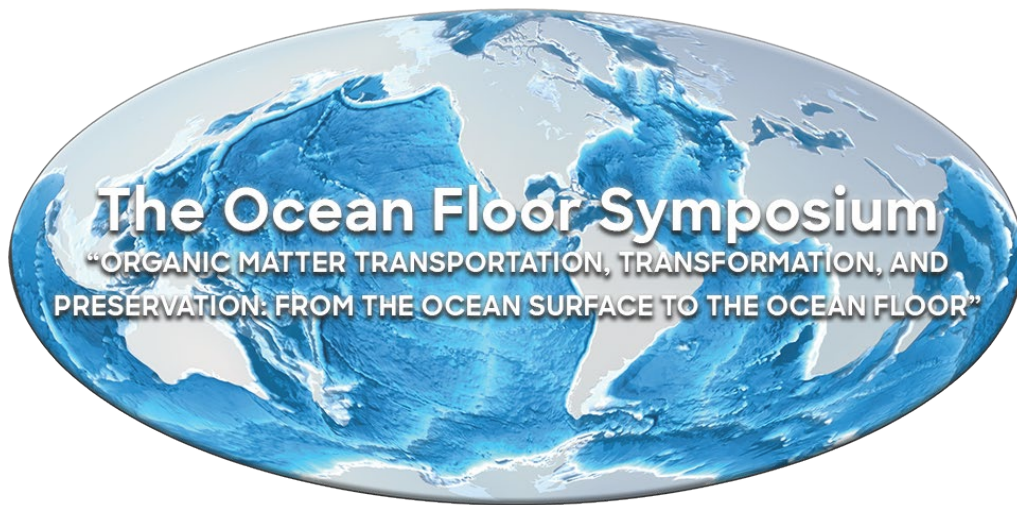




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“Organic matter transportation, transformation,
and preservation: From the ocean surface to the
ocean floor”

September 8 – September 11, 2025
at MARUM – Center for Marine Environmental Sciences,
University of Bremen

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Effects of Deep Ocean Pressure on Enzymatic Mechanisms of Organic Matter Degradation

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Microbial communities use extracellular enzymes to hydrolyze high molecular weight organic matter to sizes suited for uptake. Hydrolysis of polysaccharides yields products available to other organisms (via 'external hydrolysis'); polysaccharides may also be processed via 'selfish uptake', in which binding, hydrolysis, and uptake occur without loss of hydrolysis products to the environment. Both mechanisms are widespread in the surface ocean. We recently discovered that selfish uptake is also common throughout the depths of the water column. These experiments, however, were carried out at atmospheric pressure. To investigate the effects of pressure on enzymatic processes, we measured hydrolysis in surface and deep waters at atmospheric and high hydrostatic pressures. External hydrolysis of polysaccharides by surface-ocean communities was greatly reduced by high hydrostatic pressure; deep ocean communities showed less pressure sensitivity, and in some cases showed pressure enhancement. Even for deep ocean communities under pressure, however, some polysaccharides were not externally hydrolyzed. Selfish uptake of polysaccharides, in contrast, was considerably less affected by elevated pressure, even for surface ocean communities. Moreover, all polysaccharides tested to date were selfishly taken up under pressure. These results suggest that selfish uptake plays an important role in carbon processing, consuming polysaccharides that are not externally hydrolyzed in the deep ocean.

Towards an improved mechanistic model of microbial degradation of sinking marine particles

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Earth system models estimate that around 10 billion tonnes of Particulate Organic Carbon (POC) sink out the upper ocean annually. The Regional Carbon Cycle and Processes study (RECCAP2) recently reported that 9 billion tonnes of this settling POC is transformed to dissolved carbon by 1 km depth. As a community, our research focusses almost exclusively on what remains – the particles, and typically we refer to this massive particle transformation as particle breakdown, or degradation or remineralization. In this presentation, I will present data on vertical changes in the apparent respiratory quotient of sinking particles. I will contextualise these findings using C-RESPIRE (see Boyd et al., 2015, L&O Methods) particle interceptor/incubator data from the upper mesopelagic to explore what sets the limits on particle degradation by attached microbes. I will use these findings along with the diverse particle transformation and microbial literature to develop an improved model of how microbes degrade particles in the oceans' Twilight Zone.

Stoichiometry of Dissolved Organic Matter at the Land-Ocean Interface of the North Sea

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Dissolved organic matter (DOM) is a major oceanic carbon pool containing nitrogen (DON), phosphorus (DOP), and sulfur (DOS), which influence nutrient cycling and carbon dynamics. Lateral transport of DOM is a key pathway linking coastal production and sedimentary processes to the open ocean, yet the role of coastal seas in altering DOM stoichiometry and exporting recalcitrant fractions remains poorly understood. We combined elemental stoichiometry analyses with ultrahigh-resolution mass spectrometry of solid-phase-extracted DOM to trace sources and transformations across the southern North Sea, from river plumes and intertidal porewaters to offshore waters. The DOM composition reflected distinct endmembers: heteroatom-depleted terrestrial DOM nearshore, N- and P-rich, biologically fresh DOM in productive coastal zones; S-rich DOM from intertidal sediments; and low-heteroatom, marine DOM offshore. DOS showed strong nearshore enrichment from porewater outwelling, with high S/C ratios indicating abiotic sulfurization. Stoichiometric and molecular patterns revealed that the Wadden Sea acts as a biogeochemical reactor, contributing to the formation and export of both labile and recalcitrant DOM. DOM is laterally transported across the shelf to the North Atlantic Ocean, where labile fractions fuel food webs, and refractory DOM probably contributes to the long-term deep-ocean carbon pool.

The overlooked role of submarine canyons in the transport of organic carbon from coasts to the deep-sea

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Fluxes of carbon between the atmosphere, land and ocean reservoirs have been quantified extensively in global carbon budgets to feed climate models. In contrast, the transfer of particulate organic carbon (POC) from coastal to deep-sea environments remains poorly considered. POC transfer from coasts to deep-sea is controlled by >9000 canyons on the World's submerged margins. However, measuring carbon fluxes in submarine canyons is challenging because canyons are deep and dynamic environments, which can be harmful to monitoring instruments. Key questions thus remain unanswered, inhibiting accurate assessment of the global coast-to-deep-sea carbon flux: How is organic carbon transported from coastal to deep-sea environments? What are the fluxes of carbon involved in this transfer?

This seminar will address these questions by presenting novel observational and sampling data collected in two areas. First, I will present results obtained in small-scale submarine canyons in fjords of British Columbia where recent advances in technology to monitor canyons allowed new sediment transport processes to be discovered and carbon fluxes to be estimated. Second, I will present observations and samples collected using an ambitious array of acoustic and sampling instruments deployed for four months in one of the largest submarine canyons globally: the Congo Submarine Canyon connected to the Congo River.

Marine carbon and ecosystem feedbacks in the Earth System

Judith Hauck^{1,2}, Christopher Danek¹, Özgür Gürses¹, Onur Karakus^{1,3}, Cara Nissen^{1,4}, Laurent Oziel^{1,5}, Miriam Seifert^{1,2}

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³ now at: 3UiT The Arctic University of Norway, Tromsø, Norway

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Earth System Models are routinely used for future projections of the carbon cycle and are by definition simplifications of the real world. The ocean uptake of anthropogenic carbon is to first order a physical-chemical process related to CO₂ solubility and ocean circulation. However, changes in biological productivity and ecosystem dynamics may affect the ocean carbon cycle in the future under on-going climate change. To simulate such marine carbon and ecosystem feedbacks, relevant biological processes, so far mostly neglected for the sake of simplicity or due to missing process understanding, need to be considered in the models.

Here, we present recent developments of the ocean biogeochemistry model REcoM specifically on the extended representation of phytoplankton, zooplankton and detritus sinking speed. We further present research using FESOM-REcoM and the emission-driven AWI-ESM for CMIP6-type simulations that identify a weakening of the biological carbon pump in the Arctic Ocean and of the physical carbon pump in the Southern Ocean in future high-emission scenarios. We address interactions between ocean alkalinity enhancement and phytoplankton productivity and we finally revisit the question of how big the effect of the biological carbon pump on atmospheric CO₂ is.

