Assessment of Sampling Bias in the Bentayga Eddy: Technical Response to Reviewer Comments

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1 Introduction

During the eIMPACT2 survey, an intrathermocline eddy named *Bentayga* was extensively sampled aboard the R/V *Sarmiento de Gamboa*. The sampling strategy comprised several phases, two of which are included in the study presented by Valencia et al. [2025].

One of the main concerns raised by an anonymous referee (`https://doi.org/10.5194/egusphere-2025-99-RC3`) was the lack of synopticity in the dataset selected to evaluate the eddy's geometry and its derived properties—specifically, kinetic energy (KE), available potential energy (APE), available heat anomalies (AHA), and available salt anomalies (ASA).

Here, building on the framework proposed by Allen et al. [2001], we evaluate the degree of spatial distortion introduced during the sampling phase used for those calculations: the Oceanographic Transect (OceT) phase. The objective is to assess how accurately the eddy's true structure was captured under non-synoptic sampling conditions.

To this end, we compare the OceT results with quasi-synoptic sections that provide a more instantaneous view of the mesoscale structure. These comparisons, both visual and quantitative, help estimate the potential bias introduced by spatial distortion and are intended to directly address the methodological concerns raised during the review process.

2 Description of the non- and quasi-synoptic phases

2.1 eIMPACT OceT phase

The non-synoptic phase corresponds to the **eIMPACT OceT phase**, conducted between 19 and 28 November 2022. It consisted of a series of 26 oceanographic stations along a nearly zonal transect (OceT) that crossed the eddy from east to west (Fig. 1). At each station, vertical profiles of CTD-O and VMADCP were obtained. The stations were spaced approximately 12.7 $\pm$ 2.8 km apart, and the profiles extended from the surface to a depth of around 1500 m.

As seen in Fig. 1, some degree of distortion in the eddy's shape can be inferred from the sampling. This is explained by the fact that *Bentayga* was translating with an average velocity c of 0.051 $\pm$ 0.012 m s^{-1}, while the R/V was moving in the same direction at a mean speed v_v of 0.454 $\pm$ 0.167 m s^{-1}. As the anonymous referee pointed out, and as also discussed in Allen et al. [2001], this distortion resulting from the lack of synopticity may compromise the structural integrity of the eddy, introducing a significant bias in all calculations involving its spatial dimensions.

2.2 eIMPACT SeaSoar phase

The quasi-synoptic phase used in Valencia et al. [2025] corresponds to the **eIMPACT SeaSoar phase**, conducted during 9–14 November 2022. Continuous measurements were obtained using a towed CTD-O mounted on an undulating SeaSoar vehicle, combined with VMADCP observations. This phase employed a southwest–northeast sampling grid consisting of seven transects (each approximately 278 km long), spaced by $\sim$22 km, and sampled vertical layers between 30 and 320 m depth (Fig. 2). However, this dataset was primarily used to construct an objectively interpolated three-dimensional field, rather than to evaluate the structural shape of *Bentayga*.

In the present report, we use two of the seven along-eddy transects, selecting those closest to the eddy's center. For consistency, we retain their original numbering, with transect T3 located to the south and T4 to the north of *Bentayga*'s center. Transect T3 was conducted on 11 November, approximately between 01:00 and 17:00 UTC, with the R/V moving in the same direction as the eddy at a mean velocity of $v_v = 4.31 \pm 0.092$ m s^{-1}, while *Bentayga* exhibited a translational velocity of $c = 0.041$ m s^{-1}. T4 was recorded between 19:00 UTC on 11 November and 10:00 UTC on 12 November, during which the R/V moved against the eddy's direction at a speed of $v_v = 4.29 \pm 0.127$ m s^{-1}, while the eddy translated at a mean velocity of $c = 0.051 \pm 0.014$ m s^{-1}.

