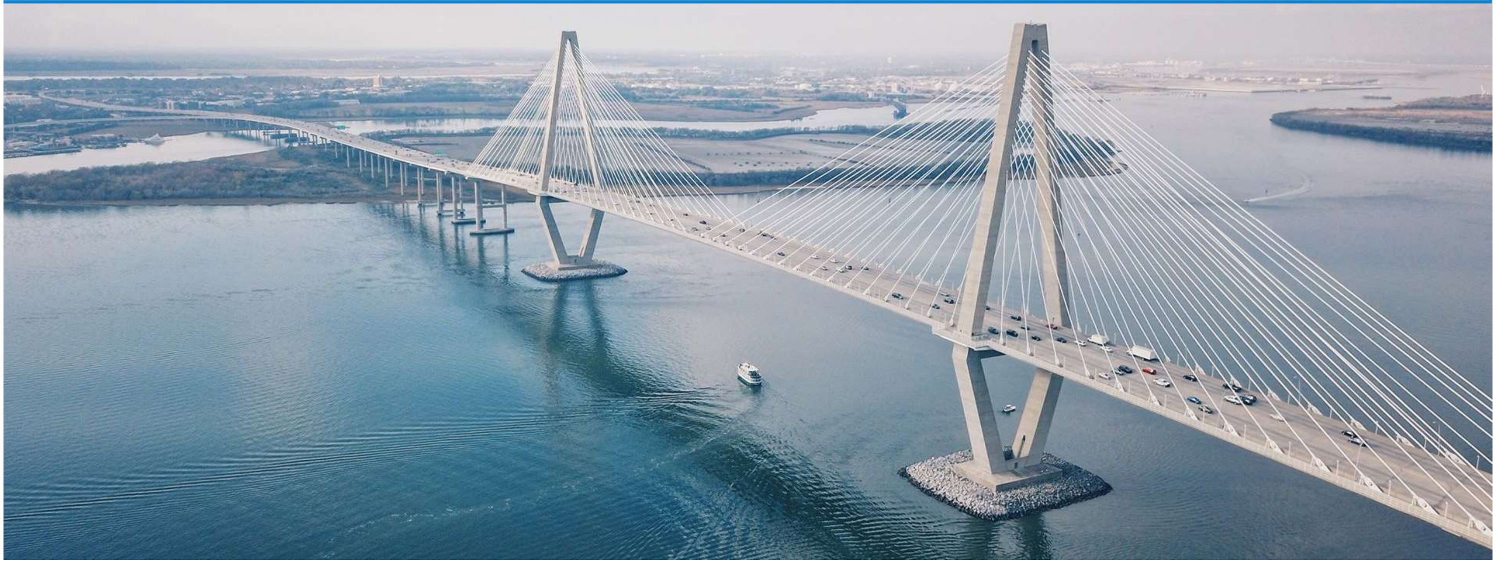
SIRMA

STRENGTHENING INFRASTRUCTURE RISK MANAGEMENT IN THE ATLANTIC AREA



Climate change indicators database

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Interreg Atlantic Area
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SIRMA

STRENGTHENING THE TERRITORY'S RESILIENCE TO RISKS OF NATURAL, CLIMATE AND HUMAN ORIGIN

Application Code: EAPA_826/2018

Climate change indicators database

WP 4 Climate Change & Natural Hazards in Atlantic Area

Deliverable ID	**D4.1**
Deliverable name	**Climate change indicators database**
Lead partner	**University of Nantes**
Contributors	University of Surrey

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SIRMA Project Synopsis

SIRMA aims to develop, validate and implement a robust framework for the efficient management and mitigation of natural hazards in terrestrial transportation modes in the Atlantic Area, which consider both road and railway infrastructure networks (multi-modal). SIRMA leads to significantly improved resilience of transportation infrastructures by developing a holistic toolset with transversal application to anticipate and mitigate the effects of extreme natural events and strong corrosion processes, including climate change-related impacts. These tools will be deployed for critical hazards that are affecting the main Atlantic corridors that are largely covered by SIRMA consortium presence and knowledge. SIRMA's objectives will address and strengthen the resilience of transportation infrastructures by:

- Developing a systematic methodology for risk-based prevention and management (procedures for inspection, diagnosis and assessment);
- Implementing a decision-making algorithm for a better risk management;
- Creating a hierarchical database (inventory data, performance predictive models, condition state indicators and decision-making tools), where information can be exchangeable between entities and across regions/countries;
- Developing a real-time process for monitoring the condition state of transportation infrastructure;
- Enhancing the interoperability of information systems in the Atlantic Area, by taking account of data normalization and specificity of each country.

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Executive Summary

Over the Earth's history, the climate has changed considerably due to natural processes (plate tectonics, volcanic activity, variations in the earth's orbit and solar variability); but in the last century, anthropogenic and natural radiative forcing have perpetrated global warming that happened faster than any such changes the earth has recorded in the last centuries, which turned out to be the influence of human activities (Holli Riebeek, 2009).

Anthropogenic greenhouse gas emissions since the pre-industrial era have driven large increases in the atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). These emissions are mainly stabilized in the atmosphere and also stored on land (in plants and soils) and oceans (IPCC, 2014), the greenhouse gas emissions lead to climate change that influences the oceanic CO_2 uptake since it is responsible for:

a) Increase in the sea surface temperature which rises the partial pressure of CO_2 in the surface ocean and increases the sea surface salinity.
b) Reduction in the meridional overturning and convective mixing and increase in the density stratification in high latitudes which slow down the transport of anthropogenic CO_2 into the ocean interior.
c) Alteration in the natural cycling of carbon in the ocean.

The mentioned consequences of climate change on the ocean will lead to a reduction of the oceanic CO_2 uptake (Halvorsen, 2008), cut in the meridional overturning circulation, weakening of the Gulf stream and cut off the warm eddies entering the Atlantic Ocean from the Indian ocean in which in turns, the Atlantic ocean is explicitly affected by climate change.

SIRMA project aims to develop, validate and implement a robust framework for the efficient management and mitigation of natural hazards in terrestrial transportation modes in the Atlantic Area, which consider both road and railway infrastructure networks. Within WP4, Deliverable 4.1 "Climate change indicators database" provides a freely available database of climate change indicators that is available to be used in the future by other research institutions/enterprises for estimating the vulnerability/consequences on transportation infrastructure at different Atlantic regions.

This report is organized as follows. The first chapter presents the test beds that are being studied in the framework of the SIRMA project. The second chapter introduces some basic principles on climate models able to predict future weather under various climate change scenarios. The third chapter provides a review of available databases in France, Spain, Ireland, Portugal and UK. Since the data that could be obtained from these databases is not consistent, the third chapter presents the database that was downloaded from Copernicus Climate Change Service and Coupled Model Inter-comparison Project Phase 5 (ESGF@DOE/LLNL). The database encompasses 17 extracted variables precisely chosen to distinctly define the extreme events in the European countries alongside 5 locations in Atlantic Ocean and cover a time series of up to 2100.

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1. Introduction

1.1 Objectives

The main objective of WP4 (Climate Change & Natural Hazards in Atlantic Area) within the SIRMA project is to assess the vulnerability of transportation infrastructure to interceptable (i.e. deterioration due to chloride ingress) and non-interceptable (e.g. scour) events under various climate change scenarios.

Within WP4, Deliverable 4.1 “Climate change indicators database” provides a freely available database of climate change indicators that could be used in the future by other research institutions/enterprises for estimating the vulnerability/consequences on transportation infrastructure at different Atlantic regions. To make these future estimations easier to compare between different Atlantic regions, it is important that researchers have access to a consistent dataset (i.e. identical parameters, resolution, climate model, climate scenarios, time-frequency, etc.), which is what this deliverable has provided.

