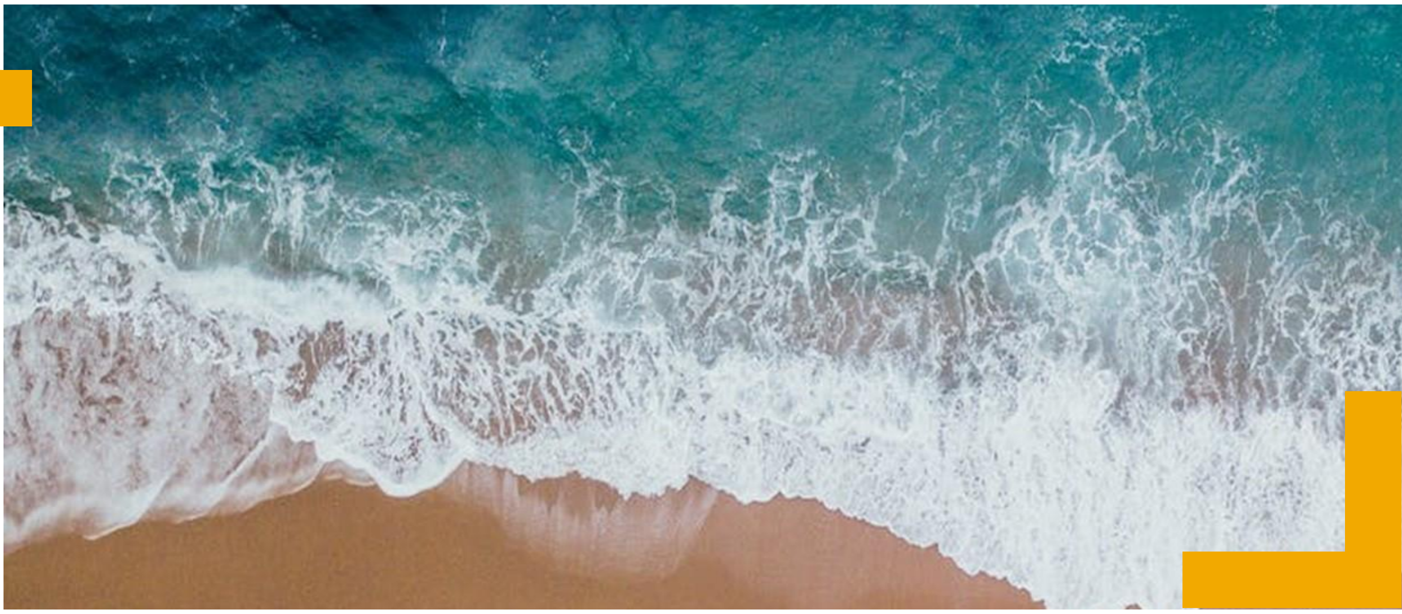
MedSeaRise | Interreg Euro-MED | Co-funded by the European Union



June 2025

Assessment of the likelihood for each dataset available for Mediterranean sub basin area

Deliverable 2.1.1.

https://medsearise.interreg-euro-med.eu/

Deliverable ID

Project acronym	MedSeaRise
Project title	Supporting Adaptation to Mediterranean Sea Level Rise
Project mission	Protecting, restoring and valorising the natural environment and heritage
Project priority	Greener MED
Specific objective	RSO2.4 Promoting climate change adaptation and disaster risk prevention, resilience, taking into account eco-system based approaches
Type of project	Study project (Thematic Project)
Project duration	01/01/2024 – 31/03/2026 (27 months)

Deliverable title	Assessment of the likelihood for each dataset available for Mediterranean sub basin area.
Deliverable number	D.2.1.1
Deliverable type	Report
Work package number	2
Work package title	Information analyses, methodology development and tools generation
Activity name	Data analysis of future sea level rise scenarios and scientific information review
Activity number	2.1
Partner in charge (author)	UM (PP6)
Partners involved	ARPA FVG (PP2), UoM-IBMK (PP4)

Table of contents

1. Introduction and Objectives

This document presents a specific contribution in the achievement of the general MedSeaRise WP2 objective, namely the evaluation of the likelihood of Mediterranean Sea level trends scenarios, to support the development of a methodology for a proper use of such data in the risk assessment processes and to provide guidelines and benchmarks for the methodology application.

Specifically, one of the expected results from Activity 2.1 is the analysis of data on future sea level rise scenarios and the review of the related scientific information. Data and scientific information have been collected thanks to Activity 1.1.

To this end, a review was carried out on the numerical models main features that have generated the dataset of sea level rise projections, for the XXI century over the Mediterranean area, which have been harvested for the project purposes. Strengths and limits of the considered numerical projections have been derived adopting a manifold approach (see fig. 1.1).

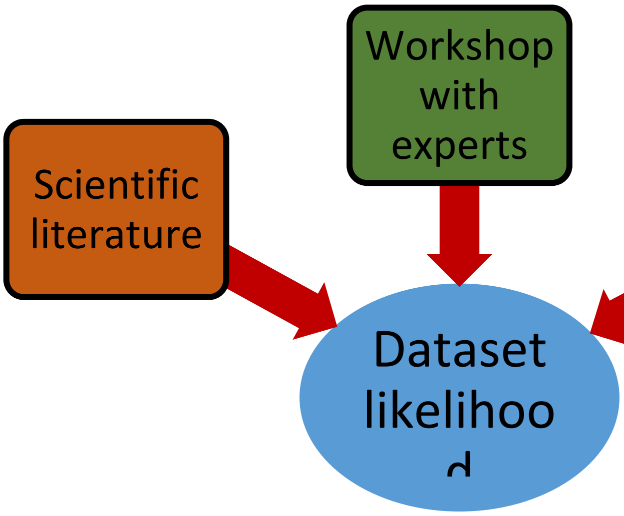


Figure 1.1: the three main perspectives of the manifold approach adopted to assess the likelihood of the mean sea level datasets.

Information on how future scenarios simulations have been conducted was retrieved from the analysis of the scientific literature, which is tied to the considered simulation datasets (Deliverable D.1.1.1). Furthermore, the summary of the discussions and the issues that arose in the frame of the workshop of experts organized in the frame of the project has been taken into account (Deliverable D.1.1.3). In addition, a set of numerical indicators based on available data have been computed for each Mediterranean sub basin area. The sub basin areas are identified according to the sea level rise risk survey information and they match the coastal areas where project partners focus their own case study.

In the frame of the MedSeaRise, the definition of dataset likelihood does not reflect the usual concept widely agreed in statistical sciences. In fact, the aim of the project is to give information on the sea level future scenarios data and on how trustable those data are. So, a specific definition of likelihood has been elaborated and fitted to the MedSeaRise needs.

In the following, this deliverable defines the concept of likelihood adopted for the datasets evaluation, then it recalls the datasets available in the frame of the MedSeaRise project, next each contribution to the dataset likelihood is described in detail and the assessment of the likelihood for each dataset is presented.

This deliverable makes synergy with deliverables D.1.1.1, D1.1.2 and D.1.1.3 [1.1].

