score

D3.1- Package of procedures for baseline characterization and projections

DATE OF DELIVERY - 22/12/2021

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003534

DOCUMENT TRACKS DETAILS

Project acronym	SCORE
Project title	Smart Control of the Climate Resilience in European Coastal Cities
Starting date	01.07.2021
Duration	48 months
Call identifier	H2020-LC-CLA-2020-2
Grant Agreement No	101003534
Deliverable Information	
Deliverable number	D3.1
Work package number	WP3
Deliverable title	Package of procedures for baseline characterization and projections
Lead beneficiary	LAMMA
Author(s)	Roberta Paranunzio (CNR), Iulia Anton (ITS), Tasneem Ahmed (ITS)
Due date	31/12/2021
Actual submission date	22/12/2021
Type of deliverable	Demonstrator
Dissemination level	Public

VERSION MANAGEMENT

Revision table			
Version	Name	Date	Description
V 0.1	Roberta Paranunzio, CNR Iulia Anton, ITS Tasneem Ahmed, ITS	10/12/2021	First draft
V 0.2	Elisa Adirosi, CNR Cécil Meulenberg, ZRS	15/12/2021	Updated draft internally reviewed
V 0.3	Roberta Paranunzio, CNR Iulia Anton, ITS Tasneem Ahmed, ITS	21/12/2021	Updated draft after contribution from partners
V1.0	Salem Gharbia, ITS	22/12/2021	Final version

LIST OF ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Meaning / Full text
API	Application Programming Interface
C3S	Copernicus Climate Service
CCLL	Coastal City Living Lab
CDS	Copernicus Data Store
CF	Climate and Forecast
CFSM	Coupled Forecast System Model
CFSR	Climate Forecast System Reanalysis
CMEMS	Copernicus Marine Environment Monitoring Service
CMIP	Coupled Model Intercomparison Project
CORDEX	The Coordinated Regional Climate Downscaling
CSV	Comma separated values
DGF	Direct Get File
DTM	Digital Terrain Model
EBA	Ecosystem-Based Approach
EC	European Commission
ECMWF	European Centre for Medium-range Weather Forecasts
EEA	European Environmental Agency
EAV	Essential Agriculture Variable
EBV	Essential Biodiversity Variable
EFAS	The European Flood Awareness System
EGV	Essential Geodiversity Variable
EMODNET	European Marine Observation and Data Network
EOV	Essential Ocean Variable
ESGF	Earth System Grid Federation
ESA	European Spatial Agency
EU	European Union
EV	Essential Variable
FAIR	Findability, Accessibility, Interoperability and Reusability
GCM	Global Climate Model
GCOS	Global Climate Observing System
GEOGLAM	GEO's Global Agricultural Monitoring
GFCS	Global Framework for Climate Services
GMAO	Global Modelling and Assimilation Office
HyMeX	HYdrological cycle in the Mediterranean EXperiment
ICT	Information and Communication Technology
INSPIRE	INfrastructure for SPatial InfoRmation in Europe
IPCC	The Intergovernmental Panel on Climate change
ISO	International Organisation for Standardisation
MedCLIVAR	Mediterranean Climate Variability and Predictability
MERRA-2	Modern-Era Retrospective analysis for Research and Applications, Version 2
NASA	National Aeronautics and Space Administration

NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NEMO	Nucleus for European Modelling of the Ocean
NetCDF	Network Common Data Form
OGC	Open Geospatial Consortium
OPeNDAP	Open-source Project for a Network Data Access Protocol
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
RCSM	Regional Climate System Model
RPO	Research Performing Organisation
SIP	SCORE ICT Platform
SME	Small and Medium-sized Enterprise
WCRP	World Climate Research Program
WMO	World Meteorological Organization
WMS	Web Map Services
WP	Work Package

BACKGROUND: ABOUT THE SCORE PROJECT

SCORE is a four-year EU-funded project aiming to increase climate resilience in European coastal cities.

The intensification of extreme weather events, coastal erosion and sea-level rise are major challenges to be urgently addressed by European coastal cities. The science behind these disruptive phenomena is complex, and advancing climate resilience requires progress in data acquisition, forecasting, and understanding of the potential risks and impacts for real-scenario interventions. The Ecosystem-Based Approach (EBA) supported by smart technologies has potential to increase climate resilience of European coastal cities; however, it is not yet adequately understood and coordinated at European level.

SCORE outlines a co-creation strategy, developed via a network of 10 coastal city 'living labs' (CCLLs), to rapidly, equitably and sustainably enhance coastal city climate resilience through EBAs and sophisticated digital technologies.

The 10 coastal city living labs involved in the project are: Sligo and Dublin, Ireland; Barcelona/Vilanova i la Geltrú, Benidorm and Basque Country, Spain; Oeiras, Portugal; Massa, Italy; Piran, Slovenia; Gdansk, Poland; Samsun, Turkey.

SCORE will establish an integrated coastal zone management framework for strengthening EBA and smart coastal city policies, creating European leadership in coastal city climate change adaptation in line with The Paris Agreement. It will provide innovative platforms to empower stakeholders' deployment of EBAs to increase climate resilience, business opportunities and financial sustainability of coastal cities.

The SCORE interdisciplinary team consists of 28 world-leading organisations from academia, local authorities, RPOs, and SMEs encompassing a wide range of skills including environmental science and policy, climate modelling, citizen and social science, data management, coastal management and engineering, security and technological aspects of smart sensing research.

EXECUTIVE SUMMARY

This document is a deliverable of the SCORE project, funded under the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003534.

WP3 deals with regional and local projections, analyses, and modelling and uncertainties. The main objectives of this work package are:

- to identify, select and organize a homogeneous dataset of climate and marine data to build a reference (historical) baseline and projections for all project areas;
- to downscale climate projections that produce data at a suitable spatial resolution for local scale/impact needs;
- to develop tools for statistical analysis for local urban-scale hazards;
- to model short-term hazards by means of hydraulic-hydrological models that simulate urban flooding scenarios;
- to model long-term evolution of the coastline by means of climate projections and local morphodynamical processes.

Deliverable 3.1 (and 3.2 accordingly) is preliminary to other WP3 project activities and is intended to provide project partners with a set of procedures and data samples of fit-for-purpose climate and marine data for the baseline climate characterization and projections, to be subsequently analysed and processed for local scale analysis. Specifically, this document aims to provide requirements and delineates an approach to collect climate data and information from the main climate services and initiatives available across Europe which are of interest for SCORE activities. As there is a large amount of different climate data sets available, we constrict our analysis on those, which are officially available through EU institutions and/or supported by them like e.g., the European Union's Earth Observation Programme Copernicus or the European Marine Observation and Data Network (EMODnet) initiative from the European Commission. The main datasets of interest to SCORE users have thus been summarised in a tailored-made file in the SCORE internal platform, whose features will be listed in this document. A procedure for data selection based on some key requirements has been adopted and is showcased.

This document will thus include the following information:

- information on available climate services across Europe;
- the main requirements for the identification and selection of datasets of interest to the project (i.e., e.g., users' needs, variables, accessibility and available spatiotemporal resolution and coverage, available documentation);
- a list of the most appropriate datasets to be used for the SCORE activities.

This document and related dataset are drafted by CNR (WP3 partner and leader of Task 3.1 activity), ITS (WP3 and Task 3.1 partner) and LAMMA (WP3 leader) with inputs from all partners. In fact, to achieve a greater impact, all members of the WP3 have been asked to participate and give contributions based on their own experience and needs in terms of data analysis and modelling for the SCORE activities. D3.1 is a demonstrator document which will be delivered at M6.

