



Thermohaline structure, sea ice variability, and circulation in Edisto Inlet, western Ross Sea (Antarctica)

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Abstract. The oceanographic characteristics of Edisto Inlet, a fjord located along Victoria Land (north-west Ross Sea, Antarctica), are described in detail for the first time using data acquired in February 2023. The summer thermohaline structure of Edisto Inlet appears to be controlled primarily by salinity (range 34.06–34.73) and, to a lesser extent, by temperature (range –1.91 to –1.10 °C). Strong vertical thermohaline gradients, found in the 150–200 m thick upper layer, are generated by the combined influence of air–sea–ice interaction and highly variable seasonal (and annual) sea-ice coverage. Conversely, relatively uniform conditions are found in the intermediate and deep layers, even on interannual basis. The dominant water masses are Antarctic Surface Water and Modified Shelf Water, while Modified Circumpolar Deep Water (mCDW), whose signal appears in laminated sedimentary records, was not clearly detected inside the inlet at the time of the cruise. However, we do not exclude episodic intrusions of mCDW into the fjord, as its signature has been detected in the upper layers bordering the open sea, about 10–15 km from the inlet mouth. We conclude that the monthly, seasonal, and interannual variability of local water masses, including potential mCDW intrusions, can be attributed to contrasting sea-ice conditions, which can modulate lateral exchanges with the Ross Sea by altering surface momentum transfer, freshwater input, and upper-ocean stratification. Circulation within the stratified fjord results from the combined effects of density gradients and local forcing, and to a lesser extent from local tides, which interact with complex seabed morphology under a strongly baroclinic regime. Edisto Inlet, potentially a representative fjord of Victoria Land, appears to be a highly dynamic environment that links sea-ice variability, shelf circulation, and water-mass transformation.

1 Introduction

To what extent have Antarctic fjords been affected by recent environmental changes? And what are the main factors driving the variability of water masses and the presence or absence of ice within them? In Antarctica, changes to the cryosphere are expected to substantially modify freshwater inputs to the Southern Ocean, influencing global sea level, ocean circulation, and ecosystem functioning. These changes, together with the feedback effects they trigger, can affect both vast areas such as the Ross Sea and small inlets such as the pristine fjords of Victoria Land. Since the Southern Ocean plays a central role in global climate regulation through heat redistribution, carbon uptake and the production of Antarctic Bottom Water (AABW), changes in Antarctic seas may also have global impacts. Approximately 8 Sv of AABW is generated around Antarctica, with the Ross Sea accounting for about 25% of the total (Budillon et al., 2011). Current estimates indicate that complete melting of the



Antarctic Ice Sheet could raise global sea level by ~58 m (Fretwell et al., 2013), while the collapse of the Ross Ice Shelf would accelerate a grounded ice loss from catchments equivalent to 11.6 m (Tinto et al., 2019). While large-scale shelf processes in the Ross Sea have been extensively documented, coastal Antarctic fjords remain comparatively understudied despite serving as crucial transition zones between continental glaciers, fast-ice covers, and open-shelf waters. Persistent sea ice and harsh environmental conditions limit their observational coverage, leaving fundamental gaps in our understanding of local circulation, thermohaline structure, and their sensitivity to atmospheric and oceanic variability. Edisto Inlet, a small fjord located along the Victoria Land Coast (72°19'S, 170°16'E), is one such understudied system. There, seasonal sea ice formation begins in March–April, while melting typically starts between mid-January and early February, resulting in complete ice-cover of the inlet during winter months and partially ice-cover during summer months (Iqbal and Aulicino, 2024). Southerly katabatic winds frequently cool the surface ocean and promote sea ice growth and dense water formation, suggesting that the inlet may play an active role in local water mass modification. Paleoenvironmental reconstructions from sediment cores provided evidence of strong Holocene variability in sea ice conditions and water mass properties within the inlet (Tesi et al., 2020). Sediment cores collected in 2017 revealed regular summer-open conditions between 2.6 ka BP and 0.7 ka BP, followed by increasingly persistent ice cover associated with regional cooling (Tesi et al., 2020; Galli et al., 2023). Additional records indicate transitions from multi-year landfast ice (3.6–2.7 ka BP) to a seasonal sea ice regime (2.5–1.2 ka BP), likely linked to episodic intrusions of Modified Circumpolar Deep Water (mCDW, Galli et al., 2025). However, its contemporary oceanographic regime—specifically the interaction between local atmospheric forcing, sea-ice cover, glacial runoff, and external oceanic intrusions—has lacked detailed multi-year physical characterization. Moreover, it is unclear to which extent large-scale and local dynamics are responsible for changes in water masses and mCDW intrusions into the Edisto Inlet. Although Edisto Inlet is not directly influenced by the Antarctic Surface Slope Current, the southwestern branch of the Ross Gyre drives a strong westward flow that facilitates the transport of mCDW onto the continental shelf (Orsi and Wiederwohl, 2009). The extent and intensity of the gyre vary with atmospheric conditions (He, 2024), while strong diurnal tides with spring-neap modulation can generate currents exceeding 1 m/s (Whitworth and Orsi, 2006). Along the Victoria Land Coast, ocean circulation is governed by the interaction between locally formed dense shelf waters and intrusions of mCDW, which represent the primary source of relatively warm and saline waters to coastal fjord systems in the region (Castagno et al., 2017; Caridi et al., 2026). How these regional drivers interact to shape circulation within Edisto Inlet remains unclear due to a scarcity of in situ measurements. Few observations have been conducted in recent years and suggest that circulation within the inlet is characterized by a two-layer structure at its entrance, with a thermocline/halocline/pycnocline between ~50 and 150 m depth, and by a gyre-like circulation pattern, with north-westward flow along the western flank and south-eastward flow along the centre of the Inlet mouth (Battaglia et al., 2024).

In this study, we present the first comprehensive set of oceanographic data collected in Edisto Inlet in February 2023. The study aims to answer the following open scientific question: “How does sea-ice variability modulate summer stratification, thermohaline properties, and exchanges between Edisto Inlet and the western sector of the Ross Sea, and how does it interact with tides and bathymetric constraints?”. In doing so, this paper contributes to a broader understanding of the sensitivity of Antarctic coastal systems to climate variability and ecosystem functioning.

2 Data and methods

The primary dataset used in this study was collected during a multidisciplinary oceanographic campaign conducted on board the icebreaker (I/B) *Laura Bassi* between 10 and 15 February 2023, as part of the PNRA (Italian National Antarctic Research Programme, XXXVIII expedition), in the framework of the project “*Laminated sediments in the magnificent Edisto Inlet (Victoria Land): what processes control their deposition and preservation?*” (LASAGNE). Field operations were carried out



under generally favourable weather conditions, with light to moderate winds and predominantly clear skies. At the time of the survey, the inlet was partially ice-free, while fragmented sea ice was present both within the bay and in adjacent coastal waters. During periods of complete or partial opening in the austral summer, few and occasional oceanographic data were collected in 2017 and 2020 (see Battaglia et al., 2024), and in 2022, when the first oceanographic mooring (MEI-Mooring Edisto Inlet) was deployed on the western side of the Edisto mouth, at 470 m depth. Here, we present the data collected during the 2023 oceanographic cruise (PNRA XXXVIII) complemented by part of the records from MEI, and few Conductivity-Temperature-Depth (CTD) vertical profiles obtained in 2020 and 2022 near the mouth of the inlet. Note that a more detailed analysis of the entire multi-year time series from the moored sensors will be performed in another manuscript (in preparation).

2.1 Study area

Edisto Inlet (72.2°S, 170 °E) is located along Victoria Land (western Ross Sea, Antarctica) in the southern part of Moubray Bay, between Cape Hallett and Cape Christie (Fig.1). It is a narrow fjord, approximately 16 km long and 4 km wide, and connects to the rest of Moubray Bay via a sill approximately 455 m deep. Several marine-terminating glaciers discharge fresh water and icebergs into Edisto: the three largest – Manhaul, Edisto and Arneb Glaciers – border the ~670 m deep basin, shaped by past glacial erosion (Battaglia et al., 2024) at the head of the inlet. Near the mouth of the inlet in Moubray Bay, two large glaciers, Ironside and Honeycomb, face the sea front. Scientific interest in Edisto Inlet increased after the recovery in 2017 of a sediment piston core from its mouth (HFL17-1; Tesi et al., 2020). The presence of rich sediment deposits enabled the reconstruction of the late Holocene climate history and sea-ice dynamics of Edisto Inlet. However, because the inlet interior is often inaccessible due to highly variable sea-ice cover, its oceanographic characteristics have remained mostly unknown. During the PNRA XXXVIII expedition, the inlet interior and the adjacent southern area of Moubray Bay were explored using a dense grid of hydrographic measurements, yielding high-resolution vertical profiles of temperature, salinity, dissolved oxygen concentration, fluorescence, turbidity, and marine currents. In addition, continuous underway measurements of temperature, salinity, and currents were collected throughout the oceanographic survey. At the present time, these measurements are unique and unprecedented.