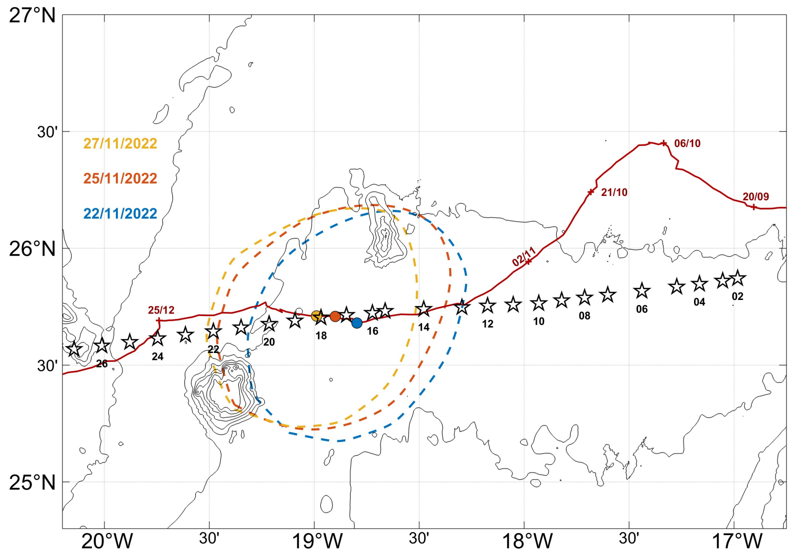

Figure 1: Study area showing the **eIMPACT OceT phase** sampling (19–28 November 2022). White stars indicate the 26 oceanographic stations where CTD-O and VMADCP profiles were collected. The thick dark red line traces the trajectory of *Bentayga* over time, with selected dates annotated. Colored dashed ellipses depict the eddy's perimeter on specific days, defined by the location of maximum circum-averaged velocity, and corresponding colored dots mark its center. Thin black contours represent isobaths every 500m, ranging from 500 to 5000m depth.

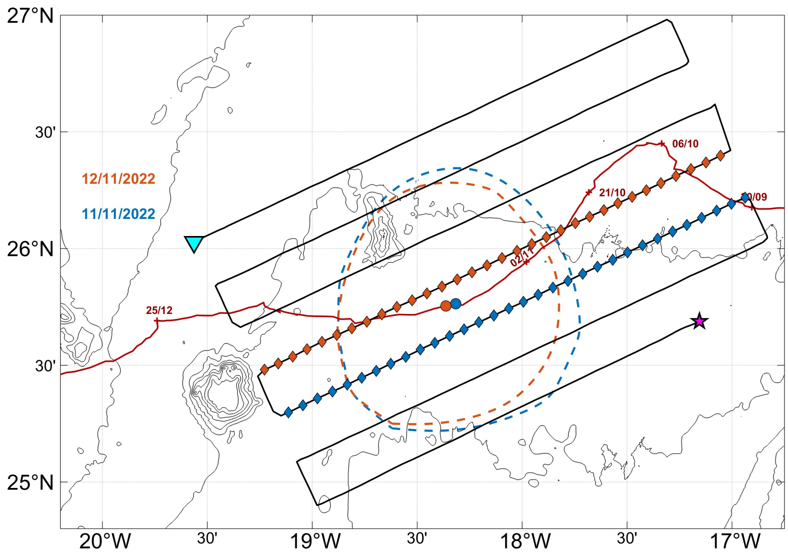

Figure 2: Same as Fig. 1, but for the spatial coverage during the **eIMPACT SeaSoar phase** (9–14 November 2022). Thick black lines indicate the grid-like trajectory of the R/V as it towed the undulating SeaSoar vehicle and simultaneously recorded VMADCP data. Diamond markers highlight the paths of transects T3 and T4, both colored by date

2.3 eIMPACT Ortho-transects phase

In addition to the main survey phases, a distinct configuration of two orthogonal transects—hereafter referred to as the **ortho-transects**—was conducted across *Bentayga*, forming a cross-shaped sampling pattern centered on the eddy (Fig. 3). These transects were carried out immediately after the end of the **eIMPACT SeaSoar phase**, between 02:00 UTC on 14 November and 03:00 UTC on 15 November.

During the **eIMPACT ortho-transects phase**, only VMADCP currents were continuously recorded. Since both transects intersected the eddy close to its center, they were used to evaluate the radial structure of its azimuthal velocities and to compare it with that obtained during the **eIMPACT OceT phase** [Valencia et al., 2025].

The transects—hereafter named the Zonal Transect (ZT) and the Meridional Transect (MT)—crossed the eddy from west to east and from south to north, respectively. The ZT was conducted on 14 November 2022 between 02:00 and 08:00 UTC, spanning a total distance of 116.07 km. During this period, the R/V moved at an average speed (v_v) of 4.60 ± 0.22 m s^{-1}, opposite to the eddy's propagation direction, which exhibited a translational speed (c) of 0.0704 m s^{-1}. The MT was carried out between 19:00 UTC on 14 November and 03:00 UTC on 15 November, covering 122.43 km from south to north. In this case, the vessel moved at a similar speed of 4.66 ± 0.24 m s^{-1}, approximately orthogonal to the eddy's translational path.

