European Research Area for Climate Services

ECLISEA

European advances on CLImate Services for Coasts and SEAs

A European database of regional climate projections of sea surface dynamcis

Work Package 3- Deliverable 3.E

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TABLE OF CONTENTS

1. Foreword

ECLISEA is a project that aims to advance coastal and marine climate science and associated services through developing innovative research of sea surface dynamics. To achieve the objectives, ECLISEA is structured in 5 Work-packages (WPs) and this report is associated to the deliverable 3.D (D3.E) of the ECLISEA project and describe a European database for future climate conditions.

The database is necessary to achieve the aims of the WP3 that is to develop an integrated research of climate factors in Sea Surface Dynamics (SSDs) over the European coasts and seas. It is carried out through the generation of a European climate database based on useful indicators and analysis of climate factors that require further study to reduce uncertainties and to better characterize coastal hazards, such as the regional mean sea level rise and changes on extreme events with a low occurrence interval.

The database has been built based on the available datasets and selected climate indicators. The ECLISEA partners manage the available datasets. The climate indicators have been adapted to the available datasets and are associated to the SSD. The database will be implemented in WP5 and it have been taken account a special emphasis on the use of established standards and common nomenclature in all metadata bases and data formats.

The aim of the report is to provide information and details about the database developed in the deliverable D3.E..

2. Available Data

Different datasets associated to the SSDs are available by the ECLISEA partners. We have selected three groups of datasets. The first group includes datasets that provide information about wave parameters, the second group are datasets that provide information about the Non-Tidal Residual (NTR, i.e. storm surge) and the third group are datasets that provide information about the Mean Sea Level Rise (MSLR).

As this package is focused on the future climate, different climate scenarios and time horizon are considered.

The available datasets to get the climate indicators associated to the wave parameters are shown in

Table 1. Each dataset has different spatial and temporal coverage. We have to select the climate indicators that can be applied taking into account the differences between the datasets.

Dataset name	Domain name	Geographical coverage		Spatial resolution	Time period: Historical	Time period: Future	Time resolution	Future scenarios	Variables name
		Latitude interval	Longitude interval						
UC-IHC (GOW)	Atlantic	[23,61]	[-35,9]	0,5° x 0,5°	1985-2005	2026-2045 2081-2100	hourly	Rcp 4.5 Rcp 8.5	Significant wave height (**hs**) zero-crossing mean wave period (**t02**) wave mean direction (**dir**) Peak period (**tp**)
	Mediterranean	[32.5,46.5]	[-14,17.5]	0,25° x 0,25°					
HZG	North Sea	[51,58.5]	[3.25,10.25]	0.05° x 0.075°	1970-2000	2001-2100	Hourly	2 x A1B, 2 x B1	Significant wave height (**hs**) zero-crossing mean wave period (**t02**) wave mean direction (**dir**) Peak period (**tp**)
	Baltic Sea	[53.5,66]	[9,31]	0.05° x 0.075°					
NCSRD	Mediterranean and Black Sea	[30,47]	[-6,42]	0,05° x 0,05°	1980-2009	2020-2049	6-h	Rcp 4.5 Rcp 8.5	Significant wave height (**hs**) zero-crossing mean wave period (**t02**) wave mean direction (**dir**) Peak period (**tp**)

Table 1: AVAILABLE WAVE HINDCAST DATASETS

The second group includes datasets that provide information about the sea level associated to the Non-Tidal Residual. In Table 2**Table 2** the available datasets are shown.

TABLE 2. AVAILABLE NON-TIDAL RESIDUAL DATASETS.

Dataset name	Domain name	Geographical coverage		Spatial resolution	Time period: Historical	Time period: Future	Time resolution	Future scenarios	Variables name
		Latitude interval	Longitude interval						
UC-IHC (GOS)	Southern Europe	[25,46.75]	[-19.9,37.33]	0.08ºx0.06º	1980-2009	2026-2045 2081-2100	hourly	Rcp 4.5 Rcp 8.5	Non-Tidal Residual
HZG	North Sea & Baltic Sea	[39.92,64.7]	[-19.9,22.82]	12,8 km	1971-2005	2006-2100	hourly	Rcp 8.5	Non-Tidal Residual
					1971-2000	2071-2100	hourly	Rcp 8.5	
					1970-2000	2001-2100	hourly	A1B, B1	

Finally, the third group provides information about the historical MSLR that covers the European coastal areas. Table 3 illustrates the datasets that provide information about the MSLR.