1.2 Background

Over the past few decades, extreme weather events have been observed all over the world, with some of these attributed to global warming (IPCC, 2014a). With global temperatures continuing to rise and weather extremes projected to worsen, there has been a great deal of interest from the scientific community in understanding these extreme events better and their links to climate change (IPCC, 2014a; Drumond *et al.*, 2019). In parallel to extreme events, long-term gradual changes to climate variables may also alter the exposure environment of infrastructure assets and their rates of deterioration. For example, the durability of reinforced concrete structures depends on temperature, relative humidity, and the concentration of chlorides and CO_2 whereas the deterioration of steel structures depends on temperature, relative humidity and the concentration of CO_2 (Stewart and Bastidas-Arteaga, 2019).

One of the main issues that has been reported by *Infraestruturas de Portugal*, a key partner of this project, includes exposure to high tides in the Lisbon area. Additionally, a recent study has also shown that the Lisbon area is one of the most vulnerable areas to coastal flooding in the future (Rocha, Antunes and Catita, 2020).

Other studies have looked at how some of the Atlantic regions, including Portugal, can be more vulnerable than northern European countries for higher temperature and heavy precipitation (Molarius and et al., 2012). The study also shows how flooding across rail lines in Oceanic regions such as Portugal and Ireland can have huge impacts on equipment, leading to accidents and delays. An increase in extreme rainfall events is likely to increase the potential risk of scour on bridges having foundations in rivers. Scour has been identified as a key issue worldwide with several number of bridges failing each year due to the effects of scour from river flooding. Further studies that have also reported many regions that are vulnerable to different hazards such as flooding and landslides include (Ferreira, Dias and Taborda, 2008; Eidsvig, 2019).

Other projects, such as the EU funded RAIN project, had previously identified through interviewing national European stakeholders that 93% of them (including *Irish Rail*) had stated that heavy precipitation affects them in some way or another with rail and roads particularly being affected (Groenemeijer *et al.*, 2015). Furthermore, 68% of the stakeholders in the RAIN project also identified windstorms and river floods to be a threat to their critical infrastructure. Some of the main impacts to road and rail had been stated to be the erosion of rail embankments, flooding of highways and streets, and flooding of railroads all leading to disruptions to the network.

Therefore, with these risks in mind, the main weather and climate parameters collected for this deliverable include: air temperature, precipitation, relative humidity, wave height, river flow, sea level rise and wind speed. Furthermore, these variables were also previously identified in the work plan of the SIRMA project due to their unfavourable consequences when they become excessive.

1.3 Test beds

The SIRMA infrastructure partners have identified two test beds to be looked at for this project. The first test bed is located on a coastal area in Portugal frequently facing tidal issues, while the other test bed is in Ireland, where some bridges could have some scour and flooding risks associated with it.

1.3.1 Dublin to Cork Railway Line

The test bed that has been identified in Ireland is the Dublin to Cork Railway Line, which starts from Dublin Heuston Station to Cork Kent Station. The line is approximately 266km in length and is frequently used by both passenger and freight services. Figure 1 below shows the extent of the test bed.

Figure 1: Test bed in Ireland

1.3.2 National Road 6 (EN6) and the Cascais Railway line

The test bed that has been identified by the Portuguese infrastructure operators is the EN6 road, which runs along the coast, and a stretch of the Cascais Railway line, which runs parallel to EN6 at certain sections. Road EN6 has a length of 16 km and the Cascais Railway has a length of 25.5 km. Figure 2 below shows the extent of the test bed.

Figure 2: Test bed in Portugal

2. Climate Models

2.1 Introduction

This chapter provides a brief overview of what different climate models mean and how they predict the weather. Each model often gives different results even when using the same location due to the different assumptions and parameters used in each climate model. This chapter will also look at the variation between the different climate model results one can get when choosing a specific location.

2.2 Global Climate Models (GCMs)

Global climate models (GCMs) are based on general physical principles of fluid dynamics and thermodynamics, which originate from numerical weather prediction (CLIPC, 2020). GCMs describe interactions between components of the global climate system; atmosphere, oceans and a basic description of the earth's surface (CLIPC, 2020).

2.3 Regional Climate Models (RCMs)

Regional climate models (RCM), forced by global climate models (GCM), allow to solve physical processes into smaller ranges and consequently with increased detail and realism when compared with results from global models (CLIPC, 2020). So, this means that RCMs are complimentary to GCMs by adding further details to global climate projections by downscaling their resolutions to a more regional level. This is particularly useful when generating information for vulnerability studies, impacts and adaptations.

Local projections have recently been produced by some institutions too such as the Hadley Centre in the UK and several French laboratories involved in climate modelling (IPSL, CERFACS, CNRM-GAME). Local projections tend to give data at higher spatial resolutions (i.e. 2.2km) which can better represent local effects and helps simulate small-scale behaviour seen in the real atmosphere (Met Office, 2019a).

2.4 Variations between different global and regional climate models

Different climate and weather variable results can be obtained from different global and regional climate models. In this case, several models identified in the IPCC 5th Assessment Report (AR5) are compared to observed data. The case below uses observed data obtained from the Portuguese mainland. The variations are demonstrated below in Figure 4 and**Erro! A origem da referência não foi encontrada.** Figure 4.

Figure 3 shows a larger variation in some climate models compared to other models. For instance, the CNRM-CM5(SMHI-RC44) and ICHEC-EC(KNMI_RAC) climate models provide the most varied predictions throughout the thirty-year period from the observed data. However, the Ensemble projections give the closest results to the observed results.

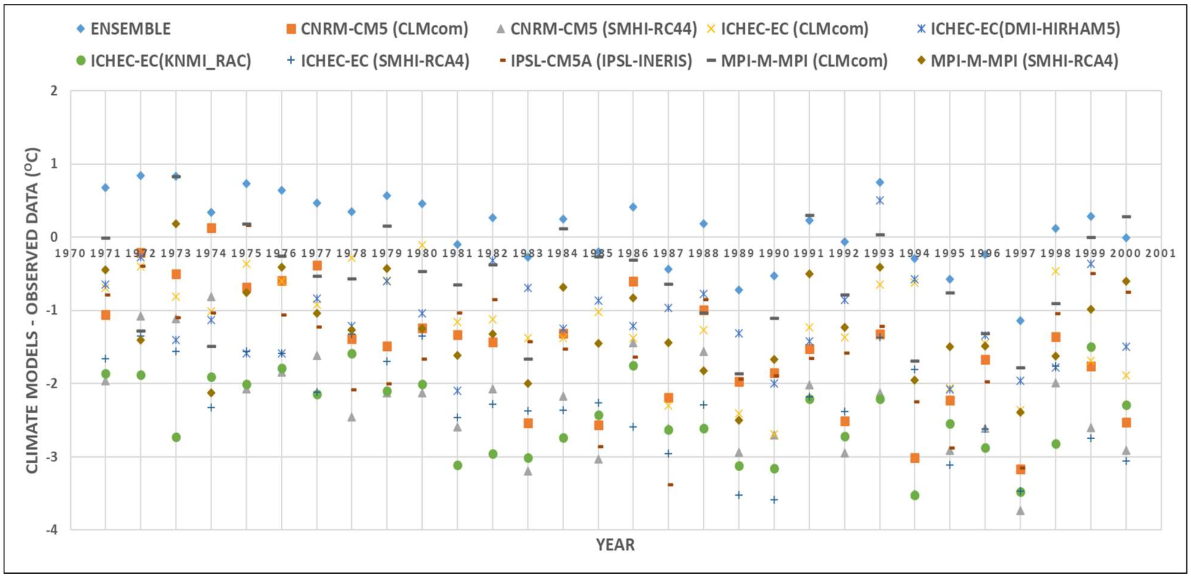

Figure 3: The difference of each climate model simulation with the observed data per year[1]

Figure 4 shows the variation of the mean of the climate models per year. In other words, it shows which particular year between 1970-2000 has resulted with a greater or lower variation using the results from all the models. The data has quite minor variations when considered in this context; with 1996 showing the least variation and 2000 having the largest variation.