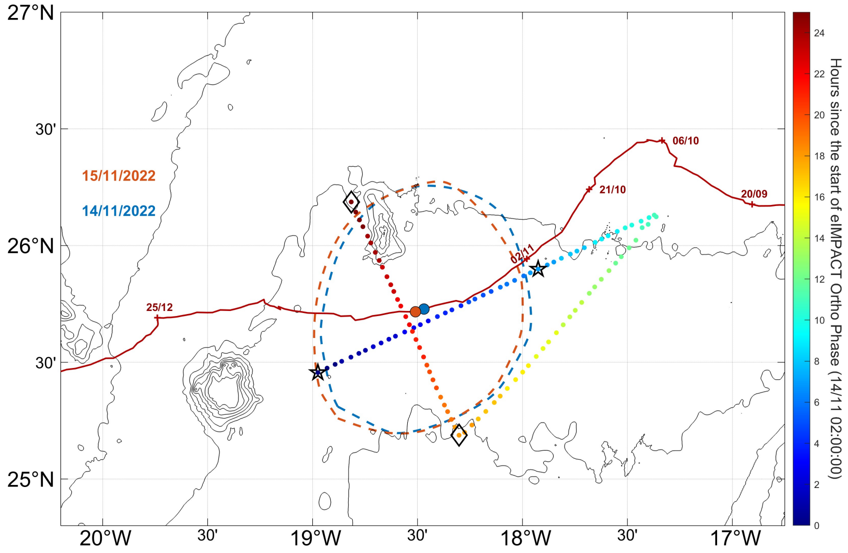

Figure 3: Same as Fig. 1, but for the **eIMPACT ortho-transects phase** (14–15 November 2022). The color-coded circles represent the full trajectory of the R/V, with colors indicating hours elapsed since the beginning of the phase (14 November at 02:00 UTC). Stars and diamonds mark the segments defining ZT and MT, which were selected for the analysis presented in this study.

3 Mathematical Formulation

Equation (10) from Allen et al. [2001] describes the effect of asynoptic sampling on the apparent wavelength of a propagating signal m, as observed from a moving vessel:

$$\lambda' = \lambda \left(1 - \frac{c}{v_v}\right)^{-1}$$

where:

- λ is the true spatial wavelength of the feature (e.g., the intrinsic horizontal scale of the eddy),
- c is the propagation speed of the feature (e.g., the eddy's translational velocity),
- v_v is the vessel speed along the same axis as the feature's motion,
- λ' is the apparent wavelength inferred from the moving platform.

This relationship captures a Doppler-like distortion introduced by the relative motion between the sampling platform and the moving feature. When the vessel travels in the same direction as the propagating feature ($c > 0$), the observed wavelength increases ($\lambda' > \lambda$); conversely, if the vessel moves against the propagation direction, the observed wavelength is shortened ($\lambda' < \lambda$).

This Doppler-induced deformation can significantly affect the interpretation of mesoscale features, particularly when diagnosing their spatial structure or computing derived quantities that depend on horizontal gradients.

To formalize this distortion, we define a **Doppler Factor** D:

$$D = 1 - \frac{c}{v_v^{(\parallel)}}$$

where:

- $c > 0$ is the propagation speed of the feature, defined as positive in a fixed reference direction,
- $v_v^{(\parallel)}$ is the component of the vessel's velocity along the same direction.

Depending on the sign of $v_v^{(\|)}$, the Doppler Factor can take two regimes:

- $v_v^{(\|)} > 0$: vessel moves in the same direction as the propagating feature (downstream),
- $v_v^{(\|)} < 0$: vessel moves in the opposite direction (upstream).

The Doppler Factor modifies the apparent wavelength as:

$$\lambda' = \frac{\lambda}{D} = \lambda \left(1 - \frac{c}{v_v^{(\|)}}\right)^{-1}$$

Thus:

Downstream sampling: $D < 1 \Rightarrow \lambda' > \lambda$. The structure appears elongated.

