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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: 2025-01-01 to 2025-10-31

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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 2025 to 31. October 2025. 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 2025 and is therefore not listed here. Please note that the current report covers utilization for a period of little over 9 months, but not until the end of 2025.

The current funding phase of CLICCS ends on 31.12.2025. The new application for DKRZ resources will be following the new project structure that is set-up in frame of the second funding phase starting on 01.01.2026.

Overall resource consumption in 2025

Below is a summarization of the overall consumption of the resources amongst all the projects in 2025:

Overall allocated 2025	Consumed (until 20.10.2025)	Remaining until end of 2025 (as of 20.10.2025)
665913	402403 (60.42%)	263510 (39.57%)

Report project 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.-20.10.2025

	Allocated for 2025	Consumed (until 20.10.2025)	Projection of consumption to end of 2025
Computing time (Levante & Mistral) [node hours]	31330	23510	31330
Levante GPU nodes (Node hours)	0	116	-
Levante storage (TB)	96	88	96
Archive project (TB)	82	-	60
Archive long term (TB)	2	-	2
Swift Object Storage (GB)	-	-	-

Experiments performed successfully at subsproject account bm1183: The ICON-AES simulations were not carried out since the testing of the model setup took longer than expected. We had to change our simulation strategy for the ICON-Sapphire simulations, as we were only granted about a third of the resources we applied for. We switched from the planned AMIP setup to an aquaplanet configuration with 5 km horizontal grid spacing to save resources. Aquaplanet simulations do not require a full annual cycle of simulation to reach a statistically stable state due to the symmetry of the setup. We implemented the new diagnostic variables required for our analysis and ran three simulations: control, +2 K and +4 K uniform surface warming. We ran a spinup of six months for the control simulation and three months of spinup for the +4 K and +2 K simulations, initialized from the control spinup. For our analysis we ran three months of each simulation.

Scientific results of subproject bm1183: Thanks to the high horizontal resolution of the aquaplanet simulations, we were able to assess how surface warming affects high clouds with different thickness. This is crucial, since the high-cloud radiative effect strongly depends on cloud thickness (Deutloff et al., 2025). Global circulation models are too coarse to resolve individual clouds and do not allow for such an analysis. Our results suggest that the high-cloud feedback might be more positive than previously thought, in agreement with radiative convective equilibrium simulations (Sokol et al., 2024).

Publications in 2025 that use data of subproject bm1183: We wrote a first draft of the paper based on the aquaplanet simulations and aim to submit the paper before the end of September. Two papers on the superdroplet model CLEO were submitted (Bayley et al. 2025a and 2025b).

Data Management of subproject bm1183: The data from the aquaplanet simulations is currently stored on Levante disk space. We will delete about 95% of it, once we can be certain that no additional analysis is required by the reviewers. For our analysis we drew random samples of atmospheric profiles from the ICON output. They will be moved to the long-term archive once the paper is accepted.

References: Deutloff, J., Buehler, S. A., Brath, M., & Naumann, A. K. (**2025***).* Insights on Tropical High-Cloud Radiative Effect from a New Conceptual Model*. Journal of Advances in Modeling Earth Systems*, 17(2), e2024MS004615. https://doi.org/10.1029/2024MS004615

Sokol, A. B., Wall, C. J., & Hartmann, D. L. (**2024**). Greater climate sensitivity implied by anvil cloud thinning. *Nature Geoscience*, 1–6. https://doi.org/10.1038/s41561-024-01420-6

Bayley et al. (**2025a**). CLEO: The Fundamental Design for High Computational Performance of a New Superdroplet Model. *Submitted to GMD*

Bayley et al. (**2025b**). CLEO: The Numerical Methods of a New Superdroplet Model including a Droplet Breakup Algorithm. *Submitted to GMD*

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.-20.10.2025

	Allocated for 2025	Consumed (until 20.10.2025)	Projection of consumption to end of 2025
Computing time (Levante & Mistral) [node hours]	73390	57342	60256
Levante storage (TB)	150	133	101
Archive project (TB)	74	25	35+
Archive long term (TB)	43		43+20
Swift Object Storage (GB)	0		0

Experiments performed successfully at project account mh1212: WP1: one simulation with MPIOM-MED on sapropel formation with the downscaled forcing from a fully coupled ESM_ICE-SHEET_SOLID-EARTH model [1] over 21,000 years with an enhanced nutrient input to the eastern Mediterranean Sea (S_{sap}); two sensitivity studies to disentangle the physical (S_{pys}) and biogeochemical (S_{bio}) drivers of sapropel; one sensitivity study (S_{cas}) to test the hypothesis of Black Sea freshwater input [2] triggering sapropel formation. **WP2:** Assessing monsoon dynamics under climate change in kilometer-scale projections and impact assessment for water availability and flood inundation.

