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multi-Risk sciEnce for resilienT commUnities undeR a changiNgclimate

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ABSTRACT

In the present document the MetOcean data employed in the RETURN Project, VS1-WP4, are described. These data represent the main forcing to implement studies related to coastal flooding and erosion hazard. The main dataset employed in the project consist of two different types of MetOcean data available to researchers, institutional agencies and coastal management professional under different kind o licensing. The first family of data is represented by the so called "Community Shared Dataset", i.e. data provided by international agency/programs that are made available to the general public. In this case we refer to the product distributed by the ECMWF and by Copernicus Services. Technical details of these data are well known and are readily accessible to the public through internet website and through typical file transfer protocols. The second family of data belong specifically to the University of Genoa and are made available to the partners of the RETURN project to develop the activities of the VS1-WP4 related to the coastal risk and impact analysis. In the framework of the RETURN project, these data are shared with other spokes that implement some activities on the coastal flooding risk analysis (such for example spoke TS2). These data are not freely available for download at the present time but they will be shared with the community through the Digital Twin of the VS1. In particular, climatic indicators for hindcast dataset (1979-2023) and for projection models (1979-2005 for baseline and 2006-2100 for projections) will be made available for the public by the end of the project through S3 protocols and zarr format. Details of the development of the DICCA dataset are reported in the present document.

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1. Community Shared Dataset – Copernicus Services

The Copernicus Marine Service (CMEMS) stands as one of the main data resources as a robust and comprehensive oceanographic data service, offering a suite of information products vital for scientists, policymakers, and stakeholders engaged in coastal risk assessment and management. CMEMS delivers high-quality, timely, and freely accessible marine data spanning global and regional scales. The service covers a broad spectrum of oceanographic parameters, including sea level, sea surface temperature, salinity, ocean currents, sea ice, and biogeochemistry. By integrating satellite observations, in-situ measurements, and numerical models, CMEMS provides an authoritative source of marine information essential for monitoring and predicting marine environments.

The Copernicus Climate Change Service (C3S) is an integral component of the European Union's Copernicus Programme, dedicated to providing comprehensive climate data and tools that are essential for simulating and understanding coastal risks. Climate change projections are based on various greenhouse gas emission scenarios and incorporate the latest scientific understanding of climate dynamics. The resulting data products include detailed projections of temperature increases, sea level rise, changes in storm intensity and frequency, and other factors that influence coastal vulnerability.

1.1. Reanalysis

The “Mediterranean Sea Waves Reanalysis” (Korres et al., 2021) is the multi-year wave product of the Mediterranean Sea Waves forecasting system (Med-WAV), available in the Copernicus Marine service (CMEMS) as MEDSEA_MULTIYEAR_WAV_006_012. The Reanalysis dataset is a multi-year wave reanalysis starting from January 1993 until 2016, composed by hourly wave parameters at 1/24° horizontal resolution, covering the Mediterranean Sea and extending up to 18.125W into the Atlantic Ocean. The wave products are the integrated parameters computed from the total wave spectrum (significant wave height, period, direction, Stokes drift, etc), as well as the following partitions: the wind wave, the primary swell wave and the secondary swell wave. The Med-WAV modelling system is based on wave model WAM 4.6.2 and has been developed as a nested sequence of two computational grids (coarse and fine) to ensure that swell propagating from the North Atlantic (NA) towards the strait of Gibraltar is correctly entering the Mediterranean Sea. The coarse grid covers the North Atlantic Ocean from 75°W to 10°E and from 70° N to 10° S in 1/6° resolution while the nested fine grid covers the Mediterranean Sea from 18.125° W to 36.2917° E and from 30.1875° N to 45.9792° N with a 1/24° resolution. The modelling system resolves the prognostic part of the wave spectrum with 24 directional and 32 logarithmically distributed frequency bins. The wave system also includes an optimal interpolation assimilation scheme assimilating significant wave height along track satellite observations available through CMEMS and it is forced with daily averaged currents from Med-Physics and with 1-h, 0.25° horizontal-resolution ERA5 reanalysis 10m-above-sea-surface winds from ECMWF. For more details, the reader is referred to CMEMS-MED-PUM-006-012.pdf (copernicus.eu).

The Med MFC physical multiyear product is created using a numerical system that includes a hydrodynamic model provided by the Nucleus for European Modelling of the Ocean (NEMO) and a variational data assimilation scheme (OceanVAR) for temperature and salinity vertical profiles, as well as satellite Sea Level Anomaly along track data. This product consists of a reanalysis dataset and an interim dataset, which covers the period from the end of the reanalysis up to one month before the present. The model operates on a horizontal grid with a resolution of 1/24˚ (approximately 4-5 km) and features 141 unevenly spaced vertical levels.

The Reanalysis datasets encompass 3D daily, monthly, and yearly mean fields of potential temperature, salinity, zonal and meridional velocity; 2D daily, monthly, and yearly mean fields of ocean mixed layer thickness and bottom potential temperature; 2D daily, hourly, monthly, and yearly mean fields of sea surface height; and hourly mean fields of sea surface zonal and meridional velocity. The Interim datasets include 3D monthly mean fields of potential temperature, salinity, zonal and meridional velocity; and 2D monthly mean fields of ocean mixed layer thickness, bottom potential temperature, and sea surface height.