LINKS WITH OTHER PROJECT ACTIVITIES

In accordance with WP3, Task 3.1 builds on previous European projects and initiatives to provide a reliable and suitable selection of existing climate and marine datasets to be subsequently, wherever needed, downscaled and processed and thus used in the other WP3-related tasks and project areas. Task 3.1 is thus preliminary and transversal to a range of WPs in the framework of the SCORE activities (Figure 1). Along with Deliverable 3.2, whose aim is to describe the data and datasets included in this deliverable, this document will provide a collection of procedures and data samples of the most important parameters related to climate-change impact on coastal cities as identified in WP1 and WP2 like e.g., sea levels, wind and precipitation extremes, air and sea temperatures, and river level extremes.

Procedures included in this document and data described in Deliverable 3.2 will be used in the following WP3 tasks. Specifically, the retrieved data will be analysed and downscaled by means of ready-to-use tools and models to be used for local-scale impact assessment (Task 3.2). Data from Task 3.1 (and downscaled time-series from Task 3.2) then will be analysed and processed in Task 3.3 for the implementation of statistical analysis tools for local urban-scale hazards. Short-term hazard modelling (Task 3.4) and long-term evolution of the coastline modelling (Task 3.5) will benefit from data produced in Task 3.1, 3.2 and 3.3. Data from task 3.1 and consecutively other tasks will be finally exploited in the testing phase (Task 3.6).

Specifically, Deliverable 3.1 will provide a possible rationale to identify and select the most appropriate datasets stored in the European climate services for SCORE users. Indeed, information on the data stored in the climate services in terms of e.g., spatial and temporal resolution and coverage, variables availability and time series lengths which are essential to deliver Task 3.2 on the Downscaling Analysis Tools. Users of Task 3.3, which are in charge of performing statistical analysis tools for urban-scale hazard, and Task 3.4 and 3.5 on short/long term modelling will benefit of the data samples and use cases presented in Deliverable 3.1 (and Deliverable 3.2) as examples of application of processing and analysis of the data stored in the mentioned climate services.

Data and models provided by WP3 will be stored, curated, homogenised and processed, along with products generated by SCORE WPs (WP4, WP6, WP7 and WP8) in a fit-for-purpose SCORE ICT Platform (SIP) developed within WP5, while ensuring findability, accessibility, interoperability and reusability (FAIR). To be easily integrated in SIP and for an efficient storage, data and information selected in Task 3.1 should thus be as homogenous and standardized as possible i.e., complying with relevant climate and forecast metadata conventions and standards. This would also facilitate usage of data by end-users and partners.

Figure 1 WP3 and related-tasks connection to other WPs

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1. INTRODUCTION

The demand for tailored climate data and information by diverse specific users (such as stakeholders, decision makers and scientists) and the public is growing worldwide together with the awareness of the challenges posed to the environment and society by climate change. In this context, climate services play a crucial role in developing and disseminating customized climate information and tools to diverse stakeholders based on relevant standards and conventions. Provided products are of help in conducting studies on climate related-hazards and related risks and vulnerabilities as well as building climate-resilient societies. Considering the swiftly developing and ongoing digital transformation and in accordance with the Green Deal adaptation goals [1] fostering the use of advanced digital technologies and climate services (e.g., remote sensing, artificial intelligence, smart sensors and weather stations) to support the decision making is thus crucial.

In the framework of SCORE project, but not limited to this, new tools like digital twins will enhance our understanding of current and future climate impact at local scale. For this purpose, open, free and reliable climate data are needed. There are a many national to European-scale services that provide data and information about climate change for large range of different user categories.

As there are a large amount of different climate data sets available, we constrict our analysis on those, which are officially available through EU institutions and/or supported by them like e.g., the European Union's Earth Observation Programme Copernicus or the European Marine Observation and Data Network (EMODnet) initiative from the European Commission. All data provided by key European scientific programmes and initiatives like Copernicus or the EMODnet are freely accessible to users worldwide. The Copernicus Climate Change Service (C3S) will continue to increase data usability and to develop further services like the monitoring and emergency management services [2].

More in detail, the Copernicus Climate Change Service implemented by the European Centre for Medium-Range Weather Forecasts (ECMWF) on behalf of the European Commission is the main European climate service that aims to support adaptation and mitigation strategies and policies of the European Union.

Regarding marine data specifically, these have been, unfortunately, gathered and stored in fragmented ways across Europe during previous decades, focusing on specific purposes or user needs. The Copernicus Marine Service (CMEMS) provides free and open access to a large range of marine products and datasets on the blue, white and green ocean states across Europe and worldwide [3]. Part of the datasets included in the CMEMS are being included in the Copernicus Data Store of the C3S as well.

The EMODnet is a network of organisations supported by the EU's integrated maritime policy. This is a collaborative service i.e., organisations that collaborate gather sea data, process and analyse data according to the international standards and make the information freely available as a single point gateway to a number of data repositories managed by local as well as international organisations [4].

Local data including local institutional climate monitoring infrastructures and low-cost sensors for citizen-science will complement the information provided by the climate services and will be the object of other tasks and project activities linked to Task 3.1.

The next sections will provide, an indication on the procedure undertaken for finding the most suitable climate services across Europe to be specifically used within the SCORE project. Information and details on the identified services will be given as well. Finally, a subsample of identified datasets will be listed as the most appropriate in the framework of SCORE's activities and the main features will be described.

2. PROCEDURES AND DATA SAMPLES

2.1. Approach for dataset identification and selection

The identification and selection of fit-for-purpose climate and marine data for the baseline (historical) characterization and projection is based on some key requirements as follows.

1. Investigating users and CCLLs needs.
2. Availability of variables
3. Accessibility.
4. Spatiotemporal coverage.
5. Spatiotemporal resolution.
6. Available documentation.
7. Data and metadata quality.
8. Standards and conventions.

2.1.1. Investigating Users' Needs

The main questions that must be answered regarding the user's needs are:

- What kind of users will interact in the framework of SCORE's activities?
- What will the users be able to do with such data?
- Are data from European climate services sufficient?

It is fundamental to understand what type of climate information the users and CCLLs are interested in to perform statistical analysis and modelling for coastal management and to address adaption options. With this purpose, internal meetings with CCLLs, WP3 and related-WPs partners have been set up in the past months to share and discuss preliminary outcomes.

User engagement is indeed the basis to perform a gap analysis of the data and information made available through the identified climate services. In this context, use cases which are examples of how data and services can be deployed, are useful tools to understand how the users interact with climate and marine data in their daily work, and how data are used to address a wide range of climate applications. The term "case study" is instead specifically referred to a particular case that has already occurred within a real-world context.

It has to be stated that in the framework of the SCORE project, data are meant to be handled and processed by expert users who have the specific skills to interpret the results and transfer information to the different range of stakeholders. Use cases address the question of what can be done with data retrieved from a generic dataset or climate service. For this, some use cases are extracted from the climate data providers and services of interest for the SCORE project and match the relevant thematic areas of the project and users' needs. These are presented in Section 2.2.4 and used in Deliverable 3.2 to guide the user through the data usage.

In addition to the European climate services products, the CCLLs will provide useful information on the local data from existing sensor networks that are currently used by municipalities i.e., meteo/marine/hydrological in situ measurements and DTM of hydrological basin, coastal bathymetry, urban digital map. These data will complement the information provided by the European climate services by e.g., filling eventual gaps and providing data for model calibration/validation. In addition, citizen science gathered data from low-cost sensors (citizen science kits) can fill the spatial/temporal gaps to produce more solid coastal city early-warning support systems.

