Universität Hamburg
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CLUSTER OF EXCELLENCE
CLIMATE, CLIMATIC CHANGE, AND SOCIETY (CLICCS)

Project: bm1173

Project title: Climate, Climatic Change and Society

Principal investigator: Johanna Baehr

Report period: 2024-01-01 to 2024-10-31

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Preface

The report summarizes the individual reports of subprojects of the Cluster of Excellence CLICCS (Climate, Climatic Change and Society). The reporting will cover the time period from 01. January 2024 to 31. October 2024. The numbers for used computation time and storage resources are taken in the early second week of October. The individual DKRZ project numbers are bm1183, bg1184, bg1186, mh1212, bu1213, and bu1214. bm1219, which had previously been part of the bm1173, did not apply for resources in 2024 and is therefore not listed here. Please note that the current report covers utilization for 9 months, but not until the end of 2024.

Overall resource consumption in 2024

Below is a summarization of the overall consumption of the resources amongst all the projects in 2024:

Overall allocated 2024	Consumed (until 15.10.2024)	Remaining until end of 2024 (as of 15.10.2024)
989474	756373	253022

Report project CLICCS A2 (bm1183)

Project title: Clouds and Tropical Circulation

Project lead: Jakob Deutloff (UHH)

CLICCS project chairs: Stefan Bühler (UHH), Bjorn Stevens (MPI-M)

Reporting Period: 01.01.-15.10.2024

	Allocated for 2024	Consumed (until 15.10.2024)	Projection of consumption to end of 2024
Computing time (Levante & Mistral) [node h]	138853	99280	39573
Levante storage (TB)	154	63	10
Archive project (TB)	78	-6	10
Archive long term (TB)	2	0	1
Mistral Lustre work (GB)	0	0	0
Swift Object Storage (GB)	10240	4	4

Experiments performed successfully at project account bm1183: The limited area simulations with ICON (ICON-NWP) were executed as planned in last year's proposal. The global ICON simulations with perturbed microphysics were not implemented, since our scientific focus shifted from the microphysics towards a conceptual understanding of the high-cloud radiative effect. To support the data analysis within this study, computational resources and storage capacities from bm1183 were used.

Scientific results of project bm1183: The results from the ICON-NWP simulations revealed how a change in lapse rate controls trade cumulus cloud thickness via stability. A publication is in preparation. In Deutloff et al. (2024) we developed a more physical conceptualization of the high-cloud radiative effect, that links the cloud thickness measured in ice water path to the cloud radiative properties.

Publications in 2024 that use data of subproject bm1183: A paper investigating the sign of stratocumulus adjustments to aerosols in the ICON global storm-resolving model that is based on the project's simulations performed in 2023 was published (Fons et al., 2024). A paper evaluating uncertainties in the representation of microphysical processes in the global storm-resolving version of ICON that is based on the project's simulations performed in 2021 was submitted (Naumann et al., in review). The paper on the conceptual model of the high-cloud radiative effect was submitted (Deutloff et al., 2024)

Data Management of project bm1183: Data of the ICON-NWP simulations is stored externally. The data used in Fons et al. (2024) is currently stored on Levante disk space. The authors are working on transferring the data to the projects archive. The data used in Deutloff et al. (2024) was small enough to be published via the UHH data service (Deutloff and Brath, 2024).

References:

Deutloff, J., & Brath, M. (**2024**). High-cloud radiative effect dataset. doi: 10.25592/uhhfdm.14754

Deutloff, J., Buehler, S. A., Brath, M., & Naumann, A. K. (**2024**). Insights on Tropical High-Cloud Radiative Effect from a New Conceptual Model. doi: 10.22541/essoar.172304300.09105583/v1

Fons, E., A. K. Naumann, D. Neubauer, T. Lang, and U. Lohmann (**2024**) : Investigating the sign of stratocumulus adjustments to aerosols in the global storm-resolving model ICON, *Atmos. Chem. Phys.*, 24, 8653–8675, doi:10.5194/acp-24-8653-2024

.Naumann, A. K., M. Esch, and B. Stevens: How the representation of microphysical processes affects tropical condensate in a global storm-resolving model, *EGUsphere*, doi:10.5194/egusphere-2024-2268, under review for ACP.