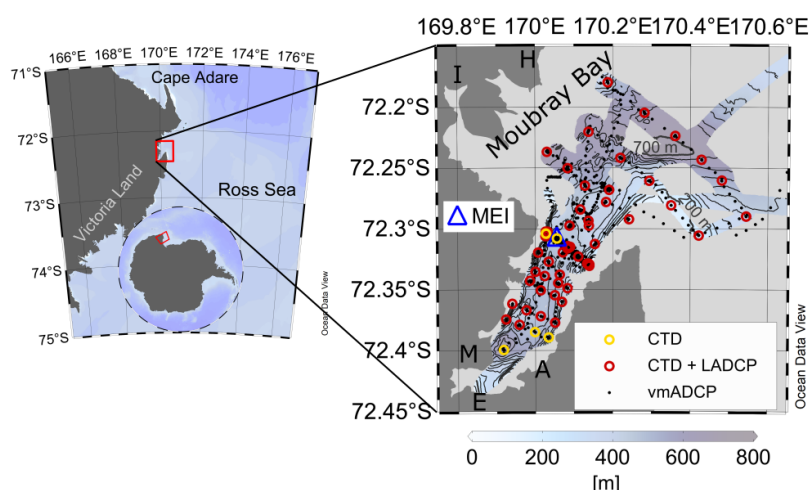


Figure 1: Map of Edisto Inlet and the surrounding area in the western Ross Sea (inset). Symbols show the locations of hydrographic stations (CTD/LADCP) with the vessel-mounted ADCP (vmADCP) survey track occupied in February 2023, and the location of the oceanographic mooring (MEI). Bathymetric data are from multibeam surveys conducted in February 2017 (Battaglia et al., 2024) and February 2023 (PNRA XXXVIII expedition). Capital letters indicate the main glaciers: Arneb (A), Edisto (E), Manhaul (M), Ironside (I), and Honeycomb (H). Maps were created using Ocean Data View (Schlitzer, 2026).



108 2.2 Oceanographic data

109 The inlet interior and the adjacent southern area of Moubay Bay were explored yielding high-resolution vertical profiles of
 110 temperature (T), salinity (S), dissolved oxygen (DO) concentration, fluorescence, turbidity, and marine currents. In addition,
 111 continuous underway measurements of temperature, salinity, and currents were collected. CTD data were recorded with an
 112 SBE911plus (Sea-Bird Scientific), processed and quality checked using Sea-Bird's SBE Data Processing software and
 113 following standard procedures. Potential temperature (θ), and potential density anomaly (σ_θ , referred to 0 dbar) were calculated
 114 from *in situ* data using the MATLAB (The MathWorks Inc.) Gibbs SeaWater Oceanographic Toolbox (McDougall and Barker,
 115 2011) including the thermodynamic equations for seawater (<http://www.teos-10.org/software.htm>, last access: 10 March
 116 2026). T and S data were quality checked and averaged every 1 m, with overall accuracy within ± 0.002 °C for T, and ± 0.005
 117 for S. Fluorescence and turbidity in the water column were measured with WET Labs ECO-AFL/FL optical sensors. DO
 118 concentration was measured using an SBE43 sensor. Water sampling was carried out using a rosette system equipped with 24
 119 Niskin bottles (12 L capacity) for laboratory analysis at selected locations and depths. A total of 63 vertical CTD profiles were
 120 obtained from 26 closely spaced locations inside the inlet and 22 stations outside the inlet, with variable distances between
 121 stations. The mouth of Edisto Inlet was covered with repeated CTD stations along a shore-to-shore transect over approximately
 122 24 hours. Two 300 kHz Lowered Acoustic Doppler Profilers (LADCPs; Workhorse I Teledyne RD Instruments, upward- and
 123 downward-looking) were used to collect ocean current data during CTD casts. A dual system mounted on the CTD-rosette
 124 frame collected 58 profiles, with vertical bins every 5 m; here we use 54 valid profiles. LADCP data were processed using the
 125 LDEO software package (version IX_14; Thurnherr, 2021), which applies the velocity inversion method of Visbeck (2002) to
 126 derive absolute velocity profiles. Processing incorporated LADCP measurements, navigation data, bottom-tracking
 127 information, angle of magnetic declination and CTD-derived temperature, salinity, and pressure for sound-speed and depth
 128 corrections. Kinetic energy (KE) density (kinetic energy per unit volume) was calculated from LADCP speed at selected
 129 depths, using a constant density of 1027.90 kg/m^3 . Ocean currents were also measured with the vessel-mounted (vm) ADCP,
 130 model RD Instruments Ocean Surveyor 150 kHz, configured to calculate long-term averages every 5 minutes of velocities
 131 binned into 4 m thick vertical cells, covering the layer between 17 m and 300 m. The original eastward and northward ocean
 132 current components from both the LADCP and vmADCP were rotated into the direction of the main longitudinal axis of the
 133 inlet, which is aligned 64° counterclockwise from east. The along-inlet component is positive when oriented at 64° (out of the
 134 inlet) and negative when oriented in the opposite direction (into the inlet). The cross-inlet component is perpendicular to the
 135 along-inlet component and is positive when oriented towards the western shore, and negative when oriented towards the eastern
 136 shore of the inlet. Geostrophic currents are calculated from the density gradients, using a depth of 300 m as a reference layer.

137 2.3 Oceanographic Mooring Edisto Inlet (MEI)

138 Because measurements taken during a single campaign are limited and underestimate tidal and subtidal variability, we also
 139 analysed time series data from an oceanographic mooring, even though, as noted, a dedicated paper on the time series is in
 140 preparation. MEI was deployed for the first time in February 2022 near the western flank at the entrance to the fjord ($72^\circ 18.419'$
 141 S, $170^\circ 03.1272'$ E; water depth 470 m; Fig. 1). The deployment site coincides with the location of sediment core HFL17-1
 142 (Tesi et al., 2020), enabling the integration of oceanographic and paleoenvironmental observations. MEI was serviced and
 143 redeployed during the oceanographic survey in February 2023, when it was equipped with a Nortek Signature 250 Acoustic
 144 Doppler Current Profiler (ADCP) at a mean instrument depth of 205.4 m, an SBE37-ODO CTD attached to a McLane sediment
 145 trap (24 bottles) at 231 m, an SBE16 CTD at 440 m, several SBE56 temperature loggers, and an Aanderaa RCM7 current
 146 meter at 450 m depth. The mooring remained operational until its recovery, occurred in February 2025 (sea ice cover prevent
 147 a recovery in 2024). Being the detailed analyses of the MEI time series beyond the scope of this paper, here we analysed 1 yr
 148 of data and presented ADCP data from February 2023, since they cover the hydrographic survey period. The ADCP recorded
 149 pressure and temperature at a mean instrument depth of 205 m. Horizontal currents were measured in 8-m vertical bins



spanning approximately 21–189 m depth. The rotated current coordinate system described in Section 2.2 was also applied to the moored ADCP currents. Sea-level variability was estimated from the ADCP pressure record converted to equivalent water depth. Because atmospheric pressure measurements were unavailable for the full deployment period, no inverse-barometer correction was applied. Therefore, variations in atmospheric pressure, as well as in the seawater density were assumed to have a negligible effect on the estimated sea-level fluctuations. To determine sea level anomaly, we use data recorded by the in-situ pressure sensor applying also harmonic analysis with the MATLAB t-tide package (Pawlowicz et al., 2002). Before the harmonic analysis, spurious measurements (e.g., associated with mooring-line tilt) were removed and the original 2-hourly records were linearly interpolated to 1-hour time series. For current velocity, each ADCP depth bin was analysed independently. Subsequently we apply the tidal parameters to construct the tidal signal for February 2023 (including the campaign interval) and to obtain the non-tidal signal (i.e., any change in ocean water level, current, or temperature driven by factors other than astronomical lunar and solar tides).