Scientific results of project mh1212: WP1 achievements:

- the first consistent simulation of the temporal evolution of sapropels, depicting the correct onset, termination and magnitude of anoxia and sediment organic matter content (Fig. 1)
- identification the necessary drivers: millennium-scale water column stagnation prior to the onset of sapropel primarily induced by surface salinity changes due to sea level rise, enhanced nutrient input during the African Humid Period, and large remineralization length scale (RLS) due to cold water temperatures
- rejection of the hypothesis on the necessity of Black Sea freshwater input

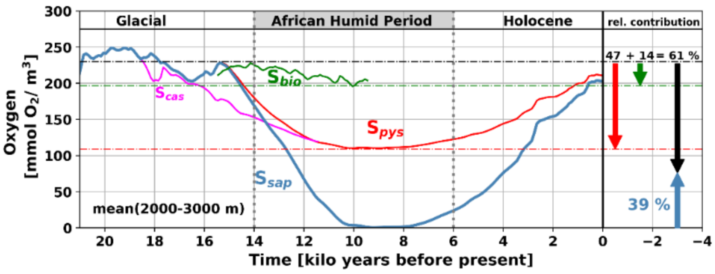

Fig 1: Oxygen concentration in 2-3 km depth for different simulations. Only S_{sap} reaches anoxia. 47% of the signal is due to physical changes alone. Nutrient addition causes 14% under a modern climate. The remaining 39% result from the non-linear interplay between physical (reduced ventilation due to stagnation) and biological processes (large RLS). Impact of Black Sea freshwater input (S_{cas}) has vanished 1500 years prior to the onset of sapropel. The necessity of this freshwater input can therefore be ruled out.

WP2 Achievement: The following activities were performed with the awarded computational resources:

- Six years of 30-year baseline climatology for a small ungauged watershed at the monsoon margin region have been simulated using WRF at 1-kilometer resolution downscaling ERA5 reanalysis in a single domain setting for onward ingestion to a hydrological model for a small reservoir water availability and dam operation optimization using adaptive model predictive control.
- A hydrological year 2020 of ERA5 reanalysis downscaled at 4km resolution for the CORDEX Flagship Study Project - Convection-permitting Tibetan Plateau. This simulation is in addition to the earlier simulation, but with the MYNN2 (Olson et al., 2019) planetary boundary layer scheme for sensitivity analysis. Results are in post-processing
- GloBCORD-HD: Three quasi-global datasets are developed at 50km spatial and daily temporal resolution by bias-correcting the dynamically downscaled Earth System Models of MPI-ESM-LR, ECEARTH, and GFDL-ESM2M from the CORDEX archive for historical, RCP2.6, RCP4.5, and RCP8.5 -- regardless of either single or multiple regional climate models -- against a single observational dataset GSWP3-W5E5 v2, using the same ISIMIP3BASD v2.5 bias correction algorithm. These quasi-global bias-corrected significantly reduce biases, decrease overall data volume by removing CORDEX domain overlaps, and provide consistent input data for robust climate impact assessments across all sectors.
- GloBCORD-QD: Four consistent quasi-global datasets were developed at 25km spatial and daily temporal resolution by bias-correcting the dynamically downscaled Earth System Models of MPI-ESM-LR, MPI-ESM-MR, NorESM1, and HadGEM2 from the CORDEX archive for historical, RCP2.6, and RCP8.5 -- regardless of either single or multiple regional climate models -- against a single observational dataset CHELSA-W5E5 v1.2, using the same ISIMIP3BASD v2.5 bias correction algorithm. These quasi-global bias-corrected significantly reduce biases, decrease overall data volume by removing CORDEX domain overlaps, and provide consistent input data for robust climate impact assessments across all sectors.