Upstream sampling: $D > 1 \Rightarrow \lambda' < \lambda$. The structure appears compressed.

Effective along-propagation velocity in cross-stream transects

In cases where the vessel traverses the feature along a path that is not aligned with its direction of propagation (e.g., a cross-stream transect), the vessel's effective speed in the direction of the feature's movement must be projected onto the propagation axis. As shown in Equation (12) of Allen et al. [2001], this projection can be expressed as:

$$v_f = v_s \frac{S}{S + \Lambda}$$

Where:

- v_v is the vessel's speed along the actual sampling path (e.g., the cross-stream transect),
- $v_f \equiv v_v^{(\|)}$ is the effective component of the vessel's speed projected along the direction of the feature's propagation,
- S is the track leg separation,
- Λ is the length of each cross front leg of the vessel's track.

This expression allows us to convert a cross-stream transect velocity v_v into an equivalent along-stream velocity v_f, which can then be inserted into the Doppler factor and apparent wavelength expressions defined previously.

In our specific case, the vessel executed a single, long transect nearly orthogonal to the direction of the eddy's propagation. This situation corresponds to the limit where the cross-track leg length Λ is much greater than the leg separation S, i.e., $S \ll \Lambda$. Under this condition, the projection of the vessel's speed onto the eddy's propagation direction—used to compute the Doppler factor—can be expanded as follows.

Starting from the projection formula given by Equation (12) of Allen et al. [2001]:

$$v_f = v_v \cdot \frac{S}{S + \Lambda}$$

we introduce the small parameter $\epsilon = \frac{S}{\Lambda} \ll 1$, and rewrite the expression as:

$$v_f = v_s \cdot \frac{\epsilon}{1 + \epsilon}$$

Expanding in powers of ϵ yields:

$$v_f \approx v_v \cdot \left(\epsilon - \epsilon^2 + \epsilon^3 - \dots\right) = v_v \cdot \left(\frac{S}{\Lambda} - \left(\frac{S}{\Lambda}\right)^2 + \left(\frac{S}{\Lambda}\right)^3 - \dots\right)$$

Since $S \to 0$ in our case, this shows that:

$$v_f \to 0 \quad \Rightarrow \quad D = 1 - \frac{c}{v_f} \to -\infty$$

That is, the **effective along-propagation velocity becomes negligible**, which implies a **strong Doppler-like distortion** when computing apparent wavelengths from a cross-eddy transect. In this regime, the classical Doppler factor and gradient-based diagnostics must be interpreted with caution or corrected using time-adjusted spatial coordinates.

Despite the theoretical sensitivity of cross-stream transects to asynoptic distortion, it is important to contextualize the impact in our specific case along MT. The eddy's translational velocity was relatively small, with $c = 0.0704\,\mathrm{m \cdot s^{-1}}$, while the R/V moved at an average speed of $v_v \approx 4.66\,\mathrm{m \cdot s^{-1}}$. The full cross-eddy transect (MT) lasted approximately 7.3 hours, during which the eddy displaced by only about 1.8 km. Given the eddy's horizontal scale—exceeding 100 km in diameter—this displacement is minor and unlikely to produce a significant distortion in the inferred structure.

Moreover, while the rotational motion of fluid parcels could also contribute to internal distortion, previous results from Valencia et al. [2025] show that the azimuthal velocities in the inner core (within a radius of ~ 25 km) result in rotation periods of approximately 4 days. Since this rotational timescale is significantly longer than the duration of the MT transect, the relative motion of water parcels during the sampling window is minimal. Additionally, this rotational period increases with radius, further reducing the likelihood of substantial deformation at larger distances from the eddy center.

Therefore, although the theoretical framework suggests a strong potential for Doppler-like distortion in cross-stream transects, both the slow drift of the eddy and the relatively slow internal rotation imply that, in our case, the effect is likely to be small. This supports the validity of using MT to compare the radial structure of azimuthal velocities, as theoretical considerations suggest that asynoptic distortions should be limited in this case.