2. Definition of likelihood adopted for sea level scenarios datasets

The likelihood concept used in the statistical sciences funds its roots in the possibility to replicate the information extraction from the system to which a model aims to be the abstract description. In that case, it is possible to define a probability function to assess the probability to observe both model reality representation and real world extracted information. The greater the probability the closer to reality the model is. Furthermore, for statistical models it is possible to change their parameters values to find the set of values that maximize such probability.

We have to remember the classical frequentist statistical paradigm that builds on the principle of repeated sampling where "statistical procedures are to be assessed by their behavior in hypothetical repetitions under the same conditions" and where measures of uncertainty are to be interpreted as hypothetical frequencies in long run repetitions.

For future climate scenarios, the uncertainty comes from the complexity of the simulated system in which interactions among system components and feedback propagate even small differences in non-random deviations.

For climate models, the statistical likelihood approach is not applicable because nobody knows what will be the future climate. Furthermore, numerical climate models are characterized by many parameters that are set according to the closeness of the simulation to the past reality, that is historical climate records. It is assumed that the best representation of the past will be so also for the future.

Then it is not possible to associate a likelihood of climate models according to the classical statistical concept. Nevertheless, there are more than one climate models used in simulating future climate and it is natural and frequent the stakeholder asks which is the most trustable dataset.

The MedSeaRise project criticizes the question: “who is the most trustable dataset?” and leads the stakeholder to use all the numerical simulations on future climate and then evaluate the spread of the outputs and its propagation in the corresponding set of impacts [2.1].

Anyway, due to the complexity of the climate models it is possible to identify strengths and weaknesses of the model simulating parts of the real climate. This is because not all the physical, chemical and biological processes are reproduced with the same degree of accuracy. Furthermore, the feedback among the climate components enriches the set of potential sources of uncertainty.

It is in this perspective that MedSeaRise is comparing climate models outputs likelihood.

Starting from the ability of the numerical model to include all the known causes producing sea level variation over a long period, each model output has received a score which is tied to the originating model. In fact, missing processes in a model could be relevant to decrease the model output likelihood with respect to future climate. Furthermore, the model is expected to be able to have produced enough information to explore the future climate scenarios, namely to cover a wide future range according to the most commonly used greenhouse emission scenarios.

To quantify this concept in a score and to compute it for each available model output, a series of questions have been formulated and addressed to the model. The set of questions are presented in section 6. According to the answer the given score is:

- -1 if the answer is negative(NO)
- 0 if it is not clear whether the answer is Yes or NO
- +1 if the answer is positive (Yes)

At the end all the scores are added to give the total score of the dataset, generated by the model.

Since the same numerical model has generated several outputs, according to different parametrization settings, initialization data and climate scenarios, with the aim to give a specific score to each model output and to cope with the project goal that is to define "indicators which are suitably thought and computed for each Mediterranean sub basin area.", then the sea level trend derived from measurements, in the specific MedSeaRise geographical area over the period 1993-2023 is compared with the trend computed using the model output. The comparison between the two trends tells us whether the model is in agreement with the measurements in a specific Mediterranean area for the thirty-one years nearest to the present. Trends are expressed as millimeters of sea level variations per year [mm/y] and their difference is the score.

These two kinds of scores are combined in a series of plots, in which all the model outputs, which have been used in the frame of MedSeaRise, are located and compared graphically too, to give the likelihood of the output in representing the future sea level.

3. Data available for MedSeaRise objectives

The sources of information on the future scenarios of Mean Sea Level (MSL), which has been considered in the frame of MedSeaRise project, are a set of monthly averages of the MSL field covering the time period ranging from 1850 to 2100 and the whole Mediterranean Sea area. These data are shortly referred to as ZOS.

Data files were downloaded for as many simulations as possible, related to the four main SSP-RCPs scenarios, namely SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5, together with their historical part. Those files are in netDCF format and are selected from Coupled Model Intercomparison Project Phase 6 (CMIP6) [3.1] data sets with 25 km of (horizontal) spatial resolution. Files are accessible from one of the nodes [3.2] of the Earth System Grid Federation (ESGF) [3.3], which is an international collaboration supporting most global climate change research [3.4], including the climate assessments of the Intergovernmental Panel on Climate Change (IPCC) [3.5].

From the downloaded files [3.6], time series are extracted (nearest neighbor interpolation) for specific geographic locations of interest by each Project Partner (see table 3.1).

location ID	latitude [°N]	longitude [°E]	notes
LP1_01	40.41616	22.75137	Point offshore in the Thermaic Gulf; ZOS
LP1_02	40.26243	22.83822	Point offshore in the Aegean Sea; ZOS
PP2_01	45.49458	13.15274	Point offshore in the North Adriatic Sea; ZOS
PP3_01	42.56954	7.34774	Point offshore the Cote d'Azur; ZOS
PP4_01	42.16527	18.40141	Point offshore in the South Adriatic Sea; ZOS
PP5_01	41.22654	2.472953	Point offshore in the Balearic Sea; ZOS
PP6_01	36.12255	14.73559	Point offshore the coastline of Malta; ZOS

Table 3.1: the locations that the MedSeaRise project has identified to conduct the project activities. Each location ID is associated with the latitude and longitude of the location and the notes report information on the location name and the environmental fields available; namely: sea level (ZOS).

Data is stored in a folder for each Project Partner (PP) and therein other subfolders storing time series files of ZOS. There is one netCDF file for each simulation, geographic location and scenario; the time series are composed by monthly average values extending from an historical part (1850 ÷ 2014) to a future RCP scenario (2015 ÷ 2100).

There is only one location where ZOS has been considered for each PP. Whereas, it is worth noting that for LP1 two locations have been considered, since for a specific scenario (GFDL-CM4_r1i1p1f1) no data close enough to the area of interest are available.

The number of simulations of ZOS for each considered scenario (historical + SSP-RCP) is listed below:

SSP1-2.6, number of available datasets: 3

SSP2-4.5, number of available datasets: 2

SSP3-7.0, number of available datasets: 6

SSP5-8.5, number of available datasets: 7

The main features of the simulations mentioned above are listed in the dedicated table 3.2.

Project	Institution ID	Model ID	SSP-RCP	Configuration run
CMIP6	AWI	AWI-CM-1-1-MR	ssp126	r1i1p1f1
CMIP6	MOHC	HadGEM3-GC31-MM	ssp126	r1i1p1f3
CMIP6	CNRM-CERFACS	CNRM-CM6-1-HR	ssp126	r1i1p1f2
CMIP6	AWI	AWI-CM-1-1-MR	ssp245	r1i1p1f1
CMIP6	CNRM-CERFACS	CNRM-CM6-1-HR	ssp245	r1i1p1f2
CMIP6	AWI	AWI-CM-1-1-MR	ssp370	r5i1p1f1
CMIP6	AWI	AWI-CM-1-1-MR	ssp370	r4i1p1f1
CMIP6	AWI	AWI-CM-1-1-MR	ssp370	r3i1p1f1
CMIP6	AWI	AWI-CM-1-1-MR	ssp370	r2i1p1f1

