epoc explaining and predicting the ocean conveyor

PROJECT NEWS

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EXPLAINING AND PREDICTING THE OCEAN CONVEYOR

The EPOC project aims to understand the Atlantic meridional overturning circulation, including its variability, structure and connectivity between latitudes. We are firmly in the middle of the project, with exciting activities across the board: using high resolution numerical modelling, new observations and new analyses of existing observations, and combining these approaches to develop a new understanding of the circulation as a whole.

In this newsletter, we focus on the observational activities of the first year. These included a dedicated EPOC research cruise to the transition zone at 47°N, some new investigations into AMOC connectivity across the region, how EPOC will use sediment cores to examine the transition zone in the pre-instrumental period, biogeochemical (BGC) parameters as measured on mooring arrays – in advance of the recovery of new lab-on-a-chip BGC sensors for EPOC that will be recovered in early 2024, and fieldwork in the Arctic gateways (the northern headwaters of the AMOC) that will move us towards creating, for the first time, a time-varying Arctic-wide estimate of inflow and outflow. In 2023, we also co-coordinated an international AMOC observing workshop in Hamburg that was attended by AMOC observing and modelling groups from around the world.

Looking ahead to 2024, we will be analysing the first of the EPOC high-resolution coupled simulations for AMOC processes and variability (as fine as 2 km ocean resolution) and planning further community workshops. Stay tuned!

Eleanor Frajka-Williams, EPOC Coordinator
December 2023

Cover image courtesy Trine Lise Sviggum Helgerud, NPI.

IN THIS ISSUE

Recovering the last CTD of the expedtion.
Image courtesy Dinora Garcia Santacruz

Monitoring the Deep Western Boundary Current at Flemish Cap: a tale of PIES and tall moorings

by Christian Mertens, University of Bremen

Expedition MSM121 aboard the German research vessel *Maria S. Merian* marked the beginning of the 2-year field experiment that forms part of EPOC's work on determining over what regions and on what timescales the Atlantic Meridional Overturning Circulation (AMOC) behaves as a coherent circulation pattern. For three and a half weeks during September-October 2023, the science team on the *Merian* worked in the so-called Transition Zone (TZ) between the subtropical and the subpolar North Atlantic, where ocean models show a breakdown of the meridional coherence of the AMOC.

In the target research area around Grand Banks and Flemish Cap the warm and salty North Atlantic Current (NAC) flows northward, close to the opposing Deep Western Boundary Current (DWBC) which is colder and fresher. Together these currents form an essential part of the AMOC and contribute significantly to the transports of heat and freshwater in the North Atlantic. Interactions between the two currents potentially influence the DWBC and affect its coherence along the path around Flemish Cap and the Grand Banks. During the MSM121 expedition, a total of nine moorings were deployed across the continental slope north of Flemish Cap and south of the Grand Banks, as well as an array of compact pressure-inverted echo sounders (PIES) south of Flemish Cap.

Our team comprised 18 scientists from the Universities of Bremen and Hamburg, Ifremer in Brest and the ETH in Zurich. On arrival at our departure port Nuuk (Greenland) we had a nasty surprise: one of the containers carrying the mooring materials had not arrived. The missing equipment was mainly the weights used as anchors for the moorings; but without anchors, the instruments cannot be deployed. Replacements were not available in Nuuk and waiting for delivery of the container would have meant a delay of several days. Fortunately, and through the great support from the ship and the control center for German research vessels at the Universität Hamburg, a solution was quickly found: St John's in Newfoundland had the necessary material available. Detouring via St John's meant only a small loss of time, which we already partly compensated for by starting the cruise earlier than planned.

The *Merian* left the port of Nuuk in the evening of Friday 22 September and made rapid progress thanks to the calm weather, reaching St John's four days later. The missing materials were already waiting and we left port just 2 hours later, heading to our first work area south of the Grand Banks. Here we deployed four moorings of the first array in water depths ranging from 1,500 to 4,300 metres, with each individual mooring comprising several acoustic current meters (ADCPs and Aquadopps) and temperature and conductivity recorders (MicroCATs).

Three landers, PIES (inverted echo sounders with pressure sensors) and bottom pressure recorders were deployed close to the moorings. All of them measure bottom pressure with high accuracy, and PIES additionally measure the travel time of an acoustic signal from the seafloor to the surface and back. Horizontal differences in bottom pressure are directly proportional to the geostrophic current between the instruments, which makes them quite useful for studying the variability of ocean transports. However, to detect small long-term changes of geostrophic transports, the accuracy of pressure measurements needs to be very high – which is why two of the landers were equipped with particularly accurate pressure sensors. To improve their ability to measure slow long-term changes, reference measurements inside the pressure sensors are used to correct their long-term drift. This internal calibration makes it easier to study multi-annual trends of the ocean circulation.

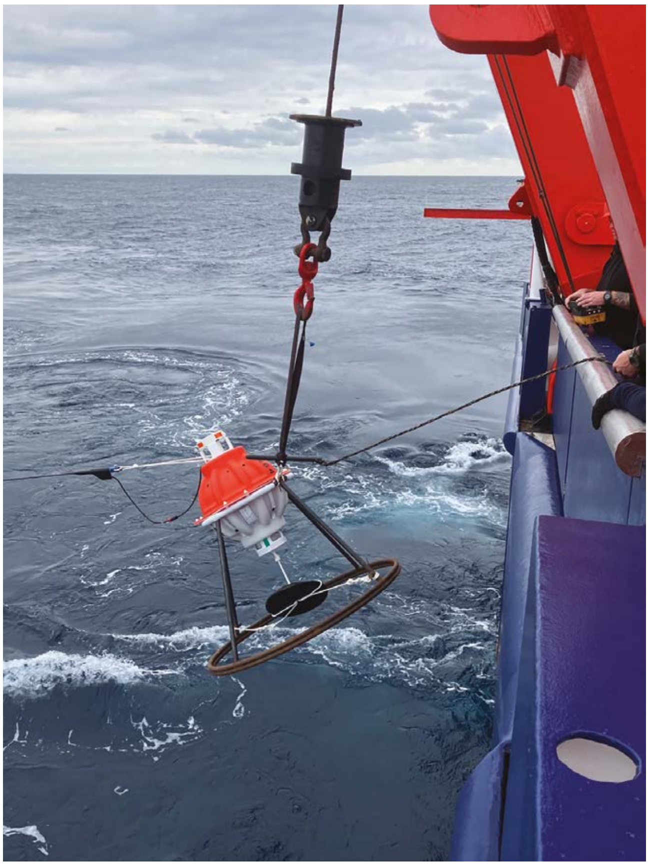
The DWBC that forms the cold southward flowing branch of the AMOC has been observed at different latitudes along the western Atlantic continental slope. However, several observations have identified a considerable loss of water from the DWBC in the Newfoundland Basin. A prominent

RV Maria S. Merian *awaiting the MSM121 science team in the port of Nuuk, Greenland. Image courtesy C. Mertens.*

example is acoustically tracked floats deployed upstream (north of Flemish Cap) within the DWBC leaking into the interior Newfoundland Basin between Flemish Cap and the Grand Banks.