4 Assessment of Apparent Structure Deformation Due to Sampling Strategy

OceT Transect: Along-Eddy Sampling

Based on the Doppler factor analysis presented above, we expect that the eddy structure observed during the **eIMPACT OceT phase** was subject to spatial distortion due to the asynoptic nature of the sampling. In particular, *Bentayga* translated westward at a mean speed of $c = 0.051 \pm 0.012\,\mathrm{m \cdot s^{-1}}$, while the R/V advanced in the same direction with a mean velocity of $v_v = 0.454 \pm 0.167\,\mathrm{m \cdot s^{-1}}$. Over the course of the ~9-day transect, the eddy displaced approximately 40 km, a distance comparable to its inner-core radius (~ 25 km) and substantial relative to its total horizontal scale (~ 100 km). This motion is expected to stretch the apparent horizontal structure of the eddy in the direction of sampling, as predicted by the Doppler framework.

Figure 5 of Valencia et al. [2025]—showing vertical sections of potential density anomaly, conservative temperature, and absolute salinity along OceT—presents signatures consistent with this elongation. In that study, however, we interpreted the structure as a physical feature of the eddy: an inner core surrounded by two distinct velocity rings, together spanning a radial width of ~ 55 km. Interestingly, this scale is close to the mean displacement of the eddy during the OceT sampling phase, suggesting that the observed ring-like structure may, at least in part, result from Doppler-induced deformation.

As derived earlier, the Doppler Factor D should quantify the distortion in the observed spatial scale due to asynoptic sampling. To express this distortion as a percentage change in the apparent spatial scale, we define:

$$\Delta_\lambda = \left(\frac{1}{D} - 1 \right) \times 100$$

where:

- Δ_λ is the percentage of deformation in the apparent wavelength,
- $D = 1 - \frac{c}{v_v}$ is the Doppler Factor.

For the **eIMPACT OceT phase**, the eddy drift (c) and vessel speed (v_v) were:

$$c = 0.051 \pm 0.012 \ \mathrm{m \cdot s^{-1}}, \qquad v_v = 0.454 \pm 0.167 \ \mathrm{m \cdot s^{-1}}$$

This yields:

$$D = 1 - \frac{c}{v_v} = 1 - \frac{0.051}{0.454} \approx 0.888$$

Thus, the expected distortion is:

$$\Delta_\lambda = \left(\frac{1}{0.888} - 1\right) \times 100 \approx 12.6\%$$

We can also estimate the uncertainty in D given by:

$$\sigma_D = \left|\frac{\partial D}{\partial c}\right| \sigma_c + \left|\frac{\partial D}{\partial v_v}\right| \sigma_{v_v} = \left|-\frac{1}{v_v}\right| \sigma_c + \left|\frac{c}{v_v^2}\right| \sigma_{v_v}$$

Then, inserting the numerical values:

$$\sigma_D = \left(\frac{1}{0.454} \cdot 0.012\right) + \left(\frac{0.051}{(0.454)^2} \cdot 0.167\right) \approx 0.026 + 0.023 = 0.049$$

To estimate the propagated uncertainty in Δ_λ, we use:

$$\sigma_{\Delta_\lambda} = \left|\frac{d}{dD}\left(\frac{1}{D} - 1\right) \times 100\right| \cdot \sigma_D = \left(\frac{100}{D^2}\right) \cdot \sigma_D$$

$$\sigma_{\Delta_\lambda} = \left(\frac{100}{0.888^2}\right) \cdot 0.049 \approx 126.8 \cdot 0.049 \approx 6.2\%$$

So, the sampling strategy during the **eIMPACT OceT phase** likely induced a spatial distortion of:

$$\Delta_\lambda = 12.6 \pm 6.2\%$$

Representing a non-negligible elongation of the apparent horizontal structure of the eddy, primarily along the sampling direction.

SeaSoar Transects T3 and T4: Opposing Sampling Directions

Transects T3 and T4 from the **eIMPACT SeaSoar phase** were conducted on consecutive days, representing contrasting sampling configurations: T3 was aligned with the eddy's propagation direction (downstream), while T4 was performed in the opposite direction (upstream).