1.2. Climate Change Projections

1.2.1. Time series

The “Ocean surface wave time series for the European coast from 1976 to 2100 derived from climate projections” is a dataset, containing wave climate timeseries for a European-wide domain, available in the Copernicus Climate Change Service (C3S). The ocean surface wave field is computed using the ECMWF's Wave Model (Stand Alone WAM, SAW) forced by surface wind and accounting for ice coverage in polar latitudes. The wave climate is defined by means of wave spectral parameters such as the significant wave height and the peak wave period. The model grid resolution is about 0.1° x 0.1° (11 km x 11 km) and it covers the region 98°W to 45°E and 9°N to 88°N. To assess the impact of climate change on the ocean's surface wave field, the SAW model is run for three different climates: current climate (1977-2005), RCP4.5 (2071-2100) and RCP8.5 (2041-2070). The wave climate in these scenarios is simulated using wind forcing from the HIRHAM5 regional climate model downscaled from the global climate model EC-EARTH. HIRHAM5 is a member of the EURO-CORDEX climate model ensemble. In addition to the three climate scenarios, the indicators are also computed using ERA5 reanalysis wind forcing (1979-2018). For more detail, the reader is referred to Product user guide for sea level and ocean wave products - time series and indicators - Copernicus Knowledge Base - ECMWF Confluence Wiki.

The dataset contains hourly data of mean wave direction and period, peak period, significant wave height and wave spectral directional width. Such data are provided along the 20m bathymetric contour, with a horizontal resolution of 30km.

1.2.2. Indicators

The “Ocean surface wave indicators for the European coast from 1977 to 2100 derived from climate projections” is a dataset, containing wave climate indicators for a European-wide domain, available in the Copernicus Climate Change Service (C3S). It serves to elucidate how climate change impacts the wave climate for both the Northwest European Shelf and Mediterranean Sea, providing invaluable insights for sectors such as port management, shipping, and coastal planning. Utilizing ECMWF's Wave Model (SAW), the ocean surface wave fields are computed, factoring in surface wind and considering ice coverage in polar latitudes. Key parameters defining the wave climate include significant wave height and peak wave period. To evaluate climate change effects on the ocean's surface wave field, the SAW model runs for three distinct climate scenarios: the current (historical) climate, an optimistic emission scenario (RCP4.5) where emissions decline post-2040, and a pessimistic scenario (RCP8.5) reflecting continued emissions rise throughout the century, akin to a business-as-usual approach.

The 'Ocean surface wave time series for the European coast from 1976 to 2100 derived from climate projections' dataset offers time series detailing the coastal wave climate across a European-wide domain, derived from ocean surface wave parameters. These scenarios employ wind forcing from a member of the EURO-CORDEX climate model ensemble, specifically the HIRHAM5 regional climate model downscaled from the global climate model EC-EARTH. However, given that the projections rely on a single combination of regional and global climate models, it's crucial for users to acknowledge the inherent underestimation of uncertainty associated with this dataset. Additionally, alongside the three climate scenarios, the dataset includes time series computed using ERA5 reanalysis wind forcing, offering a snapshot of recent historical wave climate, beneficial for retrospective analysis of specific events.

The indicators consist of the 90th and 99th percentile, and the 100-year return period level of significant wave height and peak wave period. Indicators are provided along the 20m bathymetric contour, with a horizontal resolution of 30km. 90th and 99th percentiles are obtained from the empirical distribution of the modelled hourly wave climate parameters, significant wave height and peak wave period (see Section 4.2.1). The 100-year return period value is computed by extrapolation following extreme value theory (Coles et al., 2001). The Peak Over Threshold (POT) method is applied in each epoch (~30 years of data) for identifying maxima values. Storms are defined by those values above the 90th and 95th percentiles for wave height and period, respectively. Two storms are considered independent if a minimum duration of 4 days occurs between the peaks of the events. The peaks of each storm are taken for fitting the scale parameter of an exponential distribution using the maximum likelihood estimation method. Once the scale parameter characterizing the extreme regime distribution of significant wave height or peak wave period is known, the extrapolation of the 100-year return period is possible, assuming that the average rate of storms will remain stationary. The 100-year return period indicator is omni-directional.

2. High-Resolution DICCA Dataset

The MeteOcean research group (www.meteocean.science) from the Department of Civil, Chemical and Environmental Engineering (DICCA) of the University of Genoa has developed high resolution hindcast and climate change projections datasets that are used as forcing conditions and inputs for the multi-scale modelling suite framework within Return. This section presents the characteristics of the hindcast dataset from 1979 until 2023 and the climate change multi-model ensemble projections from 1970 until 2100 under climate change scenario RCP8.5.

2.1. Hindcast

The Meteocean group has developed two comprehensive wave climate hindcast datasets to enhance the understanding of maritime conditions. One dataset features a regular 10-km grid, offering consistent spatial resolution across the entire study area and an efficient modelling scheme. The other dataset employs an unstructured grid, which allows for variable resolution, providing more detailed information in regions of interest. These datasets are crucial for accurate historical climate modeling and future projections efforts.