Quantification of the DWBC leakiness is a major goal of EPOC's fieldwork and one of the motivations for expedition MSM121. So, in addition to the current meter moorings, we started the deployment of an array of inverted echo sounders south of Flemish Cap. In this region, the DWBC flows around the southeast corner of the cap and the instruments deployed will measure time series of DWBC transport along and across the bathymetry.

Measuring the leakiness is one of the objectives of our PIES array. Inverted echo sounders are compact landers, equipped with a hydrophone that emits and receives acoustic pulses and measures the travel time of these acoustic pulses from the seafloor to the surface and back. The acoustic travel time is quite sensitive to the temperature distribution in the seawater above the instrument: low temperatures result in a longer travel time while the sound pulses travel faster at higher temperatures. The changes in travel time are quite subtle and therefore the accuracy of the measurement must be in the range of milliseconds. Pairs of inverted echo sounders can then be used to derive the horizontal gradients of temperature or density which are proportional to the baroclinic geostrophic flow between the instruments (also known as thermal wind). PIES cannot provide as much information about the flow as moorings but they are a lot



A C-PIES being lowered into the water. Image courtesy C. Mertens.

less expensive, which allows a larger number of stations to be deployed thus giving better horizontal coverage. On MSM121, we deployed a total of 14 PIES south and east of the Flemish Cap.

During the first half of the cruise the weather was quite calm so we were able to carry out all the work without delay, but later on the wind and waves picked up, making it impossible to deploy moorings and restricting us to CTD station work. After three days, just as time was beginning to run out, the weather calmed down enough for the deployment of the second mooring array north of Flemish Cap, consisting of four moorings between 500 and 3,500 metres long.

The last mooring of our cruise was deployed in Flemish Pass, a topographic gap between the Grand Banks and Flemish Cap. So, despite the initial lack of anchor weights, all moorings planned for this cruise were successfully deployed. Over the next two years the moorings will measure the DWBC upstream (north of Flemish Cap), inside (Flemish Pass), and downstream (Grand Banks) of the North Atlantic Transition Zone that separates the subpolar and subtropical gyres.

On the transit to our destination port, Ponta Delgada in the Azores, we had the opportunity to recover the telemetry buoy of a GEOMAR mooring that had torn off in the central Labrador Sea in December 2022. Our last night on the ship was disturbed by a rough storm with wind speed exceeding 30 m/s that kept many of us from sleeping, before we arrived in Ponta Delgada on Monday 16 October.

Crew and science team lower a mooring into the water via the A-frame at the stern of the ship. Image courtesy C. Mertens.

The team on board MSM121 sent back regular progress updates, available online at the EPOC website:
epoc.blogs.uni-hamburg.de/our-work/expeditions/msm121/

We would like to thank Captain Ralf Schmidt and the whole crew of *Maria S. Merian* for the excellent cooperation during this cruise.

The MSM121 expedition science team, taken on a rather windy afternoon one day before arriving in Ponta Delgada.

My first time at sea: expectations versus reality

by María Jesús Rapanague, Max-Planck-Institute for Meteorology

Ever since I was a little girl, I have felt a strong connection to the ocean. I always dreamed of sailing on a ship and wondered what it would feel like to be surrounded by water. I thought I would love it so much that I would choose a career that involved spending a lot of time on the ocean. So when I was offered the opportunity to go on the EPOC MSM121 expedition, I could not have been more excited. Finally, one of my lifelong dreams was coming true.

Even getting to the ship was exciting. We had to spend a night in Iceland, where some of us were lucky enough to see the northern lights, and then we flew to Greenland, where the ship was waiting for us. When we took off and I saw the land getting farther and farther away, with little icebergs all around, I could not believe how lucky I was.

The first few days at sea were everything I had imagined. Calm seas, meeting new people, preparing and testing the instruments, the first deployments and shifts, everything was perfect. However, I quickly realised that my idea of life at sea was too romantic, and I found out that I was quite sensitive to sea sickness. As soon as the sea got a little rough, I started feeling nauseous all the time, so much so that I could barely do my shifts, and no medication really helped me feel better. Things got worse when a storm hit us, sometimes making it difficult to even walk. All of my romantic ideas about being on a ship turned out to be the opposite of what I imagined.

A few times I really regretted accepting the offer to go on the cruise, but looking back I realise how much I learned there. I work mostly with models on a computer, so I learned a lot about instrumentation and observational oceanography, but the biggest lessons were more personal. I feel stronger and more resilient than before. I really appreciated everyone's support, they checked on me constantly and a few times when I couldn't work, someone covered my shift.

Now I know how hard life at sea can be and I deeply admire the people who work on ships for months on end. Even without seasickness, being away from home and confined to a small space is emotionally challenging. I am not sure I would go on another cruise if it were offered to me now, but I do not regret going at all. It was not how I imagined it, but I fulfilled one of my life's dreams.