Table 3: Available historical MSLR datasets.

Dataset name	Domain name	Geographical coverage		Spatial resolution	Time period: Historical	Time period: Future	Time resolution	Future scenarios	Variables name
		Latitude interval	Longitude interval						
CNRS/BRGM/UC-IHC (ICDC Hamburg)	Europe	[-180,180]	[-180,180]	1ºx1º	1986-2005	2007-2100	annual	Rcp 4.5 Rcp 8.5	Mean Sea Level Rise

The spatial coverage of the first group is shown in Figure 1. UC-IHC waves data covers the Atlantic and the West Mediterranean Sea, while HZG data cover the Baltic and the North Sea. The data available from the NCSRD covers the whole Mediterranean Sea.

Figure 2 depicts the spatial coverage of the NTR, only UC-IHC and HZG has available data, the former covers the Southern Europe, while the latter the Northern Europe. The two datasets cover the whole Europe.

The spatial coverage of the future mean sea level rise (MSLR) datasets is different. It is the lowest resolution among all the datasets, it has 1ºx1º degree of resolution.

The ICDC Hamburg dataset is global, however here the interest is to see the changes in Europe.

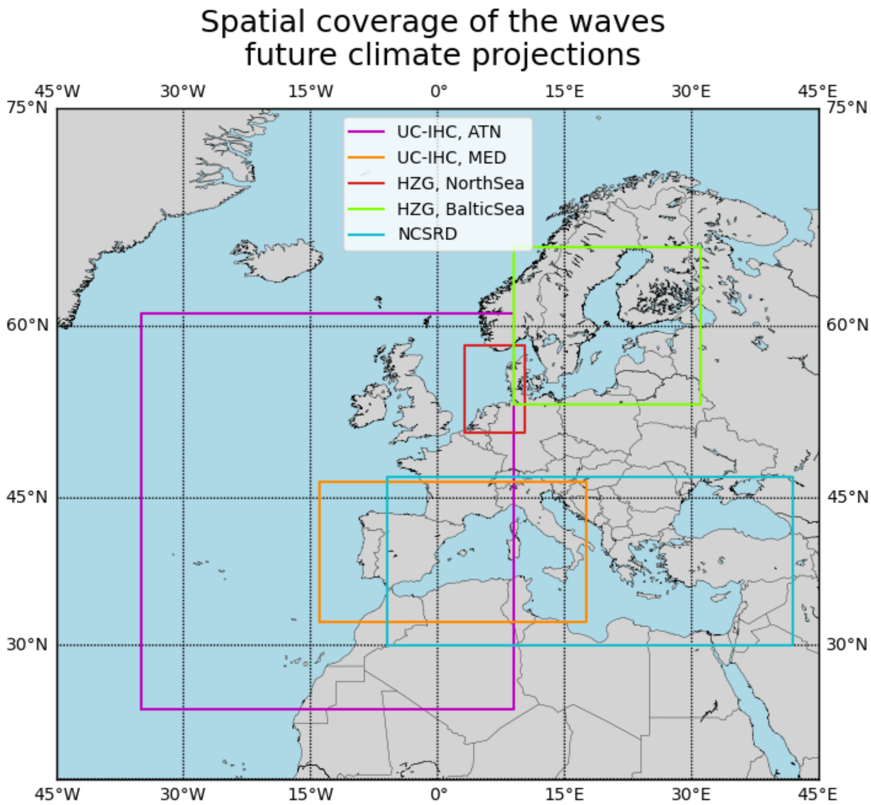

Figure 1: Domains of the waves databases

The climate indicators are calculated with the selected datasets and are useful to characterise the future climate variation of the waves, sea level associated to the NTR and the mean sea level rise over the Europe. The selected climate indicators are the overall mean and standard deviation of the ensemble of each variable.

Table 4 shows a summary of the selected climate indicators and variables that are calculated for the overall. These indicators applied to the available datasets cover all the European coast.

