Climate Change

Supporting European coastal sectors to adapt to changes in extreme sea levels

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Introduction | Coasts are high-risk regions

110 million people live in flood prone areas [2]

Without adaptation, climate change may triple this number [2]

Global models can support decision-making on mitigation and adaptation [3]

Photo by Paul Morse

[1] Kulp & Strauss (2019). Nature communications,

[2] Hinkel et al. (2014) PNAS

[3] Ward et al. (2016) Nature Climate Change

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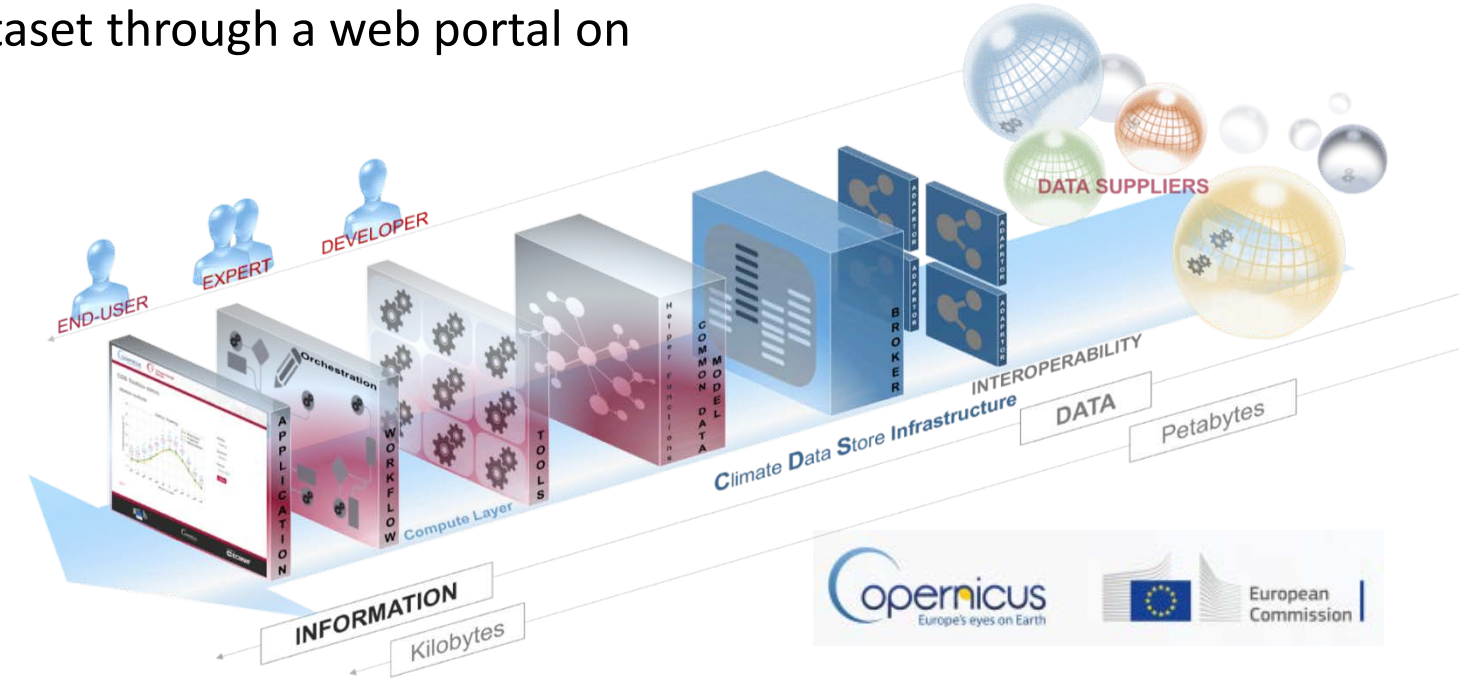
Introduction | Why develop this new climate service?

Room to improve upon the previous available data sets

- Recent **advances** in global modeling of extreme sea levels
- New **climate reanalysis** available with better performance

Project goals

- To develop a consistent European dataset for tides and storm surges, for both present-day and future climate conditions
- To provide easy access to the dataset through a web portal on Copernicus Climate Data Store



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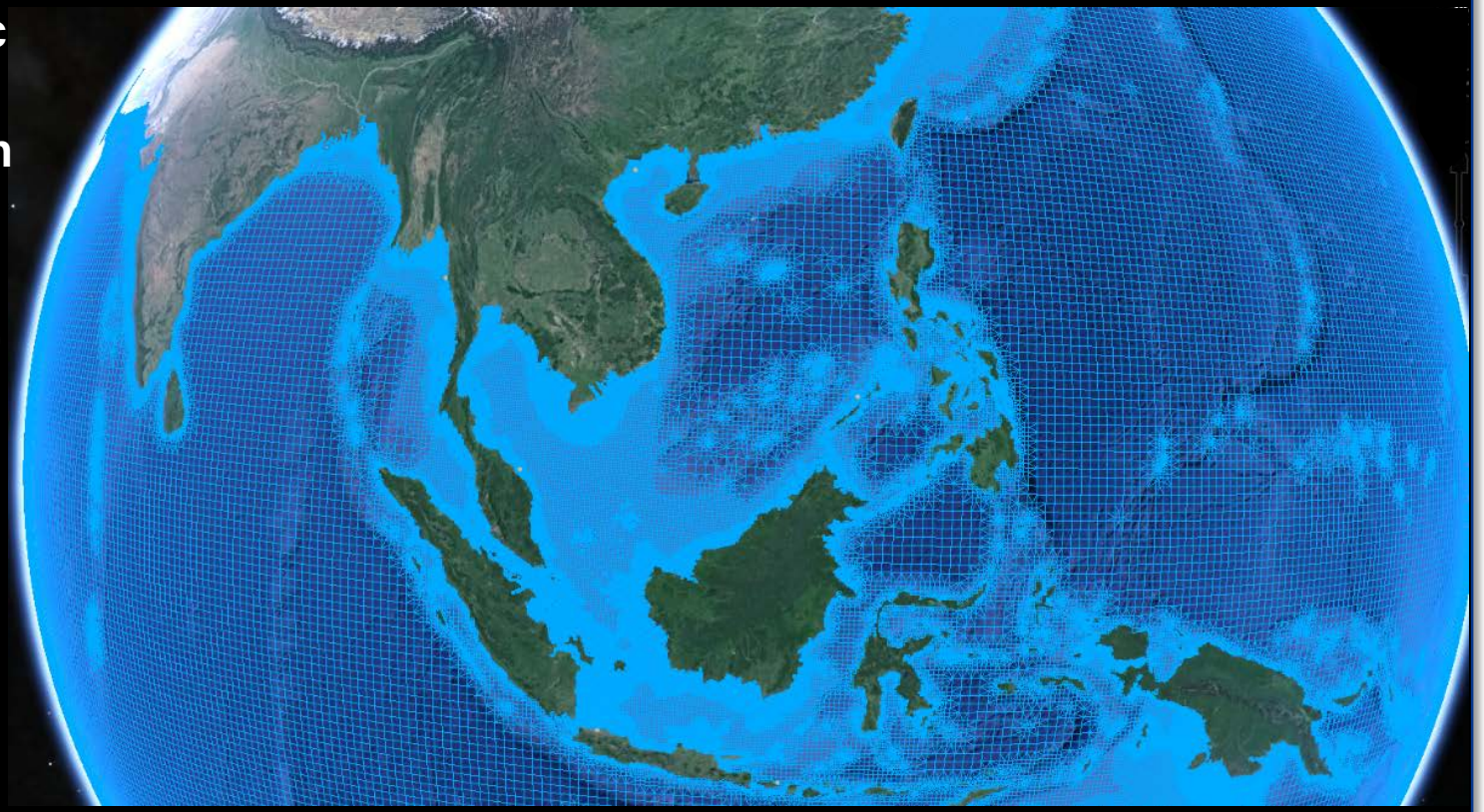
Methods | Global modelling of extreme sea levels