Report project mh1212

Project title: CLICCS A4 – African and Asian Monsoon Margins CLICCS

Project lead: Katharina D. Six (MPI-M), Shabeh ul Hasson(UHH)

CLICCS project chairs: Jürgen Böhner (UHH), Martin Claussen (MPI-M/UHH), Gerhard Schmiedl (UHH)

Reporting Period: 01.01.-15.10.2024

	Allocated for 2024	Consumed (until 15.10.2024)	Projection of consumption to end of 2024
Computing time (Levante & Mistral) [node h]	182820	146503	170000
Levante storage (TB)	147[1]	172	187
Archive project (TB)	71	48	65
Archive long term (TB)	40	0	20
Mistral Lustre work (GB)	0	0	0
Swift Object Storage (GB)	10240	0	0

Experiments performed successfully at project account mh1212:
WP1: We have extended our set of simulations with different forcing (from ice-sheet reconstructions and from one fully coupled ESM_ICE-SHEET_SOLID-EARTH model) over the entire last deglaciation by four sensitivity simulations with enhanced nutrient input from the Nile under deglaciation conditions or a constant PI climate.

Scientific results of project mh1212:
WP1: The increasing global surface temperatures during deglaciation lead to a stabilization of the water column in eastern Mediterranean Sea, which is a prerequisite for sub-oxic/anoxic conditions that are evident in sediment records. In combination with a significant increased nutrient supply to this region during the African Humid Period, high production and gravitational sinking of organic material enhances the oxygen consumption and eventually leads to sub-oxic/anoxic conditions below 1000m. About two-third of the oxygen signal is attributed to changes in the physical realm. Enhanced nutrient supply under PI climate creates only a negligible oxygen reduction.

Publications in 2024 that use data of subproject :
WP1: Six, K. D., Mikolajewicz, U., and Schmiedl, G. (**2024**): Modelling Mediterranean ocean biogeochemistry of the Last Glacial Maximum, *Clim. Past*, 20, 1785–1816, https://doi.org/10.5194/cp-20-1785-2024.

Data Management of project mh1212:
WP1: Output of all simulations is stored on /arch project. We will use some of the applied space on /arch long term by the end of the reporting period.

[1] Project has exception for utilizing 187 TiB on Levante storage until Dec. 31, 2024

Report project bg1184

Project title: CLICCS A5 - The Land-Ocean Transition Zone

Project lead: Moritz Mathis (Hereon)

CLICCS project chairs: J. Hartmann (UHH), P. Korn (MPI-M), C. Schrum (Hereon)

Reporting Period: 01.01.-15.10.2024

	Allocated for 2024	Consumed (15.10.2024)	Projection of consumption to end of 2024
Computing time [node h]	241,038	174184	241,038
Levante storage (TB)	587	500	587
Archive project (TB)	53	0	53
Archive long term (TB)	35	0	35
Swift Object Storage (GB)	10,240	0	0

Experiments performed successfully at project account bg1184: Our experiments were dedicated to development and production runs of the global ocean-biogeochemistry model ICON-Coast and the regional marine ecosystem model SCHISM-ECOSMO. We have conducted hindcast simulations and sensitivity experiments with ICON-Coast (integration time 380 yr @ 80-10km) to study mechanisms of climate feedback variability due to coastal erosion. The ocean-atmosphere coupling of ICON-Coast was put forward by coupled high-resolution tuning simulations coordinated together with project A6. SCHISM-ECOSMO was developed further to account for the variable organic matter stoichiometry on continental shelves.