Future trends and climate feedbacks on the biological carbon pump

Stephanie Henson¹, Chelsey Baker¹, Kelsey Bisson², Nathan Briggs¹, Filipa Carvalho¹, Emma Cavan³, Sari Giering¹, Matt Hammond⁴, Charlotte Laufkötter⁵, Shirley Leung⁶, Elisa Lovecchio¹, Adrian Martin¹, Colleen Mouw⁷, Hilary Palevsky⁸, Andrew Yool¹

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Without the ocean's biological carbon pump, atmospheric CO₂ concentrations would be approximately 50% higher than pre-industrial levels. However, much of the functioning of the pump remains poorly known due to its complexity and the difficulty in adequately observing its many components. As a result, it is challenging to develop or validate biogeochemical models suitable for investigating the functioning of the biological carbon pump. Climate model estimates of future pump strength and efficiency diverge and therefore the response of the biological component of ocean carbon storage to climate change is poorly constrained. In this talk, I will discuss the contemporary functioning and future projected changes in the biological carbon pump and the implications for climate feedbacks. I will also highlight the potential for new observations to inform improved estimates of the ocean's biological carbon sink.

Anthropogenic impacts on sedimentary 'Blue Carbon': current knowledge and research priorities

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Sediments hold the largest carbon stocks in coastal and shelf systems, from traditional coastal blue carbon ecosystems (salt marshes, seagrass and mangroves) to 'emerging' blue carbon habitats like intertidal and subtidal sediments. Shelf sediments hold significant carbon stores, and despite planned increase in offshore renewables infrastructure and recent focus on trawling effects, the impacts of increasing anthropogenic seabed-disturbing activities are largely understudied. Consequently, it is currently unclear to what extent marine sediments might function as a natural climate solution compared to coastal blue carbon ecosystems, and how management of these habitats could contribute to avoided emissions and enhanced CO₂ removal. Effective seabed management will need to consider impacts from human activities and spatial planning for different uses, as well as potential changes under climate change.

This talk will present some of the latest research around sedimentary carbon, and discuss the impacts of different anthropogenic activities. This will cover oil and gas decommissioning; installation of renewables infrastructure; and recent research on trawling impacts, highlighting future research priorities. Targeting knowledge gaps is of great importance given the current climate crisis, and it is increasingly important to engage with policy and stakeholders, despite some of the uncertainties around the science.

Modeling biogeochemical feedbacks in a changing climate

Tatiana Ilyina^{1,2,3}, Evangelia Boza³, Lucas Casaroli³, Fatemeh Chegini¹, Hwa-Jin Choi³, Danai Filippou³, Hongmei Li², Bo Liu¹, Moritz Mathis², Sunanda Narayanan¹, David Nielsen³, Mariana Salinas³, Nuno Serra¹, Jiajun Wu¹

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The fate of anthropogenic CO₂ emissions is modulated by the strength of the ocean and land carbon sinks. Any change in the processes regulating these carbon sinks may alter the biogeochemical feedbacks on climate and affect the rate of global change. To the first order, the relationship between global warming and cumulative CO₂ emissions is a near-linear. Yet, recent studies based on Earth system models (ESMs) highlight large uncertainty across models, due to our lacking understanding of the biogeochemical and physical processes. Computing ESMs with higher (km-scale) spatial resolutions leads to improved representations of the physical climate processes due to resolving subgrid physics. Yet, such ESMs still rely on oversimplified assumptions governing ocean microbial and ecosystem processes. Realistic representation of the complex marine biology as an interactive component in km-scale ESMs is a key scientific challenge. I will discuss the current progress, challenges and opportunities in modeling the changing ocean biogeochemical feedbacks in the Earth system with the new comprehensive ESM based on the ICON architecture and featuring higher spatial resolutions.

Beyond first order kinetics for the degradation of organic matter

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The enormous diversity of molecular compounds and microbial metabolisms makes it difficult to constrain how much of the organic carbon fixed by autotrophic organisms is respired back to CO₂ at a global scale. It is this balance that determines how much carbon reaches the ocean floor, is retained in the sediments or remains as recalcitrant dissolved organic carbon (DOC) in the water column. The lack of a quantitative understanding makes it difficult to dynamically include the fate of carbon inventories, such as DOC, into our future climate scenarios. Current ocean models implement organic carbon as a set of discrete reactivity pools, each decaying with first-order kinetics. However, this hypothesis of a first-order kinetic has never been empirically validated. Here, we propose a paradigm shift by describing organic carbon decay as a second-order process, governed by encounter rates between DOC molecules and heterotrophic bacteria. We use the 700 petagram inventory of DOC as an example. This mechanism implies that degradation is limited not by molecular lability alone, but by the probability of molecular encounters of their consumers in the dilute environment of the deep ocean. We support this concept through several lines of evidence, including statistical model fits, theoretical estimates and a global 3D numerical simulation. These results argue for a reconceptualisation of (D)OC dynamics, with implications for predicting (D)OC variability and future oceanic carbon storage.

Improving Earth System Models through simulating past climate-carbon cycle feedbacks

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Considerable uncertainties exist in predicting future climate, carbon sinks, and the feedback between them. A primary cause is the simplification of processes and unconstrained model parameters. Particularly, constraining the ocean carbon sink, which dominates on centennial to millennial timescales, is challenging because present-day observations span only a few decades. Simulating the climate-carbon cycle system in past climates, for which a wealth of geological records are available to validate models, can advance our understanding of the Earth system and help reduce model uncertainties.

We use the Max Planck Institute Earth System Model to run a suite of transient simulations for the last deglaciation (21 ka to the present). When applying an ocean biogeochemical model tuned similarly to its CMIP6 version, the ocean contributes to an atmospheric CO₂ rise of only 30 ppm (a 90 ppm rise in ice core records), driven by the weakening of the solubility pump. After adjusting the model to address uncertainties related to the parameterisations of several biological processes, the model-data agreement for the present day is improved, and a larger deglacial ocean CO₂ outgassing of 40 ppm is achieved. When employing a physical model that produces a weaker glacial AMOC, the deglacial ocean CO₂ outgassing rises to about 60 ppm. Our results emphasise the crucial role of properly representing ocean circulation in the natural carbon cycle and highlight key areas for further development.

Submarine canyons: important pathways for organic matter from shelf to deep ocean

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Submarine canyons create immense conduits for lateral transport of particulate matter from shelf to deep ocean. The existing paradigm is that at the present sea level high-stand, most canyons are relatively inactive in terms of matter transport. To determine which processes affect organic matter (OM) dispersal and deposition, moored observatories were deployed, suspended matter from the water column and sediment samples were collected along the eastern branch of Whittard Canyon. A mid canyon permanent nepheloid layer between 1200-2300m water depth was observed, related to active resuspension of OM by tidal currents during peaks in current speed when the tidal flow was directed up canyon. Long term measurements showed that significant amounts of particulate matter were transported by intermittent gravity flows, resulting in the large volume transport of matter as shown by elevated mass and organic carbon fluxes. Some events were characterized by fluorescence peaks, indicating supply of fresh OM, likely providing an important food supply mechanism to the deep-sea fauna. Analysis of surface sediments showed that the canyon head is characterized by low concentrations of fresh OM, while the lower reaches of the canyon show highest concentrations of degraded OM being the ultimate deposition sites. Whittard Canyon is an active system being a pathway and sink for organic matter, emphasizing the important role of submarine canyons in the marine carbon cycle.

Fine-scale Hydrodynamic Forcing of Food Supply to Benthic Communities – Case Studies from Atlantic Seamounts and Cold-Water Coral Mounds

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Seamounts and cold-water coral mounds are widespread deep-sea features that provide habitats for unique benthic communities and locally enhance organic matter flux driven by interactions with ocean currents. These interactions generate fine-scale hydrodynamic phenomena like Taylor caps, internal waves, and turbulent mixing, which increase vertical transport of organic matter and enhance food availability in otherwise food-limited environments. We present results from high-resolution hydrodynamic models that integrate detailed bathymetry with basin-scale and tidal forcing to examine near-bottom currents and physical drivers of food delivery to filter and suspension feeders across Atlantic seamounts and coral mounds. Our findings reveal strong links between large-scale ocean currents, internal tide dynamics, and benthic faunal distribution. We identify key physical oceanographic indicators, such as internal wave dynamics and energy dissipation rates, as potential proxies for food supply and particle encounter rates in future species distribution and habitat suitability models. Overall, we aim to advance our understanding of the bio-physical coupling that sustains deep-sea biodiversity and provides a foundation for predicting the distribution of vulnerable species and ecosystems under changing environmental conditions.