Global hydrodynamic model based on Delft3D Flexible Mesh

Global Tide and Surge Model (GTSM)

- 2D barotropic model with global coverage
- Unstructured global grid with varying spatial resolution
- Including interaction effects



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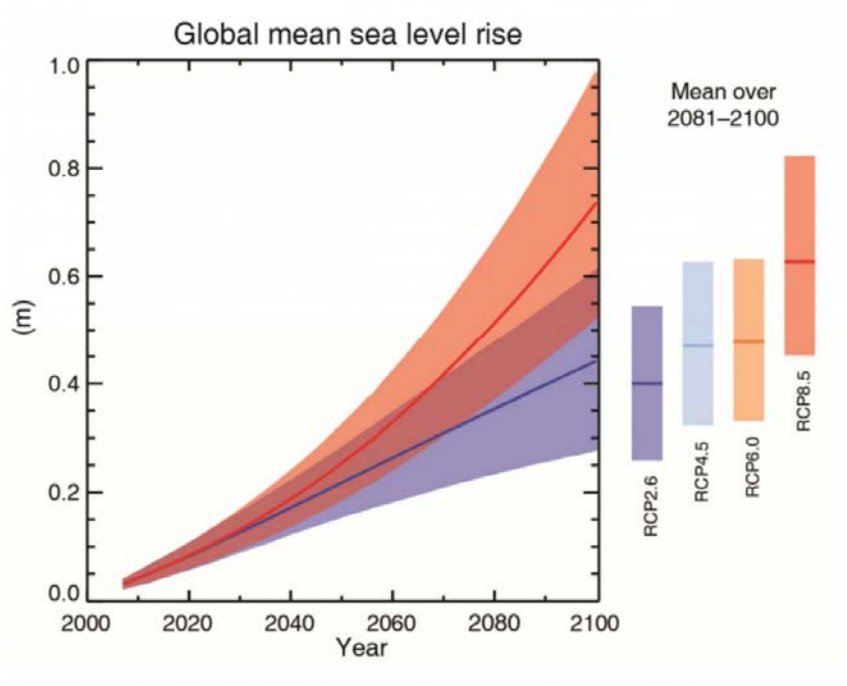
Methods | Scenarios and simulations

Simulation	Type	Period	Meteorological forcing	SLR scenarios
CoDEC-ERA5	Climate reanalysis	1979–2017	ERA5	–
CoDEC-HIST	Baseline climate scenario	1976–2005	EC-Earth CMIP5, DMI-HIRHAM5 for Europe	–
CoDEC-RCP8.5	Future climate scenario	2041–2070	EC-Earth CMIP5, DMI-HIRHAM5 for Europe	IPCC-AR5 ensemble mean RCP8.5
CoDEC-RCP4.5	Future climate scenario	2071–2100	EC-Earth CMIP5, DMI-HIRHAM5 for Europe	IPCC-AR5 ensemble mean RCP4.5

What output is produced?

- Timeseries
  - Total water levels
  - Tides
  - Surge residual
  - Annual mean sea level
- Climate Change Indicators
  - Tidal levels
  - Percentiles
  - Return periods
- Total size: 20TB
- Total runtime: 500k core hours



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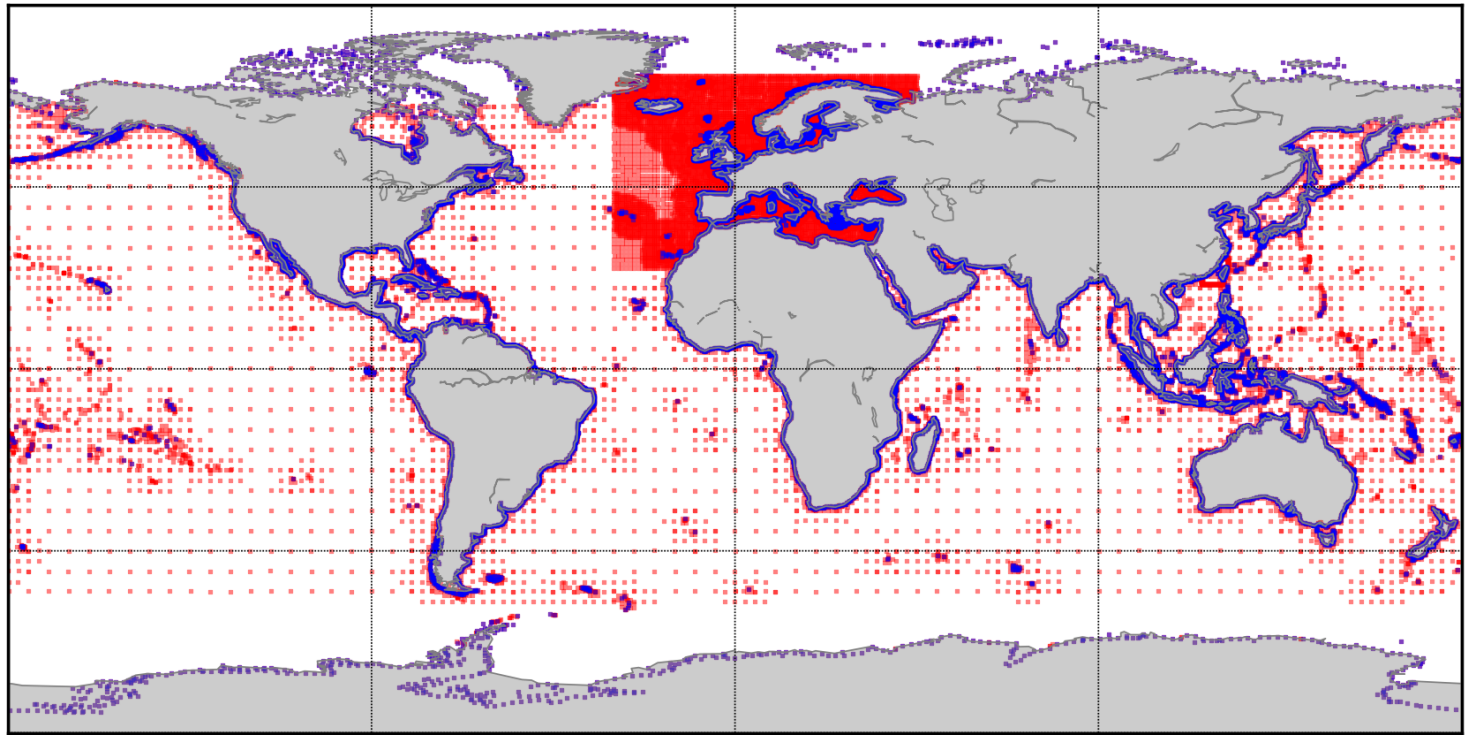
Methods | Output locations