The future climate conditions, related to the different scenarios are forced with several models, which can be GCM (Global Climate Models) or RCM (Regional Climate Models).

More information about the forcing models are available in the following table (Table 4), in which the GCM and the RCM are represented. In order to compute the climate indicators several models are used.

Ilustración 1: Domains of the NTR databases

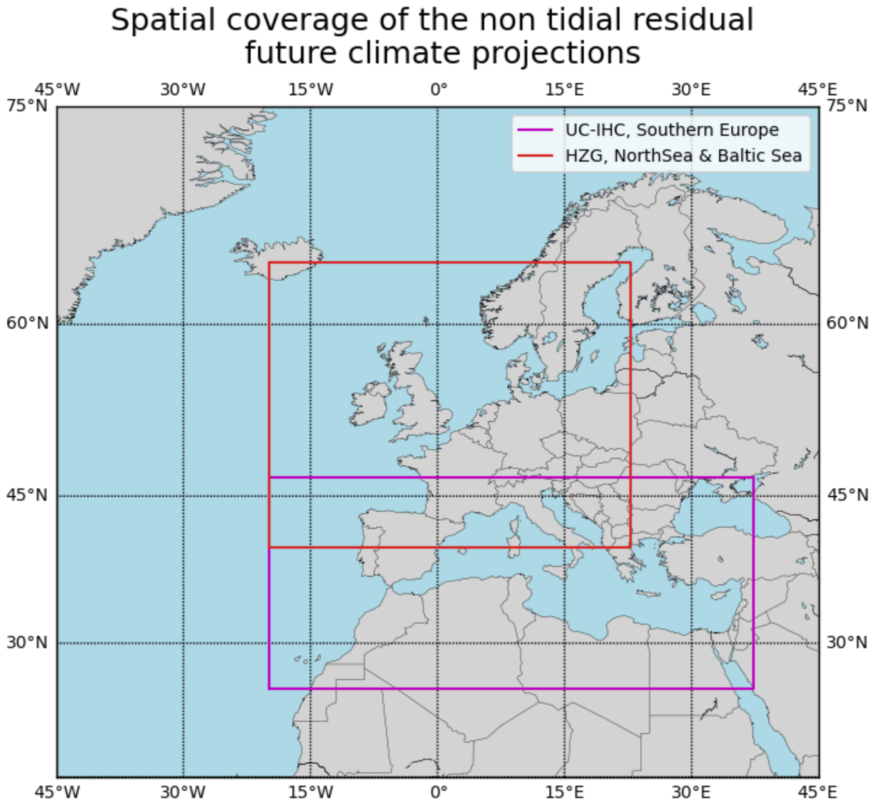

Figure 2:Domains of the sotrm surge databases

Table 4: Climate projections Models

Partner	Climate Projections	Climate Model Forcings	
		RCM	**GCM**
UC-IHC	Waves NTR	A) 7RCMs from EURO-CORDEX: RCA4,CCLM487,RCA4,RCA4, RCA4,RCA4,CCLM4-8-17. B) 1RCMs from Medcordex: ALADIN 52	A) MPI-ESM-LR,MIROC5,IPSL-CM5A-MR,HadGEM2-ES,EC-EARTH,CNRM-CM5,CanESM2CNRM-CM5. B) CNRM-CM5
NCSRD	Waves	WRF-ARW	EC-EARTH
CNRS/BRGM/UC-IHC	Mean Sea Level Rise	N/A	ACCESS1-0,BCC-CSM1-1, CanESM2, CNRM-CM5, CSIRO-Mk3-6-0, GFDL-ESM2G, GFDL-ESM2M, GISS-E2-R, HadGEM2-CC, HadGEM2-ES, INMCM4, IPSL-CM5A-LR, IPSL-CM5A-MR, MIROC5, MIROC-ESM, MIROC-ESM-CHEM, MPI-ESM-LR, MPI-ESM-MR, MPI-CGCM3, NorESM1-M, NorESM1-ME
HZG	Waves	CCLM	ECHAM5-MPIOM1
	NTR	EURO-CORDEX: RCA4 CCLM4 CCLM	EC-EARTH, CNRM, MPI-ESM, IPSL,CMCC, ECHAM5-MPIOM1

The climate indicators computed for this study are the **mean** and the **standard deviation** of the ensemble of the statistics reported in Table5.