Right: María Jesús on board the Merian *as the expedition left Nuuk.*

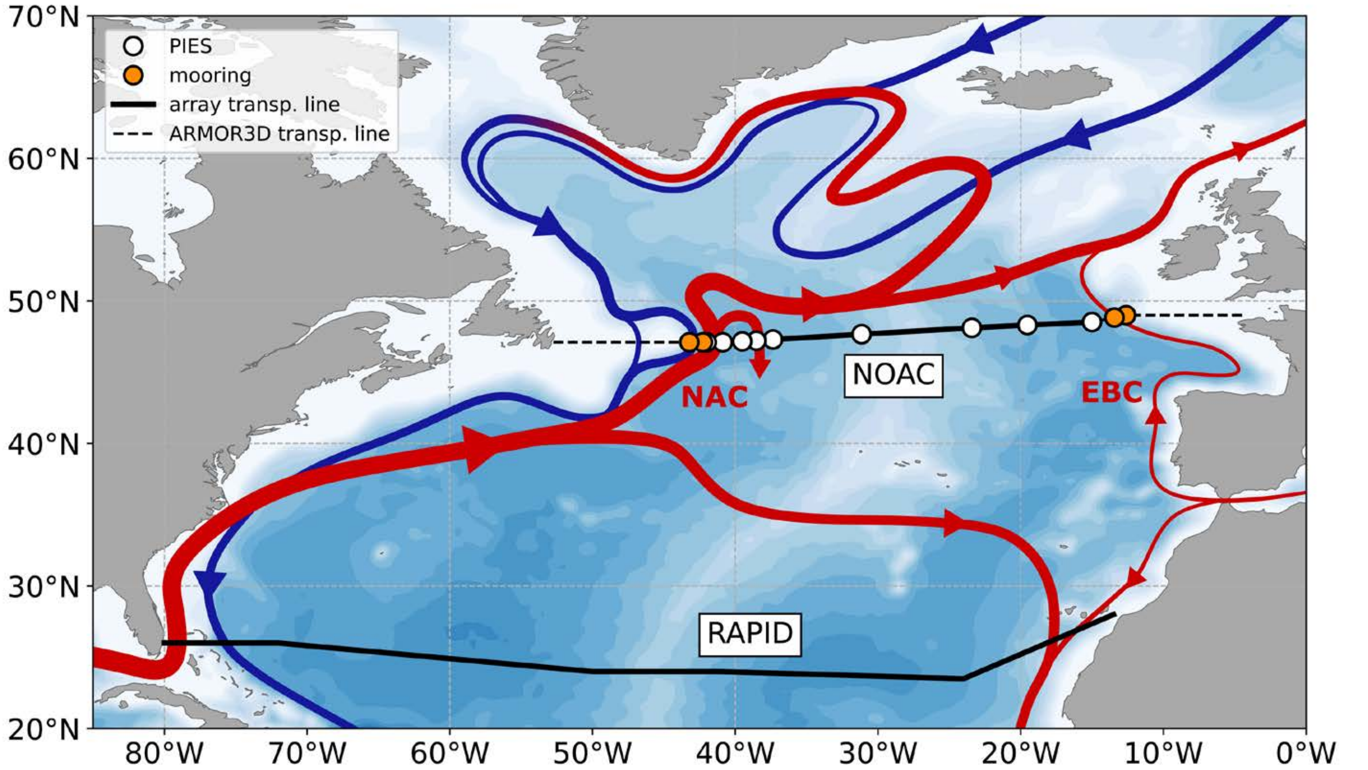
Connectivity within the AMOC identified

by Simon Wett & Ulrike Prange, University of Bremen

Researchers from the University of Bremen and the Federal Maritime and Hydrographic Agency (BSH) have compared long-term data on the Atlantic Meridional Overturning Circulation (AMOC) from two different latitudes and discovered a statistical correlation. Their aim was to investigate how the AMOC has developed over a period of 25 years, based on moored observations. The study has been published in the journal Geophysical Research Letters.

The recent IPCC report downgraded the confidence in a weakening of the AMOC since 1850 from medium to low due to disagreements between models and observations. These disagreements highlight the importance of long-term observations. While AMOC variability is expected to be coherent across latitudes on longer than decadal timescales, meridional connectivity on inter-annual and seasonal timescales is less clear. Models often indicate a breakdown of the meridional connectivity in the transition zone between the subpolar and subtropical North Atlantic. The North Atlantic Changes (NOAC) array was established at 47°N north of the subtropical gyre and south of the region where water mass transformation from the upper to the lower limb of the AMOC occurs to study the exchange between these two gyres. Its instrumentation was a combined effort of the University of Bremen and BSH.

The authors calculated basin-wide AMOC volume transports (1993–2018) from measurements of the NOAC array at 47°N, combining data from moored instruments with hydrography and satellite altimetry. The mean and inter-annual standard deviation of the NOAC AMOC agree well with estimates at the subtropical RAPID array at 26°N, while variability on



Schematic representation of the most important currents in the North Atlantic. Red (blue) arrows show the upper (deep) circulation paths. The acronyms indicate the positions of the North Atlantic Current (NAC) and the Eastern Boundary Current (EBC). The black lines show the transport lines of the observatory arrays. Graphic: S. Wett.

sub-annual timescales is larger at the NOAC array compared to the RAPID array at 26°N. The NOAC and RAPID AMOC exhibit a significant correlation when the NOAC AMOC leads by about one year. This finding either points to an extended subtropical regime reaching as far north as 47°N or challenges the notion that the subtropical and subpolar regimes are decoupled on inter-annual and longer timescales.

Read the full publication:

Simon Wett, Monika Rhein, Dagmar Kieke, Christian Mertens & Martin Moritz (2023) Meridional Connectivity of a 25-Year Observational AMOC Record at 47°N. Geophysical Research Letters, doi.org/10.1029/2023GL103284

Left: An acoustic current meter, built into a mooring buoy being prepared for deployment in the Atlantic. Image courtesy D. Kieke.

EGU General Assembly 2024

CALL FOR ABSTRACTS **Deadline 10 January 2024**

Session OS1.2

The North Atlantic: natural variability and global change

Conveners: Richard Greatbatch, Damien Desbruyeres, Caroline Katsman, Monika Rhein and Bablu Sinha

Session details: The North Atlantic exhibits a high level of natural variability from interannual to centennial time scales, making it difficult to extract trends from observational time series. Climate models, however, predict major changes in this region, which in turn will influence sea level and climate, especially in western Europe and North America. In the last decade, several observational projects have been focused on the Atlantic circulation changes, for instance ACSIS, OSNAP, OVIDE, RACE and RAPID, and new projects have started such as CANARI and EPOC. Most of these programs include also a modelling component. Another important issue is the interaction between the atmosphere, the ocean and the cryosphere, and how this affects the climate. This year we celebrate the 20th year of the RAPID array and we plan to dedicate part of the session to this anniversary. Abstracts for this part of the session are particularly welcome. We also welcome contributions from observers and modellers on the following topics:

- climate relevant processes in the North Atlantic region in the atmosphere, ocean, and cryosphere;
- response of the atmosphere to changes in the North Atlantic;
- atmosphere–ocean coupling in the North Atlantic realm on time scales from years to centuries (observations, theory and coupled GCMs);
- interpretation of observed variability in the atmosphere and the ocean in the North Atlantic sector;
- comparison of observed and simulated climate variability in the North Atlantic sector and Europe;
- dynamics of the AMOC;
- variability in the ocean and the atmosphere in the North Atlantic sector on a broad range of time scales;
- changes in adjacent seas related to changes in the North Atlantic;
- role of water mass transformation and circulation changes on anthropogenic carbon and other parameters;
- linkage between the observational records and proxies from the recent past.

