A blast from the past - presentations at the 1996 Challenger Conference in Bangor. Who can you recognise anyone in the audiance? *(Photo: Ed Hill)*.

2026 Challenger Conference

Book of Oral Presentation Abstracts

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Growth Performance, Biochemical, Antioxidant Status and Histopathology Changes of Clarias Gariepinus, Raised in a Biofloc Medium Utilizing Natural Carbon Sources

Integrated biofloc-centered aquaculture nutrient recycling offers a sustainable fish productivity with less environmental impact. A 28 days preliminary trial was conducted to evaluate the affect of biofloc technology application on Clarias gariepinus juveniles with emphasis on the growth performance and impact on physiological status. A total of two hundred and seventy juvenile Clarias gariepinus were randomly distributed into six plastic bioreactors groups (A F) in triplicates with equal volume of inoculum, maintained in 30 L tank with constant aeration. Addition of organic carbon sources (CN 10:1, 20:1) were evaluated to stimulate rapid growth of microbial dynamics biomass whereas, no carbon sources were added in the control systems. The CN ratios (cassava and wheat) of 10:1 and 20:1 were; cassava (CA 10:1, 20:1) groups C, D, and wheat flour (WH10:1 and 20:1) groups E and F, respectively. Meanwhile, the normal controls, group A (inoculum, no carbon addition) and B (no inoculum, no carbon) had 50% water exchange and received only fish feed at 3% body weight. The physicochemical parameters maintained the tolerable limit for catfish farming. Significant weight gain, specific growth rate, LWRs, survival rate, and floc volumes were observed at the end of experiment. Observed changes in the catalase, superoxide dismutase, glutathione peroxidase, and malondialdehyde activities in the gill were between day 14 and 21. Significant levels (p1 of C. gariepinus juveniles within 28-days. In conclusion, inclusion of C:N ratio of cassava and wheat flour in biofloc tank is beneficial for the growth and health parameters of Clarias gariepinus.

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Continental Synergy: A Roadmap for Unified BBNJ Implementation in Africa

The BBNJ agreement's entry into force in 2026 marks a pivotal shift in global ocean governance, and Africa is at the heart of this transformation. The continent's vast maritime domain is not just a distant frontier, but a critical ecological and economic lifeline. However, Africa faces significant hurdles, including fragmented legal frameworks, limited technical capacity, and overlapping jurisdictions between the BBNJ and existing regional instruments like the Abidjan Convention.

Currently, West African states have only ratified around 43% of relevant global environmental agreements, revealing a substantial implementation gap. Without a unified approach, African nations risk being sidelined as wealthier powers shape the rules for Marine Genetic Resources (MGRs) and Area-Based Management Tools (ABMTs). This "Continental Synergy" project provides a strategic roadmap to bridge these gaps, aligning with the Africa Union Ocean Governance Strategy (AOGS) to ensure that the "Common Heritage of Humankind" principle translates into tangible benefits for all Africans, including landlocked states. By mobilizing collective weight through Regional Economic Communities (RECs), the project will foster a "Blue Hybrid" legal model that integrates global BBNJ standards with African regional security and economic imperatives, securing the continent's rightful place at the helm of global ocean governance.

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Future North Atlantic subpolar gyre tipping point in a high-resolution ocean-ice-biogeochemistry simulation

Deep convection in the subpolar North Atlantic is crucial for the stability of ocean circulation. This process depends on the winter cooling of the gyre's surface waters with relatively high salinity, which sink to deeper depths and drive the Atlantic Meridional Overturning Circulation. Freshwater discharge into the subpolar gyre from melting of the Greenland ice sheet and Arctic sea ice threatens to disrupt this balance, by reducing surface salinity and inhibiting deep convection, potentially triggering a climate tipping point. We analyse this behaviour in a high-resolution (1/12°) simulation including ocean, sea ice and biogeochemistry components. The model is run to year 2100 under a limited mitigation climate change scenario (SSP370) and shows a future abrupt collapse of deep convection in the subpolar gyre. Our results highlight regional differences in the tipping behaviour between the Labrador, Irminger, and Greenland Seas, which show different timings of convection shutdown. Following the collapse of convection, all regions experience different degrees of surface freshening and subsurface warming, which is also accompanied by declining oxygen concentrations. Reduced mixing after the convection shutdown also results in a decline of primary productivity (chlorophyll-a availability). Such changes could have profound implications, including the disruption of marine ecosystems and intensified climate variability over Europe. We also explore how these processes and the occurrence of deep convection collapse vary at higher and lower model resolution, and with coupling to the atmosphere.

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Tele-illumination to Re-balance the Earth's Natural Carbon Cycle?

A new Nature Based Carbon Cycle Management Solution (NBCCMS) for capturing anthropogenic emission of carbon dioxide and locking it away in the deep ocean, called ECOPIA™ (Earth Climate Optimisation Productivity Island Array), empowers the natural primary production capacity of the oceans solely through the provision of light at depth, tele-illumination. The proposed solution enables the control and regulation of CO2 levels in the atmosphere via natural mechanisms; de-acidifying ocean waters and creating new sustainable fisheries, whilst allowing all world economies to grow and prosper. It is a modular, scalable solution located in the oligotrophic sub-tropical gyres of the world's oceans. These otherwise minimally productive gyres are growing at a rate of 800,000 km2 per year, at the cost of productive ocean areas. Simply providing light below the surface layers, and nothing more, the solution provides no mechanism for preferential pressure on naturally determined biodiversity. Taking the, perhaps pessimistic, view that the world as a whole can only achieve static anthropogenic fossil fuels usage by the year 2030, then tele-illuminating <0.002% of the world's oceans will be required to return atmospheric CO2 levels to 350 ppm. ECOPIA™ is preparing it's first demonstrator having found an illuminating solution. The Monitoring, Reporting and Verification (MRV) protocol is published online, ECOPIA-MRV/blob/main/ECOPIA_NBCCMS_MRV_v1_0.pdf, including a description of modelling requirements and observational instrumentation / platforms at full scale-up. A subset of these will be a fundamental part of ECOPIA™'s demonstrators. But what have we missed ? and what would you add ?

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Biogeochemical transformations in North Atlantic subpolar waters at inflow and outflow sources.

The Atlantic Meridional Overturning Circulation, conveyed through the North Atlantic Current (NAC), transports heat, carbon, and nutrients from the subpolar North Atlantic into the Arctic Ocean . Within the NAC, water masses originating from Central Waters, such as Icelandic-type Subpolar Mode Water (IrSPMW) and Irminger-type Subpolar Mode Water (IrSPMW), undergo substantial biogeochemical transformation as they are being transported northwards into the Arctic Ocean and return as part of the Southward limb of the AMOC. Although circulation pathways and baseline nutrient distributions have been well characterized in the past, key uncertainties remain regarding where and how biogeochemical modifications accumulate along water masses' pathways. Here, we combine 40 years of hydrographic and biogeochemical data from the AR7E and OVIDE surveys, spanning from 1990 to 2026 to tackle this question. We use Optimum MultiParameter (OMP) analysis to constrain specific water-mass distributions and to target transformations of biogeochemical properties along the Greenland-Ireland region. By explicitly tracking how geochemical properties evolved within the major water masses, we aim to distinguish how subpolar transformations modulate the signals that supply the Atlantic component of Arctic inflow and returns to the subpolar North Atlantic, providing a more complete framework for understanding the region's responses to ongoing climate change.

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The impact of Southern Ocean circulation on biogenic carbon sequestration

The ocean sequesters vast amounts of carbon dioxide away from the atmosphere, playing an important role in the Earth's climate. The biological carbon pump contributes to carbon sequestration by exporting carbon into the ocean interior through sinking organic matter, which is subsequently remineralized and eventually returns to the surface ocean through circulation. The time scales of carbon sequestration and re-ventilation control the amount of ocean carbon storage and atmospheric levels of carbon dioxide. Those time scales are often rationalised in terms of the remineralization depth, assuming that there is a particular depth horizon beneath which biogenic carbon is sequestered for climatically significant amounts of time. However, this framework does not consider the potential impact of ocean circulation, which can transport carbon vertically. This may be particularly relevant in the Southern Ocean, where the deep overturning circulation entails downwelling and upwelling of different water masses. We address this question through idealized experiments with an ocean biogeochemical model, where all of the biogenic carbon is remineralized within a specific Southern Ocean water mass. Our results aim to clarify the importance of specific water masses for biogenic carbon storage, and to provide insight on whether water mass circulation should be considered in more detail when determining the strength of the Southern Ocean carbon sink. Preliminary findings show that remineralization occurring in Sub-Antarctic Mode Waters has a similar effect on atmospheric carbon levels as surface water masses, despite their greater depth; organic matter must sink below mode waters to meaningfully impact ocean carbon storage.

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Tides in shelf seas dampen summer and autumn climate change signal in the United Kingdom

The UK is located on one of the most extensive continental shelves in the world. Tidal mixing reduces ocean stratification in the shallow coastal areas of shelf seas and cools British summers. Traditionally, regional climate downscaling has always used sea surface temperature from global ocean models, which do not represent these processes. For the first time, we employ a km-scale regional coupled system to downscale future climate projection. This system couples atmosphere, waves and ocean every 10mn. A dampening of the surface and air temperature warming is found both over the sea and over the UK in summer and autumn, particularly strong in tidally-active areas. This leads to a significant decrease in the intensification rate of extreme rainfall, in particular in the autumn. Analysis of the ocean stratification in the GCM and in UKC4 reveals that the GCM stratification increases in summer and lengthens into the autumn, whilst this is not happening in UKC4 because the stratification is prevented by tidal mixing.

Atkinson, Angus

Matthew Faith; Meiping Feng; Karen Tait; Clare Ostle; Abigail McQuatters-Gollop; Matthew Holland; Dafne Eerkes-Medrano; David Johns; Katrin Schmidt*; Catherine L. Johnson; Pennie Lindeque

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Climate-driven change in pelagic ecosystems of the north Atlantic: implications for fisheries management

Rapid warming of the north Atlantic over the last 60 years has driven major changes in the plankton, impacting fish stocks and posing serious issues for their management. Here we examine the mechanisms of change and the implications for fisheries management. We found that across the north Atlantic, estimated surface-layer biomass of the nutritious crustacean taxa (copepods and euphausiids) has declined by nearly 50% during summer, when food demands of their predators are maximal. A key driver of these changes appears to be indirect effects of warming, through increasing stratification and reduced summer nutrient supply. This favours increasing dominance of picoplankton of lower nutritional value, which lead to steep size spectrum slopes in pelagic communities, signifying inefficient energy flow through to fish. At the Western Channel Observatory L4 monitoring site, rapid warming over the past 17 years coincided with a steepening of the plankton size spectrum slope, resulting in a 50% reduction of biomass in the size range occupied by fish larvae. Concomitantly, eDNA revealed a 60% decline in taxonomic richness of fish over only 11 years, during which time southwest England appeared to undergo a step-change in its marine fauna. Based on these mechanistic links from climate, through plankton to fish, we used a tripartite risk-mapping approach combining hazard (projected ongoing decline in supportable fish biomass), with exposure (fishing pressure) and vulnerability (national socioeconomic dependence on these fishing grounds). This approach revealed a series of hotspots of fishery-climate risks, for instance in waters off the Azores, Morocco and UK.

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Impacts of Floating Offshore Wind on Seasonally Stratified Shelf Seas: Glider Observations

To meet the growing demand for sustainable energy, offshore wind structures are needed in deeper, seasonally stratified, waters away from well mixed coastal regions. These structures cut through the thermocline, with impacts on nutrient and oxygen transport through increased vertical mixing. As part of the eSWEETS3 project, a suite of observational platforms were deployed around the Kincardine Floating Offshore Windfarm (KFOW). Two Slocum gliders were deployed in early May 2025, flying 10 km long transects to the north and south of the array. Early results capture the onset of stratification around the windfarm, and far-field windfarm induced changes. In the wake of these structures, there is a break down in stratification, near-field towed CTD sections reveal enhanced surface cooling, whilst far-field changes in water column density are masked by the effects of existing gradients and re-stratification. The largest impacts are seen in chlorophyll concentrations, with up to a 20% increase in the wake of the residual flow. This is hypothesised to result from increased turbulent mixing in the structure's wake. A seaglider was deployed to measure the meridional gradient, capturing signals of internal waves, potentially generated through tidal interaction with the structures, providing a mechanism for the enhanced mixing.

Belcher, Anna

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The role of glaciers and land cover on nutrient supply in a southern Patagonian fjord

Glaciers and ice sheets cover about 10% of the Earth's land surface. They are important for food and water supplies, but also for biogeochemical cycling and the supply of nutrients to rivers, fjords and the coastal zone. However, glaciers are experiencing rapid rates of decline globally and are predicted to continue to do so as global temperatures rise. The retreat of glaciers and subsequent revegetation greatly impacts the supply of nutrients and supported ecosystems. This impact is not well resolved particularly in remote regions like Patagonia despite the Patagonian ice fields being among the most rapidly wasting glaciers globally.

A short sampling campaign was carried out in Tierra del Fuego, Southern Patagonia in January 2025. The region encompasses broad climatic and habitat contrasts from the ice cap and glaciers of the Darwin Cordillera to the southern beech (Nothofagus) forests, mountains and peatlands of the Karukinka Park, which grade into the dry, treeless pampa of northern Tierra del Fuego. The area remains largely intact, with minimal degradation from direct human activities, providing a natural laboratory to observe climate-driven changes. Water samples were taken in Karukinka Park, Almirantazgo Sound and, Parry and Marinelli fjords, including rivers draining glacial and non-glacial mountains, peatlands, forests and grasslands, and fjord waters. We present results on concentrations of major nutrients, examining how these vary with varying land cover, glacial influence and other environmental variables. We investigate nutrient limitation and potential impacts on marine ecosystem productivity as glaciers continue to retreat.

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Inclusivity @ Sea: Lessons from the Blue Belt Programme for maximising participatory research cruises with overseas partners

The Blue Belt Programme is the UK's flagship marine conservation programme, which is now in its tenth year of working with the Governments of the UK Overseas Territories. Since 2017, Blue Belt has conducted ten major research expeditions across nine UKOTs and central to this has been the partnerships between scientists in the UK and Overseas Territories. Critically we have aimed to address previous and ongoing difficulties experienced by the UKOTs with the well-known practice of parachute science whereby local scientists are presented with 'take it or leave it' proposals from external organisations, with limited opportunity to co-develop research objectives or even be involved at all. This presentation will summarise some of the key lessons learned from developing and delivering research cruises together with scientists in the UK Overseas Territories.

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Biomass Patterns of Colonial and Encrusting Fauna Across a Coral Framework Complexity Gradient in the Rockall Bank

Cold-water coral reefs are biodiversity hotspots that support complex assemblages of associated fauna and play an important role in deep-sea ecosystem functioning. However, compared to shallow-water coral systems, the ecology of deep-sea coral-associated communities remains poorly understood, particularly for colonial and encrusting taxa such as bryozoans and sponges. These organisms contribute substantially to habitat provision, nutrient cycling, filtration, and framework stabilisation, yet they are frequently underrepresented in ecological analyses.

Traditional biodiversity assessments of coral-associated fauna typically rely on count-based abundance data. While suitable for mobile and discrete organisms, this approach presents a major limitation for colonial and encrusting taxa, which are often reduced to binary presence–absence records. Consequently, their ecological importance and contribution to community structure may be substantially underestimated.

This study aims to address this methodological gap by utilising a biomass-based approach for quantifying encrusting fauna associated with cold-water coral framework habitats. Building upon previous work conducted on Desmophyllum pertusum reefs of the Rockall Bank, NE Atlantic, encrusting and colonial fauna were quantified across a coral framework complexity gradient. Coral framework volume was used as a proxy for habitat heterogeneity, enabling investigation of how biodiversity and faunal abundance vary with increasing structural complexity.

By incorporating biomass estimates alongside traditional biodiversity metrics, this work seeks to provide a more representative assessment of reef-associated community structure and ecosystem functioning. The findings will improve understanding of the ecological role of colonial fauna in cold-water coral ecosystems and contribute toward more accurate biodiversity assessments and conservation strategies for vulnerable deep-sea habitats.

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All at sea? The need for causal modelling and inference in marine science

A common task in marine ecology is to create a species distribution model (SDM) from well observed predictors (ie. temperature), which can be used to make smooth predictions of sparsely sampled targets, such as the picoplankton Prochlorococcus. These models may also be used to make forecasts under a perturbed predictor, such as a warming ocean. But how can we know whether a predictor is causal? Confounding and unobserved variables are two common problems encountered in developing such forecasts. Causal inference methods can be used to identify models of the processes generating your data, rather than making “naive” non-causal predictions. With a causal model in hand, future predictions should be more robust to changes in the training data distributions. Here, I make the case for the relevance of these methods in oceanographic problems, using our recent work on plankton SDMs and their reliability under a changing climate. In a coupled ocean-atmosphere domain, we test whether two different plankton growth responses (a temperature dependent and independent growth rate) can be identified from "observations" sampled from the model. A statistical SDM comparable to many published models, is generated from these observations and used to make a forecast under a climate change scenario. The modelled world is known perfectly, so we compare the predictive skill of temperature on the temperature-independent ecosystem, knowing no such mechanism exists. I will give some discussion on the challenge of causal identifiability from real observations and make some suggestions for the development of causal SDMs.

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Physical controls on the variability of Southern Ocean nutrient export

The Southern Ocean is an important source of nutrients for the global carbon cycle and ecosystem. However, little is understood about what drives the variabilty of the transport from southern latitudes into the major ocean basins. In this study we use an adjoint modelling framework to investigate the physical controls on the transport of nutrients across 30S. This methodology allows us to uncover causal chains within the model, and tells us which atmospheric fluxes matter, where they matter, and on which timescales.

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The Norwegian Trench from a glider's perspective - Variability in hydrography and biogeochemistry in spring and winter

The North Sea is a net sink of CO2 from the atmosphere, with a strong potential for carbon storage and export to the North Atlantic. However, because of the lack of observations, the fate of this carbon absorbed in surface waters is highly uncertain. The Norwegian Trench is the main gateway between the North Sea and the North Atlantic and is therefore a useful area in which to study the transport of carbon and other biogeochemical parameters between these two regions.

Within the NoSE (North Sea-Atlantic exchange) project, ocean gliders were deployed in the Norwegian Trench and North Atlantic in spring 2023 and 2024 and in winter 2025 to study the hydrographic and biogeochemical characteristics of the water column. The gliders were equipped with temperature, salinity, dissolved oxygen, fluorescence, CDOM and turbidity sensors. We combine these sensor observations with discrete carbon and nutrient measurements from two research cruises in spring 2023 and 2024.

Here, we present high-resolution data to show the properties of the different water masses in the Norwegian Trench and their spatiotemporal variability. In the winter, a bottom nepheloid layer was observed along the eastern part of the shelf edge, indicating particulate matter export from the trench into the North Atlantic. Spring observations showed a strong stratification, with a highly productive freshwater surface layer and two saltier water masses below. Isolated from the atmosphere, these deeper water masses could be a pathway for the export of carbon from the North Sea into the deeper North Atlantic.

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Freshwater-induced water column mixing from melting icebergs on the west Antarctic Peninsula

The west Antarctic Peninsula hosts hundreds of marine-terminating glaciers, but is also a region of elevated climate warming, driving a strong increase in ice mass loss in recent decades. These glaciers calve to form icebergs of different sizes, whose bases, sidewalls and surface deliver freshwater to the upper ocean at different locations and depths. Despite their ubiquity, the impact of these icebergs on the stratification, mixing and heat budget of the Peninsula is incompletely understood, a significant problem given the recognized importance of oceanic heat in driving changes in both land-based and sea ice changes. To elucidate these interactions, we document a series of hydrographic and microstructure observations from the fjord of Ryder Bay, to assess how turbulent diffusivity and heat fluxes are influenced by the presence of icebergs. Using an identical site with and without a proximate iceberg, dissipation rates are enhanced from O 10^{-4} W kg^{-1} to O 10^{-3} W kg^{-1}, with median vertical heat fluxes increasing from 1 W m^{-2} to >15 W m^{-2} between 70 m and 95 m depth. Maxima in dissipation coincide with warm and salty intrusions along isopycnals within the pycnocline, suggesting active upwelling and mixing of CDW in rising meltwater plumes. Hydrographic observations at other sites, including the much larger A-84 iceberg further south on the peninsula, exhibit very similar water property changes. The large increase in heat flux observed compared with the background wind- and tide-driven mixing reinforces the case for better representation of iceberg-driven upwelling in regional Antarctic models.

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The lifecycle of tracer variance over the global ocean

Oceanic tracer distributions over the global ocean are shaped by turbulent mixing involving a combination of mesoscale eddy stirring and microscale diapycnal mixing. To understand their relative importance, we explore a tracer variance budget over the global ocean using hydrographic observations. We find that there is a characteristic tracer variance lifecycle involving (i) variance production by turbulent flows stirring large-scale tracer gradients, (ii) redistribution of variance by currents, and (iii) variance dissipation by molecular diffusion. There are different mixing regimes over the global ocean associated with different balances in the variance lifecycle. Firstly, in quiescent regions, such as the centre of the subtropical gyres, diapycnal microscale turbulence dominates the dissipation of variance. Secondly, in dynamically-active regions—such as the Antarctic Circumpolar Current and the Gulf Stream—the dissipation of filaments is instead dominated by mesoscale stirring along density surfaces. In these dynamically-active regions, variance transport can be important, leading to a mismatch between local production of variance and its dissipation. The different mixing regimes over the global ocean, involving a dominance of diapycnal mixing or mesoscale stirring, are likely to affect how the ocean sequesters and redistributes anthropogenic heat.

Buck, Justin

Benway, Heather; Berghoff, Carla; Blanco-Bercial, Leocadio; Wrigley, Julie Ann; Currie, Kim Irene; Cotovicz Jr., Luiz C.; Kinkade, Danie; Miskin-Hymas, Charlotte; Montes, Enrique; Morkeski, Kate; Muller-Karger, Frank E; Pedrosa-Pamies, Rut; Shepherd, Adam

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FAIR marine ecology time series data for the global research community - Outcomes of the Marine Ecological Time Series Research Coordination Network (METS-RCN)

Sustained marine ecological time series (METS) are essential for understanding ecosystem change in an era of accelerating environmental pressures. Collected at stations and transects worldwide, these time series have historically evolved under inconsistent local reporting and data curation practices, resulting in fragmented and siloed repositories that are difficult to find, access, and integrate. This fragmentation limits large-scale data synthesis and highlights the need for shared standards that support Findable, Accessible, Interoperable, and Reusable (FAIR) data principles.

The National Science Foundation (NSF) EarthCube-funded METS Research Coordination Network (RCN) addresses these challenges by promoting the adoption of FAIR data practices across METS programs. The METS RCN brings together marine and data science communities to build consensus, align with broader FAIR initiatives, expand the use and applications of METS data, and strengthen capacity to integrate these datasets with complementary sources for enhanced scientific discovery.

Through workshops and community consultations, the METS RCN has developed key outputs and strategies to engage data and metadata originators and improve accessibility and reuse. These include: (1) a best-practice FAIR data primer tailored to the METS community; (2) shared metadata templates to support data discovery services; (3) the use of controlled vocabularies to harmonize naming conventions across datasets and repositories; (4) a roadmap for linking METS data to the Ocean Data and Information System (ODIS) under the UN Decade framework; and (5) exploration of visualization tools.

Together, these efforts support improved data integration, synthesis, and modelling, enhancing the overall value and impact of marine ecology time series.