Output locations

- Coastal points (blue)
- Grid points (red)

Special focus on Europe

- Higher resolution for meteorological forcing, hydrodynamic modelling, and output resolution



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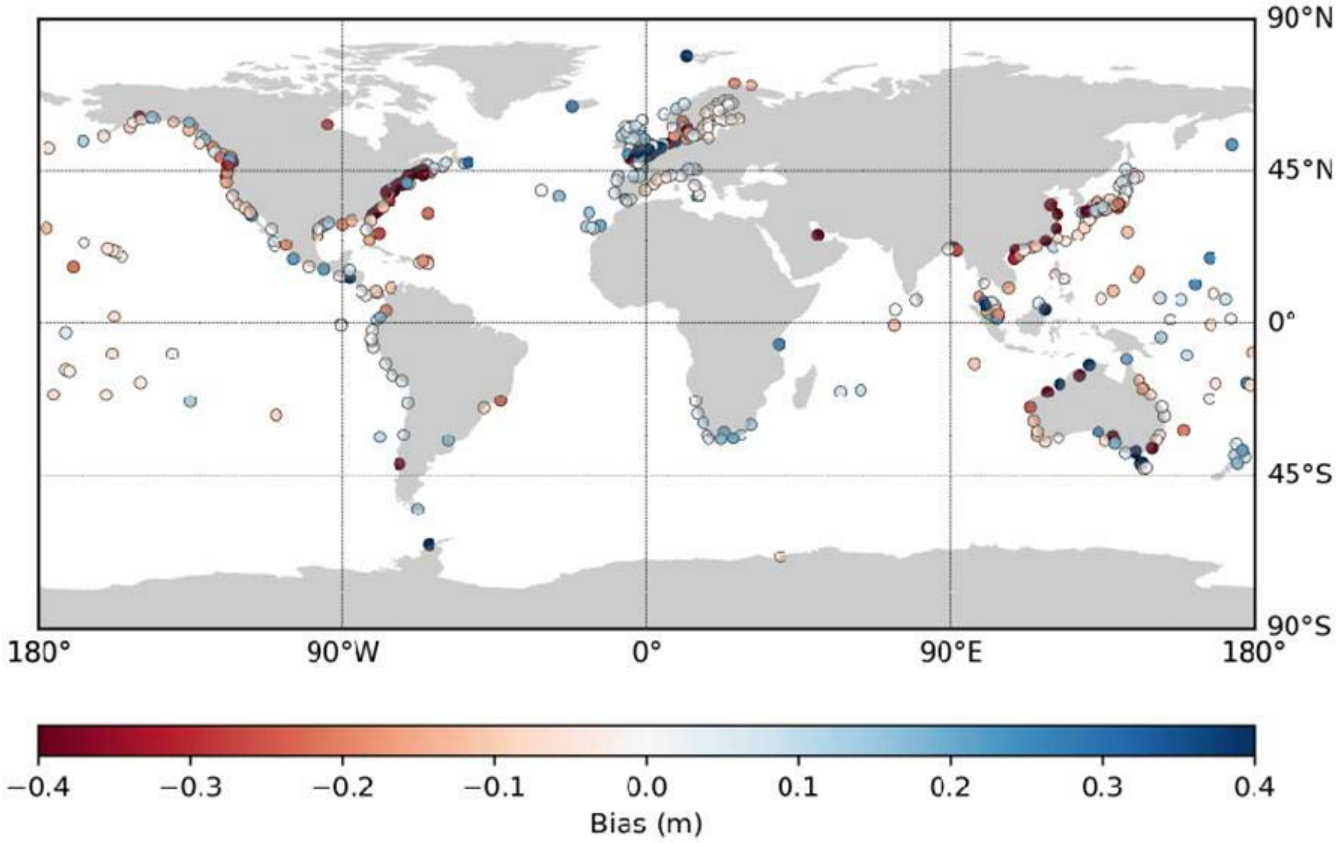
Results | Bias of the reanalaysis simulation



CoDEC-ERA5

- 1 in 10-year water levels based on 1979-2019
- Comparison against GESLA tide gauges

Results

- Good performance with mean bias of -10 cm
- Stronger negative bias in areas prone to tropical cyclones, positive bias in Europe