Scientific results of project bg1184: The development of ICON-Coast enables us to investigate the role of the coastal ocean in the global carbon cycle, while modern ESMs still fail to represent coastal carbon dynamics. First centennial simulations with this model revealed that the increasing coastal ocean CO2 uptake is primarily driven by the biological response to climate-induced changes in the circulation and increasing riverine nutrient loads (Fig. 1, Mathis et al. 2024). This result was recognized as a solid argument in support of a biologically strengthened coastal sink that is at odds with the traditional view of a passive ocean sink controlled by the rise in atmospheric CO2 (Resplandy 2024). New simulations indicate that the CO2 outgassing of permafrost organic matter (OM), supplied to the Arctic Ocean by coastal erosion, is subject to pronounced interannual variability. We found that the strength of this climate-carbon feedback is mainly controlled by OM degradation in the water column rather than previously assumed sedimentation processes (manuscript in prep). Sensitivity experiments with ICON-O showed that parameter tuning modulates the duration of simulated plankton blooms, but an explicit representation of mesoscale phenomena by increasing model resolution is required to improve plankton phenology.

The regional SCHISM-ECOSMO model framework is used to elucidate the role of key shelf-specific processes for carbon cycling in the coastal ocean. Sensitivity experiments showed that tides substantially impacts air-sea CO_2 exchange on the Northwest European Shelf (NWES) by vertical mixing and tide-induced circulation changes (Kossack et al. 2024). Further advancements were made by incorporating variable stoichiometry of organic matter into ECOSMO, addressing the limitations of traditional models that assume fixed Redfield ratios. Here, our simulations revealed that biogeochemical processes driving variable stoichiometry significantly influence the net CO2 uptake on the NWES, and lead to a more biologically driven seasonality. These findings underscore the importance of accounting for variable stoichiometry in carbon cycle models. A manuscript is currently in preparation.

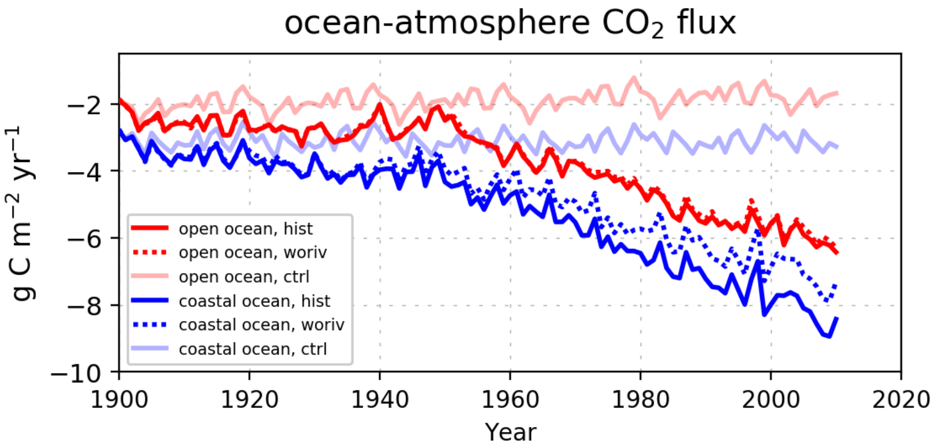

Figure 1: *Simulated CO2 uptake in the open (red) and coastal (blue) ocean during the 20th century. Solid lines: Full hindcast, considering increasing atmospheric CO2 and increasing riverine nutrient inputs. Dashed lines: Sensitivity experiment with constant riverine nutrient inputs. Shaded lines: Control run with constant atmospheric CO2 and constant riverine nutrient inputs.*

Publications in 2024 that use data of project bg1184:

Mathis, M., Lacroix, F., Hagemann, S., Nielsen, D. M., Ilyina, T., Schrum, C. (**2024**). Enhanced CO2 update of the coastal ocean is dominated by biological carbon fixation. *Nature Climate Change* 14, 373-37. https://doi.org/10.1038/s41558-024-01956-w

Kossack, J., Mathis, M., Daewel, U., Liu, F., Demir, K. T., Thomas, H., Schrum, C. (**2024**). Tidal impacts on air-sea CO2 exchange on the North-West European Shelf. *Frontiers in Marine Science* (accepted)

Data Management of project bg1184: The core simulations with ICON-Coast and SCHISM-ECOSMO used in the published papers will be transferred to LTA Doku during this year (2024) to be shared with the community for further analysis. Many of the test simulations for model development will be moved from currently /work to the DKRZ archive, as they provide valuable information for ongoing and further development but we can dispense quick and direct access.

