7th Summer School on Theory, Mechanisms and Hierarchical Modelling of Climate Dynamics - Estimating Ocean Transports: Single Sections, Box Models and Reanalysis Products | (SMR 4224)

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The Meridional Heat Flux across the SAMBA Section

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The complex large-scale ocean dynamics are a response to the Earth's rotation and stratification under forcings such as wind and buoyancy, making the Atlantic Meridional Overturning Circulation (AMOC) a proxy to climate changes measurement [1, 2]. The Meridional Heat Flux (MHF) in the Atlantic transports 25% of the global heat fluxes, with a net northward transport [3]. The main objetive of this paper is to analyze the AMOC variability in space and time, at the fixed latitude of 34.5°S, on the SAMoc Basin-wide Array (or SAMBA), with data derived from the Ocean General Circulation Model for the Earth Simulator (OFES) from January of 1958 to December of 2023 [3]. The MHF shows a mean of 0.30 PW northward, with an increasing trend of 0.045 PW/decade. The seasonal mean shows an increase of the northward transport in the winter, and a decrease in the summer, with the maximum in June, with 0.53 PW, and minimum in February, with 0.16 PW which corroborated with previous publications [4, 5]. Dividing by layers, the upper layer, where the flow is maximum northwards (0 m to 1159 m), the temperature has a mean of 0.56 PW northward, contributing with 65% of the heat transport in the section. The intermediate layer, where the flow has maximum southwards magnitude (1159 m to 3590 m), the temperature has a mean of 0,26 PW southwards, 34% of the heat balance in the section. The deep layer, which goes from the maximum southwards into the bottom (3590 m to ocean bottom), the temperature has a mean of 7×10^{-4} PW, contributing with less then 0,56% of the budget that passes through the section. When dividing by margins, the western side of the basin (western boundary to 49°W) is responsible for 52% of the total temperature flux, followed by 12% and 36% from the interior sector (49°W to 6°E) and the eastern boundary (6°E to the eastern coast). The increasing in the northwards temperature flux could be driven by temperature or velocity field changes. The next steps consists of evaluating the mechanism that drives those changes. The evaluation will involve spectral analysis to identify the dominant frequency and scales associated with the observed changes.

[1] Silvia L Garzoli et al. "South Atlantic meridional fluxes". In: *Deep Sea Research Part I: Oceanographic Research Papers* 71 (2013), pp. 21–32.

[2] Lynne D Talley, Joseph L Reid, and Paul E Robbins. "Data-based meridional overturning streamfunctions for the global ocean". In: *Journal of Climate* 16.19 (2003), pp. 3213–3226.

[3] María Paz Chidichimo et al. "Energetic overturning flows, dynamic interocean exchanges, and ocean warming observed in the South Atlantic". In: *Communications Earth & Environment* 4.1 (2023), p. 10.

[4] Molly O Baringer and Silvia L Garzoli. "Meridional heat transport determined with expendable bathythermographs—Part I: Error estimates from model and hydrographic data". In: *Deep Sea Research Part I: Oceanographic Research Papers* 54.8 (2007), pp. 1390–1401.

[5] Shenfu Dong et al. "Interannual variations in the Atlantic meridional overturning circulation and its relationship with the net northward heat transport in the South Atlantic". In: *Geophysical Research Letters* 36.20 (2009).

P02

Sea surface temperature in the Indonesian Seas is equally driven by oceanic and atmospheric processes

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The Indonesian Seas, a key conduit linking the Pacific and the Indian Oceans, display pronounced Sea surface temperature (SST) variability compared to surrounding oceans. SST variability in this region significantly influences Indo-Pacific climate and atmospheric convection. For example, a 0.5°C change in SST can alter atmospheric deep convection by $\sim 20\%$ [1]. Thus constraining the drivers of SST variability is critical for a better understanding of the air-sea coupling in this region and it's broader impacts on Indo-Pacific climate variability. Using observations and high-resolution regional ocean model simulations, we examine the mechanisms governing seasonal SST variability and its sensitivity to local wind forcing. Observations show a distinct spatial pattern of the amplitude of SST variability across the region, where it amplifies along the Indonesian Throughflow (ITF) pathways. SST variability is dominated by the seasonal band, accounting for about 68% of the total SST variance. We find that the oceanic processes contribute to this variability via monsoonal wind-driven Ekman upwelling and downwelling, acting across the shallow thermocline, generating temperature anomalies at depth. In the upper 100 meters of the ocean, this process generates three times more variance than atmospheric fluxes. Temperature anomalies generated at depth, are not confined to sub-surface levels but also get transmitted to the surface ocean via diffusion, associated with enhanced mixing within the mixed layer. Additionally we find that role of wind-driven upwelling in setting the mean SST is comparable to the effects of tidal mixing in this region. On the other hand, lateral heat advection by the ITF leads to the amplification of SST variability along ITF pathways, resulting in strongest variability observed in the Banda Sea and downstream regions. Our results imply that long term changes in the oceanic state, such as changes in the thermocline depth, can potentially impact the seasonal SST variability in this region, and thereby affect the atmospheric convection and feedback to the dominant modes of climate variability.

[1] Sprintall, J., Gordon, A. L., Koch-Larrouy, A., Lee, T., Potemra, J. T., Pujiana, K., & Wijffels, S. E. The Indonesian seas and their role in the coupled ocean–climate system. *Nature Geoscience* **7**, 487–492 (2014).

P03

Observed Recirculation and Transformation of North Atlantic Deep Water at the North Atlantic Transition Zone

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The Atlantic Meridional Overturning Circulation plays a central role in the climate system, with the Deep Western Boundary Current (DWBC) acting as the main conduit for the southward export of North Atlantic Deep Water. Previous studies have shown that the DWBC is not a simple continuous boundary pathway: part of the deep flow is diverted into interior routes, while strong recirculation and topographic effects modify its transport and properties [1–3]. The subpolar–subtropical Transition Zone near Newfoundland is therefore a key region for understanding how the lower limb of the overturning circulation evolves between the subpolar and subtropical gyres.

Here, we use hydrographic and shipboard-ADCP observations collected during the CROSSROAD-1 cruise in August 2024, together with Argo-derived geostrophic velocities, to investigate DWBC circulation and North Atlantic Deep Water transformation near two potential leakage hotspots: Flemish Cap and the tail of the Grand Banks. Our results show that Flemish Cap is the dominant hotspot for DWBC transport divergence, accounting for most of the observed loss of Labrador Sea Water and Northeast Atlantic Deep Water transport. A spatial decomposition indicates that this leakiness is primarily controlled by changes in slope geometry, consistent with topographically driven separation. In contrast, the Grand Banks plays a stronger role in water-mass transformation, producing most of the observed warming and salinification of the lighter deep-water layers. These results provide new observational constraints on how the Transition Zone disrupts DWBC coherence and modifies downstream AMOC property signals.

[1] A. S. Bower et al., Nature **459**, 243–247 (2009).
[2] C. Mertens et al., J. Geophys. Res. Oceans **119**, 7772–7793 (2014).
[3] A. Solodoch et al., J. Phys. Oceanogr. **50**, 1989–2016 (2020).
[4] I. Le Bras et al., J. Geophys. Res. Oceans **122**, 5348–5366 (2017).

P04

Vertical Transport of Nearly-Buoyant Particles in Free-Surface Boundary Layer

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Predicting the transport of buoyant particles in free-surface boundary layers is important to many environmental systems, including microplastics in the upper ocean. However, current transport models, adapted from sediment transport theory, often overlook complex fluid–particle interactions. We experimentally study the vertical mixing of buoyant, finite-sized spheres, rods, and disks in a wind-driven free-surface flow and compare their vertical diffusivities, estimated using three different methods. From this comparison, we find that diffusivity decreases as particle buoyancy dominates turbulent mixing, consistent with crossing trajectories effect. Similarly, the decrease in particle diffusivity relative to momentum diffusivity follows the same trend, yielding Schmidt numbers greater than one. We conclude that assuming a still-water rise velocity in concentration-based models significantly overestimates diffusivity because the flow reduces the particle rise velocity relative to its still-water velocity. Overall, we find that the flow and particle characteristics can both affect the particle diffusivity and rise velocity in non-trivial ways. These effects are often overlooked in microplastic transport models which can introduce substantial errors.

P05

Evaluating the Capability of NEMO to Simulate Antarctic Bottom Water

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The formation and outflow of Antarctic Bottom Water (AABW) play a central role in regulating the global climate system by mediating significant deep-ocean heat and carbon uptake and storage. However, reproducing historical AABW dynamics remains challenging due to the complex interactions among ocean, sea ice, and atmosphere and computational resources limitation. Although some models have been developed for deep-ocean research, such as ACCESS-OM2-01, can represent AABW formation and export realistically, their computational expense limits long-term simulations.

In this context, we evaluate the performance of the global ocean-sea ice model NEMO-SI^3 in reproducing historical AABW under 1/4 (eddy-permit) and 1° (no-eddy) configurations. The World Ocean Atlas (WOA) was used to assess model temperature and salinity profiles in four AABW source regions and the deep South Ocean (~4000m). Results show that the eddy-model configuration reproduces the shelf water structure well along the Antarctic continental shelf but exhibits warm bias in deep ocean, particularly in Ross Sea. By contract, the no-eddy model reduces deep ocean drift but shows freshening bias in Ross Sea and warm anomalies on the shelf.

This work highlights how model resolution affects the formation and export of the AABW, providing guidance for selecting appropriate configurations for long-term simulations. The summer school training course on multi-observational data processing and ocean transport estimation will directly support the next stage of my PhD research by evaluating NEMO's ability to reproduce AABW formation and transport along key Southern Ocean sections (such as the GO-SHIP S04P, A23, and SR03). Strengthening these observational–model comparisons is essential for understanding the mechanisms driving the multidecadal evolution of AABW, and it makes the summer school highly relevant to my research.

P06

Transformation of the Deep North Atlantic Ocean Through the Eyes of GO-SHIP: Cooling, Freshening, Pathways & Propagation

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Abstract

The deep North Atlantic Ocean plays an integral role in driving the lower limb of the Atlantic Meridional Overturning Circulation (AMOC) through the formation and equatorward export of North Atlantic Deep Water (NADW). The unique physical properties of the surrounding subpolar environment are imprinted upon the newly formed NADW masses, enabling their identification in hydrographic datasets across vast distances through time. Leveraging over 30 years of high-resolution deep ocean hydrographic surveys across the North Atlantic Ocean via the Global Ocean Ship-based Hydrographic Investigations Program (GO-SHIP), we explore the transformation and spreading pathways of NADW and deep-ocean (>2000m) water masses therein.

While the global deep ocean continues to warm, hydrographic evidence herein reveals that the North Atlantic stands apart, exhibiting decades of sustained deep ocean cooling and freshening instead. In the NADW formation region of the Subpolar North Atlantic, a continuous decline in deep ocean temperature and salinity spanning nearly four decades reached a minimum around the year 2000, followed by an abrupt transition over the next decade to warmer and more saline deep water. More than two decades later, this distinctive multi-decadal cold and fresh environmental signature continues to propagate across the deep North Atlantic via the equatorward export of these deep waters out of the Subpolar North Atlantic. Evidence of the transition from cold/fresh to warm/salty NADW in the deep ocean is now emerging along faster export pathways. Using the environmental markers unique to these exported water masses (e.g. salinity, temperature, oxygen, and chemical tracers), we trace the spread, timing, and evolution of NADW along diverse pathways across the North Atlantic basin. These observations provide critical insights into the structure and variability of the lower limb of the AMOC and help illuminate how past changes may inform the future state of the deep ocean.