2.4 Sea ice cover in Edisto Inlet

Sea ice conditions in Edisto Inlet were reconstructed using thermal infrared imagery acquired by the MODIS (Moderate Resolution Imaging Spectroradiometer) sensors onboard NASA's Terra and Aqua satellites, following the approach described by Aulicino et al. (2018) and recently applied to Edisto Inlet by Tesi et al. (2026). Satellite scenes acquired during the austral summer (December–April) were processed to distinguish between sea ice and open water based on ice surface temperature. Cloud-contaminated images were identified using the MODIS cloud mask product and excluded from the analysis. For each valid scene, the fraction of ice-free area within Edisto Inlet and the sea ice concentration in the adjacent coastal region were quantified from the classified imagery. This procedure provided an almost continuous record of summer sea ice conditions between 2000 and 2025 and enabled the identification of seasonal opening events and their temporal variability. Edisto Inlet typically becomes partially or completely ice-free between January and February, with open-water conditions generally persisting until April. Analysis of available satellite imagery for the period 2000–2024 identified 19 summers with partial opening of the inlet, of which 14 reached completely ice-free conditions (not shown), whereas no summer opening was observed in 2001, 2003, 2008, 2013, 2015, and 2018. To place the recent observations in a longer-term context, monthly sea ice concentration anomalies (%) relative to the 1991–2020 climatology were also derived from the ECMWF (European Centre for Medium-Range Weather Forecasts) ERA5 reanalysis (Copernicus Climate Change Service, not shown). The largest positive anomalies occurred in late 1976 and in 1994, while the longest period characterised by negative anomalies was extended from 1979 to 1993. In recent years, negative anomalies have been observed from 2019 to 2026, except in summer 2024.

3 Results

The thermohaline structure of Edisto Inlet, derived from CTD casts collected in February 2023, is characterised by a relatively narrow θ range (-1.91 to -1.10 °C) and a broader range of S (34.06 to 34.73, Fig. 2). Our data indicate that the thermohaline properties in Edisto are mainly associated with those of Antarctic Surface Water (AASW) and Modified Shelf Water (MSW). Although no clear signatures of mCDW were identified during the survey, our data suggest that an mCDW-like signature may be present in the outer sector, with $\theta > -1.85$ °C and $28.00 < \sigma_t < 28.27$. The two north-westernmost CTD profiles (at stations 005 and 015, Fig. 2), located near the Ironside and Honeycomb Glaciers, recorded minima θ values of -1.91 °C at mid-depth (slightly smaller than the surface freezing point, -1.87 °C). This suggests the presence of a patch of water in contact with the submerged glacier front (Domack and Scott, 1993).

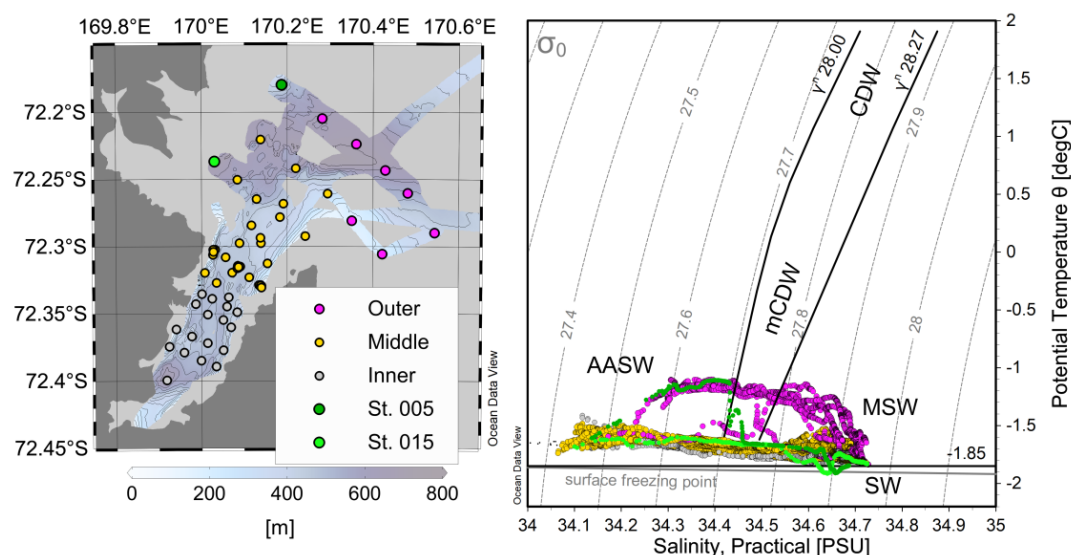
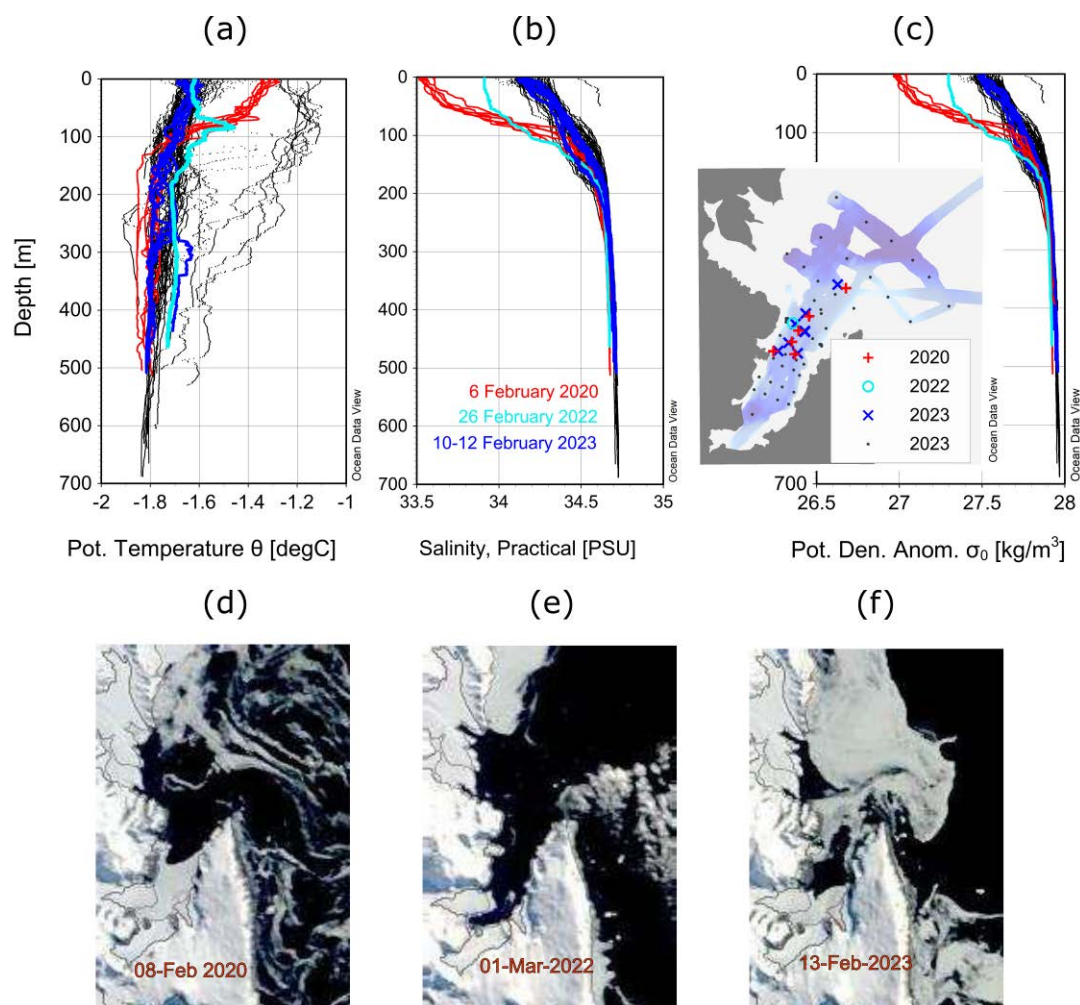


Figure 2. θ/S diagram from CTD casts acquired in February 2023. Casts are grouped (except of sts. 005 and 015) according to similar $\theta-S$ properties, referring to Inner (light grey), Middle (yellow), and Outer (magenta) sectors (see inset map). Antarctic Surface Water - AASW, Modified Circumpolar Deep Water - mCDW, Circumpolar Deep Water - CDW, Modified Shelf Water – MSW, and Shelf Water SW.

Additional CTD measurements collected in 2020 (Kovačević et al., 2023) and in 2022 help investigate variability in the water column during three recent summer seasons, characterised, among other factors, by different evolutions of the seasonal sea ice cover. Both temperature and salinity exhibit “year-to-year” variability even though temperature shows minimal differences (mostly within 0.30 °C, Fig. 3a). Salinity varies mainly within the upper 150 m, with differences reaching 0.6 at the surface. The lowest surface salinity, 33.50, was recorded in February 2020 (Fig. 3b). Consequently, the potential density anomaly is highly variable within the upper 150 m (0.50 kg/m³) and appears uniform at greater depths (Fig. 3c). Note that below 200 m depth, variability during different summer seasons is strongly limited. In the upper layer, instead, thermohaline changes may be strongly influenced by different sea ice conditions in Edisto Inlet. In early February 2020, sea ice was occupying more than half of the inlet but with limited ice belt in the offshore area (Fig. 3d). On 1 March 2022 (few days after the CTD cast) satellite image shows that Edisto was almost completely ice free (Fig. 3e). Its gradual opening during February 2022 (not shown) facilitated circulation, exchange, and mixing. During that period, at the inlet entrance, temperature and salinity were almost uniform in the 50 m thick surface layer (Fig. 3a, b), with salinity values of about 33.80. In February 2023, sea ice was present both inside and outside the inlet (Fig. 3f). At the entrance, a coastal sea ice belt extending approximately 8–22 km in the zonal direction occupied the adjacent continental shelf. Within the inlet, landfast ice persisted in the inner basin, covering approximately 38–40 km² on 3 February and decreasing to about 23 km² by 13 February. These conditions indicate that the 2023 survey took place during an active phase of seasonal sea ice retreat.