References:

Resplandy, L (**2024**). Coastal sink outpaces open ocean. *Nature Climate Change* 14, 312–313. https://doi.org/10.1038/s41558-024-01968-6

Report project bu1213

Project title: CLICCS A6 - Earth System Variability and Predictability in a Changing Climate

Project lead: Johanna Baehr

CLICCS project chairs: J. Baehr (UHH), T. Ilyina (MPI-M), J.-S. von Storch (MPI-M), E. Zorita (HZG)

Reporting Period: 01.01.-15.10.2024

	Allocated for 2024	Consumed (15.10.2024)	Projection of consumption to end of 2024
Computing time (Levante) [node h]	392165	304148	392165
Levante storage (TB)	1133	1121	1133
Archive project (TB)	351	0	100
Archive long term (TB)	323	0	0
Swift Object Storage (GB)	10240	4	10

Experiments performed successfully at project account bu1213:

WP2: Several 30-year simulations (1970-1999 and 2070-2099) with the coupled GCOAST-NEMO-WAM (3.5 km) setup, and only-ocean model NEMO. **WP3**: ICON-ESM-HAMOCC (R2B9-R2B9) simulation (1 year with default output and 2 months with hourly output ocean/obgc output). ICON-O-HAMOCC (R2B8-L128), repeated 30-year run with budget variables for obgc.

Scientific results of project bu1213:

WP2: Using the completed simulations with and without wave-coupling for the historical period from 1970-1999 and the future projection period from 2070-2099, we estimate the extreme sea level change and extreme storm surges, and to investigate the impact of wave effects on them, with a focus on the North Sea and Baltic Sea regions. For a detailed description of scientific results, we refer to the publications of Nguyen et al. (2024) and Nguyen et al. (submitted to Ocean Dynamics, 2024), and Manuscript in preparation (Nguyen, et al.)

WP3: In our ICON-ESM simulations, we represent tropical cyclones for the first time in an ESM. North Atlantic tropical cyclones (i.e. hurricanes) drive intense air-sea exchange of CO2, intensifying outgassing in the tropics, and uptake in the extratropics (see: https://www.youtube.com/watch?v=63NZSPjxv6w). Hurricanes also cool the surface ocean by up to 4°C, which decreases the surface ocean pCO2, and thus shifts the direction of the CO2 exchange in our simulation. Furthermore, hurricanes increase ocean productivity with a lasting effect of more than one month. This leads to an increase in the organic matter export, therefore impacting carbon sequestration (Nielsen et al. manuscript in preparation, Chegini et al. 2024, Figure 1). Using the 10km ICON-O-HAMOCC, we assess the seasonal and interannual variability of the Tropical Instability Waves (TIW) signal on biogeochemical tracers in the Equatorial Pacific.

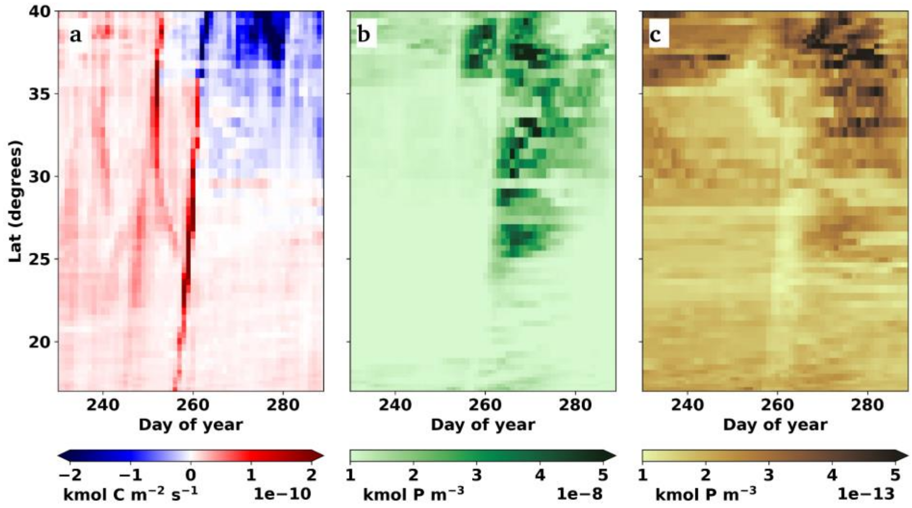

Figure 2.: *Simulated air-Sea CO_2 Flux (a), surface phytoplankton (b), and organic matter export at 90 m (c) along a tropical cyclone track in the North Atlantic*