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Lorenzo-Lopez, Alvaro; Hawes, Nick; Allsup, Ben; Baker, Chloe; Chaplin, Kevin; Darvariu, Victor-Alenxandru; Ferreira, Tobias; Jones, Dan; Jones, Owain; Kirk, James; Kokkinaki, Alexandra; Lacerda, Bruno; Iceton-Morris, Ashley; Patmore, Ryan; Polton, Jeff;

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The Marine Autonomous Systems Digital Twin (MAS-DT)

The Marine Autonomous Systems Digital Twin (MAS-DT) project aimed to enhance ocean observation and forecasting by integrating digital twin technology with ocean modelling and marine autonomous systems. This approach demonstrated how a dynamic digital framework could optimise data collection and improve ocean model accuracy, delivering benefits for environmental science and operational forecasting.

At the core of the project was the development of a prototype digital twin to optimise ocean glider observations used by the UK Met Office. The system brought together multiple components: ocean glider operations from the National Oceanography Centre (NOC) under the Met Office Glider (MOGli) programme; earth observation data; and outputs from operational ocean models. These inputs were integrated within the NOC Command and Control (C2) infrastructure to create a four-dimensional representation of the ocean. A key feature was the Autonomy Engine developed by the Oxford Robotics Institute, which optimised glider missions based on defined objectives and constraints such as battery life and speed. Supporting this, an Objective Generation User Interface enabled scientists to identify high-impact observation areas and define mission goals.

Stakeholder engagement played a central role, including a joint workshop with the Turing Research Innovation Cluster for Digital Twins (TRIC-DT), which explored interoperability, user interaction, security, and system resilience. Enhancing interoperability across environmental digital twins was identified as an ongoing priority.

Overall, the project successfully demonstrated a functional digital twin integrating marine glider operations with the AMM15 ocean model. It delivered key innovations such as a new user interface and integrated mission planning tools. However, challenges included defining effective in-water experiments, accounting for human factors, and improving understanding of data assimilation processes. These findings highlight opportunities for future development, particularly in adaptive observation systems.

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Revisiting Tide–Sea Level Rise Interactions: A Global Multi-Constituent Analysis

Tides are not static. Long-term changes in tidal amplitude and phase have been documented at many coastal sites, with implications for flood risk, navigation, and coastal ecosystems. Most prior observational global work has focused on the semidiurnal M2 and diurnal K1 constituents across three regions — the North American Atlantic coast, the European Shelf, and Australia — leaving the global picture and other major constituents largely unexplored. We extend this body of work using 106 tide-gauge stations from the GESLA-4 database, spanning nine regions and with records ending in 2022. For each station, annual harmonic analysis (UTide) is applied to records that meet strict data-completeness criteria, yielding annual amplitudes and phases for six constituents (M2, S2, N2, K1, O1, M4). Secular trends are estimated using a regression model that explicitly accounts for the 18.61- and 9.3-year nodal cycles, with lag-1 autocorrelation-corrected uncertainties. Relative sea-level rise is decomposed into absolute SLR using GIA rates from ICE-7G_NA. For stations overlapping with previous regional studies, our M2 trend estimates show broad agreement, confirming methodological consistency. Significant amplitude responses to absolute SLR are widespread but spatially heterogeneous. North America shows predominantly amplifying M2 responses, whereas Asia is dominated by dampening. Australia and Europe exhibit mixed behaviour. The additional constituents display distinct regional signatures, suggesting that local bathymetry, resonance, and shelf geometry mediate the tidal response to rising sea levels — particularly in Asia and the Southern Hemisphere, where empirical constraints have until now been sparse.

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African Ocean Biodiversity Atlas

This project centers on the development and deployment of multifunctional ocean applications and technologies aimed at enhancing ocean awareness and sustainability across Africa. Key initiatives include the creation of a Fisheries Atlas and a Blue Carbon Biodiversity platform focused on Africa's landing beaches, providing vital recommendations to governments for establishing Marine Protected Areas (MPAs). The project emphasizes data sharing among local indigenous fishermen and promotes a deeper understanding of the UN Ocean Decade's objectives. It establishes a comprehensive data repository encompassing various marine species such as fish, mangroves, algae, and seaweeds, supporting informed decision-making and conservation efforts. Recognized as an UN Ocean Decade-endorsed initiative, African Ocean Biodiversity addresses critical challenges outlined by the UN Ocean Decade, including digital representation of the ocean and ecosystem restoration and protection. By fostering regional collaboration and integrating traditional knowledge with cutting-edge technology, this project aims to advance ocean sustainability, biodiversity conservation, and ecosystem resilience in Africa. The initiative ultimately supports the global goal of safeguarding marine ecosystems, promoting sustainable use of ocean resources, and fulfilling the commitments of the UN Ocean Decade to ensure healthy, resilient oceans for future generations.

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Re-evaluating the contribution of organic matter respiration to shallow calcium carbonate dissolution

Despite bulk seawater being oversaturated with respect to calcite, alkalinity and sediment trap data reveal that a large part of sinking particulate inorganic carbon (PIC) dissolves in the upper 1000-m of the water column (mesopelagic). This shallow dissolution is often explained by the presence of undersaturated microenvironments, either in the guts of zooplankton or through the respiration of organic matter in sinking aggregates. A key modelling study by Jansen et al. (2002) concluded that respiration-driven dissolution is insignificant because of an insufficient formation of microenvironments and/or short residence times due to fast sinking velocities. However, recent laboratory and field work suggests that in fact respiration-driven dissolution does play an important role in the mesopelagic. New insights into particle sizes, porosities and sinking velocities since the 2002 study also warrant a re-evaluation of the mechanisms driving shallow dissolution.

In this work, we investigate the presence of respiration-driven undersaturation and subsequent dissolution with a 1D diffusion model of a porous particle, updating the work done by Jansen et al.. In a sensitivity study, we determine how shallow dissolution varies with particle characteristics such as organic carbon content, size, porosity, carbon-specific respiration rate and settling velocity. We find that respiration-driven dissolution may be significant for specific particle types, highlighting the need for measurements of which forms PIC sinks through the mesopelagic. In future work, these insights are used to parameterise respiration-driven dissolution in global marine biogeochemistry models, exploring its impact on alkalinity cycling and the coupling between the soft tissue and carbonate pump.

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Consequences of Antarctic sea ice loss in a high-resolution ocean-ice-biogeochemistry model

The Southern Ocean (SO) plays a vital role in regulating global climate, having taken up more than 40% of anthropogenic CO_2 since the preindustrial era. Despite its importance, it remains poorly sampled and understood. Furthermore, it is vulnerable to anthropogenic climate change and since 2016, has experienced rapid sea-ice loss. It has been suggested that this could constitute a 'regime shift' to a new low sea-ice state. Antarctic sea ice plays a pivotal role in both the biogeochemical and physical processes that regulate the SO's ability to remain a carbon sink. To predict whether future changes in sea-ice cover will lead to either an increase or decrease in the SO's carbon uptake capacity, it is vital to understand the interplay between processes such as light availability, sea ice capping, stratification and their effect on primary productivity. This study investigates the role of Antarctic sea-ice loss on the air-sea CO_2 flux in a high-resolution (1/12th degree) ocean-ice-biogeochemistry model run under SSP370. Our results exhibit substantial sea-ice loss by the end of the century and a continued increase in ocean CO_2 uptake. However, this increase becomes muted from the 2060s as the ocean's buffering capacity is progressively exhausted, causing ΔpCO_2 to plateau, meaning end of century CO_2 uptake is far smaller than would be expected. A shift in the CO_2 flux seasonal cycle is also observed, with heightened pH extremes driven by the effects of substantial sea-ice decline and atmospheric temperature increases on the timing of primary productivity.

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Export in motion: eddies, particles and carbon export in the Labrador Sea

The Labrador Sea, a region with deep winter convection, is a potential hotspot for both gravitational particle export and physically driven carbon export pathways. While models suggest a strong role for mixed-layer and eddy subduction pumps in this region, the lack of sustained small-scale observations means the net role of the Labrador Sea in the global carbon sink remains uncertain.

ReBELS (Resolving Biological Carbon Export in the Labrador Sea) established a year-long autonomous observatory in the Labrador Sea, aiming to resolve seasonal export processes and assess the impact of (sub-)mesoscale variability. Here we focus on mesoscale eddies and their influence on particle distributions and export processes.

Glider surveys showed strong spatial heterogeneity which was associated with mesoscale eddy dynamics. A detailed eddy survey during a cruise in August 2025 showed that negative sea-surface temperature anomalies corresponded to anticyclonic eddies with warm, subsurface Atlantic-origin cores. Strong density gradients and sloping isopycnals at the eddy rim coincided with enhanced chlorophyll concentrations. Further, an Underwater Vision Profiler (UVP6) mounted on the ship's CTD revealed that particle distributions within the eddy showed strong size dependence, with smaller particles distributed more uniformly across the upper eddy structure while larger particles were concentrated below the surface at the eddy rim. These observations are consistent with mesoscale eddies enhancing nutrient supply and biological production through lateral stirring at eddy boundaries, while influencing particle distributions and potential export pathways across the Labrador Sea.

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Carbon Transience Time: Quantifying Timescales of Pelagic Carbon Sequestration

Carbon sequestration by the biological carbon pump is commonly quantified using metrics that describe the magnitude and efficiency of export. In contrast, the timescales over which carbon transits from uptake at the surface to sequestration at depth remain poorly constrained. Yet these timescales are likely to change as marine ecosystems reorganise under climate warming, particularly in rapidly changing high-latitude ocean.

Here we apply the novel concept of carbon transience timescale: the time for carbon entering the ocean to transit through the pelagic ecosystem from nutrient uptake and plankton growth to particulate organic matter (POM) production and sinking to sequestration depths which vary globally. We quantify this timescale using a trait-based Nutrient-Unicellular-Multicellular (NUM) ecosystem model coupled to global ocean circulation transport matrices.

We focus on high-latitude environments where amplified warming and declining sea ice are expected to strongly modify seasonal ecosystem dynamics. Idealised warming and sea-ice-free simulations demonstrate that temperature and nutrient supply exert strong controls on plankton community composition, particularly the balance between diatom and non-diatom groups. Earlier bloom initiation in newly ice-free regions reduces carbon transience time, leading to earlier seasonal export of POM to sequestration depth. These results suggest that future ecosystem change may alter not only the magnitude of carbon sequestration, but also the rate at which sequestration occurs. By complementing traditional metrics such as export flux and export efficiency, carbon transience time provides a new framework for understanding how ecosystem change may reshape the pace of ocean carbon sequestration in a warming climate.

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Convex Seascape Survey

Bottom trawling is a major anthropogenic disturbance to benthic marine ecosystems and may significantly alter sediment carbon storage and cycling through seabed resuspension. As part of the CONVEX project at Plymouth Marine Laboratory (PML), this study examines the effects of experimental bottom trawling on sediment and carbon dynamics in the western English Channel.

Three sampling trips were conducted at the Western Channel Observatory (WCO) L4 and Hilmars' Box sites, where trawling disturbance was experimentally simulated. Water and sediment samples were collected pre-trawl, during trawling, and post-trawl using a Niskin rosette and box corer. The samples obtained are undergoing analysis for total particulate carbon and Nitrogen; C^{13} signatures of total particulate carbon; dissolved inorganic carbon and associated total alkalinity (DIC/TA); pCO_2 derived from DIC/TA; and O_2 concentrations from incubated sediment cores. These analyses are being used to assess sediment resuspension and determine the origin of suspended material within the water column. Preliminary observations suggest that trawling mobilises substantial quantities of benthic material, with resuspended particles exhibiting distinct source signatures compared with typical terrestrial and marine-derived material. These findings contribute to understanding how bottom trawling may influence carbon cycling and sediment dynamics in coastal marine ecosystems.

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Microplastics and Global Change: The effect of microplastic exposure (biodegradable and conventional) in combination with seawater inundation on the coastal plant Plantago coronopus

Coastal ecosystems face a multitude of pressures, including plastic pollution and increased flood risk due to sea-level rise and the severity of storms. This study quantified the effect of microplastics (polyethylene terephthalate (PET): a durable plastic, and polybutylene adipate terephthalate (PBAT): a biodegradable plastic), in combination with seawater inundation on ecologically relevant responses of the coastal plant Plantago coronopus. After 35-days exposure to microplastics (0.02 $g.Kg^{-1}$, <300µm diameter), P. coronopus were flooded with artificial seawater for 72-h, drained and grown for a further 24-days. Plant mortality, necrosis and photosynthetic efficiency (Fv/Fm) were recorded throughout, with root:shoot biomass and scape production (flower stalks) quantified at harvest. There were significant interactions between microplastics and seawater on the root:shoot ratio; a measure of resource allocation. Belowground biomass significantly increased under the PET + inundation treatment compared to the PBAT + inundation and the no plastic + inundation treatments, with potential consequences on the capture of water, nutrients and sunlight, affecting plant performance. Plant necrosis significantly increased, and Fv/Fm declined as a result of seawater inundation. While not significant, plant Fv/Fm responses were influenced by microplastics (17% and 7% reduction in PBAT and PET exposure respectively, compared to the control). Microplastic exposure significantly influenced potential reproductive output, with lower average scape numbers in PBAT treatments, but higher in PET treatments. Coastal plants have vital roles in mediating erosion and providing food and habitat for a diversity of species. This study highlights the complex interactions and potential for microplastics to present an elevated risk when in combination with additional stressors, like seawater flooding.

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Socio-cultural and relational values of elasmobranchs (sharks, skates and rays): current research and knowledge gaps

The socio-cultural and relational values of elasmobranchs (sharks, skates and rays) are poorly understood, despite their importance in tailoring context-appropriate conservation solutions. We conducted a systematic literature review using Boolean logic and a backwards citation search to assess their value through research, the techniques used, and whether spatial and species bias existed. Thematic coding analysis of 150 peer-reviewed articles suggests that elasmobranchs are valued for their contributions to livelihoods, storytelling and communities. Relational values relating to interactions, education, and personal identity were the most frequently identified. We also identified clear trends and biases in research. Research focused on large charismatic species. Most research was conducted by authors based in the Western hemisphere, generating a spatial bias in our understanding. Research tended to use surveys or interviews, with primarily male participants, instead of methods better suited to understanding complex values. We highlight priority gaps in values-based elasmobranch research and consider ways conservation policy could incorporate the values identified into practice.

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The overlooked majority? Dissolved organic nutrient cycling in the Western English Channel and the implications for phytoplankton communities

Here, we present an analysis of changing concentrations of organic nutrients at weekly, monthly and seasonal scales in a temperate coastal environment; the L4 station in the Western English Channel. Between, May 2025 and May 2026, dissolved organic nitrogen (DON) and dissolved organic phosphorus (DOP) concentrations were calculated from total dissolved nutrient measurements. By integrating these results with over two decades of Western Channel Observatory environmental parameters, we explore the short- and long-term drivers of organic nutrient dynamics.

Dissolved organic nutrient measurements are complimented by biological observations to understand how organic nutrients interact with phytoplankton. These include chlorophyll concentration, photosynthetic efficiency and extracellular enzyme activity. The results will be contextualised to understand the winners and losers of organic nutrient changes and the implications for human and ecosystem health.

These findings highlight organic nutrients as a critical yet overlooked component of coastal nutrient budgets, with implications for future coastal management decision making. Sampling will continue into 2027 including a spatial dimension to understand how organic nutrient phytoplankton interactions change with proximity to human actions.

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How do ocean models mix?

The equatorial cold tongue regions of low sea surface temperatures (SST) coincide with strong incoming radiative warming. This counterintuitive relationship between of cool sea surfaces despite heating air-sea surface fluxes exists in the presence of strong subsurface mixing, which transports heat from the surface to the ocean interior. From moored mixing meters, mainly at 0°N, 140° W, we know that this nearly one dimensional heat balance dominates the annual as well as the interannual cycle of SST variability (Warner and Moum, 2019, Moum et al, 2013). These rare process measurements are invaluable, but the measured turbulent fluxes are hard to compare to their model counterparts, since model turbulent heat flux output is not often archived. Here we demonstrate how to best use the existing observations together with the hydrographic measurements from the Tropical Atmosphere Ocean (TAO) moorings in the Pacific to evaluate simulated turbulence. We construct a set of process oriented diagnostics (PODs) targeting the simulated mixing rather than just the emerging quantities such as SST: mixPODs.

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Understanding carbon sequestration times in transient climate simulations

Ocean ventilation pathways shape the distribution of heat, carbon, and oxygen in the ocean. A key property describing ocean ventilation is "reemergence time", or the time for an interior parcel to reach the surface again. In particular, reemergence time describes how long carbon sequestered by the biological carbon pump is stored. However, reemergence times have almost exclusively been studied in the context of steady-state flows ("frozen-in-time", or FIT); so, our understanding of this property in the context of realistic transient ocean conditions (e.g. under climate change) is extremely limited. Here we quantify transient reemergence times across different SSP scenarios using transport matrices derived from archived CMIP6 simulations. We find that, compared to the FIT framework, transient calculations of present-day reemergence times are up to a factor of 2 larger, and trends over the 21st-century are about an order of magnitude smaller. The pattern of trends in the transient framework highlights a shift in Southern Ocean ventilation away from deep convection regions in favor of intermediate water formation regions, as well as a strong signal associated with a slowing AMOC. These transient framework trends indicate the sensitivity of carbon sequestration by the biological pump to the year of injection. For example, our results suggest that carbon injected in the Southern Ocean at 1000m (into intermediate waters) will be sequestered for several fewer decades with each passing decade over the 21st century. This work reframes our notions of carbon sequestration times in a transient climate.

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Spatiotemporal Variation in Northwest Atlantic Harp Seal (Pagophilus groenlandicus) Trophic Ecology: Insights from Stable Isotope and Stomach Content Analyses

Marine ecosystems are under increasing pressure from global environmental change and human activities, requiring effective ecosystem-based management strategies to preserve their health and resilience. Marine top predators can provide valuable insights into ecosystem dynamics because they are often sensitive to underlying changes in environmental and ecological conditions. Harp seals (Pagophilus groenlandicus) inhabiting the Northwest Atlantic (NWA) are a useful indicator species, known to reflect changes within the ecosystem in this region. We investigated the spatiotemporal trophic dynamics of NWA harp seals between 2005 and 2019, using stable isotope analysis and stomach content data to assess their foraging behaviour and interspecific competition with Atlantic cod (Gadus morhua). We found an adaptive transition of harp seals towards a more pelagic feeding strategy between 2005 and 2019, likely driven by changes in prey community composition. Furthermore, localised spatial variation in harp seal diet may suggest the presence of an ecologically important habitat for commercially important Gadus spp., such as Atlantic cod. This provided evidence of intraguild predation between harp seals and Atlantic cod in areas where their distributions may overlap, which could have implications for the population dynamics of both species. Our study demonstrates the importance of harp seals as indicators of ecosystem change and their utility in ecosystem-based fisheries management.

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Deriving and assessing seawater pCO_2 (partial pressure of CO_2) estimates from an Argo float across eddy-scale and 10-day sampling modes in the North Atlantic

The partial pressure of carbon dioxide in seawater (pCO_2) is a key variable for climate science as it is vital for calculating estimates of air-sea CO_2 fluxes. The Argo float array is a global network of profiling floats that provide continuous in situ, depth-resolving measurements of the oceans. However, there is currently no operational way to obtain direct measurements of pCO_2 from these platforms. Presently, floats equipped with pH sensors can be used to estimate pCO_2 by combining interpolation methods (to calculate total alkalinity) with carbonate-system calculations. With pCO_2 and wind reanalysis products, air-sea CO_2 fluxes can be derived. Meanwhile, the development and testing of pCO_2 sensors and acoustic wind sensors for Argo floats is ongoing through the EU GEORGE and TRICUSO projects. These will improve calculations of flux estimates and provide validation for current methods.

A pH-equipped float was recently deployed at the Porcupine Abyssal Plain Sustained Observatory (North Atlantic) as part of GEORGE, initially profiling on a daily basis and circling an eddy for over a month. The results of Delayed Mode Quality Control (DMQC) processing of the float's dissolved oxygen and pH measurements will be presented, with comparison to other in situ measurements. Estimates of pCO_2 will also be presented alongside an assessment of uncertainties. These uncertainties stem from the settings and methods used for the DMQC adjustments and derivation of pCO_2. The product presented here will contribute to an inter-comparison of data derived from other GEORGE CO_2 system sensors, supporting a multi-platform observing framework.

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More Than Just Puppy Fat: Admission Weight and Rehabilitation Success in UK Seals

Admission weight was examined as a predictor of rehabilitation duration and release success in 539 grey seals and 111 harbour seals admitted to the Scottish SPCA and Cornish Seal Sanctuary between 2021 and 2025. Admission weight was used as a proxy for body condition. Grey seals had substantially higher survival to release (74.7%) than harbour seals (34.2%). In both species, heavier seals spent less time in rehabilitation. For every 1 kg increase in admission weight, rehabilitation duration decreased by 10% in harbour seals and 2.5% in grey seals. However, admission weight did not predict release success equally between species. In grey seals, heavier individuals were significantly more likely to be released, with odds of release increasing by 6.5% per kg increase in admission weight. In harbour seals, mortality occurred across the full range of intake weights, suggesting additional factors influenced survival. These differences may reflect species variation in physiological stress, disease susceptibility, and environmental pressures. Grey seals also had higher release success and shorter rehabilitation periods overall. Overall, admission weight was useful for predicting rehabilitation duration but should not be used alone to predict survival outcomes.

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Global Observational Estimates of Thermohaline Transformations by Interior Ocean Mixing

Small-scale diapycnal mixing and mesoscale isopycnal stirring redistribute heat and freshwater and other solutes in the ocean. These processes shape regional and global circulation patterns and impact the climate system. Due to the scarcity of mixing observations, appraising such a critical role remains a major challenge. Here, we revisit and expand a recent reformulation of the water-mass transformation framework to derive global thermohaline transformation rates from estimates of variance dissipation rates of temperature $\chi\Theta$ and salinity χS in the ocean interior. To estimate $\chi\Theta$ and χS, we leverage new global, vertically resolved maps of diapycnal and isopycnal diffusivity. Global diathermal and diahaline water-mass transformations by interior mixing show respective double circulation cells transporting 600 TW of heat and 20 × 10^6 kg s^{-1} of salt to waters cooler than 20°C and fresher than 35.1 g kg^{-1}. Diathermal transformations are dominated by diapycnal mixing, involving the formation of 36 Sv (1 Sv ≡ 10^6 m^3 s^{-1}) of subtropical thermocline waters (10°–25°C) from warmer tropical waters and colder, deeper waters. Isopycnal mixing is the main driver of global diahaline transformations, forming 34 Sv of waters with intermediate salinity (34.4–35.7 g kg^{-1}), and of diathermal transformations in cold waters (<5°C). The Antarctic Circumpolar Current is the global hotspot for isopycnal mixing, controlling the redistribution of heat and freshwater between the Southern Ocean and the rest of the global ocean. Climatological estimations were validated against regional observational microstructure datasets, demonstrating that even a modest number of microstructure profiles can yield meaningful regional estimates of water-mass transformations.

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Detecting changes in Antarctic Bottom Water transport with a neural network applied to satellite-observable ocean properties

The transport of Antarctic Bottom Water (AABW) supplies the densest layers of the abyssal ocean circulation, which accounts for up to 40% of the ocean's volume and plays a vital role in Earth's climate. AABW forms when dense, cold waters from the continental shelves descend along the Antarctic slope. The physical conditions necessary for sinking are created by ice formation and freezing winds in this region.