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214 **Figure 3.** Vertical profiles of (a) potential temperature θ , (b) salinity S , and (c) potential density anomaly σ_0 from CTD casts collected in
 215 February 2020 (red), 2022 (turquoise), and 2023 (blue and dark grey) at the stations indicated in the inset map. Panels (d–f) show
 216 representative NASA MODIS Level-1B reprojected true-colour satellite images acquired on (d) **8 February 2020**, (e) **1 March 2022**, and
 217 (f) **13 February 2023**, illustrating sea ice conditions in Edisto Inlet and the adjacent coastal region during the respective surveys. Satellite
 218 images are obtained from the NASA Earthdata Data Catalog.
 219

220 3.1 Thermohaline properties and ocean currents in Edisto Inlet

221 The vertical distribution of θ and S , DO, fluorescence, and turbidity from data collected in February 2023 is analysed **along a**
 222 **longitudinal transect** (approximately N-S) and **three cross-inlet transects** (approximately NW-SE) to investigate their spatial
 223 variability across the outer, middle, and inner sectors. The most distinctive pattern for θ is observed at station 005, where in
 224 the upper layer (between 20 and 100 m depth) a maximum value of -1.11°C is reached, while the minimum of -1.91°C is found
 225 at about 250 m depth (Fig. 4a). The freshest surface layer, approximately 10–15 m thick, has a minimum S value of 34.08 (Fig.
 226 4b), and has low DO ($< 400 \mu\text{mol/kg}$, Fig. 4c). Below this layer, S increases gradually from 34.60 to 34.71 approaching the
 227 seabed. DO concentration increases to about 440–450 $\mu\text{mol/kg}$ down to 100 m depth, while at depths greater than 200 m, it is
 228 nearly uniform, with values again below 400 $\mu\text{mol/kg}$. Within the upper 100 m thick layer, fluorescence is higher at station



005 (corresponding to the higher θ) and lower along the rest of the transect (Fig. 4d). Turbidity values are higher in the upper
150 m and lower below this depth, with a local maximum near the bottom only at station 026 (Fig. 4e).

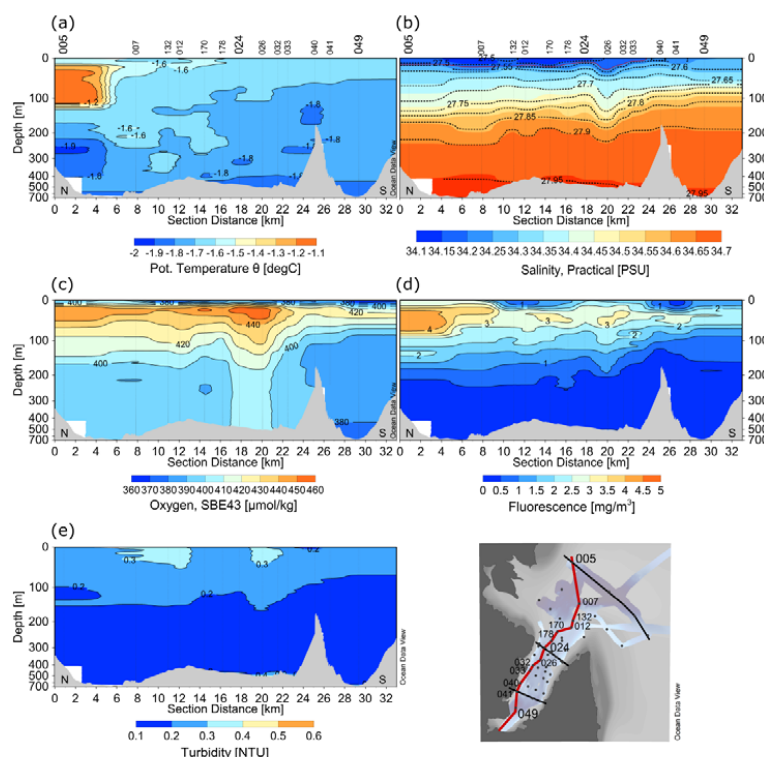


Figure 4. Longitudinal transect (highlighted in the inset map) with contours of θ (a), S shading with overlaid dotted and labelled isopycnals of σ_θ (b), dissolved oxygen concentration (c), fluorescence (d), and turbidity (e). Note the stretched top layer for better visualisation.

We now analyse the same properties described above (plus the ocean currents) along three zonal transects. Along the outermost one, T1, at station 005, the surface layer is occupied by relatively cold and fresh water (-1.50°C , 34.13) while a 100 m-thick sub-surface layer with θ of -1.20°C extends along the entire transect. The lowest values in DO are found at 150–300 m depth in the eastern part of the transect (Fig. 5). Cold but relatively saltier water (θ -1.90 to -1.80°C and $S > 34.50$) is found below 200 m depth especially in the western part. Fluorescence reaches its highest values in the middle of the transect (Fig. 5d). Turbidity is almost uniform elsewhere with the highest values in the upper layer (Fig. 5e).

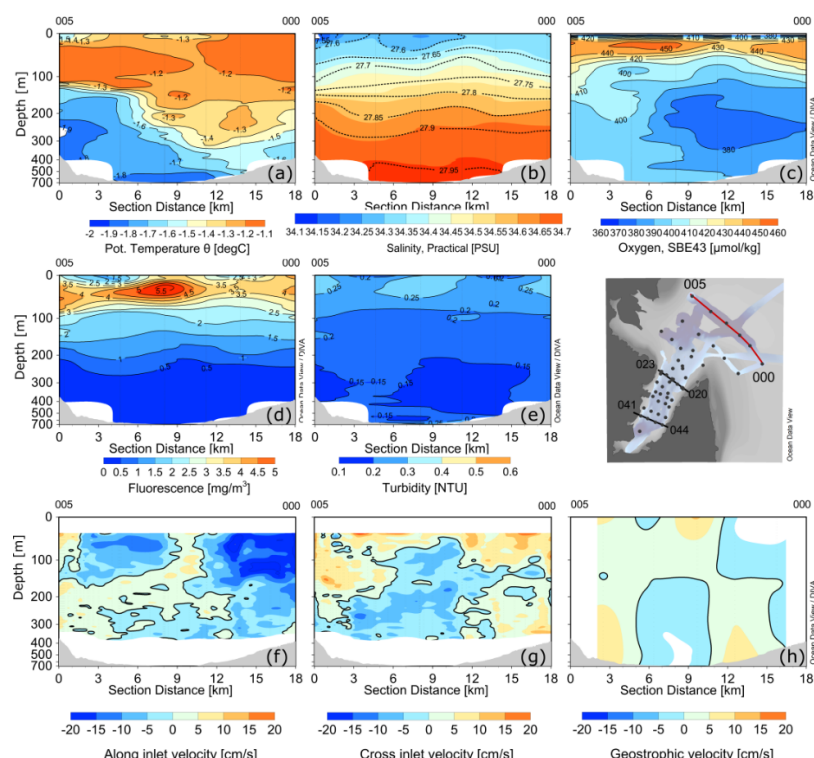


Figure 5. Vertical distribution of θ (a), S shading with overlaid dotted and labelled isopycnals of σ_0 (b), DO concentration (c), fluorescence (d), and turbidity (e), along the outermost W-E transect (T1, red line in the inset map). Note the stretched top layer for better visualisation.

Along transect T2, at the entrance of Edisto Inlet, θ appears uniform, centred around -1.60°C , in the upper layer (Fig. 6). A steep vertical halocline dominates the upper 150 meters, where S increases rapidly from fresh surface values ($\sim 34.15\text{--}34.30$) down to 34.50 . Corresponding potential density contours range from 27.55 to 27.80 kg/m^3 . Below 200 m , S becomes remarkably homogeneous. Well-ventilated surface waters exceed $440\text{ }\mu\text{mol/kg}$, whereas concentrations decrease to $400\text{ }\mu\text{mol/kg}$ in the deep layer. Also here, turbidity values are higher in the upper layer, likely because of sea ice melting. Along-inlet and cross-inlet velocity profiles show that current speeds reach up to $\pm 20\text{ cm/s}$, with the strongest flow variability concentrated in the upper stratified layer above 150 m , and the main inflowing current located on the western side and the outflowing current on the eastern side. Total velocities and the geostrophic component are substantially coherent, with the latter being weaker ($\pm 5\text{--}10\text{ cm/s}$) than the former.