Publications in 2024 that use data of subproject bu1213:

Nguyen, T.T., Staneva, J., Grayek, S., Bonaduce, A., Hagemann, S., Pham, T.N., Kumar, R., Rakovec, O (2024). Impacts of extreme river discharge on coastal dynamics and environment: Insights from high-resolution modeling in the German Bight. Regional Studies in Marine Science (RSMA). https://doi.org/10.1016/j.rsma.2024.103476

Nguyen, T.T, Staneva, J., Bonaduce, A., Jacob, B., Pein, J (2024). Seamless integration of the land-ocean continuum: the complex interplay of wave-induced processes and estuarine influences. A case study for the German Bight. *Ocean Dynamics* (in progress submitting to Ocean Dynamic)

F. Chegini, D. Nielsen, M. Salinas, L. Casaroli, N. Brüggemann, C. Hohenegger, and T. Ilyina, Impact of tropical cyclones on ocean biogeochemistry in a high-resolution Earth system model, EGU24-6464, https://doi.org/10.5194/egusphere-egu24-6464

L. Casaroli, T. Ilyina, N. Sera, and F. Chegini, Mesoscale and submesoscale biogeochemical signatures in a high-resolution ocean model, EGU24-12177, https://doi.org/10.5194/egusphere-egu24-12177.

Data Management of project bu1213: Present data storage (completed runs for present analyses) on work/, and to be archived on tape. After publication of manuscript, data will be in long-term archive (TiB):

WP1: 369 for studying the effects of surface ocean layer thickness (2m vs 10m) on climate variability, **WP2**: 315 for studying extreme sea level changes estimation, and internal variability. **WP3:** 270 and 111 (on work) for studying TIWs and TCs effect on ocean biogeochemistry, respectively.

Data storage request for 2024 (TiB)**: WP1**: 375 (work), **WP2**: 488 (work), 240 (archive), **WP3:** 1131 (work), 480 (archive).

Report project bu1214

Project title: CLICCS-C1 - Sustainable Adaptation Scenarios for Urban Areas – Water from 4 Sides

Project lead: Franziska S. Hanf

CLICCS project chairs: Jana Sillmann (UHH), Jörg Knieling (HCU), Bernd Leitl (UHH)

Reporting Period: 01.01.-15.10.2024

	Allocated for 2024	Consumed (15.10.2024)	Projection of consumption to end of 2024
Computing time (Levante & Mistral) [node h]	5098	3630	5098
Levante storage (TB)	19	16	19
Archive project (TB)	14		5
Archive long term (TB)	4		
Mistral Lustre work (GB)			
Swift Object Storage (GB)	10240		

Experiments performed successfully at project account bu1214: Simulations of small-scale convective events (July 13, 2019) were performed with the model-system COSMO-MUSCAT-DCEP. This includes multiple emission experiments with no emissions at all (zero), only emissions from the urban area of Leipzig (urban) and doubled (urban_x2) and quadrupled (urban_x4) Leipzig emissions. Intentionally, for all experiments no initial and boundary concentrations were used.

Scientific results of project bu1214: With our simulations we can demonstrate that urban emissions influence precipitation in our model chain (Bär et al., 2024). They can delay early-stage precipitation and either intensify (Fig. 1b) or further suppress later-stage precipitation (Fig. 1d), depending on the emission level. This shift, combined with convective invigoration, influences both the spatial distribution and the intensity of precipitation. These findings highlight the critical role of urban emissions in modifying local weather patterns. Experiments with different amounts of emitted aerosols highlight the nonlinearity of the underlying processes.