CMIP6	AWI	AWI-CM-1-1-MR	ssp370	r1i1p1f1
CMIP6	CNRM-CERFACS	CNRM-CM6-1-HR	ssp370	r1i1p1f2
CMIP6	NOAA-GFDL	GFDL-CM4	ssp585	r1i1p1f1
CMIP6	AWI	AWI-CM-1-1-MR	ssp585	r1i1p1f1
CMIP6	MOHC	HadGEM3-GC31-MM	ssp585	r4i1p1f3
CMIP6	MOHC	HadGEM3-GC31-MM	ssp585	r1i1p1f3
CMIP6	MOHC	HadGEM3-GC31-MM	ssp585	r2i1p1f3
CMIP6	MOHC	HadGEM3-GC31-MM	ssp585	r3i1p1f3
CMIP6	CNRM-CERFACS	CNRM-CM6-1-HR	ssp585	r1i1p1f2

Table 3.2: list of the available datasets for each location that the MedSeaRise project has identified to conduct the project activities. Besides the computational experiment (Project) that has generated the dataset, the institution (Institution ID) and the applied model (Model ID) are reported. The Scenario (SSP-RCP) is identified with a string of the type sspXY, that means the SSP X and the RCP Y. The model configuration used to run it is available too (Configuration run).

In CMIP6 [3.1] numerical simulations, the models are required to be initialized and prepared choosing a specific configuration of physical and chemical processes parametrization, besides the climate forcing. That is referred to as the configuration run (see table 3.2). So the same numerical model has produced more than one climatic simulation, then a corresponding data set.

The specific configuration run is described by an ID. It is called variant-ID and it distinguishes among closely related simulations by a single model. The variant-ID is composed by four pairs of characters **r**N**i**N**p**N**f**N (e.g. r1i1p1f2) and each pair specifies the following:

- **r**N denotes the realization, that is the ensemble member (N). An example is **r1**i1p1f2 indicating that it is the 1st (N=1) realization;
- **i**N denotes the initialization method, that is the method (N). An example is r1**i1**p1f2 indicating that it is the 1st (N=1) method;
- **p**N denotes the physics parameterizations, that is the physical parametrizations (N). An example is r1i1**p1**f2 indicating that it is the 1st (N=1) set of physical parametrizations;
- **f**N denotes the forcing adopted or scenario, that is the scenario (N). An example is r1i1p1**f2** indicating that it is the 2nd (N=2) scenario.

The variant-ID helps researchers distinguish between different model runs, ensuring that they can track which specific simulation produced a particular set of results. This is crucial for comparing and analyzing model outputs. Further details on the variant-ID and related issues are available through the CMIP Model and Experiment Documentation [3.4].

4. Contribution from scientific literature

The scientific literature collected and analyzed according to the project Activity 1.1 (see deliverable D.1.1.1 Knowledge and data availability on sea level rise projections [4.1]) highlighted differences among the numerical model that have contributed in creating the datasets used in the frame of the MedSeaRise project.

Even if all numerical models include the fundamental physical processes driving the evolution of the Earth climate, for example the large-scale dynamics and thermodynamics of the atmosphere, the mass and energy conservation, specific interactions and feedback vary from model to model. Furthermore, the possible future climate scenarios have not been simulated by all the models together with the extension far in the future may be different.

Those, not standardized, model features are considered a richness instead of a disadvantage because each model contributes in the realization of an exploration of the possible future Mean Sea Level status.

It is starting from this awareness that arose the set of questions to be addressed to each model, for the likelihood assessment. The questions are described in detail in section 6 of this document.

Answers to the questions were found exploring the available literature on the experiments carried on by each numerical model that have generated the ZOS fields considered in the frame of the MedSeaRise project, the core documentation on each of the four models have been analyzed. Namely they are: **AWI-CM-1-1** [4.2], **HadGEM3-GC31-MM** [4.3], **CNRM-CM6-1-HR** [4.4], **GFDL-CM4** [4.5]. Furthermore, the general documentation on CMIP6 Coupled Model Intercomparison Project Phase 6 (CMIP6) [4.6] was considered too to generate a common base against which to compare the scores obtained by each model.

5. Contribution from workshop of experts

MedseaRise Activity 1.1 focuses on describing the state-of-the-art of the scientific community's knowledge on the limits affecting the projections of future sea level trends, due to climate change in the Mediterranean.

To this end, the project has considered mandatory to create personal interactions among the project partners and the experts in the field of sea level variation also organizing a workshop of international scientists and experts of sea level rise, with the objective to discuss about the fundamental physical processes, which are responsible for the increase of the water level along the Mediterranean.

The workshop results are collected in deliverable D.1.1.3 [5.1]. Thanks to that workshop, the MedSeaRise partnership achieved awareness on which physical processes interact to define the comprehensive state of the sea water and consequently the mean sea level.

In summary, besides the steric effect, that is directly linked to the water temperature and resulting in the water volume expansion when the environment gets warmer, also the contribution of salt concentration to the water density plays a relevant role on mean sea level, especially on shallow waters characterized by rivers inflow. Also the inverse barometer effect, which is a consequence of persistent low atmospheric pressure, results in significant changes of the mean sea level.

The future sea level may be also dramatically affected by climate tipping points that increase the mass of liquid water over the planet. The most important are the melting of part of Greenland and Antarctica ice sheets.

The above mentioned points have been considered in formulating the critical questions addressed to the models with the aim to associate them with the score on the ability to include all the effects acting on future mean sea level.

6. Contribution from computed indicators

According to the definition of dataset likelihood in describing the future scenarios of mean sea level (see section 2), two indicators have been computed.

To give the score to each numerical model, eight questions have been formulated and addressed to each model by way of the literature sources (see section 4).

Table 6.1 summarises the results of the eight critical questions regarding climate model capabilities. These questions examine important aspects of the design of each model such as the coverage of the entire 21st century, the inclusion of main climate change scenarios, the coupling between atmosphere and ocean, simulation of tipping points (rapid ice-sheet melting), consideration of hydrological regime changes, and detailed calculation methodologies related to sea-level changes. Evaluating these questions helps determine the suitability of each model for climate research and policy planning.

To create an alternative to the answers given by the specific documentation of each numerical model, the questions have been addressed to the literature available for the whole CMIP6 experiment too.

In the following subsections 6.1 to 6.8, each of these questions is addressed, providing detailed comparisons among the five climate models discussed. Furthermore, table 6.1 summarizes the answers which have been transformed into a numerical score following the algorithm described in session 2.1, so each numerical model got its score. In table 6.2 the scores are presented.

