WP3

Decadal horizon:

benefiting from realistic initialization.

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RIVIERADE – kick-off meeting

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WP3 contributors

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WP3 ambition

- By looking at the decadal horizon, one of the most innovative and ambitious aspects of RIVIERADE, we aim to assess the added value of accounting for the predictable component of the climate low-frequency variability and the benefits of downscaling in the basins of interest.

- The challenge of exploiting what state-of-the-art decadal predictions can offer (i.e., the added value of initialization and the regional predictability stemming from the global scale) to simulating regional seas at enhanced spatial resolutions has never been faced before.

- This represents an important and ambitious step forward, both in the direction of: ***(i)*** closing the gap between sub-seasonal-to-seasonal ocean forecasts and multi-decadal projections in terms of process representation, spatial resolution and harnessing the predictability of the climate system (referring to internal variability), and ***(ii)*** towards delivering seamless predictions at regional and coastal scales as required for the development of climate services.

Contributions to RIVIERADE Specific Objectives

SO1

Improve ocean and regional climate modelling capabilities to produce climate change impact assessment in European seas (BAL, BLK, MED) and their coastal area by: i) sharing, integrating and merging existing capabilities to improve the representation of ocean and marine ecosystem processes and dynamic into climate models, and ii) developing a common framework and protocol for multi-model multi-sea evaluation to assess the representativeness of the model ensemble against available observations and to quantify its uncertainties [number of coupled atmosphere-ocean-biogeochemical modelling systems used in the ensemble; number of coupled model simulation runs; reports on protocols and on model evaluation; and open peer-review publications] (**WP3**, WP4, WP5)

SO2

Delivering a coherent ocean dataset of a first-of-its-kind coordinated ensemble of high-resolution, multi-model, multi-sea, decadal to multi-decadal climate simulations for quality assessed indicators on ocean status and health at basin scale for the three target seas, including uncertainty quantification [reports on protocols, on model development, production of ESGF-ready datasets (raw data)] (**WP3**, WP4, WP5)