2.1.2. Variables' availability

Essential variables (EV) are critical for monitoring and observing the Earth system. Many organizations and programmes (e.g., the Global Climate Observing System GCOS and the World Meteorological Organization WMO) have sponsored collaborations among institutions worldwide to identify such variables in their field of research. These EV include climatology, oceanography, geodiversity and biodiversity. The requirements for EVs are constantly reviewed by expert panels (government organizations, international space agencies and academia) in terms of e.g., spatial and temporal resolution and data quality. Standards for data collection guarantees the usability of such data across different platforms [5].

EVs include:

- Essential Climate Variables (ECVs)
- Essential Ocean Variables (EOVs)
- Essential Biodiversity Variables (EBVs)
- Essential Geodiversity Variables (EGVs)
- Essential Agriculture Variables (EAVs)

ECVs provide the key information to understand and predict the evolution of climate, support adaptation and mitigation actions and underpin climate services. ECVs, as identified by the Global Climate Observing System (GCOS), include a set of variables in the atmosphere, land and ocean domains. The atmosphere ECVs cover both upper-air and surface atmosphere, and atmospheric composition. Land ECVs cover cryosphere, biosphere, anthroposphere and the hydrosphere. Ocean ECVs cover physical, biogeochemical, biological fields and ecosystems.

EOVs cover the physics of the ocean system, the biogeochemistry, the biology and ecosystems as ocean ECVs. Critical EOVs are focused on ocean circulation, the distribution and transport of heat, salt and other water properties. Note that, as many variables are part of both ocean ECVs and EOVs, there is an overlap between the two categories.

EBVs are focused on a range of essential dimensions of biodiversity with three critical dimensions i.e., space, time and biological organization which allow to assess biodiversity and its changes properly.

EGVs consider the abiotic dimension e.g., geomorphology, mineralogy, pedology and abiotic (sub)surface geology which play a key role in terms of availability of natural resources thus directly affecting the biodiversity.

EAVs are being developed by the GEO's Global Agricultural Monitoring (GEOGLAM) and include e.g., vegetation indices, biomass, evapotranspiration, land cover information, and surface water mapping. They provide information on agricultural land use from regional to global scale.

In the framework of the SCORE project, ECVs and EOVs are the most relevant. Nevertheless, the other EVs are crucial while performing specific analysis and considerations on potential sectoral impacts of climate-related hazards experienced by the CCLLs in terms of e.g., tourism, agriculture stress, local economy, animal habitats, loss of wetlands etc. Thus, EBVs, EGVs and EAVs will be considered as well to support throughout.

Since many EOVs are also ECVs defined by the GCOS, we preferred to categorize the variables of interest in terms of the following categories related to four macro categories: climate and weather, sea and coast, pollutant and radiations. Thus, Table 1 groups the most important variables identified by the end-users. Climate and weather-related variables, along with marine data (sea and coast), are the main parameters of interest for end users and those on which the selection of the datasets has been mainly based. Pollutants and radiations-related variables are, instead, secondary parameters which can help additional and contingent analysis.

Table 1 Categorisation of variables of interest with typical examples

Climate and weather	Sea and coast	Pollutants	Radiations
Air temperature, dew point, heat index	Mean sea level	Concentration in the air (CO, CO_2, NO_2, SO_2, PM10, PM2.5)[1]	Solar irradiance
Humidity	Sea (lakes, river, channels) level	pH	Radiation in the UltraViolet
Atmospheric pressure	Storm surge residual	Mass concentration in the water	Radiation in the InfraRed bands
Cloud height and coverage	Total water depth		
Precipitation (rain, snow, haul) intensity and total Precipitation	Sea temperature		
Lightning strikes	Tidal elevation		
Wind (speed and direction)	Sea wave motion		
Zero-degree isotherm height	Shoreline position		
Tropospheric features (melting-layer height, thickness)	Salinity		

2.1.3. Spatio-temporal coverage

SCORE's CCLLs are distributed across Europe plus Turkey. Thus the datasets covering at least this spatial domain must be considered (Figure 2). These spatial domains are not always provided on regular grids. Therefore, the projections may be different depending on the domain and RCM used.

An approximate domain window of interest for the SCORE project is 27°N - 72° N (southernmost-northernmost latitude) and 22°W - 45°E (westernmost-easternmost longitude), which is pretty aligned to both the EURO-CORDEX [6] and the Med-CORDEX domains [7].

The temporal coverage should guarantee sufficient extension back in time for the historical characterization (as identified by WP1) and future projections. The historical time span will be investigated through the use of in-situ measurements wherever available, and/or reanalysis products. Well-known climate data reanalysis datasets like ERA5 and ERA-5 Land go back in time up to 1950 to near real time, providing an accurate description of the climate of the

[1] CO: Carbon monoxide, CO_2: carbon dioxide, NO_2: nitrogen dioxide, SO_2: sulfur dioxide, PM_{10}: particulate matter with a diameter of 10 microns or less $PM_{2.5}$: particulate matter with a diameter of 2.5 microns or less.

past. Climate projections generally cover the period up to 2100 at a daily scale minimally under RCP 4.5 and 8.5. However, some datasets provide more accurate temporal scales (e.g., sub-daily), and further emission scenario like CORDEX or, and in the case of CMIP5 and CMIP6, cover the period up to 2300.