This implies that, as temperatures rise and ice melts due to climate change, the circulation could diminish. Model projections also suggest this, identifying meltwater forcing as a potential primary factor in the reduction of AABW transport. However, the variability of AABW remains poorly constrained by observations. Its origin on the Antarctic continental shelf and slope presents limited opportunities for in situ measurements, and satellite observations are hindered, especially in winter, due to sea ice cover. To the north, AABW spreads deeper than 2 km below the surface, with direct monitoring, both in situ and remote, remaining complicated and scarce.

Here, we explore the plausibility of inferring AABW circulation from available satellite measurements of the ocean's surface properties, via machine learning techniques. In our work, we implement different Neural Network (NN) architectures to reconstruct the circulation's diagnostics. The NN is trained and tested on the ACCESS-OM2-01 model, focusing on specific AABW-forming areas such as the Ross Sea and Cape Adare.

These studies offer a valuable means to overcome current limitations on Southern Ocean and abyssal circulation research, making it more accessible, sustainable, and consistent.

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Deciphering diatoms contribution to carbon export: Drivers and Patterns Across Contrasting Ecosystems

Projections of particulate organic carbon export in the last generation of climate models (CMIP6) exhibit major inter-model variability. This wide variation is due to the limited understanding and poor representation of the biological carbon pump and its underlying ecological drivers within the models. Diatoms are major contributors to export fluxes, owing to their high growth and division rate, broad size spectrum and silicate shell that increases their sinking rate.

To assess the impact of diatom trait variation on carbon export, we combined two decades of sediment trap fluxes at 1000 m with surface phytoplankton composition from microscopy in the Subantarctic Southern Ocean and Caribbean Basin. We quantified seasonal and interannual variations in diatom biomass and examined variability in key functional traits—cell biovolume, cell density (inferred from Si:C stoichiometry), shape, appendix and coloniality — to assess how trait variation modulates carbon and biogenic silica export fluxes in those contrasted ecosystems.

Leveraging these empirical insights, we used the global ocean biogeochemical model PlankTOM to identify key parameters and discrepancies limiting the model's representation of diatom's export contribution. We developed an optimised diatom parametrisation in the PlankTOM model in order to improve the model's ability to represent observed seasonal and interannual export flux patterns across various ecosystems.

Our results provide a mechanistic link between diatom functional diversity and large-scale carbon export in contrasting ecosystems. This data-driven approach will allow us to refine our understanding of regional carbon export as well as future carbon export projections in global biogeochemical models.

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Shifts between light and nutrient limitation of the deep chlorophyll maximum drive changes in plankton composition and biogeochemical cycling in the South Atlantic Subtropical Gyre

The deep chlorophyll maximum (DCM) occurs at ~120m in the South Atlantic Subtropical Gyre where nutrients are more abundant than at the surface, but light is minimal and often rate limiting. The movement of internal tidal waves over the mid-Atlantic Ridge has been hypothesised to mix nutrient rich waters from depth into the deep chlorophyll maximum (DCM), relieving nutrient limitation and promoting primary production at depth. During a cruise in early 2025, we characterised the composition of plankton communities across the depth gradient at a site influenced by tidally driven diapycnal mixing and a site with no enhanced mixing. This showed a dominance of picoplankton across all sites and depths, with a minimal impact of nutrient enrichment on community composition but a stronger impact on physiological adaptations of cell size and cellular fluorescence. Additionally, we performed labelled stable isotope uptake rates for nitrate, ammonium and carbon. These results revealed a rapid 32-fold increase in community nitrate uptake in response to a tidally driven enrichment of nitrate to the DCM, but with no concurrent impact on carbon uptake. Consequently, this demonstrates that while local nutrient enrichments can have significant impacts on cellular stoichiometry, this does not necessarily translate into enhanced productivity. Instead, taxonomic and biomass responses to short-term nutrient enhancements are dependent on the interactive effects of physiological (light, nutrients) and ecological (grazing, mixotrophy) controls. These results inform our understanding of nutrient utilisation by nutrient limited plankton communities and the extent to which the DCM contributes towards carbon export in oligotrophic environments.

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Chlorophyll fluorescence dynamics in relation to hydrodynamical featues in the coastal North Sea

The North Sea is seperated into distinct regions by the onset of springtime stratification.For the East Coast of England, stratification occurs first in deeper water to the east of the Farne Islands, with density differences apparent by late March. By June, the area north of Flamborough Head is strongly stratified, whereas waters to the south are still mixed (and colder). Inshore waters also remain mixed. We investigated phytoplankton functional type composition and physiological response to the onset of stratification by sampling monthly along a line transect off the port of Scarborough, bissecting different water masses. Changes in fluorescence parameters (Fv/Fm, NPQ, rETR) could be related to prevailing conditions of stratification, underwater irradiance and nutrient availability, and will be used to improve estimates of productivity in this coastal system.

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Have deep-sea macrofaunal communities in the Rockall Trough (northeast Atlantic) changed over the past four decades?

Long-running deep-sea time series are rare yet vital in identifying baseline changes in habitats. Benthic fauna from Gage Station M at 2200m in the Rockall Trough (NE Atlantic) spanning 1980-2016 were examined. Variations in benthic community structure, functional group dominance and abundance are assessed from interannual to decadal timescales and how these relate to changes in temperature, salinity and plankton dynamics. The benthic community shows highly variable abundance ranging from ~31k – 175k ind. nmi^{-1} over the length of the time-series, with a higher number of individuals observed in the 1980s and a relatively low Shannon diversity (H') of 3.48 at the family level. From 2010 onwards, the opposite was seen, with a diversity of H'=3.81. The 1990s, however, exhibited very low abundances (<61k ind. nmi^{-1}) compared to the previous decade (<115k nmi^{-1}), except 1994, when the highest abundance was observed (175k ind. nmi^{-1}), with a relatively low diversity of H'=3.14.

Continuous Plankton Recorder and satellite data from the same region show a decrease in diatoms, dinoflagellates and small copepods over six decades. Large peaks in phytoplankton abundance and chlorophyll-a concentrations, once common, have become rare in the last 20 years. However, large copepods have experienced more population booms since 2006. With temperature in the upper 100m of the Rockall Trough steadily increasing since 1975, combined with notable changes in the phytoplankton community, this may be influencing observed changes in the benthic community composition, including the decline in biodiversity in the 1990s in the Rockall Trough deep-sea invertebrate population.

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Pycnostrophic coordinates: A framework for relating meridional overturning to ocean density structure

The Atlantic meridional overturning circulation (AMOC) is sustained by changes in seawater density, but the link between those local density changes and the global-scale overturning circulation has not been fully resolved, in part due to ambiguity in the barotropic component of the flow. We define a new depth coordinate that compensates for the barotropic vortex stretching that balances planetary vorticity changes associated with meridional motion. In this framework, the divergence of barotropic flow is identically zero, and geostrophic divergence is determined solely by zonal density gradients. As a result, the geostrophic component of the Eulerian overturning circulation can be diagnosed directly from the density field without the need for a barotropic reference velocity or assumed level of no motion. We apply this framework to diagnose AMOC structure in a high-resolution numerical model. This application provides a direct link between density structure and overturning, clarifying how diapycnal processes at high latitudes influence Eulerian overturning at lower latitudes.

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Floating offshore wind farms are reshaping nutrient availability and primary productivity in the North Sea

Shelf seas play a disproportionately large role in the global carbon cycle, supporting high rates of primary productivity and nutrient recycling relative to their area. A key driver of this productivity is seasonal stratification, which regulates nutrient availability and light conditions in the upper ocean. In these environments, even small changes to mixing regimes can have significant consequences for primary production and biogeochemical cycling.

The rapid expansion of floating offshore wind farms into deeper and more stratified systems, introduces a novel physical disturbance to shelf sea biogeochemistry. Semi-submersible floating turbines are anchored above the thermocline, where they may interact directly with water column stratification and strong nutrient gradients. Their mooring systems and submerged structures have the potential to enhance local mixing, alter nutrient supply, and influence patterns of productivity on seasonal to regional scales. Understanding these interactions becomes more critical as offshore wind energy developments continue to expand globally.

As part of the eSWEETS3 project, we present high resolution in situ biogeochemical data from the Kincardine floating offshore wind farm in the North Sea. Using CTD profiles and associated measurements collected within and around the wind farm, we investigate changes in water column structure and hydrography and assess evidence for wind farm–induced mixing. These observations provide new insight into how floating offshore wind infrastructure may influence stratification and nutrient dynamics in shelf seas, with implications for ecosystem functioning and carbon cycling in a rapidly developing energy landscape.

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Leading coherent decadal-to-multidecadal variability in a 123-year gridded instrumental dataset of subpolar North Atlantic surface salinity and temperature (1896–2018)

Temperature and salinity fluctuations in the subpolar North Atlantic Ocean (SPNA) are important for the global ocean circulation and climate system. Here, we investigate the trends and leading decadal-to-multidecadal variability of a unique long-term gridded instrumental compilation of co-located sea surface salinity (SSS) and temperature (SST) measurements over 123 years (1896–2018) between 40°N and 70°N at length scales of 200–500 km, known as BINS. The long-term BINS linear trends consist of SSS freshening across the central and western SPNA, with SST warming in the eastern SPNA margin and Gulf Stream Extension. Removing the trend, we apply principal component (PC) analysis to low-pass-filtered (7.5+ years) BINS time series to extract the key modes of decadal-to-multidecadal variability, calculated independently for SSS and SST. The leading PCs account for around a third of the respective SSS and SST variance and are significantly in-phase correlated, with maxima in the late-1930s and early-2000s, and minima in the 1970s. The PC1 spatial patterns have largely uniform sign across the central SPNA, with positive SSS anomalies associated with SST warming. The second PCs, which explain about half the variance of the leading PCs, have stronger decadal variability and project onto northwest-southeast spatial dipole patterns across the SPNA; they also show coherence between SSS and SST anomalies. Additionally, we also find that the first two PCs are significantly correlated with the winter North Atlantic Oscillation (NAO) index at different timescales, suggesting that atmospheric forcing plays a key role in modulating decadal-to-multidecadal SPNA SSS and SST variability.

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Socio-Ecological Dynamics and Governance in the Plymouth Sound National Marine Park: Stakeholder Perceptions of Ecosystem Service Provision

Human activities continue to drive the loss of global marine biodiversity, and traditional conservation approaches often fail to address this. In response, holistic models that integrate biodiversity conservation with human wellbeing are gaining traction. In the UK, National Marine Parks (NMPs) represent a new holistic non-statutory approach that builds on existing marine designations while promoting human–nature connections and delivering ecological, social and economic benefits.

This research examines how the UK's first NMP in Plymouth Sound influences the provision of ecosystem services and distribution of associated benefits and disbenefits. Eight participatory workshops were conducted with 44 stakeholders to explore perceived changes in ecosystem services and their impacts across communities and environments.

Cultural services emerged as the most immediate benefit, with the NMP supporting marine citizenship, connection to place and opportunities for inclusive engagement. Participants also identified barriers to wider impact, including unclear governance, communication challenges and uneven distribution of investment and activity.

Overall, these findings suggest that NMPs can act as important place-based governance initiatives that strengthen human–marine relationships and support more inclusive stewardship. Their long-term effectiveness will depend on embedding equity, co-production and clear governance, so they can complement statutory management and contribute to future UK coastal policy.

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Empirical determination of the interaction landscape for temperature, CO2 and nitrate for a model diatom

Accounting for more than 40 percent of marine primary production, diatoms are key drivers of silica cycling and play major roles in nutrient cycling and carbon fixation. Rising temperature (T), increasing CO2 concentrations, and changing nitrate (N) availability are major environmental changes in contemporary oceans that can alter diatom growth and physiology. While responses to individual drivers are relatively well understood, much less is known about how these factors interact. This uncertainty limits our ability to predict future diatom populations and ecosystem dynamics. To investigate these interactions, we conducted a series of two-driver experiments (CO2 × T, N × CO2, and T × N) using multiple treatment levels for each driver to characterize their combined effects on growth and associated traits in the model diatom Thalassiosira weissflogii. We first examined the interaction between temperature and CO2 on population growth, cellular composition, and stress indicators, and assessed whether variation in carbon concentrating mechanisms (CCMs) may underlie observed responses. We then investigated how nitrate and CO2 jointly affect growth, nutrient uptake, and nutrient storage. Preliminary results indicate that temperature had a stronger influence on growth than either nitrate or CO2. Under nitrate-replete conditions, temperature showed a saturating relationship with optimal CO2 concentration (CO2opt), whereas at the optimal temperature (Topt), CO2opt initially decreased when nitrate was depleted and then increased with increasing nitrate concentration. These findings will help characterize the response surface of a key marine primary producer under interacting environmental drivers and improve predictions of diatom responses in future oceans.

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Contrasting Surface and Bottom Marine Heatwave Responses to Climate Change in the Northwest European Shelf

Marine heatwaves (MHWs) are prolonged periods of unusually high ocean temperatures that are expected to become more frequent, intense, and longer-lasting under climate change. While most research has focused on sea surface temperatures (SST), less attention has been paid to benthic environments despite their ecological importance. This study examines the physical drivers of future MHWs in both SST and sea bottom temperature (SBT) across the Northwest European Shelf Seas. Future changes in SST and SBT MHWs were analysed using a 7 km downscaled regional climate model based on UKCP18 projections under the high-emissions RCP8.5 scenario, incorporating a 12-member perturbed parameter ensemble. Present-day (2003–2022), near-future (2040–2059), and far-future (2079–2098) conditions were compared by separating temperature variability into long-term warming trends, seasonal cycle variability, and residual short-term variability. Results show clear differences between surface and benthic MHWs. Long-term warming was the primary driver of future SBT MHWs, particularly along the shelf edge, where warming alone could produce near-permanent MHW conditions by 2100. In contrast, SST MHWs were influenced by long-term warming, amplified seasonal cycles, and enhanced short-term variability, leading to stronger and longer summer events in mixed regions. Seasonal amplitudes increased by up to 2–3 °C for SST across the region and by up to 2 °C for SBT, primarily in coastal areas, while residual variability increased SST MHW intensity by around 200% in some regions. These findings highlight the importance of considering both surface and benthic environments when assessing future ecological risks associated with climate change.

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The persistent impact of abyssal seafloor disturbance

Anthropogenic impacts to ecosystems can interact to intensify or alter effects, so understanding these effects is important to environmental impact assessment and the management of industrial activities. Despite the need to characterise cumulative effects, they are not often observed over long periods; this is particularly true on abyssal plains, despite increased industrial interest in this environment. We present observations of the persistent impacts of seafloor disturbance caused by epibenthic sledge operations 30+ years after their deployment at the Porcupine Abyssal Plain Sustained Observatory, assessed primarily by seabed photography. The sledge tracks appeared to result in three interactive impacts: (i) redistribution of sediment and a presumed disturbance of biogeochemical conditions by the creation of furrows, (ii) accumulation of organic matter in the furrows, and (iii) directly observed accumulation of plastic debris, concentrated 1000 times relative to the surrounding abyssal plain. These latter two impacts are likely the result of the topographic low and adjacent associated sediment spoil berm of the furrow trapping material that was advecting across the seafloor. Increases in the abundances of some fauna were potentially related to this localised organic enrichment and the increase in hard substratum availability to an otherwise soft-sedimented habitat. These observations of persistent and interacting impacts at a multidecadal scale provide an important benchmark useful to the assessment and management of activities causing abyssal seafloor disturbance.
Funding was provided by the UK Natural Environment Research Council through the AtlantiS project (NE/Y005589/1).

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From shallow to abyssal: Comparative growth dynamics of Nucula species (Mollusca: Bivalvia) from shallow British waters and the abyssal Clarion-Clipperton Zone

One of the most abundant molluscs found in the abyssal Clarion-Clipperton Zone (CCZ) is Nucula profundorum, a millimetre-scale protobranch bivalve. Despite its prevalence in this environment, very little is known about this species' growth patterns and lifespan—key factors for assessing the ability of its population to recover after mining disturbances. The study of growth patterns in shells, or sclerochronology, has traditionally focused on shallow-water species, which are larger and exhibit growth on tidal, daily, monthly, and annual cycles. These growth patterns are influenced by a combination of environmental factors (e.g., water temperature, nutrient availability) and endogenous biological rhythms. In contrast, the relatively stable environmental conditions of the abyssal CCZ have raised uncertainty about whether these deep-sea bivalves would also exhibit discernible internal growth patterns. This study has conducted sclerochronology on shallow-water relatives of N. profundorum, which show classical growth patterns, and for the first time, has extended sclerochronological techniques to CCZ bivalves including Nucula profundorum. Sporadic, non-classical growth lines have been identified in these individuals, suggesting distinct patterns of shell formation between the populations. This disparity among growth patterns raises questions about how the relatively stable environmental conditions of the abyssal CCZ affect bivalve growth. Beyond shell formation dynamics, other formerly unstudied aspects of the N. profundorum biology will be discussed, including its phylogenetic placement, larval strategy, spawning periodicity, and finer details of its shell microstructure. This information fills gaps needed to better understand the life history and ecological role of deep-sea bivalves in this unique and vulnerable region.

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Gyre revealed in front of the Dotson Ice Shelf, West Antarctica: implications for regional ocean circulation and transport of heat into the cavity.

The ice shelves of the Amundsen Sea are losing mass at an accelerating rate, largely due to ocean-induced basal melting. Ocean circulation in front of ice shelves influences heat transport into cavities and thus basal melt rates, but the mechanisms controlling this remain poorly understood. Here we show evidence from an ocean glider section for a cyclonic gyre in front of Dotson Ice Shelf (DIS), revealed by isopycnal doming and clockwise velocities. Using a high-resolution (≈2.3 km) multidecadal (1997-2017) model simulation, we confirm persistence of a gyre in this location (median volume transport 0.8 Sv with interquartile range 0.1–1.8 Sv; median diameter 29 km with interquartile range 17-36 km) and discuss its temporal and spatial variability. We present temperature and salinity observations from a mooring in front of DIS and from instrumented seals at Martin Peninsula (45 km to the north), and demonstrate that a weak gyre state contributes to an unexpected wintertime shoaling of isopycnals by up to ~100m. We composite strong and weak gyre conditions for the 20-year model run, and show isopycnal doming by up to ~70m during strong gyres, resulting in temperature increases of up to 0.4°C at depths of 300-600m. Consistent with our observations, strong gyres deepen isopycnals at the coast and along the ice-shelf front, resulting in temperature decreases up to 0.3°C. Our results highlight the key role of gyres in controlling isopycnal structure and water-mass recirculation in this region, with important implications for heat transport into the ice-shelf cavity.

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Seasonal Pelagic Production and Plankton Community Dynamics in the Irish and Clyde Seas

Bottom trawling resuspends seabed sediments rich in organic carbon, potentially altering benthic and pelagic carbon and nutrient cycling processes, and reducing the capacity of the ocean to sequester carbon and mitigate climate change. The disturbance and redistribution of nutrient-rich water and sediment may also influence net primary productivity and the composition of plankton communities. During two 3.5-week research cruises to the northern Irish and Clyde Seas (February and July 2026), we conducted high-resolution CTD and daily underway sampling across four sites that differed in sediment type, vertical mixing regime, and trawl fishing intensity/gear type. We measured total and size-fractionated chlorophyll concentrations to assess photosynthetic biomass and community composition, as well as photo-physiology using Single Turnover Active Fluorometry (STAF). Plankton community composition was further characterised using PlanktoScope imaging coupled with EcoTaxa-based classification. In this presentation, we will focus on setting the scene in a spatial and temporal sense of the plankton community composition and productivity across the two cruises. This will then set the baseline for assessing the impact of trawling-related resuspension of sediment and pore water on pelagic productivity in future studies.

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‘Linking Physical and Biogeochemical Gradients to the Phytoplankton community and size structure at the Polar Front’

The Polar Front is a dynamic mixing zone and one of the defining hydrographic boundaries in the Southern Ocean, separating warmer northern water and colder southern water. Here, there are strong gradients in temperature and nutrients, creating a unique environment that may influence phytoplankton community composition and biogeochemical cycling. However, despite the recognised importance of the PF, the extent of which fine-scale physical and chemical variability impact phytoplankton community size structure, composition and biomass remain poorly understood. Here we provide preliminary results investigating how cross-frontal gradients in physical structure and nutrient availability influence phytoplankton across fine spatial zones at the polar front. Using coupled high-resolution physical, biogeochemical and Imaging FlowCytobot (IFCB) observations, we assess how variability in the water column corresponds to shifts in phytoplankton assemblages and size structure across the frontal system. We aim to provide new insights into mechanisms linking: physical processes; trace metal and macronutrient dynamics; and phytoplankton community composition at the Polar Front. We expect mechanisms and dynamics uncovered utilizing frontal data to extend more broadly, helping us better understand ecosystem function and biogeochemical cycling in a changing Southern Ocean

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Biophysical characterization of the phytoplankton assemblage in the Barents Sea using high-resolution imaging (IFCB)

The Barents Sea, located at the interface between Atlantic and Arctic Oceans, is a heterogeneous system shaped by pronounced seasonality, frontal structures, and complex current regimes. This highly dynamic environment challenges our ability to understand phytoplankton biogeography. Concurrently, rapid ocean warming and sea-ice decline highlight the region as a key hotspot for understanding how phytoplankton communities respond to multiple, interacting environmental stressors.

In summer 2023, we deployed a McLane Imaging FlowCytobot (IFCB) to acquire high frequency images of the surface ocean phytoplankton community assemblage in the Barents Sea. Taxonomic and morphological information was derived using machine learning approaches, enabling characterization of the Barents Sea surface ocean phytoplankton community at an unprecedented spatio temporal resolution.

The polar front differentiates plankton community composition, with a higher contribution of large phytoplankton cells south of the polar front compared to north. Although dinoflagellates dominated the study area and correlated with chlorophyll and nutrients, regions of elevated biomass were dominated by flagellates or coccolithophores, supported by the inverse relationship between phytoplankton size and chlorophyll.

We developed an analytical framework to segement the Barents Sea based on biophysical properties in order to relate phytoplankton to surface ocean hydrography. Phytoplankton community composition was associated with distinct oceanographic regimes. We examined the potential for selected tracers to be used to predict the spatial pattern of phytoplankton These findings highlight the value of high-frequency imaging and machine-learning approaches in advancing our understanding of phytoplankton dynamics in rapidly changing marine ecosystems.

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Using Boundary Pressures to constrain the overturning circulation

The pressures on the continental slopes (boundary pressures) are weakly influenced by eddies and, in most places, directly reflect the global-scale processes. As a result, the boundary pressures can be used as a means to understand and monitor basin-scale flows such as overturning circulations. In this study, we identify and quantify the primary factors that are responsible for the variation in depth-integrated pressure (DIP) along the continental slopes worldwide by focusing on the difference in DIP between the east Atlantic and the east Pacific coasts. By using a theoretical model and diagnostics from a 1/12 degree NEMO run, we find that the DIP varies primarily because of the winds, overturning circulation in the Indo-Pacific oceans, Atlantic Meridional Overturning Circulation, and the western boundary currents along the Southwest Atlantic coast (which are due to the deflection of the Antarctic Circumpolar Current), and this leads to a 4-way balance. We prove the robustness of the balance by showing it works on the output of sixteen CMIP6 models. Moreover, for the CMIP6 models, we also find that the balance works very well in predicting the long-term temporal variations in a single component if the variations in the other components and/or the depth-integrated pressure are known.