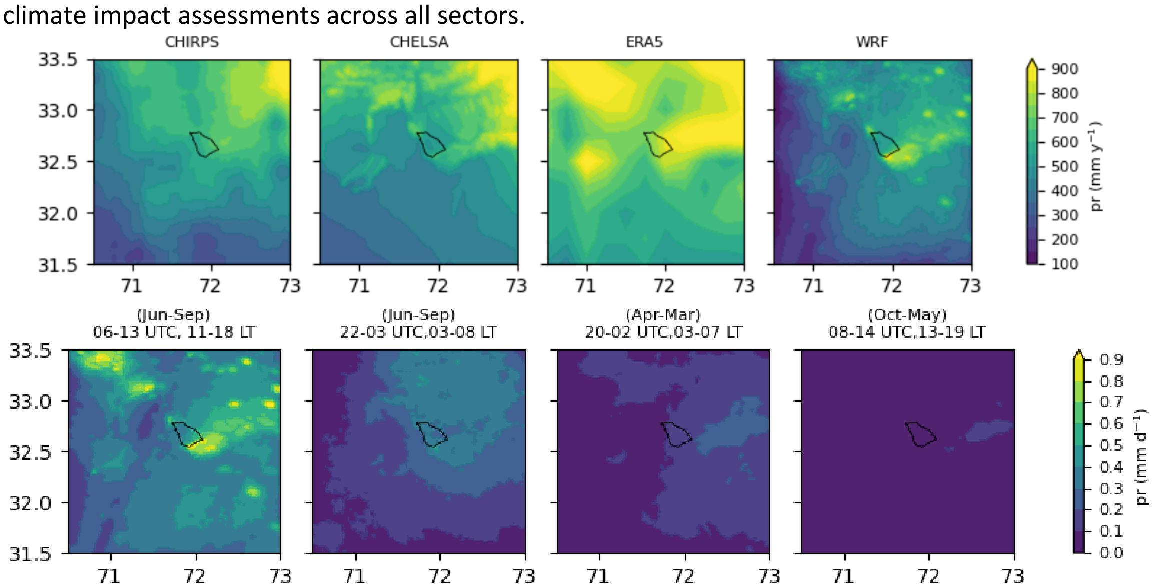

Fig 2: A 30-year climatological spatial and diurnal distribution of precipitation in the upper and lower row, respectively, downscaled at 1km resolution using WRF over the Namal watershed.

Publications in 2025 that use data of subproject: WP1: Manuscript "The drivers of sapropel formation derived from transient deglacial simulations" by K.D. Six, U. Mikolajewicz and G. Schmiedl is about ready for submission.

WP2: 1. Fuseini Yakubu, Jürgen Böhner, Udo Schickhoff, Thomas Scholten, Shabeh ul Hasson: GloBCORD-HD: Global Bias-Corrected CORDEX Datasets at Half Degree Resolution, Scientific Data, **2025** (under review).

2. Fuseini Yakubu, Jürgen Böhner, Udo Schickhoff, Thomas Scholten, Shabeh ul Hasson: GloBCORD-QD: Global Bias-Corrected CORDEX Dataset at Quarter Degree Resolution, Scientific Data, **2025** (ready for submission).
3. Work on Namal watershed climatology and CORDEX CPTP is under analysis and will be published too.

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.

WP2: Bias-corrected quasi-global datasets GlobBCORD-HD at 50km and GlobBCORD-QD at 25km containing five variables for historical and century-long RCP future scenarios are hosted at the University of Hamburg data portal at https://www.fdr.uni-hamburg.de/record/17396. GloBCORD-QD will soon be online. A 30-year climatology and CPTP dataset will also be archived on /arch and on long-term storage.

References: Mikolajewicz, U., Kapsch, M.-L., Schannwell, C., Six, K.D., Ziemen, F.A., Bagge,M., Baudouin, J.-P., Erokhina, O., Gayler, V., Klemann, V., Meccia, V.L.,Mouchet, A., Riddick, T. (**2025**): Deglaciation and abrupt events in a coupled comprehensive atmosphere–ocean–ice-sheet–solid-earth model. *Climate of the Past 21(3)*, 719–751 (2025) https://cp.copernicus.org/articles/21/719/2025/

Vadsaria, T., Zaragosi, S., Ramstein, G., Dutay, J.-C., Li, L., Siani, G., Revel,M., Obase, T., Abe-Ouchi, A. (**2022**): Freshwater influx to the Eastern Mediterranean Sea from the melting of the Fennoscandian ice sheet during the last deglaciation. *Scientific Reports* 12(1) (2022) https://doi.org/10.1038/s41598-022-12055-1

Nakanishi, M. and Niino, H., **2009**. Development of an improved turbulence closure model for the atmospheric boundary layer. *Journal of the Meteorological Society of Japan. Ser. II*, *87*(5), pp.895-912.