Competitive Strategies in Oceanic Carbon Cycling: Selfish, Sharing, and Scavenging Bacteria

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Heterotrophic bacteria drive the breakdown of phytoplankton-derived dissolved organic matter in the ocean. Their activity limits the sequestration of carbon to the deep sea and sediments. A significant component of the dissolved organic matter is glycans, which are degraded by the microorganisms using carbohydrate-active enzymes. Beyond the use of enzymes, we have also discovered three main ecological foraging strategies: sharing, selfish uptake, and scavenging. Each has a different enzyme cost and benefit, dependent on glycan complexity and availability.

To quantify the activity of each strategy in the water column, we use fluorescent substrate analogues. Furthermore, we identify active selfish bacteria via fluorescence *in situ* hybridisation. A standout finding: Bacteroidota, especially Flavobacteriia, are major players in selfish uptake. We complement our *in situ* observations with culture-based investigations to understand how genotypes become phenotypes and identify the drivers which select for each foraging strategy. Together, these insights show how microbial strategies control the breakdown of dissolved organic matter and how the fine line between sharing and selfishness drives carbon flow in the ocean.

Down the slope with the dense water pump: dense shelf water subduction as lateral particle injection mechanism from productive Arctic shelves

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Polar dense waters fill the deepest parts of the ocean basins and drive the thermohaline circulation. They are primarily formed in ice-free areas as a result of increased heat loss and brine rejection during sea ice formation. While sinking to the ocean interior, those waters can carry large amounts of dissolved inorganic carbon to depth, a process known as solubility pump and one of the major sinks in the global carbon (C) cycle. On Arctic shelves, wind stress from land keeps large areas ice-free which intensifies dense water formation. These so-called polynyas are also characterized by high primary productivity rates due to increased light availability and nutrient supply from vertical mixing. This co-location of biological C fixation and dense shelf water formation could, next to dissolved fractions, also cause an injection of C-rich particles from the productive shelves into the deep ocean basins but detailed investigations on this lateral injection mechanism within the biological carbon pump were missing so far. Here I present recent and ongoing investigations on dense water driven lateral carbon injection into the deep Arctic basins. I show latest insights about the discovery of a deep plume of particulate material in the Arctic Nansen and Amundsen Basin, representing a potential long-range transport into the central Arctic Ocean.

Sources and transformations of natural and anthropogenic DOC throughout the oceanic water column

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Marine dissolved organic carbon (DOC) is one of Earth's largest exchangeable carbon reservoirs, with an estimated budget comparable in magnitude to that of atmospheric CO₂. This vast reservoir plays a fundamental role in regulating the global carbon cycle and Earth's climate, although many of its internal dynamics remain poorly understood. Approximately 99% of oceanic DOC is considered recalcitrant, persisting in the ocean for centuries to millennia. A small fraction of DOC is of anthropogenic origin, such as that resulting from the degradation of plastics. Although the total contribution of anthropogenic DOC (ADOC) to the global DOC pool is small, its impact on marine microbial communities may be significant, particularly in polluted surface waters. Some components of ADOC may also be chemically recalcitrant, contributing to long-term carbon accumulation. The formation of recalcitrant DOC and its accumulation in the deep ocean represent a long-overlooked but potentially important pathway for oceanic carbon sequestration. However, many aspects of these processes remain unresolved. Here, we will explore the main drivers of surface DOC variability, the sources and sinks of recalcitrant DOC in the deep ocean, and how one of the most pervasive ocean pollutants -plastic debris- is contributing to the oceanic DOC pool.

Greener ocean? Interactions between ocean alkalinity enhancement and phytoplankton

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Model studies suggest that ocean alkalinity enhancement (OAE) can be a promising CO₂-removal strategy, but potential risks for the ecosystem are presently not assessed in models. We examined OAE-phytoplankton feedbacks in an Earth System Model by adding carbonate system dependencies to the phytoplankton growth term. OAE is performed between 2040 and 2100 in the exclusive economic zones of Europe, the US, and China, with alkalinity additions reaching 103.2 Tmol year⁻¹ by the end of the century. Our analysis shows that OAE does have a considerable effect on net primary production, and that biological feedbacks, in turn, modify the efficiency of OAE.

Deep-sea prokaryotes (and others) and their role in the biological carbon pump

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The deep sea (considered here as the water column at depths below 200m) represents the largest habitat in the biosphere, in terms of volume. Around 5 to 15% of the carbon photosynthetically produced in the sunlit upper ocean is exported as particulate organic carbon (POC) below 200m depth. These particles sink through the water column, primarily by gravitational processes, constituting the main input of organic carbon (OC) into the mesopelagic zone. Only around 10% of sinking POC reach depths greater than 1000 m due to multiple degradation processes involving zooplankton grazing and heterotrophic prokaryotes degradation that colonize these particles or through interactions with the free-living microbial communities in the surrounding water. However, relatively little is known about dark-ocean biological processes even though this topic has received greater attention over the past two decades. In this presentation, I will present the current status of knowledge of the deep-sea prokaryotic activity (and diversity), emphasizing the importance of distinguishing between suspended and sinking prokaryotes and the role of hydrostatic pressure. I will present also our preliminary results concerning the effect of hydrostatic pressure on zooplankton. Finally, I will conclude on the importance to better communicate about the deep sea.

List of Abstracts: Posters

Ocean Floor Symposium 2025

“Organic matter transportation, transformation,
and preservation: From the ocean surface to the
ocean floor”

September 8 – September 11, 2025

at MARUM – Center for Marine Environmental Sciences,
University of Bremen

Anion exchange purification to quantify algal sulfated fucans concentrations in millennia-old marine sediments

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Anionic polysaccharides play key roles as carbon sinks in the ocean. They assemble and aggregate into particles and are transported from the ocean's surface to deeper layers and the sediment. The buried carbon is potentially sequestered for several millennia. Complex fucose-containing sulfated polysaccharides produced by diatoms and brown algae can assemble as particles and resist bacterial degradation. Previous studies have detected the presence of these polysaccharides in marine sediments using specific monoclonal antibodies. As these methods are not quantitative, concentrations of the polysaccharides have so far remained unknown. In this study, we extracted carbohydrates from millennia-old sediment (deepest depth = 11.8 ka) from the Bransfield Strait in the Southern Ocean. From these extracts, we purified fucose-containing sulfated polysaccharides using anion exchange chromatography. Quantification of monosaccharides in the purified fraction revealed that these polysaccharides contributed 4 – 10 mg of carbon per gram of the buried organic carbon across different ages of the sediment core. This study describes an approach to purify and quantify polysaccharides from complex mixtures like sediment, to better understand their roles in the marine carbon cycle. Purification and quantification may allow us to use these polysaccharides as proxies for past climate reconstruction or to understand ecological dynamics.

Size-based contribution of the mesopelagic-migrant pump to carbon sequestration in the subantarctic Southern Ocean

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The mesopelagic-migrant pump (MMP), a component of the biological carbon pump, transports carbon from surface waters to depth via diel vertical migration. Migrating animals feed on carbon-rich surface material at night and return to the mesopelagic zone (200–1000 m) by day, injecting carbon as particulate organic carbon (POC) through feces and carcasses and as dissolved inorganic carbon (DIC) via respiration and POC degradation. While observational studies have highlighted the role of the MMP in downward carbon export, the MMP's contribution to long-term carbon sequestration has received less attention. Non-migrators and animals with overlapping vertical migrations also transfer surface-derived carbon through mesopelagic trophic interactions, highlighting the need to consider food web dynamics when assessing carbon cycling. Here, we apply a multispecies size spectrum model to estimate carbon accumulation by mesopelagic micronekton in the subantarctic Southern Ocean during summer. The model incorporates mesopelagic trophic interactions and both particulate and dissolved carbon transport pathways to assess MMP-driven sequestration. Model calibration was based on observed empirical biomass values obtained from a Southern Ocean summer voyage, focusing on organisms 20–200 mm in size. This approach provides insight into how mesopelagic food webs mediate carbon storage and offers a benchmark for evaluating future changes driven by climate variability and emerging mesopelagic fisheries.

Mass Spectrometry Guided Characterisation of Marine Fucose Containing Sulfated Polysaccharides Driving Oceanic Carbon Sequestration

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Marine algae fix ~50 gigatons of inorganic CO₂ annually via photosynthesis. A substantial portion of this fixed organic carbon is stored as glycans - some algae allocate up to 80% of their carbon to glycan synthesis. While most carbon is remineralized in the surface ocean, a fraction escapes degradation and is exported to depth, contributing to long-term carbon sequestration. Brown algae alone fix ~1 gigaton of carbon annually, with up to 15% potentially sequestered as nutrient-depleted, recalcitrant polysaccharides, equivalent to 0.55 gigatons CO₂, just below Germany's 2024 emissions.