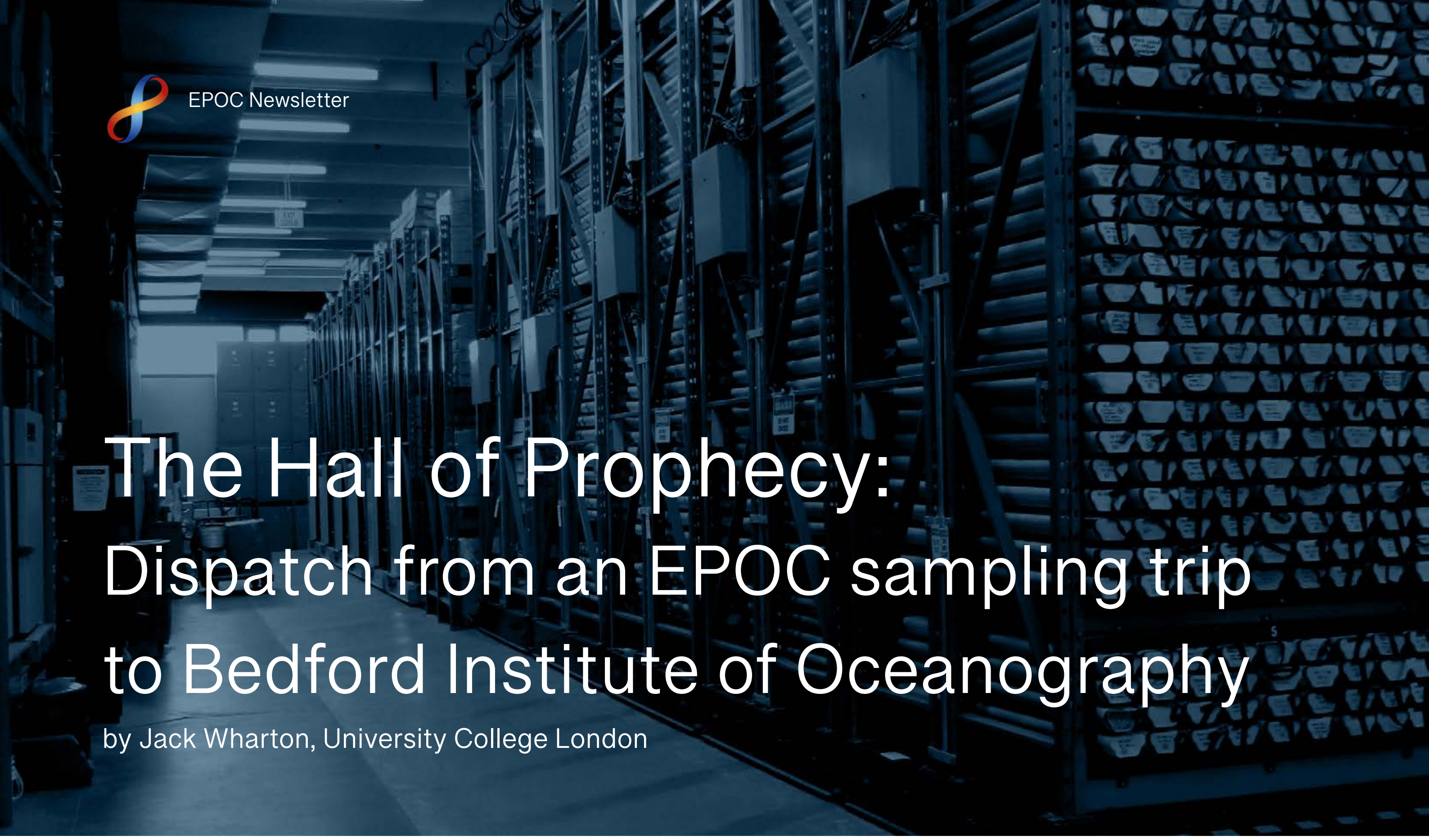
Full details at https://meetingorganizer.copernicus.org/EGU24/session/48040

Data recovery from the largest Arctic Gateway between the Arctic and Atlantic

by Laura de Steur, Norwegian Polar Institute

In September 2023, the Norwegian Polar Institute carried out their annual cruise to service the Fram Strait Arctic Outflow Observatory. This observing system has been collecting sea ice data and ocean observations since the early 1990s to monitor the export of fresh and cold Polar Water and sea ice from the Arctic to lower latitudes. The observatory has 6 ocean moorings across the East Greenland Current at 78.8°N, going from the East Greenland Shelf (~8°W) almost to the central Fram Strait (~2°W). These moorings are equipped to measure ocean hydrography, currents and sea-ice thickness year-round. Recent results have demonstrated the effect of ongoing climate change on the Arctic outflow: sea ice is getting thinner and the upper Polar Water is warming, particularly in the last decade. These long-term observations as well as moored observations from the eastern Fram Strait are used in the EPOC project, together with ocean mooring data from the other Arctic Gateways – i.e. the Bering Strait, Davis Strait, Barents Sea Opening – in order to quantify the net heat and freshwater transports into and out of the Arctic Ocean since 2004. These integrated results will provide insights into the watermass properties and transports at the northern extent of the Atlantic Meriodional Overturning Circulation and will allow us to quantify the impact of the widespread changes occuring in the Arctic Ocean on the large-scale ocean circulation.

