Project Number: 101062427

Project Acronym: PALEOSIM

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

TSR: Training and Secondment Report

James Ciarlo`

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1. Training activities

The PALEOSIM project is a multidisciplinary research initiative that integrates expertise from various scientific fields, including regional climate modelling, ecology, entomology, and paleoclimatology. Dr James Ciarlo`, the Marie Curie researcher, brings significant experience in regional climate modelling to the project. However, to fully contribute to the diverse objectives of PALEOSIM, he required specialized training from the project supervisors. This training was essential to enhance his skills and knowledge in the interconnected areas of ecology, entomology, and paleoclimatology, ensuring a holistic approach to the project's goals.

This report is divided into two parts, providing a detailed assessment of the training activities and secondments within the PALEOSIM project. It highlights the collaborative efforts and the progress made in equipping the researcher with the necessary interdisciplinary expertise. Some of this material has already been included in the Technical and Financial Report 1 (submitted to Prof. Mifsud in December 2023) and thus this report includes some repetition, but also updated material.

1.1 TR1: Training for Arthropod Classification & Species of Interest

This first training activity is a crucial component of Work Package 1 (WP1: Climate Impacts on Arthropod Habitats), specifically, this training supports task T1.1 (Arthropod Habitats and Climate Links). Led by Prof. David Mifsud, this training began with an extensive review of the literature on arthropods and their ecology. Initial meetings and discussions, guided by Prof. Mifsud, were supplemented by directed readings of essential resources, including "The Insects" (5th Ed) by Gullan & Cranston and "Insect Ecology" (5th Ed) by Schowalter. This comprehensive approach provided a strong foundation in arthropod classification and identification of species of interest.

Although TR1 was conducted mostly within the first two months of the project, direct communication with Prof. Mifsud resulted in continued access to new knowledge for the researcher and strengthen the project.

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 (**Error! Reference source not found.**) 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). 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.

These species are currently being included in the analysis for the publication of the WP1 results (D1.1).

Table 1. List of PSI used in the analysis of PALEOSIM WP1 publication. The list includes the scientific name, the common name, and the ecological role of the species.

Scientific name	**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

1.2 TR2: Field-work training

This second training activity was an integral part of task T1.2 (Arthropod Observations), which aimed to enhance field-work skills and gather new observations relevant to the sturdy region. This training began with the implementation of a comprehensive safety protocol (described below) that was followed during all field-work activities. This protocol was also a key component of the Citizen-science Observation Program (COP).

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 TR2 was conducted by Prof. David Mifsud during month 3, which took the form of preparatory discussions, guided field-work (month 4), and suggestions for additional field-work locations (the locations included/planned are listed in Table 2). 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

Table 2. 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
30/04/2024	Vulcano	Aegean Isles	D. Mifsud, P. Lo Cascio, F. Allegrino
01/05/2024	Panarea & Stromboli	Aegean Isles	D. Mifsud
02/05/2024	Lipari	Aegean Isles	D. Mifsud, F. Allegrino

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 number of observations).

1.3 TR3: proxy conversion

The third training activity is a critical component of task T3.4 (Climate Proxy Data Preparation), within Work Package 3 (WP3: Paleoclimatic Changes to the Central Mediterranean), which focuses on paleoclimatic changes in the Central Mediterranean. The objective of this task was to prepare proxy data for evaluating the paleoclimate simulations. TR3 involved discussions (during month 13) with Prof. Aaron Micallef, followed by directed reading, introducing the parameters and methods used to correlate proxy measurements, primarily core samples, with atmospheric parameters. This training included examining numerous case studies that illustrate how each proxy measurement can be linked to climate variables through correlation assessments. For this work package, data was sourced from the PAst Global changES 2k Network (PAGES2k), utilizing 49 datasets encompassing coral, documents, lake and marine sediments, speleothems, and tree data.

1.4 Additional Training

All training exercises were monitored and evaluated within Work Package 4 (WP4: Training and Transfer of Knowledge), ensuring comprehensive skill development and knowledge exchange. As part of the additional training activities under WP4, the researcher undertook a First Aid course as a refresher to enhance field safety and preparedness. Additionally, the researcher is currently enrolled in a Nature Photography course (LAS1009) at the University of Malta. This course aims to improve Dr Ciarlo`'s ability to document field observations

accurately and effectively, enhancing the quality of photos for the upcoming communication activities of the project, specifically the placement. This training will ensure that visual documentation meets the high standards required for effective scientific communication and public engagement.

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**.

2. Secondments

The secondments form a crucial part of the PALEOSIM project, facilitating advanced training and research collaboration. Both secondments were conducted at the Abdus Salam International Centre for Theoretical Physics (ICTP) under the supervision of Dr Erika Coppola. These secondments are closely associated with the tasks of WP2 and WP3. The secondments provided direct access to the ICTP team, assisting with the required simulation setups and linking the objectives of ongoing projects that ICTP is involved in, such as the new CMIP6 downscaling targets of EURO-CORDEX.

2.1 SC1: Secondment associated with WP2

The first secondment (15 Jan-16 Mar) was crucial in progressing the objectives of WP2 (Modern-day Climate Assessment). SC1 focused primarily on simulation preparations, directly supporting T2.1 (Land-Use Map Updates) and T2.2 (Model Configuration). Under the expert guidance of the ICTP team, substantial advancements were made in refining the simulation tools and updating the land-use maps.