A key mechanism in this process is the release of complex fucose-containing sulfated polysaccharides (FCSP), comprising up to one-third of the exuded carbon in marine algae. Due to their structural complexity and highly sulfated backbone, FCSPs resist microbial degradation and strongly contribute to the biological carbon pump, sinking to depths >1000 m where carbon may be stored for millennia.

Despite their importance, the molecular composition, fate, and turnover of FCSP remain poorly characterised due to analytical limitations. Here, we present a targeted LC-MS framework for environmental glycan analysis, including selective isolation from seawater, controlled hydrolysis, and quantification at the monomer level. Future development aims to extend this approach to oligomeric profiling using tandem MS and established bioinformatic tools optimised for sulfated polysaccharides.

This preliminary workflow enables high-throughput compound-level insights into marine glycan diversity, providing a path to resolve the contribution of specific polysaccharides like FCSP in carbon sequestration. While still in development, our approach aims to streamline analysis, opening new avenues for characterising blue carbon pathways relevant to climate mitigation.

Organic carbon preservation and lateral transport during Sapropel S1 period (6–10 ka bp): Evidence from a proximal to distal transect in the western part of the Ionian sea.

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Sapropel S1 (6-10 ka BP), known as an organic-rich deep-sea deposit, records major environmental changes in the Mediterranean Sea. In the Ionian Sea, within the upper Calabrian wedge (2-3 km w.d.), S1 forms an outstanding unit (up to 15 m thick) in a fault basin that enhanced sedimentation rate. This thick laminated unit is punctuated by turbidites, and have low TOC values (0.1-1.2%). High sedimentation rate is induced by efficient land-to-sea connectivity and high volcanic-detrital inputs, likely linked to an increase of precipitation and flood events during S1 period. The comparison with sedimentary facies distribution and organic carbon (OC) preservation in Sapropel S1 in the lower Calabrian wedge (3-4 km w.d.) provides key insights into lateral transport and deep-sea deposition processes of OC during this period. Geochemical analyses of four sediment cores (2.5 to 4 km w.d.) show OC distribution from proximal to distal settings. High-resolution TOC, $\delta^{13}\text{C}$, facies, XCT, MSCL and XRF data highlight how lateral transport, basin morphology and depositional processes control OC preservation from shelf to deep basin. In proximal areas, OC is diluted by turbidites. Further downslope, reworked sapropelic material accumulates at the base of turbidite along main gravity-flow pathways. In more isolated distal areas, sapropel deposits are condensed and better preserved, with high TOC and marine OC signatures.

Fucoidan: The Glue of Particulate Organic Matter?

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Marine macroalgae and microalgae produce fucoidan or fucose-containing sulfated polysaccharides (FCSP). These polysaccharides are partially recalcitrant against enzymatic digestion by microorganisms or natural degradation (Sichert et. al. 2020). This allows them to become part of the dissolved organic carbon pool and eventually to aggregate into particles. These particles may sink to the ocean floor, where they have been observed to persist into the sediment records as oligosaccharides. In this way, carbon dioxide captured from the atmosphere by algae and transformed into sugars via photosynthesis is sequestered in the deep sea. Whether FCSP aggregate through the formation of covalent bonds with other biomolecules, or are solely attracted by ionic forces needs to be elucidated to understand the formation of particles and the role of polysaccharides in this process. My approach of using fluorescently labelled polysaccharides (FLAPS) to follow their transformation from dissolved organic matter to particulate organic matter in the ocean, shows that polysaccharides can be a driving force for particle formation. For labelling the polysaccharides methods by Carol Arnosti (2003) and Lees et. al. (1996) were adapted. Milder reaction conditions and a stabilised intermediate potentially open up the reaction for more labels. Tracking FLAPS in incubation experiments can support the initial hypothesis that FCSPs are recalcitrant against degradation when they form particles.

Microbial Munchies: The Secret Life of Selfish Sugar-Loving Bacteria

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Polysaccharide turnover is a crucial process in marine ecosystems, influencing the balance of organic matter and ecosystem functioning. Heterotrophic bacteria play a key role in this turnover, degrading high molecular weight organic matter through two active foraging mechanisms: external hydrolysis and selfish uptake. Our study aimed to elucidate the role of abiotic and biotic triggers on selfish uptake in the marine water column. We phenotypically described 38 newly isolated strains from the North Sea and investigated their ability to grow on two key polysaccharides, laminarin and glycogen. Our results showed that 27 strains are capable of degrading these polysaccharides, with some species exhibiting selfish uptake behaviour triggered by low carbon concentrations and competition. Notably, we identified *Cellulophaga* sp. and *Christiangramia* sp. as capable of selfish uptake, with the latter's selfish behaviour triggered by the presence of another species. Furthermore, our co-culture experiments revealed that competition between species can significantly impact foraging strategies, with some species exhibiting cooperative behaviour while others struggle to coexist in defined laboratory conditions. This highlights the complex and dynamic nature of competition in the water column, where diverse microbial communities interact and influence each other and thus shape the degradation of organic matter.

Natural organic matter coating on iron oxide changes its role in carbon preservation in marine sediments

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Iron oxides associate with organic matter in various environments, thereby protecting organic matter from microbial degradation¹. However, research into how this association may be influenced by the sedimentary biogeochemical processes in anoxic marine sediments remains limited². Here, we studied the interaction between synthesized ferrihydrite (Feh) and ¹³C-labeled acetate in incubations with surface sediments from Cumberland Bay (South Georgia, Sub-Antarctic). We found that adding freshly synthesized Feh promoted acetate protection by 50% in the absence of microbial iron reduction. In contrast, adding Feh pre-coated with natural organic matter promoted acetate protection by 102%, likely due to a larger surface area from smaller aggregate sizes, as shown by SEM imaging. When microbial processes were active, we observed a significant difference. While only a limited amount of Feh-protected acetate was remobilized from the fresh Feh, 76% of the acetate was remobilized from the pre-coated Feh. This suggests that organic coatings can enhance the initial sequestration of small organic molecules by iron oxides, however, they also make the iron oxides more vulnerable to microbial iron reduction. Therefore, the organic coatings on iron oxides change how they further interact with organic molecules and microorganisms, and consequently the fate of iron-bound organic matter.

1. Lalonde, K., Mucci, A., Ouellet, A. & G  linas, Y. Preservation of organic matter in sediments promoted by iron. *Nature* 483, 198-200 (2012)

2. Chen, Y. et al. Cycling and persistence of iron-bound organic carbon in subseafloor sediments. *Nat. Commun.* 15, 6370 (2024).

A Bayesian approach to mapping the variability of Particulate Organic Carbon flux

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Mapping the Particulate Organic Carbon (POC) flux is key in understanding the mechanisms of the biological carbon pump and its spatiotemporal variability. Current modelling methods struggle to capture this variability and to link POC flux to predictor variables. Using Bayesian statistics, the heterogeneous variance of POC flux within a newly compiled POC flux database can be captured and described by three explanatory parameters: satellite derived chlorophyll-a concentrations, sea surface temperature and depth of POC flux measurement. A linear Bayesian model was built to estimate POC flux where both the expected value and noise changes with each parameter. This model performed considerably better than a model with a fixed level of noise and captures the same range and distribution of variability as the POC database. It also outperforms a non-Bayesian linear model built with the same parameters. These results can help improve the understanding of underlying spatiotemporal trends and heterogeneity of the environment influencing POC flux and map not only the global patterns of POC flux, but the variability too.

Concentration-Dependant Polysaccharide Uptake by Selective Marine Bacteria

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Understanding how marine bacteria regulate their mechanism of polysaccharide uptake in response to substrate concentration is essential for our understanding of the mechanisms of marine carbon turnover. This project aims to identify conditions under which fluorescently labelled polysaccharides (FLAPS), specifically laminarin, are selfishly taken up by selective bacterial cultures. Our investigation will test growth dynamics and uptake under oligotrophic and copiotrophic conditions, varying media compositions, and at different temperatures (20°C and 5°C), recognising that these conditions may differ from those in environmental communities. We focus on three strains of the class Flavobacteriia, known for selfish uptake, specifically a novel isolate from Helgoland and the reference organisms *Zobellia sp.* and *Christiangramia forsettii*. To evaluate their potential to process laminarin selfishly, represented by their ability to take up laminarin-FLAPS, we will add varying amounts of FLAPS to carbon-limiting conditions and determine uptake by microscopy. The results will reveal how each strain takes up FLAPS under carbon-limited conditions, identifying both minimal and optimal concentrations that allow clear visualisation without oversaturation or a high background signal. This optimized protocol will establish a concentration range suitable for pure culture studies and provide a foundation for applying this method to newly isolated environmental strains under controlled conditions.