3. Dataset of Climate Variables

The aim of this work is to present the results of the climate change projections of the following variables:

- **Mean Sea Level Rise:**
  The mean sea level rise is an important variable for the climate change studies along the shoreline. In the last century the sea surface temperature has increased as consequence of the global warming, this has led to the melting of glaciers and other continental water reserves. All of this is leading to a rise in global average sea level.

- **Storm Surge:**
  The storm surge is the variable that defines the variation of the sea level due to the consequences of the weathering agents on the sea surface, actually changes in atmospheric pressure and wind. Some meteorological conditions (eg: cyclogenesis), result in sea level rising; which it is combined with high astronomical tide could lead to floods and coastal erosion.

- **Waves:**
  The waves are the undulations created by the wind on the sea surface. Once generated the undulations travel in the ocean and arrive to the coast, where lose all the energy. The waves are the phenomena, which the highest contribute to the coastal erosion and flooding. This variable is also affected by the climate change, as the wind changes in magnitude and direction, the waves will change as consequence.

Therefore, for this study the Significant Wave Height (Hs), the Mean Wave Direction (Dir), sea level rise due to storm surge (zeta) and sea level rise due to global warming (MSLR) are studied.

The climate models used to force the waves and storm surge are GCMs (Global Climate Models) and RCMS (Regional Climate Models).

1) **GCMs:**
   These are the global climate models, they study the multitude of physical processes by coupling numerical simulations of the atmosphere and ocean, thus constructing the global climate response.

2) **RCMs:**
   The information proceeding from the GCMs, sometimes cannot be used for some regional studies such as in areas of complex geography (i.e. strait of Gibraltar or the coast of the Mediterranean Sea. The GCMs usually have a low spatial

resolution, for this reason it is necessary to have a more accurate models, which are the RCMs.

It is noteworthy to mention that there are uncertainties among the different climate models. Then, it is important to use many of them to reduce the uncertainty, as the mean climate change is the mean of the ensemble of the climate models. The results obtained from the climate projections lead to climate change indicators (here they are the ensemble mean and ensemble standard deviation).

The computed statistics per each model are: Mean (Hs, Tp, Dir and MSRL), percentile 99 for the variables of Hs and zeta.

Table 4: SUMMARY OF THE CLIMATE INDICATORS BY VARIABLE AND DATASET.

Variables	**Statistics**
Significant Wave Height (**HS)**	Mean, Percentile 99
Peak Period **(Tp)**	Mean, Percentile 99
Mean Wave Direction (**MWD**)	Mean
MSLR (mean sea level rise)	Mean
NTR (zeta, non tidial residual)	Percentile 99