P07

Towards an operational coastal ocean forecasting system for decision-making in central-northern Chile: development and current challenges

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High-resolution coastal ocean forecasting systems are essential tools for supporting decision-making in regions where marine activities such as aquaculture, fisheries, tourism, and coastal management are highly sensitive to ocean variability. In the southeast Pacific, however, the development and validation of such systems are often limited by the scarcity of in situ observations.

In this work, we present the implementation of an operational coastal ocean forecasting system based on the CROCO (Coastal and Regional Ocean COmmunity model) framework for central-northern Chile. The system has been developed from configuration to execution, including forcing generation and automation of daily forecasts with a 7-day prediction horizon. The model is forced with atmospheric fields from GFS and ocean boundary conditions from the Mercator Ocean global model, enabling a downscaling approach from 9 km to 3 km resolution toward high-resolution coastal dynamics.

Preliminary validation has been conducted using satellite-based products such as OSTIA for sea surface temperature and SMAP for surface salinity. Results indicate that the system captures the main patterns of thermal and salinity variability. While bulk error metrics remain of similar magnitude across resolutions, the increased spatial resolution improves the representation of coastal gradients and local features, particularly in nearshore environments where coarse-resolution models tend to smooth key processes.

A major limitation arises in the validation of ocean circulation and transport processes. The lack of local current measurements (e.g., ADCP observations) restricts the assessment of model performance beyond surface properties, particularly in a region where coastal dynamics are strongly influenced by wind-driven variability and mesoscale processes. This limitation introduces uncertainty in the representation of transport pathways and water exchange, which are key for understanding coastal circulation.

These preliminary results highlight both the potential and the current limitations of high-resolution coastal forecasting systems in data-sparse regions. Ongoing work focuses on improving model performance and exploring alternative strategies to better constrain circulation and transport processes in the absence of direct observations.

P08

A Decade of Open-Sea Observations in the Southern Adriatic: Advancing Air–Sea Flux Estimates and Model Calibration

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Air–sea heat and moisture exchanges in the Southern Adriatic Sea play a critical role in dense water formation and deep convection, key drivers of Mediterranean circulation, particularly during intense Bora wind events [1]. Quantifying these processes requires sustained, high-quality observations [2]. The EMSO-ERIC E2M3A surface buoy has provided over a decade (since 2014) of high-frequency meteo-marine measurements, including air temperature, humidity, pressure, wind, and radiative fluxes, representing a uniquely long and comprehensive open-sea dataset for the region [3].
This study develops a harmonized, quality-controlled time series to enable robust analysis of turbulent heat fluxes and their impact on mixed-layer dynamics. Data were processed using standardized quality-control procedures (RITMARE [4]) and gap-filled using Copernicus satellite-derived sea surface temperature products [5, 6]. Novel corrections were applied to radiative fluxes: shortwave radiation was adjusted for instrumental and deployment-related biases, while longwave radiation records (2014–2022) were corrected using a regression-based approach derived from 2023–2024 measurements, reducing residual errors (RMSE = 2.71 W/m²) while better capturing atmospheric variability effects.
The resulting dataset provides an unprecedented basis for quantifying air–sea interactions in the Southern Adriatic. Furthermore, these open-sea observations will be used to calibrate and tune Copernicus model outputs, improving the representation of air–sea fluxes, mixed-layer dynamics, and deep water formation processes in regional forecasting and reanalysis systems.

[1] C. Denamiel, I. Tojčić, and P. Pranić, Ocean Sci. 21, 37–62 (2025).
[2] V. Cardin and M. Gačić, J. Geophys. Res. 108, 8103 (2003).
[3] J. Le Meur, A. Wirth, F. Paladini de Mendoza, S. Miserocchi, and V. Cardin, Front. Mar. Sci. 12, 1516780 (2025).
[4] E. Partescano, A. Giorgetti, and A. Brosich, Near Real-Time Oceanographic Data Management through Sensor Web Enablement (SWE) Standards: Latest Developments (2018).
[5] A. Pisano, B. Buongiorno Nardelli, C. Tronconi, and R. Santoleri, Remote Sens. Environ. 176, 107–116 (2016).
[6] B. Buongiorno Nardelli, C. Tronconi, A. Pisano, and R. Santoleri, Remote Sens. Environ. 129, 1–16 (2013).

P09

CONFIGURATION AND VALIDATION OF A HIGH-RESOLUTION CROCO MODEL FOR THE STUDY OF COASTAL PROCESSES ALONG THE URUGUAYAN INNER SHELF

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The Uruguayan coastal region is part of a highly dynamic system influenced by wind forcing, freshwater discharge from the Río de la Plata, and strong mesoscale variability. Due to the limited availability of sustained in situ observations, numerical modelling provides a key tool to investigate coastal processes and their variability. In this contribution, we present the configuration and validation of a high-resolution regional ocean model (Coastal and Regional Ocean Community Model, CROCO [1, 2]) designed to study coastal dynamics along the Uruguayan shelf. The model domain covers 31°–36°S and 50°–59°W, with a horizontal resolution of 1/36° (~2.5 km) and 40 vertical sigma levels. It is forced with interannual atmospheric fields, river discharge, tidal forcing, and open boundary conditions from ocean reanalysis products. The model configuration has been applied to investigate coastal upwelling dynamics and associated processes in the region. Validation against reanalysis products and in situ observations shows that the model realistically reproduces the main hydrographic features, including sea surface temperature, salinity structure, and coastal circulation patterns. This modelling framework has proven suitable for analyzing both Eulerian and Lagrangian aspects of coastal dynamics, including the three-dimensional structure of upwelling and transport processes, as well as mixing and frontal dynamics [2, 3, 4]. The presented configuration provides a robust basis for future studies focused on estimating ocean transports and integrating observational and reanalysis products, in line with current international oceanographic programs.

[1] Debreu, L., Marchesiello, P., Penven, P., and Cambon, G.: Two-way nesting in split-explicit ocean models: Algorithms, implementation and validation, Ocean Model., 49, 1–21 (2012).

[2] de Mello, C., Barreiro, M., Ortega, L., Trinchin, R., and Manta, G.: Coastal upwelling along the Uruguayan coast: Structure, variability and drivers, J. Mar. Syst., 230, 103735 (2022).

[3] de Mello, C., Barreiro, M., Hernández-García, E., Trinchin, R., and Manta, G.: A Lagrangian study of summer upwelling along the Uruguayan coast, Cont. Shelf Res., 258, 104987 (2023).

[4] de Mello, C., Barreiro, M., and Renom, M.: Year-round characterization of upwelling along the Uruguayan coast using a high-resolution regional ocean model, Ocean Sci., 22, 1169–1182 (2026).

[5] Shchepetkin, A. F. and McWilliams, J. C.: The Regional Oceanic Modeling System (ROMS): A split-explicit, free-surface, topography-following-coordinate oceanic model, Ocean Model., 9, 347–404 (2005).

P10

Evaluating Ocean Heat Transport and Reanalysis Products during a Severe Marine Heatwave in the South Atlantic

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The South Atlantic Ocean is increasingly experiencing intense Marine Heatwaves (MHWs), which significantly modulate regional atmospheric dynamics and trigger extreme coastal precipitation events in southern Brazil. Understanding the physical mechanisms driving these thermal anomalies requires precise quantification of ocean heat content and advection. This study investigates oceanic preconditioning and turbulent heat fluxes during a severe MHW event in November/December 2022, culminating in extreme orographic precipitation along the coast of Santa Catarina.

To accurately capture the oceanic forcing, this work evaluates the performance of multiple oceanographic reanalysis products in representing the sea surface temperature anomalies and the upper-ocean heat budget. We analyse the role of large-scale ocean transports and boundary currents in sustaining the MHW, comparing high-resolution reanalyses with observational datasets [1, 2].

A critical assessment of these reanalysis products is essential, as they serve as the boundary conditions for subsequent regional atmospheric downscaling with the Weather Research and Forecasting (WRF-ARW) model. By isolating the oceanic transport components from the atmospheric forcing, we aim to model the ocean-atmosphere interactions hierarchically. The results will highlight uncertainties across different ocean reanalyses and demonstrate that precise ocean surface estimates are fundamental for predicting coastal extremes in the South Atlantic.

[1] R. R. Rodrigues, *et al.*, Nat. Geosci. **12**, 620-626 (2019).
[2] A. J. Hobday, *et al.*, Prog. Oceanogr. **141**, 227-238 (2016).

P11

South Atlantic Mode Water Signature in the Atmosphere

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The South Atlantic Subtropical Mode Water (STMW) is a mass water characterized by low vertical density, located between the seasonal and permanent thermoclines, and defined by homogeneity of its properties, such as temperature [1]. STMW occupies a large portion of the subtropical basin between 30°S and 40°S, and is associated with oceanic currents and fronts [2]. Its formation occurs primarily during winter and early spring through surface cooling and intense turbulent heat fluxes at the ocean–atmosphere interface, particularly latent heat loss, which enhances convective mixing and promotes the deepening of the mixed layer.

This study investigates the seasonal, interannual, and spatial variability of meteorological and oceanographic parameters in the region, with a focus on atmospheric processes that control surface heat fluxes and, consequently, STMW formation. ERA5 reanalysis data (1996–2025) [3] were used and segmented into periods of stability, pre-formation, formation, and post-formation. Additionally, the temperature climatology developed by Roemmich & Gilson (2004–2025) was employed to estimate the mode water volume, allowing the assessment of its variability in response to atmospheric forcing.

The results show that the formation period coincides with minima in sea surface temperature (SST) and maxima in heat loss to the atmosphere, highlighting the importance of heat fluxes for STMW formation. Vertical sections of mode water volume during this period indicate a consistent deepening of the mixed layer, reflecting intensified convective processes, associated with stronger winds and increased sea level pressure. SST anomalies suggest a reduction in the frequency of cold events over the analyzed period, potentially affecting the intensity of mode water formation and, consequently, its contribution to large-scale circulation.

Beyond the regional scale, STMW variability is associated with changes in meridional heat transport in the South Atlantic and fluctuations in the Atlantic Meridional Overturning Circulation [4], highlighting its role as an integrator of ocean–atmosphere processes and a potential indicator of decadal climate variability. These results reinforce the importance of STMW in modulating climate variability in the South Atlantic and in redistributing heat across the region, providing a consistent basis for future investigations of its impact on large-scale circulation.

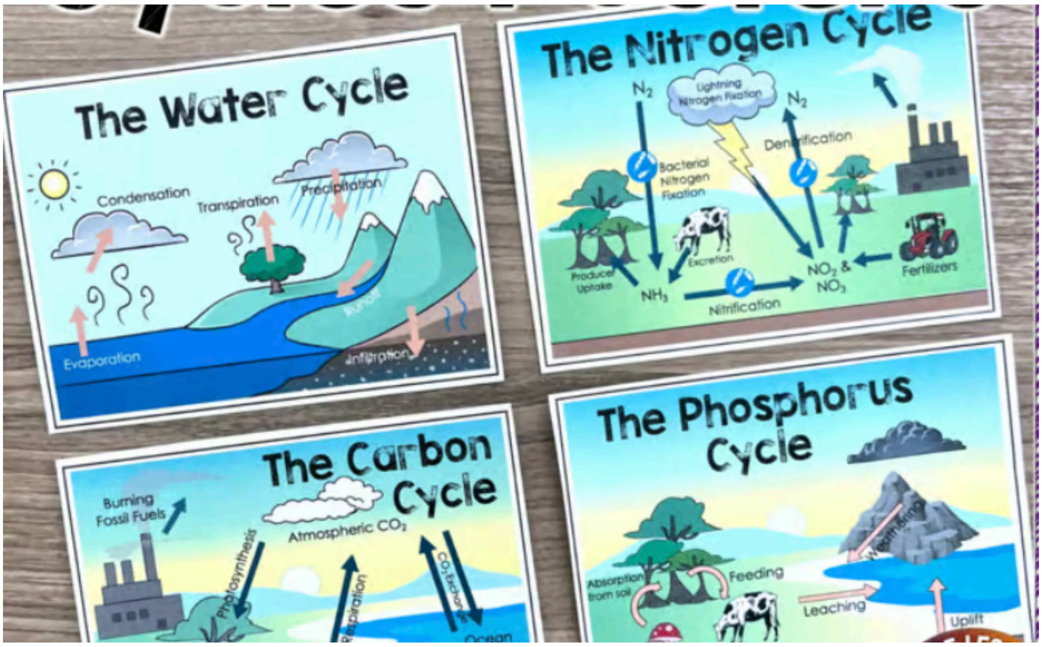
[1] K. Hanawa, L. D. Talley, Mode waters, in Ocean Circulation and Climate, Academic Press (2001).