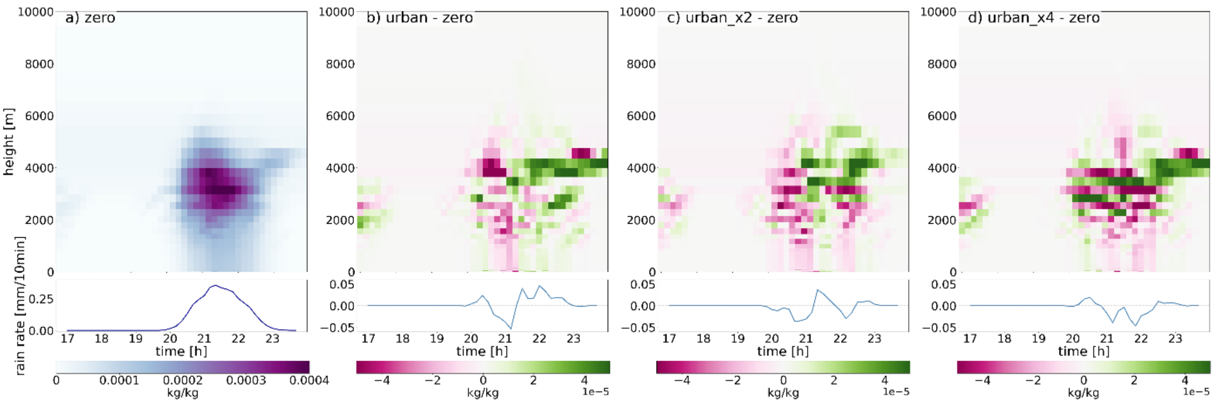

Figure 3: *The top row shows domain-averaged vertical profile of cloud condensate (water, ice, snow, graupel, rain, hail [kg/kg]) for the zero simulation (left column) and differences to the other experiments (remaining columns). The bottom row shows rain rate for the zero simulation [mm/10min] (left column) and differences to the other experiments (remaining columns).*

Publications in 2024 that use data of subproject bu1214: No publications that use data of subproject bu1214.

Data Management of project bu1214: Currently 15 TiB storage on work are used. This includes the model setup, the input data and finished model-simulations.

References:

Bär, F., Quante, M., Matthias, V., and Heinold, B. (**2024**): Model Study on Urban Aerosol-Cloud Interactions and their Influence on Precipitation, *EMS Annual Meeting 2024*, Barcelona, Spain, EMS2024-203, https://doi.org/10.5194/ems2024-203.

Report project bg1186

Project title: C3 - Sustainable adaptation scenarios for coastal systems

Project lead: Johannes Pein

CLICCS project chairs: K. Dähnke (hereon), P. Fröhle (TUHH), C. Möllmann (UHH), B. Ratter (UHH/HZG),

Reporting Period: 01.01.-15.10.2024

	Allocated for 2024	Consumed (15.10.2024)	Projection of overall consumption to end of 2024
Computing time (Levante & Mistral) [node h]	29500	28628	29500
Levante storage (TB)	206	191	206
Archive project (TB)			
Archive long term (TB)	40	0	40
Mistral Lustre work (GB)			
Swift Object Storage (GB)			

Experiments performed successfully at project account bg1186:

To drive dedicated climate change and sustainable adaptation scenarios, the SCHISM unstructured model of the southern North Sea was integrated for a historical period and for a climate change scenario, prescribing mean sea level and global temperature change expected under RCP8.5 at the boundaries. These runs were used as a forcing to run bundle of adaptation scenarios for the Elbe estuary using hydrodynamic-morphodynamic coupled model and hydrodynamic-biogeochemical coupled model (Pein et al., 2021).

A high-resolution 3-dimensional hydrodynamics-sediment transport model was applied to investigate the sediment transport and dynamics of ETMs in the PRE from 2017 to 2020. Based on the simulation results that are confirmed by observation, the relative contribution of specific physical mechanisms for the formation of the ETMs, the temporal and spatial dynamics of the ETMs as well as their interconnections were investigated.