T3 was carried out on 11 November 2022, from 00:48 to 16:33 UTC, lasting approximately 15.8 hours. During this transect, the vessel advanced at a mean speed of $v_v = 4.314 \pm 0.092\,\mathrm{m \cdot s^{-1}}$, in the same direction as *Bentayga*, which translated at $c = 0.041\,\mathrm{m \cdot s^{-1}}$, moving approximately 2.33 km, which is minimal compared to its diameter (~ 100 km). The Doppler factor was:

$$D = 1 - \frac{c}{v_v} = 1 - \frac{0.041}{4.314} \approx 0.9905$$

and the corresponding percentage of deformation:

$$\Delta_\lambda = \left(\frac{1}{D} - 1\right) \times 100 \approx 0.96\%$$

To propagate the uncertainty:

$$\sigma_D = \left|\frac{\partial D}{\partial v_v}\right| \sigma_{v_v} = \left|\frac{c}{v_v^2}\right| \sigma_{v_v} = \left(\frac{0.041}{(4.314)^2}\right) \cdot 0.092 \approx 0.0002$$

$$\sigma_{\Delta_\lambda} = \left(\frac{100}{D^2}\right) \cdot \sigma_D = \left(\frac{100}{(0.9905)^2}\right) \cdot 0.0002 \approx 0.02\%$$

Thus:

$$\Delta_\lambda = 0.96 \pm 0.02\%$$

T4 was conducted from 18:38 UTC on 11 November to 10:30 UTC on 12 November, with a duration of 15.9 hours. In this case, the vessel moved against the eddy's propagation direction at $v_v = 4.293 \pm$

$0.128\,\mathrm{m\cdot s^{-1}}$, while *Bentayga* translated at $c = 0.051\,\mathrm{m\cdot s^{-1}}$, displacing approximately 2.92 km during the transect. The resulting Doppler factor was:

$$D = 1 - \frac{c}{-v_v} = 1 + \frac{c}{v_v} = 1 + \frac{0.051}{4.293} \approx 1.0119$$

leading to:

$$\Delta_\lambda = \left(\frac{1}{D} - 1\right) \times 100 \approx -1.18\%$$

Uncertainty:

$$\sigma_D = \left(\frac{0.051}{(4.293)^2}\right) \cdot 0.128 \approx 0.0004$$

$$\sigma_{\Delta_\lambda} = \left(\frac{100}{D^2}\right) \cdot \sigma_D = \left(\frac{100}{(1.0119)^2}\right) \cdot 0.0004 \approx 0.039\%$$

Thus:

$$\Delta_\lambda = -1.18 \pm 0.04\%$$

Although T3 and T4 were performed with opposite orientations, both exhibit very small Doppler-induced deformation—less than 1.2%—with minor uncertainty. These results confirm that the SeaSoar transects can be considered quasi-synoptic, introducing negligible spatial distortion in the observed eddy structure.

ZT: Counter-Propagation Sampling

The Zonal Transect (ZT) of the **eIMPACT ortho-transects phase** was carried out on 14 November 2022, from 01:15 to 08:15 UTC, lasting approximately 7.0 hours. During this time, the vessel advanced nearly zonally in the opposite direction to the eddy's translation (i.e., upstream), at an average speed of $v_v = 4.604 \pm 0.223\,\mathrm{m\cdot s^{-1}}$, while *Bentayga* translated westward at $c = 0.070\,\mathrm{m\cdot s^{-1}}$.

Over the duration of the transect, the eddy displaced a horizontal distance of approximately 1.77 km. This displacement is relatively small compared to the transect length (116.07 km) and the horizontal scale of the eddy itself, indicating limited structural advection during the sampling.

The Doppler factor for this transect is:

$$D = 1 - \frac{c}{v_v} = 1 - \frac{0.070}{4.604} \approx 0.9848$$

The percentage of deformation in the apparent wavelength is then:

$$\Delta_\lambda = \left(\frac{1}{D} - 1\right) \times 100 \approx \left(\frac{1}{0.9848} - 1\right) \times 100 \approx 1.54\%$$

The uncertainty in D is computed using first-order error propagation:

$$\sigma_D = \left|-\frac{1}{v_v}\right| \sigma_c + \left|\frac{c}{v_v^2}\right| \sigma_{v_v} = \frac{1}{4.604} \cdot 0.000 + \frac{0.070}{(4.604)^2} \cdot 0.223 \approx 0.00073$$

Then, the uncertainty in the percentage deformation becomes:

$$\sigma_{\Delta_\lambda} = \left(\frac{100}{D^2}\right) \cdot \sigma_D \approx \frac{100}{(0.9848)^2} \cdot 0.00073 \approx 0.075\%$$

Thus, the expected distortion due to asynoptic sampling during ZT is:

$$\Delta_\lambda = 1.54 \pm 0.08\%$$

This result confirms a negligible Doppler-induced deformation in the observed eddy structure. The short duration of the transect and the minimal displacement of the eddy—less than 2% of the transect length—further support the reliability of this section for analyzing the radial distribution of the eddy's azimuthal velocities.