Both datasets are forced with atmospheric 10-meter wind field hindcast data, developed by the MeteOcean research group using the non-hydrostatic mesoscale Weather Research and Forecast (WRF) model version 3.4 (Skamarock, 2008). This simulation covers the entire Mediterranean Sea region with a 10-kilometer resolution Lambert Conic Conformal grid, as illustrated in Figure 1. Initial and boundary conditions are sourced from the National Center for Environmental Prediction (NCEP) Climate Forecast System Reanalysis for the period spanning January 1st, 1979, to March 31st, 2011, and Climate Forecast System Version 2 from April 1, 2011, to December 31, 2022. The temporal resolution is 3 hours, and the spatial resolution is 0.5° x 0.5°.

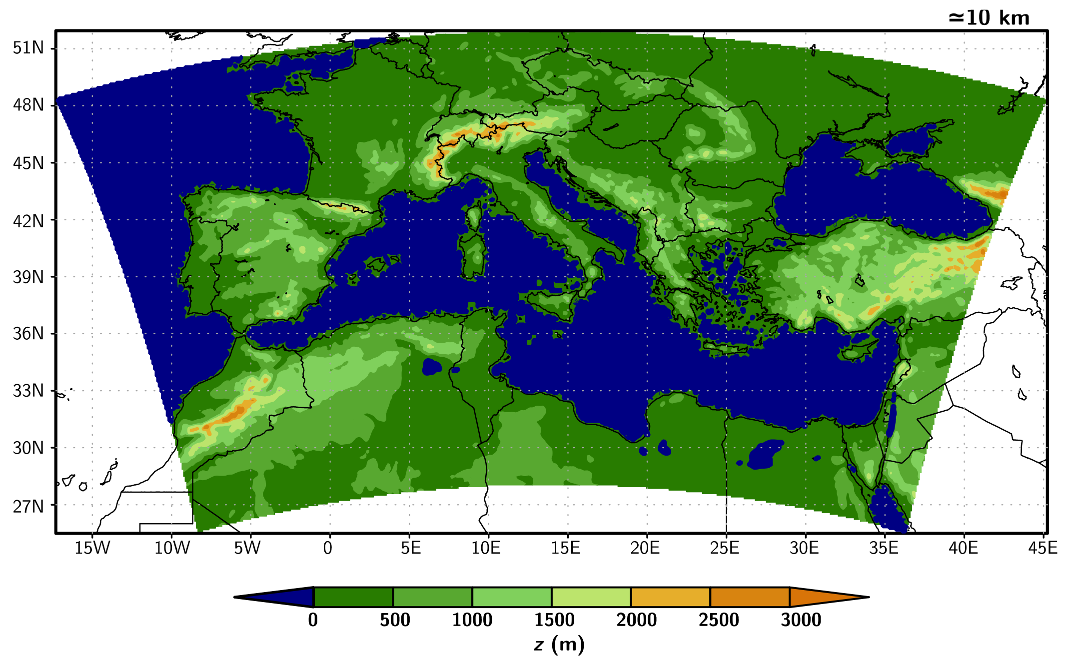

Figure 1. Location and topography (m) of the WRF domain of a 10-km resolution grid over the Mediterranean Sea.

Hourly wind fields are obtained for the period Jan. 1st 1979 until Dec. 31st 2023 for the hindcast simulations. Additional details of the WRF model configuration and its performance in the Mediterranean Sea can be found in Mentaschi *et al.*, 2023; Cassola *et al.*, 2016; and Ferrari *et al.*, 2020.

The Regular-DICCA wave hindcast provides high-resolution wave climate data from 1979 to 2020 with a regular grid of 0.127◦ in longitude and 0.09◦ in latitude, corresponding to ≈10 km (Mentaschi *et al.*, 2015). It uses the third-generation wave model WaveWatch III (version 5.16; The WAVEWATCH III ® Development Group, 2019, hereinafter WW3) with the source terms of growth/dissipation ST4 (Ardhuin *et al.*, 2010; Rascle and Ardhuin, 2013). The hindcast has been validated against buoy observations providing data of integrated wave parameters in different locations in the Mediterranean Sea.

The Unstructured-DICCA wave model employs a triangle-based unstructured grid covering the entirety of the Mediterranean Sea with varying spatial resolutions with numerical model WaveWatch III (WW3, Lira-Loarca *et al.*, 2022). The mesh resolution ranges from about 25 kilometers (≈0.22°) offshore to 10 kilometers in intermediate depths, and approximately 400-500 meters in near-coastal regions, with the highest resolution of approximately 300 meters (≈0.0027°) at the Ligurian coast, as depicted in Figure 2. This approach allows for wave modeling with multiple spatial resolutions in targeted sub-domains, thereby enhancing resolution and wave characterization in near-shore coastal areas. Information transfer between coarser and finer cells is facilitated, representing a significant advantage over nesting approaches. Moreover, the Unresolved Obstacles Source Term (UOST) methodology is utilized to parameterize the dissipative effects of small islands (Mentaschi *et al.*, 2015, 2020). This reduces the computational node count, accelerating overall computation and eliminating the need for grid refinement near small islands in open waters. The wave model is driven by wind fields obtained from WRF, with hourly time steps (Cassola *et al.*, 2016; Ferrari *et al.*, 2020). The spectral domain comprises 24 directional bins of 15° and 25 frequencies ranging from 0.07 to 0.66 Hz, corresponding to wave periods between approximately 1.5 to 15 seconds. Hindcast modeling spans 45 years, from January 1st, 1979, to December 31st, 2023, providing hourly wave climate data, including integrated parameters such as significant wave height (Hs), peak wave period (Tp), mean wave direction (θm), among others, as well as 2D directional spectra.