Additionally, SC1 played a pivotal role in the selection of an improved domain for the convection-permitting (CP) simulations. This improvement is essential for enhancing the accuracy and resolution of climate models, particularly in terms of capturing local climate phenomena and fine-scale meteorological processes.

For T2.1, the need for high-resolution simulations required updated land-use maps for the new simulations. Since the new simulations contribute to the Coupled Model Intercomparison Project Phase 6 (CMIP6) downscaling for EURO-CORDEX, all WP2 simulations follow CORDEX Flagship Pilot Studies (FPS) Land Use and Climate Across Scales (LUCAS) protocols and use annual land use land cover maps from LUCAS LUC V1.1 based on Land-

Use Harmonization 2 (LUH2). 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). 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.

The remaining activities during SC1 relate to T2.2. The newest version of the model RegCM5 was selected for the simulations of WP2 and WP3. The decision regarding the configuration were made through a series of tests, and meetings with Dr Erika Coppola and the ICTP team.

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 3 km 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 3) were also chosen for PALEOSIM. *Due to several RegCM5 bugs encountered later in the project, and the delays resulting from these bugs, the simulation objectives were reduced to MPI simulations only.*

Table 3. The driving GCMs and ensemble members used in WP2, together with the corresponding ECS.

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

The simulations were driven by the ECMWF-ERA5 reanalysis (ERA5) as an evaluation experiment, and using the microphysics schemes: NoTo, and WSM5 from the WRF modeling system.

The proposal 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 4). 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 4. 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 1) was chosen, with the possibility of excluding the western border from the impact analysis.

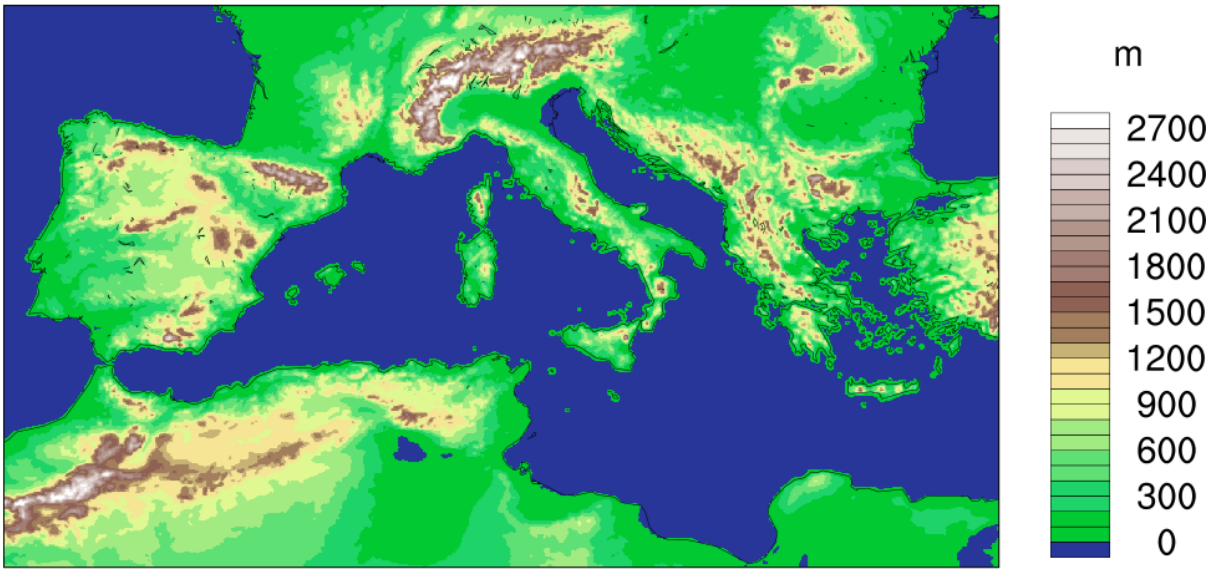

Figure 1. The 3km horizontal resolution domain, named Western Mediterranean (WMD-03), selected for the simulations of WP2 and WP3.

Finally, both the EUR-11 and WMD-03 simulations 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 (using the fpsconv-x2yn2 – meaning nest and parent have different configurations [x2], increased level of difference [y], one intermediate nest [n2]).

2.2 SC2: Secondment associated with WP3

The second secondment (14 Sep-22 Oct) was mainly about progressing the objectives of WP3 (Paleoclimatic Changes to the Central Mediterranean), and contributed to 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.

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, mid-Holocene, Medieval and Pre-Industrial Period]. 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 5. 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. *Note that due to delays in WP2, simulation time had to be re-distributed and priority was given only to MPI simulation. Although there will not be enough time during the PALEOSIM project to complete the remaining simulations, the intent is still to continue simulations after the project to expand the analysis on an ensemble of models.*

Table 5. The driving GCMs and ensemble members used in WP3, together with the corresponding ECS.

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 6) were set according to the PMIP4 protocols (https://pmip4.lsce.ipsl.fr/doku.php/exp_design:index).

Table 6. 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 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), 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 masks, calculated from the daily temperature and precipitation data of the driving GCMs. 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. 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’.

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.