To summarize the results presented throughout this section, Table 1 compiles the key parameters used in the Doppler distortion analysis for each sampling transect. The table includes the direction of sampling relative to the eddy's propagation, the average vessel and eddy speeds, total sampling duration, the eddy's displacement during each transect, and the corresponding Doppler factor and wavelength deformation. This synthesis allows for a direct comparison of the magnitude of Doppler-like effects across phases. Notably, the strongest deformation is associated with the eIMPACT OceT phase, where the eddy's slow but sustained displacement over nine days likely contributed to a non-negligible spatial bias. In contrast, transects T3, T4, and ZT exhibit minimal deformation, reinforcing their value as quasi-synoptic references. Although Doppler metrics were not formally computed for MT due to its orthogonal orientation, our earlier discussion supports its reliability as a reference transect given the minimal eddy movement and slow internal rotation during its sampling.

Table 1: Summary of Doppler distortion analysis for the different sampling phases. For each transect, we show the direction of sampling relative to the eddy's propagation, average vessel speed (v_v), mean eddy translation speed (c), total duration (Δt), eddy displacement during sampling (Δx), Doppler Factor (D), and the estimated deformation in observed wavelength (Δ_λ).

Transect	**Direction**	v_v [m/s]	c [m/s]	Δt	Δx [km]	D	Δ_λ [%]
OceT	Downstream	0.454	0.051	9.0 d	40.0	0.888 ± 0.049	12.6 ± 6.2
T3	Downstream	4.314	0.041	15.8 h	2.33	0.990 ± 0.002	1.0 ± 0.2
T4	Upstream	4.293	0.051	15.9 h	2.92	1.012 ± 0.003	-1.2 ± 0.3
ZT	Upstream	4.604	0.070	7.0 h	1.77	1.015 ± 0.005	-1.5 ± 0.5
MT	Orthogonal	4.662	0.070	7.3 h	1.84	—	—

5 Hydrographic Structure Along SeaSoar Transects T3 and T4

The SeaSoar transects T3 and T4 were conducted during the eIMPACT2 survey between 11 and 12 November 2022. Both sections crossed the Bentayga eddy along near-parallel paths, slightly offset from its geometric center—T3 sampling the southern region and T4 the northern. The undulating SeaSoar platform profiled the upper ocean (30–320 m depth) with a vertical resolution of approximately 2 m and a horizontal resolution of 1.5 km.

Figure 4 presents vertical sections of potential density anomaly (σ_θ), conservative temperature (Θ), and absolute salinity (S_A) along T4 (upper panels) and T3 (lower panels). These profiles reveal the internal hydrographic structure of the eddy and provide a reference for evaluating its spatial symmetry and vertical stratification. These quasi-synoptic observations are central to the ongoing effort to assess the potential spatial distortion introduced by the non-synoptic sampling performed during the OceT phase.

In particular, they are being used to construct an idealized radial representation of the eddy, which serves as a baseline for comparison against the potentially deformed patterns observed in OceT. This reconstruction is being approached by interpolating the hydrographic properties from T3 and T4 onto a common radial coordinate system centered on the estimated eddy core. Each data point is assigned a radial distance from this center, enabling the aggregation of values into a smoothed, azimuthally symmetric structure. The resulting fields aim to represent a reference eddy minimally affected by Doppler-like distortion, against which the features observed in OceT can be contrasted. This process is intended to help disentangle genuine physical asymmetries from sampling-induced artifacts and to clarify whether features such as elongation or displaced cores are intrinsic or methodological in origin.