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Internal tide breaking in a dendritic submarine canyon enhances cross-slope nutrient fluxes: preliminary results from PISCES

Submarine canyons are a ubiquitous feature of continental slopes worldwide and their steep, complex topography can enhance cross-slope exchange through a variety of hydrodynamic processes. As a component of the Processes drIving Submarine Canyon fluxES (PISCES) project, the hydrodynamics of Dangeard Canyon, part of the dendritic Whittard Canyon system at the Celtic Sea shelf break, were investigated using a combination of ship-borne instruments, moorings, and autonomous ocean gliders. We observed a large (150 m vertical isopycnal displacement amplitude), energetic (15 kW m−1 baroclinic energy flux) and highly asymmetric semidiurnal internal tide propagating up the main canyon axis and into three separate sub-limbs. The passing of the wave front was associated with turbulent kinetic energy dissipation rates up to 10−6 W kg−1 and elevated dissipation several hundred meters above the seabed. Time-averaged diapycnal eddy diffusivities up to 10−2 m2 s−1 were measured and, when acting on the background nitrate gradient within the canyon, responsible for an 8 mmol m2 d−1 diapycnal nitrate flux (4 mmol m2 d−1 at the depth of the canyon rim). A similarly energetic internal tide was observed in nearby Explorer Canyon, where a 24-day timeseries of dissipation rate was measured using a microstructure sensor-equipped Seaglider. Although an energetic internal tide was also observed over the adjacent continental slope, it was topographically steered along-isobaths and not associated with elevated dissipation rates. These results suggest that submarine canyons may contribute a globally significant fraction of the cross-slope flux of nutrients from the deep ocean to shallow shelf seas.

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The Influence of Ocean Model Resolution on the Circulation of the North Atlantic Ocean: A Lagrangian Perspective

The North Atlantic Ocean has been the focus of multiple studies in recent years due to the importance of the Atlantic Meridional Overturning Circulation (AMOC) for transporting heat from the tropics towards western Europe and the potential for its collapse in the coming decades. Lagrangian particle tracking provides a more comprehensive view than the traditional Eulerian viewpoint on ocean circulation, allowing for individual parcels to be tracked through time and space rather than at single locations. This study explores the impact of ocean model resolution on the circulation of the North Atlantic Ocean using three models of differing horizontal resolution, non-eddying (1-degree), eddy-permitting (1/4-degree) and eddy-rich (1/12-degree), under identical forcings. Within each of these models, Lagrangian particle tracking is used to diagnose biases in the representation of the overturning, heat transport and other key features of the ocean circulation. In particular, we focus on the complex interactions between the North Atlantic Subpolar Gyre (SPG) interior and the SPG boundary currents and the role these interactions play in driving the AMOC. This study shows that ocean model resolution is key to determining the pathways of water parcels in the SPG, which in turn impact the strength and variability of the AMOC.

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Highly resolved simulations to better understand ocean mixing under ice shelves

The melting of ice shelves into the ocean plays a major role, and is a key source of uncertainty, on sea level rise projections. Under ice shelves, meltwater moves upslope, setting up a stratified shear flow with the warmer, but critically saltier, ocean beneath, regulating the transfer of heat between ice and the ambient ocean. These stratified flows are incredibly difficult to access in situ, and so research has focussed on the use of numerical modelling, laboratory experiments and analytical models to understand these processes, each with their own assumptions, advantages and limitations.

Here we present novel direct numerical simulations that represent this basal melt process with highly resolved (sub-millimeter resolution) simulations that reveal this shear flow evolves as a unique mixed mode shear instability. Unusually, the combined input of buoyancy, and a solid boundary leads to paired Kelvin Helmholtz and Holmboe instabilities, which prove highly effective at mixing the water column. Due to the restoring effect of the boundary forcing, a cycle of growth, instability, turbulent mixing, and re-stabilisation is observed. Current ice-ocean parametrisations are fundamentally built on assumptions for stratified flow instabilities that may differ from these simulations, with potential implications for the turbulent transfer of heat and salt and ultimately basal melt rates.

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Photosynthetic adaptations of Southern Ocean phytoplankton to iron and manganese co-limitation

Iron (Fe) and manganese (Mn) are bio-essential micronutrients, required in the photosynthetic apparatus of marine phytoplankton. Both micronutrients are used in photosystem II, where iron is involved in electron transport and manganese is incorporated in the oxygen-evolving complex responsible for water oxidation. In the Southern Ocean, it is well documented that chronically low surface iron concentrations limit phytoplankton growth, reducing the efficiency of the biological carbon pump, which plays a key role in regulating the global climate. However, there is mounting evidence that manganese may co-limit productivity, alongside iron, in several regions of the Southern Ocean such as in the Drake Passage and the Weddell Sea. Despite the potential importance of Fe-Mn co-limitation for Southern Ocean productivity and carbon export, the physiological responses of Southern Ocean phytoplankton under these combined micronutrient stresses remain poorly constrained. Using trace metal-clean culture experiments, this study examines the different photophysiological signatures of Fe-, Mn- and Fe-Mn (co-)limitation in the Southern Ocean diatom Grammonema sp. and the haptophyte Phaeocystis antarctica. Fast repetition rate fluorometry was used to assess photosynthetic efficiency and electron transport dynamics under a combination of replete and growth-limiting Fe and Mn concentrations. Additionally, oxygen flash yields were used to quantify the changes in photosystem II concentrations under the different treatments, providing novel insights into how phytoplankton restructure their photosynthetic apparatus at a molecular level, in response to Fe-Mn co-limitation.

Heather Jaques

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The Role of Winter Storms in Sustaining Labrador Sea Convection

Open-ocean deep convection in the Labrador Sea is a key component of the global ocean circulation, with implications for carbon sequestration, ocean ventilation, and heat distribution. While large-scale drivers of convection such as the North Atlantic Oscillation have been extensively studied, it remains unclear how atmospheric forcing governs small-scale ocean variability due to the limited winter observations capturing these scales. Using ERA-5 reanalysis products, and five underwater gliders deployed during winter 2019/20 and 2021/22, we investigate the link between storm forcing and stratification in the Labrador Sea. We identified 183 storm tracks across the subpolar North Atlantic, of which 41 passed directly over the convective region. Spatial composites show that the strongest heat losses (-130 W/m^2) occur along the southwestern side of storms, while storm centers exhibit warming (~20 W/m^2). Mixed layer temperature and salinity budgets reveal varying mixed-layer responses, with both cooling and warming of a similar magnitude (±0.05 ^oC/day) associated with storm passage. Glider observations also reveal subsurface vertical entrainment of both heat and salt into the mixed layer during the passage of storms. This entrainment warms and increases the salinity of the mixed layer (>0.2 ^oC/day, ~0.05 g/kg/day), while air-sea fluxes cool and freshen the water column, highlighting the two opposing contributions of storms to mixed-layer stratification. To further explore the ocean response to storms, a 1D mixed-layer model with a range of initial ocean conditions is used to assess the sensitivity of convection, and evolution of mixed-layer density, to storm frequency and intensity.

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Estimating current velocities from ripples in tidal rhythmites: validation of deep-time tidal simulations

Tides have been shown to drive ocean mixing, regulate nutrient upwelling, help regulate climate, and influence evolutionary events. Most of this knowledge has come from simulating tides and investigating tidal deposits, i.e. tidalites, in geological history. This legacy is key to understanding tide-driven processes and products in the present and future. However, existing numerical tidal model simulations and paleogeographic reconstructions are poorly constrained for most of Earth's history and most locations on Earth because of a scarcity of direct paleotidal proxy data. This study aims to address this issue by: (i) utilizing relationships between current ripple dimensions and tidal flow to estimate paleotidal current velocity using Carboniferous (c. 318 Ma) tidal rhythmites in Wisemans Bridge, South Wales, U.K.; and (ii) comparing this paleoenvironmental proxy with regional tidal current velocities predicted using a numerical tidal model for the same period and paleogeographic setting. Dimensional ripple data collected from the Wisemans Bridge rhythmites suggest that the bedforms formed at tidal flow velocities of 0.25 – 0.32 m s^{-1}. These values closely match with the modelled tidal current velocity of 0.28 m s^{-1} based on a combination of the principal solar, principal lunar, and principal lunar diurnal constituents. The present study demonstrates how ripples in tidal deposits can be used to successfully reconstruct paleotidal current velocity to validate numerical tidal models, highlighting its potential to be applied to other locations and timeslices.

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Influence of submarine canyon geometry and complexity on internal tide dissipation

Submarine canyons are common features along continental slopes globally. High internal tide dissipation within these canyons can enhance the ocean-shelf exchange of nutrients, carbon and sediments. To understand how canyon geometry controls internal tide dissipation, we use a numerical model with two configurations: idealized canyons to examine the effects of canyon length and width, and a dendritic branch of Whittard Canyon to examine bathymetric resolution and rotation. The idealized canyon experiments show that energy dissipation is more sensitive to length than to width, as length controls energy reflection. The volume-averaged dissipation rate exhibits a single peak at 0.38λ in canyon length and at 0.03λ in canyon width (internal tide wavelength λ = 60 km). A key finding is that internal tide energy is not lost directly. Instead, it passes through an intermediate stage where energy is temporarily transferred to the surface tide then back to the internal tide. This unexpected process is also influenced by the adjacent continental slope, where steeper slopes lead to more energy dissipation in the canyon. The dendritic canyon experiments show that volume-averaged dissipation rate increases with bathymetric resolution but plateaus at higher resolutions. In addition, rotation can enhance dissipation with its effects modulated by the bathymetric asymmetry between the two canyon walls. Overall, global estimates of internal tide energy dissipation (34–37 GW) and eddy diffusivity (4.2×10^{-4}–2.1×10^{-3} $m^2 s^{-1}$) within submarine canyons underscore their role in abyssal mixing and biogeochemical cycling.

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How do dynamical effects escape from the latitude of the forcing? Insights from 2D gyre theory.

We develop the classical Stommel and Munk beta-plane gyre theory to explore the role of boundary pressures in balancing wind stress, determining the Green's function for the response to a local wind stress. We find that any wind stress acting in the ocean interior or western boundary is balanced by a combination of local circulation and local western boundary pressures differences relative to the constant eastern boundary. On the other hand, wind stresses parallel to the eastern boundary can produce nonlocal boundary pressure responses, requiring a global adjustment to take place. The amplitude, and even the sign of this response depends on the detail of eastern boundary friction. We demonstrate the relevance of these ideas to ocean climate models via adjoint experiments in a realistic but coarse resolution simulation, which matches the expected patterns of sensitivity to eastern boundary wind stress. We also note that the constant term in the pressure represents a second nonlocal effect which has been explored elsewhere.

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Modelling the impact of AMOC variability on carbon uptake and transport in the North Atlantic Ocean using an inverse water mass model

The North Atlantic carbon sink has variability which is linked to the Atlantic Meridional Overturning Circulation (AMOC). Continuous observation of the AMOC is limited to the RAPID and OSNAP mooring arrays, providing in situ data coverage for the past two decades. Ocean models are used to produce data with greater spatiotemporal coverage, but these are often not constrained by observations. Thus, there is uncertainty in how AMOC variability in a changing climate may impact the North Atlantic carbon sink. The EXPLANATIONS project tackles this problem by utilizing the Optimal Transformation Method (OTM), an inverse water mass model, to analyse ocean tracer transports between designated basins. A North Atlantic basin is defined between the RAPID and OSNAP mooring arrays. We compare the observed data at RAPID and OSNAP with an unconstrained OTM solution. Then, we use the data collected from these arrays to further constrain OTM, thus giving a better representation of the circulation and its impact on carbon uptake and transport. OTM simultaneously satisfies budgets of heat, freshwater and carbon based on observations. We use temperature and salinity from the EN4 objective analysis and anthropogenic carbon (Canth) to represent carbon, based on a machine learning reconstruction of ocean interior biogeochemistry and data from GLODAP. Output from OTM informs upon the transports and mixing of volume, heat, freshwater, and carbon between and within the ocean basins. It allows for the construction of carbon budgets within the North Atlantic, improving our understanding of how these may change with variability in the AMOC.

Huvenne, Veerle

Hall, Rob; Clare, Michael; Gates, Andrew; Bett, Brian; Le Bas, Tim; McBreen, Fionnuala; Farrell, Dara; Rees, Angus; Skein, Lisa; Varzi, Andrea Giulia; Wardell, Catherine; Wolfe, Morgan

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How to monitor a submarine canyon: integrating autonomous and robotic systems to capture change in a complex deep-sea system

Submarine canyons form the main connection between shelf and deep ocean, funnelling large quantities of sediment, carbon and pollutants into deep water. They exert major influence on oceanographic processes and host important hotspots of biodiversity. However, they are increasingly affected by human activities, e.g. fishing or submarine cable installation. To enable effective management, reduce impact on canyon ecosystems, and minimise risk to infrastructure from canyon dynamics, regular monitoring is needed, as well as a good understanding of the baseline natural variability (geological, ecological, oceanographic). This is a challenge due to their heterogeneous and dynamic nature. However, the rapid evolution and increasing availability of autonomous and robotic systems now enables the expansion of observations in space and time, allowing those critical changes to be captured.

Using the example of the Whittard Canyon (Celtic Margin), we demonstrate how, using the right combination of novel and traditional approaches, a nested, multi-scale, multidisciplinary observational programme can be built that addresses a wide range of monitoring objectives. Rooted in the NERC-funded National Capability programmes CLASS and AtlantiS, with important contributions from other research projects (CODEMAP, PISCES, MissingLink), repeated AUV, ROV and glider observations are integrated with conventional shipboard surveys, lander and mooring deployments in support of Marine Protected Area management, geohazard assessment and the evaluation of long-term trends under a changing climate. The approach, which aims to develop a full-systems understanding, can be transferred to other complex deep-sea systems (e.g. seamounts, mid-ocean ridges), and ultimately will lead to the development of a canyon digital twin.

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Stage-specific light preference and isolume tracking in a key North-Atlantic copepod

Diel vertical migration (DVM) is often considered the largest synchronized movement of biomass on earth. It contributes substantially to the biological carbon pump and shapes food web interactions. Although the daily light cycle is known to control DVM (down at sunrise, up at sunset), the exact mechanism of control remains unclear. This question becomes pressing considering underwater light is changing across the oceans through processes like ocean darkening and decreasing ice cover, with unknown implications for DVM.

A key North-Atlantic species is Calanus finmarchicus, a prey of various marine mammals, fish, and birds. It performs DVM, with depths that vary among its life stages. With a series of temporally fine-scale surveys in a Scottish sea loch, we investigated how C. finmarchicus light preference varied with life stage and time of year. A wide range of light conditions was captured by sampling during twilight from March to June. Zooplankton net samples were combined with active acoustics, environmental measurements, and hyperspectral light modelling which enabled quantifying irradiance too dim to measure.

Despite drastic changes in hydrography, life stages were located at depths with similar light intensities throughout the four surveys, suggesting a consistent, stage-specific light preference. Generally, the later stages were found at lower intensities. Moreover, the bulk zooplankton layer generally appeared to follow the preference intensity isolume of the abundant CV life stage. Finally, CV was found to have a different light preference in June than other months, which was likely due to an early initiation of its overwintering phase.

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A new observational view of mixing-driven transformations in the North Atlantic

The North Atlantic is a critical region for the global overturning circulation, transforming surface waters into dense waters that ventilate the deep ocean. While water-mass transformation has long been framed around surface buoyancy fluxes, the role of interior mixing has remained largely unconstrained at basin scale, despite critically redistributing heat and salt throughout the North Atlantic. Using Argo-derived finescale mixing estimates within a local water-mass transformation framework, we present the first observation-based maps of interior mixing-driven transformations in the North Atlantic. Interior mixing drives diathermal heat and diahaline salt fluxes peaking at 64 TW and 5x10^6 kg/s, resulting in 12.5 Sv of formation within subpolar mode water classes. Mixing-driven transformations preferentially occur along isopycnals and are concentrated in three hotspots – the Western Tropics, Grand Banks and Mediterranean Outflow – where contrasting water masses collide, generating strong thermohaline gradients and elevated eddy activity. Together, these hotspots mark successive stages in the modification of mode and intermediate waters en route to the subpolar gyre, with potential downstream consequences for the dense-water formation that sustains the Atlantic overturning.

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Mechanisms of North Atlantic Ecosystem and Carbon Sink Responses to Changes in the Atlantic Meridional Overturning Circulation

The North Atlantic Ocean is a prominent carbon sink, but the fate of this carbon sink under future climate and circulation changes is unclear. Previous observational work has shown the biological carbon pump to be a major component of the overall sink in this region, and simultaneously that the phytoplankton assemblage appears to be changing in recent years. Circulation changes exert forcing on regional ecosystems and their composition by modulating the delivery of different nutrients, light limitation, and temperature, all of which influence different phytoplankton in specific ways. Here, we use a unique model based on the representation of plankton functional types, PlankTOM12, to study the response of the phytoplankton ecosystem to Atlantic circulation variability, notably changes in the Atlantic Meridional Overturning Circulation (AMOC), and its implication for the biological carbon pump. We develop a diagnostic tot isolate the role of nutrient limitation for each phytoplankton functional type, as well as their contribution to the overall primary productivity. This model functionality allows us to determine the physical mechanisms that shift the system's biological functioning. Using this tool, we show responses to AMOC slowdown, focusing on ecosystem functioning and the carbon sink.

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Ocean Sports and Ocean Literacy

Depending how we define geospatial information, there are approximately 150 countries in the world that have ocean coastlines and ocean sports are a popular form of activity undertaken by millions of people every day. Collectively, the various forms of ocean sports, recreational activities and ocean related tourism, drive a substantial part of the global blue economy.

Because of the high numbers of people involved on a global scale, ocean sports are an ideal platform for the development and dissemination of Ocean Literacy, worldwide. Ocean Literacy is about having an awareness and knowledge of how the ocean has an impact on humanity and how humanity in turn, has an impact on the ocean.

In this research, a mixed methods approach has been used, including ethnographic observations of people engaged in ocean sports, semi-structured interviews and online questionnaires. Interviews with ocean sports instructors were transcribed and coded using reflexive, thematic analysis frameworks (RTA) to establish levels of ocean literacy amongst ocean sports instructors and ocean sports participants.

While the research is on-going, initial findings show that although, many individuals were able to demonstrate awareness of different and specific elements of ocean literacy, knowledge was limited and there was a stark lack of awareness of ocean literacy as a concept.

This points to a knowledge gap and suggests that ocean literacy could be included as a bespoke learning module in ocean sports activity training, so that a more sustainable human-ocean relationship and improved ocean stewardship can be promoted and established, for future generations.

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How the global ocean sequesters heat and carbon: similarities and differences in their response to carbon emissions

The global ocean absorbs the largest portion of the excess heat and carbon released into the Earth system by anthropogenic emissions. To a first order, the rate of this uptake is controlled by ocean ventilation, the process by which an atmospheric source supplies a tracer to the mixed layer that is then physically transported into the thermocline and deep ocean by circulation. However, this physical transfer is modified by climate feedbacks for heat and carbonate chemistry (carbon feedbacks) for carbon. Earth system models reveal that the ocean initially absorbs excess carbon almost three times faster than heat; while on longer timescales it takes up heat and carbon at the same rate. These similarities and differences are explained using a theoretical framework that describes ocean uptake through two characteristic adjustment timescales (fast and slow) controlled by a source, the rate of physical transfer of fluid to the ocean interior, and a feedback mechanism. Our framework explains how, despite the physical transfer of fluid being determined by ocean ventilation, climate and carbon-chemistry feedbacks lead to distinct thermal and carbon adjustments to rising atmospheric CO2. These distinctions have critical implications for understanding and predicting the Earth system's response to emissions, including any delayed warming post net-zero.

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Using ocean bottom pressure to describe variability and connectivity of the global meridional overturning circulation in the coupled km-scale ICON model

The global meridional overturning circulation (GMOC) is the ocean's primary transport mechanism. Understanding its dynamics is limited by the effects of boundary mixing, mesoscale eddies, and topographical steering. All of these phenomena are typically parameterised/under-resolved in CMIP6-type models. However, km-scale models now allow us to resolve these phenomena and key topographical features for GMOC such as the Flemish cap, the Fawn trough, and the Timor trough. We present results from ICON EPOC simulations with a variable horizontal resolution that ranges between 2 and 22 km. Ocean bottom pressure (OBP) provides a depth-integrated 2-dimensional variable containing information about the dynamics of the entire water column. The OBP output from these simulations is examined through a Hilbert principal component analysis (HilbertPCA). This allows us to examine not only the amplitude of the modes' time series and spatial patterns but also the phase, giving key insights about the dynamical behaviour. This study is then extended to examine links with vertically integrated transport through a Hilbert maximum covariance analysis (HilbertMCA), giving us descriptions of the dynamical relationships at play. The ability to use 2-dimensional variables, such as OBP, makes it feasible to perform global HilbertPCAs and HilbertMCAs of km-scale output, given the computational resources required. We conclude with a comparison of OBP variability to observations.

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Transient irreversibility of southern extratropical water mass anomalies under CO2 forcing

We use machine learning analysis to classify Southern Hemisphere extratropical water masses and explore the transient irreversibility of their changes under idealized atmospheric CO2 ramp-up, stabilisation, and ramp-down in a fully coupled general circulation model. Our definitions of individually labelled water masses are not based on fixed density and temperature ranges, arbitrary thresholds, or other subjective choices that may not be applicable across observations and models but only on the ocean layers' relative differences in stratification, salinity, temperature, and density. These flexible definitions accommodate for the anomalous warming, lightening, and increased stratification of the water masses under a simulated increase in the atmospheric CO2 concentration followed by a CO2 removal. Under increasing greenhouse gas forcing up to a peak global warming of +2K, water mass volumes remain relatively unchanged. Under higher emission scenarios, intermediate waters and Lower Circumpolar Deep Water blends decrease in volume, while the volume of mode waters and Upper Circumpolar Deep Water increases. Our machine-learning approach allows us to study the transient irreversibility of these ocean anomalies. The slowest rates of recovery of temperature and density under CO2 ramp-down are seen in the deep ocean layers mixed with North Atlantic source waters. In terms of magnitude, the largest anomalies that persist once the CO2 concentration is lowered back to preindustrial values are seen in the subtropical waters and in Upper Circumpolar Deep Water. Water mass volume anomalies that arise for warming of up to +4K do not recover on centennial timescales when negative CO2 emissions are imposed.

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The early diagenetic response of marine sediments to bottom trawling in the Irish Sea

Organic carbon (OC) burial in continental shelves is an important long-term carbon sink with the ability to regulate atmospheric CO2 levels. However, in undisturbed marine sediments only a small fraction of OC escapes early diagenetic remineralization processes. The degradation of OC is largely controlled by aerobic respiration at the water-sediment interface and anaerobic respiration within the sediment where nitrate, manganese, iron and sulfate serve as electron acceptors. Physical disturbance to the sediment, such as vertical mixing or resuspension caused by chronic bottom trawling, potentially results in changes of the benthic biological communities, the locus of metabolic processes and the sediment redox regime governing the fate of OC.

Project SeaSTORE aims to investigate bottom trawling-induced changes to the sedimentary OC storage by identifying the anaerobic pathways and OC degradation rates across varied seabed sediment types of the Irish Sea. During two campaigns in February 2026 (DY206) and July 2026 (DY213) onboard the RRS Discovery, porewater samples have been collected from sandy and muddy sediments with histories of varied trawling intensity. Here, we present our first indications of nitrogenous and sulfidic sedimentary respiration signal responses to bottom trawling, based on porewater concentration-depth profiles of nitrate and sulfide. In fine-grained sediment settings, we find shoaling of anaerobic respiration processes in response to trawling, but little to no change was observed at sandy sites.