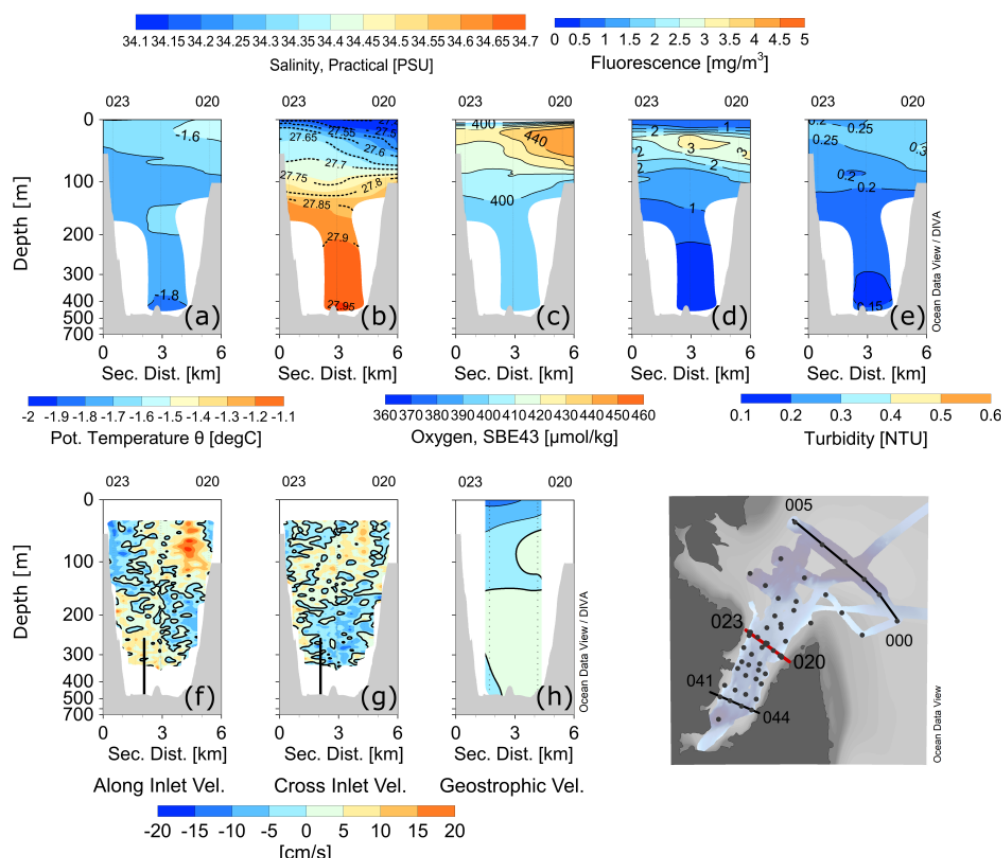


Figure 6. The W-E sections along transect T2 (red line in the inset map) at the mouth of Edisto Inlet: contours of θ (a), S shading with overlaid dotted and labelled σ_θ isopycnals (b), dissolved oxygen concentration (c), fluorescence (d), turbidity (e), along and cross inlet velocities from vmADCP (f, g) and geostrophic velocity (h). Note the stretched top layer for better visualisation. Black line in panels f and g indicate the position of the mooring MEI.

At transect T3 (the innermost one), the section reveals a sharply stratified upper water column above a homogenous, cold deep basin (Fig. 7). The upper layer is characterized by relatively warm surface temperatures (-1.60 to -1.40 °C) and lower salinity (34.15-34.35), representing solar-heated and glacial meltwater-influenced Antarctic Surface Water (AASW). Corresponding density contours (σ_θ) rapidly increase from 27.55 kg/m³ at the surface to 27.85 kg/m³ at 150 m depth. Below the thermocline/halocline, the deep basin is occupied by cold and dense water, with temperatures reaching a minimum core near -1.85°C, high salinity (34.65-34.70), and potential density reaching 27.90-27.95 kg/m³. DO is higher to the west at about 50 m depth (Fig. 7c). The velocity profiles along the inlet indicate a sharp change in velocity between the western and eastern sides, with a northward flow on the former and a southward flow on the latter according to the vmADCP data (i.e., total velocity), contrary to what was measured on transect T2 and to what was derived from geostrophic data, which refer exclusively to currents induced by isopycnals (Fig. 7f-h).

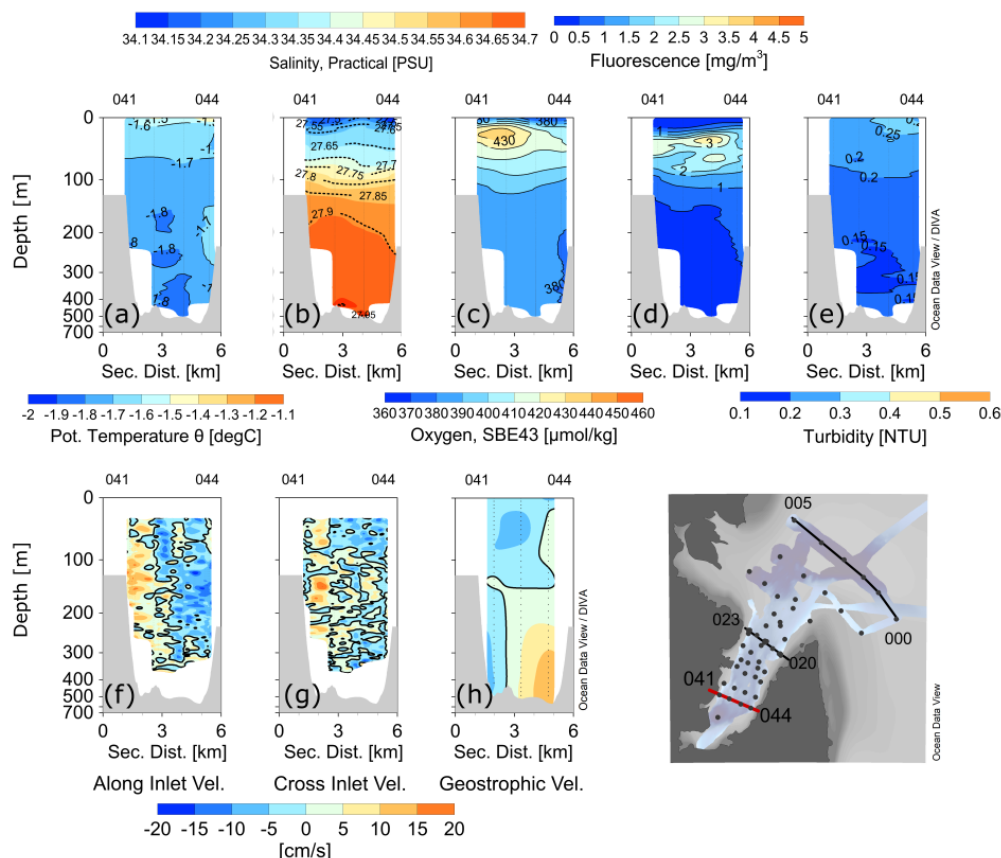


Figure 7. The W-E sections along the innermost transect **T3** (red line in the inset map): contours of θ (a), S shading with overlaid dotted and labelled σ_θ isopycnals (b), dissolved oxygen concentration (c), fluorescence (d), turbidity (e), along and cross inlet velocities from vmADCP (f, g) and geostrophic velocity (h). Note the stretched top layer for better visualisation.

The horizontal distribution of thermohaline properties and ocean currents at four key depth horizons, namely 10 m (surface), 75 m (subsurface/photic layer), 200 m (intermediate layer), and the near-bottom layer, completes the view of the large variability that characterises Edisto Inlet (Fig. 8). Horizontal current velocity vectors derived from LADCP observations are overlaid on the temperature maps to merge the thermohaline variability with the snapshot of the ocean currents at the time of the cruise (Fig. 8a). The surface layer demonstrates a distinct gradient from the inner fjord out to Moubay Bay, with temperature increasing from -1.70°C to -1.15°C and salinity rising from 34.05–34.10 (meltwater influence inside) to 34.50 offshore, where higher dissolved oxygen concentrations (375–430 $\mu\text{mol/kg}$) reflect a more active atmospheric ventilation. Surface flow is channelled along the main fjord axis with vector speeds reaching up to 15 cm/s. In the subsurface/photic layer, a pronounced dissolved oxygen peak reaching up to 455 $\mu\text{mol/kg}$ in the central and inner inlet (compared to 395 $\mu\text{mol/kg}$ offshore) highlight biological oxygen production beneath the upper halocline. In the intermediate layer, a thermal barrier separates cold local fjord water (-1.80°C to -1.85°C) inside Edisto Inlet from a warmer water core (-1.30°C) confined to the northeastern offshore area (10–15 km outside the inlet mouth). This marks a possible geographical limit of an mCDW-like signature. In the near bottom layer, cold (-1.85°C), high-salinity (34.60–34.72) MSW/SW fills the deep inner basin. Dissolved oxygen reaches domain minima (380–410 $\mu\text{mol/kg}$), indicating restricted deep-water ventilation and stagnation. Indeed, deep velocity vectors are substantially weaker than in the upper layers and are strictly guided by the bathymetric constraints.