Carbon Burial in Cold-water Coral Mounds across time and space

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Coral mounds are large seabed features structured by the carbonate framework of scleractinian cold-water corals. This framework baffles large amounts of sediment, and over geological timescales, reefs develop into mounds. Their widespread occurrence along the world's continental margins suggests that coral mounds play a vital role in long-term carbon burial processes. Yet, quantitative carbon accumulation studies on coral mounds are scarce, hindering global estimates of their contribution to the sedimentary carbon budget.

Here, we present the first carbon accumulation study for coral mounds in the South Atlantic, off northern Argentina. We combine *sediment core analyses* and *seabed mapping* to quantify carbon accumulation over the last 16 ka and upscale our findings to the entire mound province (hundreds of individual mounds).

Our results show that the mound deposits are enriched in carbon (carbonate and organic carbon), with carbon accumulation rates reaching up to $7 \text{ g C cm}^{-2} \text{ kyr}^{-1}$, which is substantially higher compared to the surrounding seabed. This highlights the northern Argentinian coral mounds as hotspots of carbon burial, with an estimated total carbon storage of ~5 megatons. Finally, we place our findings within an Atlantic-wide perspective, showing a broad comparability with other mound provinces. This suggests that the observed patterns may represent a widespread process relevant to long-term carbon burial at the interface between continental shelves and the deep sea.

Organic carbon burial in global continental margin sediments

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Continental margin sediments are the largest reservoir of organic carbon (OC) in the surficial Earth system and a key long-term sink for atmospheric CO₂. Yet, the magnitude and spatial distribution of OC burial in this environment remains poorly quantified, mainly due to the exceptional heterogeneity of the coastal ocean. Here, we integrate rapidly growing seafloor observations with machine learning and reaction-transport modelling approaches to capture the spatial heterogeneity of OC transfer fluxes in continental margin sediments. We estimate a global OC transfer flux of 441 Tg C yr⁻¹ through the base of the mixed layer, which decreases to a “long-term” burial flux of 246 Tg C yr⁻¹ at the 5 kyr age horizon. Approximately 70% of this burial occurs in the northern hemisphere, and >50% is concentrated within the latitudinal band 10°S–30°N. Tropical regions show the highest long-term OC burial flux (71 Tg C yr⁻¹), representing 29% of the global total flux, followed by marginal seas (45 Tg C yr⁻¹, 18%) and polar regions (39 Tg C yr⁻¹, 16%). A country-level analysis of our results indicates that the highest long-term OC burial fluxes occur in the Exclusive Economic Zones of Indonesia (31 Tg C yr⁻¹, 13%) and Russia (22 Tg C yr⁻¹, 9%). Our results represent the first spatially resolved estimates of natural carbon sequestration in global continental margin sediments, providing policymakers with crucially needed information to guide successful management and protection strategies.

Functional Diversity of marine microbial cohorts

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Prokaryotes make up the majority of marine biomass and are the main drivers of major biogeochemical cycles in the oceans. By transforming organic carbon ultimately back to CO₂, they exert strong control on carbon storage in the ocean, ultimately governing how much carbon arrives at the ocean floor. To assess their role in the present and future marine carbon cycle, understanding their biogeography and functional potential is crucial.

Biogeographic patterns of marine heterotrophic microorganisms have been described in multiple studies. A recent conceptual novelty is the detection of stable co-occurring groups of microorganisms (microbial cohorts) across ocean basins, which form distinct subsets of the total detected diversity in a sample.

While the taxonomy and ecology of these microbial cohorts has been characterized based on 16S rRNA gene amplicons, their functional potential remains unknown, preventing further examination of the metabolic and biogeochemical potential of their members.

Here we compare a global MAG and 16rRNA gene amplicon dataset to show that both lead to taxonomically and spatially similar microbial cohorts, a prerequisite to assess the co-occurrence cluster specific functional potential. Based on this cluster approach in combination with KEGG functional annotations we can identify those functions that show largest dissimilarities among cohorts, likely contributing to their distinct biogeography.

Linking the functional potential of microbial cohorts to their biogeography helps us understanding the ecological mechanisms behind their distributions, ultimately enabling the implementation of these processes in biogeochemical models to improve assessments of global carbon fluxes.

Instant Visualization of Polysaccharide Degradation by Marine Bacteria

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The in situ tracking of organic matter transformation in the ocean presents significant challenges, resulting in limited knowledge of the associated processes. To address this, we establish a model system for the marine carbon cycle using alginate particles and marine *Vibrio* bacteria. Alginate particles are synthesized via an emulsification and internal gelation technique. These particles, with an average diameter of 145 micrometers, exhibit stability in artificial seawater and marine minimum medium. The degradation process of alginate particles by *Vibrio crassostreae* is monitored in real time using a time-lapse microscope. Preliminary experiments demonstrate the capability of this strain to degrade alginate, and optimization of degradation conditions is ongoing. This model system enables controlled, quantitative investigation of enzymatic marine particle degradation by bacteria, providing insights into particulate organic matter turnover in the ocean.

A modeling framework for studying biogeochemical processes and their importance for carbon and nutrient budgets in the North West African Upwelling system

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The Northwest African Upwelling system is one of the four major eastern boundary upwelling systems and ranks among the most productive regions of the global ocean in terms of primary production. The transformation of particles, from their production at the surface through their transit in the water column to their eventual sedimentation at the ocean floor, is governed by the interplay between regional and large-scale atmospheric and oceanic circulation and the marine biogeochemical cycle. To investigate these processes, we developed a regional configuration of the MIT general circulation model

(MITgcm) incorporating a newly implemented biogeochemistry module that includes an established particle aggregation and disaggregation parameterization based on a continuous size spectrum model, which predicts particle sinking. Model performance was assessed through detailed comparison with observational data. We analyze the model's sensitivity to key parameterizations—flux feeding, aggregation, and mineral protection—and examine their impacts on simulated export and transfer efficiencies of carbon and phosphorus. Vertical gradients of these elements arise from depth-dependent turnover timescales, reflecting the dominant balances of fluxes at varying depths. Our findings are supported by a detailed analysis of elemental budgets in both upwelling and offshore regions.

Role of fauna in cycling and burial of nutrients in Norwegian Trench sediments

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Shelf seas like the North Sea play a crucial role in global carbon and nutrient cycling. Within the North Sea-Atlantic Exchange project (NoSE) we aim to quantify organic and inorganic carbon and nutrient cycling at the sediment-water interface in the Norwegian Trench, the main deposition area in the North Sea, and determine its impact on elemental budgets in the coupled North Sea-Atlantic Ocean system. Faunal processes play a significant role in altering benthic fluxes and the burial potential of nutrients. To enhance our understanding of mechanisms and processes involved in cycling and burial of nutrients in Norwegian Trench sediments we collected sediment cores during two research expeditions and conducted whole-core incubation experiments as well as analyzed porewater and solid-phase chemistry. Our results indicate that benthic fauna contribute to sedimentary oxygen and nutrient exchange by transferring oxygen into deeper sediment layers and exposing already buried nutrients and redox sensitive metals (e.g. iron, manganese) to oxygenated waters. Faunal processes expand the oxic zone and thus promote the role of sediments as a trap for P due to adsorption onto oxidized metals. Furthermore, sediment properties and freshness of organic matter affect bio-irrigation rates and depths and thereby sedimentary nutrient cycling. The collected data together with a modelling approach will further help to elucidate biogeochemical processes in the sediment throughout the Trench.

Intensifying bottom velocity extreme events in the Drake Passage: a traditional and Machine Learning approach

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The dynamics of ocean circulation at abyssal depths are of significant interest due to their profound implications for global biogeochemical cycles, particularly the carbon cycle. However, these dynamics remain largely enigmatic due to the lack of in situ measurements. Therefore, oceanic reanalysis is essential to acquire data from the deeper layers of the ocean. We developed a methodology to calculate the number of extreme events in the Drake Passage. To determine the number of extreme events in bottom currents, we compared two traditional methods with a Machine Learning (ML) algorithm. This approach allows us to identify trends in the frequency of extreme events over a 28-year period based on daily data. Our results show that bottom-current extreme events increased significantly from 1993 to 2020. Using the first traditional method, called "pixel," we identified a trend of 106 events per decade. Using the second traditional method, called "cluster," we found a trend of 10 events per decade. For the ML method, the trend is 17 events per decade. The "pixel" method proved to be the most sensitive, and our findings suggest that the ML and "cluster" methods effectively reproduce the data. Notably, the ML method is characterized by a higher degree of realism compared to extreme events. These results could provide new insights into ocean dynamics, particularly the relevance of the Drake Passage to the global climate and the potential effects of an increase in extreme events.