Question	AWI-CM-1-1	HadGEM3-GC31-MM	CNRM-CM6-1-HR	GFDL-CM4	CMIP6
Covers XXI Century?	Yes	Yes	Yes	Not sure	Yes
Includes RCP 2.6, 4.5, 8.5 scenarios?	Yes	Yes	Yes	No	Yes
Coupled Atmosphere-Ocean model?	Yes	Yes	Yes	Yes	Yes
Ice-Sheet tipping points simulated?	No	No	No	No	No
Changing hydrological regimes considered?	Yes	Yes	Yes	Yes	Yes
Steric change calculated on-line?	Not sure	Yes	Yes	Not sure	Not sure
Salinity included in water volume change?	Not sure	Not sure	Yes	Not sure	Not sure
Atmospheric pressure effects on sea level?	Not sure	Not sure	Not sure	Not sure	No

Table 6.1: Capabilities of the considered climate models

6.1 Do the models cover the entire XXI century?

All reviewed models imply that they cover the entire 21st century, except for GFDL-CM4, where this coverage remains unclear. AWI-CM-1-1, HadGEM3-GC31-MM, CNRM-CM6-1-HR, and CMIP6 explicitly specify that they perform simulations spanning from 1850 up to 2100 under various future scenarios [6.1, 6.2, 6.3]. In contrast, documentation for GFDL-CM4 primarily focuses on historical and idealised experiments without explicitly detailing scenario-based runs for the entire 21st century [6.4].

6.2 Do the models consider all three main climate change scenarios, namely RCPs 2.6, 4.5, and 8.5?

AWI-CM-1-1, HadGEM3-GC31-MM, CNRM-CM6-1-HR, and CMIP6 explicitly include scenarios equivalent to the three main climate-change pathways (RCPs), now termed SSP1-2.6, SSP2-4.5, and SSP5-8.5. These represent low, medium, and high greenhouse gas emission trajectories, respectively, and are critical for understanding climate projections [6.1, 6.2, 6.3]. GFDL-CM4 does not explicitly include these scenarios in its provided documentation [6.4].

6.3 Are the outputs of the models generated by a coupled atmosphere-ocean model?

All five models are explicitly designed as fully coupled atmosphere–ocean models. AWI-CM-1-1, HadGEM3-GC31-MM, and CNRM-CM6-1-HR clearly detail the coupling between their atmospheric and oceanic systems to simulate interactive climate feedbacks [6.1, 6.2, 6.3]. Similarly, GFDL-CM4 emphasises its robust coupling between atmospheric and oceanic components, essential for realistic climate simulations [6.4]. CMIP6 inherently requires coupled models for participation [6.5].

6.4 Do the models consider tipping points, such as Greenland and Antarctica ice sheets melting?

None of the models explicitly simulate dynamic ice-sheet tipping points, such as rapid melting of Greenland or Antarctic ice sheets. All models, including AWI-CM-1-1, HadGEM3-GC31-MM, CNRM-CM6-1-HR, and GFDL-CM4, handle ice-sheet contributions through prescribed external meltwater inputs. Thus, sudden ice-sheet collapse or feedback mechanisms are not interactively represented within these simulations [6.1; 6.2, 6.3, 6.4]. CMIP6 models also adopt this approach unless specifically participating in specialised Ice Sheet Model Intercomparison Projects (ISMIP6) [6.5].

6.5 Do the models consider changes in hydrological regimes?

All five models include mechanisms to simulate changes in hydrological regimes, enabling them to represent how rainfall patterns, soil moisture, river flow, and evaporation respond to climate change. AWI-CM-1-1 explicitly highlights the simulation of increased rainfall in polar regions and drying in subtropical zones [6.1]. HadGEM3-GC31-MM and CNRM-CM6-1-HR enhance surface runoff and river-routing capabilities [6.2, 6.3]. Similarly, GFDL-CM4 includes improvements in its hydrological component, enabling comprehensive hydrological cycle simulation [6.4]. CMIP6 experiments inherently include outputs relevant to hydrological regime changes [6.5].

6.6 Do the models compute water volume changes online or is the steric contribution added offline, after simulation?

The calculation of ocean volume change within climate models varies. HadGEM3-GC31-MM and CNRM-CM6-1-HR explicitly calculate ocean volume changes interactively during their model runs, a mode called "online" [6.2, 6.3]. In contrast, AWI-CM-1-1, GFDL-CM4, and general CMIP6 documentation are less explicit, creating uncertainty about whether these steric contributions are computed during the model run or appended post-simulation [6.1, 6.4, 6.5].

6.7 Do the models include salinity in the water volume calculations?

Only documentation related to CNRM-CM6-1-HR explicitly mentions the inclusion of salinity variations when calculating water volume changes, ensuring salinity-driven effects on sea-level rise are considered [6.3]. The other models (AWI-CM-1-1, HadGEM3-GC31-MM, GFDL-CM4, and general CMIP6) do not explicitly mention this aspect, leaving their treatment of salinity uncertain [6.1, 6.2, 6.4, 6.5].

6.8 Do the model outputs account for atmospheric pressure variations in sea-level height calculations?

Most documentation does not explicitly mention whether atmospheric pressure effects (inverse-barometer correction) are included in sea-level calculations, leading to uncertainty for AWI-CM-1-1, HadGEM3-GC31-MM, CNRM-CM6-1-HR, and GFDL-CM4 [6.1, 6.2, 6.3, 6.4]. However, the CMIP6 framework explicitly excludes atmospheric pressure effects from its standard sea-level datasets [6.5].

Model score table

Model	Model Config	
AWI-CM-1-1-MR	r1i1p1f1	3
	r2i1p1f1	3
	r3i1p1f1	3
	r4i1p1f1	3
	r5i1p1f1	3
CNRM-CM6-1-HR	r1i1p1f2	5
GFDL-CM4	r1i1p1f1	0
HadGEM3-GC31-MM	r1i1p1f3	4
	r2i1p1f3	4
	r3i1p1f3	4
	r4i1p1f3	4

Model
AWI-CM-1-1-MR
CNRM-CM6-1-HR
GFDL-CM4
HadGEM3-GC31-MM

Table 6.2: The score assigned to each model according to the answers given to the eight questions. Together with the model, also the model configuration (Model Config) is reported, because datasets generated by the same model can differ because of the configuration used for the simulation run. That allows to combine the score given to the model with the comparison of the trends on sea level, which depend on model configuration too.

Coming to the comparison between the sea level trends computed from the model simulation datasets and the sea level trend derived from measurements, in the specific MedSeaRise geographical area over the period 1993-2023, the source of measurements is the Sea level gridded data from satellite observations for the global ocean [6.6], which are available through the Copernicus Climate Data store [6.7]

The comparison between the two trends for each of the MedSeaRise areas (figure 6.1) are presented in the Appendixes, while in section 7.1 the summary of the behavior of all the models is reported.

Figure 6.1: the six Mediterranean Sea areas where the MedSeaRise project focuses the attention on the impacts of the future scenarios of the sea level. For each of these areas, model and observed sea level trends, computed across the period 1993-2023, have been compared.

From the results of the trends computed using measurements, the comparison with scenario trends is easy. In fact, the observed sea level trend in the last three decades (1993-2023), changes across the considered Mediterranean area, see figure 6.2, but considering all the places it ranges from 3.3 mm/y to 4.1 mm/y.