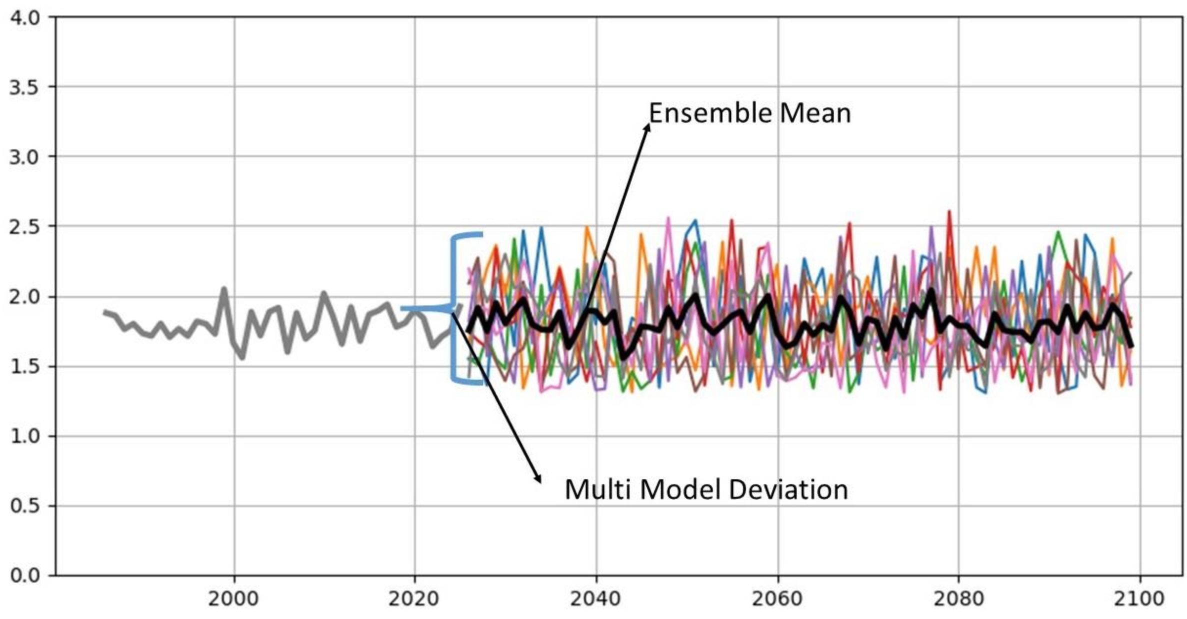

Figure 3: Climate models uncertainty, mean and standard deviation of the ensemble

Figure 3 shows the uncertainty of the different climate models and the ensemble mean and its standard deviation.

In order to compute the climate indicators, it is important to compute each statistic (mean, percentile 99) for the overall (i.e. mean for all the future/historic data) periods (future and historic). Then, the changes between the future and the historic values per each model are studied (i.e. mean of the future – mean of the historic and percentile 99 of the future – percentile 99 of the historic). Once it is done, the climate indicators can be computed, they usually are the ensemble mean and standard deviation of the changes per each statistic.

The used future climate scenery used by the institute are based on the Representative Concentration Pathway (RCP). The RCP is a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC. Four pathways were used for climate modelling and research for the IPCC fifth Assessment Report (AR5) in 2014. The pathways describe different climate futures, all of which are considered possible depending on the volume of greenhouse gases (GHG) emitted in the years to come. The RCPs – originally RCP2.6, RCP4.5, RCP6, and RCP8.5 – are labelled after a possible range of radiative forcing values in the year 2100 (2.6, 4.5, 6, and 8.5 W/m2, respectively).

- **RCP 4.5** is described by the IPCC as an intermediate scenario. Emissions in RCP 4.5 peak around 2040, then decline. According to the IPCC, RCP 4.5 requires that carbon dioxide (CO_2) emissions start declining by approximately 2045 to reach roughly half of the levels of 2050 by 2100. It also requires that methane emissions (CH_4) stop increasing by 2050 and decline somewhat to about 75% of the CH_4 levels of 2040, and that sulphur dioxide (SO_2) emissions decline to approximately 20% of those of 1980-1990. Like all the other RCPs, RCP 4.5 requires negative CO_2 emissions (such as CO_2 absorption by trees). For RCP 4.5, those negative emissions would be 2 Gigatons of CO_2 per year ($GtCO_2$/yr). RCP 4.5 is more likely than not to result in global temperature rise between 2 degrees C, and 3 degrees C, by 2100 with a mean sea level rise 35% higher than that of RCP 2.6. Many plant and animal species will be unable to adapt to the effects of RCP 4.5 and higher RCPs.

- **RCP 8.5** emissions continue to rise throughout the 21st century. Since AR5 this has been thought to be very unlikely, but still possible as feedbacks are not well understood. RCP8.5, generally taken as the basis for worst-case climate change scenarios, was based on what proved to be overestimation of projected coal outputs. The RCP8.5 scenario has thus become relatively unlikely, with one report calling it "increasingly implausible with each passing year." Despite its relative unlikelihood, RCP8.5 remains useful for its aptness in both tracking historical total cumulative CO_2 emissions and predicting mid-century (and earlier) emissions based on current and stated policies.

