Variability of the North Atlantic Deep Water in the South Atlantic

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ABSTRACT

The SAGA (South Atlantic GAteway) project aims to quantify and monitor the return limb of the Atlantic Meridional Overturning Circulation (AMOC). As part of this project, three moorings have been deployed along the 10°W in the South Atlantic from 21° to 31°S. This area has been recently identified as the Atlantic Gateway, serving as an observatory for the starting and returning branches of the AMOC. Each mooring includes two MicroCat Conductivity-Temperature (CT), two Nortek Aquadop, four Anderaa SeaGuard, and one Anderaa RCM11. Data were collected over 2 years and one month in the approximate depth range of 1950 to 4000 m, thus characterizing the North Atlantic Deep Water (NADW) along the Mid-Atlantic Ridge (MAR). This study analyzed data from Mooring 1 (31.5°S, 9.9°W) and Mooring 2 (27.4°S, 9.85°W), showing predominant flow directions towards the west-southwest and northwest, respectively. It was also observed that the presence of Rossby waves explains part of the large-scale variability in the current velocity signals. Finally, it was highlighted that bathymetry influences the measurements at both moorings.

DATA

This study uses observational data from Mooring 1 and Mooring 2, which are part of the SAGA Array (Figure 1). Additionally, Sea Surface Height (SSH) data, covering the area from 36°S to 26°S latitude and from 19°W to 1°E longitude, were used to identify the presence of Rossby waves. The SSH data, spanning from 22- 01-2021 to 31-07-2023, were downloaded from the Copernicus Marine Environment Monitoring Service (CMEMS) .