[2] O. T. Sato et al., Observation of subtropical mode water in the South Atlantic, Journal of Geophysical Research (2014).

[3] H. Hersbach et al., The ERA5 global reanalysis, Quarterly Journal of the Royal Meteorological Society **146**, 1999–2049 (2020).

[4] M. P. Chidichimo et al., Energetic constraints on the AMOC, Journal of Climate (2023).

P12


The Water Cycle
Condensation
Transpiration
Precipitation
Evaporation
Runoff
Infiltration
The Nitrogen Cycle
N_2
Lightning Nitrogen Fixation
N_2
Denitrification
Bacterial Nitrogen Fixation
Produce Uptake
Excretion
NH_3
Nitrification
NO_2 & NO_3
Fertilizers
The Carbon Cycle
Burning Fossil Fuels
Atmospheric CO_2
Photosynthesis
Respiration
CO_2 Exchange
Ocean
The Phosphorus Cycle
Absorption from soil
Feeding
Leaching
Weathering
Uplift

P13

Opposing impact of climate perturbations on natural and anthropogenic carbon in the ocean under CO2 emission reversibility

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Ocean carbon storage responds to changes in atmospheric CO_2, reflected in particular in the uptake of anthropogenic carbon under contemporary "net-positive" CO_2 emissions. Under future net-negative emissions scenarios, however, the ocean is expected to release part of the previously absorbed anthropogenic carbon back to the atmosphere. In addition to this direct atmospheric CO_2 effect, anthropogenic climate change modulates the uptake of anthropogenic carbon as well as impacts the natural carbon cycle, for instance an increase in sea surface temperature decreases solubility of CO_2 in the ocean, and changes ocean stratification and hence ocean circulation. Previous studies have largely focused on how climate change effects natural and anthropogenic carbon storage together, and compared this to the direct effects of the atmospheric CO_2. This approach obscures differences in the mechanisms governing natural versus anthropogenic ocean carbon response to climate change perturbations. To isolate these mechanisms, we use an Earth system model with idealized tracers to separately track natural and anthropogenic carbon. We analyse the ocean carbon under an emissions reversibility scenario ("flat10-cdr"), characterized by symmetric CO_2 emissions: a net-positive phase followed by a net-negative phase, ultimately returning cumulative emissions to zero. Despite the reversal of cumulative emissions to zero, our results reveal persistent and irreversible changes in the total ocean carbon response to climate perturbations. This behaviour primarily arises from climate-driven accelerated loss of natural carbon from the intermediate overturning (500–2000 m) during the net-negative emissions phase. The dominance of the intermediate overturning waters arise as climate-driven responses of natural and anthropogenic carbon partially compensate within deep overturning waters (>2000 m), reducing the net deep-ocean signal, with compensating responses in Antarctic Bottom Water and amplifying responses in North Atlantic Deep Water. Our mechanistic separation provides new insight into ocean carbon responses to climate perturbations and highlights the role of circulation-driven processes in shaping asymmetric and irreversible behaviour.

P14

ASSESSING AIR-SEA HEAT EXCHANGE THROUGHOUT THE LIFE CYCLE OF A LONG-LIVED WARM CORE EDDY

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Mesoscale eddies are fundamental drivers of heat and gas transport between the ocean and the atmosphere especially in high energy regions like the Brazil-Malvinas Confluence. While most mesoscale features are transient, long-lived eddies represent persistent anomalies that can sustain air-sea exchanges over extended temporal and spatial scales. This study examines the life cycle of a long-lived warm core eddy that persisted for 422 days in the South Atlantic Ocean. This eddy originated at 47°S 53°W and displaced eastward toward 43°S 40°W. Situated between the Zapiola Rise and the Subantarctic Front the longevity of this feature likely results from interactions with the frontal system and the isolation of mass within its core [1, 3, 4]. Mesoscale feature identification was conducted using the 0.25° daily META3.2DT atlas, while associated air-sea heat fluxes were extracted from the 0.25° hourly ERA5 reanalysis. The mesoscale signal was isolated from low and high frequencies by applying a temporal Butterworth filter [2] and a spatial Hann window [8] to remove large scale environmental variability. The physical evolution of the eddy demonstrates a gradual amplitude decay from 0.7 to 0.2 meters while the diameter fluctuated between 100 and 400 kilometers. Observed expansions in diameter correspond to significant drops in amplitude which is a relationship consistent with the conservation of potential vorticity where a radius expansion necessitates a reduction in amplitude to maintain dynamic equilibrium [6]. This conservative behavior indicates the structure remains a stable vector for the long range transport of hydrographic properties throughout its trajectory [5]. Analysis of the heat flux time series confirms that the WCE acted as a persistent heat source to the atmosphere for the majority of its 14 month lifespan. At its formation, the eddy initiated air-sea exchange with latent heat anomalies near 8 W/m^2. Sensible heat anomalies exhibit frequent peaks exceeding 16 W/m^2 while latent heat anomalies reach values near 30 W/m^2 during periods of intense interaction. Even in its final stages, the feature sustained a strong thermal signature with latent heat peaks reaching 18 W/m^2 before dissipation. The predominance of these positive fluxes indicates that the feature provides a localized but intense forcing on the lower atmosphere. The non-linearity of the feature isolates central water masses [1] allowing it to maintain its thermal signature far from its origin [7]. This observational synthesis serves as a necessary baseline for applying the hierarchical modeling and inverse techniques discussed in this program to resolve the broader role of mesoscale variability in South Atlantic transport budgets.

[1] D. B. Chelton, M. G. Schlax, R. M. Samelson, Prog. Oceanogr. **91**, 167 (2011).
[2] Y. Chen, L. Yu, J. Geophys. Res. Oceans **129**, e2023JC020479 (2024).
[3] I. Frenger, et al., Nat. Geosci. **8**, 102 (2015).
[4] A. Ioannou, et al., Sci. Data **11**, 582 (2024).
[5] R. Morrow, P. Y. Le Traon, Adv. Space Res. **33**, 10 (2004).
[6] J. Pedlosky, Geophys. Fluid Dyn. Springer (2013).
[7] F. Schutte, et al., Biogeosciences **13**, 1935 (2016).
[8] A. B. Villas Bôas, et al., J. Geophys. Res. Oceans **120**, 1313 (2015).

P15

Future Global Warming Constrained by Observed AMOC Strength

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Global warming presents unprecedented challenges to both the Earth's climate system and socioeconomic stability. However, future projections of global warming exhibit large uncertainty across current climate models. In this study, we demonstrate that this uncertainty can be reduced using observational estimates of Atlantic Meridional Overturning Circulation (AMOC). Inspired by previous findings that link the cAMOC to inter-model differences in projected warming under the Coupled Model Intercomparison Project Phase 5 and 6 (CMIP5 and CMIP6) idealized 1pctCO_2 forcing, we employ a zero-layer energy balance model (EBM) to investigate the physical connection between cAMOC and future surface warming by analyzing a suite of CMIP5 and CMIP6 models under low-, medium-, and high-emission future scenarios. We find that enabled by weaker ocean stratification, a stronger cAMOC is associated with more efficient ocean heat uptake and more negative climate feedbacks. Integrating this process into the zero-layer EBM yields an inverse relationship between cAMOC and surface warming. Applying observed AMOC strength to this relationship constrains the 95% confidence interval of future sea surface warming from 0.87-2.09 °C, 1.26-2.94 °C, and 2.43-5.30 °C to 0.97-2.05 °C, 1.68-2.90 °C, and 3.14-4.92 °C under low- to high-emission scenarios, respectively. Notably, despite the buffering effect of AMOC, meeting the targets of the Paris Agreement remains unattainable without substantial reductions in CO_2 emissions.

P16

Modelling incompressible flow regimes using Physics-Informed Neural Networks

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This contribution explores the development of a modeling architecture based on Physics-Informed Neural Networks (PINNs) to solve canonical regimes in fluid dynamics [1]. We focus on the following cases: Kovasznay steady flow, Taylor–Green vortex, von Kármán vortex street, and cyclonic geostrophic equilibrium. Our architecture simultaneously reconstructs velocity and pressure fields, working as a high-fidelity interpolator constrained by an optimization framework that satisfies the conservation of mass and momentum, while enabling the discovery of *latent dynamical* parameters [2]. The model performs well in direct problems through the accurate reconstruction of velocity and pressure fields, and also in inverse problems by successfully identifying latent dynamical parameters such as kinematic viscosity and the Coriolis coefficient. These results demonstrate the model versatility for systems governed by conservation laws and complex differential operators, even in the presence of noise. We found that the physical constraints act as a regulator superior to traditional statistical or numerical methods. The ability of PINNs to filter stochastic noise emerges as an additional advantage derived from the physical inductive bias that enforces dynamical coherence.

[1] M. Raissi, P. Perdikaris, and G. E. Karniadakis, Journal of Computational Physics. **378**, 686-707 (2019).

[2] M. Raissi, A. Yazdani, and G. E. Karniadakis, Science **367**, 6481, 1026-1030 (2020).

P17

Modeled and observed seasonal to interannual variability in the Nordic Seas

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Using a new high-resolution (1.0-4.5 km) configuration of the MITgcm ocean–ice model, we present a modeling perspective on Nordic Seas circulation based on more than two decades of simulation. By synthesizing long-term observations, we examine modeled and observed seasonal to interannual variability across the Nordic Seas, including volume, heat transports, and overturning across the Greenland–Scotland Ridge, Barents Sea Opening, and Fram Strait, as well as freshwater transport, sea-ice extent, and mixed-layer depth in the Greenland Sea. Overall, the model convincingly reproduces key observed features and provides a valuable tool for investigating air–sea interactions and circulation variability in the Nordic Seas. For instance, using a heat budget analysis, we show that eddy heat flux divergence offsets more than 70% of heat flux convergence induced by the mean flow along the Norwegian Atlantic Slope Current.

[1] Jian, D., Zhai, X., Stevens, D. P., & Renfrew, I. A. (2026). Oceanic heat transport along the Norwegian Atlantic Slope Current and the role of eddies. Journal of Geophysical Research: Oceans, 131(1), e2025JC022960.