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.-20.10.2025

	Allocated for 2025	Consumed (20.10.2025)	Projection of consumption to end of 2025
Computing time [node hours]	109956	64197	77221
Levante storage (TB)	207	187	200
Archive project (TB)	55	81	55
Archive long term (TB)	35		20
Swift Object Storage (GB)	-		0

Experiments performed successfully at subproject account bg1184: Resources were used primarily to finish high-resolution multi-decadal simulations with the model ICON-Coast and to run test simulations related to development work for the model SCHISM-ECOSMO. With ICON-Coast we ran 3 core experiments over the period 1900-2024 to study the impact of permafrost erosion on the carbonate system of Arctic shelves, that is a control run, a full hindcast run, and a sensitivity experiment of a hindcast without increasing permafrost organic matter inputs. SCHISM-ECOSMO was further developed by including the

CICE/ Icepack (v1.3.4) sea ice model, and the numerical grid for the Northwest European Shelf (NWES) region was modified to improve exchange between the North Sea and Baltic Sea. We also completed the development of a variable stoichiometry representation for particulate and dissolved organic matter in ECOSMO, which allowed us to address the limitations of Redfield stoichiometry-based models and to assess the effects of variable organic matter stoichiometry on carbon cycling on the NWES.

Scientific results of subproject bg1184: The ICON-Coast simulations are used for two studies (manuscripts in prep). In the first one, we are investigating impacts of increasing organic carbon inputs to the Arctic Ocean due to coastal permafrost erosion. In particular, we are focusing on the carbonate saturation state of shelf waters, critical for marine ecosystem integrity. We find that the increasing carbon inputs at the coasts lead to increases in carbonate undersaturation frequency, intensity and duration. This impact, however, is mainly confined to the boundary areas of coastal regions that are already permanently undersaturated due to increasing atmospheric CO2, making greenhouse gas emissions the dominating pressure for the Arctic marine carbonate system.

In a second study, we are using a combination of observational datasets alongside our ICON-Coast simulations to assess how marine heatwaves affect CO2 uptake and carbonate chemistry in the global coastal ocean (manuscript in prep). Elevated water temperatures generally reduce the ocean's capacity to absorb CO2 due to decreased solubility. In coastal regions, however, carbon dynamics are strongly influenced by biological processes sensitive to changes in temperature, stratification, particle sinking rates, and oxygen availability. Contrary to trends observed in the open ocean, we find that marine heatwaves can enhance coastal CO2 uptake, driven by sea ice loss and biologically mediated processes. These findings emphasize the importance of accounting for regional variability when evaluating impacts of extreme events on the global carbon cycle.

The regional SCHISM-ECOSMO model framework is used to elucidate the role of key shelf-specific processes for carbon cycling on the NWES. New advancements were made regarding the representation of inter-basin exchange, and the implementation of variable stoichiometry of organic matter cycling. Building on these improvements, we are evaluating the individual and combined effects of two pathways for variable organic matter stoichiometry: preferential remineralization of organic nitrogen and phosphorus, and extracellular release of dissolved organic matter under nutrient limitation. In Demir et al. (2025a), we provide the first quantitative assessment of their impacts on the balance between carbon fixation and respiration, and the influence on air–sea CO2 exchange on the NWES. We find that compared to fixed Redfield stoichiometry, the annual net CO2 uptake of the NWES increases by 10-30% (Fig. 1) due to intensified organic matter cycling, which results in higher net autotrophy in surface waters and higher net heterotrophy in deeper layers. In another study (Demir et al. 2025b), we address related changes in the complete organic and inorganic carbon budgets, focusing on the changes in lateral carbon export from the NWES to the adjacent North Atlantic.