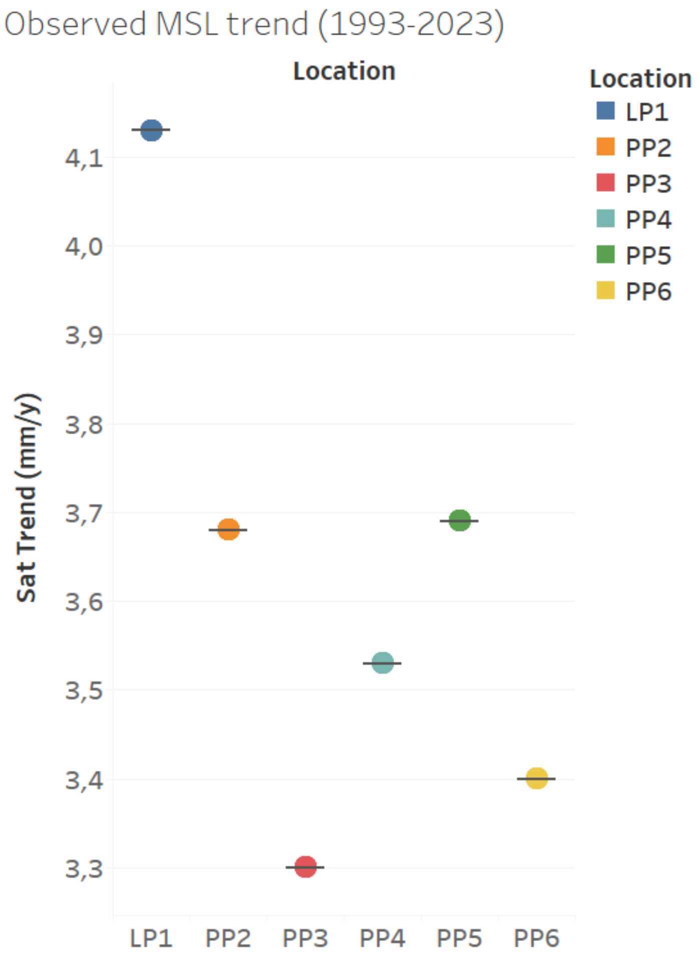


Figure 6.2: Observed sea level trends for each of the six Mediterranean Sea areas where the MedSeaRise project focuses the attention on the impacts of the future scenarios of the sea level. The observed sea level trends are computed over the period 1993-2023, using the satellite measurements available from the Copernicus Climate Data Store [6.7].

7. Likelihood of each dataset

The likelihood of each dataset used in the frame of the MedSeaRise project has been evaluated combining the score given to the numerical model that generated the output dataset, together with the comparison between the sea level trend computed from model output data and the remote sensing measurements. Both trends refer to the last three decades, namely the period 1993-2024

Trends are expressed as millimeters of sea level variations per year [mm/y] and model score is associated with the corresponding dataset. These two kinds of information are combined in a plot where observed trends and simulated ones are reported for each simulation. The size of the points representing the simulated trends is a function of the model score. Also the measured trends changes the marker size according to the model score, to let the information available from the graph easy to be interpreted.

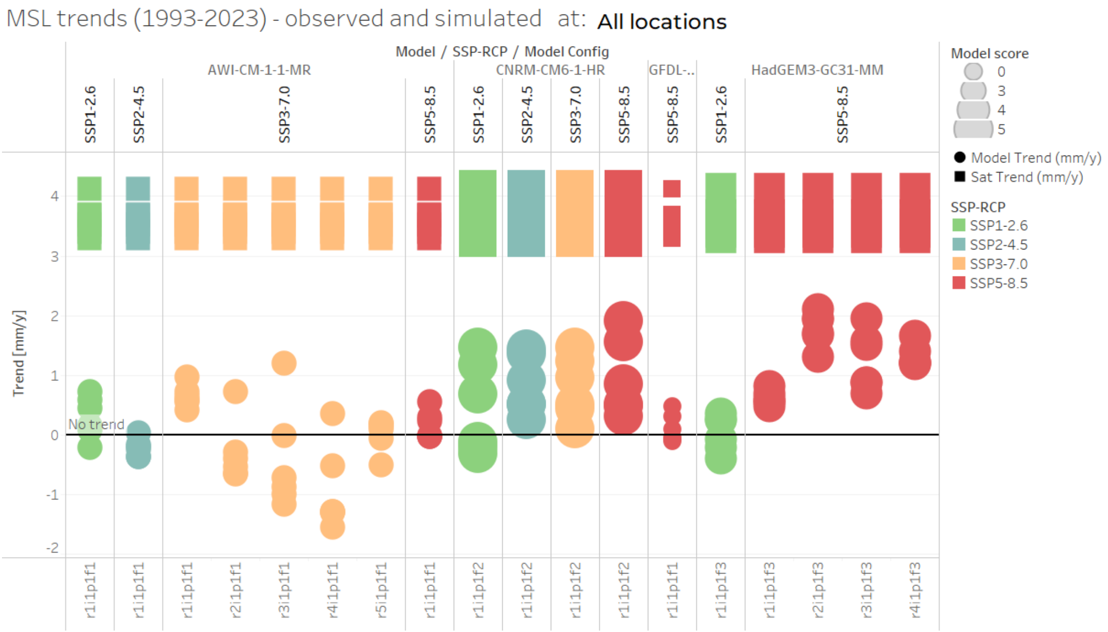


Figure 7.1: for each simulation, the filled circles report the value of the sea level trend, over the period 1993-2023, computed from simulations, while filled squares report the corresponding observed trends. The size of the circles and the squares are proportional to the score achieved by the model, according to the answers given to the eight questions detailed in session 6. Colors distinguish the future climate scenario to which the simulation refers to. The information of all the six project locations are presented in this plot.

The kind of plot presented in figure 7.1 is replicated for each project location in appendixes, retaining the data referring to the specific area only. That allows a detailed interpretation of the dataset likelihood for each of the datasets.

8. Deliverable indicators

This deliverable is summarized by means of the indicators reported here below. For each of them the expected indicator value and the actual one are presented. In addition, comments are reported too, if any.

Indicator	Expected value	Actual value	Comments
Documents	1	1	None

Further plots and supplemental material are available in Google Drive Data area [2.1]

9. Conclusions

MedSeaRise Activity 2.1 was conducted from the 2nd project period to the 4th and in the 3rd period delivered this document. This document acts as the deliverable describing the assessment of the likelihood for each dataset, on sea level future scenarios, according to a set of indicators which are suitably thought and computed for each Mediterranean sub basin area. The sub basin areas are identified according to the sea level rise risk survey information.

This deliverable contributes in achieving the goal of the Activity 2.1 which is summarized as providing the project with Data analysis of future sea level rise scenarios and scientific information review.

10. References to additional material

[1.1] Basecamp Key Production WP1

[2.1] Google Drive MedSeaRise shared area (MedSeaRise_Interreg Euro-MED)

[3.1] CMIP6 - Coupled Model Intercomparison Project Phase 6 https://wcrp-cmip.org/cmip-phases/cmip6/

[3.2] Earth System Grid Federation (ESGF) data search node https://aims2.llnl.gov/search

[3.3] Earth System Grid Federation (ESGF) https://esgf.github.io/mission.html

[3.4] CMIP Model and Experiment Documentation https://wcrp-cmip.org/cmip-model-and-experiment-documentation/

[3.5] The Intergovernmental Panel on Climate Change (IPCC) https://www.ipcc.ch/

[3.6] MedSeaRise Deliverable D.1.1.2 "Data collection on sea level rise scenarios"

[4.1] MedSeaRise Deliverable D.1.1.1 Knowledge and data availability on sea level rise projections.