P18

Influence of ENSO, Southern Annular Mode, and IOD on the Interdecadal Change of the East Africa 'short rains'

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This study investigates the abrupt shift in the Southern Annular Mode (SAM), El Niño-Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) and East Africa 'short rains' (EASR) during 1961, to understand the associated physical mechanisms. The mechanisms are examined through composite, correlation and regression analysis for the period 1901 – 2020, using multiple datasets. Findings show that in the pre-1961 period, SAM was associated with the EASR variability through its connection with the variability of the South Indian Ocean (SIO) sea surface temperature (SST) anomaly. The September SAM is related to a change in surface wind speed, which drive meridional oceanic Ekman transport and influence the surface heat exchange, redistributing heat near the surface. Warm SIO SST induces ascending motion throughout the atmosphere, favouring deep convection and Congo Basin westerlies, leading to enhanced EASR. The findings suggest that the September SAM provide an important forecasting signal for the EASR. However, post 1961, the SAM is decoupled from the EASR, and the IOD demonstrates a significant role in influencing the short rains. The anomalous Indian Ocean Walker circulation related to the IOD provides an essential driving process for anomalous moisture transport and convection in East Africa (EA), leading to EASR variability. El Niño events predispose the Indian Ocean to positive IOD events, and thus, the absence of the former has ramifications to the EASR variability. The observational results show that prior to 1961, there was virtually no significant relation between the EASR and the zonal winds in the central equatorial Indian Ocean. The findings of this study have important implications for regional season climate prediction.

References

[1] S. E. Nicholson, “Long-term variability of the East African ‘short rains’ and its links to large-scale factors,” *Int. J. Climatol.*, vol. 35, no. 13, pp. 3979–3990, Nov. 2015, doi: 10.1002/joc.4259.

[2] D. Manatsa, C. Mudavanhu, T. D. Mushore, and E. Mavhura, “Linking major shifts in East Africa ‘short rains’ to the Southern Annular Mode,” *Int. J. Climatol.*, vol. 36, no. 4, pp. 1590–1599, Mar. 2016, doi: 10.1002/joc.4443.

P19

Meridional Variability of AMOC in South Atlantic

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The Atlantic Meridional Overturning Circulation (AMOC) is a major component of the global climate system, responsible for the redistribution of heat, salt, and oxygen between low and high latitudes and for the coupling between surface and deep ocean layers [1]. Although significant observational and modeling efforts have improved the understanding of its large-scale structure, uncertainties remain regarding its meridional variability and the role of regional processes in modulating overturning intensity. Therefore, the main objective of this study is to quantify the meridional variability of AMOC strength across the Atlantic basin.

In this study, the variability of the AMOC is investigated using the output of the Estimating the Circulation and Climate of the Ocean Version 4 Release 4 (ECCO V4r4) ocean state estimate [2], which is here validated against climatological fields of the World Ocean Atlas 2023 (WOA23) [3]. The temperature and salinity distributions were first analyzed to characterize the large-scale thermohaline structure along a meridional Atlantic section and to assess the consistency of the reanalysis at 34.5°S. The comparison indicates that differences between ECCO and WOA23 are mainly restricted to the upper 1000 m of the water column, where stronger thermodynamic variability is expected, while deeper layers exhibit greater agreement.

We assessed the overturning strength, cumulative vertical transport, and meridional velocity time series to diagnose the meridional volume transport at three key latitudes (34.5°S, 11°S and 26°N), where are stablished permanent monitoring arrays (SAMOC/SAMBA, TRACOS and RAPID, respectively). The results reveal pronounced interannual variability, with typical AMOC values ranging from approximately 15 Sv to 20 Sv across the basin. The depth of maximum northward transport varies significantly with latitude, occurring near 1300 m at 34.5°S, around 1100 m at 11°S and close to 800 m at 26°N, indicating substantial differences in the vertical structure of the overturning circulation. Enhanced variability is primarily associated with western boundary regions, consistent with previous observational estimates of highly variable overturning cells in the South Atlantic [4].

These findings support the hypothesis that regional dynamics contribute to shaping the meridional structure of the AMOC while reflecting the influence of basin-scale forcing mechanisms. The study provides a consistent diagnostic basis for future investigations of overturning signal propagation and its relationship with climate variability. Ongoing work will focus on improving transport estimates using complementary inverse modelling approaches [4].

[1] L. D. Talley, Descriptive Physical Oceanography, Academic Press (2011).

[2] G. Forget, J.-M. Campin, P. Heimbach, C. N. Hill, R. Ponte, C. Wunsch, Geosci. Model Dev. **8**, 3071 (2015).

[3] J. R. Reagan, O. K. Seidov, T. P. Boyer, D. S. Locarnini, H. E. Garcia, A. V. Mishonov, NOAA Atlas NESDIS **90** (2023).

[4] C. Arumí, M. D. Pérez-Hernández, J. L. Pelegrí, P. Vélez-Belchí, M. Emelianov, V. Caínzos, L. Cana, Y. Firing, D. Santana-Toscano, A. Hernández-Guerra, J. Geophys. Res. Oceans **128**, e2022JC019614 (2023).

P20

Twenty Years of Atlantic Freshwater Meridional Transport and Budget from Argo Observations

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Freshwater transport in the South Atlantic is a key component of the Atlantic Meridional Overturning Circulation (AMOC) and, consequently, contributes to global climate regulation. Recent studies suggest that a significant trend in freshwater transport southwards across 34.5°S (the SAMBA line) in the Atlantic could act as an early warning signal of an AMOC tipping point, potentially leading to its collapse. However, understanding the implications of freshwater transport for the AMOC requires computing the freshwater budget within a closed system to ensure mass conservation. Due to the limitations and biases of models, observations such as Argo measurements are important sources of data for obtaining more reliable estimates of the trends and variability of this transport. Thus, our goal is to quantify the seasonal-to-interannual variability of the freshwater transport across the Rapid (26.5°N), TSAA (11°S) and SAMBA (34.5°S) arrays, and to compute the basin-scale freshwater budget to isolate oceanic and atmospheric contributions to freshwater content changes using derived RG Argo climatology compensated with WOA23 climatology as well as precipitation and evaporation from ERA5. Our preliminary results indicate a positive trend in southward freshwater transport, along with increases in the Meridional Overturning Circulation (MOC) and meridional heat transport across the Rapid, SAMBA, and TSAA arrays. Comparison with surface freshwater fluxes and freshwater divergence between the SAMBA and Rapid sections indicates that ocean circulation controls the freshwater balance in this basin, with a mean freshwater accumulation of 0.04 Sv. The results also suggest a freshening of the South Atlantic between the TSAA and SAMBA arrays, while the North Atlantic between Rapid and TSAA is becoming saltier. Thus, the freshwater fluxes in the South Atlantic reinforce the intensity of the MOC in the South Atlantic. In other words, an intensification of the southward freshwater flux results in a stronger MOC in the South Atlantic.

[1] Vanderborght, Elian, René M. van Westen, and Henk A. Dijkstra. "Feedback processes causing an amoc collapse in the community earth system model." *Journal of Climate* 38.19 (2025): 5083-5102.

[2] Arumí-Planas, C., Dong, S., Perez, R., Harrison, M. J., Farneti, R., Hernández-Guerra, A., 2024. A multi-data set analysis of the freshwater transport by the Atlantic meridional overturning circulation at nominally 34.5ºS. Journal of Geophysical Research: Oceans 129 (6), e2023JC020558.

P21

Drivers of variability in the Arctic overturning circulation

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The Arctic meridional overturning circulation (ArMOC) involves the production of water masses that are key to the global ocean circulation. The Arctic climate is, however, rapidly changing, and it is currently not known how the ArMOC is responding. Here, we investigate ArMOC variability between 1979 and 2024 in several reanalyses and hindcasts. The ArMOC variability is then compared to inverse-model based overturning estimates constrained by observations across the four major Arctic gateways. ArMOC variability is typically reported via the peak overturning streamfunction. We argue that this approach offers a limited perspective, and instead consider variability of the full streamfunction. Here we relate the ArMOC variability to changes in circulation strength, density, and sea ice extent. A regional decomposition highlights substantial variations in the local processes driving water mass transformation along distinct Atlantic Water pathways that collectively shape the ArMOC. In addition, we identify atmospheric forcing over the Nordic and Barents Seas as a major contributor to ArMOC variability. Our work highlights the dominant processes sustaining the ArMOC and contributes to understanding its evolution and resilience to ongoing Arctic climate change.

P22

The South Atlantic Meridional Overturning Circulation and Mesoscale Eddies in the First GO-SHIP Section at 34.5°S

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The variability of the Atlantic meridional overturning circulation (AMOC) has considerable impacts on the global climate system. Past studies have shown that changes in the South Atlantic control the stability of the AMOC and drive an important part of its variability. That is why significant resources have been invested in a South (S)AMOC observing system. In January 2017, the *RV Maria S. Merian* conducted the first GO-SHIP hydrographic transect along the SAMOC-Basin Wide Array (SAMBA) line at 34.5°S in the South Atlantic. This paper presents estimates of meridional volume, freshwater (MFT), and heat (MHT) transports through the line using the slow varying geostrophic density field and direct velocity observations. An upper and an abyssal overturning cell are identified with a strength of 15.64 ± 1.39 Sv and 2.4 ± 1.6 Sv, respectively. The net northward MHT is 0.27 ± 0.10 PW, increasing by 0.12 PW when we remove the observed mesoscale eddies with a climatology derived from the Argo floats data set. We attribute this change to an anomalous predominance of cold core eddies during the cruise period. The highest velocities are observed in the western boundary, within the Brazil and the Deep Western Boundary currents. These currents appear as a continuous deep jet located 150 km off the slope squeezed between two cyclonic eddies. The zonal changes in water masses properties and velocity denote the imprint of exchange pathways with both the Southern and the Indian oceans.

P23

HYDROGRAPHY AND GEOSTROPHIC CIRCULATION IN THE SOUTHERN GULF OF CALIFORNIA IN LATE WINTER

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The Gulf of California is a semi-enclosed, evaporative basin located between the Baja California Peninsula and the Mexican mainland, with a length of approximately 1,100 km and a maximum width of about 180 km at its mouth, covering an area close to 210,000 km^2 [3]. Its circulation exhibits pronounced seasonal variability, primarily driven by regional wind forcing and water exchange with the Pacific Ocean [1,2]. To characterize winter hydrography and geostrophic circulation in the southern Gulf of California, *in situ* conductivity–temperature–depth (CTD) measurements were collected at 64 hydrographic stations during February 2023 aboard the R/V *El Puma*. These observations were used to describe the vertical structure of temperature, salinity and density and to compute geostrophic currents relative to 500 m, following standard oceanographic methodology [4]. The results reveal the presence of six distinct water masses, with a well-defined mixed layer extending to depths of approximately 80–100 m. Within this layer, exchange with the Pacific Ocean is characterized by an inflow of relatively warm water along the Baja California Peninsula and a compensating outflow along the mainland coast. Below the mixed layer, the circulation becomes predominantly zonal, reflecting the influence of large-scale density gradients. In addition, the surface circulation along the gulf axis exhibits a sequence of four alternating cyclonic and anticyclonic eddies, consistent with winter circulation patterns previously documented for the southern Gulf of California [1,2].

References

[1] R. Castro, R. Durazo, A. Mascarenhas, C. A. Collins, A. Trasviña, *Deep Sea Res. Part I* **53**, 188 (2006).
[2] M. F. Lavín, S. G. Marinone, *Nonlinear Process. Geophys. Fluid Dyn.*, 173 (2003).
[3] J. Ledesma-Vázquez, M. E. Johnson, O. González-Yajimovich, E. Santamaría-del-Ángel, *Atlas of Coastal Ecosystems in the Western Gulf of California*, 1 (2009).
[4] S. Pond, G. L. Pickard, *Introductory Dynamical Oceanography*, Gulf Professional Publishing (1983).