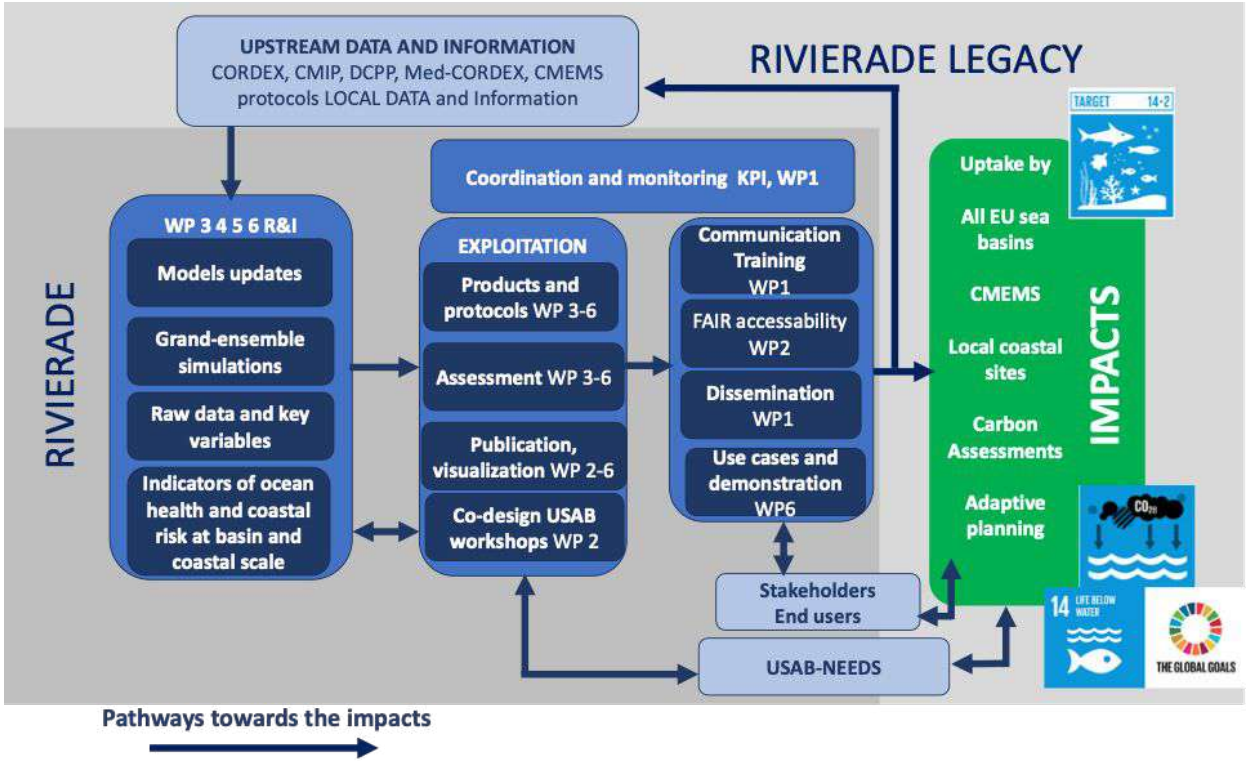
SO5

Delivery of a RIVIERADE catalogue produced in compliance with Open Science recommendation and FAIR principles, including key variables data sets, indicators, documents and codes, **to support future studies and further climate services**, and in order to favour the integration of project products and results into the digital perspective and the Digital Twin Ocean activities [digital catalogue] (WP2, **WP3**, WP4, WP5, WP6)

WP3 in the project context and overall architecture

WP3 is at the beginning of the project chain:

- modelling
- indicators
- services
- users
- impacts



WP3 in the project workflow

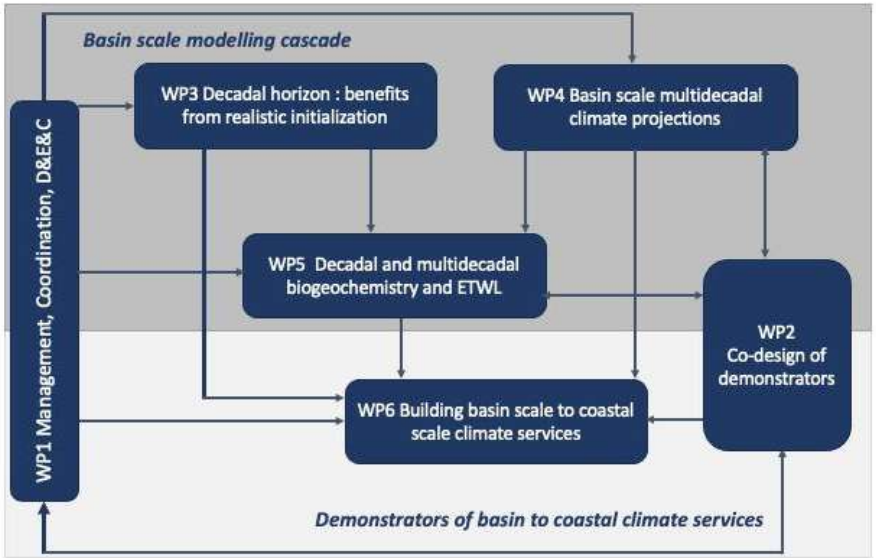
Inputs:
CMEMS observations & reanalysis, DCPP A-hindcasts, CMIP and CORDEX data for evaluation of the added-value. Input from WP2 to define details of the experimental design.

Outputs:
High-resolution model output (suitable portfolio of variables, CMOR-compliant files) to be made available to other WPs.

Core activities:
Decadal ensemble simulations (re-forecasts) and evaluation of the added value of initialization and downscaling.

Users:

- WP4 ⟶ Receive WP3 data for comparative evaluation.
- WP5 ⟶ Receive WP3 data for Tasks 5.3 (sea-level rise), 5.4 (decadal constrains).
- WP6 ⟶ Receive high-resolution WP3 data for ocean indicators (Task 6.1.1).
- Scientific community (recommendations).



WP3 interactions with other WPs

WP3 — WP1: continuous interaction and alignment with WP1 (financial management, monitoring, reporting, dissemination, exploitation).

WP3 — WP2: to interact with WP2 from early on so as to ensure that model design and model output in WP3 meet downstream application needs.

WP3 — WP4: exchange data for a comparative evaluation of decadal and multi-decadal simulations.