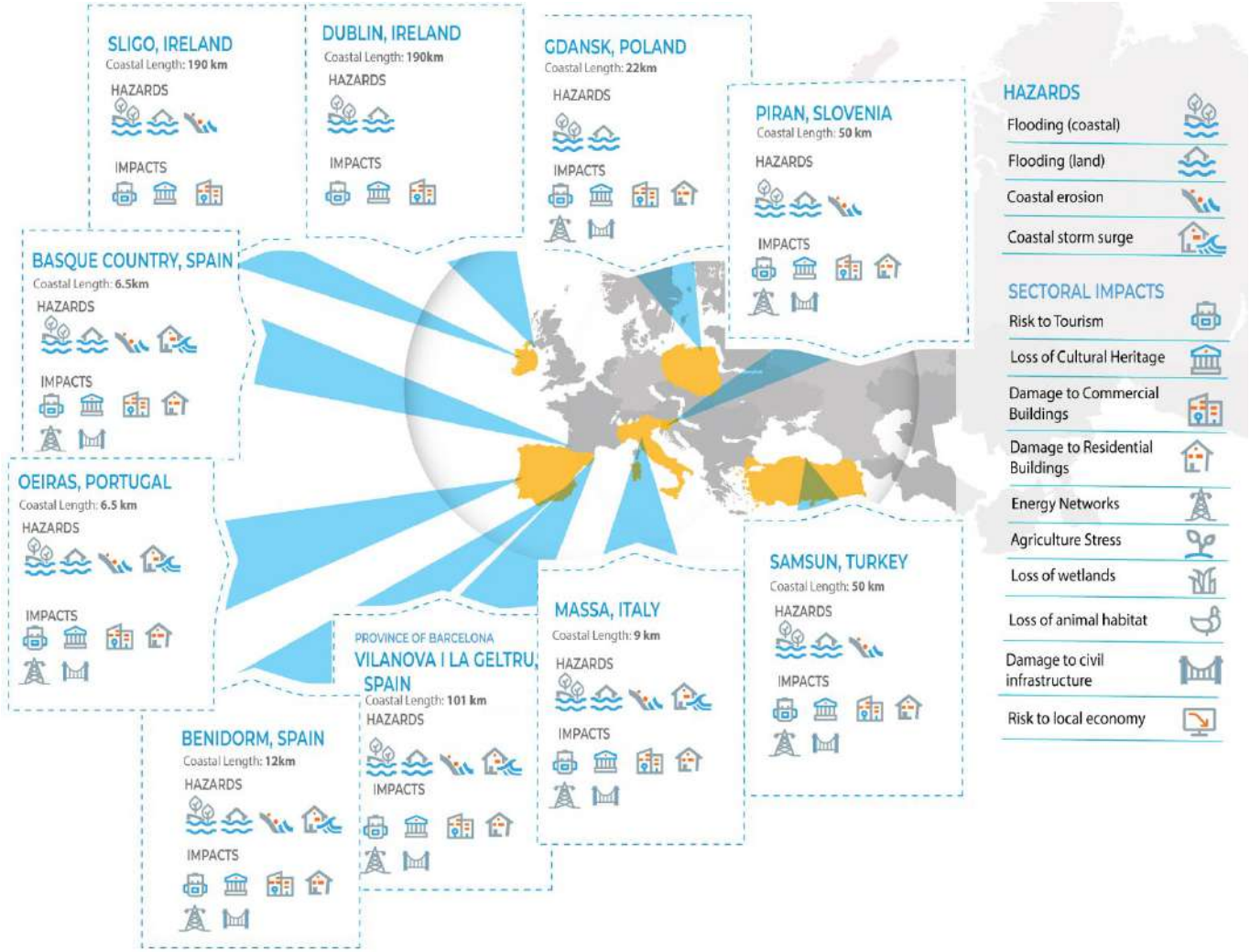

Figure 2 CCLLs across Europe and related hazards and impacts. Source: H2020 SCORE website [8].

2.1.4. Spatio-temporal resolution

The above-mentioned general temporal and spatial resolutions should be suitable for the project CCLLs' application needs. Nevertheless, to support local impact studies and adaptation decisions at the urban scale such as those considered in the SCORE project, spatial downscaling of the regional datasets to the coastal scale will be necessary.

Climate projections are run typically until 2100 based on the assumed Representative Concentration Pathway (RCP) scenarios for the concentrations of greenhouse gases, atmospheric constituents and aerosols that affect the radiative balance of the planet [9]. Global Climate Models (GCM) can provide reliable climate information on global and larger regional scales, covering what could be a broad area with very different local extreme events and the subsequent impacts. Of note is that horizontal resolution limits the possibility to cover smaller scales, from regional to local.

In the context of the SCORE project, Regional Climate Models (RCMs) will be preferred against GCMs, since the former allow to reach a higher spatial resolution and a relatively fine detail over a limited area to support more detailed adaptation assessments. A large number of regional projections for the European region have been run under the CORDEX project [10]. RCMs are still driven from the GCMs which provide lateral boundary conditions to the regional

models and provide a more accurate representation of localized extreme events. Nevertheless, estimating uncertainties in climate projections and in their sources is not that straightforward, also considering the internal variability of the systems.

Temporal resolution should be at least at daily and/or sub-daily scale to support properly the subsequent statistical analysis and modelling for a more robust coastal city early-warning support.

Spatial and temporal gaps will be filled by low-cost sensors whose aim it is to complement the official climate monitoring infrastructures and generate more detailed local data.

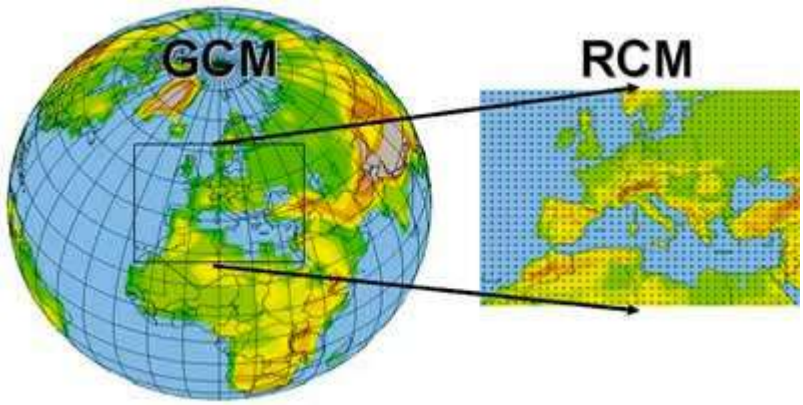

Figure 3 Example of RCM domain embedded in a GCM grid. Source: [11].

2.1.5. Accessibility

The data gathered from the different climate services in the framework of SCORE's WP3 should be free of charge and open to any public or private organization. In general any individual could access and exploit the data. This matters, since the provision of climate data and information services is intended to help not only the scientific community but society and citizens as well in understanding the risks associated to climate change and empowers all to respond to them. Data, metadata and information delivered by the different climate services should be available online to guarantee easier accessibility with/without prior registration on services websites and platforms, through direct download or sub-setting services. The identified climate services should guarantee a strong usability and user experience of the web portals/websites. Thus, data access should allow an easy manipulation of data and products available in the climate service repository. Repositories that guarantee a single point access and/or assembling different datasets making them openly accessible, thus providing a comprehensive overview on a variety of different datasets across Europe (like e.g., the C3S CDS [12] or EMODnet initiative portal), will be preferred against national or local initiatives to ease accessibility.

2.1.6. Data and metadata quality

Each data set should be available as a quality-assured information with independent quality assessment about the past, current and future states of the climate in Europe. It is fundamental to assure that the identified dataset is a reliable source of climate data and outputs. Moreover, this allows to ensure that data are robust and sufficient for SCORE users to judge the fitness of the selected datasets for their own application and analysis. In general, climate services provide quality-controlled data with a metadata quality control procedure, that together ensure high standards of reliability. Most climate services across Europe like e.g., the C3S, guarantee, through an operational framework of processes, that the service meets the users' needs in terms of high-quality data and information provision and information. Thus, the advantage of using subsets of data stored in such comprehensive platforms (like the CDS) is related to the fact that a metadata quality control is guaranteed, since data come often with no quality assurance and may have gaps, inconsistencies or metadata errors. The user-engagement process of the CDS

continuously guarantees to identify gaps that the Service has to recognize and/or adapt/erase to meet the needs of a range of users for high-quality data and information. In proposing the requested adaptations, the necessary evolution of the service itself can be warranted, while shaping the research agenda to attend the most important challenges.

2.1.7. Standards and conventions

The data and products provided by the data suppliers and stored in the climate service must be consistent with the international data sharing principles and comply with agreed standards and specifications, such as OPeNDAP, ESGF, Open Geospatial Consortium (OGC) Web Coverage Service, the International Organisation for Standardisation (ISO) specifications, or a web-based REST API through adaptors (which translate generic data request into dataset-specific requests). In this framework, the INSPIRE Directive 2007/2/EC aims at establishing an Infrastructure for Spatial Information in the European Community supported by technical guidelines and legislation regarding data models and metadata and network services [13]. Conformity with Common Data Model and data format specifications is desirable to ensure easy import into the SCORE ICT platform developed in WP5. The data products standardisation ensures ease of use, harmonisation and consistency. Variables available in the identified datasets should follow the Climate and Forecasting (CF) convention, thus using standard name and metadata and be stored in the NetCDF file. The recent version of the CF convention allows the use of new NetCDF-4 data types along with the classical version as well. If NetCDF-4 cannot be used, earlier format versions will be considered.

2.2. Exploring Climate Services of interest for SCORE activities

2.2.1. The Copernicus Programme

Copernicus is a European programme supported by the European Space Agency (ESA) for the space component and the European Environment Agency (EEA) for the in-situ component aimed at developing data and information services based on satellite Earth Observation and in situ data [14].

The objective of Copernicus is to monitor and forecast the state of the environment on atmosphere, sea and land to support climate change adaptation and mitigation strategies, to efficiently manage emergency situations and to improve citizens' security by providing information on natural hazards and helping to prevent the loss of lives and assets.

The information services provided by Copernicus are available to its users, mostly public authorities, on a full free-of-charge and open basis and with continuity.