P24

Kilometer Scale Modelling

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Extreme weather events, including floods and wildfires, are increasing in frequency and severity as a consequence of anthropogenic climate change - underscoring an urgent need for accurate, high-resolution regional climate simulations (Capua et al., 2023). Kilometer-scale (km-scale) climate models represent a significant advancement in this regard, enabling the explicit representation of deep convection, cloud microphysics, and complex topography, thereby producing more physically realistic and actionable climate projections. However, the feasibility of running such computationally demanding models remains largely untested in resource-constrained regions of the Global South, where data availability and high-performance computing (HPC) access are limited.

This study demonstrates the feasibility of km-scale regional climate modelling at the Centre for High-Performance Computing (CHPC) in South Africa. Using the Conformal Cubic Atmospheric Model (CCAM), we conduct weak scalability tests and evaluate model performance on the Lengau cluster across a range of resolutions and configurations. We then assess CCAM's ability to simulate key climate variables by comparing 4 km model output against ERA5 reanalysis (31 km) and CHIRPS high-resolution observational data (5 km) over East-Southern Africa.

CCAM demonstrates near-linear strong scaling up to approximately 384 processors, with performance degradation beyond 768 cores attributable to communication overheads. Higher output frequency reduces scalability, while increased vertical resolution improves computational efficiency, achieving up to approximately 10 simulated years per day (SYPD) at 50 km resolution. At 4 km resolution, CCAM produces a more realistic spatial distribution of precipitation and temperature over the domain compared to ERA5, despite exhibiting localised warm and wet biases. Notably, CCAM captures deep convective processes with greater fidelity, particularly over areas of complex terrain.

These results establish CHPC as a viable platform for km-scale regional climate modelling and provide a foundation for future high-resolution climate projections over Southern Africa - a region where improved climate information is critical for informing adaptation strategies in the face of accelerating climate change.

P25

Arctic Sea Ice Export Under Idealized CO_2 Emission Experiments from TIPMIP

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We analyse the changes in sea ice export across the main Arctic gateways using data from Earth System Models contributing to the Tipping Points Modelling Intercomparison Project (TIPMIP). The TIPMIP experiments are designed to support an assessment of abrupt/rapid Earth system change, the long-term response to zero CO2 emissions, and the reversibility of earth system change[1]. The TIPMIP ESM Tier 1 simulations that we analyse here include a pre-industrial control simulation (piControl), a positive CO2-emission experiment branching from the piControl simulation with warming rate of 2°C per century (ramp-up), zero-emission runs at different warming levels branched off from the ramp-up run, and a ramp-down simulations branched from the different zero emission runs using negative emissions. Preliminary results reveal strong weakening of sea ice volume and consequently sea ice export during the ramp-up simulation, followed by a complete disappearance at higher CO_2 concentrations in the final decades. In the ramp-down simulations, it recovers to values comparable to the piControl state, suggesting strong reversibility of the earth system. Additionally, we computed the Deep Mixed Volume (DMV) within the main convective areas of the region. The DMV exhibits changes similar to those described above for sea ice export, suggesting a potential linkage between these processes; however, further analysis is required to robustly establish this connection.

[1] Jones et al.: The TIPMIP Earth system model experiment protocol: phase 1, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2025-3604, (2025).

P26

Conservative compact coupled space-time constancy-preserving schemes for vertical transport in oceanic models

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The state-of-the-art coupled schemes, fail to retain the formal order of accuracy when used for nonlinear transport. This problem is fixed by developing a space-time generalization of the fourth-order semi-implicit conservative compact schemes in this study. The scheme is obtained in flux-form by correcting the successive error terms in Taylor series expansion in time and space. Space-time order of accuracy is successfully maintained for the solution of nonlinear scalar transport. The scheme is coupled in space and time, conservative in flux-form, semi-implicit in time, and compact due to its tri-diagonal matrix. The approach includes variable velocities and non-uniform grids on the adapted 1-D coordinate.
For example, vertical grid refinement for oceanic models remains an issue to consider in particular because it requires very robust numerics to properly integrate vertical advective terms in a stable way. Traditionally, centered advection schemes are used in the vertical to avoid excessive numerical mixing. It is shown that the coupled space-time schemes behave very well as expected with the increase of spatial and/or temporal resolutions. With this approach, high-order accuracy is retained for the variable velocity. An important feature of the scheme is that the high-order solution is obtained in one step in contrast to the decoupled schemes where the higher-order solutions are obtained in multiple stages (e.g. RK4). The scheme is very efficient due to the tri-diagonal matrix and stable in the range of Courant number up to 1 which is the domain of this study. Constancy of the scalar is preserved through the agreement of the advection and continuity equations or is imposed by the pseudo-density approach. It ensures the consistency of the solution and the order of accuracy. Furthermore, the stability and efficiency of the matrix inversion associated to the scheme is studied. For the application of the schemes for larger Courant numbers, there exist different methods that are being applied for the upcoming studies. A general form of 1D nonlinear advection along with continuity equation is shown for oceanic vertical transport, which is very important in the representation of physical processes in the ocean.

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Oceanographic data reveal deep waters warming along the south-western coast of Svalbard associated with inflow of Atlantic water driven by internal oscillations

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The West Spitsbergen Current (WSC) is the main pathway for the inflow of relatively warm and salty Atlantic Water (AW) into the Arctic Ocean, playing a crucial role in regional heat transport and mass transformation [1, 2]. In this study, we analysed the seasonal and interannual variability of thermohaline properties and ocean currents along the southwestern continental slope of Svalbard (Fram Strait, Arctic) using oceanographic data collected over a decade (2014–2024) from an oceanographic mooring together with outputs from atmospheric reanalyses and high-resolution ocean model.

Our findings indicate that the deep layer is mainly occupied by Norwegian Sea Deep Water, but is frequently disrupted by episodic intrusions of warmer, saltier, and less dense intermediate waters associated with AW. These intrusion events peak during winter (October–March) and show a significant interannual increase in frequency over the study period, although the average duration and ocean heat content do not exhibit significant long-term trends. The cumulative effect of these events is contributing to measurable warming of the deep layer (~0.07 °C per decade), consistent with recent observations [3, 4].

Atmospheric forcing is a key factor in variability across both short- and long-term timescales. Over a ten-year period, higher wind speeds and lower mean sea-level pressure are linked to more intense deep currents and greater AW intrusion. Short-term observations show that changes in wind patterns modulate dynamics, affecting exchanges between the continental shelf and slope, the formation of internal oscillations, and vertical mixing processes. Southerly winds favour deepening and intrusion of AW through intensified currents and increased sea surface height, while northerly winds promote changes in stratification, reduced mixing, and possible dense water upwelling.

These findings highlight the combined influence of atmospheric variability, mesoscale dynamics, and stratification in controlling deep-ocean processes along the continental slope southwest of Svalbard. The increasing frequency of AW intrusions and resulting deep-water warming emphasize the importance of slope processes in propagating Atlantification signals within the Arctic Ocean. Long-term continuous observations and integrated numerical modelling outputs are essential to better define the mechanisms governing vertical exchanges and their implications for the Arctic climate system.

[1] A. Beszczynska-Möller et al., ICES J. Mar. Sci. **69**, 852–863 (2012).
[2] M. Bensi et al., Water **11**, 683 (2019).
[3] I.V. Polyakov et al., Science **356**, 285-291 (2017)
[4] M. Årthun et al., Science Advances **11** (2025)

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THERMOHALINE STRUCTURE AND WATER MASSES IN THE VICINITY OF THE ANTARCTIC PENINSULA IN HIGHRESMIP/CMIP6 MODELS

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This study aims to evaluate the representation of the thermohaline structure and water masses in the vicinity of the Antarctic Peninsula in high-resolution global climate models, using observational data from the MEOP project (Marine Mammals Exploring the Oceans Pole to Pole) as a reference. The analysis covers four subareas with distinct oceanographic characteristics, including sectors of the Weddell and Bellingshausen Seas, as well as the northern and western Antarctic Peninsula. Six HighResMIP/CMIP6 models were analyzed: ECMWF-IFS-HR, BCC-CSM2-HR, CMCC-CM2-HR4, MPI-ESM1-2-HR, HadGEM3-GC31-HH, and EC-Earth3P-VHR, for the period from February to November 2008. CTD data from 22 instrumented southern elephant seals, provided by MEOP, were used, totaling 16,074 temperature and salinity profiles as a function of depth. The observational data were interpolated to the same vertical levels as the models and converted into absolute salinity, potential temperature, and potential density based on TEOS-10[1]. In parallel, model data were extracted at the closest geographical and temporal points to the observational profiles. After this processing, statistical metrics were applied to evaluate model performance, and θ-S diagrams were used to identify the water masses.The results indicate that HadGEM3-GC31-HH showed the best overall performance in representing water masses and the thermohaline structure, while MPI-ESM1-2-HR stood out in the simulation of salinity and water masses associated with shelf surface waters. In contrast, ECMWF-IFS-HR and EC-Earth3P-VHR showed weaker representations, especially for potential temperature. The best representations occurred in subareas A1, the Atlantic sector of the Southern Ocean north of the Weddell Sea, and A2, the northern Antarctic Peninsula, while the greatest limitations were observed in A3, the western Antarctic Peninsula, and A4, the Bellingshausen Sea. Overall, model performance was better during the austral winter than during the austral summer. The statistical metrics indicated that potential density was the best-represented variable, with correlation coefficients above 0.8 in most models, followed by salinity, while potential temperature showed larger biases, especially in the surface layers. It is concluded that the quality of the simulations does not depend exclusively on spatial resolution, but also on how oceanic physical processes are represented in the models[2].

[1] DINH, A. et al. Southern Ocean high-resolution (SOhi) modeling along the Antarctic Ice Sheet periphery. Geophysical Research Letters, v. 51, n. 3, e2023GL106377, 2024.

[2] ROBERTS, M. J. et al. Sensitivity of the Atlantic meridional overturning circulation to model resolution in CMIP6 HighResMIP simulations and implications for future changes. Journal of Advances in Modeling Earth Systems, v. 12, n. 8, 2020.

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Abstract template for Smr 4224 Activity

Title Banda Sea Salinity Maximum Evolution

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The Banda Sea, a semi-enclosed low-latitude basin, plays a crucial role in the Indonesian Throughflow (ITF) pathway, facilitating significant transformation of Pacific water masses. While prior research, based on limited historical data and models, suggested that intense, tidally-driven vertical mixing within the complex bathymetry of the archipelago erodes the distinct thermohaline signatures of Pacific waters (e.g., the prominent Salinity-maximum [S-max] >35 psu of subtropical Pacific waters) before they reach the export ITF passages, a detailed understanding of the persistence and vertical structure of these water masses in the Banda Sea has been hindered by a scarcity of long-term, high-resolution in situ observations.
This study investigates the evolution of the S-max in the Banda Sea, utilizing profiling floats that operated synchronously within the ITF region from 2022 to mid-2025. Our findings, for the first time, reveal a robust S-max imprint between October and February, residing at depths of 50–150 m in the Banda Sea. This depth range is shallower than that of Pacific subtropical waters, despite a concurrent net air-sea freshwater gain in the region. Strong vertical mixing in the Banda Sea, evidenced by turbulence kinetic energy dissipation rates exceeding 10^{-6} m^2s^{-3}, entrains salty subtropical Pacific water upward from the lower thermocline, explaining the relatively shallow S-max observed. This work demonstrates that the subtropical Pacific S-max is not entirely eroded, contrary to previous assumptions, and confirms the ITF eastern route as a key conduit for salt flux into the Indian Ocean.

Keywords: Banda Sea, profiling floats, Salinity Maximum, Indonesian Throughflow.

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Impact of Assimilating Observed Salinity on Indian Ocean Using MOM5-GODAS

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Salinity plays a crucial role in regulating upper-ocean stratification, circulation, and air–sea interactions in the Indian Ocean, particularly over the northern basin where strong freshwater forcing influences ocean dynamics. In this study, the impact of assimilating observed salinity on ocean analysis is investigated using a MOM5-based Global Ocean Data Assimilation System (GODAS) with focus on the Indian Ocean region.