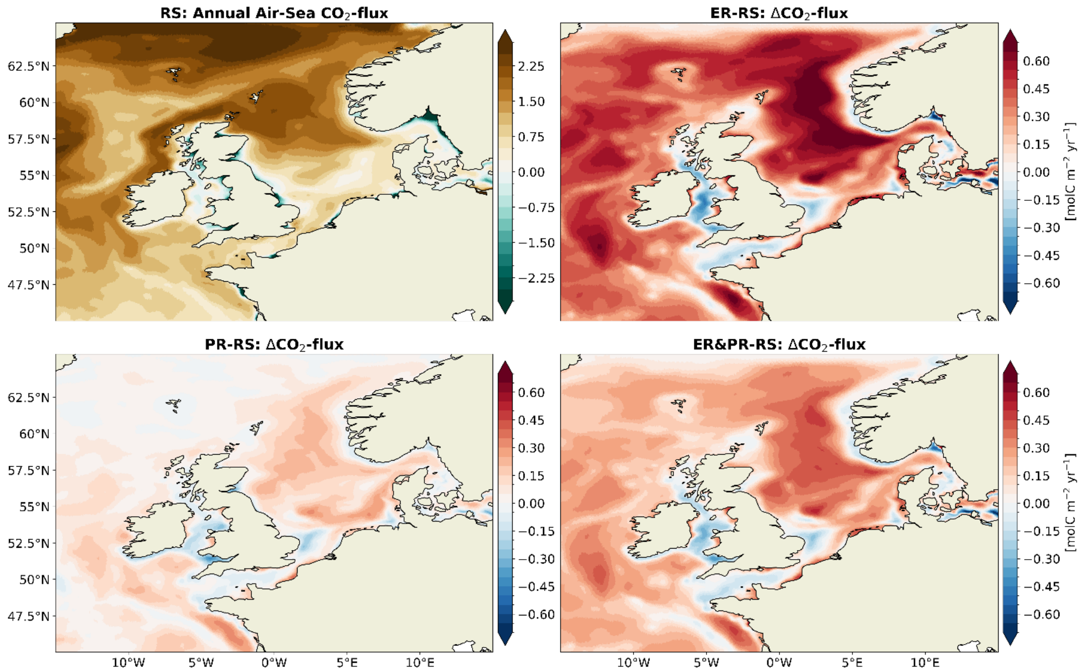

Fig 3: Annual mean air–sea CO2 flux of the standard Redfield stoichiometry (RS) configuration over the simulation period 2000–2010, and differences of the variable stoichiometry configurations: extracellular release (ER), preferential remineralization (PR), and the combined pathway (ER&PR). Positive fluxes indicate CO2 uptake by the ocean and negative values CO2 outgassing to the atmosphere.

Publications in 2025 that use data of subproject bg1184:

Demir, K. T., Mathis, M., Kossack, J**.,** Liu, F., Daewel, U., Stegert, C., Thomas, H., and Schrum, C**. (2025)**: Variable organic matter stoichiometry enhances the biological drawdown of CO2 in the northwest European shelf seas*, Biogeosciences*, 22, 2569–2599, https://doi.org/10.5194/bg-22-2569-2025, 2025.

Demir, K. T., Mathis, M., Kossack, J., Liu, F., Daewel, U., Stegert, C., Thomas, H., and Schrum, C**. (2025)**: Organic matter stoichiometry regulates the continental shelf carbon pump efficiency of the northwest European shelf seas*. ESS Open Archive*, https://doi.org/10.22541/essoar.175088438.85557149/v1, 2025.

Data Management of subproject bg1184: ICON-Coast simulations are currently on /work for ongoing analysis and shall be moved to the long-term archive after publication. SCHISM-ECOSMO runs that are published in Demir et al. (2025a) will be moved to the long-term archive till the end of the year.

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.-20.10.2025

	Allocated for 2025	Consumed (20.10.2025)	Projection of consumption to end of 2025
Computing time [node hours]	381459	206339	371459
Levante GPU nodes (Node hours)	0	48	
Levante storage (TB)	1580	978	1580
Archive project (TB)	370	134	370
Archive long term (TB)	0		0
Swift Object Storage (GB)	-	4	4

Experiments performed successfully at subproject account bu1213: WP1: Control and 4xCO_2 simulation, were generated using the ICON-XPP model — 10 km in the ocean and 80 km in the atmosphere. The control simulation is 90 years long and was based on the HighResMIP protocol (1950 conditions) with a constant CO_2 concentration of 312.82 ppm. To generate the 4xCO_2 simulation, we branched off the control simulation in 1975, and instantly quadrupled the CO_2 concentration in the atmosphere and ran this parallel experiment until 2040. **WP2:** Several two-year experiments were conducted using the GCOAST-WAM-NEMO/GCOAST-NEMO model (ocean model with 1.8km horizontal resolution for the North Sea setup). OpenDrift model for simulating the migration of C. Crangon North Sea brown shrimp (simulations of 150 days starting from different initial times). Four high-resolution (2.5km) numerical experiments using the WAM model were conducted for the entire Black Sea. The first experiment simulated historical wave conditions for 1975–2005. The remaining experiments investigated future wave climate projections under RCP2.6, RCP4.5, and RCP8.5. For the western Black Sea, four additional experiments were conducted to downscale the wave climate at a finer spatial resolution of approximately 900 m. **WP3:** ICON-ESM-HAMOCC (R2B9/R2B9) was run for 3 years. The simulations were run for 2020 and 2021. One year of the simulations had to be repeated after fixing a bug in sea ice in ICON.