The Copernicus Programme is served by dedicated satellites (i.e., the Copernicus Sentinel families) and a set of additional Contributing Missions (i.e., satellites run by various commercial and national agencies). Since the launch of Sentinel-1A in 2014, the European Union set in motion a process to place a constellation of almost 20 more satellites in orbit before 2030. This satellite data is complemented by and validated with in situ data.

Six Copernicus Services transform the full, free and open data into value-added information by processing and analysing the data and transforming them into services and products such as informative maps and data sets:

- The Copernicus Atmosphere Monitoring Service
- The Copernicus Marine Environment Monitoring Service
- The Copernicus Land Monitoring Service
- The Copernicus Climate Change Service
- The Copernicus Emergency Management Service

- The Copernicus Security Service

For further readings on the Copernicus' space and ground components users can refer to the Copernicus in detail page on the Copernicus website [15].

In the framework of the SCORE project, the Copernicus Climate Change Service and the Copernicus Marine Environment Monitoring Service are the services of predominant interest that will be further discussed in the next sections.

Figure 4 What is the Copernicus programme (Screenshot from video)

The Copernicus Climate Change Service (C3S) and the Climate Data Store (CDS)

The Copernicus Climate Change Service [2] aims to support adaptation and mitigation strategies and policies of the European Union through the provision of reliable and consistent information about climate change. C3S is implemented by the European Centre for Medium-range Weather Forecast (ECMWF) on behalf of the European Commission. Information included in the C3S relies on climate research carried out within the World Climate Research Programme (WCRP) by responding to user (scientists, consultants, planners and policy makers, the media and the public) requirements defined by the Global Climate Observing System. C3S provides an important resource to the Global Framework for Climate Services (GFCS). C3S benefits from a robust engagement of the scientific community: most part of the service elements included in the C3S have been implemented by approximately 200 organizations, agencies, research centres and companies across Europe which have been selected on a competitive Invitations to Tender base [16]. C3S is thus designed as a distributed system which act a single point access to existing datasets otherwise sparsely available.

C3S's hearth is the Climate Data Store [12] which is an operational data access portal implemented by ECMWF on behalf of the European Commission. The CDS provides access to a wide range of climate information and datasets including observations, historical climate data records, global and regional reanalyses of past observations, seasonal forecast, climate projections, estimates of ECVs derived from Earth observations and indicators. CDS is thus an operational single web interface to a number of existing climate repositories distributed on the cloud. Access to these data is free, open and unrestricted. CDS also offers a series of tools for data processing and analysis. The CDS is

progressively extending to include Copernicus Atmosphere Monitoring Service, (CAMS) Copernicus Marine Service (CEMS), ESA CCI, EUMETSAT SAF and others. Evaluation and information about quality control and assessments of the C3S products are also available on the CDS.

Among the myriad of datasets stored in the CDS, some of the most interesting and complete for SCORE activities are ERA5 [17] and CORDEX [10]. ERA5 provides hourly estimates of a large number of atmospheric, land and oceanic climate variables. The data cover the Earth on a 30 km grid and resolve the atmosphere using 137 levels from the surface up to a height of 80 km. ERA5 includes information about uncertainties for all variables at reduced spatial and temporal resolutions. Quality-assured monthly updates of ERA5 (1979 to present) are published within three months of real-time. Preliminary daily updates of the dataset are available to users within five days of real-time.

The Coordinated Regional Climate Downscaling is supported by the World Climate Research Program (WCRP) and assessed by the Intergovernmental Panel on Climate change (IPCC). The CORDEX's vision is to enhance and manage regional climate downscaling science and applications through worldwide collaborations. Its goal is to assess the performance of regional climate models through a series of experiments aimed at providing regional climate forecasts. For the CORDEX subset stored in the CDS (CDS-CORDEX), the boundary conditions are currently derived from the CMIP5 global predictions [18].

Further details on the datasets stored in the C3S are provided in Deliverable 3.2.

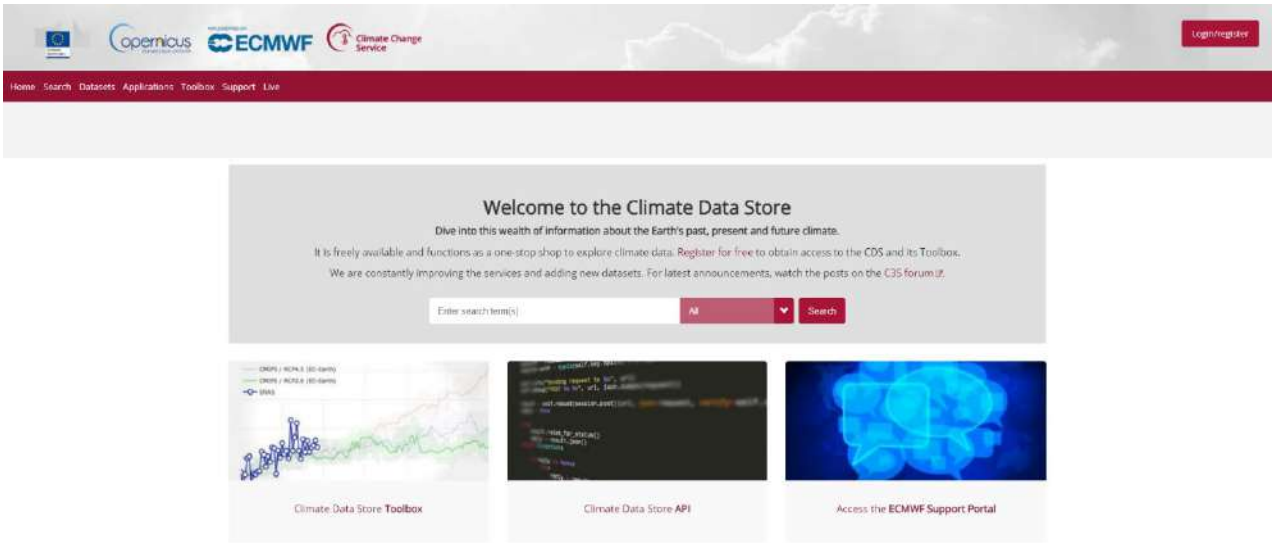

Figure 5 CDS Platform. Source: CDS platform [12]

2.2.1.1. The Copernicus Marine Environment Monitoring Service (CMEMS) portal

The Copernicus Marine Service (or Copernicus Marine Environment Monitoring Service; CMEMS) is one of the six services part of Copernicus [19]. CMEMS is a user-driven service because it directly involves its users in the definition of the services and delivery. It provides oceanographic products i.e., state-of-the-art analyses and forecasts of oceanographic parameters. Similarly to the CDS, CMEMS offers a single point access to oceanographic products through an online catalogue. CMEMS is operational since May 2015 and is currently operated by Mercator Ocean, the French centre for analysis and forecasting of the global ocean. As for the CDS, users can access quality and validated data on the marine environment, access the interactive web-based forum and use this information as an input to their-own analysis and services. Targeted users are especially in the maritime safety, marine and coastal environment, seasonal forecasting and climate-related activities. CMEMS also publishes the annual Ocean

State Report i.e., a reference document for the ocean community, decision makers and society providing a state-of-the-art assessment of the global ocean and European regional seas. The observations and forecasts produced by the service support all blue economy sectors: Polar Environment Monitoring, Marine Conservation and Policies, Science and Climate, Natural Resources and Energy, Water Quality, Coastal Monitoring, Society and Education, Marine Food, Marine Navigation, Safety and Disaster.