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[1]In this figure, the first part of the model name is the global climate model while the writing in the parenthesis is the regional climate model used. For instance, for CNRM-CM5 (SMHI-RC44), CNRM-CM5 is the global climate model and SMHI-RC44 is the regional climate model.

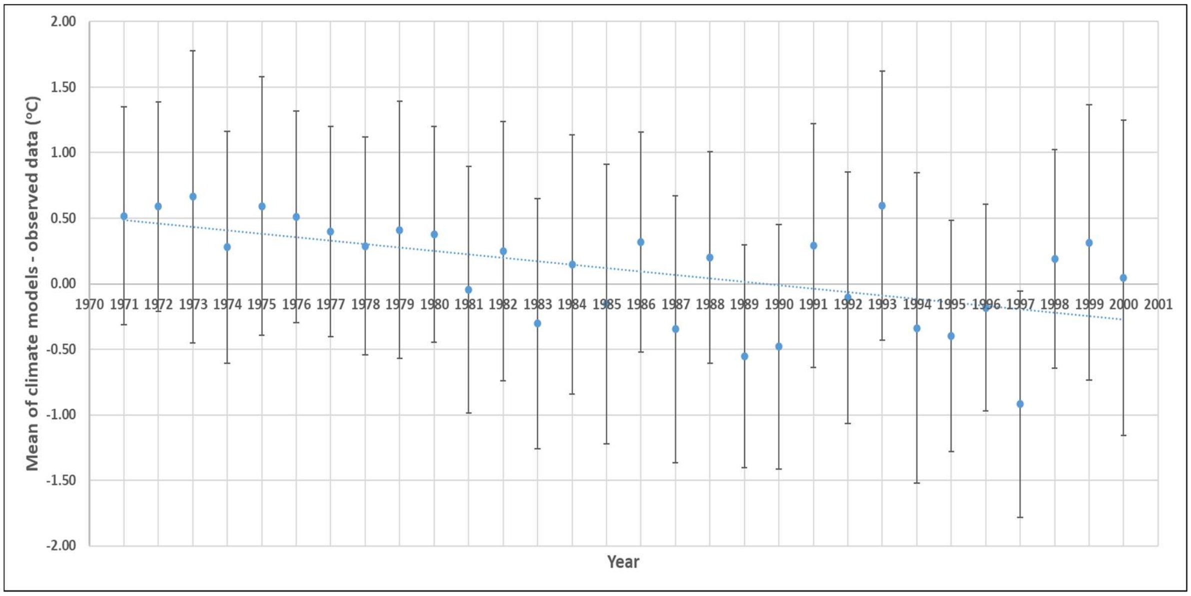

Figure 4: The difference of the mean of all the climate model simulations for each year with the observed data

3. National Databases

3.1 Introduction

This chapter includes a brief introduction of all the national authorities responsible for the river, weather and climate databases for each of the respective Atlantic countries involved in the SIRMA project. The different countries included in the study include the UK, Ireland, Portugal, France and Spain.

3.2 UK

3.2.1 MET Office

In the UK, the Met Office is the national meteorological service responsible for providing critical weather services and collecting weather and climate records for the UK. The MET Office is also responsible for predicting long term changes in the climate.

The two main sources of data relevant to this deliverable that can be obtained from their website are listed below.

3.2.1.1 Historic station data

Historic data is available for several long-running historic stations through this link. The historic station data consists of the following variables:

- Mean daily maximum temperature (tmax)
- Mean daily minimum temperature (tmin)
- Days of air frost (af)
- Total rainfall (rain)
- Total sunshine duration (sun)

The MET Office provides both monthly and annual data for these variables. However, the list doesn't include the full list of stations operated by the MET Office. To obtain station data about other stations not available on the website, the MET office's Customer Centre would need to be contacted to provide such information and can often charge a fee depending on the size of the data required.

Gridded climate observations are also available through the HadUK-Grid dataset in the Centre for Environment Data Analysis (CEDA) Catalogue. To facilitate comparison with the climate projections provided by UKCP18, the dataset is provided at 1km, 12km, 25km and 60km resolutions. Knowledge of working with large datasets is required to work with this model though.

3.2.1.2 UK Climate Projections (UKCP)

The UKCP was initially developed by the Met Office in 2009, released as UKCP09, which evaluated how the climate of the UK would change in the future. The latest UKCP was released in 2018 as UKCP18, with some further modifications and improvements to the climate projections compared to UKCP09. UKCP18 also includes models from the most recent IPCC assessment report (CMIP5 models as opposed to CMIP3 models used in UKCP09) (Lowe *et al.*, 2018).

The UKCP User Interface can be accessed through this link. To start downloading data, users need to register at the Sign-Up page to be able to access and download the data.

A summary of the variables for marine and land projections included in the UKCP18 is presented in Table 3.1. As shown the list includes a large variety of variables that are covered in the UKCP18.

Table 3.1: Obtainable UKCP18 variables for the marine and projections overland (Source: MET Office)[2].

Variable at the surface (short name in CEDA catalogue)	Units	Marine	Probabilistic	Global (60km)	Regional (12km)	Local (2.2km)	Derived
Cloud cover (clt)	%		✓	✓	✓	✓	
Precipitation (pr)	mm/day		✓	✓	✓	✓ hourly	✓+
Radiation, total downward short wave flux (rsds)	Wm^{-2}		✓				
Radiation, net long wave (rls)	Wm^{-2}		✓	✓	✓	✓	
Radiation, net short wave (rss)	Wm^{-2}		✓	✓	✓	✓	
Relative humidity (hurs)	%			✓	✓	✓	✓
Sea level pressure (psl)	hPa		✓	✓	✓	✓	
Sea water level	m	✓					
Snow: snowfall amount (prsn)	mm				✓	✓	
Snow: lying snow amount (snw)	mm				✓	✓	
Specific humidity (huss)			✓	✓	✓	✓	
Temperature, maximum (tasmax)	°C		✓	✓	✓	✓	
Temperature, Mean (tas)	°C		✓	✓	✓	✓ hourly	✓+
Temperature, minimum (tasmin)	°C		✓	✓	✓	✓	
Wind gusts (wsgmax10m)	m/s					✓ 3-hourly	
Wind speed (sfcWind)	m/s			✓	✓	✓ 3-hourly	✓
Wind speed eastwards (uas)	m/s			✓	✓	✓	✓
Wind speed northwards (vas)	m/s			✓	✓	✓	✓
Time steps		Dataset-dependent	Monthly Seasonal Annual 20/30-year means	Daily Monthly Seasonal* Annual* 20/30-year means*			Daily+ Monthly

The variables can be accessed through several different datasets. Table 3.2 shows a summary of the UKCP18 datasets and their geographical characteristics.

[2] *Note that all daily variables are provided on a 360-day year. *these are available over the UK only +only daily precipitation and temperature are available for the derived projections*

Table 3.2: Summary of geographical characteristics of UKCP18 data (Source: MET Office)

Dataset	Spatial resolution	Domain	Spatial coordinate system	Regional averages available
Probabilistic projections	25km	UK Channel Islands Isle of Man	British National Grid (OSGB)	Country Administrative Regions River basin regions
Global (60km) projections	60km	Global	Regular latitude-longitude in geographic projection	Country Administrative Regions River basin regions
	60km	UK only Channel Islands Isle of Man	British National Grid (OSGB)	
Regional (12km) projections	12km	Europe	Latitude-longitude in rotated pole coordinates	Country Administrative Regions River basin regions
		UK Channel Islands Isle of Man	British National Grid (OSGB)	
Local (2.2km) projections	2.2km	UK Isle of Man	Latitude-longitude in rotated pole coordinates	Country Administrative Regions River basin regions
	5km		British National Grid (OSGB)	
Marine projections	12km	UK Channel Islands Isle of Man	Regular latitude-longitude in geographic projection	None

Each of the different projections also considers a number of different emission scenarios. These are highlighted in Table 3.3 below.