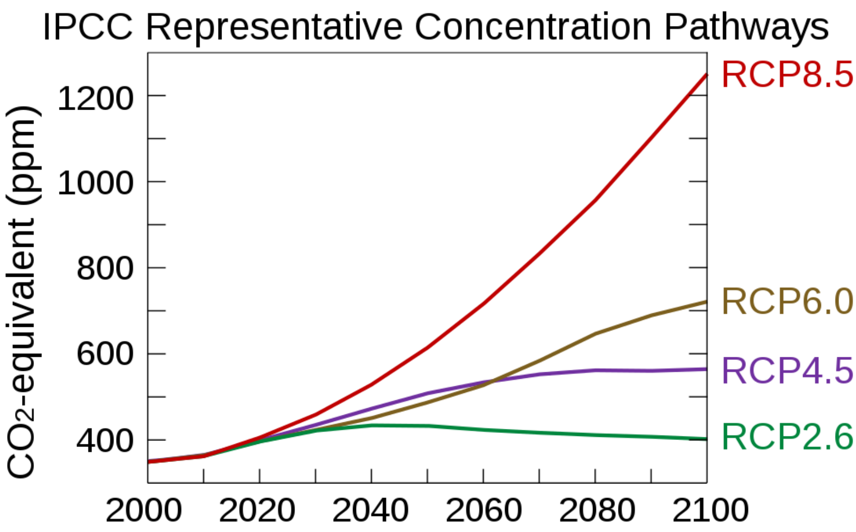

Figure 4: Future climate scenery used by the IPCC. They describe the evolution of the CO2 from the century XXI to the XXII century.

Figure 4 illustrates the different scenery from the 2.6 to the 8.5, it can be seen how the RCP8.5 is the worse scenario, having more than 1200 CO2-equivalent (ppm), while le RCP4.5 is a middle scenery between the 2.5 and the 6.0, in 2100 the CO2-equivalent (ppm) is the half of the RCP8.5.

4. The Database processing

The climate indicators results are saved in files with format NetCDF (Network Common Data Form). NetCDF is a set of interfaces for array-oriented data access and a freely distributed collection of data access libraries for C, Fortran, C++, Java, and other languages. The NetCDF libraries support a machine-independent format for representing scientific data. Together, the interfaces, libraries, and format support the creation, access, and sharing of scientific data (Rew et al 1990). For more information about the NetCDF see the next link https://doi.org/10.5065/D6H70CW6.

The NetCDF convention used to provide the files and name the variables and attributes is the CF convention 1.7 with the CF Standard Name Table Version 63, 05 February 2019.

The NetCDF format enable to read the files from a specific web server that provides metadata and data access using a variety of remote data access protocols. The specific web server is a THREDDS (Thematic Real-time Environmental Distributed Data Services) data server. The THREDDS Data Server (TDS) goal is to provide students, educators and researchers with coherent access to a large collection of real-time and archived datasets from a variety of environmental data sources at a number of distributed server sites. So, the TDS is the suitable web server to provide the information about the results of the climate indicators to the students, educators and researchers.

TDS provide a wide number of access protocols and viewers, the protocols are the next:

- OPENDAP
- HTTPServer
- WMS
- WCS
- NetcdfSubset

The viewers that provide are the next:

- Godiva2 (browser-based)
- NetCDF-Java ToolsUI (webstart)
- Integrated Data Viewer (IDV) (webstart)