[4.2] Specific documentation for model AWI-CM-1-1 Semmler, T., Danilov, S., Gierz, P., Goessling, H. F., Hegewald, J., Hinrichs, C., et al. (2020). Simulations for CMIP6 with the AWI climate model AWI-CM-1-1. *Journal of Advances in Modeling Earth Systems*, 12, e2019MS002009. https://doi.org/10.1029/2019MS002009 (https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2019MS002009)

[4.3] Specific documentation for model: HadGEM3-GC31-MM Sellar, A. A., Walton, J., Jones, C. G., Wood, R., Abraham, N. L., Andrejczuk, M., et al. (2020). Implementation of U.K. Earth system models for CMIP6. *Journal of Advances in Modeling Earth Systems*, 12, e2019MS001946.

https://doi.org/10.1029/2019MS001946 (https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2019MS001946)

[4.4] Specific documentation for model: CNRM-CM6-1-HR Voldoire, A., Saint-Martin, D., Sénési, S., Decharme, B., Alias, A., Chevallier, M., et al. (2019). Evaluation of CMIP6 DECK experiments with CNRM-CM6-1. *Journal of Advances in Modeling Earth Systems*, 11, 2177–2213. https://doi.org/10.1029/2019MS001683 (https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2019MS001683)

[4.5] Specific documentation for model GFDL-CM4 Held, I. M., Guo, H., Adcroft, A., Dunne, J. P., Horowitz, L. W., Krasting, J., et al. (2019). Structure and performance of GFDL's CM4.0 climate model. *Journal of Advances in Modeling Earth Systems*, 11, 3691–3727. https://doi.org/10.1029/2019MS001829 (https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2019MS001829)

[4.6] General information on CMIP6 are available here: Coupled Model Intercomparison Project Phase 6 (CMIP6) Experimental Design and Organization, Veronika Eyring, Sandrine Bony, Gerald A. Meehl, Catherine A. Senior, Bjorn Stevens, Ronald J. Stouffer, and Karl E. Taylor Geosci. Model Dev., 9, 1937–1958, https://doi.org/10.5194/gmd-9-1937-2016, 2016 (https://gmd.copernicus.org/articles/special_issue590.html)

[5.1] MedSeaRise Deliverable D.1.1.3 Knowledge and issues on sea level rise scenarios in Mediterranean area

[6.1] Semmler, T., Danilov, S., Gierz, P., Goessling, H. F., Hegewald, J., & Hinrichs, C. (2020). Simulations for CMIP6 with the AWI climate model AWI-CM-1-1. *Journal of Advances in Modeling Earth Systems*, 12, e2019MS002009. https://doi.org/10.1029/2019MS002009

[6.2[Sellar, A. A., Walton, J., Jones, C. G., Wood, R., Abraham, N. L., & Andrejczuk, M. (2020). Implementation of U.K. Earth System Models for CMIP6. *Journal of Advances in Modeling Earth Systems*, 12, e2019MS001946. https://doi.org/10.1029/2019MS001946

[6.3] Voldoire, A., Saint-Martin, D., Sénési, S., Decharme, B., Alias, A., & Chevallier, M. (2019). Evaluation of CMIP6 DECK experiments with CNRM-CM6-1. *Journal of Advances in Modeling Earth Systems*, 11, 2177–2213. https://doi.org/10.1029/2019MS001683

[6.4] Held, I. M., et al. (2019). Structure and Performance of GFDL's CM4.0 Climate Model. *Journal of Advances in Modeling Earth Systems*, 11. https://doi.org/10.1029/2019MS001829

[6.5] Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., & Taylor, K. E. (2016). Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization. *Geoscientific Model Development*, 9(5), 1937–1958. https://doi.org/10.5194/gmd-9-1937-2016

[6.6] Copernicus Climate Data Store - [Sea level gridded data from satellite observations for the global ocean from 1993 to present]

[6.7] The [Copernicus Climate Data Store]

11. Appendixes

In these appendixes, the information of the likelihood of MedSeaRise future scenarios datasets, which have been considered in the frame of the project are presented for each Mediterranean subareas.

Appendix A: Likelihood of model outputs in area LP1

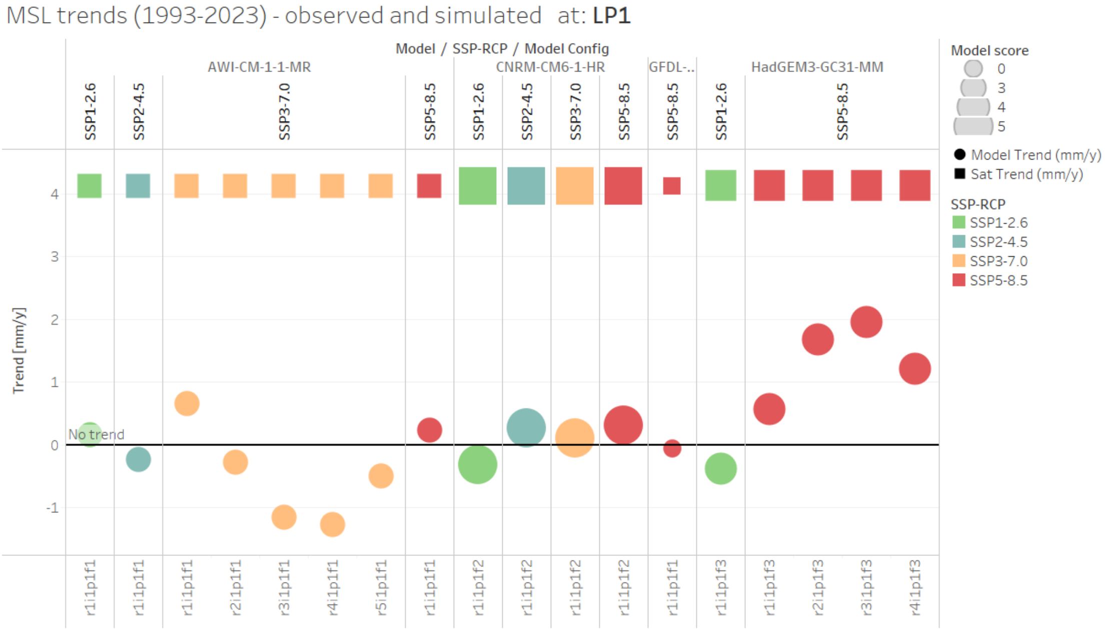


Figure A.1: Considering data related to project area LP1, the figure presents the comparison between the mean sea level trends computed from measurements, over the period 1993-2023, and the corresponding trend computed from the simulated dataset. For each dataset of future climate scenarios considered in the MedSeaRise project, the filled circles report the value of the sea level trend, computed from simulations, while filled squares report the corresponding observed trends. The size of the circles and the squares are proportional to the score achieved by the model, according to the answers given to the eight questions detailed in session 6. Colors distinguish the future climate scenario to which the simulation refers to.