Using the completed simulations with and without wave-coupling for the historical period from 1970-1999 and the future projection period from 2070-2099, we estimate the extreme sea level changes and extreme storm surges, and to investigate the impact of wave effects on the extreme sea-levels, with a focus on the North Sea and Baltic Sea regions. For a detailed description of scientific results, we refer to the publications of Nguyen et al. (2024) and Nguyen et al. (submitted to Ocean Dynamics, 2024), and Manuscript in preparation (Nguyen, et al.). To assess the skill of historical regional ocean-wave coupled model simulations and use them as a reference to assess the frequency and intensity of extreme events (e.g., extreme sea-levels, extreme storm surges) in the projection of the future sea levels with a particular focus on the coastal ocean of the North Sea and Baltic Sea by the end of 2100.

Several experiments were conducted to simulate the sediment plume after the Kahkovka dam breach. Intensive virtual sediment particles were tracked using SedimentDrift, a subclass of the open-source software OpenDrift. The model uses driving forces including high resolution wind data from the ICON-EU model of the German Weather Service (DWD), near real-time 3D ocean current data from the Copernicus Marine Environment Monitoring Service (CMEMS), and Stokes drift data from the WAM model.

Scientific results of project bg1186:

The global warming applied at the open boundaries and water surface propagated into the model area, however sites dominated by tides did not heat up as much as dynamically calmer areas. The climate impacts in the estuary were straightforward and in agreement with expectation, especially bottom oxygen strongly degenerated. The sustainable adaptation scenarios - including two flood-control and two scenarios with increased connectivity and tidal prism – reduced sediment accumulation in the estuarine freshwater reach. However, they could not counter the drop of oxygen concentrations under warming and sea level rise. It is clear that geometric adaptations of the estuarine shape can overcome threads like flooding but they need to be accompanied by reduction of nutrient loads in the river catchment.

We isolated and quantified the estuarine turbidity maxima (ETMs) in Pearl River estuary system. All three ETMs exhibit distinct seasonal and spatial variations. Advection and tidal pumping are the main processes mediating the sediment flux of the ETMs. These factors are largely influenced by river runoff and stratification dynamics.

The simulated sediment plumes were in good agreement with the satellite data obtained by the Sentinel-3A/B OLCI. The wind plays an important role in transporting the sediment particles in the sea surface, moving towards the Crimea. The sediment plume is also sensitive to the grain size of the sediment. The significant results will be summarized and presented in a manuscript to be submitted soon to a scientific journal.

Publications in 2024 that use data of subproject bg1186:

Ma, M., Porz, L., Schrum, C., & Zhang, W. (**2024**). Physical mechanisms, dynamics and interconnections of multiple estuarine turbidity maximum in the Pearl River estuary. *Frontiers in Marine Science*, *11*, 1385382. https://doi.org/10.3389/fmars.2024.1385382

Nguyen, T. T., Staneva, J., Grayek, S., Bonaduce, A., Hagemann, S., Pham, N. T., Kumar, R. & Rakovec, O. (**2024**). Impacts of extreme river discharge on coastal dynamics and environment: Insights from high-resolution modeling in the German Bight. *Regional Studies in Marine Science*, *73*, 103476. https://doi.org/10.1016/j.rsma.2024.103476

Pein, J., Staneva, J., Mayer, B., Palmer, M. D., & Schrum, C**.** (**2023**). A framework for estuarine future sea-level scenarios: Response of the industrialised Elbe estuary to projected mean sea level rise and internal variability. *Frontiers in Marine Science*, *10*, 1102485. https://doi.org/10.3389/fmars.2023.1102485

Steidle, L., & Vennell, R. (**2024**). Phytoplankton retention mechanisms in estuaries: a case study of the Elbe estuary. *Nonlinear Processes in Geophysics*, *31*(1), 151-164. https://doi.org/10.5194/npg-31-151-2024

Data Management of project bg1186:

To reduce amount of data kept in the work folders, relevant data were sampled along the estuarine main channel as these data are frequently asked by users and related projects. After finishing the analyses, climate simulation runs were moved to archive for long-term storage.

References:

Pein, J., Eisele, A., Sanders, T., Daewel, U., Stanev, E. V., Van Beusekom, J. E. E., Staneva, J. & Schrum, C. (**2021**). Seasonal stratification and biogeochemical turnover in the freshwater reach of a partially mixed dredged estuary. *Frontiers in Marine Science*, *8*, 623714. https://doi.org/10.3389/fmars.2021.623714