Image courtesy Hege-Beate Fredriksen



The Hall of Prophecy:

Dispatch from an EPOC sampling trip to Bedford Institute of Oceanography

by Jack Wharton, University College London

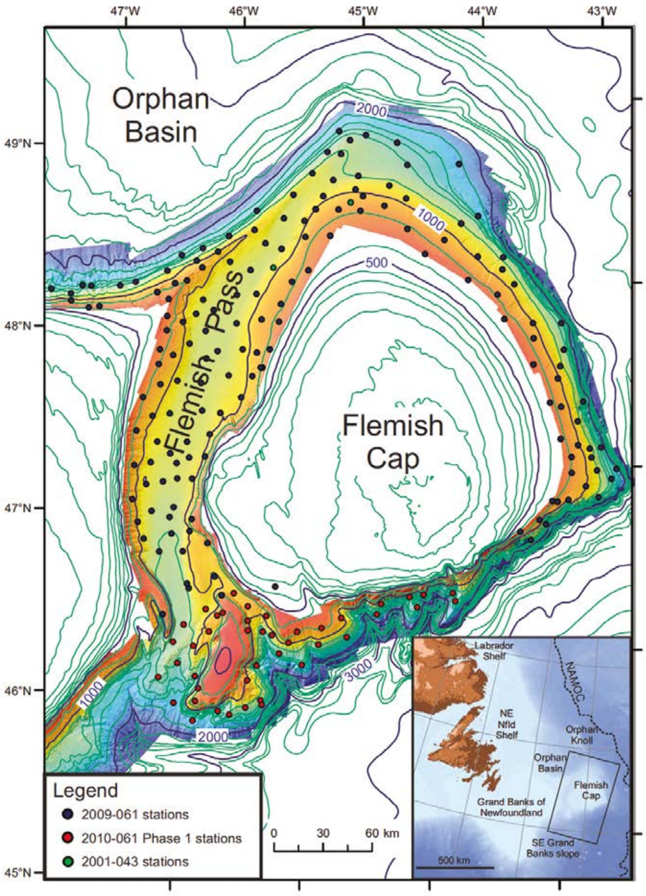
In addition to the enormous feat of physically measuring the Atlantic Meridional Overturning Circulation (AMOC) and modelling AMOC behaviour using high-resolution models powered by super computers, EPOC also has an important paleoceanography component. We are trying to understand what AMOC was doing in the past, with a focus on the last 150 years but also looking as far back as the beginning of the current interglacial known as the Holocene, which began about 11,700 years ago. The rationale is that because our observations of past AMOC behaviour, or variability, are limited to the last couple of decades, it's difficult to assess whether current variability is out of the ordinary. But by generating longer-term records of AMOC variability, we can better contextualise recent variability, allowing us to determine whether these changes are exceptional with respect to the past. To do this, we turn to paleoproxies preserved in natural archives. In our case, we use marine sediment cores retrieved from the bottom of the ocean – mud! Clearly, it would be impossible to look at sediment cores from all areas of the ocean bathed by the AMOC and its constituent currents; it's therefore important to pick a study region that is oceanographically important, but also not too large to prohibit effective investigation. One particular area in the North Atlantic that fulfils these criteria is Flemish Cap (see map), which is located right in the middle of a 'Transition Zone' between the subtropical and subpolar North Atlantic where several component currents of the AMOC flow and interact with one another. By focusing our efforts on this relatively small (at least compared to the whole Atlantic Ocean), but oceanographically complex region, we can get the best scientific bang for our buck!

Flemish Cap is a promontory of continental crust (basically a large submarine mountain) located ~600 km due east of Newfoundland. The Cap is separated from the Grand Banks of Newfoundland by Flemish Pass, a channel ~50 km wide and ~1 km deep to the west, while the North Atlantic Ocean lies to the east. Oceanographically, Flemish Cap is predominantly bathed by the southward-flowing Labrador Current (the western boundary current of the North Atlantic Subpolar Gyre), which either flows due south through the pass or in a clockwise direction around the Cap. Underneath the Labrador Current, at depths below ~1 km, flows the Deep Western Boundary Current (DWBC) of the AMOC. The warmer Gulf Stream System also passes relatively close to the Cap, offshore of the Labrador Current.

Given the oceanographic complexity of this region, we can use proxy reconstructions of flow speed, temperature, and salinity to better understand past AMOC variability. In particular, we want to know:

- How coherent is the flow around Flemish Cap?
- How does flow through the pass compare to flow around it?
- Can we relate changes in past flow speeds to surface ocean conditions?
- Is it possible to constrain past surface freshwater fluxes in the region?

But to answer these questions, we need the mud! So earlier this year, I took a trip to the Bedford Institute of Oceanography (BIO) in Bedford, Nova Scotia, where I was graciously hosted by Kate Jarrett (curator of the Geological Survey of Canada National Marine Geoscience Collection), who allowed me to sample sediment cores previously taken from around Flemish



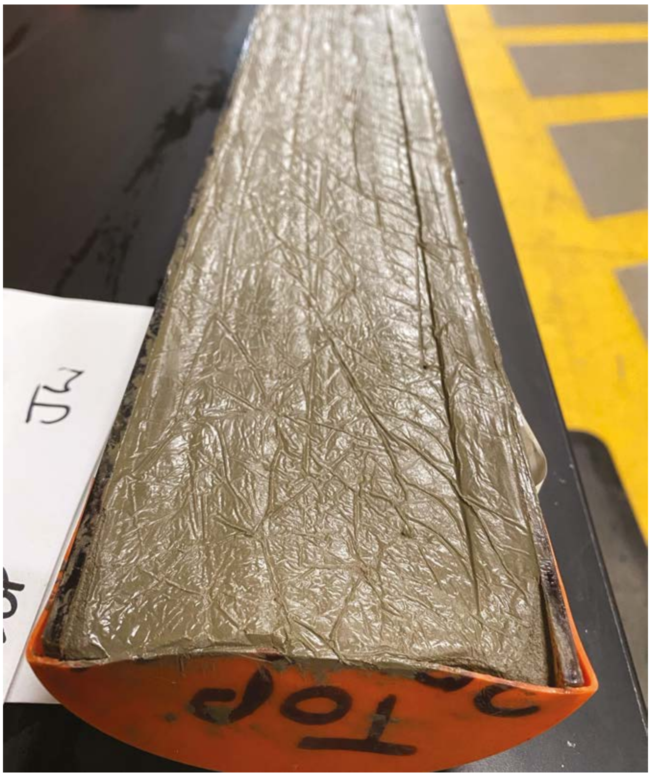
Above: Flemish Cap and location of core sites (from Weitzman et al., 2014).