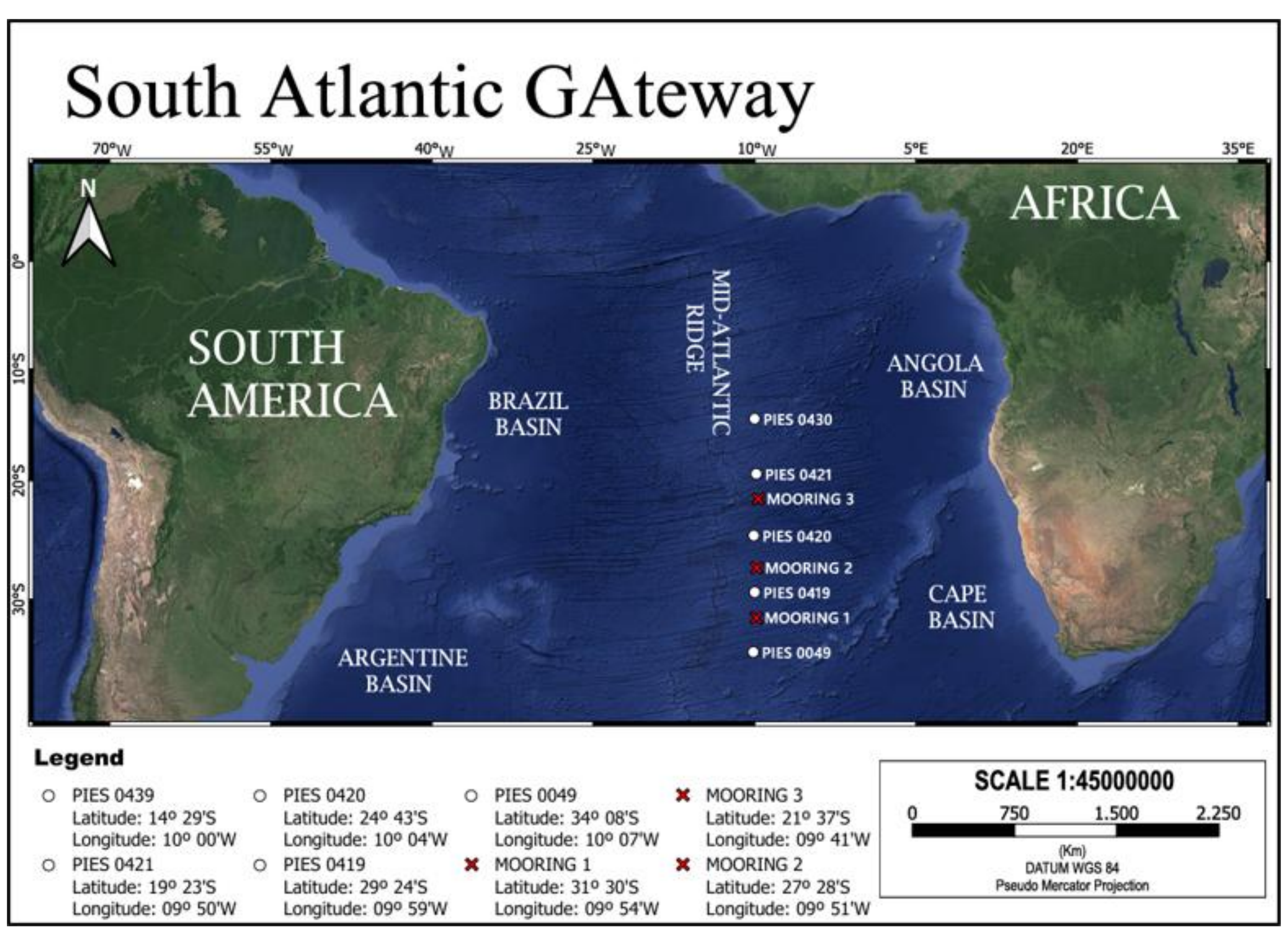

Figure 1. Map of the South Atlantic GAteway (SAGA) array indicating the location of instruments. The atitude and longitude of the SAGA instruments are indicated in the legend.

Mooring 1 consists of two MicroCAT CT sensors, two Nortek Aquadop current meters, three Anderaa SeaGuard current meters, and one Anderaa RCM11 current meter (Figure 2a). Similarly, Mooring 2 includes one additional Anderaa SeaGuard compared to Mooring 1 (Figure 2b). Data were sampled in the deep NADW zone, from 1,950 to 4,000 m depth, from 22- 01-2021 to 31-07-2023.