The series of 28 simulations of future climate for the high emission RCP8.5 scenario is made up of 15 simulations of the new Met Office Hadley Centre climate model (HadGEM3-GC3.05; hereafter GC3.05) and 13 simulations from the CMIP5 multi-model ensemble that was used to inform the IPCC 5th Assessment (Met Office, 2018). The regional projections cover Europe and are driven from the Hadley Centre climate model subset of the global projections, resulting in 12 simulations at 12km. The local projections, which cover the UK only, are in turn driven by the regional projections. The probabilistic projections combine information from several collections of computer models with observations using advanced statistical methods (Met Office, 2019b).

Table 3.3: Summary of the three main UKCP18 land projections.

	Probabilistic projections	Global model projections	Regional model projections
Description	Probabilistic changes in future climate based on assessment of model uncertainties.	A set of 28 projections with detailed data on how climate may evolve in the 21st century.	A set of 12 high-resolution climate projections over Europe downscaled from the global projections.
Period	1961-2100	1900-2100	1981-2080 for 12km
Temporal resolution	Monthly Seasonal Annual	Daily Monthly Seasonal Annual	Daily Monthly Seasonal Annual
Spatial resolution	25km	60km	12km
Geographical extent	UK and regions	UK and regions Global	UK and regions Europe
Emissions scenarios	RCP2.6 RCP4.5 RCP6.0 RCP8.5 SRES A1B	RCP2.6 (UK only)† RCP8.5 2°C world (UK only) † 4°C world (UK only) †	RCP 8.5
Why use it?	▪ The most comprehensive assessment of uncertainties in UKCP18. ▪ Explores emissions scenario uncertainty. ▪ Explores uncertainty in key processes in climate models. ▪ Helps characterise future extremes in risk assessment.	▪ Long time series. ▪ Spatially coherent*. ▪ Direct access to 'raw' climate model data. ▪ Includes results from the Met Office Hadley Centre global climate model. ▪ Includes CMIP5 model results.	▪ Enhanced spatial detail. ▪ Spatially coherent. ▪ Improved extremes. ▪ Direct access to 'raw' climate model data.

3.2.2 National River Flow Archive (NRFA)

The NRFA is the main body responsible for maintaining and providing access to a wide-ranging database of the country's river flows to the UK Government and its devolved administrations. NRFA also provides information on water resources nationally.

Hydrometric data is provided from 1570 gauging stations across the UK that allow the NRFA access to daily, monthly and flood peak river flow data. These gauging stations are maintained by the Measuring Authorities, which is the main organisation that provides river flow data to the NRFA. Data from the NRFA can be accessed through this link.

3.2.2.1 Future Flows Hydrology

The Future Flows Hydrology (FF-HydMod-PPE) is an 11-member ensemble projection of river flow and groundwater level time series for 283 catchments and 24 boreholes in Great Britain (UKCEH, 2015). It is derived from Future Flows Climate, 11-member 1-km climate projection products based on the SRES A1B emission scenario. River flow data are provided at a daily time step from January 1951 to December 2098.

Future Flows Hydrology was developed in 2012 during the partnership project 'Future Flows and Groundwater Levels' funded by the Environment Agency for England and Wales, Defra, UK Water Research Industry, NERC (Centre for Ecology & Hydrology and British Geological Survey) and Wallingford HydroSolutions (UKCEH, 2015). The dataset is freely available for non-commercial use under certain licensing conditions.

3.3 Ireland

3.3.1 Met Éireann

MET Éireann is the national meteorological service for the Republic of Ireland. It is mainly responsible for monitoring, analysing and predicting Ireland’s weather and climate.

3.3.1.1 Historic data

There are currently numerous stations around the island of Ireland that capture different climate variables including both manned and automated weather stations. The variables that can be obtained from these stations include:

- Precipitation Amount (mm)
- Maximum Air Temperature (^{o}C)
- Minimum Air Temperature (^{o}C)
- Grass Minimum Temperature (^{o}C)
- Mean 10cm Soil Temperature (^{o}C)
- Mean Wind Speed (knot)
- Highest ten-minute mean wind speed (knot)
- Wind Direction at max 10 min. mean (deg)
- Highest Gust (knot)
- Mean Convective Boundary Layer (CBL) Pressure (hpa)
- Sunshine duration (hours)
- Global Radiation (j/cm sq.)
- Potential Evapotranspiration (mm)
- Evaporation (mm)
- Soil Moisture Deficits(mm) well-drained
- Soil Moisture Deficits(mm) moderately drained
- Soil Moisture Deficits(mm) poorly drained

MET Éireann provides both daily and monthly data for these variables. To obtain station data about other stations not available on the website, they would need to be contacted to provide such information and can often charge a fee depending on the size of the data required.

3.3.1.2 Projections

MET Éireann does not have a similar user interface such as the UKCP, where data could be easily obtained by users for different variables. Although data can be provided by Met Éireann by requesting it from their contact page by paying a fee.

Met Éireann has been using the EC-Earth Global climate model for their projections. Together with the Irish Centre for High End Computing (ICHEC) they form the EC-Earth consortium for Ireland. The EC-Earth European consortium (which doesn't include the UK) was set up to develop a new improved fully coupled atmosphere-ocean-land-biosphere global climate model. Furthermore, Met Éireann has carried out a series of CMIP5 ensemble runs to 2100, under medium to high radiative RCP forcing's previously.

3.3.2 Marine Institute (Foras na Mara)

The Marine Institute is the state agency responsible for marine monitoring, research and technology development in Ireland. The variables that can be obtained from their website for different locations around Ireland include:

- Atmospheric Pressure (mb)
- Wind Direction (degrees_true)
- Wind Speed (kn)
- Gust (kn)
- Wave Height (m)
- Wave Period (s)
- Mean Wave Direction (degrees_true)
- Hmax (m)
- Air Temperature (°C)
- Dew Point (°C)
- Sea Temperature (°C)
- Relative Humidity (%)

Data for these different variables can be downloaded from the following link. The data typically starts from February 2001 up to the present day.

3.3.3 Environmental Protection Agency (EPA) HydroNet

The EPA HydroNet website gives access to surface water hydrometric data and groundwater level data that has been collected at the network of Local Authorities (LA) hydrometric stations and processed by the EPA. The data available includes water levels, river flows and summary statistics using data from more than 200 sites in Ireland. The website also includes station information and data links for hydrometric stations contained in the National hydrometric register but operated by organisations other than the EPA such as the Office for Public Works and the Electricity Supply Board (ESB).

The various types of data that they provide include:

- 15-minute data of water levels, flows and groundwater levels
- Daily Mean Data for the period of record of water levels, flows and groundwater levels)

3.3.3.1 Non-EPA/LA stations

Data for stations not operated by the EPA/LA can also be obtained by following the data link contained in the station information page for these stations on the EPA HydroNet website. This would take the user to another external website where data for those websites can either be downloaded or requested as per the procedure currently followed by individual organisations.

Organisations like the Office of Public Works (OPW) have more than 380 surface water stations in the OPW hydrometric surface water network. The OPW Hydro-Data website provides access to the hydrometric data from these stations that has been collected and processed for over 70 years. OPW's main concern is flooding whereas the EPA's main concern is water quality and low flows (Bruen, 2009).

Other organisations like the ESB also collect flow data for the rivers leading to their main hydropower installations divisions (Bruen, 2009). This data can be requested from their hydrometric section.

3.4 Portugal.

3.4.1 Instituto Português do Mar e da Atmosfera (IPMA)

The Portuguese Institute for Sea and Atmosphere, I. P. (IPMA), is a publicly owned organisation, which has responsibilities at national level in the areas of the sea and atmosphere.

3.4.1.1 Portal Do Clima

The climate portal provides several climatic indicators that quantify the occurrence and risk of different atmospheric events; such as, air temperature or wind on the surface, or indicators that result from complex algorithms that combine model variables to create new variables to address the needs of users as guides that measure the risk of events with significant impact potential, such as, droughts, rainstorms, heat and cold waves, fire risk, etc.