Scientific results of subproject bu1213: WP1: The results are documented in **Fate of the ocean's energy in a warmer world (in prep)** and have been presented at AGU, EGU and recently at CELLO. We analysed 2 aspects of the ocean's Lorenz Energy cycle (LEC): (i) robustness of the LEC by comparing the LEC from a coupled model to that from an uncoupled setup and (ii) the response of the ocean's LEC to CO_2 warming. We showed that: (i) the coupled model simulates an intensified main energy pathway in the ocean. However, the direction of all the energy conversions is consistent in both simulations and the LEC is therefore robust. (ii) CO_2 warming leads to strengthening of the westerlies which counters the freshening and acts to strengthen the general working of the ocean (main energy pathway) and (iii) The oceanic response is contrary to the atmospheric response — the atmosphere slows while the ocean intensifies. This is tied to differences in the driving of the two systems.

WP2: The projected future changes of the extreme storm surges and extreme marine heatwaves along the Northern European continental shelf were investigated using sets of the GCOASTv3.6: NEMO-WAM model simulations for the pair of 30-year in the future period (2070-2099) relative to historical period (1970-1999). The role of internal variability on the future projections was also assessed. For more details refer to Nguyen et al., Manuscript in preparation. Model outputs obtained from wave climate simulations, comprising significant wave height, mean wave period, and Stokes drift, were systematically analyzed to assess spatiotemporal variability in the Black Sea wave climate as well as the western Black Sea. Historical wave simulations were evaluated against hindcast data to assess model performance. Future scenario experiments provided high-resolution projections of wave climate conditions toward the end of the 21st century. These results offer valuable input for a range of coastal engineering applications, including simulations of sediment transport, morphodynamics, and particle dispersion. The significant results regarding the wave climate of the western Black Sea will be submitted to a scientific journal.

WP3: Our first coupled 5 km ICON-ESM-HAMOCC simulation resolves category-4 tropical cyclones in the North Atlantic, whose impacts on the ocean carbon cycle have remained unexplored with global coupled models. We investigated the effects of two such hurricanes and showed that they invert the air-sea CO2 flux direction from outgassing to ocean uptake. Our simulated TCs also cause a widespread regional phytoplankton bloom, which is in agreement with observations and systematically missed by coarser CMIP-type global models (Nielsen et al. *in review*). Here we can link km-scale ocean-atmosphere extreme events, such as hurricanes, with the carbon cycle at global scale in ICON for the first time. In the next step, we aim at quantifying how much of the air-sea CO_2 exchange is mediated by mesoscale processes acting in scales of less than 100 km, such as storms and ocean eddies. We apply implicit spatial filters, adapted for ICON (Novak et al. 2024). We use spatial filters that follow the Rossby radius of deformation, with sensitivity tests (e.g. how many Rossby radii cutoff). Our analysis shows high mesoscale variability in pCO2 in the tropics, coastal regions, and along fronts bounding the Antarctic circumpolar current. In the next step, we will run another 3 years of coupled 5 km simulations (R2B9/R2B9), which will allow us to robustly quantify the role of mesoscale, while accounting for interannual variability.

Publications in 2025 that use data of subproject bu1213:

Nguyen, T.T., Staneva, J., Bonaduce, A., Jacob B., and Pein J. (**2025**): Seamless integration of the land–ocean continuum: the complex interplay of wave-induced processes and estuarine influences. *Ocean Dynamics* 75, 58 (2025). https://doi.org/10.1007/s10236-025-01705-3

Pham, T.N, Gramcianiov, C.B., Ricker, M., Staneva, J.: Wave climate projections in the western Black Sea using regional EURO-CORDEX wind forcing data. *Ocean Engineering (to be submitted).*

Nowak, K., Danilov, S., Müller, V., and Liu, C.(**2024**): Implementation of implicit filter for spatial spectra extraction, *EGUsphere [preprint]*, https://doi.org/10.5194/egusphere-2024-1119.

Nielsen DM, Chegini F, Serra N, Kumar A, Brüggemann N, Hohenegger, Ilyina T. Resolved tropical cyclones trigger CO2 uptake and phytoplankton bloom in an Earth system model simulation *(In review)* https://doi.org/10.31223/X5KF05

Ssebandeke, J., von Storch, J .S., & Bruggemann, N. (**2025**). Fate of the ocean's energy in a warmer world (*In prep*)

Data Management of subproject bu1213: WP1, WP3: We will archive the primary data**; WP2**: 264 for studying coastal extremes, and the role of internal variability.