Two experiments were conducted for the period 2003–2009: (i) assimilation of observed temperature and salinity profiles from in-situ platforms including Argo, XBT, XCTD, buoys, and moorings, and (ii) assimilation of observed temperature along with synthetic salinity profiles derived from temperature observations. Outputs from both experiments were evaluated against independent datasets including EN4 salinity analysis, OSCAR surface currents, and ADCP observations from RAMA moorings.

Results show that assimilating observed salinity significantly improves the representation of salinity across the Indian Ocean, with reduced RMSE compared to the synthetic salinity experiment. Notable improvements are also seen in upper-ocean currents, both spatially compared to OSCAR and in subsurface current profiles from ADCP observations. In contrast, SST and temperature fields show little difference between the two experiments.

This study demonstrates that assimilating actual salinity observations enhances upper-ocean state estimation and circulation variability in the Indian Ocean. The findings highlight the importance of sustained salinity observations for advancing ocean reanalysis and prediction systems, and provide new insights into the role of freshwater forcing in shaping Indian Ocean dynamics.

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Comparing AMOC in Depth and Density Space Using CESM Pre-Industrial High- and Low-Resolution Simulations

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The Atlantic meridional overturning circulation (AMOC) differs from other meridional overturning circulations by transporting heat northward, regardless of hemisphere. This transport is vital for the interhemispheric energy budget and plays a significant role in determining the position of the intertropical convergence zone. Given its importance for the climate, the AMOC has been the subject of extensive research in recent decades, from both modeling and observational perspectives. However, different methodological approaches can yield different interpretations of the same phenomenon. Some studies indicate that the AMOC calculated in depth space differs from that obtained in density space, particularly in regions of strong mixing, where isopycnals are more vertical. This suggests that using density space for AMOC analysis may be advantageous, as it reduces cancellations in North Atlantic volume transport. In this study, we compare the AMOC computed in density and depth spaces using high-resolution (nominal 0.1°, eddy-resolving) and low-resolution (nominal 1°, coarse-resolution) simulations from the Community Earth System Model (CESM), covering 350 years of pre-industrial conditions. We find that the location of overturning in the North Atlantic is farther north in density space than in depth space for both resolutions. For both methods, the upper (abyssal) cell weakens (strengthens) with increasing resolution. Higher resolution also introduces greater variability, particularly in the abyssal cell, which is reflected in both AMOC calculation methods. Differences between the two resolutions in the strength of the AMOC in depth space at the latitudes of RAPID and SAMBA are more pronounced than in density space. Finally, the high-resolution simulation in depth space shows the greatest meridional coherence of the AMOC. Our results emphasize that using different frameworks and model resolutions can significantly alter our understanding of the AMOC.

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Preliminary Analysis of Dissolved Oxygen Variability in the Southwest South Atlantic

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Studying the variability of biogeochemical properties in the ocean is relevant for improving regional and global climate assessments, enhancing the identification of water masses, and analyzing changes in the productivity of marine ecosystems [1]. Oxygen concentrations in the ocean are declining as a result of global warming, changes in stratification, and other factors. In particular, the continental shelf and slope regions in the northern Southwest Atlantic have been identified as areas where oxygen has decreased [2] and as a hotspot in terms of global climate change trends, where the ocean is warming faster than in adjacent regions, particularly in the Brazil Current region and the Brazil-Malvinas Confluence [3][4]. However, very little is known about the temporal evolution and spatial distribution of dissolved oxygen variability and the impacts of ocean warming on ocean stratification and associated potential deoxygenation processes regionally. Here we analyze in situ hydrographic profiles of temperature, salinity, and dissolved oxygen collected during oceanographic surveys in the Southwest Atlantic from 1950 to the present. The main tasks consisted of a comprehensive analysis of data availability and a preliminary assessment of the spatial and temporal variability of the analyzed properties in different regions selected according to the oceanic dynamics: Brazil Current in the subtropical South Atlantic; offshore of Río de la Plata; Northern Patagonian Shelf; Southern Patagonian Shelf; and the Malvinas Islands. The results indicate significant horizontal and depth-related spatial variability. A substantial interannual variability was observed in all study regions, while the robust detection of long-term trends may be limited by the irregular distribution and frequency of sampling. Ongoing work will extend the analyses using oceanic gridded products, which use sophisticated interpolation techniques (e.g., AI/ML techniques) to fill in gaps where data are scarce, and biogeochemical Argo floats. These analyses complement ongoing efforts to increase biogeochemical monitoring in the transport mooring arrays.

[1] C. Garcia-Soto et al., Front. Mar. Sci. **8**, 642372 (2021).
[2] D. Breitburg et al., Science **359**, 6371 (2018).
[3] D. B. Risaro et al., Front. Mar. Sci. **9**, 829144 (2022).
[4] M. P. Chidichimo et al., Comm. Earth & Environ. **4**, 10 (2023).

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Impact of South Atlantic Marine Heatwaves on Seasonal Climate Prediction over South America using MONAN/MPAS-A

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Marine heatwaves (MHWs) are persistent oceanic extreme events characterized by anomalously high sea surface temperature (SST), with potential impacts on air-sea interactions and regional climate variability [1]. In the South Atlantic, recent studies have shown that MHWs can influence atmospheric circulation, precipitation patterns, and extreme events over South America. For example, Rodrigues et al. [2] associated a severe South Atlantic MHW during the 2013/2014 summer with persistent atmospheric blocking, suppression of the South Atlantic Convergence Zone, and severe drought conditions in southeastern Brazil. More recent studies have also indicated that MHWs in the South Atlantic are becoming more frequent, intense, and long-lasting, reinforcing the need to understand their role in seasonal predictability [3,4]. Despite this relevance, conventional seasonal prediction approaches often prescribe fixed or persistent SST anomalies, which may not properly represent the daily to subseasonal variability associated with MHWs. This study investigates the impact of South Atlantic MHWs on seasonal climate prediction using the Model for Prediction Across Scales in its atmospheric configuration (MONAN/MPAS-A) [5]. Two paired seasonal experiments are proposed: EXP_SEASON, forced with daily climatological SST plus persistent seasonal mean anomalies, and EXP_OCM, forced with daily SST fields containing MHW-related anomalies identified using a percentile-based methodology [1]. Both experiments use the same atmospheric initial conditions, allowing the atmospheric response to MHW variability to be isolated. The analysis will focus on changes in atmospheric circulation, precipitation, and pressure fields over South America, with particular attention to mechanisms related to blocking patterns, moisture transport, and the South Atlantic Convergence Zone. By comparing simulations with and without daily MHW anomalies, this work aims to assess whether these events act as relevant oceanic forcings for seasonal atmospheric variability and to support future improvements in regional climate prediction systems.

[1] A. J. Hobday et al., Prog. Oceanogr. 141, 227 (2016).
[2] R. R. Rodrigues, A. S. Taschetto, A. Sen Gupta, and G. R. Foltz, Nat. Geosci. 12, 620–626 (2019).
[3] C. Artana, R. R. Rodrigues, J. Fevrier, and M. Coll, Commun. Earth Environ. 5, 555 (2024).
[4] R. R. Rodrigues et al., Nat. Commun. 16, 1–15 (2025).
[5] W. C. Skamarock et al., Mon. Weather Rev. 140, 3090 (2012).

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The OGSTM-BFM model provides a service consisting of forecast, analysis [1] and reanalysis [2] of different biogeochemical variables which are important for monitoring marine ecosystems (life and environment conditions that allow and sustain life itself) since 2007 [3]. Its products are made available through the European Copernicus Marine Service (CMS) and, in the simplest approach, can be visualized as maps of biogeochemical properties of the Mediterranean Sea at different depth levels.

Data Assimilation (DA) [4] is a technique utilized to optimize the model parameters based on the fundamental constraint that model results must be kept as close as possible to the values of the observed data sets. Several upgrades have been implemented for DA: one of the most recent uses a Multi-Layer Neural Network to obtain artificial profiles of Nitrate concentrations from Oxygen Argo float profiles [5]. The synthetic Nitrate profiles can be utilized for more precise DA.
Recently, a Data Informed Inversion Model (DIIM) was developed within the NeCCTON project [6,7]. It is utilized to determine the concentrations of different biogeochemical components from the reflectance values given by satellite measurements. It was validated through comparison of Chlorophyll-A values against the ones from state-of-the-art DA algorithms used within CMS, aiming to strengthen the existing DA algorithms.

This work aims at illustrating the status of the OGSTM-BFM model workflow for what concerns data assimilation (DA) techniques and inverse models.

[1] Mediterranean Sea Biogeochemistry Analysis and Forecast DOI (Product): https://doi.org/10.48670/mds-00358.
[2] Mediterranean Sea Biogeochemistry Reanalysis DOI (Product): https://doi.org/10.48670/mds-00374.
[3] Pre-operational short-term forecasts for Mediterranean Sea biogeochemistry, Lazzari, Teruzzi, Salon et al., 2010, DOI: https://doi.org/10.5194/os-6-25-2010.
[4] A 3-D variational assimilation scheme in coupled transport-biogeochemical models: Forecast of Mediterranean biogeochemical properties, Teruzzi et al., 2014, DOI: https://doi.org/10.1002/2013JC009277.
[5] Combining neural networks and data assimilation to enhance the spatial impact of Argo floats in the Copernicus Mediterranean biogeochemical model, Amadio et al., 2024, DOI: https://doi.org/10.5194/os-20-689-2024.
[6] Determination of biogeochemical properties in sea waters using the inversion of the three-stream irradiance model, Lazzari et al., 2024, DOI: https://doi.org/10.1038/s41598-024-71457-5.
[7] Data-Informed Inversion Model (DIIM): a framework to retrieve marine optical constituents using a three-stream irradiance model, Soto et al., 2025, DOI: https://doi.org/10.5194/gmd-18-7575-2025.

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Oceanographic investigation in the atlantic sea: : ocean-depth trans-basin measurements

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After many decades of oceanographic investigations, the consideration of the Atlantic sea cannot longer be maintained. The Atlantic is a changing environment. Several dramatic changes in the oceanographic and biogeochemical conditions have been observed during the past decades, emphasizing the need to investigate more thoroughly and understand the changing conditions and their drivers. The South Atlantic is a crossroad for water masses from the Southern, the Indian and the North Atlantic oceans. This paper aims to analyze the ocean-depth trans-basin measurements of the southernmost enclosed section of the Atlantic between South Africa and Brazil. Our results confirm a northward transport of heat at certain latitude.