The basis of the construction of these indicators refers to observations and simulated projections of the current, past and future climate, from multiple combinations of CORDEX models (EURO-CORDEX programme) and forcing general circulation models (IPMA, 2015). A summary of the climate models available in the climate portal is shown in Table 3.4.

Table 3.4: Global and Regional Climate models available on the Portuguese Climate Portal (Source: Portal do Clima)

		Regional Climate Models				
		CLMcom-CCLM4-8-17	DMI-HIRHAM5	KNMI_RACMO22E	SMHI-RCA4	IPSL-INERIS-WRF331F
Global Climate Model	ECMWF-ERAINT	✓	✓	✓	✓	✓
	CNRM-CERFACS-CNRM-CM5	✓			✓	
	ICHEC-EC-EARTH	✓	✓	✓	✓	
	IPSL-CM5A-MR					✓
	MRI-ESM-MR	✓			✓	

The historic data collected starts from 1971 to 2000 while projections start from 2011 to 2100 at a spatial resolution of 12km. A list of the variables that can be obtained from the website is listed below:

- Temperature (ºC)
- Precipitation (mm)
- Wind speed (m/s)
- Relative humidity (%)
- Global radiation (W/m^2)
- Diurnal temperature range (ºC)
- Drought index (No unit)
- Aridity index (No unit)
- Evapotranspiration (mm/d)
- Fire risk index (No unit)

3.4.2 Sistema Nacional de Informação de Recursos Hídricos (River flows)

The National Water Resources Information System (SNIRH) is a national website developed by the Portuguese Water authorities that includes hydro-meteorological and water quality data (surface and underground), collected by the Ministry of Environment's water resources monitoring network. The monitoring network consists of automatic and conventional stations, some of which are equipped with tele-transmission.

From the data collected by the stations, the website releases river flow data in the form of monthly and annual observed flows. The data is freely available for users.

3.5 Spain

3.5.1 *State Meteorological Agency (AEMET)*

AEMET is the national meteorological service in Spain. Its main purpose is to develop, implement, and provide meteorological services competently to the state including maintaining and updating historical meteorological and climatological data, and preparing and updating climate change scenarios.

3.5.1.1 Historic weather data

Although AEMAT is the national meteorological service in Spain, data collection is often delegated to the autonomous regions. Therefore, each region has the authority to monitor and maintain its own weather and climate network. However, most of the station data from all the regions collect data for similar variables as listed below:

- Temperature (^{o}C)
- Precipitation (mm)
- Relative Humidity (%)
- Atmospheric pressure (hPa)
- Wind Speed (Km/h)
- Solar Radiation (Kj/m^2)

Further information on historic data on a national and regional level can be found on AEMAT's weather data section.

3.5.1.2 Climate projections

Climate projections for Spain up to 2100 can be accessed from the AEMAT website. The climate data provided is generated from the CORDEX, ENSEMBLES and local AEMET projects. Further details of the projects can be found through this link (information in Spanish).

The models generally provide daily and monthly data for four different scenarios as follows:

- Historical (1961-2006)
- RCP4.5 (2006-2100)
- RCP6.0 (2006-2100)
- RCP8.5 (2006-2100)

Only the Precipitation and Temperature variables have daily data available. A summary of some of the variables available for download from AEMAT's website is presented in Table 3.5.

Table 3.5: Summary of variables available from AEMAT

Atmospheric variable	Indicators	Units	Period
Temperature	Daily minimum temperature Daily maximum temperature 95th percentile of daily maximum temperature 5th percentile of daily maximum temperature	[ºC] [ºC] [ºC] [ºC]	1961-2100
Precipitation	Total accumulated precipitation	[mm]	
Humidity	Relative humidity	[%]	
Radiation	Surface Downwelling Shortwave Radiation Surface Downwelling Longwave Radiation	[W/m^2] [W/m^2]	
Wind Speed	Maximum wind speed at 10m Wind speed at 10m	[m/s] [m/s]	

3.5.2 Hydrographic Confederations

In Spain, unlike other countries, there is no central body that oversees water management across the country but is rather split into nine different hydrographic confederations with their own legal personality and distinct from the state. Some of the responsibilities each of these confederations have include data banks, hydrological planning, resource management and use, protection of the hydraulic public domain, control of water quality and dam security programmes.

Flow data for the rivers in each of the confederations can be accessed separately on their websites. There is often flow data available from the early 20th century up to the present day, if the gauging station is still active. Links to each of the individual hydrological confederations are available here.

3.6 France

3.6.1 *Météo France*

Météo-France is the national meteorological and climatological service in France. Its responsibilities include developing and maintaining a weather observation network, collecting and processing climatological data, weather forecasting and developing climate projections.

3.6.1.1 Historic weather data

Historic data is available for a number of long-running historic stations through this link. The historic station data consists of the following variables:

- Temperature (K)
- Precipitation (mm)
- Humidity (%)
- Atmospheric pressure (Pa)
- Average Wind Speed(m/s)
- Radiation/Sunshine
- Horizontal visibility (m)

Météo France provides daily, monthly and annual data for these variables. However, to obtain station data a fee is often charged depending on the size of the data.

3.6.1.2 Future Climate Predictions

In France, the DRIAS web portal is the main climate service that gives free access to French regional climate data. The Portal has been coordinated by Météo-France since 2012 by including climate models from three French institutions, which are Institut Pierre-Simon Laplace (IPSL), Centre Européen de Recherche et Formation Avancée en Calcul Scientifique (CERFACS) and Centre National de Recherches Météorologiques (CNRS/Météo-France). To start downloading data from these three models, users need to register on the Sign-Up page.

The Portal provides climate projections for three different emission scenarios, which are:

- RCP2.6
- RCP4.5
- RCP8.5

A summary of the variables available for download in the DRIAS Portal is presented in Table 3.6 below.

Table 3.6: Summary of variables available in the DRIAS Portal

Atmospheric variable	Indicators	Units	Period
Temperature	Daily minimum temperature	[^{o}C or K]	1950-2100

Atmospheric variable	Indicators	Units	Period
	Daily maximum temperature	[°C or K]	
Precipitation	Rainfall Snow precipitation	[mm] [mm]	
Humidity	Specific humidity	[g/kg]	
Radiation	Surface Downwelling Shortwave Radiation Surface Downwelling Longwave Radiation	[W/m²] [W/m²]	
Wind Speed	Near-Surface Wind Speed Daily Maximum Near-Surface Wind Speed of Gust	[m/s] [m/s]	

3.6.2 Banque Hydro

Banque Hydro is the main body responsible for providing access to a wide-ranging database of the country's river flows to the French Government. The data provided includes knowledge of the river flows, flood forecasting, statistical flow calculations, and control of regulatory flows. They have access to over 5,000 hydrometric stations. Users will need to register first to obtain access to the data.

3.7 Conclusions

Having listed the national climate and hydrology databases for each of the five countries identified for this deliverable in the previous sections, a summary table has been drawn to show what variables are currently available in the public domain. This is summarised in Table 3.7.

Table 3.7: Summary of data available in the public domain by country

Historic							
Country	Variables						
	Mean temperature	Precipitation (amount)	Average surface wind speed (10m average)	Relative air humidity	River flows	maximum wave heights	sea level rise
Portugal	[green]	[green]	[green]	[green]	[green]	[red]	[red]
Ireland	[green]	[green]	[green]	[green]	[green]	[green]	[green]
UK	[green]	[green]	[green]	[green]	[green]	[red]	[green]
France	[green]	[green]	[green]	[green]	[green]	[red]	[red]
Spain	[green]	[green]	[green]	[green]	[green]	[red]	[red]

Projections							
Country	Variables						
	Mean temperature	Precipitation (amount)	Average surface wind speed	Relative air humidity	River flows	maximum wave heights	sea level rise
Portugal	[green]	[green]	[green]	[green]	[red]	[red]	[red]
Ireland	[red]	[red]	[red]	[red]	[red]	[green]	[green]
UK	[green]	[green]	[green]	[green]	[green]	[red]	[green]
France	[green]	[green]	[green]	[green]	[red]	[red]	[red]
Spain	[green]	[green]	[green]	[green]	[red]	[red]	[red]

[red]	Data not available in public domain
[green]	Data available in public domain

As shown in Table 3.7, historical data tends to be more easily accessible than future projections. In particular, marine projections and historical data are not publicly available except for a very short period of time (i.e. ± 3-5 days from the present).