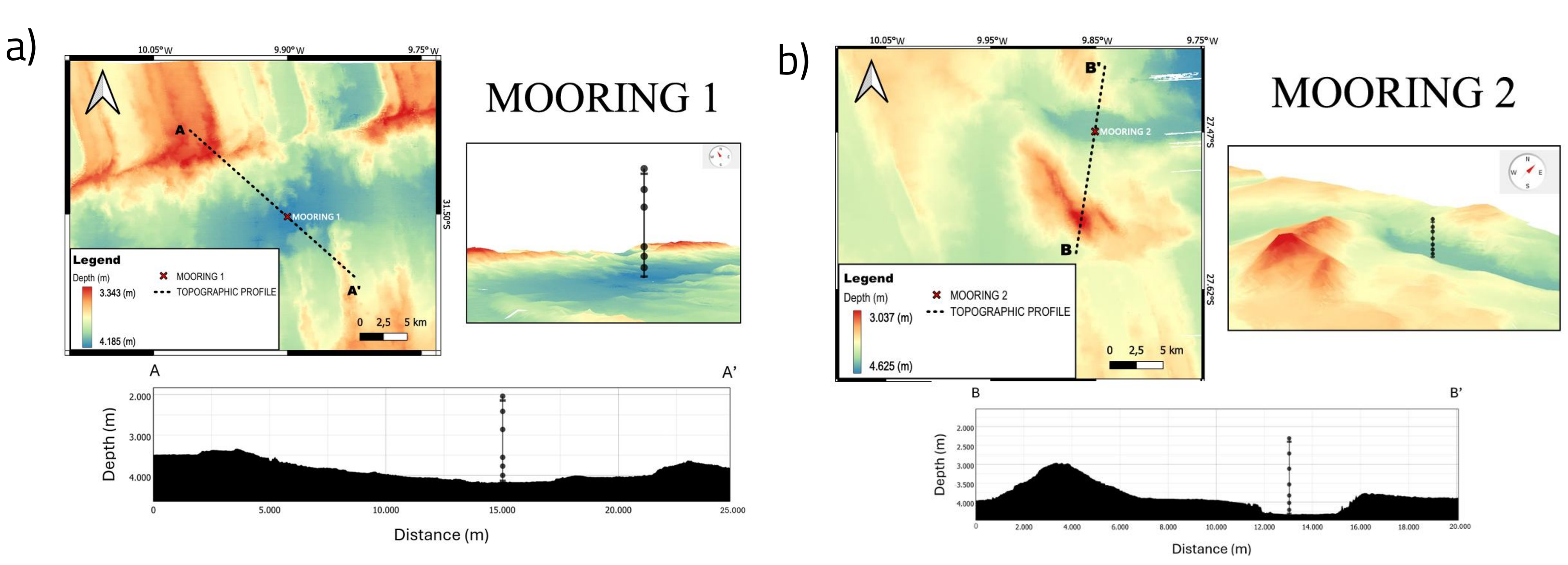

Figure 2. Map showing the locations of Mooring 1 (a) and Mooring 2 (b). It includes a 3D composition and a topographic profile that illustrates the orography of installation area. Additionally, the mooring line and the instruments are scaled to the image, with current meters represented as spheres and MicroCATs as rectangles.

METHODS

- **Water Masses**

1. The **depths** at which the current meters were deployed were compared with the **vertical sections** of **potential temperature** and **salinity** from Arumí-Planas et al. (2023), identifying the water mass in which each measurement was taken.
2. Water masses **were corroborated** using observational potential temperature and salinity data from the MicroCATs

- **Flow Direction**

1. A **40-day** low-pass filter was applied to focus this study on large scale processes.
2. The **principal axes** of the velocity components measured by the different current meters were calculated following Thomson & Emery (2014).
3. The **angle** between the principal axis and the original east axis was then determined. For each mooring line, an angle close to the primary angle of the series was assigned (15° and -35°, respectively), which represented the flow direction.
4. The time series **referencing system** of u and v was **rotated** to obtain the $\vec{v}$ (U, V), from which the component corresponding to the axis of **maximum variance**, U, was extracted.

- **Rossby Waves**

1. **Hovmöller diagrams** of SSH were used to identify the presence of Rossby waves.
2. **Fourier analysis** was applied to the SSH time series at the moorings locations and to the U-component velocity time series.

RESULTS

The results indicate that for Mooring 1, the two current meters deployed at 2,044 m and 2,406 m depth measured in Upper Circumpolar Deep Water (UCDW), while the others (at depths of 2,846 m, 3,573 m, 3,788 m, and 4,001 m) measured in NADW. For Mooring 2, only the current meter deployed at 2,316 m measured in UCDW, with the others (at depths of 2,717 m, 3,116 m, 3,531 m, 3,822 m, 4,016 m, and 4,210 m) measuring in NADW.