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Northward pathways of Antarctic Bottom Water from the Vema Channel: A Lagrangian Perspective

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The South Atlantic links central water mass formation areas to the North Atlantic within the Meridional Overturning Circulation (MOC). In this basin, the MOC is organized into three layers: upper, intermediate, and abyssal, which are dynamically connected [1]. Both the upper and abyssal branches flow northward, with the latter transporting Antarctic Bottom Water (AABW) formed in Antarctic regions. As the densest water mass in the global ocean, AABW is central to ventilating the abyssal ocean and regulating the storage and redistribution of heat and carbon [2]. Despite significant advances in monitoring the South Atlantic MOC through observational programs such as the SAMOC/SAMBA array at 34.5°S, which have revealed its strong variability across multiple timescales [3], these efforts primarily provide an Eulerian perspective of the circulation. As a result, while the large-scale transport and variability of the overturning are relatively well constrained, the Lagrangian pathways that connect key regions of water mass formation and transformation remain poorly understood. This study investigates the pathways and transformation of AABW after it exits the Vema Channel and flows northward within the Brazil Basin, focusing on identifying regions of systematic upwelling along its trajectory and assessing the extent to which vertical mixing contributes to this upwelling. We evaluate GLORYS and OFES in terms of their representation of AABW, focusing on how well they reproduce the Vema Channel topography and the associated volume transport through the channel, in order to select the most suitable velocity fields for Lagrangian advection experiments. As part of the Lagrangian analysis, we perform a test experiment in which particles are released along a longitudinal section in the Vema Channel, covering the full vertical extent of the AABW layer. Releases are performed monthly over the course of one year, and the particles are then advected for 10 years. The number of particles in each grid cell is set proportional to the local volume transport, so that regions with stronger flow are better represented and the resulting trajectories reflect the actual transport of AABW. This transport-weighted release also allows the trajectories to be interpreted in terms of a Lagrangian streamfunction, providing a dynamically consistent view of the pathways and their contribution to the overall flow. Preliminary results are expected to quantify the main northward pathways of AABW after crossing the Vema Channel, including their spatial distribution, relative transport, and connectivity toward the subtropical and equatorial Atlantic. The analysis will also identify preferential regions of upwelling along these pathways and estimate the associated changes in depth. In addition, the results will help assess how much vertical mixing contributes to the transformation of AABW as it propagates northward.

[1] Kersalé, M. et al. "Highly variable upper and abyssal overturning cells in the South Atlantic." Science Advances (2020), 6(32).

[2] Ferrari, Raffaele, et al. "Antarctic sea ice control on ocean circulation in present and glacial climates." Proceedings of the National Academy of Sciences 111.24 (2014): 8753-8758.

[3] Chidichimo, María Paz, et al. "Energetic overturning flows, dynamic interocean exchanges, and ocean warming observed in the South Atlantic." Communications Earth & Environment 4.1 (2023): 10.

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The interaction between the Amazon rainforest and the Atlantic Meridional Overturning Circulation (AMOC)

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The Atlantic Meridional Overturning Circulation (AMOC) is a major component of the global ocean circulation and plays a crucial role in regulating Earth's climate. Similarly, the Amazon Rainforest (ARF), often referred to as the "lungs of the planet", is a key regulator of the global carbon and hydrological cycles. Both systems are considered to be climate tipping elements, characterised by the existence of multiple equilibrium states separated by a critical threshold. Anthropogenic climate change is pushing these systems closer to their respective tipping points, potentially leading to an AMOC slowdown or collapse and a transition of the Amazon from a rainforest to a savanna-like state.

While the AMOC and the ARF have been widely studied separately, their potential interactions remain poorly understood. Rising global temperatures are associated with reduced precipitation over the Amazon and a weakening of the AMOC. These coupled changes suggest two-way interactions, as AMOC weakening can decrease rainfall over the Amazon, while changes in Amazon vegetation can affect AMOC strength, potentially stabilising the climate system or triggering a tipping cascade. In this study, we investigate whether changes in the Amazon Rainforest can influence the stability of the AMOC.

We use the Community Earth System Model (CESM) to perform a set of numerical experiments in which the Amazon region is prescribed with different land-cover states, representing rainforest and grassland conditions. By comparing these experiments, we investigate the climate response to prescribed Amazon vegetation changes and their influence on large-scale atmospheric and ocean circulation.

Our results show that replacing rainforest with grassland leads to a global increase in near-surface air temperature, with the strongest warming occurring over the Amazon region. This transition is associated with pronounced changes in precipitation patterns and atmospheric moisture transport. These findings indicate a potential coupling between Amazon land-cover changes and large-scale climate dynamics, suggesting that Amazon tipping may have implications for AMOC stability.

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How Low Can You Go: Reduced Complexity Modelling of Global Carbon Transportation Timescales - Abstract

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Exceeding 1.5°C above pre-industrial levels has sharpened scrutiny of the Paris Agreement goals and, consequently, the assumptions through which net-zero carbon emissions are evaluated and accounted[1]. The emergence of cumulative carbon budgets established that peak CO_2-induced warming is better constrained by cumulative emissions than by concentration stabilisation pathways[2–4]. This highlights the persistent accounting problem found within annual reports of governing bodies and conglomerates that treat passive carbon uptake by natural sinks as equivalent to active anthropogenic carbon dioxide removal, particularly where residual fossil emissions continue to drive warming[5,6]. These questions are especially important for the ocean, which remains one of the largest active sinks of anthropogenic carbon, yet whose future uptake, permanence, and response to proposed marine carbon dioxide removal pathways remain uncertain[7].

This project develops a hierarchy of approaches for representing post-emissions ocean carbon uptake. We use the Zero Emissions Commitment Model Intercomparison Project (ZECMIP) dataset as a benchmark for FaIROcean, a reduced-complexity model designed to capture ocean carbon uptake through physically interpretable response timescales[8–10]. In doing so, the project builds on the impulse-response tradition used to represent carbon-cycle adjustment in simple climate models, while asking how far such fitted timescales can be connected to identifiable oceanographic processes[11].

The second stage of the work aims to connect these response timescales to ocean transport mechanisms more explicitly, through an adaptation of the Marshall and Zanna conceptual framework and the Gnanadesikan model of ocean circulation, constrained using WOCE hydrographic observations and extended to include eddy parameterisation[12–14]. Rather than treating fast, multidecadal, and long-term uptake modes as purely empirical fitting terms, this work asks how they relate to ventilation, stratification, overturning, and eddy-mediated exchange.

By placing FaIROcean within a broader hierarchy of ocean carbon models, this project aims to bridge policy-facing climate emulation and observationally informed physical oceanography. The broader objective is to improve how simplified models represent the ocean's role in post-net-zero climate evolution, particularly where long-term carbon storage, marine carbon dioxide removal, and net-zero accounting depend on assumptions about the persistence and efficiency of the ocean carbon sink.

References

[1] Copernicus Climate Change Service. 2024 is the first year to exceed 1.5°c above pre-industrial level, January 2025. URL `https://climate.copernicus.eu/copernicus-2024-first-year-exceed-15degc-above-pre-industrial-level`. Accessed 15 May 2026.

[2] Myles R. Allen, David J. Frame, Chris Huntingford, Chris D. Jones, Jason A. Lowe, Malte Meinshausen, and Nicolai Meinshausen. Warming caused by cumulative carbon emissions towards the trillionth tonne. *Nature*, 458(7242):1163–1166, 2009. doi:10.1038/nature08019. URL `https://doi.org/10.1038/nature08019`.

[3] H. Damon Matthews, Nathan P. Gillett, Peter A. Stott, and Kirsten Zickfeld. The proportionality of global warming to cumulative carbon emissions. *Nature*, 459 (7248):829–832, 2009. doi:10.1038/nature08047. URL https://doi.org/10.1038/nature08047.

[4] Kirsten Zickfeld, Michael Eby, H. Damon Matthews, and Andrew J. Weaver. Setting cumulative emissions targets to reduce the risk of dangerous climate change. *Proceedings of the National Academy of Sciences*, 106(38):16129–16134, 2009. doi:10.1073/pnas.0805800106. URL https://doi.org/10.1073/pnas.0805800106.

[5] Myles R. Allen, Pierre Friedlingstein, Cécile A. J. Girardin, Stuart Jenkins, Yadvinder Malhi, Eli Mitchell-Larson, Glen P. Peters, and Lavanya Rajamani. Net zero: Science, origins, and implications. *Annual Review of Environment and Resources*, 47:849–887, 2022. doi:10.1146/annurev-environ-112320-105050. URL https://doi.org/10.1146/annurev-environ-112320-105050.

[6] Myles R. Allen, David J. Frame, Pierre Friedlingstein, Nathan P. Gillett, Giacomo Grassi, Jonathan M. Gregory, William Hare, Jo House, Chris Huntingford, Stuart Jenkins, Chris D. Jones, Reto Knutti, Jason A. Lowe, H. Damon Matthews, Malte Meinshausen, Nicolai Meinshausen, Glen P. Peters, Gian-Kasper Plattner, Sarah Raper, Joeri Rogelj, Peter A. Stott, Susan Solomon, Thomas F. Stocker, Andrew J. Weaver, and Kirsten Zickfeld. Geological net zero and the need for disaggregated accounting for carbon sinks. *Nature*, 638:343–350, 2025. doi:10.1038/s41586-024-08326-8. URL https://doi.org/10.1038/s41586-024-08326-8.

[7] Scott C. Doney, Wiley H. Wolfe, Darren C. McKee, and Jay G. Fuhrman. The science, engineering, and validation of marine carbon dioxide removal and storage. *Annual Review of Marine Science*, 17:55–81, 2025. doi:10.1146/annurev-marine-040523-014702. URL https://doi.org/10.1146/annurev-marine-040523-014702.

[8] Chris D. Jones, Thomas L. Frölicher, Charles Koven, Andrew H. MacDougall, H. Damon Matthews, Kirsten Zickfeld, Joeri Rogelj, Katarzyna B. Tokarska, Nathan P. Gillett, Tatiana Ilyina, Malte Meinshausen, Nadine Mengis, Roland Séférian, Michael Eby, and Friedrich A. Burger. The zero emissions commitment model intercomparison project (zecmip) contribution to c4mip: quantifying committed climate changes following zero carbon emissions. *Geoscientific Model Development*, 12: 4375–4385, 2019. doi:10.5194/gmd-12-4375-2019. URL https://doi.org/10.5194/gmd-12-4375-2019.

[9] Andrew H. MacDougall, Thomas L. Frölicher, Chris D. Jones, Joeri Rogelj, H. Damon Matthews, Kirsten Zickfeld, Vivek K. Arora, Nicholas J. Barrett, Victor Brovkin, Friedrich A. Burger, Michael Eby, Alexey V. Eliseev, Tomohiro Hajima, Philip B. Holden, Aurich Jeltsch-Thömmes, Charles Koven, Nadine Mengis, Laurie Menviel, Martine Michou, Igor I. Mokhov, Akira Oka, Jörg Schwinger, Roland Séférian, Gary Shaffer, Andrei Sokolov, Kaoru Tachiiri, Jerry Tjiputra, Andrew Wiltshire, and Tilo Ziehn. Is there warming in the pipeline? a multi-model analysis of the zero emissions commitment from co_2. *Biogeosciences*, 17:2987–3016, 2020. doi:10.5194/bg-17-2987-2020. URL https://doi.org/10.5194/bg-17-2987-2020.

[10] Nicholas J. Leach, Stuart Jenkins, Zebedee Nicholls, Christopher J. Smith, John Lynch, Michelle Cain, Tristram Walsh, Bill Wu, Junichi Tsutsui, and Myles R.

Allen. Fairv2.0.0: a generalized impulse response model for climate uncertainty and future scenario exploration. *Geoscientific Model Development*, 14:3007–3036, 2021. doi:10.5194/gmd-14-3007-2021. URL https://doi.org/10.5194/gmd-14-3007-2021.

[11] Fortunat Joos, Reto Roth, Jan S. Fuglestvedt, Glen P. Peters, Ian G. Enting, Werner von Bloh, Victor Brovkin, Eleanor J. Burke, Michael Eby, Neil R. Edwards, Tobias Friedrich, Thomas L. Frölicher, Paul R. Halloran, Philip B. Holden, Chris Jones, Thomas Kleinen, Fred T. Mackenzie, Katsumi Matsumoto, Malte Meinshausen, Gian-Kasper Plattner, Andy Reisinger, Joachim Segschneider, Gary Shaffer, Marco Steinacher, Katherina Strassmann, Katsumasa Tanaka, Axel Timmermann, and Andrew J. Weaver. Carbon dioxide and climate impulse response functions for the computation of greenhouse gas metrics: a multi-model analysis. *Atmospheric Chemistry and Physics*, 13:2793–2825, 2013. doi:10.5194/acp-13-2793-2013. URL https://doi.org/10.5194/acp-13-2793-2013.