Differences between what sort of data is collected by each national meteorological institution and how the organisations are structured in each country can be seen in the different sections of this chapter. These differences also make it difficult in using the data consistently as each country collects the variables in different ways. Furthermore, records of data can be missing for some countries for some of the variables compared to another country.

For forecasted data, each country tends to provide projections at different spatial and temporal resolutions according to what climate models they use but also the initial conditions of the GCM simulations. Hence, making it more difficult to create one consistent source of data and determining which one should be used.

Based on these differing data and for the purposes of this deliverable, it is recommended that the climate database is collected from one climate model that covers all five countries. This would be more suitable in acquiring consistent data for each of the variables previously identified. Therefore, in Chapter four, a more consistent database will be explored and discussed.

4. Climate Models Database

4.1 Introduction

The climate database provides an objective basis for understanding and predicting climate change effects on built environment. The climate database is divided into atmosphere, river and ocean categories, each has its own driving methods to generate the data (e.g., ensemble-data source, institution-Jet stream, influence- aerosols-forcing, initial state of run, etc.).

The climate database variables were extracted from a variety of climate models that are indicated in section 4.4 Models variables availability. Climate database was extracted from two platforms (see Appendix 1 for a detailed description):

a) Copernicus Climate Change Service
b) Coupled Model Inter-comparison Project Phase 5 (ESGF@DOE/LLNL)

4.2 Database variables

The climate database variables are precisely chosen to distinctly define the extreme events in the European countries alongside the Atlantic Ocean and extracted at a specific elevation "height above the surface/ pressure level". These variables are divided into three categories:

a) Ocean category:

- Sea Surface Temperature
- Sea Surface Salinity
- Sea Water X Velocity
- Sea Water Y Velocity
- Water Flux into Sea Water From Rivers
- Sea Water Pressure at Sea Water Surface
- Significant height of combined wind waves and swell
- Mean wave period
- Sea Surface Height Above Geoid
- River Flow
- Global Average Sea Level Change
- Global Average Steric Sea Level Change
- Global Average Thermosteric Sea Level Change

b) Atmosphere category:

- Near Surface Air Temperature
- Near Surface Relative Humidity
- Precipitation
- Daily Mean Near-Surface Wind Speed

c) River category:

- River Flow

4.3 Geographical locations

The geographical locations Table 4. 1 chosen for the extraction of typical data are located alongside the Atlantic Ocean, in which the climate database variables selected will lead to the occurrence of extreme events of different climate scenarios, that will affect infrastructure for example by deterioration due to chloride ingress and scour.

Table 4.1: Climate database geographical locations of interest

Country	Location of interest (City)
France	Saint Nazaire
Spain	Vigo
Portugal	Caxias
Ireland	Dublin and Cork
Uk	Brighton

The river flow is presented by four simulations per projection and extracted depending on the model's resolution and extraction point for the following rivers (check 4.7.1 D.SIRMA-WP4-2.2-RD for a detailed resolution distribution) :

- France: Loire
- Ireland: Bann-OwenSlieve-Fergus-County Clare
- Portugal: Tage - Sorraia
- Spain: Rio de Pontevedra-Rio de Vigo
- United Kingdom: Adur-Solent-Medina

4.4 Models variables availability

The database variables described in section 4.2 are freely available and aims to cover historical period and several climate change scenarios (Rcp26, Rcp45, Rcp60, Rcp85). Therefore, simulations from 11 models (4 for ocean, 1 for river and 6 for atmospheric) were used to ensure the availability of this data in a consistent way.

The data available in the database provided is described in Tables 4.2, 4.3 and 4.4. It could be observed that some information is available from different models which is useful to provide an evaluation of the uncertainty of the model on the consequence analysis or lifecycle assessment.

Table 4.2: Availability of information for each model used to download ocean variables

Model	Start period	End period	Projections	Sea Surface Temperature	Sea Surface Salinity	Sea Water X Velocity	Sea Water Y Velocity	Water Flux into Sea Water From Rivers	Sea Water Pressure at Sea Water Surface	Significant height of combined wind waves and swell	Mean wave period	Sea Surface Height Above Geoid	Global Average Sea Level Change	Global Average Steric Sea Level Change	Global Average Thermosteric Sea Level Change
				Celsius Degree	PSU	m/sec	m/sec	kg m-2 s-1	decibar	m	sec	m	m	m	m
CANESM2	Jan. 1850	Dec. 2100	Rcp26-Rcp45-Rcp85	+	+	+	+					+	+	+	+
MOHC-HadGEM2	Dec. 1859	Dec. 2099	Rcp26-Rcp45-Rcp60-Rcp85	+	+			+				+		+	+
NIMR-KMAHadGEM2-AO	Jan. 1860	Dec. 2100	Rcp26-Rcp45-Rcp60-Rcp85	+	+	+	+		+						
ERA5	Jan. 1979	Dec. 2099	No projections							+	+				

Table 4.3: Availability of information for each model used to download atmosphere variables

Model	Start period	End period	Projections	Near Surface Air Temperature	Near Surface Relative Humidity	Precipitation	Daily Mean Near Surface Wind Speed
				Celsius Degree	%	kg m-2 s-1	m/sec
RCA4	1/01/1971	31/12/2100	Rcp26-Rcp45-Rcp85	+	+	+	+
HIRHAM5	26/12/1950	27/06/2098	Rcp45-Rcp85	+	+	+	+
WRF381P	01/01/1951	30/11/2099	Rcp85	+			
CCLM4-8-17	01/01/1951	31/12/2100	Rcp45-Rcp85	+			
RACMO22E	26/12/1950	27/06/2098	Rcp26-Rcp45-Rcp85	+	+	+	+
REMO2015	12/01/1951	11/01/2101	Rcp85	+	+	+	+

Table 4.4: Availability of information for each model used to download river variable

Model	Start period	End period	Projections	River Flow
				m3/sec
IMPACT2C	1/01/1979	31/12/2100	Rcp26-Rcp45-Rcp85	+

4.5 Resolution

The extraction phase was performed for a specific region as area by using the nearest point of data extraction of the model's coordinates given in Excel Worksheet D.SIRMA-WP4-2.2-RD (see section 4.7.1 to see the complete list of the deliverable files) The resolution of each model is not the same (Table 4.5), resulting in differences in the areas covered for each extraction (see section 4.7.4 for a summary). The resolutions for atmosphere variables were obtained from regional models and provides information that is representative of the studied place. However, the data for ocean variables should be validated because of the larger resolutions provided by the models. The resolution for the river flow could cover several rivers in the area. Therefore, a post-treatment of the data is necessary to determine the river flow for a specific river.

Table 4.5: Models' resolution

Category	Model	Approx. resolution (km)	
		Latitude	Longitude
Ocean	CANESM2	103.2	156.1
	MOHC-HadGEM2	111.0	111.0
	NIMR-KMAHadGEM2-AO	111.0	111.0
	ERA5	55.5	55.5
Atmosphere	RCA4	12.2	12.2
	HIRHAM5	12.2	12.2
	WRF381P	12.2	12.2
	CCLM4-8-17	12.2	12.2
	RACMO22E	12.2	12.2
	REMO2015	12.2	12.2
River	IMPACT2C	55.5	55.5

4.6 Climate database access

A form available in the SIRMA project website will allow to download easily the information for end users. The end user could filter the location and variable of interest to get access to an worksheet containing the requested data.