WP3 — WP5: provide data to WP5 for Tasks 5.3 (sea-level rise), 5.4 (decadal constrains).

WP3 — WP6: provide high-resolution data to WP6 for ocean indicators (Task 6.1.1).

WP3 Objectives

1) Develop downscaling approaches designed specifically for the three target seas and use them to produce high-resolution decadal predictions: models, methodologies (e.g., data assimilation, skill assessment), data from CMEMS will be integrated into the downscaling tools developed, in order to exploit the wealth of available knowledge and information from CMEMS, DCPP, international databases (e.g., EMODnet).

2) Provide predictions for the next 10 years in the target regions: these predictions will then be combined with the multi- decadal projections (outputs of WP4) to provide a coherent assessment of the future climate in the target regions for the coming decades (including an ex-post subsampling of the projections).

3) Share the high-resolution, high-quality, decadal prediction model data with the other WPs for their use in assessing decadal predictions of basin scale coastal impacts and inform users and stakeholders.

WP3 Methodologies

- Use decadal hindcasts from DCPP to provide the initial and boundary conditions of the dynamical donwscaling simulations. Yet, in contrast to CMIP ininitialized historical simulations and projections, DCPP predictions do not provide suitable data for dynamical downscaling. Therefore, different modelling approaches will be adopted in the three target seas by the WP3 partners;
  - for the BAL, high-resolution ocean–atmosphere coupled simulations will be produced, making use of IOW-ESM and MPI-ESM simulations (boundary conditions) and reanalysis products (including CMEMS) for initialization. Selected members will be chosen from the respective ensembles based on how well the former matched the observed variations [more information in the IOW presentation].
  - for the MED and BLK, instead, ocean-only simulations will be run. Initial conditions will come from available reanalysis, while the upper boundary conditions will be provided from DCPP systems exhibiting best skill in the respective basins. Suitable statistical downscaling will be applied to the 2D boundary conditions to match the ocean-model grid.
- Comparing the above-described downscaled simulations to the parent decadal predictions and observations in the hindcast period (1960–2020), will demonstrate the added value of higher resolution, whilst comparing the former to the downscaled historical simulations will assess the added value stemming from decadal predictability.
- All simulations will cover the decadal temporal horizon (1–10 years) with ensemble re-forecasts and will include the computation of very-high resolution of sea level rise and extreme total water level along all coasts of the three basins.

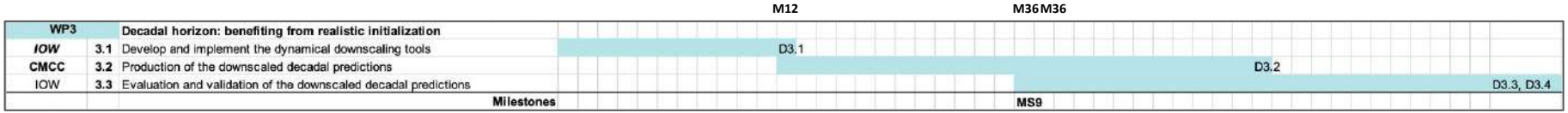
WP3 Tasks

Task 3.1 Develop and implement the dynamical downscaling tools [**M1–M12**] (**IOW**, CMCC, SMHI, ULiege).
This task will develop a protocol for each target basin according to its specificity, using global and regional models, observational data and CMEMS reanalysis products (see Section 1.2, methodological pillar n.2). Protocols will consider coordination with WP4 and WP5. Interactions with other WPs in kick-off and quarterly meetings will ensure decadal predictions meet downstream application needs (WP2). Dynamical models will be implemented and tested in target domains.

Task 3.2 Production of the downscaled decadal predictions [**M12–M36**] (**CMCC**, IOW, SMHI, ULiege).
All the model simulations (dynamical downscaling) will be produced, post-processed and shared across the project. Specific data standards will be followed, to the largest part ensuring compatibility with DCPP model output (data suitable to be flagged and uploaded on ESGF nodes).

Task 3.3 Evaluation and validation of the downscaled decadal predictions [**M24–M48**] (**IOW**, CMCC, SMHI, ULiege).
The downscaled decadal oceanic predictions will be comparatively assessed in respect to the WP4 and WP5 simulations.