Algal glycans promote microbial turnover of organic matter fluxes in permeable sands

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Permeable sands on continental shelves host microbial communities that drive organic carbon turnover, oxygen fluxes and nitrogen loss. Bedform-associated, advective porewater flow maintains these rates and fluxes. Modeling and laboratory studies suggest advective porewater flow is tightly coupled to bedform stability. However, the impacts of *in situ* bedform stability on biogeochemical fluxes in subtidal sands remains unconstrained. We deployed a benthic lander at six stations in the North Sea to measure *in situ* bedform geometries, oxygen fluxes and primary productivity accompanied with *ex situ* incubations, glycan extraction and microscopy. We observed strongly reduced bedform migration velocities (0-3.2 cm h⁻¹) compared to expected values from mechanistic models. Bedform stability may be enhanced by interstitial colloidal and particulate algal glycan concentrations (2-52 mmol C l⁻¹) that were visualized via targeted immunolabeling. Glycan accumulation was attributed to the filtration of algal biomass from the water column by advective flow through the permeable sand. Benthic primary productivity as a source of carbon was negligible. Benthic glycan concentrations correlated significantly with oxygen consumption rates per volume porewater (17-207 μmol l⁻¹_{PW} h⁻¹), whereas sediment oxygen fluxes (6-17 mmol m⁻² d⁻¹) significantly correlated with modeled porewater velocities. Overall, the impact of pelagically derived algal glycans were two-fold: (1) they drove higher oxygen consumption rates in surface sediments and (2) contributing to stabilize bedforms, which almost doubled oxygen fluxes into the sediment. To simulate oxygen fluxes into ocean floor sands, we implemented these observations into numerical models.

Effects of mesoscale features on mesopelagic dark carbon fixation and carbon budgets

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The mesopelagic zone (100-1000m) is a crucial oceanic layer for carbon transformation and transport to the deep. Mesoscale oceanographic features, such as eddies and fronts, are known to influence surface productivity and carbon export, but their effects on microbial processes within the ocean remain poorly understood. Here we show the importance and relative contribution of dark inorganic carbon fixation (DCF)—the conversion of inorganic carbon into organic carbon by prokaryotes—across five contrasting hydrological features in the North Atlantic Ocean, using isotopic tracers and quantification of chemoautotrophy genes. A key originality of this work is the simultaneous quantification of DCF and heterotrophic activity of prokaryotes living in suspension in seawater and those attached to gravitational settling particles. Our results reveal that mesoscale variability strongly modulates mesopelagic microbial processes, highlighting the key role of the influence of eddy fronts in carbon sequestration. Heterotrophic prokaryotes attached to sinking particles contribute up to 21% of the total carbon demand, whereas DCF by suspended prokaryotes can contribute up to half of the total carbon input to the mesopelagic zone. These findings challenge the perception of a uniform deep ocean and highlight the need to integrate microbial fractions and physical heterogeneity into ocean carbon models.

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Ridge-proximal refractory dissolved organic carbon production hotspots in the Western Pacific

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Complex seafloor topography pervades global oceans, modulating currents and driving material transport and transformation, including dynamic organic carbon (OC) cycling. However, the role of massive ridges in shaping OC transformation and preservation across the entire water column remains poorly constrained. Here we conduct a comprehensive carbon-oriented geochemical investigation spanning the entire water column along a 1,000 km transect across the Kyushu-Palau Ridge in the western Pacific Ocean. We observe that the ridge promotes the accumulation of refractory dissolved OC (RDOC) by enhancing microbial transformation of elevated primary production, meanwhile, coupling tightly with DIC retention in the water column. This process likely reflects the coupling of the primary production via the biological pump, RDOC generation via the microbial loop, and DIC retention via the solubility pump. Physical-biogeochemical coupling around the ridge connects multiple carbon pumps, amplifying carbon sequestration pathways that retain RDOC in the deep ocean for millennia. With >40,000 global ridges and seamounts, this topographic control represents a previously unrecognized mechanism governing oceanic carbon storage.

How the sulfated algal polysaccharide fucoïdan alters microbial activities in marine ecosystems

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Annually fixing ~50 gigatons of inorganic carbon via photosynthesis, algae invest up to 80% of their organic carbon into glycans. Some of these glycans are highly complex and accumulate in the ocean because they are difficult to break down. Fucoïdan is such a complex highly sulfated glycan that is produced and released by marine algae, particularly brown algae and diatoms. The global abundance of these producers and the recalcitrance of fucoïdan make it a frequent compound that marine microbes are subjected to. In this study, we investigate how the omnipresence of this compound affects microbial life in the ocean. As a proxy of activity, we measure respiration rates and cell densities of microbial communities in response to different fucoïdan concentrations. We first performed these measurements using *E. coli* monocultures, followed by a coastal microbial community, and finally with an open ocean microbial community. Across all experiments, we observe a consistent pattern: The bulk respiration rate increases significantly along with the cell numbers, whereas the respiration rates per cell are significantly reduced in microbes subjected to fucoïdan. These results highlight a neglected influence of complex polysaccharides like fucoïdan on microbial communities, which may also impact biogeochemical cycles on a larger scale.

Catalytic fragmentation of fucoidan into oligosaccharides for studies of bioactivity & carbon sequestration

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Fucoidan is a highly sulfated, branched polysaccharide found in the cell wall and extracellular matrix of brown algae. Recent studies have highlighted the biotechnological potential of fucoidan polysaccharides and oligosaccharides, focusing on their bioactive properties, such as antimicrobial and anti-tumor effects as well as their potential for carbon sequestration. However, the underlying mechanisms remain poorly understood, and analytical methods are still limited. In this study, we present two distinct methods for generating well-defined fucoidan oligosaccharides to help identify key functional components. We found that enzymes from the marine bacterium *Winogradskyella vidalii* are capable of breaking down fucoidan from *Laminaria hyperborea*. This enzymatic approach offers a targeted and efficient way to degrade fucoidan structures for further analysis. In the absence of enzymatic activity, partial acid hydrolysis offers a broader, less selective method that allows for the production of large quantities of defined fucoidan oligosaccharides across a wide variety of fucoidan substrates. Our results demonstrate simple and efficient methods for the generation of oligosaccharides providing a valuable starting point for structural characterization, functional analysis, and bioactivity testing.

Revisiting Artificial Upwelling: The Role of Bacteria-DOC Interactions in Marine Carbon Sequestration

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The goal to limit global warming to below 1.5 or 2°C has increased the urgency to consider marine carbon dioxide removal (mCDR) techniques for compensating hard to abate CO₂-emissions. Artificial upwelling (AU), one proposed mCDR approach, involves pumping nutrient-rich deep waters to the surface to stimulate ocean productivity to enhance atmospheric CO₂ draw-down via the biological carbon pump. As such, AU affects both the amount of organic carbon that is stored in the deep sea or ultimately reaches the ocean floor, and the fraction converted to dissolved organic carbon (DOC) that remains in the water column. However, current state-of-the-art modeling approaches used to assess AU's effectiveness typically do not consider explicit representation of microbial DOC remineralization, despite DOC being a major component of the marine carbon cycle, exhibiting substantial temporal variability. Such variability is likely to influence AU's ability as an mCDR scheme, as the balance between carbon fixation and remineralization depend on interactions between primary producers and marine heterotrophs that vary under different ecological conditions. In this study, we use a recently extended biogeochemical model with an explicit representation of DOC-bacteria interactions to evaluate the impact of AU on long-term DOC dynamics and mCDR effectiveness. We explore the balance between carbon fixation and remineralization by performing several in-silico scenario simulations that systematically test the impact of the relative competitive strength between phytoplankton and bacteria on DOC concentration in an AU scenario. Our model results show that long-term DOC concentrations are impacted by the balance between phytoplankton production and heterotrophic degradation, shaped by their competition for nutrients. AU modulates the balance between them, and therefore impacts the DOC inventory either by enhancing the production or degradation. The overall net effect depends critically on the relative competitive strength between phototrophs and heterotrophs with respect to the limiting resource (iron, macronutrients).