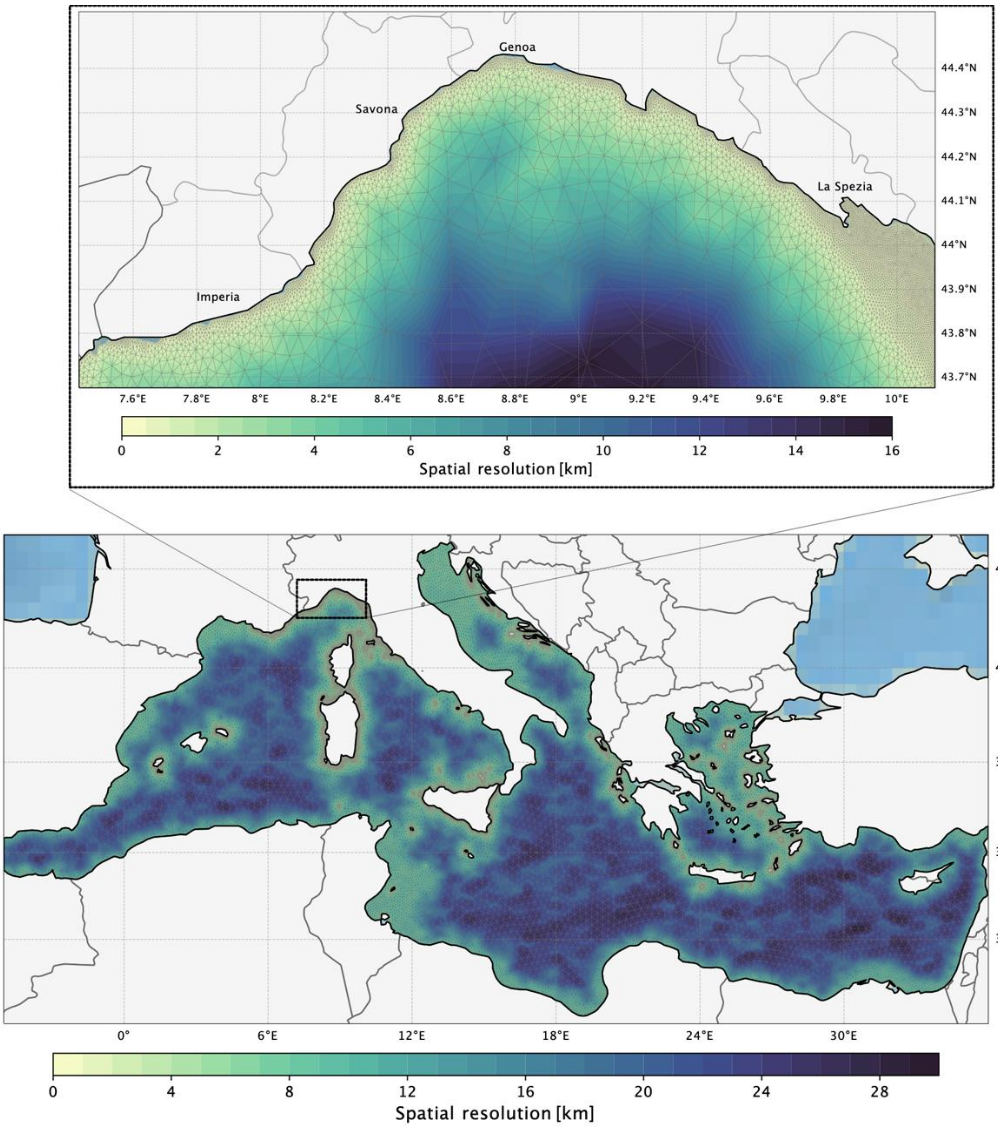

Figure 2. Mediterranean Sea unstructured grid and a zoom-in at the region of Liguria, Italy (top). The colour bar represents the grid size in km

WW3 was first calibrated against in-situ buoys data, and next validated with satellite data. The model was run for a series of storm events and calibrated by evaluating its performance with respect to observed buoy data from the EMODnet Physics database in different locations of the Mediterranean Sea. Once the WW3 model was calibrated, the hindcast time series was validated against Hs satellite altimeter data provided by the GlobWave database (GlobWave, 2020) from 1992 until 2016. This data collection has been already post processed, corrected and validated (Queffeulou, 2006; Queffeulou and Bentamy, 2007) in order to provide information of satellite altimeter measurements including the ERS 1 and 2, ENVISAT, Topex/POSEIDON, Jason-1, Jason-2, CryoSAT and GEOSAT space missions. Figure 3 and Figure 4 present the spatial index of agreement (d1) and normalized mean absolute error (NMAE). The closer d1 to 1 the better the numerical performance. To estimate d1 and NMAE, initially, the satellite data was filtered by removing the records located within the first 50km closest to the coast, to avoid any inaccuracy in the wave height measurements due to land interference (Albuquerque et al., 2018); later, based on a 6.5km radius from every hindcast point, the satellite data was grouped and double-averaged (space and time). The spatial average is applied to the data inside the 6.5km radius, and afterwards, a 24-hour temporal window is used for the temporal average.