WP3 Deliverables & Milestones



D3.1 – Report on modelling methods and experimental protocols for dynamical downscaling of decadal predictions in regional seas.
Task 3.1, [M12, **SMHI**]

D3.2 – Report on delivery of the downscaling model simulations.
Task 3.2, [M36, **CMCC**]

D3.3 – Report on valuation of downscaled decadal predictions for regional seas.
Task 3.3, [M48, **IOW**]

D3.4 – Report on recommendations for the production of regional climate predictions in the format of a white paper for the scientific community.
Task 3.3, [M48, **IOW**]

MS9 – Initial ensemble of decadal downscaling simulations ready to be used in other WPs. DATA, CMOR-complient files in the CINECA internal storage [M24, **CMCC**]

Risks

- **Insufficient computational resources to perform the WP3 basin-scale simulations (low/high).**

  Most of the modelling centres have access to their own supercomputing which guarantees the computing hour access. Some partners can increase their simulation contribution in case of partner failure. Also, ensemble sizes and number of start-dates in the hindcasts can be adjusted accordingly.

- **Failure in producing high-quality dynamical WP3 downscaling of the decadal forecasts due to missing forcing data, or lower than expected predictability of the climate in the target seas (low/medium).**

  Even if the forcing data are missing, or if these data are of poor quality, predictive skill can still be expected through the initialisation or an improved spin-off strategy of the three target seas. Initialisation data are available through CMEMS and DCPP products.

- **CMIP7 external forcings are not available in time (low/medium).**

  Partners can still use existing CMIP6 / CMIP6plus simulations to provide boundary forcings.

- **Substantial drifts in the regional simulations limit the value of the respective model output.**

  The anomaly-initialization strategy may be employed to avoid this problem.

Work plan for the first year

Task 3.1 – Develop and implement the dynamical downscaling tools [M1–M12]

Each partner to verify the technical details and the requirements of their experimental design, discuss possible issues/problems with the WP3 leads and prepare and test the model configuration (including a preliminary analysis of sample output) – [M1–M9].

D3.1 – Report on modelling methods and experimental protocols for dynamical downscaling of decadal predictions in regional seas [M12, SMHI].

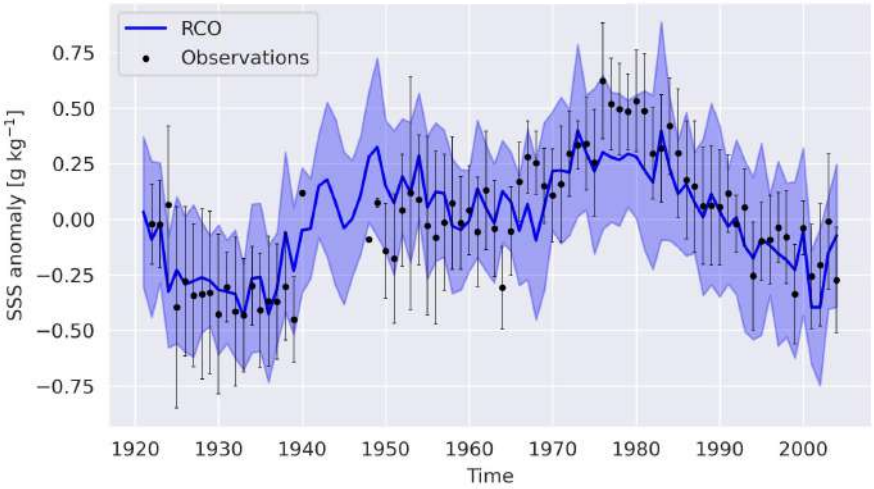
Each partner to provide early input for this Deliverable, including a detailed description of their experimental design (specifications, required input, defined data output, expected added value, etc).

Questions?

WP3 - partner contributions (IOW)

Rationale: teleconnections between the North Atlantic and the Baltic Sea region: low-frequency variability is probably caused by the AMV / NAO.