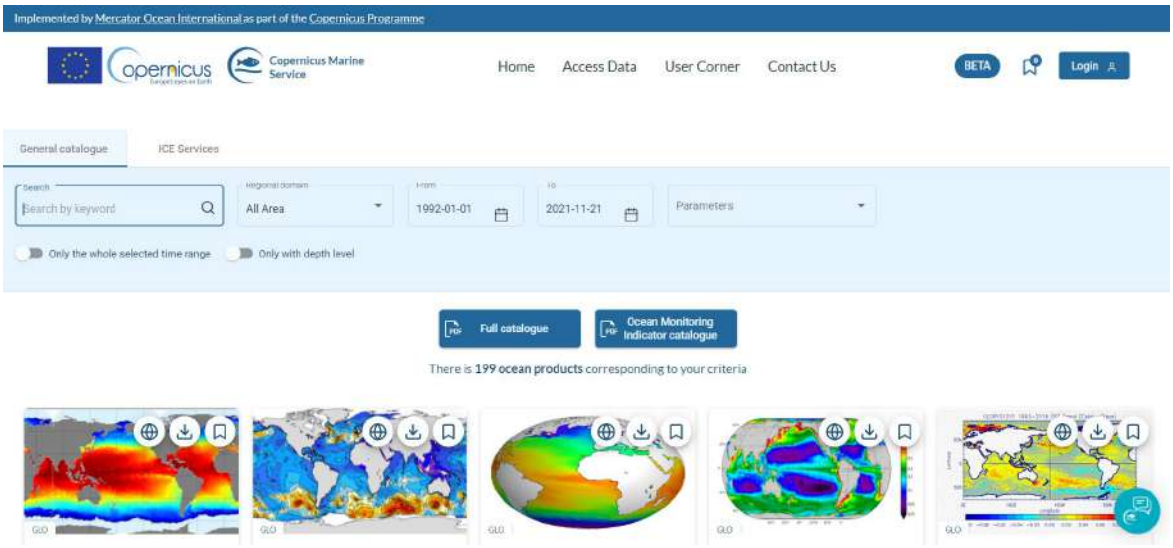

Figure 6 CMEMS platform. Source: CMEMS portal.

2.2.2. The European Marine Observation and Data Network (EMODnet) initiative

The European Marine Observation and Data Network (EMODnet) is a long-term marine data initiative from the European Commission Directorate-General for Maritime Affairs and Fisheries (DG MARE) underpinning its Marine Knowledge 2020 strategy [4]. EMODnet is basically a data assembler and broker. Specifically, it is a network of organisations working together to assemble European marine data, data products and metadata from different sources. This means that EMODnet does not own the data, but rather incorporates datasets from different sources and providers to make marine data and products openly accessible from a single access point. EMODnet's mission is thus to provide in a uniform way hidden and sparse marine data resources, and to make them available through a harmonised, quality-assured, free of restrictions and standardised way. The EMODnet data infrastructure is developed through three stepwise phases of development (currently, the 3rd phase is starting). Seven main themes are covered: bathymetry, geology, physics, chemistry, biology, seabed habitats and human activities. For each of these themes, EMODnet provides a gateway to a range of data archives managed by local, national, regional and international organisations. All these data products are free to access and use. EMODnet is continuously updated with new products and functionalities. Users and stakeholders contribute to make the portals more user friendly and fit-for-purpose. More information about EMODnet can be found at the EMODnet Central Portal.

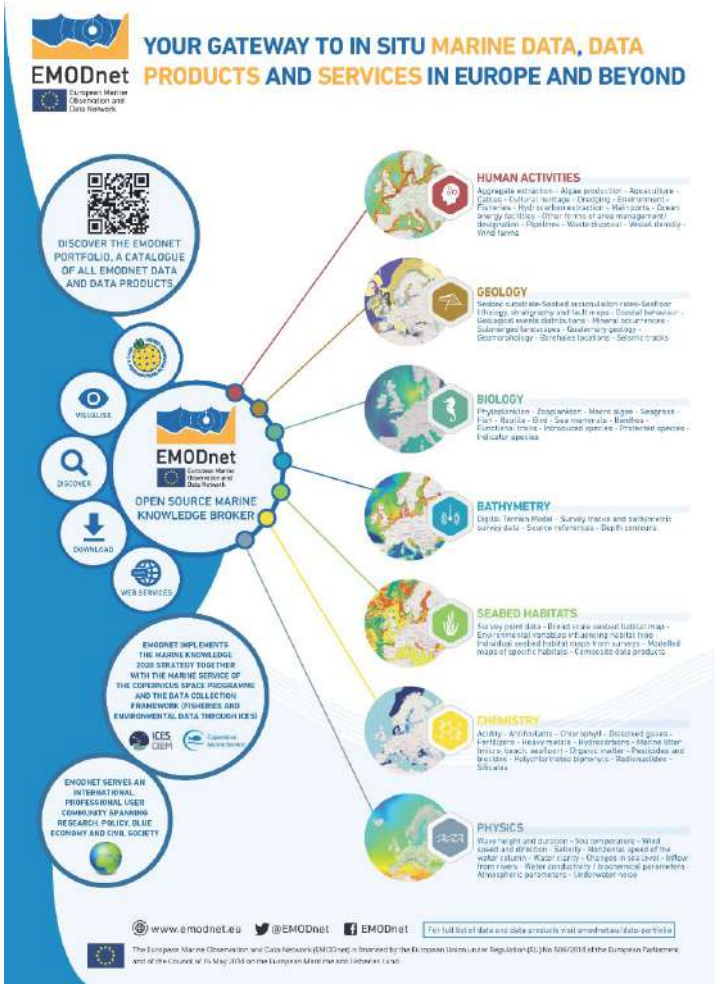

Figure 7 EMODnet Infographic. Source: EMODnet website [4]

2.2.3. Complementary datasets and climate services

Part of the datasets previously mentioned show a reduced historical extension back in time for the historical period. This is particularly true for the marine data (e.g., extreme storm surges, tide and wave conditions data). For this reason and for the sake of completeness as well, further datasets and services from extra-European initiatives should be considered. These additional datasets are required to cover the global scale, thus including the European area too, provide high resolution data and fill potential gaps in marine and ocean data requests. Based on these specific requirements for the SCORE activities and among the myriad of available repositories worldwide, the following datasets have been considered to potentially complement the information provided by the European services.

Climate Forecast System Reanalysis (CFSR) - NCEP Climate Forecast System Version 2 (CFSv2)

The National Centers for Environmental Prediction (NCEP) Climate Forecast System (CFS) is initialized four times per day (0000, 0600, 1200, and 1800 UTC). NCEP upgraded their operational CFS to version 2 on March 30, 2011 [20]. This is the same model that was used to built the NCEP Climate Forecast System Reanalysis (CFSR), and the aim of this dataset is to extend CFSR [21]. The 6-hourly atmospheric, oceanic and land surface analyzed products and forecasts, available at 0.2°, 0.5°, 1.0°, and 2.5° horizontal resolutions, and have been archived here beginning with January 1, 2011 as an extension of CFSR. Further details are available on the official website [20].

Modern-Era Retrospective analysis for Research and Applications, version 2 (MERRA-2)

The Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) is a reanalysis data product from NASA/GMAO and it is currently being produced with the GMAO/GEOS-5 Data Assimilation

System Version 5.12.4 [22]. MERRA-2 replaces the MERRA reanalysis product. Data provision start in 1980 and the native resolution is 0.5° (which corresponds to about 50 km in the latitudinal direction) x 0.625° x 72 hybrid sigma/pressure levels. In MERRA-2, some advances in the meteorological assimilation system have been made related e.g., to hyperspectral radiance and microwave observations, along with GPS-Radio Occultation datasets, NASA's ozone profile observations, GEOS model and GSI assimilation system. Data provision started in 1980 and the spatial resolution is about 50 km in the latitudinal direction as in MERRA. Further details are available on the official website [22].