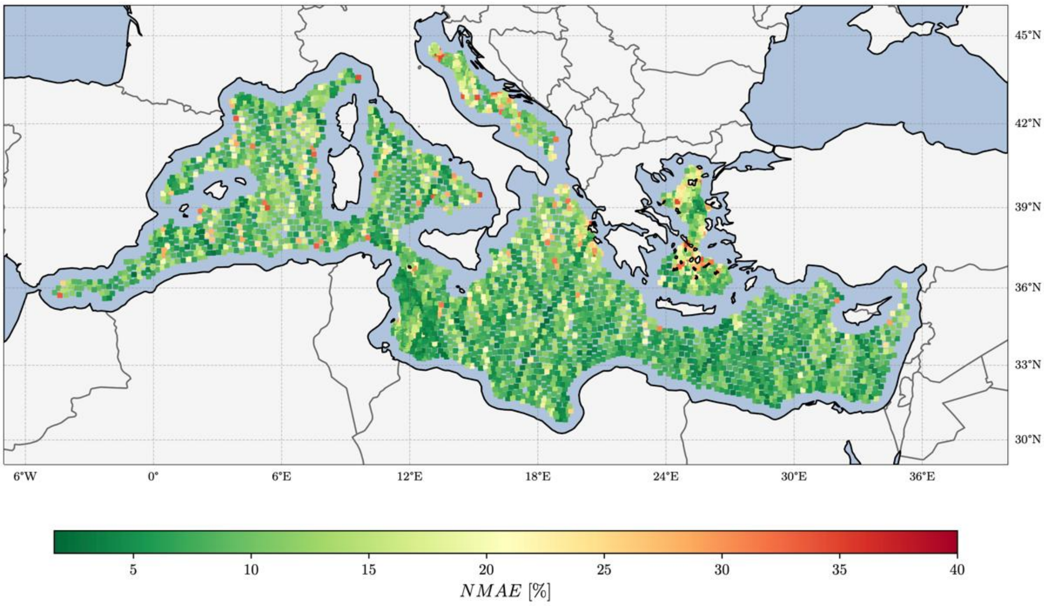

Figure 3. Spatial NMAE for H_s based on the comparison between satellite data and the hindcast wave simulation.

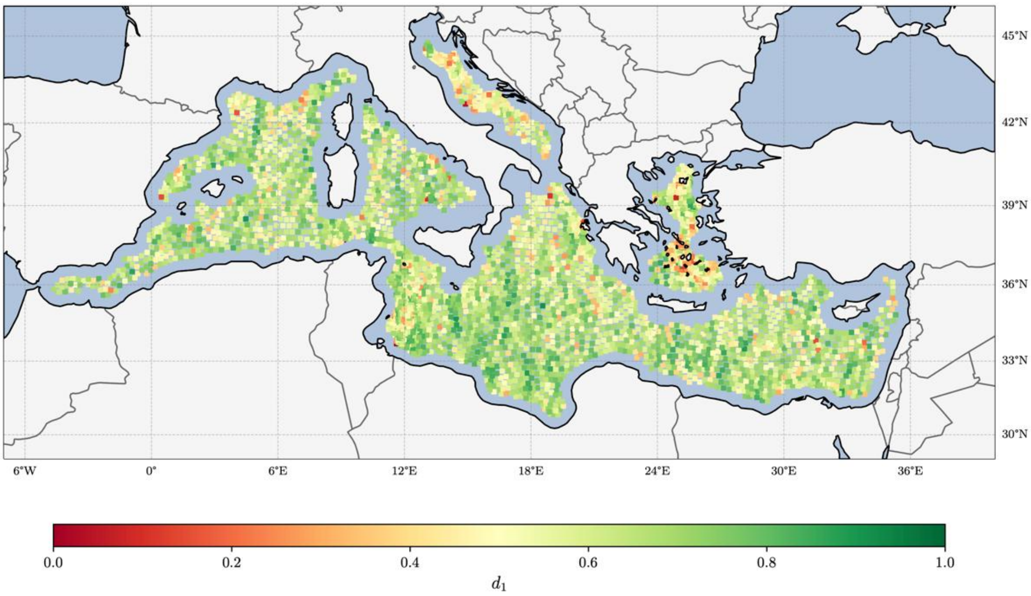

Figure 4. Spatial d1 for H_s based on the comparison between satellite data and the hindcast wave simulation.

2.2. Climate Change Projections

A multi-model ensemble of wave climate future projections were obtained using the same WW3 configuration as the hindcast, forced by surface wind fields of 21 different Euro-CORDEX Jacob *et al.* (2014, 2020) models (GCM-RCM combinations) with 6-hour temporal resolution and 0.11◦ (≈12.5 km) spatial resolution (Lira Loarca *et al.*, 2021a, b; Lira Loarca and Besio, 2022a, b). The EURO-CORDEX (Coordinated Regional Climate Downscaling Experiment) provides a large and comprehensive set of CMIP5 downscaled simulations particularly suitable for future climate and impact studies in Europe (Kjellström *et al.*, 2016). The multi-model ensemble of 21 models (GCM–RCM combinations) are presented on Table 1. For details on the definition and performance of the different RCMs used in this work, the reader is referred to Strandberg *et al.* (2014) for the Rossby Centre regional climate model RCA4, Will *et al.* (2017) for the CLM-Community CCLM4-8-17 model, Christensen *et al.* (2007) for the Danish Climate Centre regional climate model HIRHAM5 and Leutwyler *et al.* (2017) for the COSMO-CLM accelerated version COSMO-crCLIM-v1-1.