Cap. These particular cores were retrieved by a Spanish vessel conducting ecological surveys back in 2009 and 2010, before being stored at BIO in a large warehouse filled completely with thousands upon thousands of sediment cores, all neatly stacked into racks, reaching from floor to ceiling and wall to wall. For something that sounds so inherently messy – i.e., mud – the organisation and efficiency of storage was a sight to behold. My mind was instantly drawn to the Hall of Prophecy in the Ministry of Magic from the Harry Potter films, but instead of glass orbs containing prophecies neatly arranged on each shelf as far as the eye could see, these were, instead, plastic tubes filled with marine sediment cores (I think there might be a poetic link to be made between prophecies in glass orbs and oceanographic histories preserved in sediment cores, but as a strictly physical scientist I'm probably not qualified to do).

One problem associated with cores from the Flemish Cap region is the potential influence of trawling on the seafloor. However, it's possible to identify this influence using downcore measurements of calcium and titanium, the basic premise being that cores impacted by trawling will exhibit relatively homogenous downcore Ca/Ti values (here I have to thank and acknowledge Prof. David Piper and Jenna Higgins for conducting these analyses prior to my visit). Apart from this, the actual sampling was relatively straightforward: it's just a case of rinse and repeat (approximately five hundred times) while trying not got get too much mud on oneself, and involves using a spatula to cut out small 0.5 cm or 1 cm samples along the length of a core, which were typically between 30-60 cm long. Over the course of my week at BIO, I sampled ten different cores from around the circumference of Flemish Cap, achieving good spatial coverage that should enable us to answer the aforementioned questions about coherency. I also got to spend a week in Nova Scotia, which is a fantastic place – I definitely want to go back as a tourist!

Finally, as I write this, the cores should be on their way to our laboratory in central London, where we are ready and waiting to get started on the science!

Reference: Weitzman, J. et al. (2014) Logs of short push cores, deep-water margin of Flemish Cap and the eastern Grand Banks of Newfoundland, Geol. Surv, Canada Open File 7148.

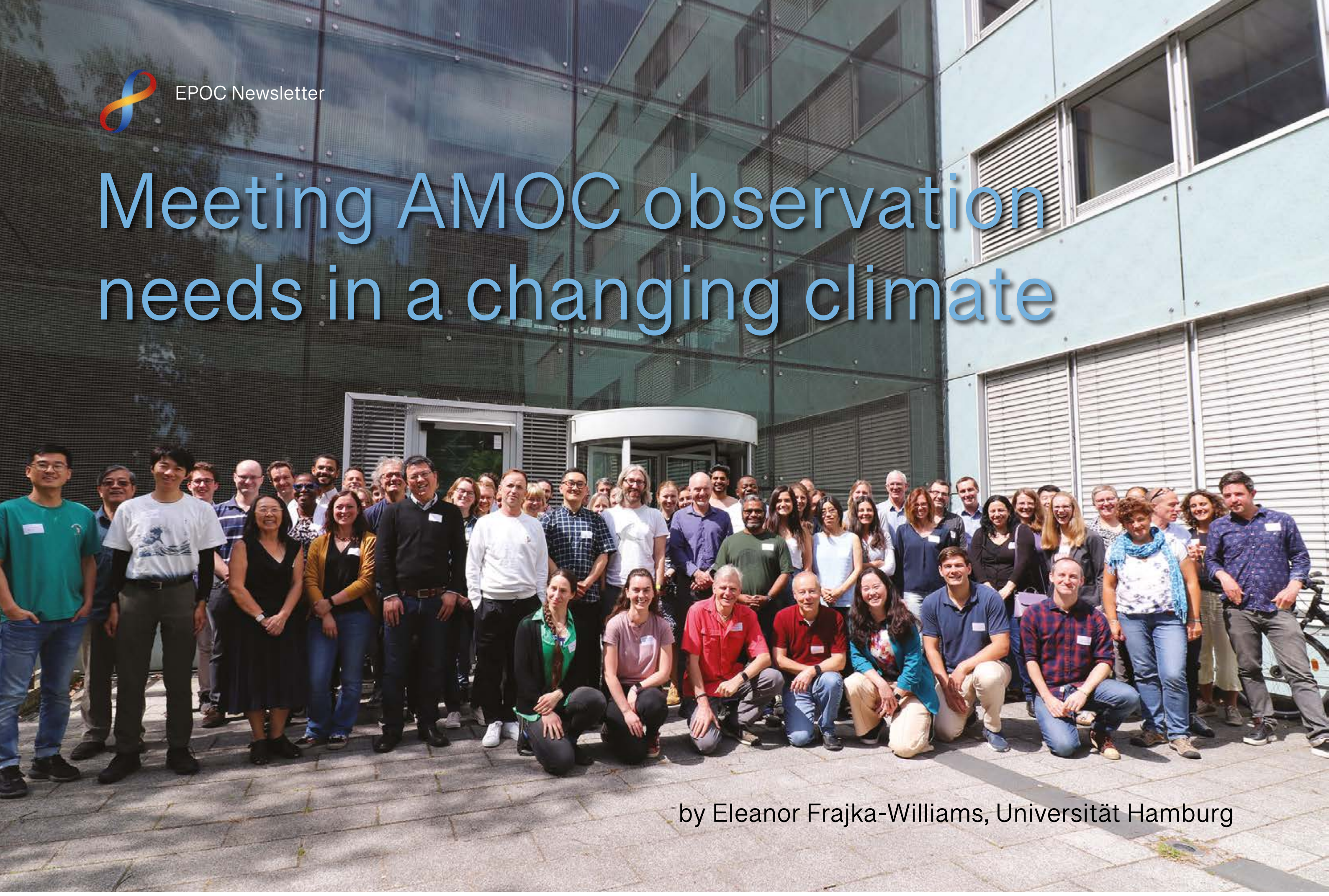


Opposite page: the core stacks at BIO.

Right: Jack at work sampling cores.

Far right: a typical sediment core, split and ready for sampling.

Images courtesy J. Wharton.