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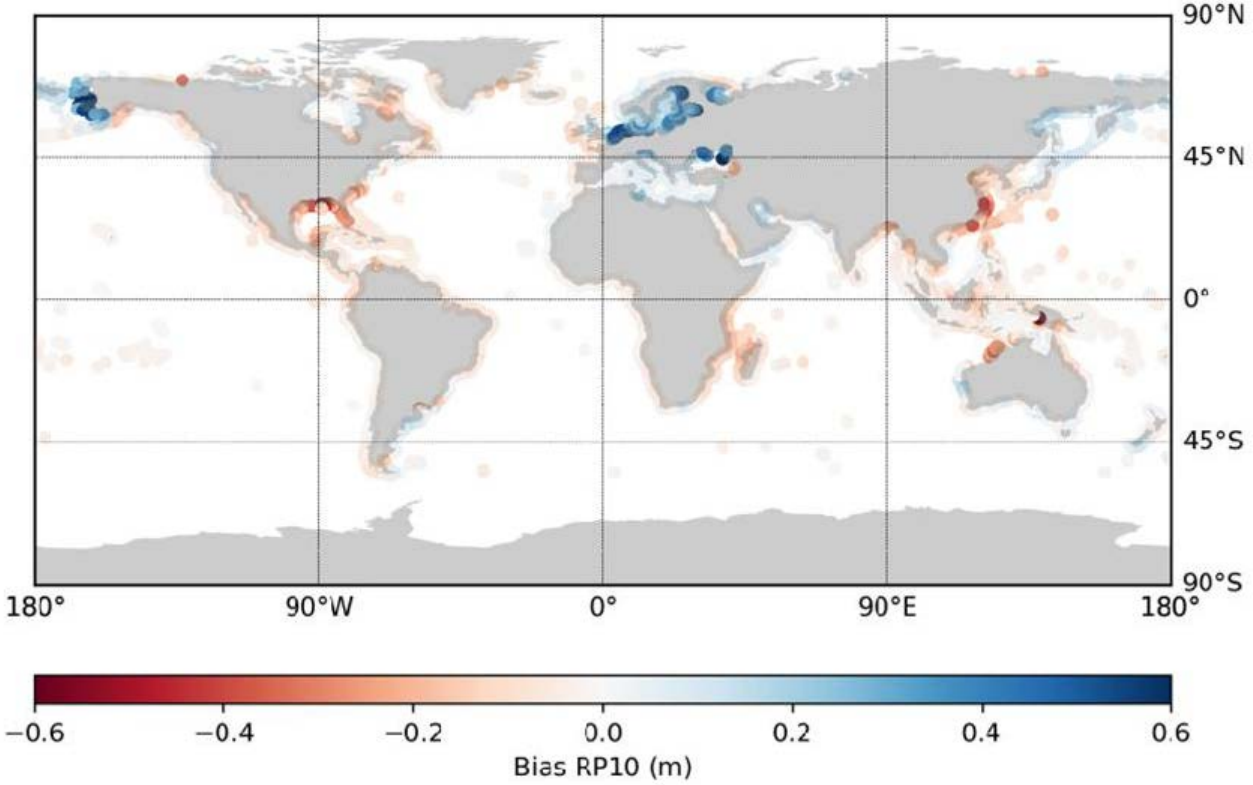
Results | Bias in the historical climate simulation



CoDEC-HIST

- 1 in 10-year water levels based on 1979-2019
- Comparison against CoDEC-ERA5

Results

- Spatial bias with underestimation of extremes, expect for Europe
- Mean bias of -13 cm with indicates a performance comparable to CoDEC-ERA5
- Performance is sufficient to support large-scale assessments of climate impacts

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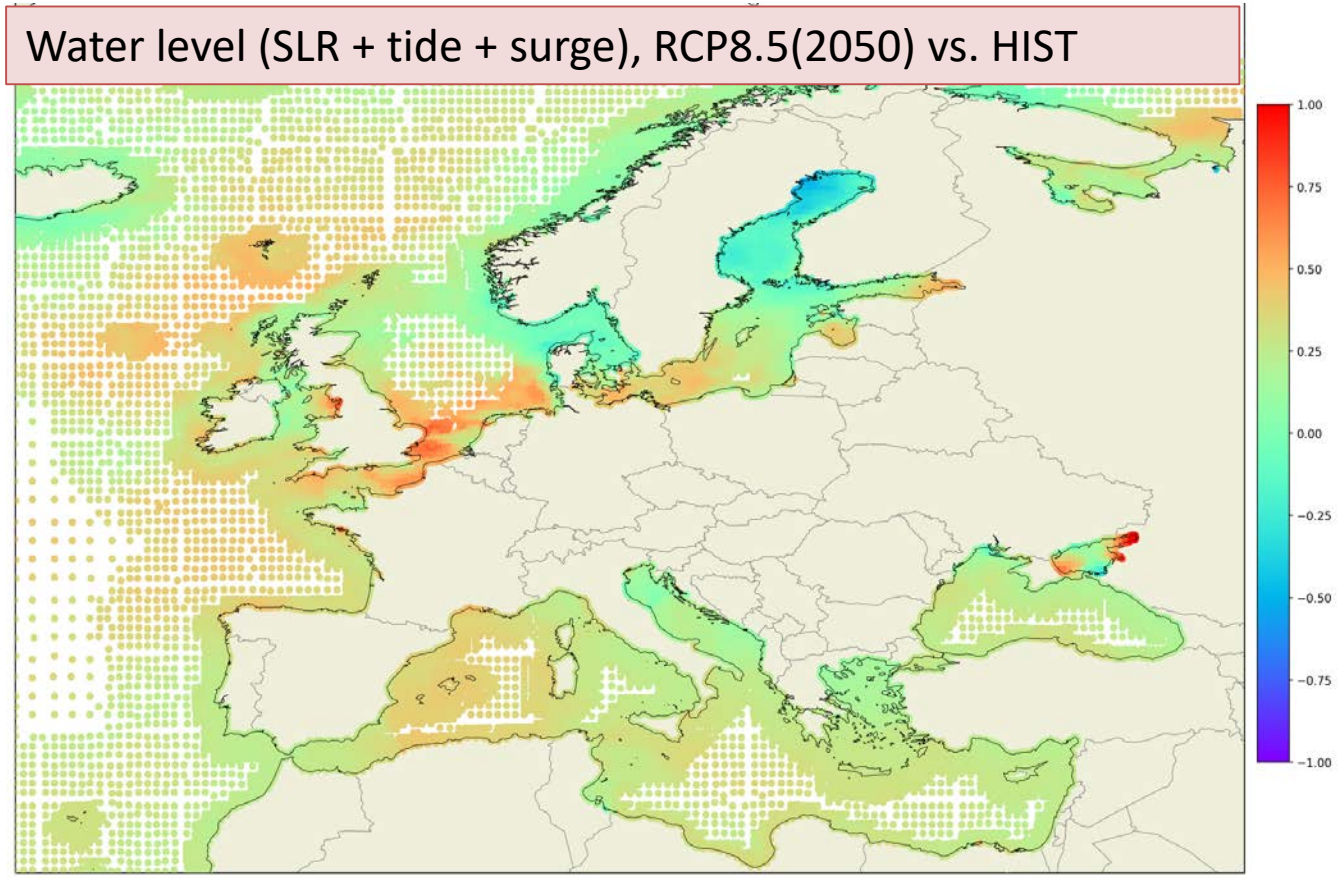
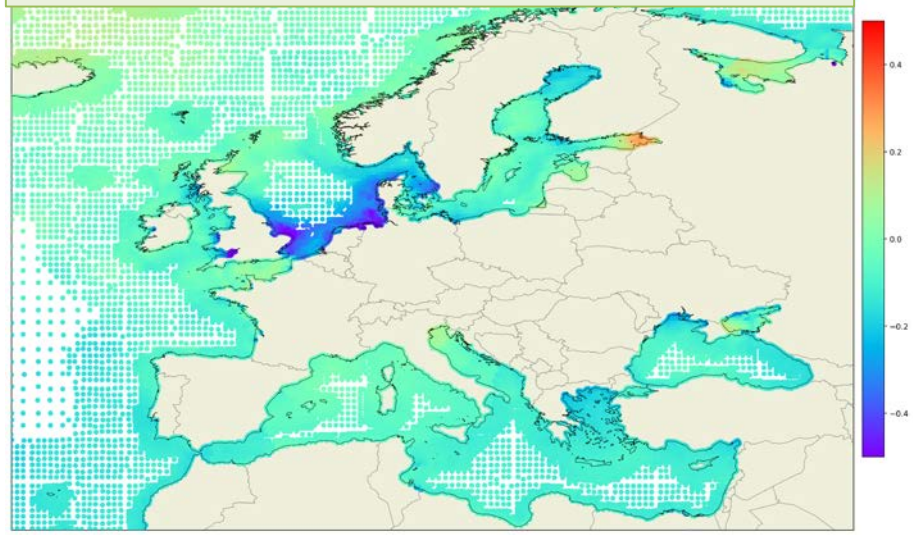
Results | Change in 1 in 10-yr water level