GCMs \ RCMs	CCLM4-8-18	RCA4	HIRHAM5	COSMO-crCLIM	RACMO22E
CCCma-CanESM2	■				
MIROC-MIROC5	■				
CNRM-CERFACS-CNRM-CM5		■	■		■
MOHC-HadGEM2-ES		■	■	■	■
MPI-M-MPI-ESM-LR		■	■		
NCC-NorESM1-M		■	■	■	
ICHEC-EC-EARTH		■	■	■	■
IPSL-IPSL-CM5A		■	■		■

Table 1. GCM-RCM combinations for the Wavewatch III wave projections.

Wave integrated parameters and 2D directional spectra for the 11 locations (Figure 5) were obtained for each GCM-RCMs for the base-period from 1970 until 2005 and RCP8.5 scenario from 2006 until 2100.

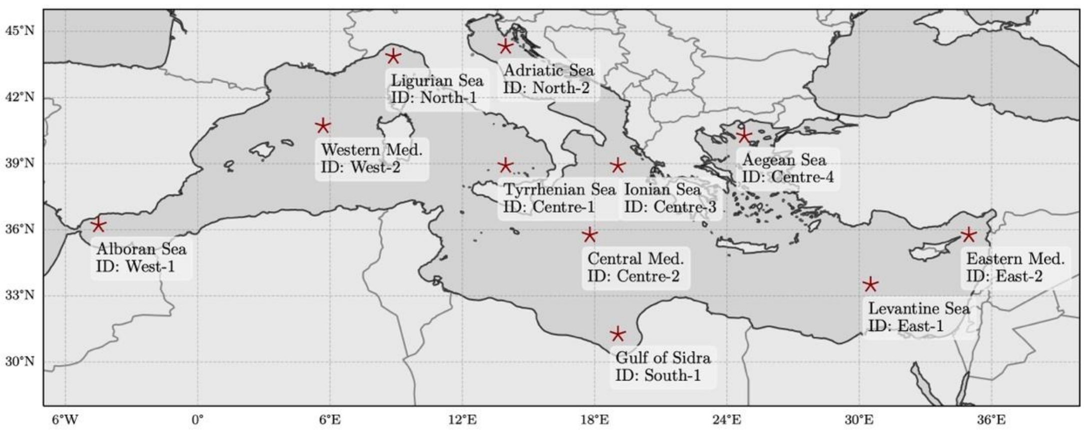

Figure 5. Location and identification of the analyzed locations

2.2.1. Bias correction of wave projections

GCMs and RCMs outputs exhibit varying levels of systematic errors or biases when com- pared to observations or hindcast data. Said biases are derived from simplified physics and discretization, coarse spatial resolution, internal variability, numerical parameterizations, among others Christensen *et al.* (2008); Teutschbein and Seibert (2012), which can be inherited in downscaling processes i.e, when using wind surface fields to force wave numerical models. This work uses the EQM-Month technique which consists of applying the traditional Empirical Quantile Mapping technique (also known as Distribution Mapping or Probability Mapping) to correct the distribution function of the GCM-RCM projections to agree with the hindcast distribution as,

$$X^{\cdot} = F_{hind}^{-1}\left(F_{RCM_{hist}}(X)\right)$$

where X^{*} is the bias-adjusted value of the raw GCM-RCM variable, X and F_{hind} and $F_{RCMhist}$ are the empirical distribution functions of the hindcast data and GCM-RCM, respectively, during the baseline period. The EQM method is applied to the data grouped by months therefore obtaining twelve different groups to be corrected, to account for the temporal variability of wave climate (Lira Loarca *et al.*, 2023).

2.3. Indicators

The MeteOcean research group, has developed two significant hindcast datasets to analyze wave climate and extremes in the Mediterranean Sea. These datasets are crucial for understanding historical weather patterns and predicting future conditions up to the year 2100.

2.3.1. Wave Climate and Extremes Statistics Dataset

The dataset***, MeteOcean wave climate and extremes statistics in the Mediterranean Sea: hindcast and multi-model ensemble of GCM-RCMs projections by 2100*** (Lira-Loarca and Besio, 2023a) provides comprehensive wave climate data and extreme statistics. This dataset is based on a regular 10 km grid, which ensures a consistent spatial resolution across the Mediterranean Sea. The regular grid facilitates uniform data analysis and comparison, making it suitable for broad-scale studies of wave climate and extreme weather events.