Mooring 1

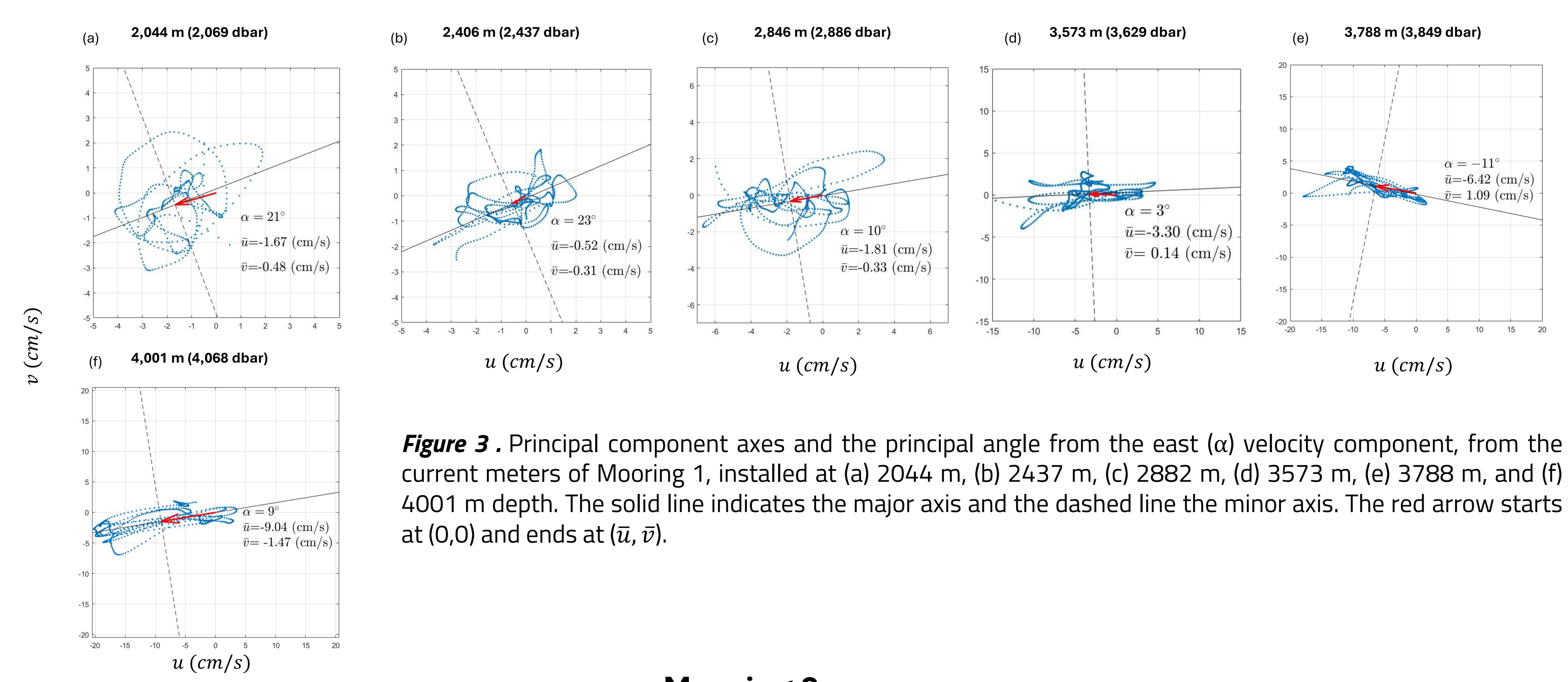

Figure 3 . Principal component axes and the principal angle from the east (α) velocity component, from the current meters of Mooring 1, installed at (a) 2044 m, (b) 2437 m, (c) 2882 m, (d) 3573 m, (e) 3788 m, and (f) 4001 m depth. The solid line indicates the major axis and the dashed line the minor axis. The red arrow starts at (0,0) and ends at $(\bar{u}, \bar{v})$.