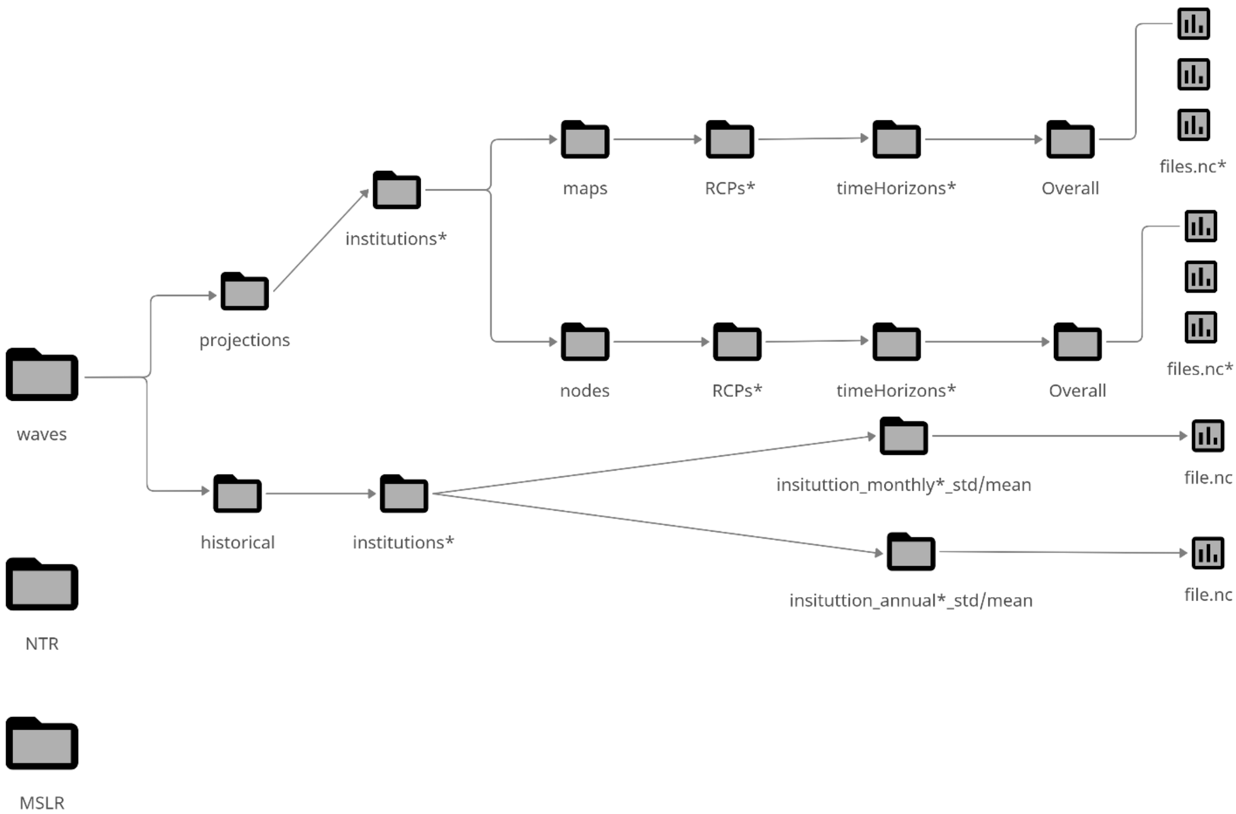

Figure 5 Folder organization in thredds. The folder of NTR(non tidal residual) and MSLR(mean sea level rise) follow the same pattern as the folder of waves. For the projections: institution is the name of the institution that has provided the data, . The RCPs are the 4.5 and the 8.5, the timeHorizons* are the future time horizons that are available, the two studied here are 2026-2045 and 2081-2100. Finally the files.nc* are all the netCDF files containing the information about the future changes. For the historical the subfolders are lower, the isititutions* are as before, while inside these folders another folders with name of institution_monthly or annual_ std or mean are inserted and each folder has inside the corresponding netCDF which shows the historical data, corresponding to the annual or monthly mean or standard deviation.*

For more information about the THREDDS Data Server see the next link https://doi.org/10.5065/D6N014KG.

¡Error! No se encuentra el origen de la referencia. Figure 5 illustrates the folder organization inside the thredds database, as can be seen the MSLR and the NTR follow the folder organization of the waves folder. They are organized with a principal folder which has the name of the SSD illustrated. For example the folder waves will have the netCDF with the SSD corresponding to the waves. These folders are divided in maps and nodes, the nodes folder cover only the nearshore data and have resolution of 0.5x0.5 degrees. Once selected nodes or maps, the next subfolder is the RCPs, they are 4.5 and 8.5, however depending on the data provided by the institutions they can appear both or only one, such are the time horizons, which are 2026-2045 and 2081-2100, however it can appear only one of them due to the time horizon of the institution. Finally, the overall folder is found, it is the overall because the values represented are the average value within the 20 years. Inside this folder there are the corresponding netCDF files.

The available files and variables are the illustrated in Table 5, which represents the historical and projection files with the corresponding variables and a short description of them.