Appendix B: Likelihood of model outputs in area PP2

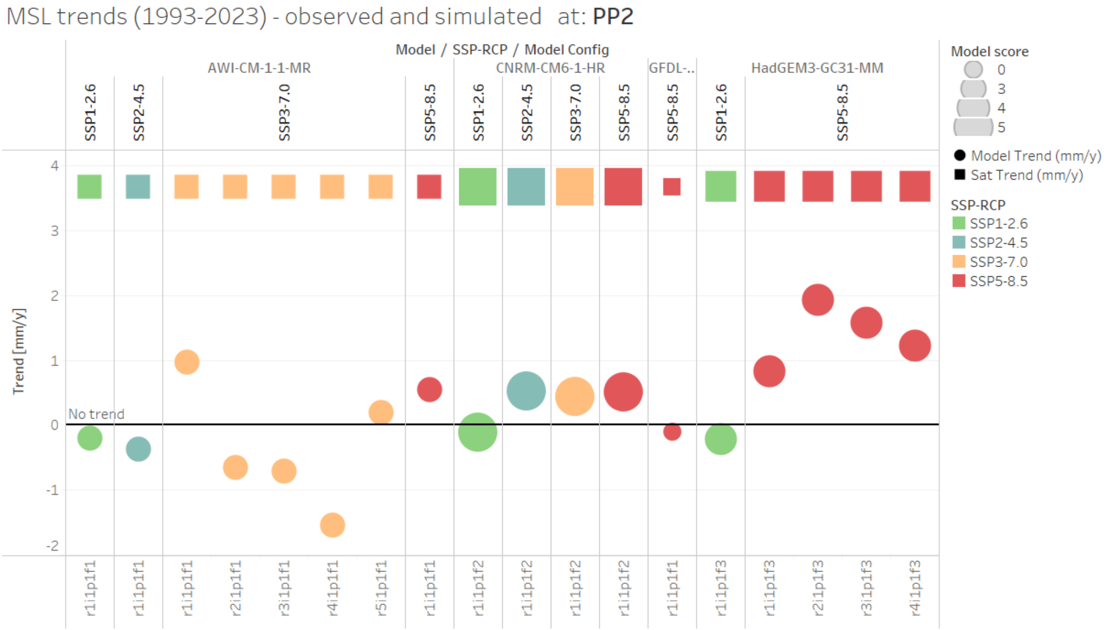


Figure B.1: Considering data related to project area PP2, the figure presents the comparison between the mean sea level trends computed from measurements, over the period 1993-2023, and the corresponding trend computed from the simulated dataset. For each dataset of future climate scenarios considered in the MedSeaRise project, the filled circles report the value of the sea level trend, computed from simulations, while filled squares report the corresponding observed trends. The size of the circles and the squares are proportional to the score achieved by the model, according to the answers given to the eight questions detailed in session 6. Colors distinguish the future climate scenario to which the simulation refers to.

Appendix C: Likelihood of model outputs in area PP3

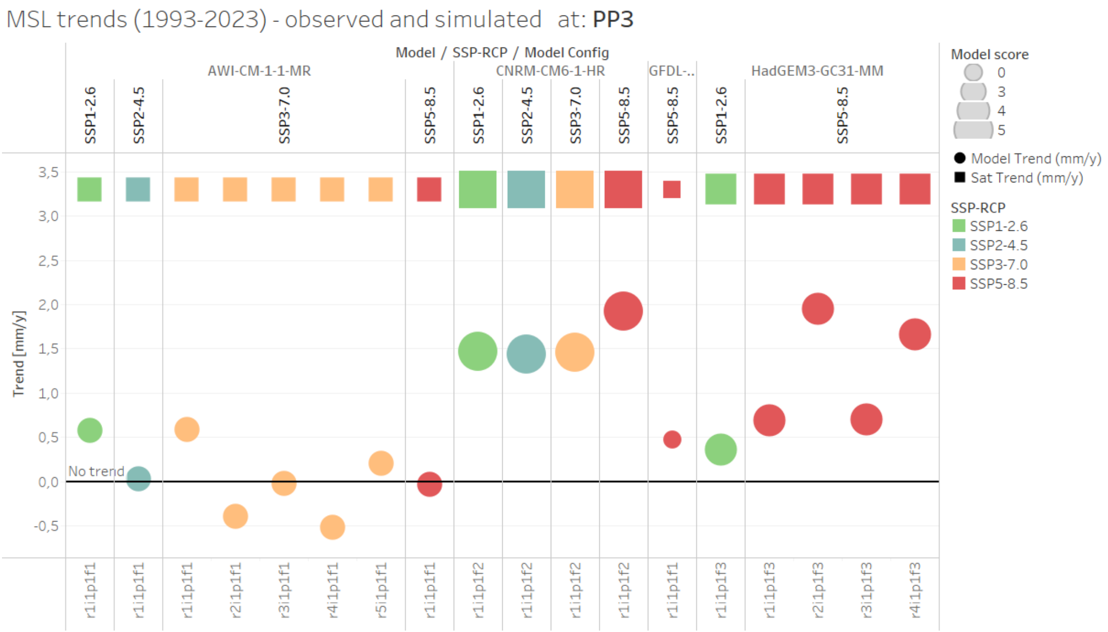
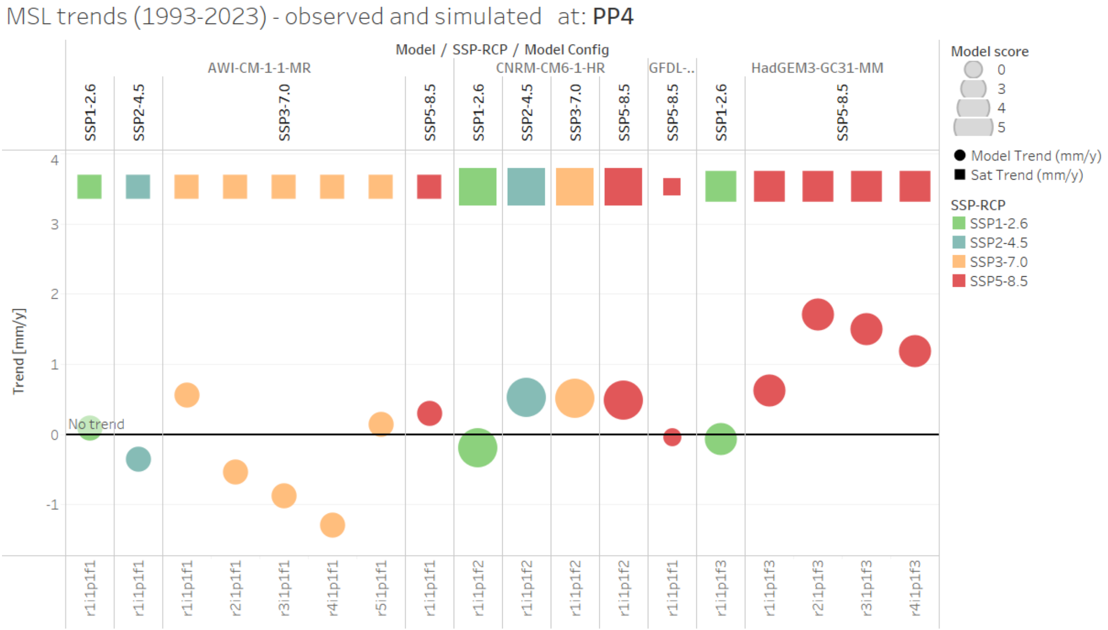


Figure C.1: Considering data related to project area PP3, the figure presents the comparison between the mean sea level trends computed from measurements, over the period 1993-2023, and the corresponding trend computed from the simulated dataset. For each dataset of future climate scenarios considered in the MedSeaRise project, the filled circles report the value of the sea level trend, computed from simulations, while filled squares report the corresponding observed trends. The size of the circles and the squares are proportional to the score achieved by the model, according to the answers given to the eight questions detailed in session 6. Colors distinguish the future climate scenario to which the simulation refers to.