Mooring 2

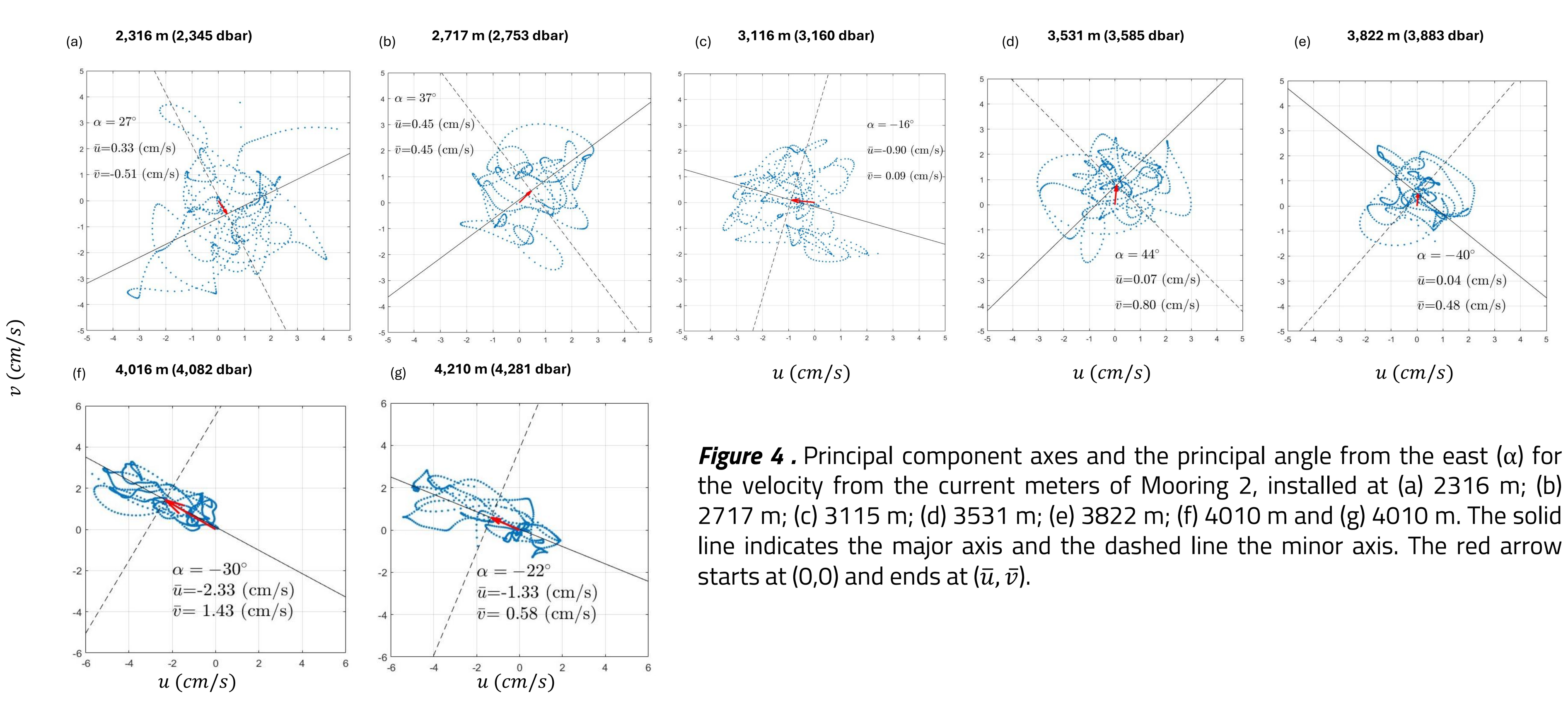

Figure 4 . Principal component axes and the principal angle from the east (α) for the velocity from the current meters of Mooring 2, installed at (a) 2316 m; (b) 2717 m; (c) 3115 m; (d) 3531 m; (e) 3822 m; (f) 4010 m and (g) 4010 m. The solid line indicates the major axis and the dashed line the minor axis. The red arrow starts at (0,0) and ends at $(\bar{u}, \bar{v})$.