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Microstructure measurements obtained from Argo floats

Ocean mixing is an essential process in driving vertical tracer transports, water-mass transformations and nutrient supply, thereby affecting the ocean circulation, carbon sequestration and climate. Observations of turbulent ocean mixing are traditionally obtained by use of ship-based profilers, gliders and moorings. This makes these type of measurements scarce and prone to seasonal bias.

Here we report on several unique and ongoing timeseries of mixing obtained with 4 BGC Argo floats equipped with a Floatrider turbulence package. The Floatrider contains two high frequency temperature sensors (FP07) and provides estimates of the dissipation rate of thermal variance $\chi\Theta$ and of the dissipation rate of turbulent kinetic energy ε.

Over the past year, these floats have deployed in a range of oceanic mixing regimes including the Antarctic Circumpolar Current, the Ross Sea and the Labrador Sea, providing timeseries of several months in length, with profiles being collected daily and up to 2000 dbar in depth.

Over the duration of these timeseries, float observations document a wide plethora of mixing processes and their rates, including double diffusion, thermohaline interleaving and deep convection and subsequent restratification.

These deployments not only enable assessment of the microstructure sensors' durability on long float missions, but they also demonstrate the potential of collecting year-round mixing measurements from Argo floats in traditionally challenging environments. They therefore lay the path for the future inclusion of microstructure measurements in the wider Argo program.

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Tracing glacial meltwater pathways across the Bellingshausen Sea

The Bellingshausen Sea is a climatically important yet historically under-sampled region of Antarctica, characterised by high ice shelf basal melt rates. Freshwater released from ice shelves can strongly influence regional stratification and circulation, but observations capable of tracking meltwater pathways across the continental shelf are scarce, largely due to historical sea ice restrictions. In particular, the pathways linking ice-shelf outflow regions with the wider Bellingshausen shelf circulation remain poorly understood.

In the austral summers of 2025 and 2026, an expedition aboard the R/V Falkor (too) deployed autonomous underwater gliders, CTDs, and profiling floats throughout the Bellingshausen Sea. The observations include rare, high-resolution measurements collected close to both ends of George VI Ice Shelf (i.e. within Ronne Entrance to the south and Marguerite Bay to the north), as well as extensive sections extending offshore toward the shelf break. Together, these observations provide a relatively unprecedented view of hydrographic structure across the Bellingshausen continental shelf.

We investigate the distribution of glacial meltwater and its relationship to shelf circulation and water mass distribution. We discuss meltwater pathways and fluxes, regional circulation, and routes of Circumpolar Deep Water intrusion across the Bellingshausen shelf. These observations provide new insight into the circulation and transport processes governing the redistribution of freshwater and oceanic heat across the Bellingshausen shelf.

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From HNLC to LNLC: frontal shifts in phytoplankton communities in the South Atlantic and their bio-optical characteristics.

Phytoplankton underpin the biological carbon pump, with shifts in community structure influencing the efficiency of carbon export. Community composition is primarily driven by resource availability: smaller cells are favoured under low nutrient and low light scenarios, while larger cells thrive in well-mixed, nutrient-rich environments.

The South Atlantic is characterised by two 'Low Chlorophyll' regimes considered bio-optically distinct. Unlike low-latitude oligotrophic waters dominated by high-light adapted pico-cyanobacteria, Southern Ocean phytoplankton communities are characterised by low-light adapted, larger microalgae. Global algorithms developed from predominantly lower-latitude datasets tend to underestimate chlorophyll-a concentrations in subpolar waters, and consequently, remote-sensing estimates of primary production.

Using a novel dataset spanning subtropical to subpolar South Atlantic waters, we investigate how phytoplankton communities and their bio-optical properties shift across iron-limited High Nutrient, Low Chlorophyll (HNLC) regions and nitrate-limited Low Nutrient, Low Chlorophyll (LNLC) regions. Community composition is characterised using High Performance Liquid Chromatography (HPLC) pigment analysis, CytoSense pulse-shape recording flow cytometry, and in vivo phytoplankton absorption coefficients.

Preliminary results reveal pronounced shifts in phytoplankton community structure across the contrasting nutrient regimes sharing similarly low chlorophyll-a conditions. Analyses highlight the prevalence of nano-phytoplankton (predominantly nano-flagellates and diatoms) in HNLC waters, while LNLC regions are dominated by pico-phytoplankton.

Applying both absorption 'decomposition' and 'reconstruction' methods, we show that changes in spectral shape are strongly driven by functional shifts in pigment composition. These spatial patterns are interpreted in an ecophysiological context, with particular focus on the roles of photoprotection and nutrient stress in shaping the absorptive characteristics of natural phytoplankton assemblages.

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The Kelp Trail: Bridging Art and Science to Inspire Change

Macroalgae surround the coasts of the UK, but to what extent? What is their abundance? And most of all, do people know what kelp forests are, and why should we care so much about them? Those are all questions that the Kelp Trail wants to tackle, but using a less conventional strategy: art. The aim of The Kelp Trail is to raise awareness of our kelp forest ecosystems and to initiate a conversation within the scientific community with a focus on collaboration, monitoring, and mapping kelp forests across the UK and beyond. The Kelp Trail explores the ecological significance and aesthetic beauty of kelp forests and associated life. This will be achieved by working with artists and the public to run workshops and exhibitions that combine artwork, food-based demonstrations, and digital content. This project is funded by Trusted Voices Wales and The Williamson Trust.

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Nutrient enrichment reorganises nitrogen and carbon pathways in the oligotrophic Atlantic Ocean

Nutrient enrichment is assumed to enhance primary production in nutrient-limited oceans. Here, we investigate the outcomes of two mesoscale in situ enrichment experiments in the subtropical North Atlantic Ocean, as part of the Phosphate and Iron Addition Experiment (FeeP). The first experiment, in which phosphorus was added, lasted for 12 days, the second with iron and phosphorus addition for 7 days. These treatments resulted in substantial alterations in nutrient pools and biogeochemical rates and the nutrient enrichments reorganised nitrogen–carbon pathways. Under phosphorus-only enrichment, enhanced nitrogen fixation was associated with autotrophic pathways, whereas combined phosphorus-iron enrichment shifted nitrogen fixation towards heterotrophic pathways. In both cases the waters remained heterotrophic. These results suggest that nutrient pulses in oligotrophic oceans reorganize nitrogen and carbon flows without efficiently switching the system towards a net autotrophic state, the system is thereby “stirred” but not “shaken”.

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Mechanisms of poleward heat transport in the Southern Ocean

Heat transport in the Southern Ocean is critical for ocean heat uptake, sea ice dynamics, and Antarctic ice sheet mass balance. Features that determine the transport, such as ocean circulation and surface fluxes, are highly zonally asymmetric in the Southern Ocean. Using an observation-constrained model, we investigate the characteristics and consequences of this zonal asymmetry. We decompose meridional heat transport into an overturning component arising from the zonally averaged baroclinic structure of flows and water properties, and a horizontal component contributed from the zonally asymmetrical throughflows across a latitude section. Our analysis finds that poleward heat transport in the Southern Ocean is due to the horizontal component at all latitudes, implying a dominant role of down-gradient stirring of temperature anomalies by non-zonal flow along isopycnals. This prevailing poleward isopycnal heat transport is accompanied by equatorward isopycnal freshwater transport, indicating a density-compensated coupling between the two. The overturning component, by contrast, moves heat equatorward in the mid-latitudes (corresponding to the surface heat gain between 40S and 50S) and poleward at high latitudes. Our findings emphasise the significant role of freshwater flux and zonally asymmetric flow in delivering heat polewards in the Southern Ocean.

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Enhanced mixing due to tidal flow past a floating wind farm

Here we present novel measurements of mid-water turbulence in a wake generated by a moderate tidal flow past a floating wind turbine foundation. Multiple transects of TKE dissipation profiles are taken across the wake, whose position is estimated from simultaneous measurements of velocity profiles, are presented. The measurements reveal that the mid-water turbulence is enhanced by an order of magnitude when compared to the non-wake situation. They also show that the form of vertical profile of TKE dissipation within the wake differs significantly from that observed under non-wake conditions. These new results demonstrate the potential of the tidal flow past floating wind farms to disrupt stratification and enhance diapcynal fluxes of heat, nutrients, and oxygen in stratified shallow seas. These results imply that in assessing the environmental impact of proposed new wind farms it is important to consider the impact of mixing associated with the wake generated by the tidal flow past the turbine foundation.

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Quantifying potential contribution of tropical cyclones to oceanic near-inertial internal waves

Near-inertial internal waves (NIWs) play a crucial role in upper-ocean turbulent mixing through shear instabilities. Tropical cyclones (TCs), with their intense variable winds, contribute significantly to NIWs, yet their global impact has been poorly quantified due to observational and methodological challenges. In this study, we developed a novel data-driven model that integrates hourly satellite-tracked surface drifter data and refined TC records to provide a high-resolution global estimate of TC-induced near-inertial wind power (NIWP), representing a major energy source for the generation of NIWs. Our results show that TCs contribute 0.019–0.024 TW annually to global NIWP, with nearly 45% of this in low-latitude oceans. Moreover, a notable NIW-induced enhancement in thermocline mixing during TC events is identified in subtropical regions, particularly in the northwestern Pacific, based on fine-scale parameterization. Our findings uncover the episodic yet potentially important role of TCs in powering NIWs, with implications for ocean turbulent mixing.

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Mixed layer depth (MLD) controls the effect of Particle-Associated Copepods (PAC) on carbon flux attenuation in the Atlantic ocean

Particle-associated copepods (PAC) attenuate sinking fluxes of carbon in the global ocean by fragmenting large, fast-sinking particles of detritus into smaller, slow-sinking material. This process reduces the time-scale over which detrital carbon remains in the ocean. We examined how particle fragmentation by PAC influences the efficiency with which carbon is transferred to >1000m using a 1-D ecosystem model between 0-60°N at 20°W in the Atlantic Ocean. Implementation of PAC generates transfer efficiencies of 13-21% at subpolar latitudes, consistent with observational estimates (9-25%). Mixed layer depth emerges as the primary physical driver of PAC distribution throughout the water column (R2 = 0.945), and hence controls their role in flux attenuation.

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Eddy-induced Transport and Residual Circulation in the North Atlantic Subtropical Gyre

The residual circulation, involving the competition between Ekman and opposing eddy-circulations, has been widely accepted as controlling the overturning circulation in the Southern Ocean, but has received less attention in subtropical gyres. Despite the key role of cross-stream circulation in sustaining biological activity and carbon uptake in gyres, the degree of eddy cancellation of Ekman transport, which controls property exchanges between the gyres and their boundaries, remains uncertain. By combining wind stress and isopycnal mixing rates, the Eulerian and cross-stream residual circulations are estimated in the North Atlantic subtropical gyre. To achieve this, the eddy-induced streamfunction is constructed by inferring an eddy-induced transport from the eddy potential vorticity flux. Along the Gulf Stream, subsurface eddy-induced transport prevails, driving upwelling and a northward cross-stream flow of ~1.5 Sv above 1000 m, with a seasonal maximum of ~2 Sv in summer. At low latitudes (~20N), the southward eddy-induced transport governs the residual circulation in cross-stream coordinates, as the gyre streamlines become orthogonal to the wind stress. At mid-depths (~1500m), away from the wind-driven circulation, eddies further reinforce the eastward mean flow and its flanking westward recirculating jets. South of the Gulf Stream, convergence of the eddy potential vorticity flux supports the existence of an eddy-driven recirculating gyre. This study identifies the primary drivers of eddy fluxes and elucidates their contrasting roles in two regimes. In the shallow across-gyre residual circulation, eddy fluxes govern cross-gyre tracer transport; at mid-depth, they control the zonal component of the mean flow, which sets the latitudinal coherence of deep water masses.

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Autonomous lab-on-chip sensor for monitoring the marine carbonate system

The ocean plays a central role in the global carbon cycle, currently absorbing ca. a quarter of anthropogenic carbon dioxide (CO2) emissions, which is having a significant impact on marine organisms. Constraining this uptake, and the associated changes in ocean carbonate chemistry, requires accurate, reliable and autonomous sensing technologies. Investigation of the marine carbonate system requires data from at least two of the four measurable carbonate parameters i.e., partial pressure of CO2, pH, total alkalinity (TA), and dissolved inorganic carbon (DIC). At present there is a lack of sensors that can provide the spatial and temporal requirements needed to address knowledge gaps in our understanding of the global carbon cycle. To meet this need, we developed a novel combined TA-DIC sensor based on lab-on-chip (LOC) technology, which offers miniaturisation and automation of high-performance reagent-based analytical techniques. An early prototype LOC TA-DIC sensor was successfully deployed and validated during a five-day mission on the Autosub Long Range in 2024.

This contribution will focus on our latest research and development efforts into LOC-based TA-DIC sensor technology and will cover sensor operation (e.g., measurement principle, power requirements, reagent/waste management, measurement frequency, etc.), sensor performance from calibration/validation efforts, and results from preliminary shallow-water field tests. The work is being advanced within the EU-funded TRICUSO and UK-funded MaSCOt projects, where integration of LOC carbonate sensors on floats and gliders aims to strengthen sustained, high-quality observations of the marine carbonate system in support of European research infrastructures and the UK's Future Marine Research Infrastructure (FMRI), respectively.

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Seasonality in the warming trends of the surface ocean

Sea surface temperatures (SSTs) are increasing in response to anthropogenic climate change, with anticipated consequences for ocean stratification, atmosphere-ocean exchange, and climate sensitivity. The evolution of this warming, including its feedback on atmospheric circulation and its translation into the ocean interior, is likely to depend on the prominent seasonality of the surface ocean. Here, it is shown that between 1980 and 2024, there was a robust pattern of elevated SST warming trends in the autumnal season and suppressed warming trends in spring, with the signal being zonally uniform and more pronounced in the northern hemisphere. This pattern is evident across SST observational platforms including satellite data, profiling floats, ship-based measurements, and ocean state estimates, and is reproduced consistently in coupled climate models. Mechanisms behind this seasonality are explored using an energetically-constrained boundary-layer heat budget constructed from atmospheric reanalyses and upper ocean observations. Exploring the seasonally-varying trends in atmosphere-ocean heat fluxes and ocean boundary layer depths reveals the latter to be the more prominent driver of warming seasonality. Consequences of this seasonality for large-scale ocean heat uptake, the pattern effect, and transient climate sensitivity, are investigated and discussed.

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An independent estimate of the ocean's carbon budget and its decadal trend using a water mass inverse method

The ocean is an important sink for anthropogenic CO2 (Canth), absorbing 25–30% of emissions and thereby mitigating climate change. At the same time, this uptake causes ocean acidification, which damages marine ecosystems. Variability in the strength of the sink on decadal timescales is driven partly by changes in ocean circulation. Circulation can enhance Canth uptake by transporting carbon into the deep ocean, where it is stored for decades to centuries, while also modulating the outgassing of natural carbon that upwells to the surface. The relative contributions of surface fluxes and interior processes, including ocean circulation, to changes in the ocean carbon inventory together constitute the carbon budget.

We present a novel estimate of the ocean carbon budget that integrates observationally derived surface fluxes and interior changes in ocean physics and biogeochemistry within a consistent framework. We combine machine-learning reconstructions of interior biogeochemistry with a water-mass inverse method that simultaneously constrains heat, freshwater, and carbon budgets to diagnose the ocean circulation consistent with these observations. Comparing two decades, we estimate a global carbon sink of 2.04 ± 0.19 Pg C yr^-1 for 1993–2002 and 2.85 ± 0.19 Pg C yr^-1 for 2003–2012, with the increase driven largely by the North Pacific and Southern Ocean basins. Our results suggest that intensified carbon uptake during mode and intermediate water formation in the Southern Ocean, together with a circulation-driven reduction in uptake in the North Atlantic, contributed to a southward redistribution of Atlantic carbon between the two decades.

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Controls on Circulation, Stratification, and Ventilation in Subpolar Gyres

Subpolar gyres, found in the high latitudes of both the Northern and Southern Hemispheres, are important features of the global ocean – often being key regions for deep water formation and the uptake of heat and carbon. However, unlike the predominantly wind-driven gyres of the subtropics, a first-order unifying framework for their circulation is not straightforward. This is because subpolar gyres – despite sharing the fundamental characteristic of cyclonic circulation – exhibit considerable complexity with markedly different configurations and surface forcings. Differences include seasonal sea ice cover, continental boundaries and spatial extents, bathymetric influences, and styles and magnitudes of surface buoyancy fluxes. This complexity limits our intuition about these gyres and hampers efforts to predict future change in these critical regions.

Here we investigate controlling factors on subpolar gyre circulation, stratification, and ventilation using the ECCOv4 ocean state estimate and an idealized ocean-sea ice model. With ECCOv4, we explore the observed characteristics of the world's subpolar gyres, making informative comparisons and guiding the design of our model experiments. We then carry out idealized ocean-sea ice simulations (MOM6-SIS2) to test the sensitivity of a generic high-latitude cyclonic gyre to various forcing and boundary conditions. These include wind stress configuration, bathymetric features, sea ice conditions, and equatorward boundary type (e.g., a subtropical gyre versus a circumpolar channel such as the Antarctic Circumpolar Current). By isolating the effects of these factors on gyre circulation, stratification, and ventilation, this work advances our understanding of subpolar gyre diversity and informs assessments of their vulnerability to future change.

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Remote Ocean Influences on Interannual–Decadal Dynamic Sea-Level Variability over the Northwest European Shelf

Sea-level variability along the UK coastline exhibits coherent oscillations with a large-scale eastern boundary mode in the North Atlantic, suggesting that remote oceanic processes influence the Northwest European Shelf (NWES). Previous studies linked this variability to along-slope wind stress and steric anomalies in the adjacent deep ocean; however, the mechanisms driving this connection remain unclear.

This study investigates remote influences on NWES dynamic sea level (DSL) associated with large-scale ocean circulation variability at interannual to decadal timescales. Forcing-sensitivity experiments are performed using a 1/12° NEMO configuration of the Atlantic–Arctic region to identify the drivers of low-frequency NWES DSL variability.

In an experiment without wind variability, the NWES mean DSL still explains 36% of the variance in the reference simulation, indicating that processes not directly forced by wind play an important role. Consistent with previous findings, the reference simulation shows coherent DSL oscillations across the NWES linked to variability along the eastern boundary of the North Atlantic. The no-wind variability experiment also reproduces a similar coherent pattern, although over a broader spatial scale. In addition, the NWES mean DSL in the no-wind experiment lags behind the reference simulation, suggesting that wind-driven processes accelerate the sea-level response.

Our results indicate that adjacent deep-ocean sea-level anomalies are redistributed quasi-simultaneously onto the shelf, generating coherent and significant DSL variability that is not directly forced by local winds. Atmospheric wind forcing, therefore, enhances and accelerates this remotely driven response. As deep-ocean sea-level variability is linked to large-scale circulation, future work will further examine its relationship with the Atlantic Meridional Overturning Circulation (AMOC).

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Long Rossby waves with uniform rotation and variable bottom topography

Rossby waves are central to understanding how the ocean circulation adjusts to forcing anomalies, following the seminal theory first developed by Carl-Gustav Rossby in 1939. In the long-wave limit, relevant to the basin-scale ocean circulation, Rossby waves propagate westward with a speed that decreases with increasing latitude, and proportional to the planetary vorticity gradient. In contrast, over variable bottom topography, it is typically assumed that the Rossby wave speed is set by the topographic slope through its impact on the potential vorticity gradient.

In this paper we consider the limit of long Rossby waves in a uniformly-rotating ocean over variable bottom topography, under the assumption of constant stratification on each density surface. In the limit, the only potential vorticity gradient is associated with the topographic slope. Nevertheless, we find that the long Rossby wave propagation speed is set by the bottom flow, independent of the bottom slope and rotation rate! A simple physical explanation will be presented for this surprising and counterintuitive result.

This result may have implications for the adjustment of the Atlantic Meridional Overturning Circulation to high-latitude forcing, for which some previous studies have suggested that overturning anomalies propagate southward at a rate set by the speed of the Deep Western Boundary Current.

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ML-based wave height forecasting on the Scottish continental shelf: from transfer learning to wind-forced ensembles

Data driven machine learning models offer a computationally efficient alternative to traditional numerical models, but they are often restricted to a specific location and suffer from forecasting skill decay over lead times. This research evaluates the generalisability capabilities of the well-established convolutional long short-term memory (ConvLSTM) architecture to forecast significant wave height over a 12-hour horizon in different areas of the Scottish Continental Shelf using historical hourly wind and wave data as inputs. The model was trained on ERA5 reanalysis data and initially deployed off the west coast of Scotland, a swell-dominated regime.

The results highlighted the importance of spatial boundary information, showing a c.17% accuracy improvement when introducing a buffer zone adapted to dominant wave propagation. To test physical robustness, the model was then deployed in the mixed wave climate of the North Sea via transfer learning, using fine-tuning techniques. This approach reached the same accuracy as a fully retrained model, proving the robustness of the model when forecasting outside its training distribution, i.e., in a different wave climate.

Finally, to mitigate the temporal skill decay, the model was adapted into a probabilistic framework. By driving the fine-tuned ConvLSTM with multi-member exogenous wind forecasts from the UK Met Office ensembles, we evaluate the model's capacity to translate atmospheric forcing uncertainty into wave forecast variance. This framework demonstrates how computationally lightweight deep learning architectures can be leveraged to generate high-member wave forecasting ensembles, providing rapid, physically-grounded uncertainty quantification for real-time maritime risk management and coastal protection.

Martin, Adrian

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How can we improve diversity in marine science by working with primary schools?

Marine science is far from reflecting the diversity of the wider UK. Correcting this is a long process. The first step is to understand where we are now. What prevents children of primary school age (4-11 yrs) from seeing themselves as ocean explorers? What are the barriers to those who do? The second step is to identify ways in which their aspirations can be widened and the barriers removed.

Funded by the NERC Opening up the Environment programme, the Primary Focus project developed a map - a Theory of Change - to take us from the low diversity situation that marine science finds itself in now, to a future where primary school children of all backgrounds recognise what they can offer to marine science, aspire to do so, and can visualise pathways into marine jobs.

The project assembled a team providing a 360 degree perspective on the problem, including primary school teachers, marine scientists, organisations focussed on marine science and technology education and outreach, a local education authority and representatives of national and international networks of STEM Learning, marine researchers and employers.

By using questionnaires, circulated to the teaching and research communities through well-established networks, Primary Focus collated information to inform a writing workshop. There, the core team worked with additional teachers from around the UK to co-design a Theory of Change. This presentation is to advertise that plan and to help build momentum in the community to deliver it.

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Idealized modelling of compound flooding effects in estuaries with differing topo-bathymetries

The risk from compound flooding is increasing due to unavoidable consequences of climate change. Compound flooding events occur when extreme sea levels coincide with high river discharges and can have devastating impacts on local communities. However, our current knowledge of flooding patterns and impact in relation to estuary shape and type -such as convergence characteristics and bathymetry- is limited. Yet, this information can be critical for coastal practitioners when developing coastal protection strategies.

In this study, idealized numerical modelling using Delft3D-FM was conducted to explore generic flooding patterns across estuaries with varying convergence, bathymetry, and intertidal extents. Simulations were setup based on historical data from past storm events that severely affected UK's coasts. The influence of each driver—tide and river discharge—was assessed by comparing results from experiments in which one parameter was held constant while the other varied. Storm clustering was also considered to investigate the impact of successive storm events.