Appendix D: Likelihood of model outputs in area PP4



fFF

Figure D.1: Considering data related to project area PP4, the figure presents the comparison between the mean sea level trends computed from measurements, over the period 1993-2023, and the corresponding trend computed from the simulated dataset. For each dataset of future climate scenarios considered in the MedSeaRise project, the filled circles report the value of the sea level trend, computed from simulations, while filled squares report the corresponding observed trends. The size of the circles and the squares are proportional to the score achieved by the model, according to the answers given to the eight questions detailed in session 6. Colors distinguish the future climate scenario to which the simulation refers to.

Appendix E: Likelihood of model outputs in area PP5

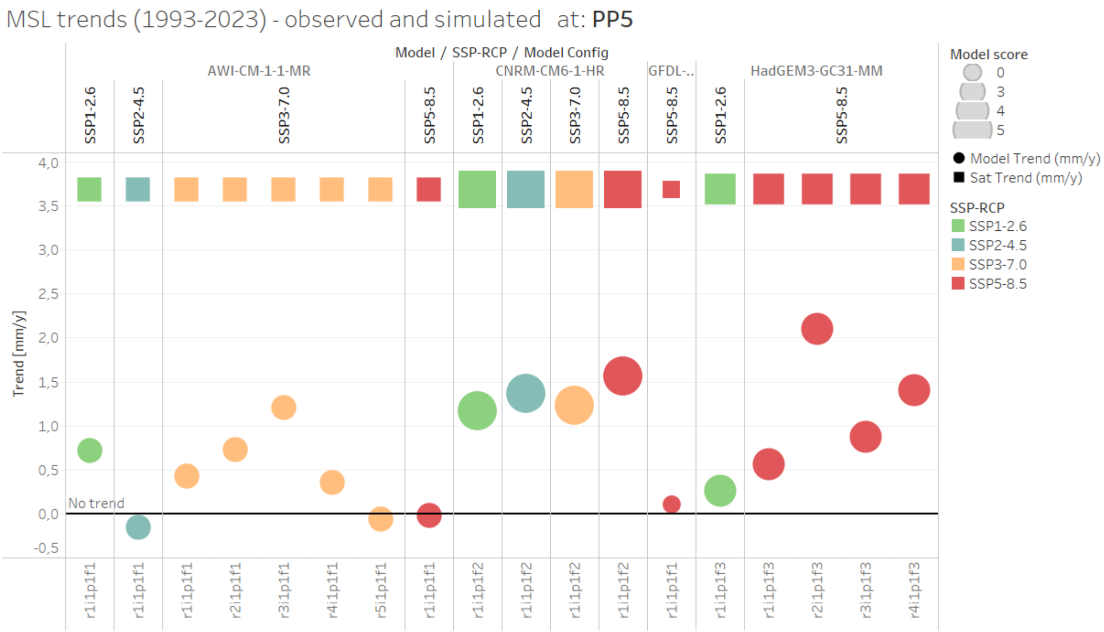


Figure E.1: Considering data related to project area PP5, the figure presents the comparison between the mean sea level trends computed from measurements, over the period 1993-2023, and the corresponding trend computed from the simulated dataset. For each dataset of future climate scenarios considered in the MedSeaRise project, the filled circles report the value of the sea level trend, computed from simulations, while filled squares report the corresponding observed trends. The size of the circles and the squares are proportional to the score achieved by the model, according to the answers given to the eight questions detailed in session 6. Colors distinguish the future climate scenario to which the simulation refers to.

Appendix F: Likelihood of model outputs in area PP6

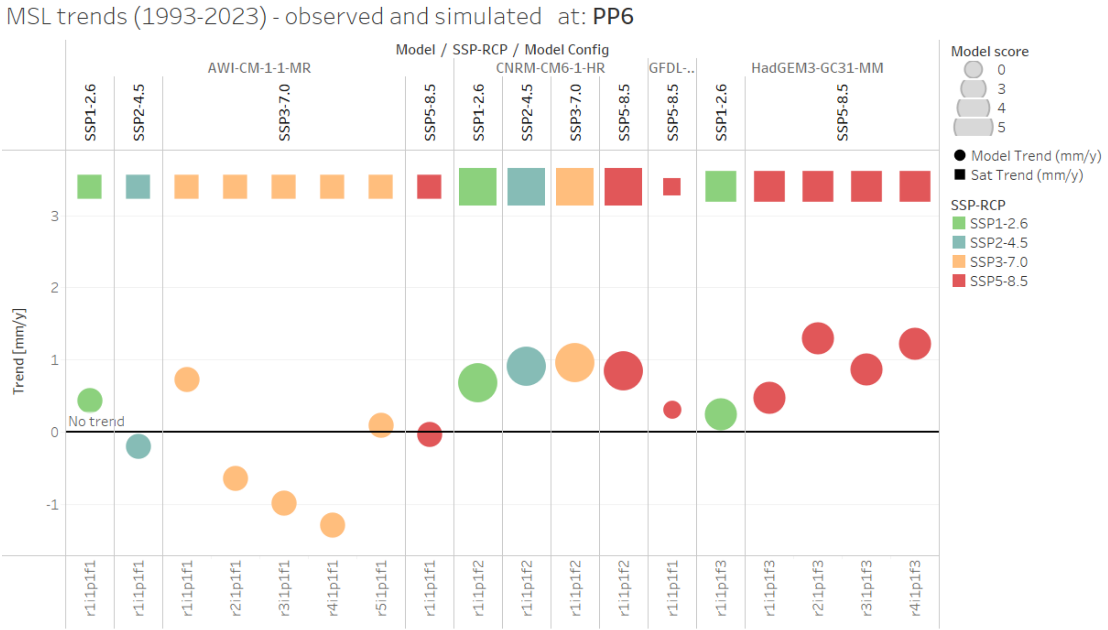


Figure F.1: Considering data related to project area PP6, the figure presents the comparison between the mean sea level trends computed from measurements, over the period 1993-2023, and the corresponding trend computed from the simulated dataset. For each dataset of future climate scenarios considered in the MedSeaRise project, the filled circles report the value of the sea level trend, computed from simulations, while filled squares report the corresponding observed trends. The size of the circles and the squares are proportional to the score achieved by the model, according to the answers given to the eight questions detailed in session 6. Colors distinguish the future climate scenario to which the simulation refers to.