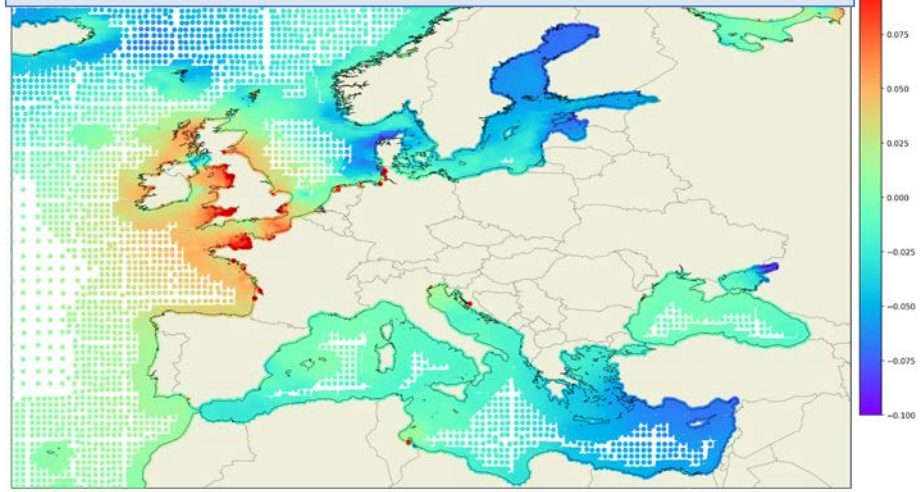
Water level (SLR + tide + surge), RCP8.5(2050) vs. HIST



Surge for RP10, RCP8.5(2050) vs. HIST



Water level (SLR + tide) for HAT, RCP8.5(2050) vs. HIST



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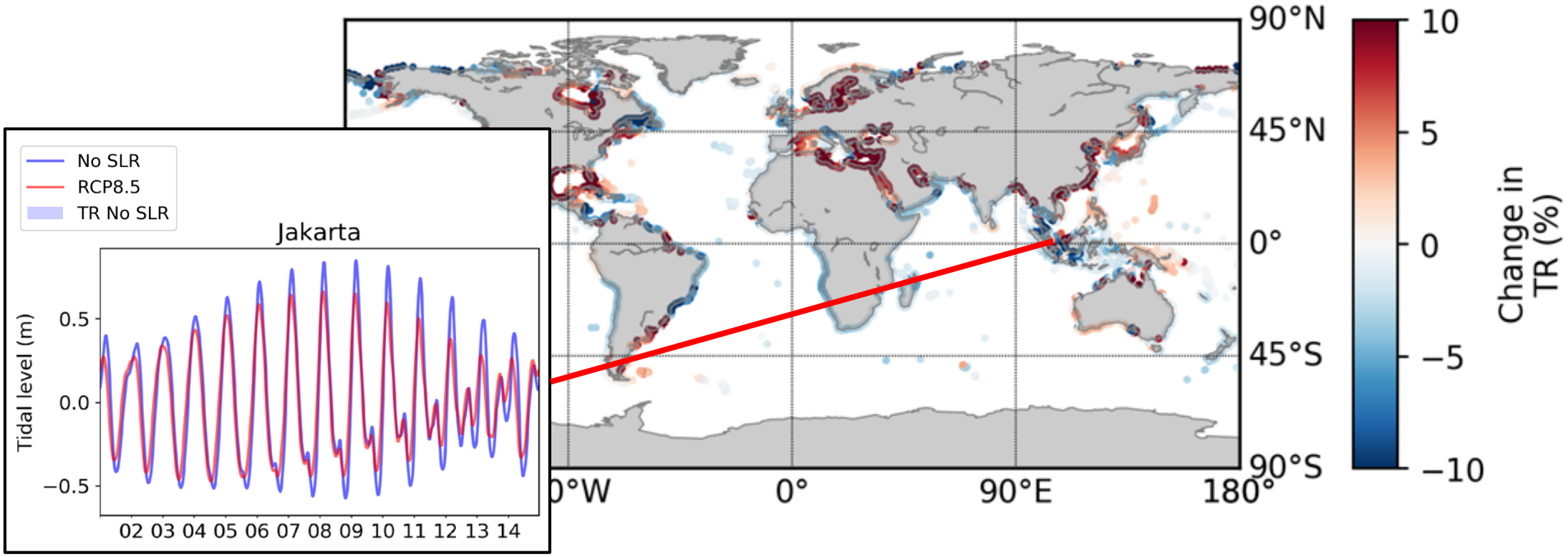
Results | Changes in tidal range in response to SLR



- Changes in tidal amplitude occur particularly in shelf seas with changes up to 15%
- Results emphasize the need to dynamically combines tides and mean sea level when assessing climate change impacts