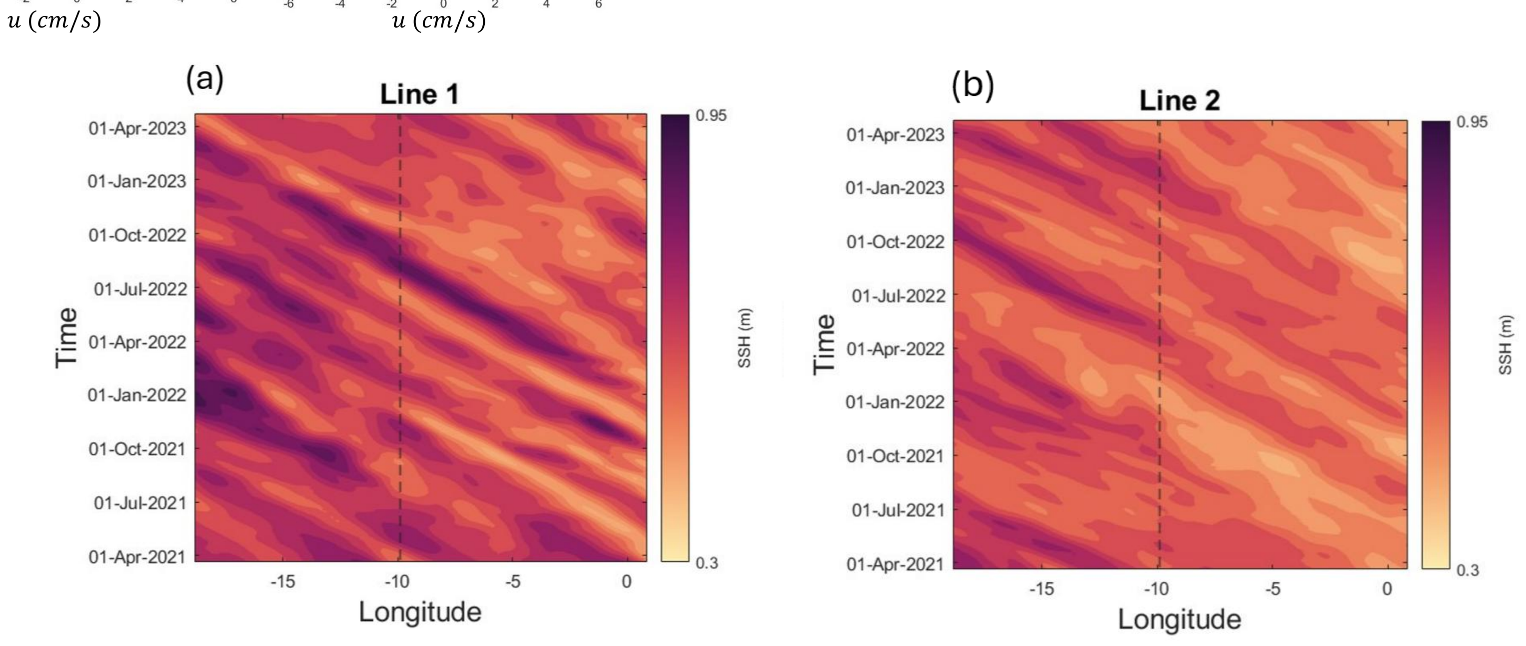

Figure 5. Hovmöller diagram showing the SSH at the Mooring 1 (a) and Mooring 2 (b) positions. The black dashed line indicates the exact latitude where the instruments were installed.

Fourier analysis of the SSH time series determined a dominant frequency of 0.0078 (1/day) (corresponding to a 128-day or 4-month period) for the location of Mooring 1, and a frequency of 0.0039 (1/day) (corresponding to a 256-day or 8-month period) for the location of Mooring 2.

Table 1. Time series frequencies of the U velocity component for the current meters at Mooring 1 and Mooring 2. For each current meter, the corresponding depth, frequency, period, and Power Spectral Density (PSD) are indicated.

Mooring 1			Mooring 2		
Current meter depth m (dbar)	Frequency $months^{-1}$ ($days^{-1}$)	Period months (days)	Current meter depth m (dbar)	Frequency $months^{-1}$ ($days^{-1}$)	Period months (days)
2,044 (2,069)	0.25 (0.0078) 0.33 (0.0117)	4 (128) 3 (85)	2,316 (2,345)	0.12 (0.0039)	8 (256)
2,406 (2,437)	0.25 (0.0078)	4 (128)	2,717 (2,753)	0.12 (0.0039) 0.25 (0.0078)	8 (256) 4 (128)
2,846 (2,886)	0.25 (0.0078) 0.33 (0.0117)	4 (128) 3 (85)	3,116 (3,160)	0.12 (0.0039) 0.25 (0.0078)	8 (256) 4 (128)
3,573 (3,629)	0.25 (0.0078) 0.33 (0.0117)	4 (128) 3 (85)	3,531 (3,585)	0.12 (0.0039) 0.50 (0.0078)	8 (256) 2 (64)
3,788 (3,849)	0.25 (0.0078) 0.33 (0.0117)	4 (128) 3 (85)	3,822 (3,883)	0.12 (0.0039)	8 (256)
4,001 (4,068)	0.25 (0.0078) 0.33 (0.0117)	4 (128) 3 (85)	4,016 (4,082)	0.12 (0.0039) 0.25 (0.0078)	8 (256) 4 (128)
-	-	-	4,210(4,281)	0.12 (0.0039) 0.25 (0.0078)	8 (256) 4 (128)

CONCLUSIONS

This study shows that the flow at Mooring 1 is directed toward the west-southwest. At Mooring 2, there is no clear direction, but a northwest direction can be observed in some layers. This study identifies the influence of bathymetry on both moorings, especially at depths near the ocean bottom. Finally, this study highlights that Rossby waves are associated with barotropic changes in the study area, which contribute to some variability in the NADW.

ACKNOWLEDGEMENTS

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References: