RIVIERADE

Kick-off meeting

Trieste 16-18 Feb 2026

WP5 Basin-scale decadal predictions and multi-decadal projections for the European target seas biogeochemistry and extreme total water level

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This project has received funding from Horizon Europe RIA under Grant Number 101181983

Please list all partners who will contributing to this WP

WP5 contributors

OGS

LIÈGE université

cnrs

SMHI

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

IHE DELFT Institute for Water Education
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iow

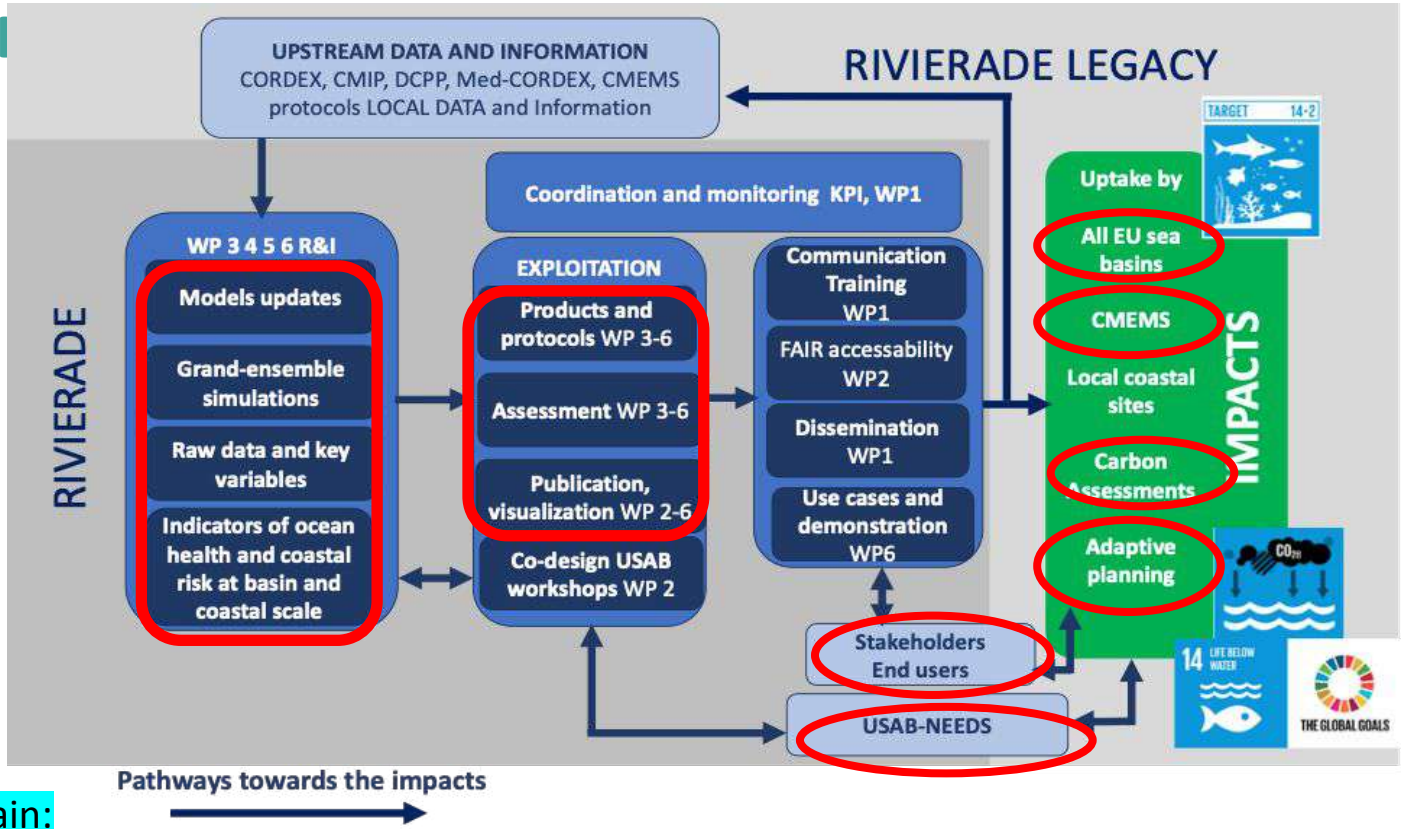
ENEA

WP5 Contributions to RIVIERADE SOs

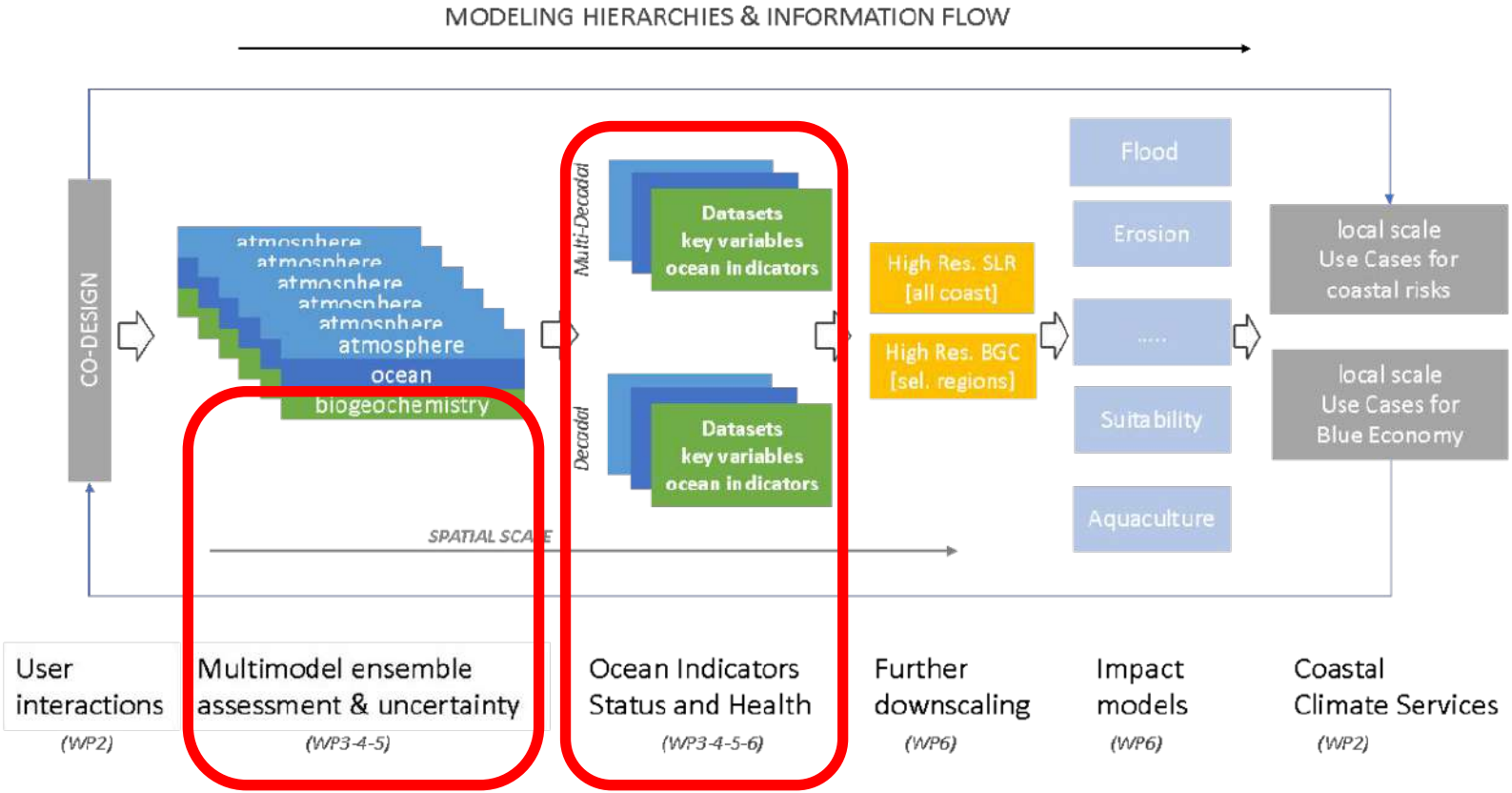
Table 1.1. *RIVIERADE specific objectives.*

SO#	Specific Objective [means of verification] and WPs
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)
SO4	Delivery of regional ocean climate impact/risk services and of regional ocean climate services supporting blue economy (aquaculture, fishery, tourism) in 4 *local selected coastal sites* to be chosen and co-designed with end-users and stakeholders board. [use cases documentation, fact sheets] (WP1, WP2, WP5, WP6)
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)

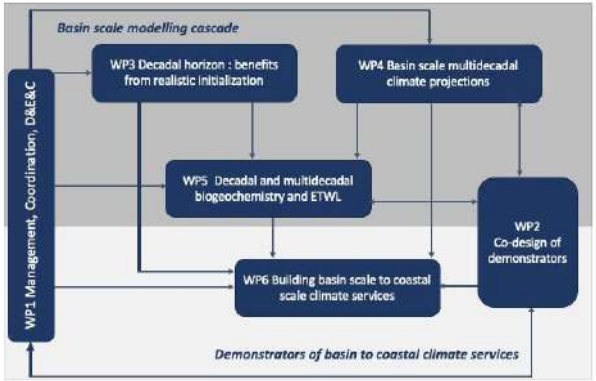
WP5 in the project context and overall architectu



Its position along the chain:
modelling → indicators → services → users → impacts


MODELING HIERARCHIES & INFORMATION FLOW
CO-DESIGN
atmosphere
atmosphere
atmosphere
atmosphere
atmosphere
atmosphere
ocean
biogeochemistry
Multi-Decadal
Datasets
key variables
ocean indicators
Decadal
Datasets
key variables
ocean indicators
SPATIAL SCALE
High Res. SLR
[all coast]
High Res. BGC
[sel. regions]
Flood
Erosion
.....
Suitability
Aquaculture
local scale
Use Cases for
coastal risks
local scale
Use Cases for
Blue Economy
User
interactions
(WP2)
Multimodel ensemble
assessment & uncertainty
(WP3-4-5)
Ocean Indicators
Status and Health
(WP3-4-5-6)
Further
downscaling
(WP6)
Impact
models
(WP6)
Coastal
Climate Services
(WP2)

WP5 in the project workflow



Inputs:
Physical decadal predictions from WP3
Physical multi-decadal projections from WP4
CMEMS observations & reanalysis
Riverine nutrient scenarios

Outputs:
Basin-scale BGC indicators
ETWL projections & coastal hazard forcing
Climate change impact assessment

Core activities:
BGC model development & validation
ETWL modelling (RSLR + surge + tides + waves)
Decadal & multi-decadal simulations
Ensemble production and uncertainty assessment

Users:
- WP6 ⟶ indicators, coastal risks, local services
- WP2 ⟶ co-designed demonstrators
- Scientific community & CMEMS downstream services

WP5 interactions with other WPs (1)

Interactions with WP3

Exchange of: physical forcings, initialization
Joint design of: decadal BGC prediction framework

Key challenge: consistency between physical and biogeochemical decadal signals

Interactions with with WP4

Input: physical ensemble simulations, ETWL

Joint definition of: simulation protocols and scenario consistency

Output: coherent multi-decadal BGC & ETWL projections

WP5 interactions with other WPs (2)

Interactions with WP6

Exchange of: biogeochemical variables, SLR, ETWL projections

Joint design of: indicators, coastal hazard product, risk metrics

Iterative development: tuning outputs to services needs

Interactions with with WP2

Contributes to: demonstrators, service validation, uncertainty communication

Joint definition of: indicators …

Iterative development: based on users feedback

WP5 Objectives

1. **Design, produce, evaluate and analyse a first-of-its-kind coordinated grand ensemble of high resolution, multi-model, multi-sea and multi-decadal climate simulations** (hindcast and projections) for the biogeochemistry and the extreme water total levels in the three target European seas.

2. **Provide an assessment of the climate change impact on the target seas biogeochemistry** and extreme water levels at the basin scale and at the decadal and multi-decadal temporal scale.

3. Establish the basis for the **development of the climate services at basin to coastal scales** in WP2 and WP6.

4. **Standardise and share** the simulation outputs as a project legacy for further use in climate services. (SO1, SO2, SO4, SO5)

WP5 Methodologies, biogeochemical modelling

Coordinated runs for decadal and multi-decadal horizons

Definition of simulation and calculation protocols for biogeochemical models applied to the BLK, BAL ad MED basins

Identification of the **coupling strategies** of the multi-model grand ensemble simulations (online/offline)

Definition of the **experiment design:** hindcast + historical + future scenarios (SSP1-2.6, SSP3-7.0)

Ensure **physically consistent forcings**: atmosphere, rivers/nutrient inputs, ocean lateral boundary conditions

Definition of products (nutrients, oxygen/carbon cycles, plankton functional types)

Model evaluation: vs observations/reanalysis + ensemble-based uncertainty quantification

WP5 Methodologies, ETWL

Definition of simulation and calculation protocols for extreme water total level models

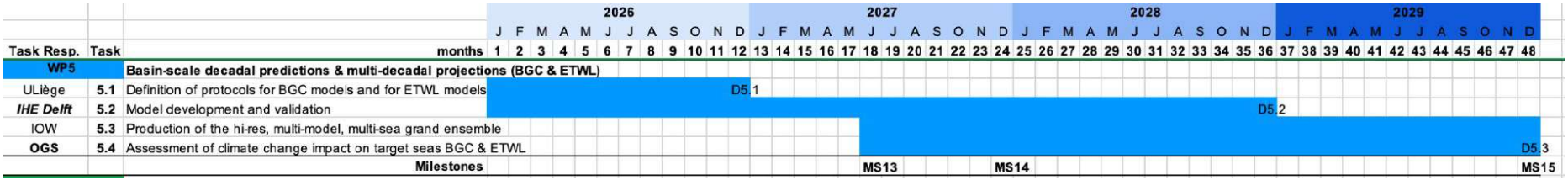
Computation of **very-high-resolution sea level rise and Extreme Total Water Level (ETWL)** along all coastlines of the Baltic, Black and Mediterranean Seas

ETWL estimated using a **probabilistic framework** combining Relative Sea Level Rise, tides, storm surge, and wave setup

Simulations performed for **baseline and future climate scenarios (SSP1-2.6, SSP3-7.0)** and **multiple return periods (1–1000 years)**

ETWL computed at **high coastal resolution** and used as **boundary conditions for coastal flood and erosion risk modelling**

WP5 Timeline, Deliverables and Milestones



Tasks:

Task 1, ULiége:1-12 Task 2, IHE Delft: 1-36 Task 3, IOW: 18-48 Task 4, OGS: 18-48

Milestones

MS 5.1 BGC and ETWL model configuration ready and start of the production. (Task 5.2). [M18, IHE Delft]

MS 5.2 Initial ensemble of hindcast simulations ready to be used for WP6 (Task 5.2). [M24, SMHI]

MS 5.3 Final list of simulations and CMOR-compliant and ESGF-ready files. (Task 5.3). [M48, IOW]

Deliverables

D5.1 Final protocol documents for the coordinated BGC and ETWL grand ensemble (Task 5.1). [M12, ULiege]

D5.2 Report on model development and evaluation for BGC and ETWL models (Task 5.2). [M36, IHE Delft]

D5.3 Production of climate change assessment in the three target European seas based on the BGC and ETWL grand ensemble (Task 5.4). [M48, OGS]

Working discussion: Task 5.1

Definition of simulation and calculation protocols for biogeochemical models and for extreme water total level models (M1-M12) (ULiege, all PPs)

Definition of the rules for the production of:

Biogeochemical simulations and their products (e.g., nutrients, oxygen, pH, carbonate chemistry, low to mid trophic level variables, primary production) and **Extreme total water level.**

The protocol will define:
the **coupling strategy** (offline or online), **physical forcings** and **boundary conditions** (including scenarios of nutrients input from rivers, computed by considering river freshwater loads and land use and land use change scenarios) for the **hindcast, historical runs, decadal predictions and multi-decadal projections -**selection of the corresponding simulations performed within WP3 and WP4 (hindcast, historical and scenarios SSP1- 2.6, SSP3-7.0) the **list of output variables** with **spatial and temporal resolution**; the **filenames standardisation**

The **protocol** guidelines will be **shared** with the international community through WP1 (e.g., contributing to the biogeochemical working groups into Med-CORDEX, HELCOM and ICES). This task will be performed in coordination with Tasks 3.1 and 4.1.

Working discussion: Task 5.2

Model development and validation (M1-M36) (IHE Delft, all PPs)

Biogeochemical model development, running and validation:
Development and evaluation of model configurations
Production of hindcast runs, comparing results with available reference datasets to estimate model uncertainty.
Validation will align with CMEMS quality assessment framework for biogeochemical products.
A multi-coupling approach for biogeochemical models with ocean physics (offline and online) will be adopted for the three target seas.

Extreme Total Water Level validation:
Development of extreme total water level (ETWL = RSLR + tide + storm surge + wave setup) using available AR6 RSLR projections.
Development of present-day RSLR scenarios for the three target seas, using as input the grand ensemble steric and dynamic contributions to SLR produced in WP4, and adding other components such as regional variations of SL, VLM, GIA etc. from sources used in IPCC AR6 presentday baseline scenario. Validation of ETWL against available global and regional reference datasets.

Working discussion: Task 5.3

Task 5.3 Production of the high-resolution, multi-model, multi-sea grand ensemble of multi-decadal projections and of selected decadal predictions [M18-M48] (IOW, all PPs)

Biogeochemical model production for decadal and multi-decadal horizon: Production of the ensemble of multidecadal, historical and scenario BGC simulations in the three seas production of CMOR-compliant ready for ESGF BGC model outputs, in line with CORDEX CMIP6. Selected **decadal predictions** of BGC in the three target seas, initialised with CMEMS products, will be carried out with ocean-atmosphere physics produced in WP3.

Extreme Total Water Level projections for decadal and multi-decadal horizon: Production of multi-decadal scale probabilistic RSLR scenarios for the 3 target seas, input from WP4, (and WP3 for **decadal predictions**) and from external forcing defined as used in IPCC AR6. Combination of RSLR scenarios with storm surge, wave setup and tide data to develop ETWL projections.

Working discussion: Task 5.4

Task 5.4 Assessment of climate change impact on target seas biogeochemistry and extreme water total level [M18-M48] (OGS, all PPs)

Assessment of the key state variables of the BGC and ETWL models
Uncertainty quantification (with Tasks 3.3 and 4.4).
Guidance on how to best use or sub-sample the grand ensemble depending on the applications (with T. 4.4) , including the definition of possible plausible futures, the placing of the WP5 ensemble within the larger CMIP6 ensemble, as well as the *use of WP3-derived constraints to sub-sample the grand ensemble for the study of the next 10 years.*

List as appropriate with due date and partner responsible for Deliverable/Milestone

Deliverables and Milestones

Deliverables

- D5.1 Final protocol documents for the coordinated BGC and ETWL grand ensemble (Task 5.1). [M12, ULiege]
- D5.2 Report on model development and evaluation for BGC and ETWL models (Task 5.2). [M36, IHE Delft]
- D5.3 Production of climate change assessment in the three target European seas based on the BGC and ETWL grand ensemble (Task 5.4). [M48, OGS]