2.2.4. Use cases as examples of data usage

To explain how to access the data, understand and download them for specific users' needs in the framework of the SCORE project, we make use of use cases to guide the reader though the abovementioned climate services. We here recall that use cases are examples of how data and services can be deployed while case study defines something real i.e., something that has already been deployed. This step-by-step approach will be included in Deliverable 3.2 where the data will be described in detail, along with the databases structures, interfaces and data formats for all the main climate services and initiatives of interests for the SCORE activities. This is intended to provide a practical application of data usage i.e., addressed datasets, in different contexts, including data visualization, exploration, data handling. Details on data usage are included in D3.2. Hereinafter, indications where to gather use cases that match the SCORE topics and users' needs in the C3S, CMEMS and EMODnet portal will be provided. Table 2 showcases a list of selected use cases from these climate and marine services that are considered particularly appropriated to address potential application areas and activities of the SCORE project, and that are in line with problematics extracted from CCLLs questionnaires. Then, these use cases will be used in D3.2 as examples of data access.

Table 2 Use cases for CDS, CMEMS and EMODNET

Provider	Use Case	Related Thematic Areas	Examples of Data Products Variables needed
Copernicus Climate Change Service	Coastal Flooding in Ireland [23]	Climate Change Service, Emergency Management Service	Water level, Mean sea level change, Wave climate and wind
CMEMS	WAX-COAST: wave extreme value analysis at the coast [19]	Marine Environment Monitoring Service	Sea waves analysis and forecasts, Sea physics reanalysis,
EMODnet	EMODnet Physics' integrated wind, wave and sea level data supports Coastal Infrastructure Risks and Safety Management in South Italy (GRISIS research project) [4]	Physics	Wind, wave and sea level

2.2.4.1. The Copernicus Climate Change Service showcases

C3S provides a number of use cases, case studies and demonstrator projects that aim to demonstrate and support applications based on the tools and products available on the CDS platform. These use cases and case studies make use of a set of C3S products and address topic climate-related issues in a wide range of sectoral themes across Europe. The outcomes of these demonstrator projects include e.g., climate data tools and indicators of interest for businesses or communities for adaptation purposes. Use cases and demonstrator projects in the C3S can be accessed through "Sectoral Impact" page [24]. Below a user case study relevant interest for SCORE users is presented.

Coastal Flooding in Ireland

The impact of climate change on coastal flooding at local scale in Ireland is particularly relevant for other CCLLs in the framework of the SCORE project. To date in Ireland there are no metocean datasets available for future climate projections, and thus simplified assumptions are taken, defining fixed ratios of increase for a range of variables (e.g., water level per year, percentage change of wind height) in the medium and long term. The situation described in this case requires the knowledge of both meteorological and hydrogeological models. Input data include, but are not limited to, water level, mean sea level change, wave features and wind.

Stakeholders and end users benefit from easily accessible climate and marine data and products to understand the impact of storm surges and sea level on the Irish coastline. Impact indicators provided by the C3S helped the end users through the decision-making process and to take actions to improve climate resilience adaptions measures at different time scales in the future. Indeed, outputs of this activity are planned to be included in the national Climate Change Sectoral Adaptation Plan for Flood Risk Management, flood risk management plans and erosion risk management plans. Additional details are provided on the C3S [23].

2.2.4.2. The CMEMS use cases

CMEMS provides a wide range of hands-on use cases filtered by region, country and markets [25]. Moreover, use cases show how marine data can be used for different sectoral applications funded by the Copernicus Marine User Uptake programme. The User Uptake programme is based on users' feedback and requirements collected through the Service Desk or satisfaction inquiries while addressing scientific gaps and needs. Examples of marine data application are included in publications like e.g., the Use Case books [26].

WAX-COAST: wave extreme value analysis at the coast

WAX-COAST, powered by ARTELIA Group, provides automated extreme value estimates near the shore for any location in the Mediterranean Sea to address marine work contractors and parametric insurance requirements like e.g., dredging/nearshore construction and income protection solutions against climatic hazards. Indeed, the number of infrastructures and activities close to the coast is steadily growing and the business models of parametric insurance are not compatible with consultancy services. For this, quick and accessible extreme values estimate nearshore are needed. In the framework of WAX-COAST, these values are provided and visualized through a user-friendly platform in less than 48 hours. The offshore data are propagated at the coast with a third-generation numerical wave propagation model by means of a statistically robust and consistent methodology. Further information can be found on CMEMS portal [19].

2.2.4.3. The EMODnet use cases

EMODnet provides a range of use cases that can be selected by portal (e.g., physics, bathymetry, geology, biology), case type (e.g., business, policy makers and research) or by searching text [27]. It offers also the possibility to submit your own use case.

EMODnet Physics' integrated wind, wave and sea level data supports Coastal Infrastructure Risks and Safety Management in South Italy (GRISIS research project)

Coastal urban areas may be exposed to a range of different types of risk. Thus, safety management of civil infrastructures should be oriented towards a multidisciplinary approach to achieve a holistic analysis of human-made and natural risks.

The GRISIS research project (Risks and Safety Management of Infrastructures at Regional Scale) deals with the development of a multi-risk technological platform for the Campania region in Southern Italy. The platform allows to store a range of different data concerning the area of interest in order to develop tools for the management and

mitigation of multiple risks to building networks and infrastructures. In this framework, physics data like wind, wave and sea level data are made available by EMODnet Physics. These data can be easily integrated in machine learning platform to manage and mitigate the multi-risks considered in GRISIS project.

2.3. Datasets Evaluation and Selection

Based on the requirements in Section 2.1 and on the outcomes of data search on the main providers and services across Europe, a subsample of datasets has been selected. This selection is meant to act as a suggestion to answer users' needs based on WP3 and related WP activities. Thus, it is not intended to be exhaustive. Indeed, depending on the specific activity or data needed, other dataset included in the above-mentioned climate services could be considered.

2.3.1. Baseline characterization (historical)

The ERA5 family set [17] guarantees the provision of a large number of atmospheric, marine and land variables from 1979 (extended back to 1950) up to date at global scale on an enhanced horizontal resolution of 30 km grid compared to the previous ERA-Interim. In terms of vertical resolution, ERA5 resolves multiple levels from the surface up. Such resolution will need further downscaling to infer high-resolution information for local scale impact studies to be developed in SCORE. Information about uncertainties for all variables are included as well. The provision of hourly estimates (ERA5-hourly data) allows to perform an accurate analysis at high temporal resolution. Moreover, a dedicated land product at 9 km (HTESSEL) is available (ERA-5 Land). In terms of accessibility, to ensure fast access to ERA5 data, a post-processed product has been made available on the CDS [12]. This simplifies issues encountered by users when retrieving ECMWF reanalysis data. Expert users can also access additional data sorted in MARS through the CDS, but data retrieval will be much slower in this case. The ERA5 family set is likely to be the main suggested dataset to characterize the reference baseline for the historical period.

- ERA5 family set e.g. (but not limited to)
    - *ERA5 hourly data on single level from 1979 on*
    - *ERA5-Land*
- ERA5-related datasets e.g. (but not limited to)
    - *Water level change time series for the European coast from 1977 to 2100 derived from climate projections*
    - *Ocean surface wave time series for the European coast from 1976 to 2100 derived from climate projections*
- *River discharge and related historical data from the European Flood Awareness System (EFAS)*
- *EMODnet Data Portals*

Moreover, to fill gaps in the historical marine data and variables, the Climate Forecast System Reanalysis (CFSR) - NCEP Climate Forecast System Version 2 (CFSv2) on the European domain can be considered as well as a complement to the listed datasets [20].