[12] David P. Marshall and Laure Zanna. A conceptual model of ocean heat uptake under climate change. *Journal of Climate*, 27(22):8444–8465, 2014. doi:10.1175/JCLI-D-13-00344.1. URL https://doi.org/10.1175/JCLI-D-13-00344.1.

[13] Anand Gnanadesikan. A simple predictive model for the structure of the oceanic pycnocline. *Science*, 283(5410):2077–2079, 1999. doi:10.1126/science.283.5410.2077. URL https://doi.org/10.1126/science.283.5410.2077.

[14] K. P. Koltermann, V. V. Gouretski, and K. Jancke. *Hydrographic Atlas of the World Ocean Circulation Experiment (WOCE), Volume 3: Atlantic Ocean*. International WOCE Project Office, Southampton, UK, 2011. ISBN 090417557X. URL https://woceatlas.tamu.edu/.

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Outflows of Gulf of Mexico Waters Through the Yucatan Channel Suggested by Biogeochemical Tracers and Hydrography

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Based on data collected during two summer cruises in the Gulf of Mexico (GoM), an extended optimum multiparameter analysis (eOMP) was applied in order to quantify the mixing of water masses and to estimate nutrient concentration changes through biogeochemical processes within the gulf. The eOMP results from the Yucatan Channel west of 85.9° W and the slope of the isopycnals were used to infer the inflow/outflow of water properties below the mixed layer. A decreasing gradient into the GoM in the contribution of the three water masses dominating the thermocline, i.e., the North Atlantic Subtropical Water, the Eighteen-degree Mode Water and the Tropical Atlantic Central Water, reflect the inflow of the Yucatan currents. Below 600 m, waters were characterized by relatively high nitrate and silicate concentrations indicating an enrichment within the GoM that is not explained only from mixing. The presence of nutrient enriched waters reflects an outflow between 700 and 1200 m, where the Antarctic Intermediate water mass has a large contribution (~70%) between 700-800 m and the North Atlantic Deep water mass dominates below 800 m. Particularly noticeable is the enrichment in silicate in the deep water of the basin where its concentration remains constant (~25-26 µmol kg^{-1}) below ~1200 m, however, the source of enrichment has yet to be determined. Our results show that nutrients and dissolved oxygen are useful in tracing water mass exchange through the Yucatan Channel and can complement direct current measurements. However, higher spatial and temporal sampling resolution is required to better understand the complex water exchange with the Caribbean basins.

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The impact of storm Minerva on the upper layer of the Mediterranean Sea

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In May 2023, a low-pressure system named Minerva brought heavy rainfall and strong winds to Italy and neighbouring countries, resulting in widespread damage and tragic loss of life.

During this event, autonomous instruments, along with satellite and modelling products, monitored the Tyrrhenian Sea, the Sicily Channel, the Ionian Sea and the south Adriatic Sea. In this work, we have combined these data to investigate the physical and biogeochemical responses of the upper layer of the Mediterranean Sea to Storm Minerva.

The upper ocean feedback typically consists of the sea surface cooling and subsurface warming ("heat pump" effect) [1], driven by a combination of different physical processes. This effect can be more or less pronounced and can have different characteristics depending on the oceanic conditions encountered by the storm on its path [1,2].

Our findings reveal that Minerva triggered three different responses in the subbasins studied, which were influenced by the circulation structures and thermohaline conditions in the affected areas. This result underscores the importance of understanding the regional oceanographic characteristics when assessing the impacts of extreme weather events and how this information contributes to improved forecasting and mitigation strategies for future events.

[1] Han Zhang, Hailun He, Wen-Zhou Zhang, Di Tian, Upper ocean response to tropical cyclones: a review, Geosci. Lett. 8, 1 (2021)

[2] Babita Jangir, Marco Reale, Milena Menna, Alok Kumar Mishra, Riccardo Martellucci, Gianpiero Cossarini, Stefano Salon, Elena Mauri, Ehud Strobach, The Response of the Physical and Biogeochemical Marine Environment to the Passage of Mediterranean Cyclones in the Presence of Eddies, Gyres, and Marine Heat Wave, Journal of Geophysical Research: Oceans, 131, 2 (2026)

P41

A multiscale Gaussian process regression framework for high-resolution gridded sea surface temperature products derived from satellite observations

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Sea surface temperature (SST) is a key tracer of processes that exchange heat, momentum, and moisture between the ocean and atmosphere across many spatial and temporal scales. Infrared (IR) satellite radiometers provide SST observations at ~1 km resolution, but are frequently obscured by clouds; microwave radiometers penetrate cloud cover but are limited to ~25 km resolution. High-resolution, gap-free, gridded SST maps that retain the fine-scale variability of IR observations are essential for studying the role of small-scale ocean surface processes in weather and climate, yet existing fusion methods are computationally expensive and rarely provide rigorous uncertainty estimates.

We present a multiscale Gaussian process (GP) regression framework that reconstructs daily SST and corresponding analytic gradient estimates at 2 km resolution with inherent probabilistic uncertainty quantification. First, we construct a large-scale climatological mean field by fitting local polynomial regressions in a sliding window approach [1, 2] from low-resolution microwave data, which we subtract from the observations to isolate SST anomalies. We then train a convolutional neural network to approximate the likelihood-to-evidence ratio [3] for the covariance parameters of a hierarchical GP model with a locally stationary, differentiable, anisotropic covariance function, using synthetic SST observations that span the full parameter space and contain realistic missing data patterns [4-7]. The trained neural surrogate model enables rapid inference of local covariance parameters from SST anomaly data, first at low-resolution (10 km) and then at high-resolution (2 km). Using these parameter estimates, we construct daily SST anomaly and corresponding gradient maps at multiple scales and merge them with the climatology to obtain daily, gap-free 2 km resolution SST and SST gradient maps, along with full pixel-wise uncertainty fields from the posterior GP variance.

[1] M. Kuusela, M. Stein, Proc. R. Soc. A. **474**(2220), 20180400 (2018).
[2] B. Park, *et al.*, Ann. Appl. Stat. **17**(2), 1491-1520 (2023).
[3] J. Walchessen, A. Lenzi, M. Kuusela. Spat. Stat. **62**, 100848 (2024).
[4] J. Richards, *et al.*, J. Mach. Learn. Res., **25**(390), 1-49 (2024).
[5] Z. Wang, J. Hasenauer, Y. Schälte, PLoS Comput. Biol., **20**(6), e1012184 (2024).
[6] M. Sainsbury-Dale, *et al.*, arXiv:2501.04330 [stat.ME] (2026).
[7] J. Walchessen, Carnegie Mellon Univ. Thesis. (2025).

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On the reliability of reanalysis-derived heat transport in the North Atlantic

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The North Atlantic is a key region of the climate system, where ocean circulation redistributes heat across latitudes and drives pronounced variability on interannual to multidecadal time scales. Observational programs have provided valuable insights into Atlantic circulation and variability, but their spatial and temporal coverage remains limited. Global ocean reanalyses offer a complementary, spatially complete view of the ocean and therefore provide potentially valuable tools to investigate heat transports and their variability in the North Atlantic.

This contribution aims to provide a clear and quantitative assessment of the usefulness and reliability of ocean reanalyses for diagnosing ocean heat transport and its variability in the North Atlantic. It is carried out within the framework of the Marine Environment Reanalyses Evaluation Project (MER-EP), which aims to systematically evaluate and intercompare global marine reanalyses. By systematically comparing multiple reanalyses with observational and budget-based constraints, we aim to identify where and under which conditions reanalysis-derived transport estimates are robust and where important limitations remain. This assessment is essential for the appropriate use of ocean reanalyses in studies of North Atlantic variability and its role in climate change.

We evaluate ocean heat transport and related diagnostics in the North Atlantic using a large ensemble of global ocean reanalyses from different modelling centers. Transport calculations are performed using the newly developed StraitFlux (Winkelbauer et al. 2024) diagnostic framework, which enables consistent transport estimates across different model grids and vertical coordinate systems.

Our analysis focuses on the North Atlantic sector and its variability, with particular attention to major observing systems such as RAPID, SAMBA, OSNAP (Winkelbauer et al., 2026) and transports across the Greenland-Scotland Ridge, Fram Strait and the Barents Sea Opening. In addition to transports obtained from ocean reanalyses and insitu observations, we estimate meridional ocean heat transport indirectly from the ocean heat budget. These inferred transports are obtained by combining surface heat fluxes inferred from the atmospheric energy budget, ocean heat content tendencies and contributions from sea ice melt, and by imposing appropriate boundary conditions at basin chokepoints. This approach provides complementary ocean heat transport estimates that are largely independent of both the reanalysis circulation fields and the insitu observations. It allows to assess ocean reanalysis performance consistently across the entire North Atlantic, including regions and latitude bands where no insitu transport measurements are available.

Winkelbauer, S., Mayer, M., and Haimberger, L.: StraitFlux – precise computations of water strait fluxes on various modeling grids, Geosci. Model Dev., 17, 4603–4620, https://doi.org/10.5194/gmd-17-4603-2024, 2024.
Winkelbauer, S., Winterer, I., Mayer, M., Fu, Y., and Haimberger, L.: Subpolar Atlantic meridional heat transports from OSNAP and ocean reanalyses – a comparison, Ocean Sci., 22, 629–651, https://doi.org/10.5194/os-22-629-2026, 2026.

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Multidecadal overturning variability linked to subpolar North Atlantic–Nordic Seas exchanges

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The Atlantic Meridional Overturning Circulation (AMOC) transports warm, saline waters northward near the surface and returns cold, dense waters southward at depth. As a key component of the global climate system, understanding the dominant drivers of AMOC variability and long-term trends is crucial. However, the AMOC exhibits pronounced decadal to multi-decadal variability, making it challenging to detect persistent trends. One potential source of this variability is the formation of dense water at high northern latitudes, particularly in the subpolar North Atlantic and the Nordic Seas. The mechanisms linking subpolar North Atlantic-Nordic Seas exchanges to large-scale AMOC variability nevertheless remain poorly understood. Here, we investigate multidecadal variability of the overturning circulation using the new CoRea1860+ coupled reanalysis spanning 1860-2022. Using low-frequency component analysis, we identify a mode of variability that captures multidecadal AMOC variability and trends. During its positive phase, a strengthening of the AMOC lower limb in the subpolar North Atlantic is preceded by overturning changes in the Nordic Seas and enhanced transport of dense waters across the Greenland-Scotland ridge and OSNAP sections. Our findings indicate that variability originating in the Nordic Seas acts as a key driver of multidecadal AMOC variability.

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Contributions of Indo-Pacific forcings to interannual variability of the Indonesian Throughflow in the upper and lower layers

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The paper uses reanalysis data and model outputs to quantify relative contributions of the El Niño-Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) to the vertical structure variability of the Indonesian Throughflow (ITF) using multiple regression analysis. In comparing ENSO to IOD events, it becomes evident that ENSO plays a more significant role in ITF upper layer (0-300 m) transport, while the IOD has a greater impact on ITF lower layer (300-760 m) transport. Given the larger anomaly in ITF upper layer transport, ENSO dominates the interannual variability of ITF transport. Moreover, ITF transport is influenced by different physical processes associated with varying phases of ENSO and the IOD. The month-by-month contributions reveal that the IOD primarily controls ITF transport during El Niño development years, while ENSO has more influence during El Niño decaying years.