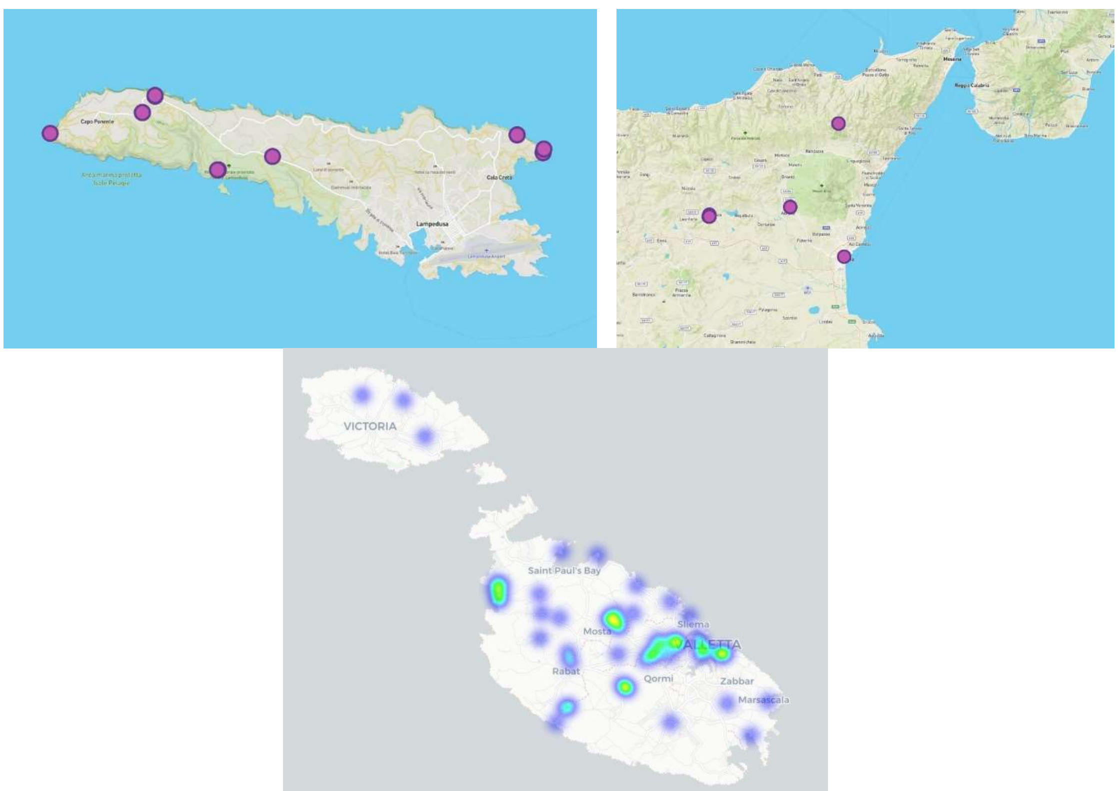


Figure 15. Input locations taken in Lampedusa and Sicily (top) and heatmap of observations in the Maltese islands (bottom) from the COP.

At the end of the research-phase of the project, a **Report on Suggested Policies** will be prepared as the final **deliverable (D5.2)** of WP5.

WP6 – Project Management

This WP handles the overall management of the project, and was started with a general meeting of all supervisors, discussing the plans for PALEOSIM. This was followed by individual discussions with the supervisors on project updates at irregular intervals, depending on the requirements of the project.

A **Project Management Plan** was set up achieving the **milestone M6.1** and later the **Personal Career Development Plan (PCDP)** was completed as **deliverable D6.1**. This included a Financial Management Plan (FMP), Risk Contingency Management Plan (RCMP), and Data Management Plan (DMP). Currently, discussions are still underway on the progress and challenges of each WP (detailed above).

This **Technical and Financial Report (TFR1)** will serve as **deliverable D6.2**, and will be followed by a second report (**TFR2**) as **deliverable D6.3**, which will be prepared at the end of the research-phase.

Financial Overview

The list presented below is an update from the FMP included in the PCDP (D6.1), on the completed and upcoming expenses associated with the project.

Expense	Cost (€)	WP	T
Book: The Insects (5th Ed) - Gullan & Cranston	78.00	4	TR1
Book: Insect Ecology (5th Ed) - Schowalter	162.75	4	TR1
First Aid course	55.00	1	T1.2
Secondment 1: Domain setup (Trieste)		2, 4	SC1
Flights	157.46		
Accommodation	1100.00		
Islands Visit 1: Catania & Lampedusa		1	T1.2
Flights	162.09		
Subsistence Allowance (6 nights)	1242.00		
Secondment 2: Paleoclimate setup (Trieste)		3, 4	SC2
Flights	90.92		
CORDEX Conference registration	200.00		
Accommodation	950.00		
ECE 2023 Conference		5	C1
Conference registration	575.00		
Flights	490.95	5	
Subsistence Allowance (7 nights)	1160.00	5	
Social Media Adverts	45.70	5	WS
Advertising Specimen	115.00	5	WS
Malta International Airport Data	4535.55	1	T1.3
Education Supplies (insect models + thermometers)	73.50	5	LS
AGU 2023 Conference		5	C2
AGU 2023: Year Membership	51.32		
AGU 2023: Application	63.03		

AGU 2023: Registration	690.87		
AGU 2023: San Francisco flights	1042.35		
Subsistence Allowance (6 nights)	1854.00		
Total Spent	**14,895.49**		
Open-access: Open Research Europe	0.00	1	D1.1
Open-access: Journal of Advances in Modelling Earth Systems	2120.04	2	D2.1
Open-access: npj Climate and Atmospheric Science	2571.70	3	D3.1
EGU 2024 Conference		5	C3
Annual Membership	20.00		
Application Fee	40.00		
Registration Fee	450.00		
Flights	150.00		
Subsistence Allowance	1218.00		
20 TB Hard Drive	350.00	2	T2.3
20 TB Hard Drive	350.00	3	T3.3
Islands Visit 2: Aeolian islands	1600.00	1	T1.2
Placement expenses	5000.00	4	P
Total Estimated	**13,869.74**		
Total Spent + Estimated	**28,765.23**		
Current Estimated Surplus	***1,234.77***		

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