HISTORICAL	
Files	Description
	instModel: models of the institution, such as GOS,GOW,CoastDat or NCSDR. *grid*: which is the covered area, such as ATN,MED,… *average*: Annual, Monthly. *timeInterval*: historical time interval
*instModel*_*grid*_*average*_*statistic*_*timeInterval*.nc	
Variables	
	var: tm,tp,dir,hs,mslr,zeta *stat*: computed statistic, such as the mean or the standard deviation.
*var*_*stat*	These are map files
PROJECTIONS	
Files	Description
	instModel: models of the institution, such as GOS,GOW,CoastDat or NCSDR. *grid*: which is the covered area, such as ATN,MED,… *SSD*: such as MSLR, NTR or waves *statistics*: quantile 0.99 or mean *RCPs*: rcp45 or rcp85 *timeHorizons*: 2026_2045 or 2081_2100

*instModel*_*grid*_Overall_changes_*SSD*_*statistic*_*RCPs*_*timeHorizons*.nc	These are the map files.
*instModel*_Nodes_*grid*_Overall_changes_*SSD*_*statistic*_*RCPs*_*timeHorizons*.nc	These are the node files.
Variables	
	var: hs,tp,dir, zeta or mslr. For the zeta the computed statistic is the quantile 0.99, while for the dir only the mean was computed.
diff_*var*_mean	Projected change (%) of the 0.99 quantile or the mean of the *var*, concerning the **ensemble mean**.
diff_*var*	Projected change (%) of the 0.99 quantile or the mean of the *var*.
*var*_uncertainty	Uncertainty of the change of *var*.This data is present only for the **ensemble mean** data.

Table 5: names of the files and the variables inside the files in the thredds of eclisea.

The data will be also available and shown in a viewer built in on purpose to show the data computed for the ECLISEA project.

The viewer of the data is illustrated in Figure 6. Frist of all it is needed to select between historical and projections, buttons near the ECLISEA logo, then select the data that is wanted to display (Ocean waves or Ocean levels), once selected the button has to be pressed and then the research starts. On the right a panel will be opened, on the top there are the netCDF files and on the lower part there are a short guide. It is possible now to proceed with the display of the data, select the file and all the variables inside the netCDF will be illustrated and then the data are plotted on the map.

The ECLISEA data viewer can be found at the following link: https://ecliseadev.ihcantabria.com/.

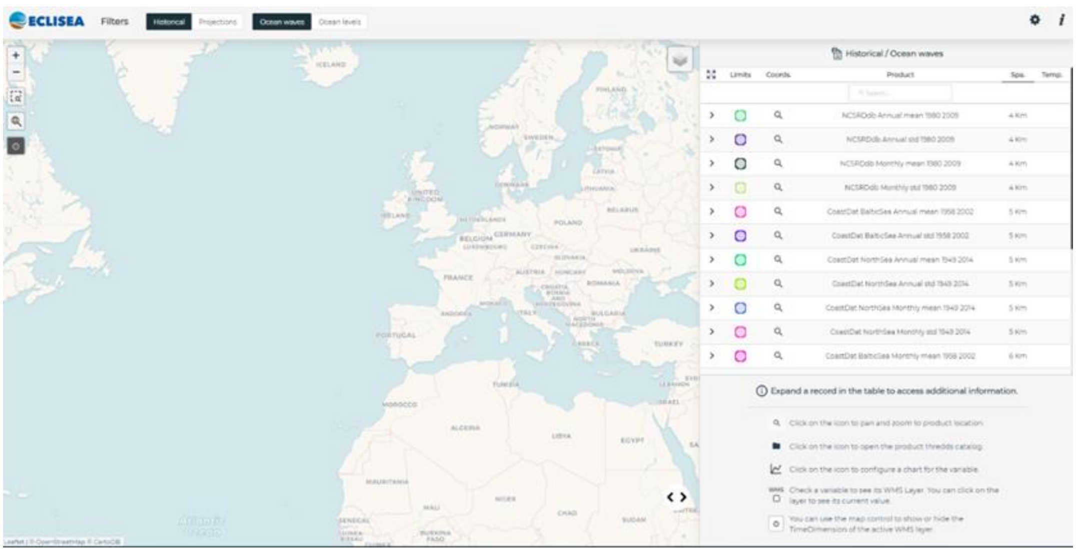

Figure 6: ECLISEA web data viewer.

5. References

Rew, Russ; Davis, Glenn. NetCDF: an interface for scientific data access. IEEE computer graphics and applications, 1990, vol. 10, no 4, p. 76-82.