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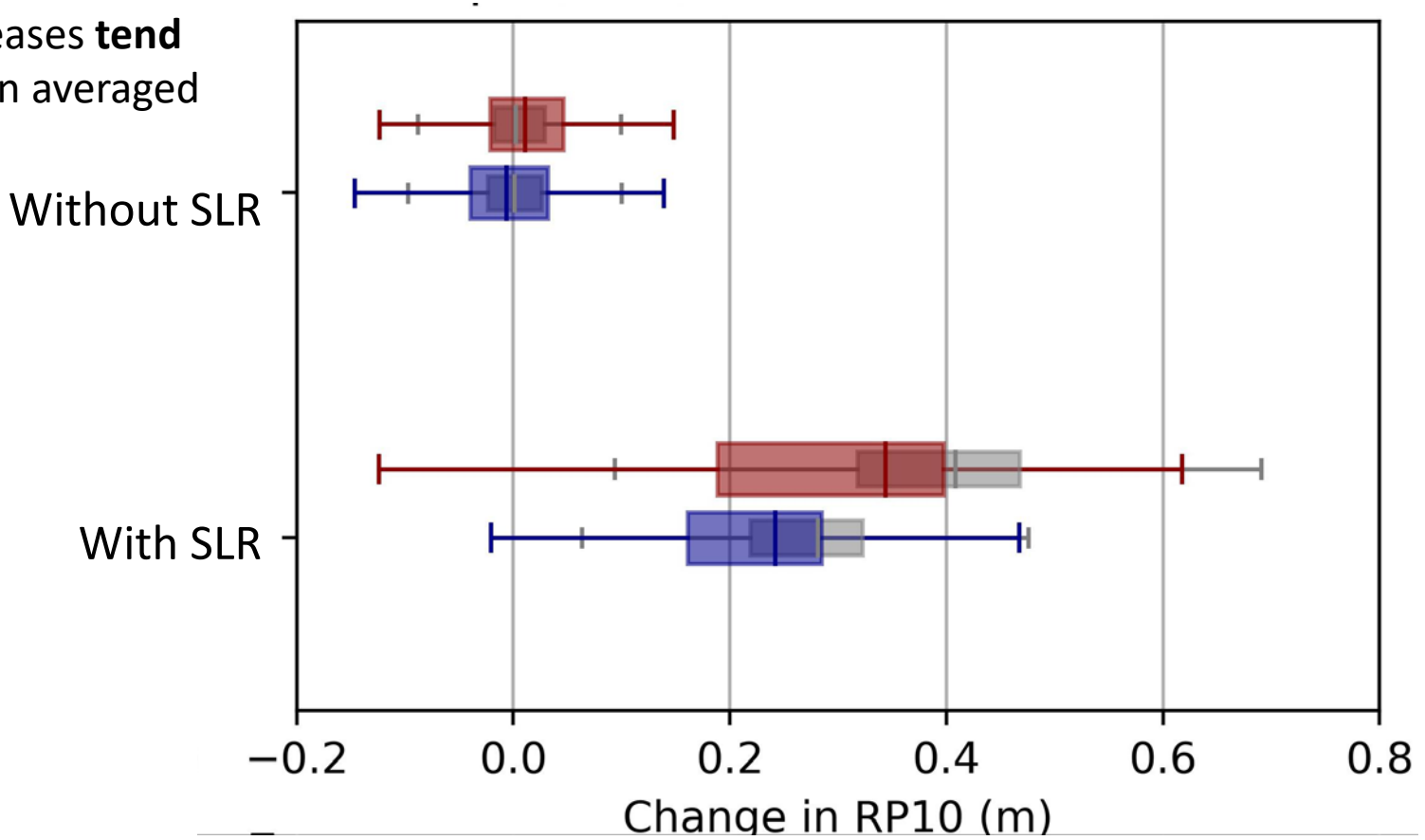
Results | Aggregated change over Europe

- Without SLR **no significant large-scale change** in extreme sea levels across all output, although large spread
- Projected increases and decreases **tend to cancel each other out** when averaged over larger areas



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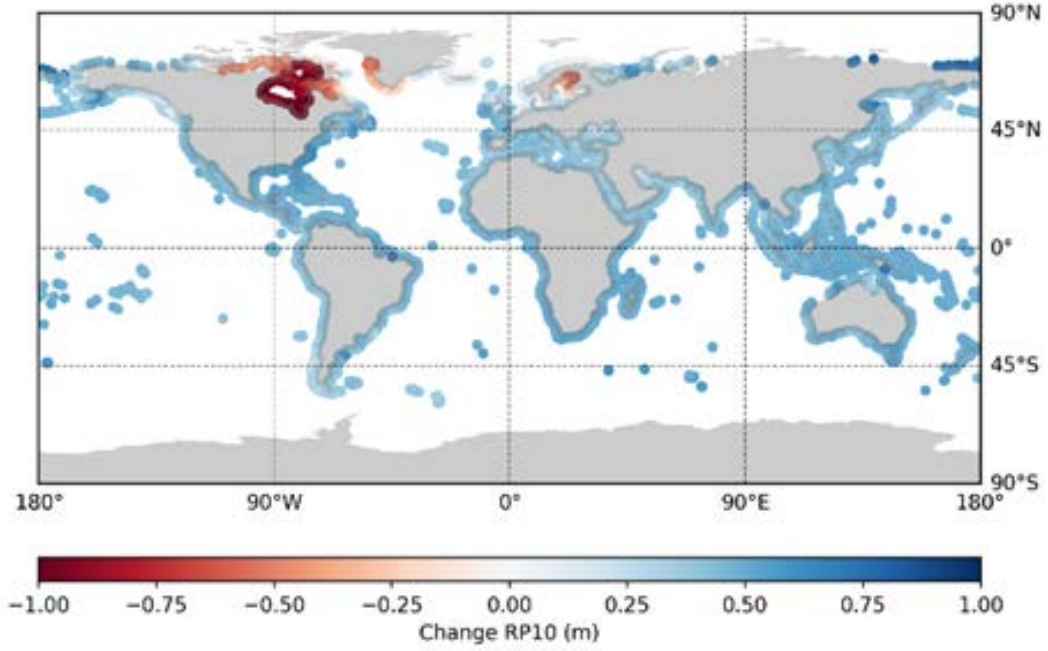
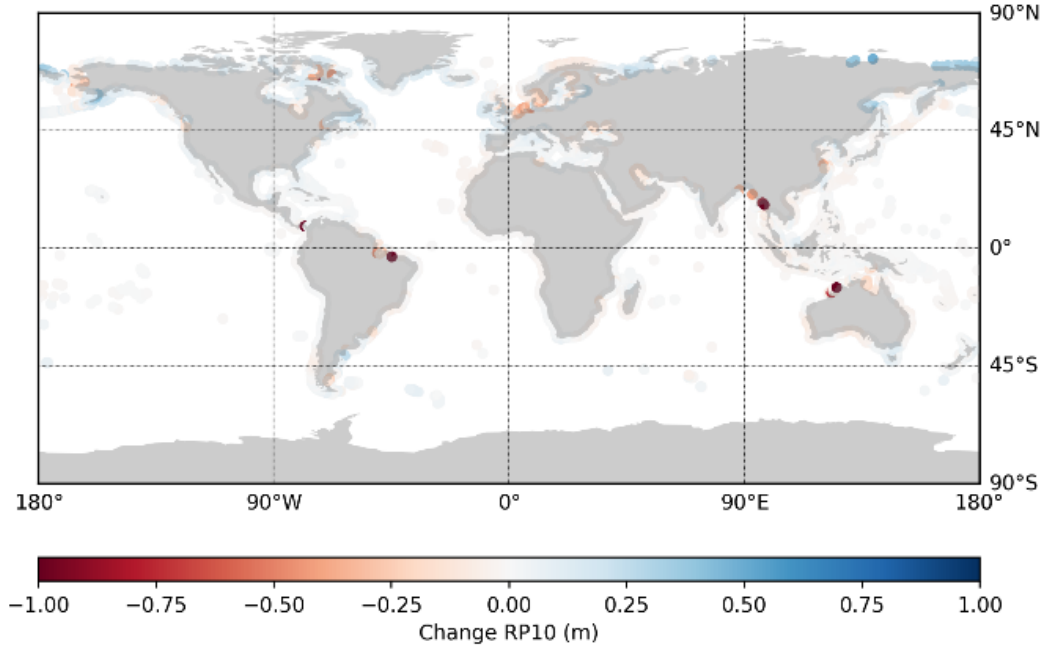
Results| Changes largely driven by sea-level rise