Our analyses focus on inundation depth, duration and extent. Adaptation measures can depend on the type of flooding experienced (e.g. coastal vs fluvial). Our results show that the spatial patterns on flooding dominance (coastal vs fluvial) vary with both the estuary type and the time lag between peak sea level and river discharge. These results provide important information for flood managers to plan optimal interventions or adaptations measures.

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Modelling the combined influence of offshore wind farm infrastructure, sea level rise and climate change

Offshore wind farm (OWF) infrastructure modify local hydrodynamics and sediment dynamics. Separately, sea level rise (SLR) and climate change will also affect hydrodynamics in the future. It is unclear how the combined influence of OWFs, SLR and climate change will impact hydrodynamics and the seabed.

The Eastern Irish Sea has experienced rapid OWF development with nine existing OWFs and a combined capacity of 2905 MW. Three additional wind farms are proposed under the current leasing round. It is a data rich environment with hydrodynamic observations and sediment sample data and is therefore an ideal environment to assess the cumulative effects.

Fully coupled TELEMAC2D-TOMAWAC-GAIA models were developed for past, present, and future scenarios of OWF development. Tidal forcing was extracted from NEMO models of the UK continental shelf. Wave spectra were applied from Wave Watch III models of similar extent and resolution. Wind and atmospheric pressure fields were applied across the model domain. A hybrid bed shear stress method was used to resolve turbulent generated bed shear stresses in the OWF monopiles wakes.

The results highlight the effects of existing and proposed OWF infrastructure on hydrodynamics and sediment dynamics. SLR decouples bed shear stresses from the bed, but higher water levels allow wave energy to propagate further inshore than present conditions. SLR Decoupling of bed shear stresses is dominated by the wake-generated bed shear stresses of the monopiles locally. Wake generated bed shear stresses are enhanced by the increased storm intensity associated with the future climate scenarios.

Meng linghan

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Seismic imaging of thermohaline interleaving north of the Brazil–Malvinas Confluence

Interleaving layers commonly occur near subsurface thermohaline fronts, indicating lateral exchange of water-mass properties and influencing lateral and vertical mixing. However, their spatial structure is difficult to resolve with sparse hydrographic profiles. North of the Brazil–Malvinas Confluence in the southwest Atlantic, vertically complex water-mass structure, horizontal density compensation, and active mesoscale to submesoscale dynamics make the Brazil Current system favourable for thermohaline layering. Here we test whether seismic data, an active acoustic method of mapping interior thermohaline vertical gradients, can image water-column interleaving.

We use a joint seismic-oceanographic dataset from the COSSMoSS cruise (Capturing Oceanic Submesoscales, Stirring, and Mixing with Sound and Simulations), including multichannel reflection seismic data crossing a canyon, with hydrographic and current velocity observations. Hydrographic sections reveal a sloping front within the canyon near the water boundary, and a vortex-like lens with a horizontal scale of O(10 km). These structures are expressed in the seismic images. Enhanced reflections occur around the front and lens edges, suggesting interleaving layers.

Hydrographic diagnostics support this interpretation. Turner angles indicate widespread double-diffusive conditions, with alternating salt-fingering and diffusive-convection regimes particularly evident between 750 and 1250 m. Diapycnal spiciness curvature indicates extensive interleaving and agrees well with synthetic seismograms, suggesting reflectivity captures interleaving-related structure. Double-diffusive dissipation estimates correspond with enhanced seismic reflections.

These results suggest that interleaving reflects an interaction between water-mass fronts, submesoscale stirring and double diffusion, with implications for small-scale dissipation. This study demonstrates the potential of seismic oceanography to image and quantify detailed interleaving in frontal environments.

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Stable isotope and diet analyses reveal trophic differences between sizes in Skipjack Tuna from Southeastern Sulu Sea, Philippines

The Skipjack Tuna (Katsuwonus pelamis (Linneaus,1758)) is an important economic and ecological tuna species, but its feeding ecology is poorly understood in Philippine waters. This study examines the trophic ecology of K. pelamis in Northern Zamboanga Peninsula, Philippines using stable isotope analysis, Bayesian mixing models, and isotopic niche metrics. Values of C and N stable isotopes were analyzed in adults (52.9–84.4 cm TL) and juveniles (17.4–18.6 cm TL) of K. pelamis and 17 prey taxa. Bayesian mixing models revealed that adult individuals exhibited a generalist feeding strategy, consuming a mix of small pelagic fishes, small squids, and few zooplankton, while juveniles showed a more specialized diet dominated by zooplankton consistent with ontogenetic dietary shift. Posterior quantiles showed broad variability in individual prey contributions, and model deviance indicated a better fit to the model. Isotopic niche analysis showed that adult individuals had broader isotopic niches with maximum likelihood overlap implying multiple fish prey species, with high preference for the mackerel small pelagic species Rastrelliger kanagurta. The isotopic niche of juvenile Skipjack Tuna was narrow and low overlap among zooplankton prey groups as suggested by Bayesian mixing models. Overall, the results highlight ontogenetic differences between adult and juvenile Skipjack Tuna diet and demonstrate the value of integrating various methods to understand trophic strategies.

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Microbial respiration from electron transport system measurements across diverse oceanic ecosystems

Marine microbial respiration is a critical loss process mediating the efficiency of the biological carbon pump. Yet, it is one of the least constrained metabolic processes in the marine system, with large mismatches between predictions and observations. Microbial respiration is particularly difficult to measure in the mesopelagic zone where rates are frequently below the level of detection of traditional methods. Additionally, these traditional methods, such as determining oxygen consumption from Winkler titrations or optodes, provide rates for a mixed microbial community but do not allow the determination of respiration attributable to specific size classes of the community. Here, we measure the activity of the electron transport system (ETS) to derive rates of maximum potential respiration attributable to size fractions (0.1-0.8, 0.8-2.0 and >2.0 µm) of the microbial community from samples collected in oceanic regimes from the Icelandic Basin, along the 13,500 km Atlantic Meridional Transect, and in the Weddell Sea. The three field campaigns sample oceanic regions with very different ecosystem characteristics and allow us to compare potential respiration across a range of productivity and varying phytoplankton communities (cyanobacteria, diatoms or coccolithophores). Along the Atlantic Meridional Transect and in the Icelandic Basin, we apply an enzyme kinetic model (EKM) to convert potential respiration into respiration in a an experimental rather than stoichiometric manner. Furthermore, we compare ETS-based respiration to various environmental parameters, highlighting that environmental influences on microbial respiration are complex and spatially variable.

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Loss of A23a iceberg leaves Weddell sea-ice vulnerable to wind-driven decline

The A23a iceberg calved in 1986, and remained grounded on the continental shelf of the Weddell Sea until 2020. This iceberg provided a buttressing effect for sea-ice, preventing extreme sea-ice losses. In 2025, strong winds associated with variability in the Amundsen low created polynyas in front of the Filchner and Brunt ice shelves, triggering a loss of sea-ice across the Weddell continental shelf recorded only once before in the satellite record. Using a network of in-situ seal-tag CTD data, we find that the rapid and intense 2024/2025 melt season facilitated a marine heatwave in the newly uncovered surface ocean. With A23a gone, we show an increased correlation between high winds and sea-ice loss, suggesting that we may see a stronger sea-ice-atmosphere feedback going into the future. Therefore, there is a potential increase in warming of surface waters on the Weddell continental shelf, with implications for further sea-ice and ice shelf melting, and deep water formation.

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Discriminating tidal mixing fronts from other satellite-detected frontal features to monitor the ecological consequences of offshore wind

Floating offshore wind (FLOW) turbines are key to accessing the huge resource of renewable energy in deeper shelf seas: 35% of UK's offshore wind capacity is projected to be floating by 2050. Seasonally-stratified shelf seas contain dynamic tidal mixing fronts that are critical to biophysical processes. There is concern that wake-related changes in mixing due to large-scale FLOW development may alter stratification and frontal dynamics with knock-on effects on nutrient transport, plankton, and higher-trophic biodiversity. The Frontline project in NERC's ECOFlow programme develops integrated, multi-scale observations across frontal regions to assess the possible ecological impacts of FLOW involving shelf-sea fronts.

To unlock the potential of satellite Earth observation of shelf-sea fronts we need to discriminate tidal mixing fronts from other types of fronts (e.g. coastal upwelling, shelf-break, river plume). Here, we present preliminary results on a novel method that fuses satellite-derived fronts with Simpson–Hunter stratification parameters from an operational hydrodynamic model. These data will enable frequent and sensitive monitoring of changes to shelf-sea stratification that could be impacted by offshore infrastructure. Near-real-time implementation of this approach will also be run alongside autonomous underwater vehicle missions to help target frontal features and provide insight into associated subsurface oceanographic and lower-trophic dynamics in the Celtic Sea.

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Deep Shark Research Group - An overview and call for collaboration

Deep-sea sharks remain among the least studied vertebrates in the world's oceans, despite growing concern regarding their vulnerability to fisheries exploitation, climate-driven ecosystem change, and habitat disturbance. The Deep Shark Research Group (DSRG) at the University of Exeter is developing an interdisciplinary research programme aimed at advancing understanding of the ecology, distribution, behaviour, and conservation of deep-water elasmobranchs in the North-East Atlantic and beyond.

Here, we present an overview of current DSRG activities, highlighting a collaborative and interdisciplinary research framework encompassing analyses of fisheries-independent survey data, investigations into sensory ecology, assessments of trophic and dietary shifts, and the application of imagery derived from remotely operated vehicles (ROVs) and crewed submersibles to investigate behaviour and species distributions in deep-sea environments.

We further outline future directions for the group, including the development of electronic tagging programmes for deep-sea sharks and the emerging use of privately operated submersibles and exploratory platforms to facilitate "extreme citizen science". Finally, we issue an open call for collaboration to address critical knowledge gaps surrounding deep-water sharks and to support evidence-based conservation and management of vulnerable deep-sea ecosystems.

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The role of sea ice in the import/export of carbon from the Weddell Gyre

The physical circulation and biogeochemistry of the Southern Ocean has proved crucial to understanding the sensitivity of global climate. The ventilation of deep water, rich in carbon and nutrients, throughout the subpolar Southern Ocean is usually framed in terms of the residual overturning. This places the emphasis on the up- and down-welling of different water masses. However, for the Weddell Gyre it has been proposed that casting the carbon cycle in terms of the horizontal gyre circulation may be more informative (MacGilchrist et al., 2019). This emphasises the role of remineralisation of organic carbon at mid-depth and the differential transport in/out of the Weddell Sea in the longitudinal direction.

Using MITgcm as an idealised two-basin model with a Weddell Sea at the southern boundary of the Atlantic basin, we examine the physical controls of the import/export of carbon & nutrients from the Weddell Sea. The idealised nature of the model allows us to easily change the surface forcing and bathymetry. By perturbing the idealised model's Scotia Ridge and Weddell Sea wind stress curl, we are able to influence the connection between the Weddell Gyre and the rest of the Southern Ocean. Other perturbation experiments, including the diapycnal diffusivity at depth, are used to perturb the overturning circulation. Using simple biogeochemistry and a carbon pump decomposition we are able to see how individual reservoirs are altered and the role of their transport in the overall carbon budget of the Weddell Sea. In particular, we are able to use Reynolds averaging to split the import/export of carbon & nutrients into the Weddell Gyre into components due to overturning and gyre circulations. Our experiments allow us to consider the physical aspects that control the relative strength of these components.

We find that sea ice, and its export across the mouth of the idealised Weddell Sea, plays a crucial role in the model's carbon cycle. Changes in the seasonal cycle of the sea ice are reflected in the decomposition of carbon transport into overturning and gyre components. A stronger (weaker) export of sea ice from the Weddell Sea results in a stronger (weaker) apparent carbon transport due to the need to replace the volume of freshwater "lost" to the north with ocean influx containing a high concentration of carbon. The intricacies of the carbon transport decomposition are related to many aspects of the basin geometry and forcing.

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Friction: important or just a drag? How does bottom drag influence Southern Ocean overturning?

The Southern Ocean is a key component of the global ocean circulation. Due to the lack of zonal continental barriers, eastward wind forcing steepens meridional density surfaces which drives an opposing eddy-induced overturning, a critical component of the global overturning circulation.

We present novel results on the sensitivity of the eddy-induced overturning to bottom drag, a parameter that is generally overlooked in literature. In an idealised eddy-resolving model, for fixed density gradients, we find that greater drag leads to lower eddy-induced overturning.

The dominant energy pathway begins with mean potential energy from the density gradients. This is then converted to eddy energy through baroclinic instabilities and ultimately dissipated through bottom drag. The rate of conversion is controlled by drag, with strong drags supressing instabilities. We empirically find a scaling law between eddy energy and eddy-induced overturning which agrees with the energetic constraints predicted by the GEOMETRIC eddy parameterisation.

These findings highlight the important role bottom drag plays as a controller of Southern Ocean overturning. As the ocean experiences net warming due to climate change, the buoyancy gradients in the Southern Ocean will change. The rate at which this translates into changes in overturning will depend on bottom drag.

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Remembered Lives: a tribute to the forgotten crew of the Challenger expedition

This presentation, 'Remembered Lives' gives voice to the hardy crew of the long-famed Challenger expedition, whose sailors have vanished from history. The voyage transformed our understanding of the oceans, yet the elite on the ship, the scientists and officers, found fame and fortune denied ordinary men. One such was my great–grandfather, one of a dozen stokers on board whose story lives on today. I first learned about the Challenger voyage from my mother and her siblings for their grandfather, Charlie Collins, had run away to sea & volunteered for the voyage.

I wrote about Charlie and Mary Collins in A Challenger's Song (2021). But I kept returning to the question: what about the rest of the crew?

The ship's muster books and the crew's service records helped identify the 211 original seamen, Boys and marines, the focus of this study. Annotated Photographs in the archive of naturalist Henry Moseley helped put a face to a name of 60 crew. Tracing their ancestors where possible revealed that many were indeed remembered in their family's oral history and memorabilia.

Discovery of letters, memoirs, poems and some 60 watercolours by seamen artists enriched an understanding of their experience and contributions to the voyage. An analysis of service records and other sources revealed that scarcely half of the original crew returned with the ship, many deserting or hospitalised, with explanations linked to the arduous, repetitive and dangerous sea work.

Drawing on original sources and analysis, the presentation seeks to provide a more inclusive narrative and understanding of the famed expedition.

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Technology Push and Science Pull: Continuing to Enhance the Marine Autonomous and Robotic Systems Facility's Capabilities to Support UK Science

Marine Autonomous and Robotic Systems (MARS) are a key component of the UK's national marine science capability, enabling persistent and adaptive observations from coastal seas to the deep ocean and polar environments. Supported by the Natural Environment Research Council (NERC) and hosted by the National Oceanography Centre (NOC), the MARS facility combines autonomous underwater vehicles (AUVs), underwater gliders, remotely operated vehicles (ROVs) and uncrewed surface vehicles (USVs) with advanced engineering and operational expertise.

Recent developments have focused on extending endurance, enhancing onboard autonomy and enabling increasingly remote and over-the-horizon operations. Investments in command-and-control infrastructure, adaptive mission planning and near real-time data delivery are supporting more efficient and responsive scientific operations. Yet emerging technologies and new scientific requirements continue to expose capability gaps.

This presentation considers three recent case studies illustrating both the successes and challenges of deploying marine autonomy in demanding environments.

1) The FMRI BioCarbon campaign demonstrated the deployment of an AUV from Iceland to Scotland for mid-water biogeochemical observations.

2) The Defiant campaign advanced under-ice autonomy through AUV deployments mapping the underside of sea ice in polar conditions.

3) Under the AtlantiS programme AUV and ROVs are demonstrating the growing role of coordinated robotic systems in marine protected area assessment through integrated seabed and water-column surveys.

For each case study, we identify future technology developments required to support increasingly ambitious scientific campaigns, outlining a roadmap for the continued evolution of MARS capability for the benefit of UK marine science.

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Droplet in the Ocean: Development and Deployment of Droplet Microfluidic Total Alkalinity Sensors in Wide-Range Environments

Total alkalinity (TA) is the balance of proton acceptors and donors in the ocean. With increasing ocean acidification, TA measurements are more important than ever for monitoring the ocean's buffering system. In situ TA sensors allow us to measure rapidly changing alkalinity in environments like estuaries or coral reefs, or to evaluate marine Carbon Dioxide Removal (mCDR) applications. Currently, commercially available and research prototype in situ TA sensors have measurement range and sample frequency limitations. To address this, a cost-effective droplet microfluidic sensor has been developed, utilizing lab-on-chip (LOC) technology to create discrete aqueous droplets suspended in hydrophobic oil. In each droplet, a single-point closed-cell titration occurs, sampling ~0.75 µL every 2 seconds. The small volume, high throughput nature of droplet flow improves on the limitations of current sensors, increasing the effective measurement ranges with alternating titrant acid concentrations. This improves the analytical range and speed of analysis for in situ, high-frequency TA measurements. Here I will present results from an initial closed-cell lab-based prototype and from field deployments on the underway system of a tall ship and in a local estuary. Measurements are in close agreement with those made by equivalent benchtop methods. This technology could offer a new and important tool in the analysis of the marine carbonate system in fast-changing environments.

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Antarctic upper ocean carbonate chemistry: contrasting regions near an ice shelf and on the continental slope

Upper ocean interplay of ice–ocean interactions and biogeochemistry in controlling pH, dissolved inorganic carbon (DIC) and ocean carbon uptake remains poorly constrained for the eastern Antarctic Peninsula where data are sparse. We present pH observations from a Lab-on-Chip sensor on a profiling Seaglider (surface to 1000 m depth) from the PICCOLO campaign in February 2024, a 16-day transect across the continental slope and a 24-hour deployment in front of the Larsen C Ice Shelf (LCIS). The 180 dives yield 3049 pH measurements with an accuracy of 0.03, validated against DIC and total alkalinity (TA) samples. For the glider measurements, DIC was derived from pH, and estimated TA (from a regional TA-salinity relationship).

We focus on observations within the surface mixed layer. At LCIS, chlorophyll fluorescence was three times higher than at the slope corresponding to a pH higher by 0.4 and DIC lower by 90 µmol kg-1, caused by biological carbon uptake. Clear differences were observed in surface properties under ice and in open water. At LCIS, lower pH and higher DIC indicate gradients in meltwater inputs and biological productivity. Across the slope, lower pH, DIC, TA, temperature and salinity reflect regional gradients in vertical mixing and meltwater input. These results indicate that sea ice cover contributes to spatial gradients in the marine carbonate system in summer alongside gradients in regional water masses.

We discuss the mechanisms driving variability in pH and carbonate chemistry and implications for ocean carbon uptake in these different Southern Ocean regions.

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Distribution modelling of adult and juvenile grey triggerfish along the coastline of Brazil

The grey triggerfish (Balistes capriscus) (family Balistidae) is widely distributed across North and South America, the west coast of Northern and central Africa, and parts of Europe. Adults are typically found between 10–100 m depths, whilst juveniles more commonly occupy pelagic habitats, often associated with floating Sargassum. Although not currently IUCN-listed as endangered, grey triggerfish stocks require careful monitoring due to overfishing, growing human populations, and habitat disturbance. Understanding the location of essential fish habitats is therefore vital for effective protection, healthy populations, and predicting future change. Whilst the commercial importance of grey triggerfish in Brazil is recognised, the footprint of its essential fish habitats remains poorly defined.

A Random Forest algorithm was used to model the spatial distribution of adult grey triggerfish along Brazil's northeastern and southeastern coastlines. These outputs were overlain with floating Sargassum distribution, mapped via satellite imagery and compiled using Google Earth Engine. Juvenile populations were modelled using a rule-based classification system, providing a useful proxy for identifying areas attractive to juvenile fish and highlighting their link to floating Sargassum, part of the Great Atlantic Sargassum Belt, consistent with existing literature.

Based on these distribution maps, several areas have been identified as candidates for stock enhancement, informed by the spatial extent of adult and juvenile populations, prevailing offshore currents, and fishing activity along the Brazilian coast. This work provides an essential fish habitat map for grey triggerfish and a foundation for future stock enhancement efforts for one of Brazil's most important food sources.

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Air-sea buoyancy fluxes seasonality and overturning circulation in the Southern Ocean

The Southern Ocean has long been established as a critical component of the global oceanic conveyor belt. Understanding how the Southern Ocean meridional overturning circulation (SO-MOC) is set and reacts to changes in wind and buoyancy forcing is thus critical to a comprehensive picture of the climate system and its potential future trends.

Previous studies investigating the basic structure of the SO-MOC assume a temporally fixed buoyancy forcing profile; yet the Southern Ocean exhibits significant seasonal variability in heat and freshwater (FW) fluxes and watermass transformation (WMT). The specific contribution of this variability has not been addressed, being overall either ignored or intertwined with other complex processes resolved by more realistic models.

In this study, a classic ocean-only, reentrant channel model mimicking the basic features of the Antarctic Circumpolar Current is forced thermally with a series of buoyancy forcing profiles of increasing seasonality and mechanically with a stationary wind stress profile.

We observe that including seasonality in surface buoyancy forcing results in a strengthening of the deep cell and a weakening of the middle and upper cells of the SO-MOC. These changes are examined in the light of Marshall and Radko's residual overturning theory (JPO 2003) and it is found that, when seasonality is included, a previously neglected contribution from surface diabatic eddy fluxes plays a crucial role in controlling the interior SO-MOC.

These results highlight the important contribution of seasonality in governing the SO-MOC structure and WMT rates and underscore the need to further investigate its specific role in climate and climate change.

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Impact of synoptic storms and ocean forcing on observed sea ice variability in the Weddell Sea marginal ice zone

Climate models have struggled to capture the dramatic decline in Antarctic sea ice over the past decade, indicating that key atmosphere--ice--ocean interactions are poorly simulated. To investigate these unresolved processes, here, we use observations from two Seasonal Ice Mass Balance buoys deployed in the Weddell Sea marginal ice zone in 2019. We estimate the sea ice energy budget using a one-dimensional thermodynamic ice model, which demonstrates that ice thickness changes are strongly tied to synoptic storms and episodic ocean heat fluxes. Snow insulation further modulates the conductive heat transfer through the ice in response to these transient forcings. Our results suggest that synoptic variability and fine-scale ocean dynamics have a rectified effect on the seasonal ice growth and melt. Therefore, accurate representation of these high-frequency processes in climate models is essential to improve Antarctic sea ice prediction.

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Changing Photosynthetic Strategy in Response to Nutrient Availability in Phytoplankton Communities.

Global oceanic ecosystems are sustained by phytoplankton, which perform oxygenic photosynthesis. This biochemical process is mediated by a handful of highly conserved protein catalysts that transfer energy from light to organic carbon. As such, photosynthetic protein catalysis represents a significant sink of resources for the cell. How this resource is allocated, i.e. the abundance and stoichiometry of photosynthetic catalysis, impacts the resources required for primary production. While evidence of changes in stoichiometry is available for isolated phytoplankton cultures, it is limited in mixed phytoplankton communities in situ. Here, both fluorescence and molecular approaches were used to analyse the relative abundance of the two chlorophyll-binding photosynthetic complexes, photosystem II (PSII) and photosystem I (PSI), in mixed phytoplankton communities. Samples from the South Atlantic and Southern Ocean that encompass a range of both nitrogen and iron-limited oceanic regions that collectively represent ~80% of the world's surface ocean were analysed. Our findings highlight that nutrient limitation not only suppresses growth, but also changes the relative abundance and stoichiometry of photosynthetic catalysts, with direct implications for energy transfer Efficiency and primary production.