Meeting AMOC observation needs in a changing climate

by Eleanor Frajka-Williams, Universität Hamburg

EPOC coordinated an AMOC observing workshop on 'Meeting AMOC observation needs in a changing climate' in July 2023 in Hamburg, co-sponsored by the WCRP CLIVAR and US CLIVAR. The primary goal of the workshop was to inform the design of a future-focused system that can provide continuous measurements of key variables while also remaining sustainable over multiple decades. Towards this end, we welcomed 65 participants (plus 20 online) from 16 different countries, including around 30 early career researchers, to Hamburg, Germany for 3 days of scientific presentations, breakout discussion sessions on the capabilities, limitations and priorities of AMOC observing, and outlining a roadmap for a future AMOC observing strategy.

While the focus of the workshop was on the future, a key issue highlighted several times was the urgent need to deal with uncertainties in the present AMOC observing system which are known, existing and critical. Turning towards future observations, several presentations highlighted how models can be used to evaluate and plan the observing system – both through observing system simulation experiments (OSSEs) and through adjoint methods, at least for near-term AMOC changes that are well captured in the model simulations. The discussion on future observing capabilities was more open, with examples showing how blended mooring + autonomous platform approaches have added resilience and broader spatial coverage for AMOC observing, but also highlighting some substantial and unexplained differences between blended approaches and *in situ* moored approaches. The potential of new emerging technologies was discussed, particularly the potential for high resolution SWOT altimetry to solve identified problems with the use of current-generation altimetry for AMOC estimation (but this would need to be verified), and so-called 'smart cable' systems where oceanographic sensors are deployed on commercial telecommunication cables laid on the Atlantic seabed. The first of these smart cable systems has yet to be run, but if successful could offer the potential to more permanently (10+ years) recover AMOC transport information from a fixed array, rather than the current strategy of deploying and redeploying moorings every 1-2 years. Finally, and surprisingly, the workshop participants identified the need for further communication and collaboration within the AMOC community – not only between observing and modelling groups (which is often discussed) but also between observational groups working at different latitudes.

In the next few years, we anticipate continuing the discussion from this workshop with a workshop on high resolution modelling of the AMOC and on biogeochemical AMOC observations.

Main image: Participants at the AMOC workshop in Hamburg, July 2023.

Advancing climate science for a sustainable future

2nd Open Science Conference of the World Climate Research Programme, Kigali, 23-27 October 2023

The 2nd Open Science Conference of the World Climate Research Programme (WCRP) took place in Kigali, Rwanda, at the Kigali Convention Centre on 23-27 October 2023, hosted by the Rwanda Environment Management Authority (REMA) on behalf of the Government of Rwanda.

This once-in-a-decade conference brought together the climate, environment, and related communities to discuss the latest developments in climate science and explore the transformative actions urgently needed to ensure a sustainable future. Taking place at a critical moment in Earth's history, the conference culminated in the 'Kigali Declaration' – a conference statement that was submitted to the UNFCCC 28th Conference of the Parties (COP28) that took place in the United Arab Emirates immediately after the conference.

The conference highlighted advances and challenges in research on the coupled Earth system. Major themes across the conference included advances in climate research, human interactions with climate, and co-produced climate services and solutions. The conference included over 40 oral and poster sessions, as well as high-level plenary sessions every morning.

EPOC scientists Rym Msadek (CNRS-CERFACS, France) and Rowan Sutton (University of Reading, UK) attended the WCRP meeting. Rowan co-chaired conference Theme 1 on 'Advances in Climate Research' which comprised 12 topic-led sessions showcasing progress and future challenges in understanding Earth's climate system, and advances in climate science capacity around the world. Within this programme, Rowan presented on *The impact of anthropogenic aerosols on North Atlantic and Eurasian atmosphere and ocean circulation* which included some of EPOC's research into impacts on the AMOC. Outcomes from the Theme 1 session were presented by Rowan to COP28 during the segment on 'Physical Science Challenges for AR7 (WG1)' on Saturday 2 December 2023.

Rym's contributions at WCRP included an oral presentation on the *Large-scale oceanic response to Arctic sea ice decline* focusing on the multi-model response of the AMOC to Arctic sea ice decline. In addition, she presented a poster and side event talk on the *Imprint of intrinsic ocean variability on Arctic sea ice and ocean dynamics on subseasonal to annual time scales*, focusing on the role of ocean mesoscale eddies on the natural chaotic variability of the ocean and sea ice in the Arctic and subpolar North Atlantic.

The recordings from all WCRP sessions are available on a hybrid platform for registered participants, but will be made freely available on the WCRP Youtube Channel after March 2024.

4th km-scale climate hackathon: Hamburg, 4-8 March 2024

The Max-Planck-Institute for Meteorology will host the 4th km-scale hackathon in Hamburg, Germany on 4-8 March 2024. Following the three previous hackathons, mainly organised under the nextGEMS project, the 4th event promises to be even bigger. and is co-organised by three projects: EERIE, WarmWorld, and nextGEMS.

Hackathons are communal exploration, analysis and development activities – all various forms of 'hacking'. They prioritise working together over lecturing one another.

The main drive of this event is to learn to handle and analyse ultra-high-resolution (1.25 km to 10 km) coupled model simulations. The event will be preceded by a virtual data handling seminar to get everyone on the same page and equip participants with tools for the following in-person meeting.

Registration for the 4th hackathon costs EUR 150 per person to cover coffee breaks and a hackathon dinner. Registration deadline is **1 January 2024.** A limited number of travel stipends are offered for early career researchers.