4.7 Deliverable files

4.7.1 Deliverable files list

The deliverable files list Table 4.6 demonstrates the abbreviation used in naming the WP4 deliverable files, indicating the deliverable files function and content.

Table 4. 6: Deliverable files list

Deliverable abbreviation files list	Elucidation
D.SIRMA-WP4-1.1-VFD	Variables and climate models forcing definitions
D.SIRMA-WP4-2.1-MD	Models description
D.SIRMA-WP4-2.2-RD	Resolution distribution
D.SIRMA-WP4-3.1-Ocean	Climate database for CANESM2-ES
D.SIRMA-WP4-3.2-Ocean	Climate database for ERA5
D.SIRMA-WP4-3.3-Ocean	Climate database for MOHC-HADGEM2
D.SIRMA-WP4-3.4-Ocean	Climate database for NIMR-KMA-AO
D.SIRMA-WP4-3.5-Atmos	Climate database for EC-EARTH-RCA4
D.SIRMA-WP4-3.6-Atmos	Climate database for HadGEM2-ES-WRF381P
D.SIRMA-WP4-3.7-Atmos	Climate database for HadGEM2-ES_DMIHIRHAM5
D.SIRMA-WP4-3.8-Atmos	Climate database for MPI ESM LR-CCLM4-8-17
D.SIRMA-WP4-3.9-Atmos	Climate database for HadGEM2-ES_KNMI-RACMO22E
D.SIRMA-WP4-3.10-Atmos	Climate database for NorESM1-M-REMO2015
D.SIRMA-WP4-3.10-Ocean	Climate database for IMPACT2C

4.7.2 Climate Database Variables and Forcing Definitions

The Pdf file 4.7.1 :D.SIRMA-WP4-1.1-VFD demonstrates clear definitions for the climate database variables (check Appendix 3 for a detailed sample) and models' forcing definitions. Table 4. 7 represents the definitions of the forcing that are used in the climate models.

Table 4. 7: Models forcing definitions

Forcing	Definition
Nat	Natural forcing as a combination that might include, for example(Solar and Volcanic)
Ant	Anthropogenic forcing as a mixture that might include, for example, well-mixed greenhouse gases, aerosols, ozone and land-use changes
GHG	Well mixed greenhouse gases as a mixture
SD	Anthropogenic sulfate aerosol, accounting only for direct effects
SI	Anthropogenic sulfate aerosol, accounting only for indirect effects
SA=(SD+SI)	Anthropogenic sulfate aerosol, accounting for direct and indirect effects
TO	Tropospheric ozone
SO	Stratospheric ozone
OZ=(TO+SO)	Ozone=(Tropospheric and Stratospheric ozone)
LU	Land-use change
SI	Solar irradiance
VI	Volcanic aerosol
SS	Sea salt
Ds	Dust
BC	Black Carbon
MD	Mineral Dust
OC	Organic Carbon
AA	Anthropogenic aerosols as a mixture of aerosols

4.7.3 Models Description

The Model description Excel Worksheets describe the Dataset Metadata for each climate model, indicate the available variables that are available from each climate model and provides information of the climate model. Table 4.8 represents a sample of this excel worksheet file.

Table 4. 8: Dataset Metadata climate database Sample

	Dataset Metadata	
Climate Model	HadGEM2-AO	
Project	CMIP5	
Product	Output1	
Institute	NIMR-KMA	
Experiment	Historical & All RCP	
Time-frequency	Monthly	
Reaim	Ocean	
Ensemble	r1i1p1	
Version	20121018	
Data source	HadGEM2-AO r6.6.3 (2010): atmosphere: HadGAM (HadGAM2, N96L38); ocean: HadGOM (HadGOM2, 1x1L40, increased resolution at Equator); sea ice: part of HadGOM2; land: MOSES-2	
Forcing	Nat, Ant, GHG, SA, Oz, LU, Sl, Vl, SS, Ds, BC, MD, OC	
Start time	1860	
	Climate database variable	**Unit**
	Sea Surface Temperature	Celsius Degree
	Sea Surface Salinity	PSU
	Sea Water Y Velocity	m/sec
	Sea Water X Velocity	m/sec
	Sea Water Pressure at Sea Water Surface	decibar

4.7.4 Resolution Distribution

The resolution differs in the models, which leads to differences in the areas covered for each extraction depending on the extraction point and model's resolution, a sample is presented in Table 4. 9. Therefore, the area covered in each model is provided by the resolution distribution worksheets D.SIRMA-WP4-2.2-RD in terms of the area covered for each model and extraction points.

Table 4. 9: Resolution distribution for regional atmosphere database

City	Resolution Distribution (Degree)				Middle point	
	lat1	lat2	lon1	lon2	Latitude	longitude
Caxias	38.595	38.705	350.755	350.645	38.65	350.7
Saint Nazaire	47.255	47.365	357.885	357.775	47.31	357.83
Vigo	42.135	42.245	351.275	351.165	42.19	351.22
Brighton	50.795	50.905	359.945	359.835	50.85	359.89
Dublin	53.235	53.345	353.755	353.645	53.29	353.7
Cork	51.815	51.925	351.515	351.405	51.87	351.46

4.7.5 Licences

- CMIP5_Licensing_and_Access_Control: The license is available taking into consideration the terms of usage that must be fulfilled in order to use this climate database by indicating that "Neither the project's institution nor SIRMA project are responsible for the usage of this database in vulnerability assessments of (structures / Infrastructures)". (CMIP5, no date)
- Copernicus_Licensing_and_Access_Control: The license is available taking into consideration the terms of usage that must be fulfilled in order to use this climate database. (Copernicus, 2014)
- CMIP5 Modeling Groups and their Terms of Use: This deliverable Pdf file declares the availability of the models, the models used are presented as unrestricted use.
- CMIP5 Data access License from Copernicus: The license of CMIP5 data access obtained by Copernicus illustrates the availability of CMIP5 models that are used in the Copernicus.

5. Conclusions

In this deliverable, a freely available database of climate change indicators has been provided, which can be used in the future for estimating the vulnerability/consequences on transportation infrastructure at different Atlantic regions. The deliverable aims to make these future estimations easier for users to compare between different countries by presenting a consistent dataset.

First part of the deliverable reviews initially the national climate and weather databases that are available in each of the respective Atlantic countries involved in the SIRMA project. Differences between the type and resolution of data have been identified which makes it difficult in using national data consistently as each country collects the variables in different ways. As a result, the larger scale pan-European Copernicus Climate Change and WRCP Databases, have also been reviewed and data extracted for selected locations on the respective Atlantic countries.

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SIRMA

STRENGTHENING THE TERRITORY'S RESILIENCE TO RISKS OF NATURAL, CLIMATE AND HUMAN ORIGIN

Application Code: EAPA_826/2018

Climate change indicators database - Appendices

WP 4 Climate Change & Natural Hazards in Atlantic Area

Deliverable ID	**D4.1**
Deliverable name	**Climate change indicators database**
Lead partner	**University of Nantes**
Contributors	University of Surrey

[PUBLIC]

Appendices Contents

Appendix 1. Description of platforms used to download data

Copernicus Climate Change Service

The Copernicus Climate Change Service provides climate information of a wide range for the Earth-system components and time scales spanning between decades to centuries. It governs the past, present and future climate in Europe and worldwide(Thépaut, 2014).

In November 2014, the European Commission signed a Delegation Agreement with the European Centre for Medium-Range Weather Forecasts (ECMWF) for the implementation of the Copernicus Climate Change Service (European Comission, 2015), in which the Copernicus services include the following sectors:

Atmosphere, Marine, Land, Security, Climate Change and Emergency, in which the data is essential to climate change adaptation. Copernicus services provide climate information and knowledge by means of accessible, time series and reliable products.