Sea surface salinity

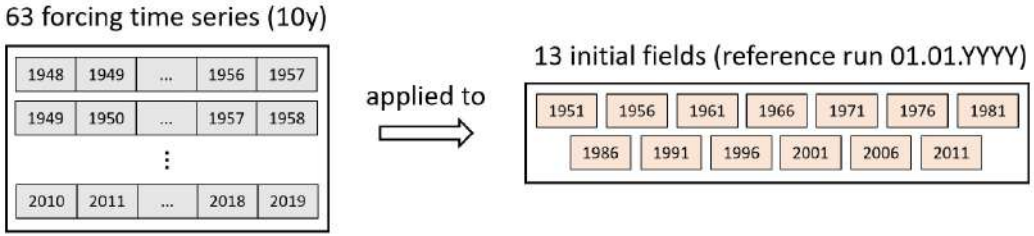


Meier et al. (2023), npj climate and atmospheric science
https://doi.org/10.1038/s41612-023-00380-9

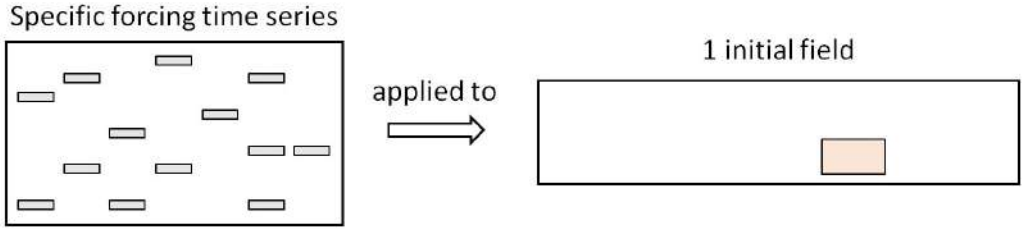
WP3 - partner contributions (IOW)

Experimental design & planned work

- Reference run 1948–2019
- Full ensemble of 819 members (10-yr simulations)



- Subsampling of the forcings:



(MSc thesis of Marti Wolff)

- Analysis of climate variability across Europe (Northern Europe) to better understand low-frequency variability in temperature and precipitation (e.g. 30-year variability of precipitation over the Baltic Sea region)
- Selection of ensemble members with AMOC, NAO states, etc. in existing SMILE simulations
- Determination of predictability for Northern Europe and the Baltic Sea through downscaling using “identical twin” experiments
- Downscaling of CMCC DCPP data, predictions and comparison with observations.

WP3 - partner contributions (SMHI)

- Running subsample of IOW ensemble (multimodel)
- Analysis of predictability for biogeochemistry and physical variables
- Analysis of long term memory, perhaps it can be in the sediments?
- Perhaps an analysis of numerical noise
- Leading D3.1: report on modelling methods and experimental protocol for decadal prediction in regional seas.

WP3 - partner contributions (CMCC)

CMCC plans to **assess the added-value of initialization and that of dynamical downscaling** in simulating marine extremes and low-frequency variations in the Mediterranean Sea and the Black Sea through the use of an ensemble of decadal re-forecasts contributed to DCPP and used currently in the C3S decadal operational service (C3S2_375 contract).

For this CMCC willl **employ a regional configuration of NEMO[1] at 1/16° resolution** and will run this model with lateral and surface boundary conditions provided by the global decadal predictions (ocean-only dynamical downscaling).

This exercise will be repeated running an **ensemble of simulations for a number of start-dates** —regularly spaced in the post-1960 historical period— so as to allow for an assessment of both the realism of the extremes and the predictive skill of low-frequency variations in the Med & Black Seas against observations & ocean reanalyses.

After the added value of initialization and downscaling is demonstrated, the natural extension of these retrospective downscaled regional marine forecasts will be to run respective **real-time forecasts**, an exercise that we commit to conduct in the second half of the project.

WP3 - partner contributions (ULiege, 3MM)

(tentative)

Simulation 1–10 years using the coupled ocean atmospheric system run in WP4 initialized with CMEMS reanalysis and ERA5 (DCPP?) for MAR. Assessment of the predictability of seasonal/ interannual/decadal scale: Intercomparison exercise of CMEMS (reference), WP3, WP4 model simulations, (DCPP?).

2 decades

- 2015-2025: (Sentinel Era), hindcast
- 2028-2038 (Forecast)

Comparison of the two sets of simulation in representing the Black Sea dynamics (stratification, Cold content, MLD dynamics).

Simulations performed in WP3 will be done using the same atmosphere-ocean modelling system but changing the initial conditions.