For full details and registration visit
https://mpim-po.pages.gwdg.de/km-scale-hackathon

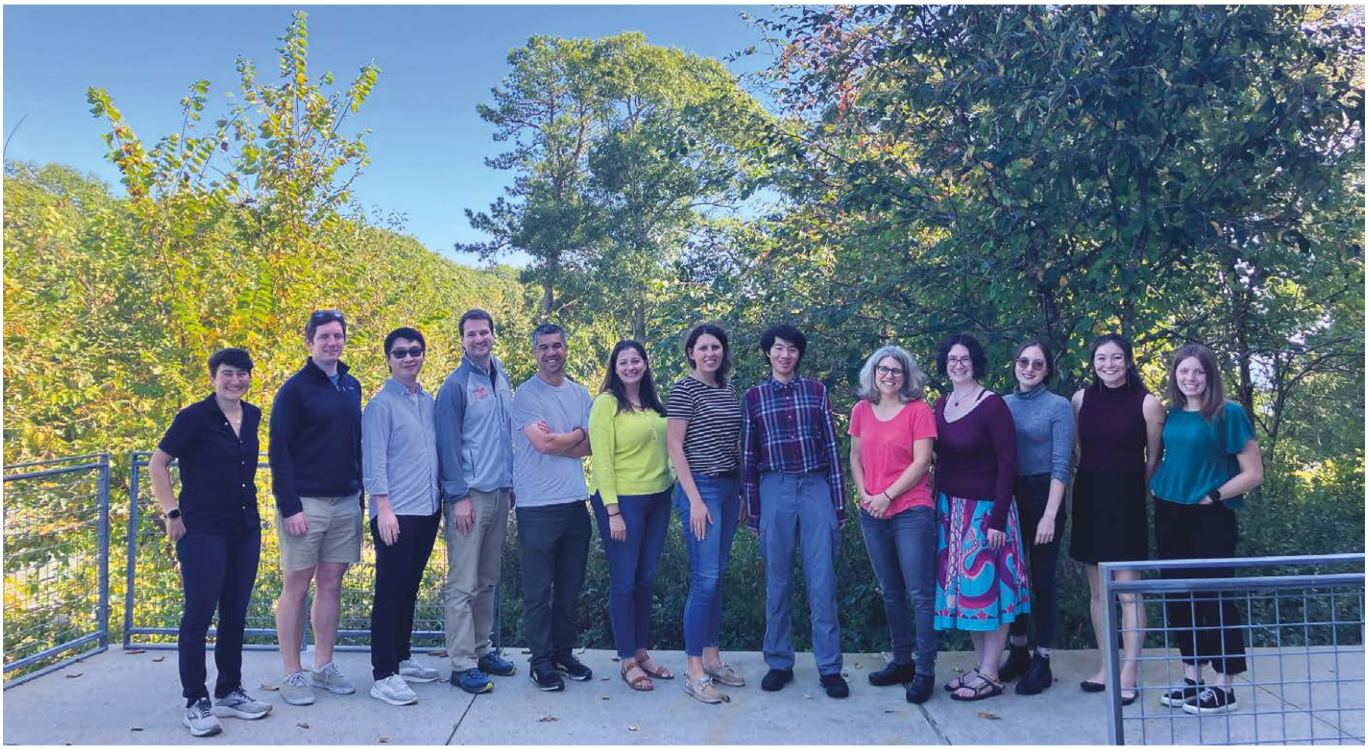
GOHSNAP: Gases in the Overturning and Horizontal circulation of the Subpolar North Atlantic Program

by Jaime Palter, University of Rhode Island and the GOHSNAP team

Though it is often assumed that a slowdown of the Atlantic Meridional Overturning Circulation (AMOC) will lead to deoxygenation of the deep ocean and a decline in the uptake and storage of carbon, observations to test these assumptions have been sparse. Therefore, in 2020, we launched the Gases in the Overturning and Horizontal circulation of the Subpolar North Atlantic Program (GOHSNAP), with funding from the US National Science Foundation (NSF) and the support of a legion of international collaborators – many GOHSNAP PIs, contributors, and partners are pictured below.

GOHSNAP leverages the existing mooring arrays of the Overturning in the Subpolar North Atlantic Program (OSNAP), adding 25 oxygen optodes and 6 pCO_2 sensors in the Labrador Sea to the nearly one dozen oxygen optodes that have been maintained since 2016 by scientists at Dalhousie University (Canada) and Geomar (Germany). With further funding from the Woods Hole Oceanographic Institution (WHOI), 25 additional oxygen optodes were also added to the East Greenland Current region of the Irminger Sea. While the pCO_2 sensors suffered a systematic failure after collecting data for just a few months – the manufacturer later identified and remedied a firmware bug – we successfully recovered the first two years of data from virtually all of the oxygen optodes in the summer of 2022. Despite the many challenges to field work during the most restrictive days of the early pandemic, we were able to perform careful calibration activities during the deployment and recovery cruises for all of the oxygen optodes. Now, equipped with 2 years of 15-minute data from over 70 oxygen optodes, we have refined a set of methodologies to remove pressure effects and instrument drift and ultimately extract the highest-quality oxygen time series from these lengthy deployments. Once published, these methods should help future groups successfully deploy oxygen sensors on transport mooring arrays.

We are now working with OSNAP collaborators to create the first estimate of trans-Labrador basin oxygen transport, which will reveal how much oxygen is added to the deep ocean due to processes in the Labrador Sea. Though the first years of OSNAP revealed that mass overturning in the Labrador Sea is small relative to processes occurring in the eastern subpolar North Atlantic and Nordic Seas, we hypothesise that the Labrador Sea may still be a major player in supplying oxygen to the deep ocean. We now have the data in hand to test this hypothesis.



Participants at the September 2023 GOHSNAP project meeting at Woods Hole Oceanographic Institution. Left to right: Isabela Le Bras, Jannes Koelling, Yao Fu, Greg Koman, David (Roo) Nicholson, Kristen Fogaren, Daria Atamanchuk, Hiroki Nagao, Jaime Palter, Hilary Palevsky, Una Miller, Ellen Park, and Meg Yoder.

epoc explaining and predicting the ocean conveyor

About EPOC

EPOC (**E**xplaining and **P**redicting the **O**cean **C**onveyor) is a 5-year research project funded under the European Union's Horizon Europe programme. Involving 21 institutions from France, Germany, Norway, UK, USA and Canada, and led by Universität Hamburg, EPOC aims to generate a new concept of the Atlantic meridional overturning circulation (AMOC), its function in the Earth system and how it impacts weather and climate.

EPOC has five overarching scientific objectives:

- Generate comprehensive records of AMOC transports across the whole Atlantic, to assess the timescales of transport variability and the degree to which the AMOC behaves as a conveyor belt.
- Determine key processes that make or break meridional connectivity of ocean transports, and assess their representation in models, especially in high resolution coupled simulations.
- Identify the processes and drivers of recent change in the AMOC, and infer the likely roles of natural and anthropogenic forcings, and internal variability.
- Assess the key processes of future AMOC changes, and identify indicators of abrupt changes and AMOC-related climate impacts with societal relevance.
- Design, and deploy elements of, a next generation observing system for the entire system of the AMOC.

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