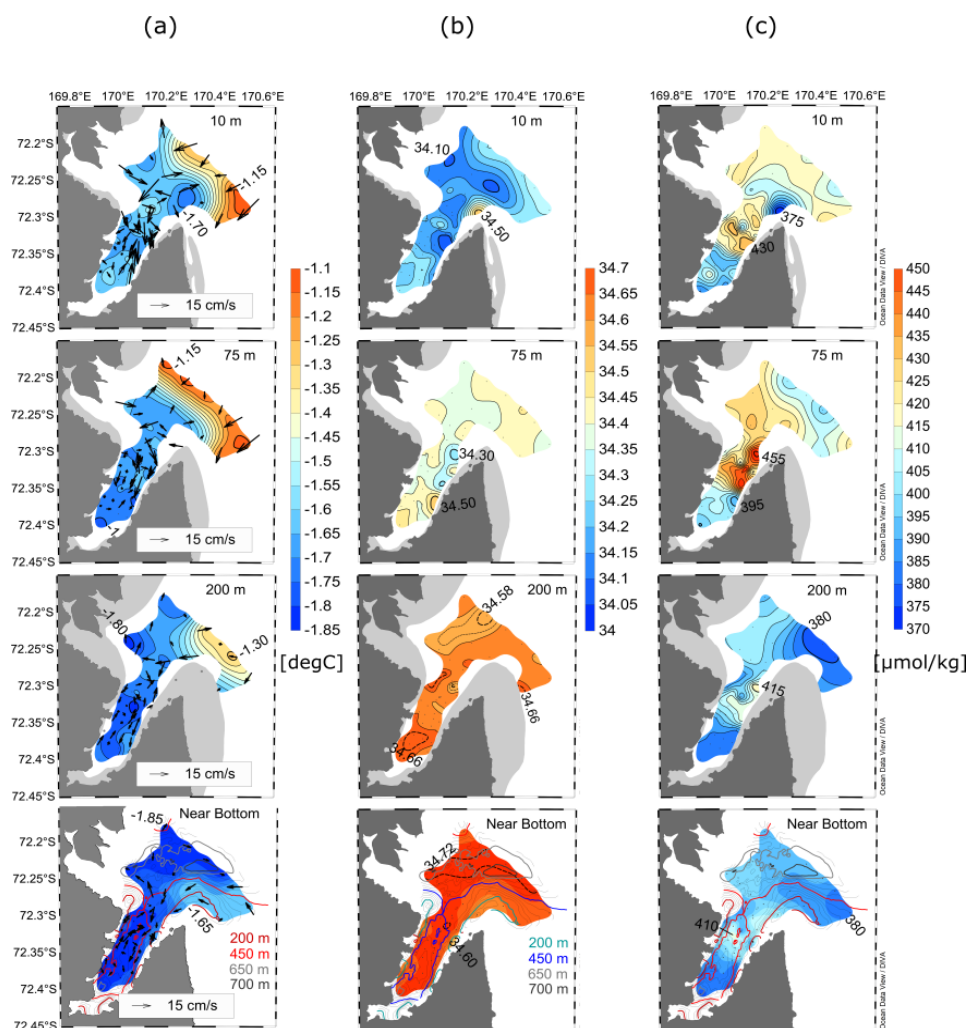


Figure 8. Horizontal distribution of θ and ocean currents from LADCP data (a), S (b), and DO concentration (c) at four depths (10, 75, 200 m, near-bottom).

Kinetic energy density (KED) is displayed in the same way as the thermohaline distribution. It resulted higher in the upper layers, where maximum values range between 30 and 40 J/m³ and peaks are mainly located in the eastern part of the outer sector (Fig. 9). In the inner sector, KED peaks are found on the eastern flank where the seabed morphology shows relatively steep slope. Below the pycnocline (at 200 m depth), KED decreases with maximum values of 8–10 J/m³. Overall, its distribution is uneven in the deep layer, with local peaks occurring only near the eastern slopes at the mouth of the inlet and in the outer sector (Fig. 9e).

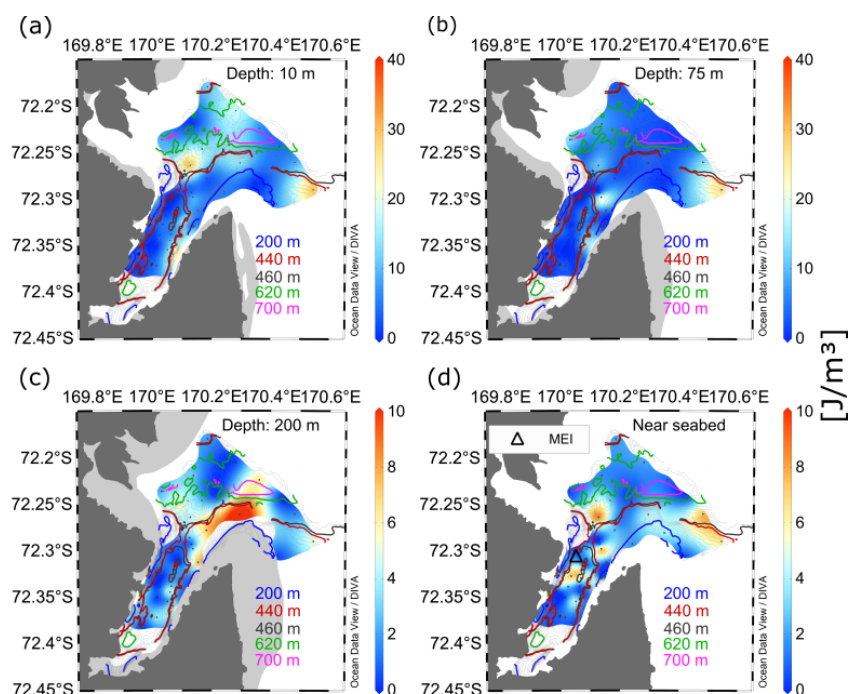


Figure 9. Kinetic energy density [J/m^3] distribution at four depths: (a) 10 m, (b) 75 m, (c) 200 m, and (d) near seabed, based on current speeds measured by LADCP. Note the scale change between (a-b) and (c-d).

3.2 Tidal analysis based on ADCP data from the MEI – Oceanographic mooring

To quantify the tidal contribution to the complex circulation in Edisto Inlet, sea level oscillation derived from pressure and temperature sensors (positioned at 205.4 m depth) have been analysed together with ocean currents recorded in the upper layer (between 21 and 189 m depth) at MEI. The most characteristic phenomena evident in the time series are periodic fluctuations in sea level of up to 0.80 m, while temperature fluctuates irregularly, mostly within a range of 0.10 °C and, in exceptional cases, up to 0.30 °C (Fig. 10). Current speeds are greater, up to 15–20 cm/s, at 50–100 m depth than in the intermediate layer. High-frequency current variability along the main fjord axis is controlled by diurnal astronomical tides (constituents K1 and O1), which operate alongside counter-clockwise near-inertial oscillations with a period of $T \sim 12.57$ h. The harmonic constants from the tidal analysis have been used to reconstruct sea level oscillation, temperature and current tidal variability during the period covered by the oceanographic survey (tidal anomaly in Fig.10). The effect of tidal variability on the temperature range during short periods, instead, is estimated up to 0.03°C and, being much smaller than the overall temperature range (0.30°C), can be considered negligible. This confirms that other processes occurring at different time scales (weekly, seasonal, and annual) are more relevant for temperature than the astronomical tides. Diurnal periodicity prevails in the tidal signal of both sea level and currents, and amplitudes and speed increase during the period 10-16 February, between the full and new Moon. Both tidal and non-tidal velocities have similar magnitudes (up to about 15 cm/s in the along-inlet and up to 10 cm/s in the cross-inlet directions), and both exhibit vertical shear, with speed decreasing from the surface to a depth of 181 m. Tidal and non-tidal along-inlet currents show alternating inward and outward flows at the diurnal time scale. However, their superposition sometimes prevents flow inversion and maintains inward flow, as observed in the upper 100 m layer in the original currents on 14–16 February 2023 (Fig. 10d). Overall, our data show that the steep lateral bathymetry reduces cross-inlet flow and channels tidal motion mainly along the N–S fjord channel (Fig. 10d-e). Moreover, filtering out the tidal anomaly