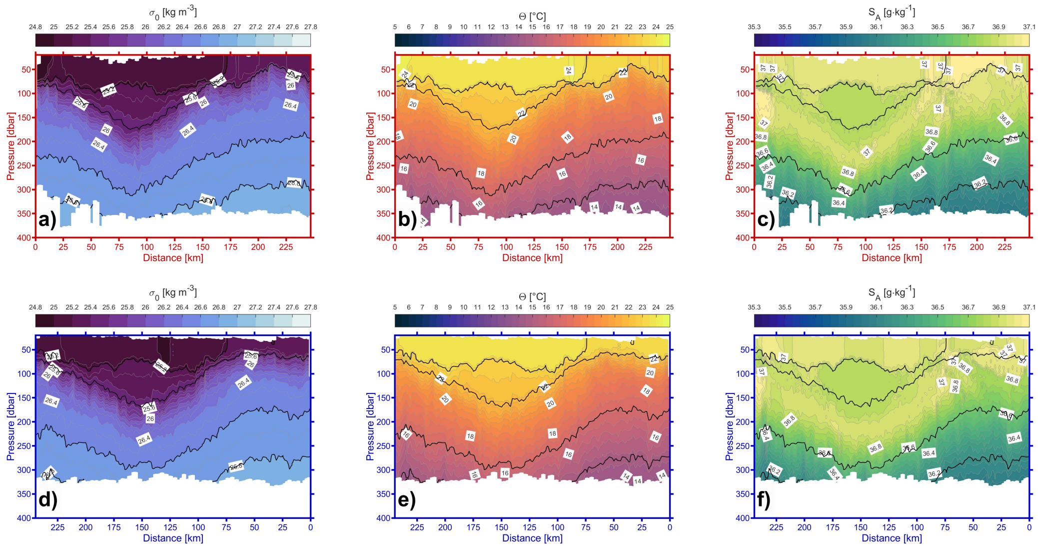

Figure 4: Vertical sections of (a,d) potential density anomaly (σ_θ), (b,e) conservative temperature (Θ), and (c,f) absolute salinity (S_A) for transects T4 (top row) and T3 (bottom row). The distance axis is defined along the transect track, with pressure as the vertical coordinate. Data were collected using the SeaSoar platform during the eIMPACT2 survey.

6 Conclusions

This study highlights the importance of sampling strategy in capturing the mesoscale structure of eddies. The differential movement of the eddy and the survey grid affects data interpretation, requiring correction factors such as the Doppler shift to properly reconstruct dynamic features.

7 Conclusions

This report provides a focused assessment of the spatial distortion introduced by non-synoptic sampling during the eIMPACT OceT phase, in response to concerns raised during the EGU Discussion process. Using the Doppler framework proposed by Allen et al. [2001], we quantified the expected deformation of the observed eddy structure and compared it to quasi-synoptic references obtained during the eIMPACT SeaSoar and ortho-transects phases.

Our analysis shows that the sampling configuration during OceT likely introduced a non-negligible elongation of the eddy's apparent structure, with an estimated deformation of 12.6±6.2% in the sampling direction. In contrast, the SeaSoar transects T3 and T4 and the ortho-transect ZT present much lower distortion values (all $< 1.6\%$), supporting their use as quasi-synoptic references. The MT transect, while not formally evaluated due to its orthogonal orientation, was also deemed reliable based on the low drift and slow internal rotation of the eddy during its sampling.

To further evaluate the impact of distortion, we are constructing an idealized, azimuthally averaged structure of the eddy using interpolated data from T3 and T4. This reconstructed structure will serve as a baseline to compare with the eddy as observed during the OceT phase, helping to distinguish between genuine physical asymmetries and sampling-induced artifacts. Additionally, a comparison of azimuthal velocity distributions has been initiated using data from the ortho-transects (ZT and MT), which intersect the eddy near its geometric center. These will be contrasted with the azimuthal velocities derived from the OceT sampling to assess the spatial consistency of the rotational structure, particularly the radial extent of the solid-body core. This dynamical cross-check provides an independent validation of the eddy structure and will help determine whether the kinematic features captured in OceT are robust or artifacts of spatial distortion.

Although the analysis is ongoing, the results obtained so far suggest that the non-synoptic sampling in OceT may introduce biases in the computation of dynamical metrics such as APE, KE, and ASA. Future work will aim to quantify the magnitude of these biases and determine whether corrections or reinterpretations are necessary for the affected estimates. Overall, this report confirms the relevance of considering synopticity when interpreting oceanographic structures and highlights the value of multiple sampling approaches to validate the robustness of derived conclusions.

Appendix: Altimetric Eddy Metrics

The altimetric eddy metrics used in this study—including the eddy's trajectory, center position, and the perimeter corresponding to the maximum circum-averaged geostrophic speed—were obtained from the near-real-time (NRT) product META3.2exp distributed by AVISO+ (SSALTO/DUACS) (`https://www.aviso.altimetry.fr`). Further details can be found in Valencia et al. [2025].

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