Report project bu1214

Project title: CLICCS-C1 - Sustainable Adaptation Scenarios for Urban Areas – Water from 4 Sides
Project lead: Franziska Hanf
CLICCS project chairs: Jana Sillmann (UHH), Jörg Knieling (HCU), Jürgen Oßenbrügge (UHH), Bernd Leitl (UHH)
Reporting Period: 01.01.-20.10.2025

	Allocated for 2025	Consumed (20.10.2025)	Projection of consumption to end of 2025
Computing time [node hours]	3160	2619	3160
Levante storage (TB)	20	17	20
Archive project (TB)	14		14
Archive long term (TB)	4		4
Swift Object Storage (GB)	-		

Experiments performed successfully at subproject account bu1214: Simulations of two convective events (July 13, 2019, and July 20, 2019) were performed with the model-system COSMO-MUSCAT-DCEP. These included a base experiment (base) and multiple emission experiments with zero (nonurban), halved (urban_x0.5), doubled (urban_x2), quadrupled (urban_x4) and tenfold (urban_x10) urban emissions, while all other emissions were kept constant. For each experiment, a five-member ensemble was conducted by varying the model spin-up time.

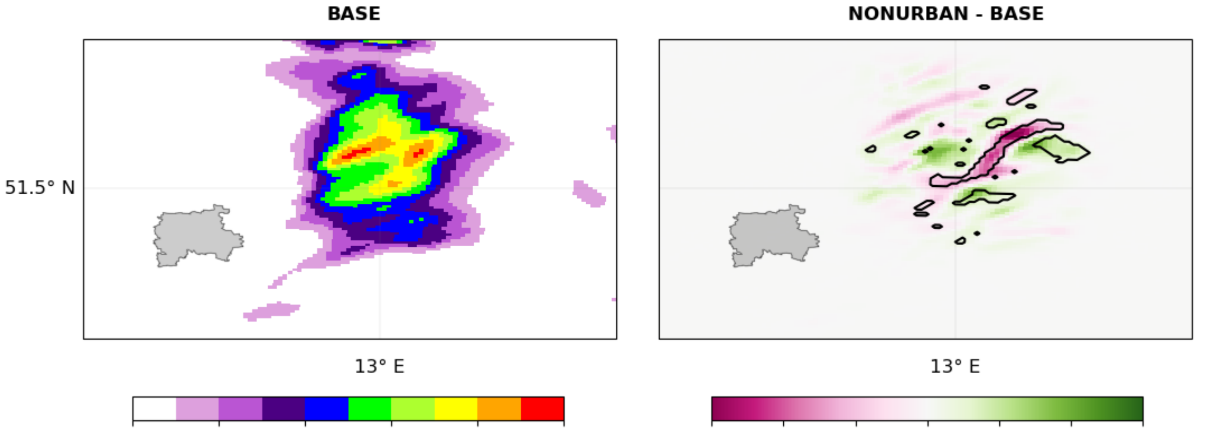

Figure 1: Ensemble mean of accumulated precipitation for the convective event on July 20, 2019, 20:00–20:30 UTC: (left) ensemble mean (BASE), and (right) ensemble mean differences (NONURBAN minus BASE). Black contours indicate areas with statistically significant differences ($p < 0.1$). City boundaries of Leipzig are outlined in grey.

Scientific results of subproject bu1214: Our results show that urban emissions can modulate microphysical processes in convective systems and affect precipitation amounts (Fig. 1). (Keil et al., in review). However, the responses are strongly case-dependent. Under moderate atmospheric instability, urban aerosols locally modify the cloud microphysics and precipitation without altering the overall structure of the convective system. Under stronger initial instability, urban emissions intensify precipitation and strengthen downdrafts, which in turn cause a premature system decay and a shorter lifetime compared to the zero-emission scenario. Ensemble analysis further demonstrates that emission-induced changes are of similar magnitude to internal variability, underscoring the need for multiple realizations and significance testing.

Overall, the results highlight that urban aerosol effects are highly case-dependent, making assumptions about uniform impacts challenging. The same urban emission source can either delay, enhance or suppress convection depending on prevailing atmospheric conditions.

Publications in 2025 that use data of subproject bu1214: A manuscript based on the project data was submitted to Atmospheric Chemistry and Physics in September 2025 (Keil et al.).

Data Management of subproject bu1214: Currently 16 TiB storage on work are used. This includes the model setup, input data, and completed model simulations. The finished simulations are planned to be transferred to the project archive by the end of the reporting period.