Vertical distribution patterns of lipids and lipid-carbon in the western Atlantic sector of the Southern Ocean

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Lipids account for 10-30% of the carbon within phytoplankton cells, yet we still know little about how lipid-carbon is transferred and exported through the water column and whether individual lipid species are preferentially degraded by microbes and/or digested by zooplankton. Using state-of-the-art lipidomics we investigated the lipid composition and lipid-carbon content in the water column and in sinking particles collected using drifting sediment traps at the tip of the Antarctic Peninsula and north of South Georgia. We found that lipid-carbon accounts for up to 25% of the total organic carbon at 100 m depth and for up to 15% at 400 m depth, suggesting that lipids play an important role in the transfer of particulate organic matter into the mesopelagic. Following a phytoplankton bloom along the Polar Front, we found that the vertical distribution of lipids and lipid-carbon were mainly driven by pigments and lipid groups associated with photosynthetic membranes (e.g., Phaeophytin *a*, Glycolipids). Moreover, the direct comparison of the lipidome of plankton to that of zooplankton faecal pellets showed that mainly phospholipids are retained, indicating an efficient digestion of pigments and related lipid groups. These results show that lipids play an important part in carbon cycling and provide an important step towards a better understanding of lipid-carbon patterns and the composition of sinking particles, e.g., faecal pellets, contributing to the vertical flux of POM.

From shore to seafloor: Microbial controls on carbon transfer in submarine canyons

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One of the greatest challenges to constrain the strength and efficiency of the Biological Carbon Pump (BCP) lies in resolving the mechanisms that control the fate of organic particles along their transit to the deep sea. The efficiency of the BCP depends largely on the microbial community dynamics on sinking particles, which determine the amount of carbon that reaches the deep ocean and its long-term sequestration – key aspects with profound impact on the Earth's climate. Despite the central role of marine microbes on biogeochemical cycles and carbon flux attenuation, very little is known about the impact that microbial community succession can have on the degradation of particulate organic carbon.

My current work investigates the relationship between particle-attached microbial communities and the transfer and degradation of particulate organic carbon in submarine canyons of the NW Mediterranean. These canyon systems provide the ideal setup to examine the microbial connectivity across strong environmental gradients— from coastal to open-ocean waters, and from the surface to the seabed — and estimate if changes in particle-attached community composition are linked to transfer efficiency of organic carbon in the land-ocean interface environments. The findings will contribute to a mechanistic understanding of microbial mediation of the BCP and improve our capacity to predict microbial responses to environmental changes and their implications for oceanic carbon cycling.

Impact of changing sea ice conditions on carbon export in the central Arctic Ocean

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The Arctic Ocean is a region that is particularly vulnerable to climate warming, with temperatures increasing nearly four times faster than the global average since 1979. As a result, sea ice extent, concentration, and thickness are changing, with implications for biological and biogeochemical processes. In order to improve our understanding of the biological carbon pump at high latitudes and optimize predictions of future carbon sequestration, it is essential to investigate how changing sea ice conditions influence productivity, community composition, trophic interactions, remineralization, and carbon export.

In Summer 2023, nine ice stations were visited during Polarstern expedition PS138 (ArcWatch-1). In contrast to expedition PS80 in 2012 to the same geographical region, the sea ice sampled in 2023 was formed in the central Arctic Ocean and did not originate from the Laptev Sea shelves. One major difference was that the ice formed in the central Arctic Ocean did not have any associated ice-algae, while the shelf-formed ice observed in 2012 had high concentrations of ice-algae.

Here we are presenting under-ice export fluxes (e.g., particulate organic carbon) and the vertical distribution and characteristics of sinking particles in the context of the environmental pelagic and sea ice conditions investigated during expedition PS138 and compare these findings with corresponding data from expedition PS80.

The triplet diatom glycan system of *Conticribra weissflogii*

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Diatoms gain energy through photosynthesis. A large portion of this energy is conserved in glycans that are secreted into the surrounding water column and serve as a precursor molecule for spontaneous marine particle formation. However, little is known about the nature of these glycans due to analytical challenges arising from low analyte concentrations and high sample complexity. On this poster, I present a workflow that allows the purification and concentration of various glycans from diatom cultures using ion exchange chromatography (IEX). Moreover, detailed information on the glycan composition was obtained using HPAEC-PAD and ion chromatography. With this workflow, we were able to identify and characterize the glycan system of the abundant marine diatom *Conticribra weissflogii*. We show that this phototroph secretes at least three distinct polysaccharides with different chemical properties. In summary, this glycan profiling enables the exploration of diatom glycans and allows downstream applications of the purified glycans, like selective bacteria cultivation and studying polysaccharide aggregation.

Permafrost organic carbon feedback from Arctic waters and sediments

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About one-third of the world's coastlines lie in the Arctic, where they are predominantly underlain by permafrost. Rising Arctic temperatures cause these unconsolidated, often ice-rich, coastal deposits to thaw and erode, releasing their stored organic carbon (OC) directly into marine waters. Terrestrial analogues and past incubation experiments suggest that this OC is rapidly oxidized upon entering the ocean. However, in situ case studies remain scarce.

In these studies, we used dual carbon isotopes to trace permafrost-derived OC from Canadian coastal deposits (Herschel Island - Qikiqtaruk) through the water column—including aquatic heterotrophs—and into nearshore sediments. This allowed us to (1) quantify heterotrophic consumption in the water column and its effects on the local food web, and (2) estimate carbon burial and release from nearshore sediments.

Contrary to prevailing assumptions, we found little to no utilization of permafrost OC in either the water column or the sediments. Consumers largely utilized marine OC, supplemented by modern terrestrial OC from the active layer. These results challenge the widely held view that most permafrost OC re-enters the active carbon cycle upon release into marine waters.

Mesoscale Eddy Influence on Southern Ocean CO₂ Fluxes and DIC Budgets

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Global ocean biogeochemical models estimate that the Southern Ocean absorbs 1.3 ± 0.3 Pg C yr⁻¹. However, these carbon uptake estimates present large uncertainties and disagreement with observations. One potential reason for the uncertainties is the lack of biogeochemical datasets that can capture the large eddy activity in the region. To address this, we analyze 27 years of global eddy-permitting simulations at 10 km resolution using the ICON-O ocean model coupled with the HAMOCC biogeochemistry model. Relative vorticity and strain are used to classify flow regimes: mesoscale anticyclones, mesoscale cyclones, their peripheries and background flow, allowing to generate composites of relevant quantities for each compartment. Our results show that CO₂ flux is always directed into the ocean, with the magnitude of CO₂ uptake varying across flow regimes. Anticyclones have a greater capacity for CO₂ uptake compared to cyclones. In certain regions (i.e. Agulhas Retroflection and Brazil-Malvinas Confluence) anticyclones exhibit the highest CO₂ uptake capacity among the flow regimes, a pattern linked to the greater eddy intensity of these areas. Our analysis of the terms contributing to CO₂ flux shows that wind speed and $\Delta p\text{CO}_2$ are the primary contributors to flux magnitude and variability. The oceanic pCO₂ variations are primarily driven by dissolved inorganic carbon (DIC). To explore DIC changes, we analyze DIC budgets in the first 300 m. In particular, we investigate how seasonal variations of DIC budget terms are modulated by mesoscale eddies. The seasonal evolution is analyzed in terms of the divergence of advective and diffusive fluxes and of the biogeochemical sources and sinks.

Effects of ecosystem complexity on the air-sea CO₂ flux in an ocean biogeochemistry model

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Ocean biogeochemistry (BGC) models are used to assess the air-sea CO₂ flux and the ocean carbon cycling. They also represent ecosystem and species composition, but only with limited complexity caused by finite knowledge about nuanced responses to ecosystem drivers and by increasing computational costs with each additionally modeled organism group. Nonetheless, current BGC models apply a range of ecosystem complexities and vary between very simplistic models and models with numerous size-resolved plankton groups. We investigate uncertainties in carbon cycle estimates that are caused by ecosystem complexity using the BGC model FESOM2.1-REcoM with four complexity levels which differ in the number of phytoplankton, zooplankton, and detritus groups. We analyse differences in the CO₂ flux, surface carbonate chemistry, the surface-to-depth gradient of dissolved inorganic carbon, biological production as well as carbon export. After spin-up simulations of 1430 years, the global air-sea CO₂ flux varies between 0.46 Pg C year⁻¹ in the simplest and 0.71 Pg C year⁻¹ in the most complex version of our model. This points towards a low robustness of the ocean carbon cycling against changes in the modeled ecosystem complexity. Simulations of the historical period (1958-today) will allow us to examine the effect of modeled ecosystem complexity on the model performance in comparison to observations and on transient air-sea CO₂ fluxes under increasing anthropogenic CO₂ emissions.