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Seasonal dynamics of carbon export in the Southern Ocean

Multiple pathways contribute to carbon export from the surface ocean, including the gravitational pump and episodic processes such as the eddy subduction pump. During the FOCUS voyage, two biogeochemical Argo floats and two autonomous gliders were deployed in an energetic region of the Southern Ocean near the Polar Front to investigate fine-scale physical and biogeochemical dynamics that influence the BCP. This is a rare opportunity to compare export properties from autonomous platforms with different sampling patterns in an area with strong eddy subduction and mixed layer variability.

Observations of optical backscatter and hydrographic properties were applied to existing parameterisations to estimate export fluxes over a period of months (gliders) to years (BGC-Argo floats). Unlike the passively drifting floats which sample once every 10 days, gliders were actively navigated across mesoscale and submesoscale features ~6 times per day, enabling direct sampling of eddy interiors. Export fluxes estimated from the floats show strong seasonal variability in total carbon export, with peak values during the austral summer (up to 960 mg C m^{-2} d^{-1}) and a decline into early autumn. Over an annual cycle, the gravitational pump dominated export. While the BGC-Argo floats identified two eddy subduction events (160 – 190 mg C m^{-2} d^{-1}), the higher-resolution glider observations captured multiple strong subduction events, consistent with vertical velocity estimates, suggesting that the contribution of Eesp to total export is substantially larger than indicated by the BGC-Argo floats alone.

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Transport of physical and biogeochemical properties by the Antarctic Slope Current in the western Weddell Sea

The circulation of the Weddell Sea converts warm deep circumpolar waters into colder waters that exit the Weddell Sea both as dense bottom water and near-surface waters. As a result, carbon is transported into the deep ocean, where it can remain for centuries, thus slowing anthropogenic climate change. Despite the importance of these physical and biogeochemical processes, they remain poorly understood. The PICCOLO campaign in early 2024 advanced our understanding of the physical, biogeochemical and biological processes contributing to the carbon export from the Weddell Sea. Here we focus on a zonal multidisciplinary section undertaken across the continental slope east of the Antarctic Peninsula, crossing the Antarctic Slope Front and Weddell Front. The section is composed of 53 CTD casts, including vertical velocity profiles from an LADCP. In addition we analysed samples for a range of biogeochemical properties and elements (nutrients, carbon, iron), as well as zooplankton nets and flow cytometry. We will present observational results along this transect focussing on the influence of the Antarctic Slope Front on the deep water transport of water, salt, iron and carbon.

The cross-slope transect has a net northward transport of 57.6 Sv during our study, and we observe a northward transport of cold, dense bottom water of 4 Sv. This bottom water is enriched in iron and oxygen, and depleted in nutrients relative to overlying warm deep water. Thus, it carries the signal of its recent contact with the atmosphere to the deep, where it accumulates iron though interacting with sediments.

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Pellets in Pieces: The Role of Zooplankton Fragmentation of Faecal Pellets in Arctic Carbon Export

Understanding how food-web processes regulate carbon export is essential for predicting ecosystem responses in rapidly changing Arctic systems. During fieldwork in the Greenland Sea, we examined how zooplankton mediated fragmentation modifies carbon export across ice covered and ice free environments. Ice free southern transects were characterised by elevated surface particulate organic carbon (POC) concentrations associated with a developing Phaeocystis bloom, whereas particle fields near the ice edge were enriched in copepod faecal pellets, supported by in situ imaging . These contrasting particle regimes indicate a shift from phytoplankton dominated particulate carbon in open waters to zooplankton processed, pellet dominated carbon near the ice edge. Incubation experiments using both intact pellets and pellets actively fragmented by the copepod Metridia sp. showed consistently higher microbial respiration rates in fragmented material, based on oxygen consumption. End point POC and dissolved organic carbon (DOC) concentrations were quantified from the same incubation vials. Whilst POC remained broadly comparable between treatments, DOC concentrations were lower in fragmented pellets, suggesting rapid microbial scavenging of DOC. Our preliminary results suggest an additional mechanism in how zooplankton fragmentation reduces carbon export attenuation, through promoting release and rapid microbial scavenging of labile DOC which accelerates surface recycling. As Arctic systems undergo warming and sea ice loss, shifts in plankton community structure toward increased zooplankton processing and pellet production may enhance fragmentation driven recycling. Understanding this mechanism is therefore critical for predicting future changes in carbon export efficiency and the strength of the biological carbon pump in polar regions.

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Drivers of stratification change in the Barents-Kara Seas (BKS)

The Barents-Kara region is an Arctic warming hotspot. It has experienced increased water column and lower troposphere temperatures, pronounced sea ice loss, and ecosystem change. Ocean stratification here is important: the strength of density stratification controls vertical mixing and the fluxes of quantities, including heat and salt, which determine the properties (temperature, salinity, and density) of water throughout the water column. At the surface, these properties influence sea ice processes and heat loss to the atmosphere in a region ostensibly linked to Northern Hemisphere mid-latitude weather. More generally, they govern the characteristics and behaviour of water masses undergoing transformation in the BKS, which participate in Arctic and North Atlantic circulation.

We use the potential energy anomaly (PEA), a metric of density stratification, to investigate changes in the region from 1993 to 2020. Representing the energy required to hypothetically mix stratified water to vertical homogeneity (strongly stratified water columns require more energy to mix), PEA is calculated spatio-temporally from the GLORYS12v1 reanalysis product. The rate of change of PEA with time can be expressed as the sum of contributions from physical processes that increase stratification (e.g., surface heating and sea ice melting) or decrease it (e.g., wind-driven mixing and tidal stirring), each of which can be computed from reanalysis products or model outputs. We thus determine the processes dominating BKS stratification and identify those driving stratification regime shifts in parts of the region. Implications for ocean-atmosphere coupled interactions, water masses, downstream circulation, and ecosystem structure and function are discussed.

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Towards simulating inorganic suspended particulate matter on the Northwest European Shelf

We implemented a novel model for inorganic suspended particulate matter (SPM) on the Northwest European Shelf (NWES) and report first results here. SPM is resuspended from the seabed mainly by tidal currents and waves, but also through human influences such as constructing and operating offshore wind farms. SPM for example affects turbidity and therefore the ecosystem.

We integrated the SPM model into a NEMO-FABM-ERSEM set-up for the NWES with 7 km resolution. The SPM model simulates deposition, resuspension, mud flocculation mud, and cohesive seabed behaviour at high mud concentrations. The bottom stress from NEMO is used to derive the critical erosion threshold, but wave effects are not yet included and the SPM model is not yet coupled to ERSEM.

We simulate the behaviour of one mud class and one sand class in the seabed and water column over one year. SPM varies with the tidal currents (strength and location), capturing the spring-neap cycle. The vertical distribution differs between sand and mud, in line with their sinking speeds, and is affected by seasonal stratification. However, the simulated surface SPM concentrations are 1-2 orders of magnitude larger than observed. Some regions also show complete erosion of benthic sand and mud over the one-year simulation, possibly because of a too-high bottom stress derived by NEMO. These results are promising first steps towards a dynamic simulation of SPM, with opportunities to couple the inorganic SPM to biogeochemical models to represent variability of turbidity.

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Recent variability in deep water masses exported through the South Sandwich Trench

One of the most important formation sites of Antarctic Bottom Water (AABW) is the Weddell Sea, where it comprises of denser Weddell Sea Bottom Water (WSBW) and lighter Weddell Sea Deep Water (WSDW). Two of the main export routes north for these water masses are Orkney Passage and the South Sandwich Trench. While the Orkney Passage export route has been monitored for many years via an array of moorings, here we present the first ever year-long time series of deep water mass properties from two oceanographic moorings deployed in the South Sandwich Trench.

We observe significant variability in temperature and current speed throughout the year, that is independent to variability observed upstream in the northern Weddell Sea. We link changes in barotropic current velocity to local winds over the trench and suggest this variability is due to changes in local clockwise circulation within the trench. Using CTD profiles, we also show that there has been a deepening of the WSDW layer in the South Sandwich Trench, while water in the density class of WSBW is no longer present, due to both freshening and warming, similar to that observed upstream in the northern Weddell Sea and at Orkney Passage.

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Basin-scale comparison of the Underwater Vision Profiler (UVP5) and conventional nets to study mesozooplankton communities across the Atlantic Ocean (46°S to 39°N)

Zooplankton play a central role in the flow of energy in oceanic ecosystems, acting as a trophic link between phytoplankton and higher trophic levels such as fish, birds and marine mammals. From a biogeochemical perspective, zooplankton are a key component of the biological carbon pump, interacting with, transforming, and transporting carbon from surface to deep layers of the ocean. UK and EU commitments to reducing carbon emissions in oceanographic research are driving the integration of in-situ instruments such as the Underwater Vision Profiler (UVP) onto autonomous platforms for in-situ planktonic data collection. With growing interest in using UVP data to inform biogeochemical and climate models, understanding how the UVP compares to conventional 200µm-meshed net sampling to quantify zooplankton abundance and composition is essential. Comparing UVP5 and Bongo net datasets across the Atlantic Ocean (46°S–39°N), we found that <13.8% of net-sampled zooplankton fell within the UVP5's detectable size range and propose a portion of the UVP5's unidentifiable particle data <950µm may instead represent the missing 86.2% of zooplankton too small to be reliable identified with the UVP5. This further poses the question whether UVPs are overestimating what is currently classified as particle data and highlights the need for caution against using UVP data as a direct substitute for mesozooplankton net sampling in model validations.

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Short growing seasons and low temperatures prevent mesozooplankton biomass accumulation on the north-western Weddell Sea shelf

Due to unique geography and ocean currents, the Weddell Sea contains higher sea ice concentrations and more multi-year pack ice than any other region around Antarctica, making it a candidate for a marine protected area that can act as a refuge for cold-adapted species. However, the heavy sea ice cover has traditionally limited scientific sampling in this region. In austral summer 2024, weather conditions provided a brief window for the PICCOLO expedition (SD035) to explore the pelagic community in oceanic and shelf-regions of the north-western Weddell Sea, including the Larsen shelf (~ 66^{0} South). The phytoplankton and postlarval krill biomass were similar to that of other Southern Ocean regions, but the mesozooplankton biomass was 1-2 orders of magnitude lower than observations elsewhere. The abundances of large calanoid copepods and the euphausiid Thysanoessa macrura were highest offshore and very low over the shelf, pointing to their advection with warmer deep-water within the Weddell Gyre. In contrast, the larvae of Antarctic krill (Euphausia superba) and ice krill (Euphausia crystallorophias) were most abundant on the shelf, suggesting it provided a suitable habitat. With average water temperatures of -1.6°C, this region is the coldest spawning ground for Antarctic krill reported so far. The developmental stage distribution of the various copepod and euphausiid species revealed a delayed development for herbivores, relative to that of omnivores and carnivores. This suggests that the short growing season and very low temperatures hinder the accumulation of mesozooplankton biomass in this high latitude region.

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Patterns of turbulent dissipation in a submarine canyon on tidal to monthly timescales

The continental shelf break is almost everywhere incised by shelf break canyons; canyons are known to be hotspots for the generation and dissipation of internal tides, and are thought to play a key role in facilitating exchange across the shelf break. The Whittard Canyon system incises the northwest European shelf break and is known to host a strong internal tide. We use month-long time series of glider turbulence observations and near full-depth ADCP observations to investigate the propagation and dissipation of internal tide energy in Explorer and Dangeard Canyons, sub-limbs of the Whittard system. There are high mixing rates (> 10^7 W/kg)) within both canyos; much lower rates (< 10^9 W/kg) are found below the mixed layer, above the canyons. There are complex patterns of turbulence that vary coherently over a tidal cycle. In both canyons, near-bed mixing is strongly enhanced during periods of up-canyon flow and is depressed during period of down-canyon flow. At mid-depths, elevated turbulence but does not appear to be linked to near-bed mixing. In Explorer, this mid-depth mixing peaks during up-canyon flow, but in Dangeard, it peaks during up- and down-canyon flow. We explore the links between internal tide behaviour and turbulent mixing in both canyons. On longer time scales, there is almost no signal of spring-neap variability in turbulence, suggesting a complex response to the varying strength of barotropic tidal forcing.

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Evaluating the heat transport variability of the subpolar North Atlantic Ocean

Oceanic heat transport (OHT) is a key controlling factor on global climate, with ocean heat loss in the North Atlantic influencing both local regional weather systems and ice coverage as it tends towards the Arctic. Furthermore, OHT drives the Atlantic Meridional Overturning Circulation (AMOC) through its role in the formation of deep water, and is a contributing factor behind Arctic Atlantification. While it has been observed that the magnitude of OHT through the North Atlantic has been increasing, how this is distributed between the different northward and recirculating branches remains an unresolved question with serious consequences. For instance, in the far north, two-thirds of the northwards flowing OHT has been diverted through the Barents Sea Opening rather than Fram Strait for the last few decades. This has resulted in a more rapid progression of Atlantification across the central and south Barents Sea, as compared to the Arctic Eurasian basins. Clearly, to understand how the Arctic and North Atlantic climate are changing and may change in future requires an understanding of the variability and drivers of OHT distribution throughout all the North Atlantic branches. Using data from the GLORYS12V1 Global Reanalysis dataset spanning 1993-2020, we evaluate heat transport variability across key cross-sections of the main OHT pathways within the subpolar North Atlantic. We compare and contrast the redistribution of OHT over time between the branches and investigate its sensitivity to major climate drivers including the North Atlantic Oscillation, AMOC and subpolar North Atlantic SST.

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Atmospheric drivers of basin-wide geostrophic transport in the Atlantic

The Atlantic Meridional Overturning Circulation (AMOC) is the overall effect of basin-wide meridional transport in the Atlantic, and is a central component of the climate system. Basin-wide geostrophic transport is frequently found to be a dominant component of observed and simulated AMOC variability and arises from across-basin pressure differences. Adjoint models have been used to quantify the sensitivities of the AMOC to past atmospheric forcing, however the sensitivities of the basin-wide geostrophic component are unquantified. We use an adjoint modelling framework to investigate the forcings and relevant timescales behind the interannual variability of the basin-wide geostrophic transport in the subtropical North and South Atlantic. We find that a combination of wind-driven and heat-driven variability, operating on a maximum timescale of 10 years, can explain 79-94% of the variability exhibited by the model. Wind-driven variability is mostly interannual and essential in all cases (64-88% explained variability). The heat-driven variability is largely decadal and only noticeable in the subtropical North Atlantic (48-52% explained variability). In the subtropical North Atlantic, western boundary pressures are more sensitive to atmospheric forcing events than the eastern boundary. We identify four spatial patterns of sensitivity that are relevant to our reconstructions. These include the sensitivity to: interior zonal wind stresses at local latitudes; along-slope winds at local and remote boundaries; interior heat fluxes at local latitudes; and interior heat fluxes at remote northern latitudes. We demonstrate how our sensitivity fields can inform perturbation-style experiments which quantify the significance of non-linear responses and diagnose the underlying physical processes.

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Unifying theories on the Southern Ocean bio-optical anomaly

The Southern Ocean plays a vital role in regulating Earth's climate, yet it remains one of the most difficult regions to observe. Satellite ocean-colour data offer a powerful way to monitor phytoplankton biomass and community structure across this remote ocean. However, standard satellite algorithms often perform poorly in the Southern Ocean because of a long-recognised bio-optical anomaly, leading to large uncertainties in chlorophyll-a retrievals. Using a large in-situ dataset, we show that this anomaly is closely linked to the unique size structure of Southern Ocean phytoplankton. For a given chlorophyll-a concentration, Southern Ocean communities contain a greater contribution from larger cells than those at lower latitudes. When this size difference is incorporated into an ocean-colour model, the observed anomaly can be reproduced without changing the underlying optical parameters. Further simulations show that the anomaly reflects systematic shifts in the bulk optical properties of both phytoplankton and non-algal components, thereby reconciling previous explanations of the Southern Ocean bio-optical anomaly. This new understanding offers a pathway to improve multispectral satellite retrievals in the Southern Ocean by incorporating information on phytoplankton size structure. It also implies that accurate, long-term monitoring of phytoplankton in the Southern Ocean requires explicitly accounting for size variability, a factor that is sensitive to climate change.

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Buckling and knotting in filamentous cyanobacteria

Filamentous cyanobacteria are often major components of attached communities in submerged habitats, and many of them form macrostructures that incorporate organic and inorganic matter. However, how macrostructures form remains unknown due to a lack of tractable model systems. We overcome this limitation through a combination of experiments on a species that reproducibly forms macrostructures in laboratory conditions and a physical model of these motile filaments.

We discover an emergent microparticle collection behaviour, mediated by gliding motility and leading to granular macrostructures, which doesn't occur in shorter species and shortened filaments. Through our simulations and model, we link collection and aggregation to filament buckling and entangling and predict a dependence on filament length and stiffness. We study buckling, plectoneme formation and knot formation in this gliding filaments. These findings link macrostructures to gliding motility and filament physics, giving insight into their formation in nature and design for biotechnologies.

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Mesozooplankton body size influences their contribution to active carbon flux into the mesopelagic

Mesozooplankton diel vertical migration (DVM) is amongst the largest migration of animal biomass on Earth, actively transporting carbon into the deep ocean - a key aspect of the biological carbon pump. Nevertheless, the factors controlling DVM remain elusive. We addressed this by collecting paired day and night mesozooplankton vertical net hauls across the Northeast Atlantic and Arctic, providing spatial and temporal insight into the composition of the migrating biomass. We show that mesozooplankton DVM, and its contribution to the active flux, varies with animal size, community composition, and environmental conditions. This has important ramifications for representing DVM in ocean ecosystem models.

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Interannual Variability of the North Atlantic Subpolar Gyre in the Reykjanes Ridge Region: Circulation and Transports

Circulation and Water Mass variability in the Reykjanes Ridge Region

The Reykjanes Ridge (RR) is a significant topographic feature extending from Iceland to 55°N along a northeast/southwest line. The RR constrains circulation in the North Atlantic Subpolar Gyre (SPG) by acting as a barrier between the south-westward East Reykjanes Ridge Current and the north-eastward Irminger Current. At the same time, the presence of a fracture zone along this feature allows dense water masses, such as the Iceland-Scotland Overflow Water, to cross the ridge. Recent studies have revealed a top-to-bottom circulation pattern in this region; however, there is limited knowledge regarding its temporal and spatial variability.

Using hydrographic data from the Reykjanes Ridge Experiment (RREX), we investigated the interannual variability of water mass distribution and transport inside the SPG. We found significant changes in water mass properties along the RR, such as the lightening of water masses in the upper 1,000 meters between 2015 and 2017. This indicates a lower presence of subpolar mode water (SPMW) in the intermediate layer. Additionally, there was a shift in the location of the cross-ridge and along-ridge currents, indicating a transition between different pathways. Finally, we showed that the variability in the southern part of the region, across all layers, is driven by surface changes in the North Atlantic Current.

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Calcium carbonate dissolution rate changes under future climate scenarios

Calcium carbonate is known to be dissolving throughout various portions of the water column, but little is known about how this will change in the future. Model output of a large range of climate scenarios and an established diagnostic approach are used to understand the future of calcium carbonate dissolution rates. Changes in ocean salinity and mean age are of leading-order importance to future calcium carbonate dissolution rates. The calcium carbonate dissolution rates can range by an order of magnitude across climate scenarios in regions such as the subtropical Atlantic Ocean basins. Some geoengineering methods are more effective than others at decreasing calcium carbonate dissolution rates in particular regions of the ocean. However, no single technique is effective everywhere. Altered calcium carbonate dissolution rates have implications for the physical ocean state projections, such as those for sea level, which are discussed in terms of direct and indirect impacts. Direct impacts due to the presence of suspended sediments comprised of calcium carbonate can be significant in some river deltas and nearby coasts.

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Hydrothermal Contributions to Elevated Dissolved Organic Carbon Concentrations and Cycling Along the Mid-Atlantic Ridge

Hydrothermal systems along the Mid-Atlantic Ridge (MAR) are spatially variable sources of dissolved organic carbon (DOC) to the deep ocean, with implications for carbon cycling and trace-metal transport. We present DOC measurements from four research cruises focusing on major vent fields at Menez Gwen, Rainbow, TAG, and Broken Spur (25–40°N). Distinct DOC patterns were observed across sites. At Rainbow and Menez Gwen, DOC maxima (>1000 µM) were decoupled from Fe and ^{3}He plumes, indicating diffuse DOC sources and potential chemosynthetic production. In contrast, CTD casts intercepting buoyant plumes at TAG and Rainbow showed elevated DOC (90–140 µM) coincident with Fe and ^{3}He, consistent with direct hydrothermal inputs and possible Fe-ligand complexation. No DOC enrichment was detected at Broken Spur. These results demonstrate that hydrothermal vents both supply and transform DOC, with highly variable magnitudes and sources, leading to spatially heterogeneous impacts on deep-ocean carbon cycling and metal-organic interactions.

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Revisiting benthic community depth zonation patterns on contemporary coral reefs

Changes in biophysical conditions and energetic resource supply across depths are predicted to promote or limit the abundance of different coral reef benthic groups. On tropical coral reefs, depth has long been acknowledged as a key determinant of benthic community zonation patterns. Classic coral reef studies consistently described benthic communities as strongly structured along depth gradients, with predictable and repeatable changes in coral assemblages from shallow to deep habitats. However, many historic studies were geographically limited and conducted prior to widespread human impacts, raising questions about their contemporary relevance. This PhD project uses benthic survey data from 0–30 m depth across unpopulated and populated Pacific islands to assess depth zonation patterns on modern coral reefs. By comparing reefs across gradients of biophysical drivers and human impacts, this work revisits a foundational ecological paradigm and evaluates its generality on contemporary coral reefs, addressing whether benthic depth zonation patterns have persisted or been reshaped in recent decades.

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Quantifying relationships between environmental drivers and fish school space use, using an ADCP with echosounder capability.

The identification of physical and biological drivers of spatial variation in species abundance is a major focus of marine ecological research, particularly in the context of understanding anthropogenic impacts on marine environments. Both human-induced change and natural variability are important determinants of species distributions and are essential considerations for monitoring and conservation strategies. This study addresses the need for non-invasive monitoring techniques, while investigating the relationship between oceanographic conditions, and space use of schooling fish. Data were collected during a 51-day period between May and June 2024, in the North Sea. The study area lies within the Firth of Forth Banks Complex, a Nature Conservation Marine Protected Area (NCMPA) characterised by unique bathymetry formed by banks and river outflows. This region exhibits distinctive hydrodynamic regimes associated with tidal cycles, making it an area of ecological interest. Fish school parameters were extracted from an Origin ADCP dataset along with multiple hydrodynamic parameters to investigate relationships between biological responses and oceanographic drivers. Significant relationships were observed between fish school presence, categorised by Sv class, and environmental variables, with temperature emerging as a key predictor. Higher backscatter schools were generally associated with cooler water conditions, while weaker-backscatter schools often exhibited the opposite trend. Among schooling space-use metrics, depth showed the strongest associations with environmental conditions, including vertical velocity, TKE dissipation rate, temperature, current speed, and solar altitude. These findings demonstrate the potential of combined ADCP echosounder based acoustic monitoring to improve understanding of environmental interactions and support ecosystem-based management within the marine environment.