- Changes in RP10 for RCP4.5 (2100)



- Changes in RP10 for RCP4.5 (2100) minus effects of SLR



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Set examples of good practice in the development of climate services for coastal users

Use cases in C3S_422 Lot2

Industrial:
Offshore wind, Port operations (UK)

Coastal erosion:
Northsea (Netherlands)

Flood risk:
Adriatic Sea (Italy)
Baltic Sea (Denmark)
Irish Sea (Ireland)
Atlantic Ocean (Ireland)

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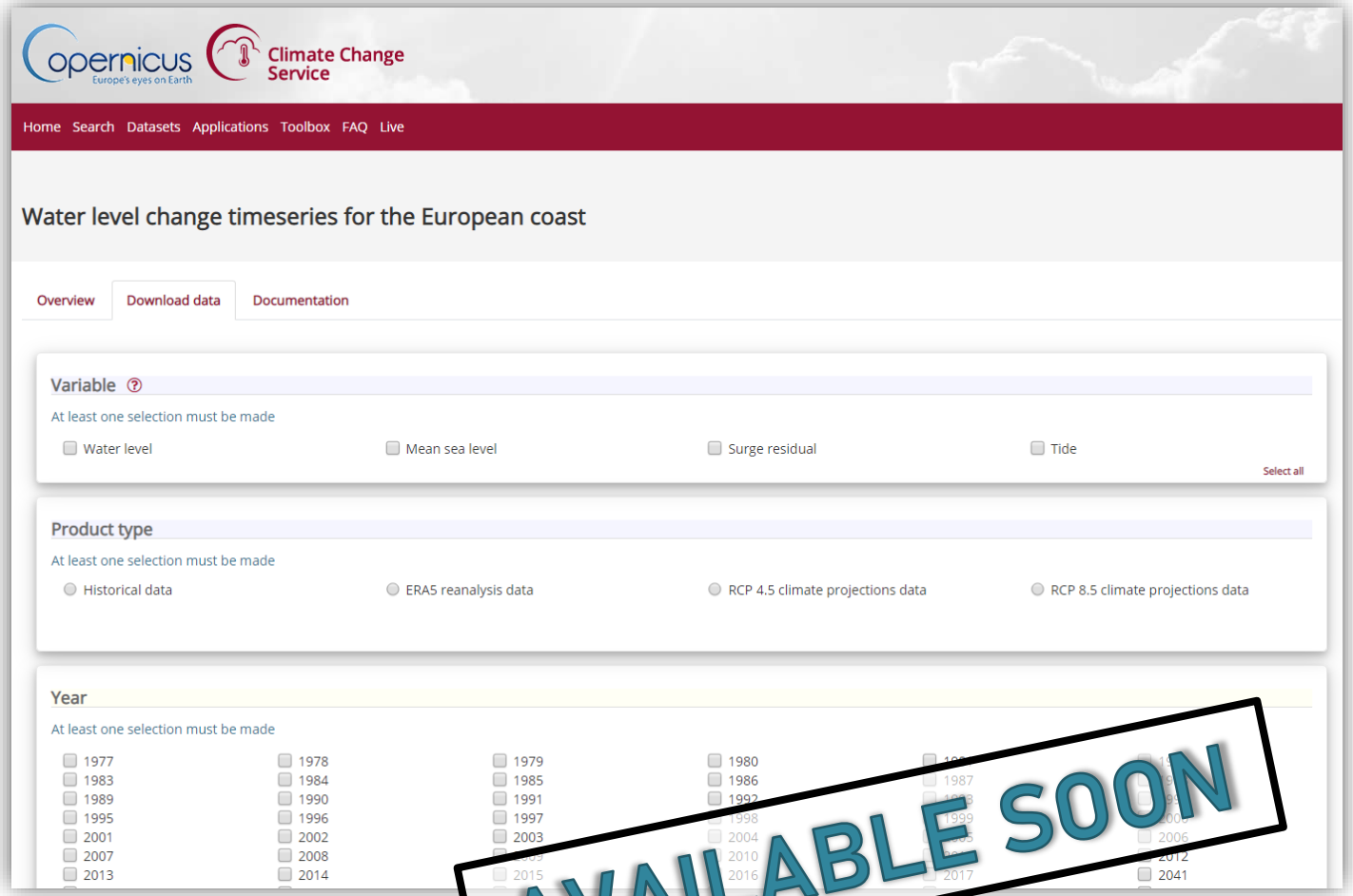
Data availability | Which data can you access in the CDS?