References: Keil, F., Quante, M., Heinold, B. and Matthias, V. (*submitted at ACP*): Tracking the Impact of Urban Air Masses on Convective Precipitation: A Multi-Member Modeling Study

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.-20.10.2025

	Allocated for 2025	Consumed (20.10.2025)	Projection of consumption to end of 2025
Computing time [node hours]	66616	48396	66616
Levante storage (TB)	173	158	173
Archive project (TB)	0	-1	1
Archive long term (TB)	155	-	
Swift Object Storage (GB)	-	-	-

Experiments performed successfully at subproject account bg1186: During the reporting period works focused on deepening the cross-sectoral coupling of the numerical models across domains. For the domain of the southern North Sea (SNS), model runs were performed in different coupling configurations such as hydrodynamics-windwaves, hydrodynamics-windwaves-sediment, hydrodynamics-biogeochemistry and hydrodynamics-windwaves-biogeochemistry. All experiments were run for at least one year and some of the also for time-slices under a climate scenario 100 years into the future.

The SNS simulations from the current reporting period and from previous periods were also downscaled to coastal domains such as the Jade Bay, Weser estuary and Elbe estuary resolving upper- and lower end as well as median trajectories of the climate scenario simulations for the SNS (Pein et al., 2023). Furthermore, the nested model chain was used to produce hindcasts of extreme years with extreme events like the drought of 2018.

A series of experiments using SCHISM-WWM-SED3D was conducted to develop applications for coastal erosion along the Western Black Sea. During these experiments, an average of 10,000 CPU hours was employed using a grid with a spatial resolution of 100–3000 m and 21,000 nodes, with simulations performed for the years 2015–2017. The results were post-processed and applied with a focus on tuning individual modules and assessing the risks for hazards such as coastal flooding and erosion.

Scientific results of subproject bg1186: Deeper integration of surface-related physical processes but also of tailored mixing schemes led to improvements in simulating crucial patterns such as the estuarine salinity front, sediment distribution in the water column and in horizontal dimension as well as chlorophyll-a patterns in the SNS domain including the estuarine environment (Fan et al., 2025). These improvements were achieved without improving mesh resolution or even with moving to horizontally coarsely resolved set-ups (of SNS). Scientifically this demonstrates the relevance of vertical processes to constrain 3D advection of tracers and biogeochemical dynamics depending on three-dimensionally advected tracers. It became clear that certain advantages of structured models at similar or coarser resolution were related to sophisticated mixing schemes or use of wave models and that unstructured models become equally potent when integrating such schemes.

Specific outcomes for coastal risks in the domain of the Western Black Sea are summarized as follows: Full coupling between modules with improved computation of bottom shear stress. The identification of erosion hotspots based on the intensity of bottom shear stress exceeding thresholds or sediment erodibility was achieved. Further, the model experiments enabled characterization of erosion drivers along the Western Black Sea with unprecedented detail for small embayments and coastal cells.

Publications in 2025 that use data of subproject bg1186: Drewes, D., Schrum, C., Pein, J., Benkort, D., & Daewel, U. (**2025**). Environmental controls on the development of early life stages of European smelt in the Elbe estuary. *Ecological Modelling*, *510*, 111313. https://doi.org/https://doi.org/10.1016/j.ecolmodel.2025.111313

Fan, H., Pein, J., Chen, W., Staneva, J., & Cheng, H. (**2025**). Effects of heatwave events on dissolved oxygen in the Elbe Estuary. *Water Research*, 124125. https://doi.org/10.1016/j.watres.2025.124125

Hosseini, S.T., Stanev, E., Pein, J. *et al.* (**2025**). Tidal impacts on volume and salt transport through the Strait of Hormuz and on Persian Gulf salinity. *Ocean Dynamics* **75**, 88. https://doi.org/10.1007/s10236-025-01735-x

Nguyen, Thao Thi, Joanna Staneva, Antonio Bonaduce, Benjamin Jacob, and Johannes Pein. (**2025**). "Seamless integration of the land–ocean continuum: the complex interplay of wave-induced processes and estuarine influences." *Ocean Dynamics* 75, no. 6 (2025): 58. https://doi.org/10.1007/s10236-025-01705-3

Pein, Johannes, Joanna Staneva, Johanna Biederbick, and Corinna Schrum. (**2025**). "Model-based assessment of sustainable adaptation options for an industrialised meso-tidal estuary." Ocean Modelling 194 (2025): 102467. https://doi.org/10.1016/j.ocemod.2024.102467

Steidle, L., Pein, J., Burd, A. B., & Vennell, R. (**2025**). Effects of coagulation processes on phytoplankton mortality in the Elbe estuary from a Lagrangian perspective. *Frontiers in Marine Science*, *12*, 1624762. https://doi.org/10.3389/fmars.2025.1624762

Data Management of subproject bg1186: To reduce the 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. In addition, geophysical and biogeochemical fields were interpolated to structured meshes from often used Copernicus satellite products for feasible storing and sharing of the data for downstream uses. After finishing the analyses, climate simulation runs were moved to archive for long-term storage.

References: 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