2.3.2. Projections (future)

Climate projections are based on GCMs and RCMS. The results of GCMs are the main source of information for the international community to make decisions on worldwide climate change adaptation, but they generally provide

information at low-resolution. To conduct studies at regional and national levels, climate information with a much higher horizontal resolution are needed. RCM simulations need lateral boundary conditions from GCMs. Combining GCMs outputs with more detailed local information, RCMs could provide much more accurate climate projections that are a better representation at smaller scale supporting more detailed impact studies.

In terms of GCMs, the C3S provides access to global climate projections under CMIP5 (Coupled Model Inter-comparison Project Phase 5, [28]), which the Coordinated Regional Downscaling Experiment (CORDEX, which is a RCM instead) uses as an input [10]. A more recent set of global projections, CMIP6 [29], has been available in the CDS since March 2021, and is also informing the Intergovernmental Panel on Climate Change's (IPCC) Report.

CMIP5 the standard experimental protocol for studying the outputs of coupled atmosphere-ocean general circulation models. CMIP6 is the sixth phase of the Coupled Model Intercomparison Project and consists of 134 models from 53 modelling centres. CMIP6 data publication began in 2019 and most of the data publication will be completed by 2022. The scientific analyses from CMIP6 will be used extensively in the IPCC 6th Assessment Report (AR6, [30]).

Both CMIPs and CORDEX are endorsed by the World Meteorological Organization (WMO) and the World Climate Research Programme (WCRP). CORDEX coordinates activities for the application of RCMs worldwide and plays a crucial role by providing much more detailed information at finer scale and filling the gap in GCMs in a systematic way. More in detail, GCMs like CMIP5 and CMIP6 are useful to understand climatic drivers and differences in model results and include around 100 modelling groups worldwide. CORDEX, being a RCM, allows to understand regional climate processes and is thus suitable for impact studies. CORDEX climate projections cover the global scale through 14 domains. A set of 26 core variables is included in the CDS, provided by 5 different CORDEX experiments (evaluation, historical and RCP scenarios). To date the CDS-CORDEX subset boundary conditions are extracted from CMIP5 global projections. The C3S EURO-CORDEX subset aims to fill the gaps in this matrix between the driving models (GCMs) RCMs and RCPs [18]. This is intended to ensure a better representation of uncertainties coming from GCMs, RCMs and RCP scenarios. For these reasons, EURO-CORDEX promises to be one of the most appropriate reference datasets for climate projections to be used in the context of SCORE project [6]. In this framework, it is advisable to consider Med-CORDEX as well. Med-CORDEX is a coordinated contribution to CORDEX that is supported by HyMeX and MedCLIVAR international programs [7]. Med-CORDEX initiative has been proposed by the Mediterranean climate research community as a follow-up of previous and existing initiatives. Med-CORDEX takes advantage of new high-resolution Regional Climate Models (up to 10 km) and of new fully coupled Regional Climate System Models (RCSMs), coupling the various components of the regional climate.

Based on the previous consideration, the suggested datasets to be used in the framework of SCORE project are:

- EURO-CORDEX and Med-CORDEX
- ERA5-related datasets e.g. (but not limited to)
    - *Water level change time series for the European coast from 1977 to 2100 derived from climate projections*
    - *Ocean surface wave time series for the European coast from 1976 to 2100 derived from climate projections*
    - *Marine biogeochemistry data for the Northwest European Shelf and Mediterranean Sea from 2006 up to 2100 derived from climate projections*

2.3.3. Summary of the selected datasets for baseline characterization and projections

We summarized the information related to the climate and marine datasets included in the climate services/providers in Section 2.2 in an excel file. The full dataset can be accessed by SCORE end-users through the H-SCORE internal platform. This file is constantly updated by SCORE users when new information comes available thus offering the possibility to interact and propose new potential datasets to complement the information available to date. Indeed, since the project started in July 2020 and has a duration of four years, the possibility to consider further new tools and updated data should not be excluded, during SCORE's execution and beyond in the future. The excel file with the full list of consulted datasets is accessible through the following link.

SCORE-deliverable-D3.1-RP-v1.0.xlsx

The first sheet refers to the historical datasets for the baseline characterization, while the second sheet refers to available climate projections' datasets. The datasets highlighted in yellow are those identified as the most appropriate for SCORE activities as indicated in Section 2.3 of this document.

Specific details and information on this selection are included in Deliverable 3.2.

Table 3 showcases the main fields considered in the dataset, along with the set of available options and meaning on the mentioned fields. Further instructions are included in the guidelines of the excel file.

Table 3 Example of current dataset list template as part of SCORE's Deliverable 3.2

Field	Options	Meaning
No.	Numbers	Order number
Variable domain	Atmosphere Atmosphere/Land Atmosphere/Land/Ocean Ocean Land	Earth system component the variable refers to
Provider	Free text	Name of the Climate Service/Operational Service/Research centre providing the service
Dataset name	Free text	Product name as identified by the data producer
Data type	Gridded/Gridded and catchments/Point data, Others (free text)	Type of object
Main variables	Free text as specified by the provider	Climate variable name
Product type	In-situ observations, Reanalysis, Seasonal Forecast, Scenario, Satellite-derived product, Projections-derived product, Model and observation-derived product, Others (free text)	Type of climate data
Horizontal coverage	Global, Europe, Global land, Global ocean, European coastline, Others (free text)	Spatial domain
Horizontal resolution	Free text as specified by the provider	Geospatial resolution

Field	Options	Meaning
Vertical resolution	Single level (surface), Multiple levels (plus specifications), Others (free text)	Number of vertical levels
Temporal resolution	Daily, Sub-daily, Monthly, Others (free text)	Information about the discrete resolution of a measurement with respect to time
File format	NetCDF, NetCDF-4, GRIB2, Others (free text)	Standard way to encode information for storage in a file
Source	Link	Direct link to the climate/operational service webpage to download data
Licenses	Link	Terms of use agreement for model output
Conventions	Climate and Forecast (CF) Metadata Convention v1.3, 1.4, 1.6, 1.7 Others (free text)	Name of the conventions for climate and forecast metadata designed to promote the processing and sharing of files

3. CONCLUSIONS AND RECOMMENDATIONS

This document showcases the procedures and data samples for the baseline characterization of the historical period and for the climate projections. This document focuses on the procedures to select and gather climate and marine data from a set of European climate services based on the requirements illustrated by the SCORE project, embracing involvement of different users not limited to CCLLs, scientists, technical staff and decision makers. Hence, in this document we try to ensure the best coverage for local scale impact studies in terms of variables of interest for modelling and spatiotemporal resolution.

The climate services described in this study represent a single point access to a number of diverse climate and marine datasets across Europe otherwise sparsely accessible and available. Thus, they complement capabilities existing at the national level and provide a comprehensive climate information for a variety of different purposes and studies. This is possible by a constant collaboration from a network of organizations, supported by the EU, working together to provide updates and quality-checked data according to international standards and making the products freely available. As such, the climate services and datasets included in this document are not intended to be exhaustive, but surely cover a wide range of the climate information of interest for the SCORE activities available at the European level. Climate services are constantly updated with new tools and products and this is something that has to be considered during the project's life-cycle. Thus, this document and the related Deliverable 3.2 provide a snapshot of the climate information available to date, including the possibility to consider further future new tools and updated data. This is particularly true in the perspective that new climate projection information will become available.

In this document, data coming from the official institutional infrastructures available in the CCLLs areas (e.g., local agencies and consortiums) have not been included, as well as citizen science low-cost sensors, since they are not the focus of this deliverable. Nevertheless, they will constitute a valuable and essential complement to the information retrieved by the main climate services identified and will be the object of other project activities related to task 3.1.

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