isolates the non-tidal residual, which include the estuarine and atmospheric residual circulation at timescales different from the diurnal tide. The tidal contribution to the total variance in sea level (considering a year-long time series) reaches approximately 77%. Consequently, non-tidal sea-level variability accounts for about 23% of the total variance. Conversely, the tidal signal in the currents of the upper layer—which is 190 m thick—accounts for between 4% (at a depth of 189 m) and 34% (at a depth of 21 m) of the total annual variance, increasing in February 2023 to as much as 78% in the shallowest layers. The non-tidal along-inlet velocity field isolates a sustained multi-day, featuring persistent, opposing inflow and outflow layers consistent with density-driven estuarine exchange and wind-driven setup in the upper layer. Both tidal velocities and variance decrease from the surface to about 180 m depth. This provides strong evidence of how the tidal signal departs from the barotropic astronomical tide, and how the tidal contribution to the overall variability of the currents in the upper layer decreases.

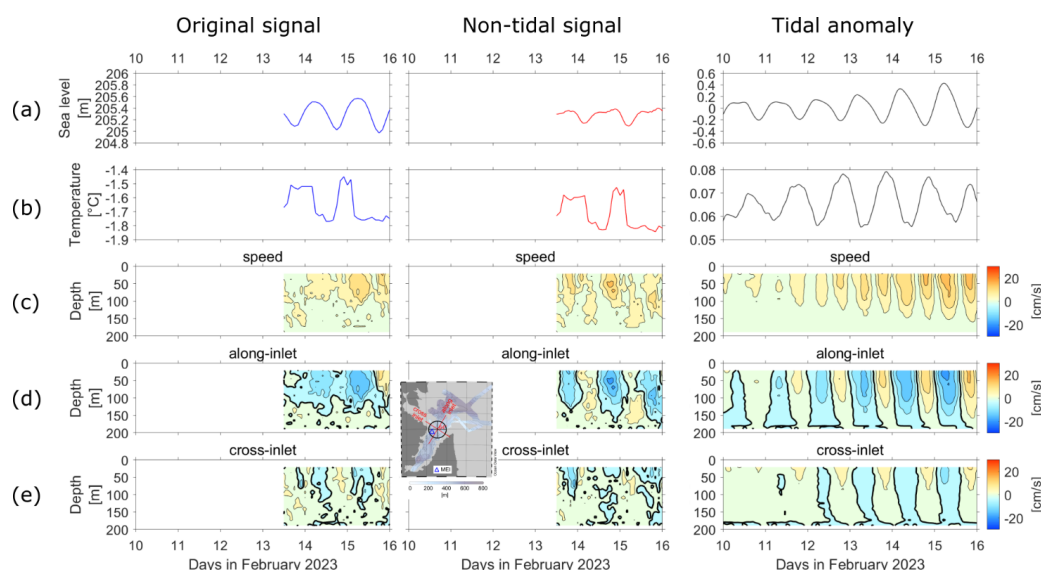


Figure 10. MEI time series from 10 to 16 February of the original and non-tidal signal, and reconstructed tidal anomalies: (a) sea level, (b) in-situ temperature at 205.4 m mean depth, (c) current speed, and current vectors decomposed into (d) along-inlet and (e) cross-inlet directions. Anomalies are with respect to the long-term mean value. Contour interval in (c-e) is 5 cm/s, while a bold line indicates a zero velocity.

4 Discussion

In this paper, we analyse unique oceanographic data collected in Edisto Inlet. The data set primarily consists of CTD and ADCP measurements, and secondarily of pressure and marine current records from the mooring MEI located at the inlet mouth. This small Antarctic fjord is covered by fast ice for most of the year, with the only exception being a seasonal (partial or total) opening in February–March that is characterised by a strong monthly, seasonal, and interannual variability. Indeed, long-term satellite observations spanning 25 years indicate that summer opening is non-uniform: 14 out of 19 open-ice events resulted in complete ice clearance, and in six specific years (2001, 2003, 2008, 2013, 2015, and 2018) the inlet remained entirely ice-covered even during the austral summer (not shown). On the one hand, sea ice variability is likely driven by large-scale atmospheric events and large-scale ocean circulation variability, which may or may not facilitate the inflow of the relatively warm water from the Ross Sea, e.g., the mCDW, close to Edisto, favouring seasonal ice melting. On the other hand, sea ice variability strongly influences the local thermohaline properties in Edisto Inlet not only through sea ice formation and melting, but also through its capacity to act as a physical barrier to lateral water exchange between the inner part of the fjord and the offshore area, at least in the upper layer. Moreover, different sea-ice conditions may indirectly modulate lateral exchange with



the Ross Sea by altering surface momentum transfer, freshwater input, and upper-ocean stratification. Our data show that ocean temperature in Edisto Inlet and the surrounding area varies from -1.91 to -1.10 °C, whereas salinity varies from 34.06 to 34.73. Consequently, the density stratification of the water column in Edisto Inlet, with a pronounced pycnocline in the upper 100–200 m, appears predominantly driven by salinity changes, which are strongly influenced by sea-ice variability (i.e., melting during the summer and sea ice formation and drift) and glacier freshwater discharge. This pycnocline layer separates the upper from the deeper layers. The coldest waters (-1.91 °C), found between 230–280 m depth in the northwesternmost sector of the study area in front of the Ironside and Honeycomb glaciers, may be categorized as potential iceshelf supercooling according to Haumann et al. (2020). At the same time, the warmest waters are also found in the outer region, but on its northeastern most part. This suggests that large-scale circulation processes are strongly influenced by local ones, making it particularly difficult to identify a clear signal of the mCDW within the Inlet, which may sporadically have major or minor influence in the inner part. Indeed, sea temperatures inside Edisto Inlet remain well below the typical mCDW ranges found in the open Ross Sea (Orsi and Wiederwohl, 2009) or near the Antarctic coast (Williams et al., 2015). Although the data collected in February 2023 did not show mCDW inside the fjord, we cannot rule out its occasional intrusion into the inlet. In fact, the intrusion of mCDW has been inferred at the mouth of Edisto Inlet based on the presence of the benthic foraminifera *Epistominella exigua* from 2 ka to 1.5 ka BP (Galli et al., 2023). Hence, we could assume that favourable conditions, such as tidal or wind-driven circulation, can facilitate the entry or approach of mCDW to the inlet mouth. There, in the absence of sea ice, surface waters pushed offshore by winds can be counterbalanced by the upwelling of warmer, saltier intermediate waters. However, also certain regional factors could interfere with the currents' ability to transport mCDW near the mouth of the Edisto Inlet. For example, increased production of High Salinity Shelf Water (HSSW) in the Terra Nova Bay polynya, moving northward along the coast of Victoria Land (Fig. 11), could create a dynamic barrier that would prevent mCDW from entering, and *vice-versa*. Overall, sea ice, freshwater runoff from glaciers, seasonal surface heating, and wind intensity and direction are among the main factors that control the vertical and horizontal distribution of thermohaline properties, the mixed-layer depth, and the lateral exchange with the surrounding areas in Edisto Inlet. However, the role of these factors within Edisto remains unclear and may vary not only seasonally but also spatially. For example, in the uppermost layer, wind and tides may play a predominant role, whereas in the deepest layer of the water column their influence diminishes and is replaced by morphological effects and thermohaline gradients. This is, indeed, what appears from our data: shipboard LADCP and moored ADCP profiles reveal pronounced vertical velocity shear. In the upper stratified layer (0–100 m), current speeds peak at 25–28 cm/s during summer ice-free conditions. In contrast, deep-layer velocities (depth > 200 m) remain below 13 cm/s, dropping to 5 cm/s during periods of winter fast-ice cover (not shown). The strong vertical shear in the currents, with locally enhanced near-bottom flow, is thought to result from the complex interaction of tidal and non-tidal motions (such as geostrophic and inertial motions) in a strongly stratified environment with complex seabed morphology. The analyses reveal that the tidal effect on the temperature range is much smaller than the overall temperature range (0.30°C) and can be considered negligible. Hence, variations in the thermohaline properties in Edisto Inlet remain largely attributable to sea-ice effects (coverage, formation and melting) and to atmospheric processes that induce strong monthly to seasonal variability in both temperature and salinity. The absence of sea ice exposes the sea surface to major wind effect, which may allow meltwater from open-sea areas to spread into the ice-free outer and middle sectors of Edisto Inlet, as in February 2020, when we observed a relatively warm, fresh, 50 m thick upper layer both seaward and landward of the inlet entrance. Gradual opening promotes circulation, exchange, and mixing. Prolonged sea ice cover inside Edisto Inlet and the presence of an external sea ice belt probably prevent the outflow and spreading of meltwaters, as well as heating of the upper layer, as in February 2023, when we observed low temperatures and high salinity and density. Moreover, a very shallow (within 10 m below the sea surface), low-oxygen surface layer was thought to result from the influence of meltwater. Lower dissolved oxygen values have been also found in the innermost deep layer. Benthic foraminiferal communities are tightly linked to these strong environmental gradients. Differences in hydrodynamic energy, sedimentation rates, organic matter input, pH, and redox conditions drive the diverse composition and



spatial distribution of taxa within the study region (Caridi et al., 2026). We found that water masses in Edisto Inlet have mainly the characteristics of Antarctic Surface Water in the uppermost layer and Modified Shelf Water in the deep layer. The latter may also originate locally and can be further altered by processes such as mixing and vertical convection, with a contribution from HSSW (Fig. 11) flowing northwards from Terra Nova Bay along the Victoria Land coast (Bergamasco et al., 2004).