Copernicus Climate Change Service is provided by the Copernicus Earth Observation Programme of the European Union, it provides an important resource for the Global Framework for Climate Services. Copernicus is an operational programme related to existing research infrastructures and knowledge available in Europe and worldwide. The Copernicus Climate Change Service relies on climate research carried out within the World Climate Research Programme defined by the Global Climate Observing System and in accordance with the user requirements (C3S.Service, 2014). The climate database variables presented by the Copernicus Climate Change Service are with respect to:

a) Product type: climate indices, climate projections, in situ observations, reanalysis, satellite observations and seasonal forecasts.
b) Variable domain: atmosphere (composition, surface & upper air), land (biosphere, cryosphere & hydrology) and ocean physics.
c) Spatial coverage: Europe and global.
d) Temporal coverage: past, present and future.

The Copernicus Climate Change Service possesses unique products due to the cooperation with the ECMWF, which has achieved a breakthrough in this service by providing wind component variables at a specific height and wave derivatives. An interesting variable can be declared as extreme event which is wave height and so-called significant height of swell and/or waves, provided with information about the mean wave period. The provided data are derived from ERA5 which is the fifth generation of the European Centre for Medium-Range Weather Forecasts reanalysis of the global climate.

The reanalysis combines model data and observations from around the world into a universally consistent and complete dataset using the laws of physics in which this principle is called data assimilation. Despite this peculiarity, there are still missing climate dataset variables that are not included in the CMIP5 models partaking in the Copernicus Climate Change Service.

World Climate Research Programme

The Working Group on Coupled Modelling (WGCM) presided by the World Climate Research Programme (WCRP) established the Coupled Model Inter-comparison Project (CMIP) as a standard experimental protocol to study the outcome of the coupled atmosphere-ocean general circulation models. The Coupled Model Inter-comparison Project (CMIP) provides a community-based infrastructure in support of climate model diagnosis, validation, inter-comparison, documentation and data access. Virtually the entire international climate modeling community has participated in this project since its inception in 1995 (ESGF, 2017).

The Working Group on Coupled Modelling (WGCM) mission is to foster the development and review of coupled climate models which includes the organization of the model inter-comparison projects and predicting the response of the climate system to changes in the natural and anthropogenic forcings (WCRP, 2012).

The Working Group on Coupled Modelling activates are implemented in close cooperation with the World Climate Research Programme (WCRP) core projects, current activities:

a) Leading the WCRP challenge on clouds, circulation and climate sensitivity.
b) In collaboration with many groups and partners within the World Climate Research Programme (WCRP) and beyond, is overseeing the ongoing Coupled Model Inter-comparison Project (CMIP) (WCRP, 2012).

A new set of coordinated climate model experiments has been agreed to be promoted in September 2008, during the meeting involving 20 climate modeling groups from around the world, the WCRP's Working Group on Coupled Modelling WGCM with input from the IGBP and AIMES projects, these experiments comprise the fifth phase of the Coupled Model Inter-comparison Project (CMIP5) (CMIP5, 2012).

The Working Group on Coupled Modelling (WGCM) endorsed the CMIP5 protocol in its 12 sessions which defined a set of thirty-five climate model experiments designed for:

a) Assessing the mechanisms responsible for model differences in poorly understood feedbacks associated with the carbon cycle and with clouds.
b) Examining climate "predictability" and exploring the ability of the models to predict climate on decadal time scales.
c) Determining the reason of similarly forced models produce a variety of responses.

CMIP5 promotes a standard set of model simulations to:

a) Evaluating the realism of models in simulating the recent past.
b) Providing projections of future climate change reaching beyond 2100.
c) Understanding the factors responsible for the differences in the model projections including quantifying key feedbacks such as those involving clouds and carbon cycle.

The fifth phase of the Coupled Model Inter-comparison Project contains 4 products, 25 institutions and 52 models, in which specific variables were chosen from models taking into consideration the models forcing, initial run state and data source. The extracted variables are precisely chosen to distinctly define the extreme events in the European countries alongside the Atlantic Ocean and to study their influence on the infrastructure.

Appendix 2. Climate database excel sheet deliverable sample

Country	France				
City	Saint Nazaire				
Variable	Sea Surface Temperature	Sea Surface Salinity	Sea Water X Velocity	Sea Water Y Velocity	Sea Surface height Above Geoid
Unit	Degree Celsius	Practical Salinity unit	Meter / Second	Meter / Second	Meter
01/1850	12.22158203	35.63586426	0.052721739	0.001136731	-0.11490
02/1850	11.8434082	35.64274979	-0.004990807	0.000920739	-0.14659
03/1850	11.63848267	35.64847565	0.033222623	-0.016835563	-0.14528
04/1850	12.00222168	35.64904022	0.032899007	-0.012851252	-0.13637
05/1850	12.46828613	35.62971115	-0.009756005	-0.026102804	-0.14493
06/1850	13.90648804	35.63913345	-0.024156081	-0.001059544	-0.15457
07/1850	14.78499756	35.63953018	-0.020947337	-0.015615813	-0.15059
08/1850	15.4800354	35.65068436	-0.010566637	-0.006650525	-0.13976
09/1850	15.38244019	35.66562271	-0.00829964	0.001493969	-0.14920
10/1850	14.83718262	35.65063477	0.037108112	-0.003257938	-0.13317
11/1850	13.57848511	35.62423706	0.051718798	-0.022523198	-0.12067
12/1850	12.66750488	35.62530518	0.054076564	-0.006334493	-0.11216
etc.	etc.	etc.	etc.	etc.	etc.

Appendix 3. Climate database variables definition sample

Variable	Definition
Sea water X velocity	Eastward horizontal surface velocity of a water parcel, as calculated by the physical circulation model. The horizontal surface velocity is a vector quantity, which is broken up into Northward and Eastward components. “Eastward” indicates a vector component which is positive when directed eastward (negative westward). Several factors can influence the horizontal velocity field and thus drive ocean currents.
Significant height of combined wind waves and swell	This parameter represents the average height of the highest third of surface ocean/sea waves generated by wind and swell. It represents the vertical distance between the wave crest and the wave trough. The ocean/sea surface wave field consists of a combination of waves with different heights, lengths and directions (known as the two-dimensional wave spectrum). The wave spectrum can be decomposed into wind-sea waves, which are directly affected by local winds, and swell, the waves that were generated by the wind at a different location and time. This parameter takes account of both. More strictly, this parameter is four times the square root of the integral overall directions and all frequencies of the two-dimensional wave spectrum. This parameter can be used to assess sea state and swell. For example, engineers use significant wave height to calculate the load on structures in the open ocean, such as oil platforms, or in coastal applications.
Near Surface Air Temperature	1-Temperature of air at 2m above the surface of land, sea or inland waters. 2m temperature is calculated by interpolating between the lowest model level and the Earth's surface, taking account of the atmospheric conditions. Temperature measured in kelvin can be converted to degrees Celsius (°C) by subtracting 273.15 2- comment: Daily-mean near-surface (usually, 2 meter) air temperature.
Sea Surface Temperature	1-The temperature a parcel of seawater would have if moved adiabatically to sea level pressure. The potential temperature field is 4D (time, location, depth), and is calculated by the physical circulation model. 2-This parameter is the temperature of seawater near the surface. This parameter is taken from various models and can be taken from various provides, who process the observational data in different ways. Each provider uses data from several different observational sources. For example, satellites measure sea surface temperature (SST) in a layer a few microns thick in the uppermost mm of the ocean, drifting buoys measure SST at a depth of about 0.2-1.5m, whereas ships sample seawater down to about 10m, while the vessel is underway. Deeper measurements are not affected by changes that occur during a day, due to the rising and setting of the Sun (diurnal variations). Sometimes this parameter is taken from a forecast made by coupling the NEMO ocean model to the ECMWF Integrated Forecasting System (IFS). In this case, the SST is the average temperature of the uppermost meter of the ocean and does exhibit diurnal variations. This parameter has units of kelvin (K). Temperature measured in kelvin can be converted to degrees Celsius (°C) by subtracting 273.15.