- **Hydro dataset European coast**
  - Timeseries: mean sea level, tides, surge residual, tide, total water level
  - Scenarios: ERA5, HIST, RCP45, RCP85
- **Hydro indicators European coast**
  - Percentiles
  - Tidal indicators
  - Return periods

https://cds.climate.copernicus.eu



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Future research directions| What is next?

- Explore additional links to the data and downscaling
  - Regional/local studies to translate changes into morphological changes, impact on ecology
  - Socio-economic impacts, cultural heritage

- ERA5 will become available from 1950 onwards
  - Longer record make it possible to improve extreme value statistics and analyze climate variability

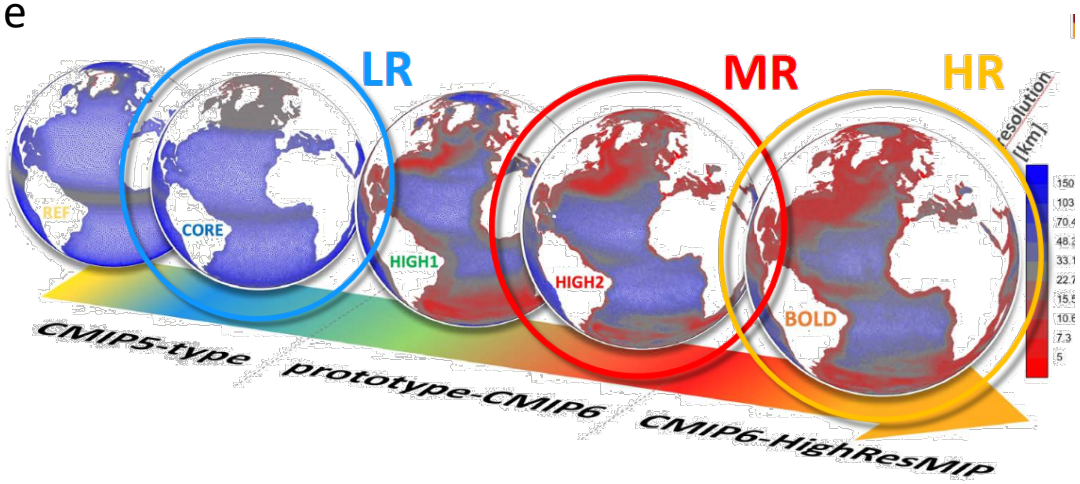
- Large uncertainty because of the use of a single climate model
  - new GTSMip6 project will run the CMIP6 ensemble of IPCC climate simulations

Global Tide and Model intercomparion project

Research Objectives To develop future projections for the HighResMIP model ensemble (better physics, higher resolution)

- To analyse differences historical vs. future differences
  - Contributions of the different sea level components
  - Bias and spread in the model ensemble

Rackow, et al. (2019), GMD



Scenarios

- 1950-2050 based on RCP8.5
- SLR from IPPC-SROCC

Output

- Timeseries of waterlevels, tides and surges
- Indicators of climate change (return periods, tidal levels, percentiles, etc.)
- Model ensemble consisting of 5 climate models

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Outlook | New GTSMip project

Computational costs

- ~80TBs of storage
- 2 million core hours

Project objectives…

- To develop high-accuracy projections of future storm surges and assess how coastal extremes will change over time, this to identify high-risk areas and inform policy-makers
- To built a community that collaborates to jointly develop future projections of extreme sea levels

International consortium

- Each partner is running 1 climate model to generate an model ensemble
- GTSM is run at different HPC computing clusters

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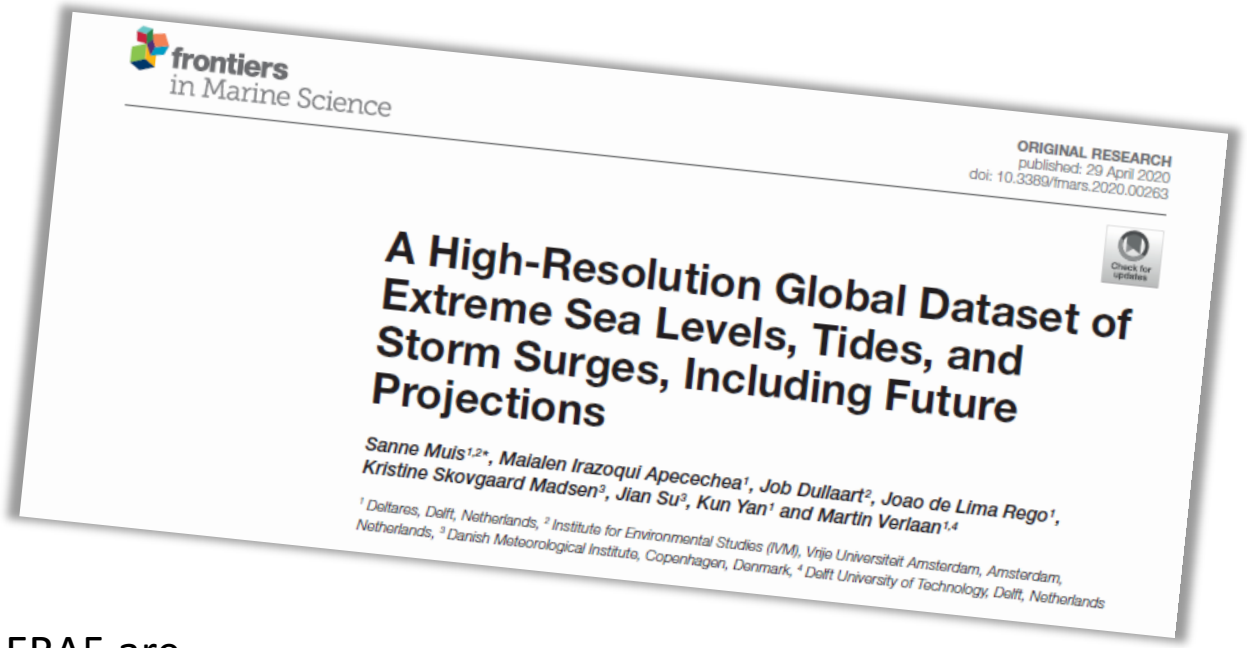
Further reading|

- **Paper** just got published in Frontiers in Marine Science!



- **Data availability**
  - Return periods based on CoDEC-ERA5 are openly available at https://doi.org/10.5281/zenodo.3660927
  - Time series and derived climate change indicators will soon be available at the CDS

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If you want to know more… get in touch!

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