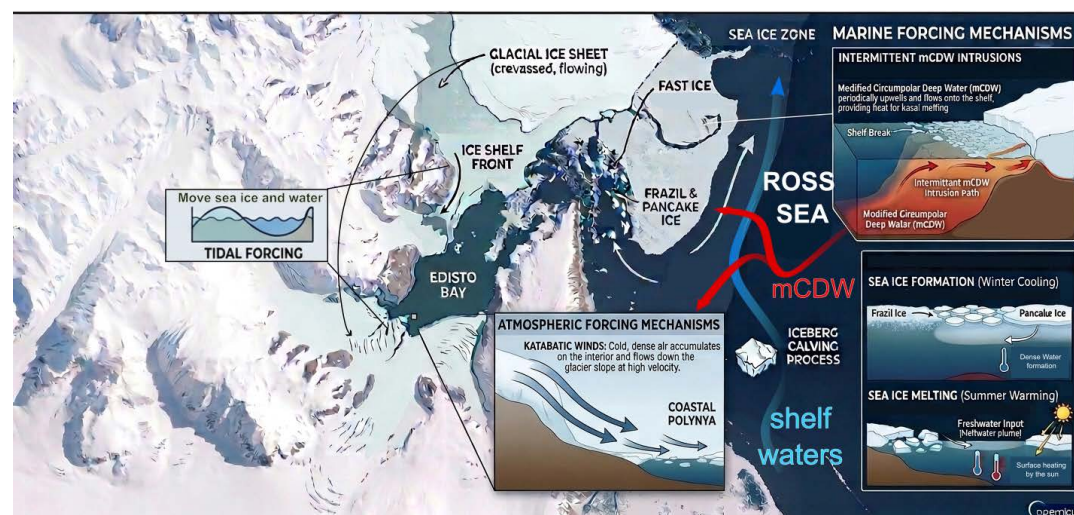


Figure 11. Conceptual diagram of the main mechanisms governing water mass exchange in the Edisto Inlet.

Concerning tidal variability, time-series from the ADCP at the western flank of the inlet mouth show that the prevailing pattern is driven by diurnal constituents, followed by semi-diurnal ones and a well-defined spring–neap cycle. However, there is a significant difference between the response to tidal forcing in sea level and in currents. On a yearly basis, tides account for approximately 77% of the total variance in sea level but contribute much less to flow variance. Moreover, the tidal contribution to current variance decreases from around 40% for the near-surface flow to approximately 4% at a depth of about 190 m. Ocean current measurements revealed that not only do along-inlet flows develop (favoured by the geometrical shape of Edisto Inlet), but cross-inlet flows also occur, even though steep lateral bathymetry reduces cross-inlet flow and channels tidal motion mainly along the main (N-S) fjord channel. The geostrophic currents (inferred from thermohaline gradients) along the selected transects, with values up to 15–20 cm/s, comparable to those measured, exhibit both lateral and vertical shear. Overall, ocean current data reveal a two- or three-layer structure in the water column. The observed pycnocline corresponds to the level in the vertical profiles of the horizontal currents at which currents may reverse their direction. Another aspect of the seasonal stratification is the potential development of internal waves of shorter periods (on the order of tenths of minutes) within the area, interacting with the complex bathymetry. Compared with data collected in 2017 (see Figure 5 in Battaglia et al., 2024), there appears to be a discrepancy in the upper-layer flow along the western flank within Edisto Inlet. On 17 February 2017, during low tide, 8-hour vmADCP data recorded a prevailing NNE (i.e., outward) current in the upper 150 m along the western flank, whereas in our 2023 survey the prevailing current in the same area was in the opposite direction (i.e., SE, inward). These findings underline the dynamic nature of Edisto Inlet. At this latitude, inertial motion due to the Earth's rotation has a local period of 12.6 hours, which lies within the range of the semi-diurnal tidal constituents. The non-tidal signal contains energy at inertial and diurnal frequencies. In addition, non-linear effects and interactions between inertial and tidal flows may generate a series of short-term harmonics, with periods of about 6.25 hours and shorter (Xing and Davies, 2002). All these aspects of multiperiodic flow may strongly affect not only the dynamics but also the mixing and thermohaline variability in the area, as



well as the pycnocline interface, with consequent repercussions on the distribution of biological species both in the water column and in the sediment (Galli et al., 2026, Caridi et al., 2026).

5 Conclusions

Our study, based on the first extensive oceanographic observations carried out in Edisto Inlet in February 2023, provides a complete baseline of the oceanographic variability in this pristine and understudied fjord of the North Victoria Land. The principal oceanographic conclusions are summarized below:

- **Dominance of Local Coastal Processes:** Hydrographic conditions inside Edisto Inlet exhibit high thermohaline and current variability, governed primarily by local coastal drivers rather than direct open-shelf intrusions. The main water masses occupying the fjord include **Antarctic Surface Water**, **Modified Shelf Water**, and **Shelf Water**. The thermohaline structure inside Edisto Inlet is primarily controlled by salinity rather than temperature. During the February 2023 survey, potential temperature varied within a relatively narrow range (-1.91 to -1.10 °C), whereas salinity ranged from 34.06 to 34.73, producing strong density gradients in the upper 150–200 m of the water column.
- **No clear signature of Modified Circumpolar Deep Water (mCDW) inside the inlet was detected during the 2023 observations.** However, in the upper layers bordering with the open sea the observed thermohaline characteristics may be attributed to an mCDW-like signature, hence suggesting that any influence of it on the fjord is episodic and/or substantially modified by local processes.
- **Diurnal tides dominate sea-level variability but exert a weaker control on local currents.** Tidal constituents explain approximately 75% of the sea-level variance, whereas their contribution to current variability decreases from about 40% near the surface to less than 5% at 190 m depth, revealing the potential for a prominent baroclinic circulation regime.
- **Circulation patterns are characterized by a strong vertical shear and frequent flow reversals with depth and alternating along- and cross-fjord flows.** Subsurface flow speeds vary mainly between 15 and 30 cm/s, often decreasing within the upper layer (150–200 m) and increasing again, locally, in the near-bottom layer.
- **Edisto Inlet appears also influenced by a strong interannual variability in terms of sea ice coverage:** in the last two decades (2000–2024), we observed 19 partial opening events, 14 of which resulted in completely ice-free conditions, while in 2001, 2003, 2008, 2013, 2015, and 2018 the inlet remained closed even during the austral summer. Changes in the sea ice coverage are reflected in monthly and interannual differences in hydrographic properties. Most of the variability is largely confined to the upper water column and reflects the influence of seasonal sea-ice formation and melt, and freshwater discharge from local glaciers. Flow advection, wind forcing, tidal and non-tidal motions also exert an influence, conditioning the interannual changes.

In conclusion, Edisto Inlet appears to be a highly dynamic Antarctic fjord that acts as a site for the local transformation of water masses and their interaction with the adjacent western Ross Sea. The interplay between sea-ice processes, freshwater inputs, and circulation produces hydrographic conditions that differ from those typically observed on the Ross Sea continental shelf, leading to local baroclinic processes and pronounced spatial and temporal variability.



474 **Author contributions**

475 VK: Writing original draft – review and editing, Data processing, Investigation, funding acquisition. MB: Writing original
476 draft – review and editing, Data acquisition and processing, Investigation, funding acquisition. LU: data processing, review.
477 NK: data processing, review. GA: data processing, review. LL: Investigation, review, Data and Funding acquisition, Project
478 Administration.

479 **Competing interests**

480 The contact author has declared that none of the authors has any competing interests.

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