Comparing POM Fluxes from Free-Drifting Sediment Traps across the Atlantic Ocean

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Global estimates of CO₂ sequestration via the particulate biological carbon pump remain highly uncertain, partly due to an insufficient understanding of its spatial variability. To address this gap, I compiled in-situ data of particulate organic matter fluxes gathered with free-drifting sediment traps across the Atlantic Ocean in the past 12 years. Comparative analysis of POC and ballasting mineral fluxes revealed that shallow POC fluxes (100 m) can vary strongly between regions, and between years within the same region. In turn, differences in POC transfer efficiency to depth (300-400 m) were better explained by mineral and lithogenic ballasting than by region. Arctic and subarctic fjord systems displayed a relatively high shallow flux variance and higher POC transfer rates than shelf and open-ocean systems. In turn, similarities in POC flux characteristics were observed for Fram Strait and Antarctic sites. Observations from gel traps unveiled a wide range of particle appearances (size spans, shapes, and shades) existing across the Atlantic. General trends included a decreasing mean particle size with depth, but abundance increases in some cases which could hint towards fragmentation. The presented data set is unique for its spatial coverage with consistent methods and rich detail, thus offering a strong foundation for further investigating and modeling carbon pump variability across the Atlantic Ocean and beyond.

The ocean's gravity-driven carbon flux from serendipitous particle traps

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Particles sinking into the ocean's interior are a food source for deep-sea ecosystems and help sequester carbon from the atmosphere. Yet, measurements of the sinking flux are sparse, leaving substantial uncertainties in its magnitude and variability. We demonstrate how Biogeochemical-Argo floats have serendipitously measured the sinking flux for the last decade using particles settled onto the floats themselves while adrift deep below the surface. With these new-found particle "traps", we estimate a global sinking flux of $\sim 1 \text{ PgC yr}^{-1}$ at a depth of 1 km, where carbon is sequestered on timescales of centuries. Our approach lays the groundwork necessary to constrain the wide variability in numerical model and satellite-based estimates, which is essential for reliably detecting changes related to climate and rapidly-developing initiatives aimed at sequestering atmospheric carbon.

Chemical and biological gradients at the Orca Basin oxycline indicate distinct life zones

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Orca Basin, located on the northern Gulf of Mexico slope, is the largest hypersaline seafloor brine lake (over ca. 400 km²). 200 meters of its total depth of 2400 m represent the brine-filled basin. Its chemocline and halocline show a complex layered sequence of geochemical gradients, extending from overlying seawater towards concentrated, anoxic brine of approximately 8-fold seawater salinity, produced by gradual dissolution of surface-breaching salt deposits. Here we present a renewed investigation of biological zonation and nutrient gradients (NO_x, NH₄, Silicate, Phosphate) in Orca Basin, based on *Alvin* and CTD sampling surveys in 2010 and 2014. Most nutrients and TOC showed maximum increases during transition into the brine (from 2220 to 2240 m depth), reflecting accumulation from organic matter input. Northern and Southern sub-basin gradients were comparable, with the possible exemption of lower NH₄ concentrations in the northern sub-basin. Combined Nitrate/Nitrite concentrations declined towards the detection minimum in the brine, a likely result of microbial utilization as electron acceptors. Deep-sea sponges were observed consistently on the sedimented slopes of Orca Basin between 2159 to 2172 m depth during *Alvin* dives 4648, 4649 and 4650. Benthos (anemones, eel pout, worm holes) was observed at 2186 m before fauna disappeared downslope, most likely due to oxygen limitation. Scale and complexity of the oxycline requires meter-scale sampling resolution.

Quantifying the distribution of nepheloid layers off NW Ireland, Rockall Trough (NE Atlantic Ocean): response to hydrodynamics

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Suspended particles particularly within nepheloid layers, can act as pivotal mediators of oceanic carbon transport and benthic-pelagic coupling. However, nepheloid layer identification and especially discrimination from backscattering layers composed of living organisms remain challenging due to the limited multidisciplinary observations. Here, multi-frequency hydroacoustic data, CTD measurements, and optical cameras are integrated to identify suspended particles off NW Ireland, Rockall Trough (NE Atlantic Ocean). Nepheloid layers present high turbidity, particle abundance, buoyancy frequency, and synthetic seismograms, distinct from plankton and fish shoals, validated by direct camera observations. Nepheloid layers occupy 200–800 m water depth, extending 40 km shelf-to-basin and covering the continental slope. Maximum thickness and echo intensity occurred in the upper slope, where breaking internal waves and M_2 internal tide caused sediment resuspension to induce nepheloid layers. Internal-tide beams and turbulent diffusion laterally transported sediments, while vertical pumping brought particles to the upper water layers. During the neap-to-spring tidal transition, intensified tides enhanced bottom currents and turbulent mixing, vertically diffusing and thickening the nepheloid layers. A cyclonic eddy affected the study area, which carried particles from the slope to the open ocean and thickened nepheloid layers by Ekman upwelling. This study quantifies spatiotemporal variability of nepheloid layer and studies their hydrodynamic responses, revealing their role as efficient particle highways vital for Atlantic carbon budgets.

Refining blue carbon accumulation rates in sediments impacted by anthropogenic pressure

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Continental shelf sediments are vast areas which accumulate and store organic carbon. However, these regions are increasingly impacted by anthropogenic pressures, particularly from infrastructure related to energy extraction. While determining the standing stock of carbon within sediment provides a useful snapshot for current carbon budgets, determining the accumulation potential allows for assessments of how carbon stocks will vary temporally. However, estimating carbon accumulation potential of sediments can be confounded by anthropogenic outputs.

This study describes carbon stocks, sediment type and carbon accumulation rates (CARs) in sediment surrounding the North West Hutton decommissioned oil and gas platform in the northern North Sea. By using alpha spectrometry and accounting for heavy metals derived from ICP-MS to create correction factors, previous estimates of CARs from gamma spectrometry have been corrected and CARs close to North West Hutton which were previously undetermined have been calculated. Results show that CARs determined by gamma spectrometry alone are consistently lower than those corrected by heavy metal attenuation factors and alpha spectrometry. This indicates that in areas impacted by heavy metal input may have previously underestimated CARs.

This novel method provides an opportunity to determine CARs in areas with similar anthropogenic pressure, especially coastal regions with input from activities such as mineral extraction and runoff from industrial activities. While this work highlights CARs in offshore environments may be underestimated, if this is applied to coastal sites where accumulation rates are considerably higher, this could have widespread implications for blue carbon accounting.

Lateral transport: From shelf to deep sea

Reactivity of terrestrial organic matter across Eurasian Arctic Shelf Seas

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Organic matter stored in Arctic permafrost is a major component of the global carbon cycle, yet its reactivity across large and heterogeneous permafrost regions is not well constrained. We use the four shelf seas of the Eurasian Arctic as natural receptor systems to assess terrestrial organic matter reactivity, quantified from organic carbon preservation as a function of ¹⁴C-based cross-shelf transport time. Results show pronounced spatial contrasts, with higher terrestrial organic matter reactivity in the Laptev Sea and eastern East Siberian Sea, lower reactivity in the western East Siberian Sea, and negligible degradation in the Kara Sea. These patterns are primarily determined by source degradation status and composition, with potential microbiological influences during transport. Our findings highlight regional variability in terrestrial organic matter reactivity across the Eurasian Arctic margin, underscoring the need for detailed assessments of region-specific carbon release and modeling parameterization.

Advancing the Ocean Nitrogen Cycle in ICON-XPP: From Ammonium Pathways to N₂O Emissions

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We present recent extensions to the oceanic nitrogen cycle in ICON-XPP's biogeochemical module, HAMOCC. Newly implemented processes include ammonium oxidation, anaerobic ammonium oxidation (anammox), and dissimilatory nitrate reduction to ammonium (DNRA), alongside a mechanistic representation of nitrification and denitrification. The dynamics of nitrous oxide (N₂O), a potent greenhouse gas, are also explicitly incorporated into the extended nitrogen cycle. These additions enable a more complete simulation of nitrogen transformations involving NH₄⁺, NO₂⁻, NO₃⁻, N₂O, and N₂ gas.

To constrain and evaluate these pathways, we use observational profiles of NH₄⁺ and NO₂⁻ to drive the model and tune nitrogen process rates based on observed N₂O concentrations and air–sea fluxes. Initial results show improved spatial patterns and magnitudes of marine N₂O production and emissions, providing a more realistic foundation for Earth system projections toward CMIP7.