The dataset contains statistics for significant wave height (H_s), mean wave period (T_m), peak wave period (T_p) and mean wave direction (THEHTA m) for Hindcast (1979-2005) and a multi-model ensemble of 17 EURO-CORDEX GCM-RCMs projections for the following periods:

- Baseline (1979-2005)
- Mid-century (2034-2060) for RCP 8.5,
- End-of-century (2074-2100) for RCP 8.5

The following statistics are included providing seasonal and monthly means:

Significant wave height:

For hindcast, raw GCM-RCMs and bias-adjusted GCM-RCMs

- Average significant wave height
- 10, 50, 90, 95 and 99th
- Maximum significant wave height

- Average Hs when Hs>90 and 95th percentiles of the hindcast
- Number of sea states when Hs>90 and 95th percentiles of the hindcast
- Percentage of sea states when Hs>90 and 95th percentiles of the hindcast
- Average Hs when Hs>1.25, 2.5 and 4 m
- Number of sea states when Hs>1.25, 2.5 and 4 m
- Percentage of sea states when Hs>1.25, 2.5 and 4 m
- Number of days with at least two consecutive days when daily-max Hs>90th and 95th percentiles of the hindcast
- Percentage of days with at least two consecutive days when daily-max Hs>90th and 95th percentiles of the hindcast

Mean wave period:

For hindcast and raw GCM-RCMs

- Average mean wave period
- 10, 50, 90, 95 and 99th percentiles
- Maximum mean wave period

Peak wave period:

For hindcast and raw GCM-RCMs

- Average peak wave period
- 10, 50, 90, 95 and 99th percentiles
- Maximum peak wave period

Mean wave direction:

For hindcast and raw GCM-RCMs

- Mean Circular mean
- Circular standard deviation

2.3.2. 2D Wave Spectra Statistics Dataset

The dataset, ***MeteOcean 2D wave spectra statistics in the Mediterranean Sea: multi-model ensemble of GCM-RCMs projections by 2100*** (Lira-Loarca and Besio, 2023b) focuses on 2D wave spectra statistics. The dataset supports in-depth analysis of wave spectra and is essential for localized marine and coastal engineering applications. The dataset contains statistics for bias-adjusted 2D wave spectra for a multi-model ensemble of 17 EURO-CORDEX GCM-RCMs projections for the following periods:

- Baseline (1979-2005)
- Mid-century (2034-2060) for RCP 8.5,
- End-of-century (2074-2100) for RCP 8.5

for 11 locations in the Mediterranean Sea (Figure XX). The dataset provides monthly means and monthly maxima statistics.

3. Pilot sites observations systems

3.1. Longarini-Cuba coastal wetland

3.1.1. Field survey data

Field surveys were conducted to investigate abiotic and biotic variables, with six sampling stations selected for the Longarini lagoon and four for the Cuba lagoon (Figure 6). Sediment samples were collected seasonally in July 2022, December 2022, March 2023, July 2023, and November 2023.

Figure 6. Map of the Longarini-Cuba lagoons system and the sampling locations of the field surveys.

For each sample site, the lagoon name, site number, abbreviation, and survey date were recorded, and coordinates were determined using a Garmin Global Position System. At each station, in-situ physicochemical parameters (such as dissolved oxygen, pH, and salinity) were measured at surface water depths using a Hanna HI 98194 multiparametric probe (Figure 7).

Figure 7. Sediment sampling surveys at the lagoons. Each sampling station is identified by its site name and acronym, with coordinates and the date of the survey also noted. Three sediment samples were collected from each site for grain-size, micro-, and macrobenthic analyses.

Phytosociological surveys were carried out using the Braun-Blanquet method. Phytosociological relevés were conducted at each sampling station within the Cuba lagoon. The field analysis considered plot size, altitude, total vegetation coverage, vegetation height, and species occurrence. Each species was assigned a coverage value ranging from 1 (1-5% coverage) to 5 (75-100% coverage), while sporadic species were given a + (<1% coverage). Samples of species from different sites were collected to create herbarium specimens, which will be stored in the Herbarium of Catania (CAT). Additionally, water analysis of the lagoon was performed using a multiparametric meter to measure salinity, pH, and dissolved oxygen.

Sedimentological and benthos surveys were conducted at each site, collecting lagoon floor surface and sub-surface sediments for grain-size analysis. Approximately 200-300 g of sediments were collected and carefully preserved in polythene bags, with water content minimized. For the macrobenthic community survey, samples were taken by deepening about 10 cm into the lagoon floor, and around 500 g of surface sediments were collected and preserved in polythene bags. For the microbenthonic community survey, a few millimeters of surface sediments were sampled and immediately washed and sieved (mesh size 63 µm) with lagoon water. These samples were preserved in 95% ethanol with Rose Bengal solution (2 g l^{-1}) and kept at low temperature.

3.1.2. Habitat maps

A spatially detailed habitat map of the Sicily lagoon system is available (Figure 8), created through the cross-analysis of two map datasets: the Corine Biotopes map of Sicily (scale 1:10,000), freely provided by the local regional administration, and the Corine Coastal Zones Land Cover/Land Use 2018 (CZ_2018_DU004_3035_V010, https://land.copernicus.eu/pan-european/corine-land-cover).