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Dissolved iron distribution on the shelf of the eastern Antarctic Peninsula and transport in the lower limb circulation

The Southern Ocean is recognised as a hub of overturning circulation causing upwelling, high productivity and subduction of dense Antarctic bottom waters near the continental shelves. Consequently subduction and particulate organic flux in the upper and lower limb circulation are key routes for carbon removal but it is not known to what degree these rely on iron (Fe) sources and transport from the continental and ice shelf systems of Antarctica.

The supply of Fe is integral to the functioning of ecosystems around the Southern Ocean as it is a high-nutrient low-chlorophyll region with varying gradients of Fe stress and limitation of primary production. This study presents data from the NERC funded Piccolo cruise (RRS Sir David Attenborough, Jan-March 2024) where we conducted the first biogeochemical study alongside the Larsen ice shelf and determined iron distributions in a transect from the shelf into the abyssal plain in the western Weddell Sea in the region of the lower limb circulation. Pronounced surface depletion and regional differences in the concentrations of dissolved Fe were observed (0.1 – 3 nmol/L) as shelf waters became enriched in Fe as water moved over the continental shelf. We also observed cross shelf slope gradients and characteristic Fe concentrations in intermediate and deep water masses that will help inform future Southern Ocean biogeochemical models.

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Stratification changes in the Beaufort Gyre Layer Cake

The Beaufort Gyre of the Arctic Ocean has accumulated freshwater over the past two decades, profoundly influencing upper ocean stratification and vertical exchanges of heat and freshwater. Here, we investigate changes in Beaufort Gyre stratification using 58437 vertical profiles of temperature and salinity collected between 2004 and 2025. By resolving the near-surface, Pacific, and Atlantic water mass layers, we quantify variability and trends in stratification using a Potential Energy Anomaly (PEA) framework, which represents the energetic barrier to vertical mixing and enables separation of thermal and haline contributions to density stratification. Despite pronounced warming of the Pacific Water layer, salinity remains the dominant control of density stratification throughout the water column. Over the full record, a significant increase in stratification is observed only within the Pacific Winter Water layer, driven by enhanced layer thickness and associated freshwater accumulation. However, since 2019, stratification has weakened across the gyre despite continued warming in all layers. These results suggest that recent changes in layer thickness and freshwater distribution, rather than temperature, are increasingly governing the stability of the Beaufort Gyre, where freshwater release decreases stratification of the gyre, with implications for future Arctic Ocean ventilation.

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Implications of collapse of deep convection in SPNA to the NWES hydrography and nutrient flux

The circulation around UK shelf seas plays crucial role in shaping the local ecosystems, fisheries and climate. In its mean state, this circulation is influenced by both local processes -atmospheric forcing and tides - and remote connections to the Atlantic and Arctic oceans, with important role in determining the availability of nitrate at the shelf. Anthropogenic climate change has profound impacts on the drivers, with a potential to alter the Atlantic water inflow or the signals from Arctic Ocean that propagates downstream to the UK shelf seas through modified transport pathways. However, accurate assessment of these pathways remains limited due to the lack of dedicated modelling studies. Hence, using a dynamically downscaled model simulation, we assess the climate change impacts on the hydrography and the nitrate availability in the NWES. Our results reveal robust regime shift in the shelf volume flux ~2040s in the northern NWES. Other regions around NWES also experiences significant long-term changes, reflecting modified regional circulation under warming scenario. The nitrate concentration in the euphotic layer shows coherent evolution with MLD changes. We further demonstrate that the Sub Polar Gyre changes play a crucial role in determining the shelf hydrography as well as the nitrate in the future scenario.

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Two-Layer Vertical Partitioning of Phytoplankton Biomass and Stoichiometry in the North Pacific Subtropical Gyre

Phytoplankton habitat can be separated vertically into two distinct layers in stratified waters. These two layers present distinct ecological niches and nutrient regimes that govern primary production and biogeochemical cycles. Here, we present a conceptual modelling approach to estimate in situ phytoplankton biomass and stoichiometry by partitioning vertical profiles of chlorophyll, particulate carbon and particulate nutrients into two phytoplankton communities that dominate these distinct layers. The model resolves the surface and subsurface specific phytoplankton carbon-to-chlorophyll (C:Chl), nitrogen-to-chlorophyll (N:Chl) and carbon-to-nitrogen-to-phosphorus (C:N:P) ratios, with associated uncertainties. The approach is intended for use with discrete bottle datasets collected on research ships but has the potential to retrieve additional stoichiometric ratios from particulate profiles of other elements. Applied to Station ALOHA in the North Pacific Subtropical Gyre, the approach yields C:Chl ratios and C:N stoichiometric estimates for the surface consistent with known ranges, while revealing distinct values for the subsurface. Subsurface communities dominated total water column Chl-a stocks (74%) and contributed substantially (31-36%) to depth-integrated phytoplankton carbon, nitrogen and phosphorus stocks, underscoring their important role in sustaining total water-column biomass in this permanently stratified system. Results highlight how phytoplankton-specific stoichiometric estimates can reveal vertical structure that bulk particulate metrics may mask. This capability may provide valuable observational constraints for Earth System Models, which increasingly require or call for observation-based, depth-specific C:Chl ratios and flexible stoichiometry rather than fixed Redfield constants.

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Transport induced by an isolated propagating eddy in a dynamic and kinematic model

Eddies play an important role in many aspects of the world's oceans. In particular, eddies play an important role in the transport of tracers such as heat and salt. Commonly, the contribution to tracer transport by eddies is split into a trapping component and a swirl component. We investigate the transport induced by an isolated eddy in a kinematic and a reduced gravity model together with a particle advection model. In both models we observe regions of increased particle transport in the path of the eddy. We can see the trapping region eroding near the kinematic saddle node leading to particle leakage from the eddy. Overall, the isolated eddy stays more coherent than typical eddies identified via satellite altimetry and coupled ocean models.

These results advance our understanding of eddy-induced transport and form a starting point for future studies with more complex scenarios.

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Constraining hydrothermal iron fluxes and their impact on productivity and the carbon cycle in the Southern Ocean

As an important external iron source, hydrothermal vents buffer the ocean iron inventory against variability by providing a continuous source of large quantities of dissolved iron (DFe). Hydrothermal vents have also been hypothesised to be a key driver for the carbon cycle in the iron-limited Southern Ocean via supporting the export production. However, this contribution not only relies on physical circulation, but also on the hydrothermal inputs and the extent to which biogeochemical processes remove iron during transport. These processes introduce substantial uncertainty in how hydrothermal iron is supplied, transported, and retained on relevant timescales. Here we use a state-of-the-art global ocean biogeochemical model linking with new Southern Ocean observations to constrain the fluxes of hydrothermal iron and its transport pathways. To isolate the role of circulation, hydrothermal iron fluxes were redistributed as a constant flux while conserving the same global hydrothermal iron input. The resulting impacts on Southern Ocean export production exhibit strong regional variability, highlighting the dominant role of circulation pathways in controlling where hydrothermal iron reaches the upper ocean and influences biological productivity. We further conducted passive tracer experiments in which tracers were released at hydrothermal source regions and transported solely by circulation using spatially constant tracer inputs. Comparing these tracers with simulated DFe anomalies allows us to quantify the extent to which scavenging and other non-conservative processes modify hydrothermal iron during transport. Weighting tracers by hydrothermal iron flux magnitude provides insight into the characteristic timescales and relative importance of different vents in supplying iron to downstream regions.

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Predictive modelling of fine, organic carbon-rich sediment accumulation on the Patagonian Shelf over the last 21,000 years

Understanding and mapping seabed sediment distribution across continental shelf seas is essential for marine conservation, coastal management, fisheries, offshore infrastructure, and Blue Carbon assessment. However, the quality, quantity, and availability of shelf sea sediment data vary widely across regions and shelf seas, affecting the accuracy of regional-scale maps and analyses. In data-poor areas, such as the Patagonian Shelf, predictive or synthetic mapping of seabed sediment distribution is a valuable tool. Here, we use a high-resolution paleotidal model to investigate how tidally modulated processes have influenced the accumulation of fine, organic carbon-rich sediments on the Patagonian Shelf over time. First, we developed a Generalized Additive Model (GAM) using contemporary surface sediment samples and present-day tidal model outputs, including bed shear stress, seasonal stratification, and residual currents, to predict the presence of mud versus other sediment types based on simulated hydrodynamic conditions. We then apply this GAM to the paleotidal model outputs, which simulate evolving tidal dynamics across the Patagonian Shelf since the Last Glacial Maximum (ca. 21,000 years ago), to identify areas where mud may have been accumulating over long timescales. These predictive mud accumulations are compared with the limited open-source age-depth models from dated core samples from across the shelf. This first-order predictive regional substrate mapping is designed to help inform future data collection campaigns and to support regional carbon stock estimates. Our approach demonstrates the value of a palaeoceanographic perspective in understanding long-term sedimentary processes and highlights its relevance for guiding Blue Carbon strategies in data-poor regions.

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A mesopelagic biomass hotspot within an anticyclonic eddy in the Rockall Trough, NE Atlantic

Mesoscale eddies are dynamic environments that play a major role in primary production and energy transfer, structuring diverse biological communities from primary producers to top predators. Yet knowledge of the mid-trophic organisms, including mesopelagic fish within eddies, remains fragmented, leaving a largely unresolved key gap. Here, acoustic (EK80 echosounder) and hydrographic data (CTD and autonomous glider), combined with mid-water trawls, were used to characterise the mesopelagic biomass and deep scattering layers (DSL) within a semi-permanent mesoscale anticyclonic eddy, identified using real-time satellite-derived sea level anomaly. Acoustic data collected through 18 and 38 kHz were pre-processed to identify DSL, and the identification of mesopelagic swimbladder fish was carried out using a depth-limited multifrequency algorithm developed using Echoview (v.16.1). Hydrographic observations revealed a well-defined positive sea level anomaly, with an oxygen-rich, well-mixed eddy core as a consequence of the previous deep winter convection. Intense daytime backscatter signals were recorded between 450 and 800 m within the eddy core. Furthermore, daytime mesopelagic NASC (200-1000 m) was significantly higher at the eddy core, positively correlated with the sea level anomaly. A combination of diel vertical migration during the day and eddy-driven physical processes seems to induce less distinct scattering layers, changes in community structure and retention of biomass towards the deeper portion of the eddy core. Results suggest that such eddies in the NE Atlantic may significantly structure the spatial distribution of DSL, forming hotspots for mesopelagic biomass.

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Importance of mesoscale eddies to the Beaufort Gyre and Arctic sea-ice melt in a warming climate

Mesoscale eddies in the Arctic Ocean are projected to intensify as sea ice declines and open-water area expands. To understand how these eddies regulate the strength of the Beaufort Gyre (BG) circulation and freshwater storage, we compare an eddy-rich global ocean-sea ice simulation using NEMO-SI3 (1/12°), forced by surface fluxes from the Earth System Model UKESM1.1 (1°, NEMO-CICE)], with a coupled climate model HadGEM3 GC3.1 (1/4°, NEMO-CICE), which is effectively eddy-poor in the Arctic. Both simulations consider the SSP3-7.0 emission scenario.

Results show contrasting responses of the BG, freshwater storage, and sea-ice melt to atmospheric forcing between the two models. In the eddy-rich model, the BG and freshwater storage exhibit strong multidecadal variability and sensitivity to atmospheric changes. This variability is associated with the presence of mesoscale eddies that provide a negative feedback to the increase in wind-driven spin-up, reducing the stratification and available potential energy by eroding the halocline and exporting freshwater. In contrast, in the eddy-poor model, the BG and freshwater storage increase steadily throughout the 21st century despite strong interdecadal atmospheric changes. These differences also affect sea-ice evolution. In the eddy-rich model, stronger variability in freshwater storage leads to more rapid winter sea-ice melt. In the coarser model, faster summer sea-ice melt is observed, likely because heat is more locally concentrated in the absence of eddy-driven lateral redistribution.

Our results highlight the importance of mesoscale eddies in shaping the BG and sea-ice dynamics, and underscore the need to resolve these processes to improve projections of future Arctic change.

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Hornsea to Space: Offshore Wind and the Changing Dynamics of Frontal System Productivity

Shelf seas support exceptionally high primary productivity and support >90% of global wild caught seafood, making them critical to marine ecosystems and food security. As offshore wind development accelerates, it is increasingly important to understand how large scale wind farms alter the physical and biological processes that sustain these productive waters. Key knowledge gaps remain around turbine driven hydrodynamic changes and their influence on primary productivity, particularly in sensitive frontal regions such as the Flamborough Frontal System (FFS), where small shifts in water column structure can trigger major ecological consequences.

Hornsea One and Two, the world's largest offshore wind complex, lie adjacent to the FFS, providing a unique opportunity to investigate how offshore infrastructure interacts with a shelf sea front that regulates chlorophyll a distributions, turbidity, and seasonal bloom dynamics. During expedition DY197 aboard the RRS Discovery, in situ measurements (CTD profiles, fluorometry, and HPLC pigment analysis) captured fine scale vertical and horizontal gradients in chlorophyll, temperature, salinity, turbidity, and dissolved oxygen across the Hornsea region. Additionally, Sentinel 2 imagery revealed sediment and chlorophyll wakes as well as tidal variability associated with turbine foundations, providing insight into how offshore structures modify local hydrodynamics.

Together, these datasets allow us to evaluate how offshore wind infrastructure interacts with the marine environment and how phytoplankton dynamics are influenced across mixed and stratified waters. By integrating remote sensing with in situ observations, this work advances our ability to detect subtle shifts in productivity, water clarity, and frontal structures, key indicators of ecosystem change in an increasingly industrialised marine environment.

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Influence of a Restored Intertidal Wetland on TA/DIC Dynamics in the Tamar Estuary

Analysis of total alkalinity (TA) and dissolved inorganic carbon (DIC) along the River Tamar and estuary provides insight into carbon transport and processing across the land–ocean aquatic continuum. As part of AgZero+, a project supporting sustainable domestic food production in the UK, Plymouth Marine Laboratory (PML) has investigated how innovative agricultural practices influence downstream aquatic systems. This includes a newly created intertidal wetland at Calstock, designed to function as both a natural flood defence and a potential carbon sink.

Monthly monitoring campaigns along the Tamar estuary collected samples for nutrient concentrations, greenhouse gases (methane and nitrous oxide), total alkalinity, dissolved inorganic carbon, and particulate organic carbon (POC). Initial analyses indicate that the Calstock wetland is not acting as a sink for nutrients or greenhouse gases, with elevated concentrations observed in waters flowing from the wetland into the river system. Ongoing TA/DIC analyses aim to determine whether carbon cycling within the wetland differs from observed nutrient and greenhouse gas dynamics, and to assess the wetland's overall influence on carbon fluxes and downstream coastal waters.

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Enhanced ocean-shelf exchange across the European shelf-edge: Tides, seasonality, submarine canyons and model resolution

Ocean-shelf exchange circulations are crucial to global biogeochemical cycles, bringing essential nutrients onto the shelf and exporting carbon into the deep ocean. Numerical models are essential for upscaling observations to estimate shelf-scale exchange budgets. Coupled models often have coarse resolution and smooth small-scale bathymetric features, such as submarine canyons, that are ubiquitous features of the continental margin. We compare a model of the Northwest European shelf (NWES) configured at 1.5 km (AMM15) and 7.5 km resolution to investigate the impact on ocean-shelf exchange. We find a nonlinear, advective exchange circulation emerges where submarine-canyons are resolved along the Armorican-Celtic shelf-edge (and more weakly through to the Rockall Trough). The circulation is heavily modulated across the spring-neap tidal cycle, indicating an internal-tide rectified circulation. The circulation is also highly seasonal with amplified transports in summer and autumn. This process increases the simulated 2015 ocean-shelf exchange circulation across the Armorican-Celtic shelf-edge by 9.5x when increasing resolution from 7.5 to 1.5 km resolution. Similarly, total annual-mean NWES exchange increased from 0.8 Sv to 2 Sv. Our results indicate the importance of model resolution and small-scale flow-topography interactions when simulating ocean-shelf exchange. This has implications for the uncertainty in model derived ocean-shelf exchange budgets.

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Global patterns of nutrient limitation governed by phytoplankton stoichiometry acclimation

Phytoplankton acclimate to increasing nutrient stress by reducing their cellular quotas (nutrient:carbon ratios). Lower quotas decrease the export efficiency of the growth-limiting nutrient, sustaining biological productivity while increasing carbon export efficiency. Surface nutrient concentrations and global patterns of nutrient limitation depend on nutrient supply ratios and the elemental composition of exported organic matter, which often differs due to stoichiometric acclimation. Because phytoplankton have a weaker ability to acclimate to nitrogen stress, marine ecosystems tend toward nitrogen limitation. Only when nutrient supply ratios are strongly skewed do other nutrients become limiting. Over time, stoichiometric acclimation promotes nutrient co-limitation by enhancing the drawdown and export of non-limiting nutrients relative to limiting ones.

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Mixed layer depth (MLD) controls the effect of Particle-Associated Copepods (PAC) on carbon flux attenuation in the Atlantic ocean

Particle-associated copepods (PAC) attenuate sinking fluxes of carbon in the global ocean by fragmenting large, fast-sinking particles of detritus into smaller, slow-sinking material. This process reduces the time-scale over which detrital carbon remains in the ocean. We examined how particle fragmentation by PAC influences the efficiency with which carbon is transferred to >1000m using a 1-D ecosystem model between 0-60°N at 20°W in the Atlantic Ocean. Implementation of PAC generates transfer efficiencies of 13-21% at subpolar latitudes, consistent with observational estimates (9-25%). Mixed layer depth emerges as the primary physical driver of PAC distribution throughout the water column (R2 = 0.945), and hence controls their role in flux attenuation.

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Drivers of oceanographic variability in the South Orkney Islands region

The South Orkney Islands, in the southwest Atlantic sector of the Southern Ocean, lie in an oceanographically complex region located between the Antarctic Circumpolar Current to the north and the Weddell Gyre to the south. Interaction of large-scale ocean flows with the rugged bathymetry, including precipitous shelf edges and deep canyons on the northern shelf, drive complex regional flows that impact the transport and retention of Antarctic krill (Euphausia superba), a key prey item for large colonies of higher predators and the target of a commercial fishery. Using 20 years of output from a regional ocean-sea ice model, we highlight the influence of large-scale Weddell Gyre dynamics on cyclonic flows in the Powell Basin, including southward flows west of the South Orkney Plateau, and clarify the impact of regional-scale environmental variability on the southward flows. We describe the dynamics of a flow divergence northwest of the plateau in the context of variability in the regional-scale flows and consider its role in shelf-edge exchanges and regional krill flux. This work forms part of the K-POD project (Krill between currents and predators: connecting climate, ocean and ecosystem dynamics in the South Orkney Islands region).

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Illegal Fishing Gears: Quantifying Distributions and Impacts on Fish Populations in Khartoum State: Implications for Sustainable Tropical Fisheries.

While global conservation focus often misses inland waters, the health of major river systems like the River Nile is linked to coastal marine productivity. As the first systematic assessment of its kind in Sudan, this study reports illegal fishing gear extent in Khartoum State, evaluating "ghost gear" impacts on fish populations at Wad Alagaly, Jebel Aulia, and Almorada. Using an integrated approach, we combined fishermen interviews (N=50) and field surveys of derelict fishing gear (DFG) to evaluate gear distribution and impacts via SPSS 16 (Frequency, T-test, Chi-square, One-way ANOVA). Interviews revealed 82.5% of owned gear was illegal. Although 90% observed ghost gear, 46% admitted abandoning unused gear on beaches and 22% to water disposal. Notably, despite 100% union membership, 96% stated these organizations play no role in enforcement. Field surveys identified 121 DFG pieces; ghost nets comprised 78.5% and lines 21.5%. Most recovered nets (63.7%) were in deep-water zones, with 89% identified as 'part nets.' Material analysis confirmed 62.6% were non-biodegradable nylon. Crucially, 35% of recovered nets contained live entangled organisms, proving evidence of active ghost fishing. These findings confirm that illegal gear and ghost gear persistence degrade ecosystems through entanglement, ingestion, and habitat disruption, reducing fish size and abundance. By establishing the first quantitative baseline and impact assessment for ghost gear in a major tropical river system (the Sudanese Nile and White Nile fisheries), this research provides a vital foundation for integrated watershed management, ensuring the sustainability of aquatic resources from inland waters to the sea.

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Intensification of Near-Inertial Currents in the Atlantic Ocean Over the Past Two Decades

Near-inertial currents (NICs) play a key role in surface material redistribution and ocean mixing, yet their long-term variability remains poorly known. Using in situ current measurements from surface drifters, we provide the first observational evidence of a pronounced intensification of surface NICs in the Atlantic Ocean over the past two decades (2003–2022). Basin–mean NIC strength increases at a rate of 3.8 ± 1.7% per decade, with a spatial pattern characterized by strengthening in the South Atlantic and the high-latitude North Atlantic, and weakening in the low-latitude North Atlantic. We further show that these trends in Atlantic NICs are primarily driven by changes in near-inertial wind forcing, particularly those associated with mesoscale weather systems, while variations in mixed-layer depth exert a secondary influence. This observed intensification of Atlantic NICs may have important implications for ocean transport and mixing, and needs to be properly represented in the current generation of climate models.

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Asymmetric Circulation Changes in the Eastern Amundsen Sea Associated with 2010s Cooling

The rapid basal melting of ice shelves in the Eastern Amundsen Sea contributes to mass loss of the West Antarctic Ice Sheet and consequent global sea-level rise. The melt exhibits decadal variability, with low-melt periods linked to a weaker circulation in Pine Island Trough, a bathymetric channel that connects the shelf break with the ice shelf cavities. Using a numerical model, we show that during the 2010s low-melt phase there is a west-east asymmetry throughout the Pine Island Trough, with opposing circulation anomalies at depth on its western (weakening) and eastern (strengthening) flanks. This baroclinic circulation contributes more than 50% to the barotropic heat flux anomaly in some area and originates from spatial heterogeneity in meltwater input and local upwelling/downwelling anomalies of warm water. The baroclinic structure acts to reduce poleward heat flux generating a positive feedback between currents and ice shelf melting that can potentially intensify the coldness of of low-melt periods.

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Bacterioplankton reveal more-frequent-than-daily deep winter mixing in the surface layer that could double productivity of the oligotrophic ocean

Nearly one-half of the Earth's surface is covered by the nutrient-depleted, oligotrophic ocean. The continuing debate about its trophic status indicates that our understanding of the primary drivers of the photosynthetic CO2 fixation, i.e. phytoplankton production, in the surface, photic layer is still partial. According to the accrued knowledge, the odds are against significant increase of phytoplankton production by continuous vertical mixing in the surface layer. However, the implications of frequent rather than continuous vertical mixing in the surface layer of the oligotrophic ocean for the CO2 fixation and productivity remain unrecognized because it is too challenging to determine frequency of vertical mixing directly. By comparing uptake times of ambient molecules by resident bacterioplankton at the top and bottom of the surface layer we assessed that the surface waters of the South Atlantic oligotrophic gyre mixed reproducibly to 50–150 m within 17 ± 10 h at the end of winter. The Argo float monitoring in the gyre combined with the validatory study of deep winter mixing in the Gulf of Aqaba permitted us to infer that such frequent mixing persisted throughout winter. Our modelling predicted that vertical mixing with a frequency of 6–48 h could increase the standing stock and daily production of phytoplankton by 100–150 % as compared with stratification at the same depleted nutrient level. Therefore, recurring vertical mixing in the surface layer could drive and double photosynthetic CO2 fixation in the oligotrophic ocean.