Milestones

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Work plan for the first year

			2026												
			J	F	M	A	M	J	J	A	S	O	N	D	J
Task Resp.	Task	months	1	2	3	4	5	6	7	8	9	10	11	12	13
WP5		**Basin-scale decadal predictions & multi-decadal projections (BGC & ETWL)**													
ULiège	**5.1**	Definition of protocols for BGC models and for ETWL models												D5.1	
IHE Delft	**5.2**	Model development and validation													
IOW	**5.3**	Production of the hi-res, multi-model, multi-sea grand ensemble													
OGS	**5.4**	Assessment of climate change impact on target seas BGC & ETWL													
		Milestones													

WP5 Methodologies

Table 1.2. *RIVIERADE modelling platforms (components, spatial resolution) for the multi-decadal simulations at basin-scale (ocean physics, PHY, biogeochemistry, BGC, ETWL, coastal flooding, CF, coastal erosion, CE). [1]: model configuration involved in CORDEX before the start of the project, [2]: model configuration involved in CMEMS before the start of the project. IOW, CMCC, SMHI, ULiege modelling platforms used for downscaling decadal predictions will match or be largely based on these configurations.*

Partner	Atmosphere and land surfaces	Land hydrology and rivers	Ocean PHY	Ocean BGC	ETWL, CF, CE	Target sea
IOW[1] **(a)**	CCLM 12 km	ML routing 12 km	MOM5 5.4 km	ERGOM 5.4 km	-	BAL
SMHI[1,2] **(b)**	HCLIM43-ALADIN 12 km	EHYPE4 per catchment	NEMO-Nordi 3.7 km	SCOBI 3.7 km	-	BAL
ULiege[2] **(c)**	MAR 10 km	CTRIP 10 km	NEMO4.2 2.5 km	BAMHBI 2.5 km	-	BLK
METU[2] **(d)**	HCLIM43-ALADIN 12 km	Wflow-SBM 2 km	NEMO 3 km	TURSEM 3 km	-	BLK
CMCC[1,2] **(e)**	WRF-ARW 12 km	Hydros 11 km	NEMOMFS 6 km	BFM 6 km	-	BLK MED
CNRS-CNRM[1] CNRS-LEGOS[1] **(f)** OGS[2] **(g)**	ALADIN 12 km	CTRIP 10 km	NEMOMED 6 km	ECO3M-S 6 km BFM 6 km	-	MED
ENEA[1] **(h)**	WRF 12 km	CaMa-flood 3 min	MITgcm 9 km	DARWIN 9 km	-	MED
IHE Delft **(i)**	-	-	-	-	SFINCS 12 km*^	All

(a) Steger and Bucchignani, 2020; Neumann et al., 2022; Karsten et al., 2024. **(b)** Hordoir et al., 2019; Ruvalcaba Baroni et al., 2024. **(c)** Grégoire et al., 2008. **(d)** Butenschön et al., 2016; Yakushev et al., 2007, 2017; Salihoglu et al., 2017, Sadighrad et al., 2021. **(e)** Conte et al., 2020; Skamarock et al., 2019; Lawrence et al., 2019; Clementi et al., 2023. **(f)** Sevault et al., 2014; Waldman et al., 2018; Nabat et al., 2020; Darmaraki et al., 2019b; Moullec et al., 2019; Ulses et al., 2023. **(g)** Reale et al., 2020; Marshall et al., 1997; Vichi et al., 2015. **(h)** Marshall et al., 1997; Yamazaki et al., 2011, 2013; Anav et al., 2024. **(i)** Leijnse et al., 2021. *Modified Bruun Rule 1 km; ^PCR model + ShorelineS (1 km) in MED.

Risks

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

Delay in producing the physics basinscale multi-decadal grand ensemble which will delay the WP5 and WP6 work (medium/medium)

Not all planned model devolpment completed in due time due to the short development phase and acknowledging the inherent risks related to complex model development (high/low)

Others?

Questions?

RIVIERADE

Partners