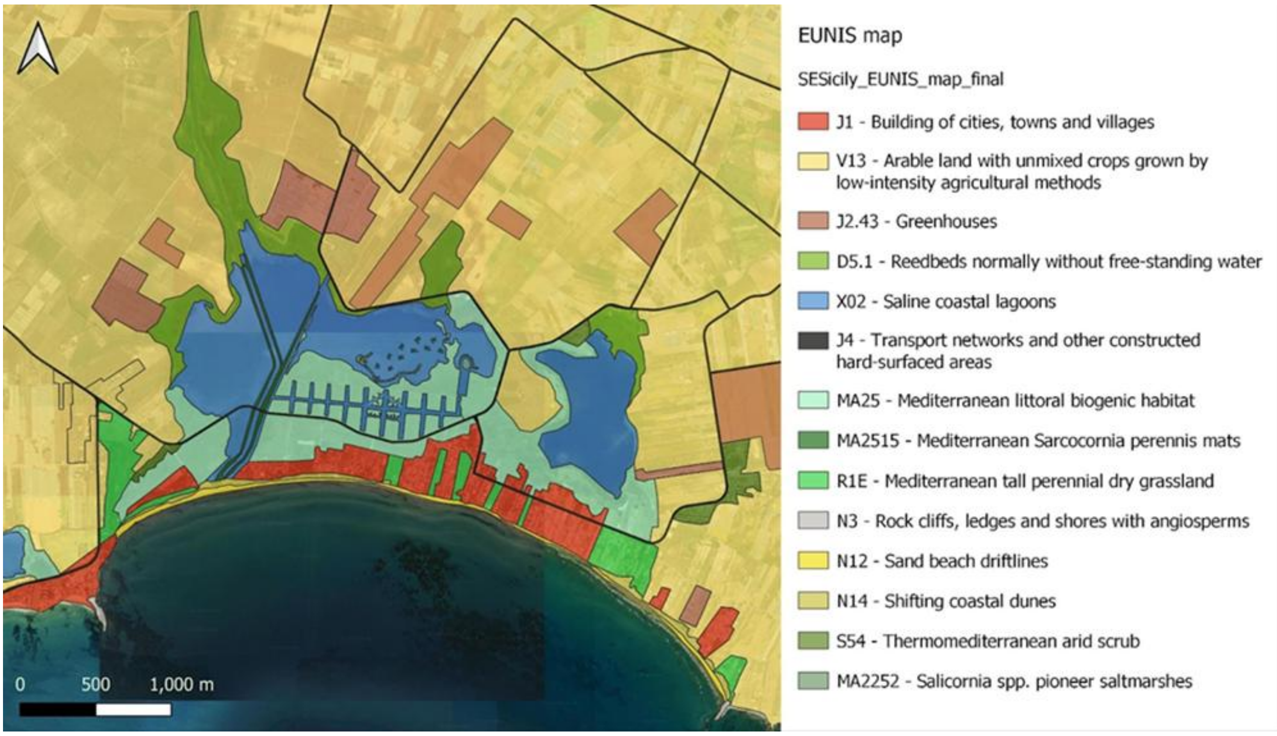

Figure 8. Sicily pilot site habitat map.

The Corine Biotopes classification was converted to EUNIS 2012 using the Italian Interpretation Manual of the 92/43/EEC Directive habitats, which encompasses all natural habitat types. To convert semi-natural and artificial habitats within the Sicily lagoon system area, a crosswalk table between EUNIS 2012 habitats classification and Corine Land Cover from the European Topic Centre on Biological Diversity (http://biodiversity.eionet.europa.eu) was used. Conversion to the updated EUNIS 2021 terrestrial habitat classification was achieved by applying the crosswalks listed at https://eunis.eea.europa.eu/habitats-code-browser-revised.jsp. In some cases (e.g., class J1 – Buildings of towns, cities, and villages), EUNIS 2012 codes and nomenclatures could not be converted to EUNIS 2021 due to the lack of a conversion system. Once the EUNIS map was completed, it was validated through field surveys and satellite imagery analysis. Habitats found in the study site, alongside their EUNIS classification code, are listed in Table 2.

CB	**EUNIS2012**	**EUNIS2122**	**EUNIS2122D or EUNIS2012D**
15.1	A2.5	MA25	Mediterranean littoral biogenic habitat
15.12	A2.5513	MA2252	*Salicornia* spp. pioneer saltmarshes (artificial island)
15.5	A2.5261	MA2515	Mediterranean *Sarcocornia perennis* mats
16.12	B1.1	N12	Mediterranean and Black Sea sand beach
16.21	B1.3	N14	Mediterranean, Macaronesian and Black Sea shifting coastal dune
16.21	B1.3	N14(d)	Mediterranean, Macaronesian and Black Sea shifting coastal dune (degraded)
21	X02	N/A	Saline coastal lagoons
32.2	F5.5	S54	Thermo-mediterranean arid scrub
34.6	E1.4	R1E	Mediterranean tall perennial dry grassland
53.1	D5.1	N/A	Reedbeds normally without free-standing water

18	B3	N3	Rock cliffs, ledges and shores with angiosperms
82.3	I1.3	V13	Arable land with unmixed crops grown by low-intensity agricultural methods
86.1	J1	N/A	Buildings of cities, towns and villages
N/A	J1.2	N/A	Residential buildings of villages and urban peripheries
N/A	J4	N/A	Transport networks and other constructed hard-surfaced areas
N/A	J2.43	N/A	Greenhouses

Table 2. Habitats identified in the case study site with Corine biotope codes and EUNIS-2012 and EUNIS-2021. CB = Corine Biotopes. When the EUNIS-2012 class could not be converted to the EUNIS-2021 class (indicated in the table as N/A), the EUNIS-2012 code and classification were adopted.

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