Response: We sincerely thank the reviewer for the time and effort dedicated to evaluating our manuscript. The comments and suggestions provided have been immensely helpful in improving the quality of our work. We have carefully addressed each point raised in the comments.

Comments

● The reader could be helped by the inclusion of the geostrophic and cyclogeostrophic balance equations, a discussion of the differences, and a schematic to illustrate this. This could then be used to explain some of the differences in the results e.g. why the geostrophic assumption is suitable for the ACE EKE in CC region (Fig 1) but not in the KE region. Are there largerpressure/centrifugal differences? And on line 196 'Thus the discrepancy…' could give further insight here by including equations and discussion.

Response 1: Thank you for your comments. Following your suggestion, firstly, we have added the relevant formulas for the cyclogeostrophic balance in Section 2. Secondly, to describe and explain Figure 1 more clearly, we have reorganized the corresponding paragraph. (L202-206, L210-212, L227-229)

2.2 Cyclogeostrophic balance equations

In the context of an horizontal, stationary, and inviscid flow, the momentum equation which links SSH and surface horizontal currents U is：

$$U \cdot \nabla U + f k \times U = -g \nabla \eta \tag{1}$$

where f is the Coriolis parameter, $\vec{k}$ is a vertical unit vector, η and g are the sea surface height and gravitational acceleration parameter, respectively. For Mesoscale curved ocean currents, the nonlinear term induced by the local curvature of the streamline cannot be ignored. Introducing the geostrophic velocities U_g from (1), this equation can be transformed to the form

$$\vec{U} - \frac{\vec{k}}{f} \times (\vec{U} \cdot \nabla \vec{U}) = \vec{U}_g \tag{2}$$

In cylindrical coordinates, this equation simplifies for the azimuthal velocities to the gradient wind equation (Knox and Ohmann, 2006):

$$\frac{V^2}{fR} + V = V_g \tag{3}$$

where V is the azimuthal velocity, V_g is the geostrophic velocity derived from the pressure gradient, and R is the radius of curvature. This equation admits an analytical solution for V.

According to Eq.3, the cyclogeostrophic Rossby number can be given by:

$$Ro_c = \frac{V}{fR} = \frac{V_g - V}{V} \tag{4}$$

Analysis shows that the discrepancies between geostrophic and cyclogeostrophic currents are governed by curvature:

$$\kappa = \frac{f\left(V_g - V\right)}{V^2} \tag{5}$$

where, κ is the curvature.

Additionally, the weaker Coriolis force in this region leads, according to Eq. 5, to a more significant cyclogeostrophic correction effect. Driven by the combined effects of the Coriolis force and prevailing wind belts, the North Pacific Subtropical Gyre exhibits basin-wide cyclonic circulation. Within this gyre, the CC region shows a notable prevalence of cyclonic eddies among long-lived surface eddy populations (Kurian et al., 2011). (L202-206)

This is primarily because the larger Coriolis force in high-latitude regions results in a smaller Rossby number under the cyclogeostrophic balance (Eq. 4), leading to an insignificant difference between the cyclogeostrophic and geostrophic flow velocities.(L210-212)

● The 'Discussion' section appears to be a continuation of results, focusing on case studies of ACE and CE in each region. Should a

separate section within the results be made called 'Case Studies'? I would not put new results in a discussion section.

Response 2: Thank you for your comments. The Results and Discussion sections have been integrated, and We have expanded the Discussion section to provide amore in-depth of analysis our research. (L555-562)

3.6 Case Studies

Statistical analysis of eddies in five North Pacific regions exhibiting significant differences between cyclogeostrophic and geostrophic EKE differences shows that streamline curvature substantially influences both fundamental eddy characteristics (such as lifespan, radius, formation, and dissipation) and key eddy parameters, including intensity, strain rate, and effective EKE. This influence is particularly strong in high-energy and low-latitude areas. In order to further explore the impact of streamline curvature on the evolution process of eddies, a comprehensive analysis was conducted on selected individual cases of both cyclonic and anticyclonic eddies from the SCS, KE, and HI regions.(L555-562)

● In the abstract there is mention of a few process changes but no actual discussion of this in the paper. Please consider what is written in the abstract should be discussed in the paper. For example, 'possess stronger potential energy'. I think this line refers to the 'Discussion' section and Figure 18 (?), but there is no discussion of this in the paper. I would disagree that the eddy possesses stronger potential energy. Is the eddy barotropic, is it baroclinic? The sea level anomaly does not change, and no subsurface examination is carried out, so it is hard to say this.

Response 3: Thank you for your comments. We have re-written the abstract. (L11-25)

The curvature of streamlines plays a significant dynamical and structural role in meandering currents. At scales comparable to the deformation radius, the motion of eddies is governed by a balance between the pressure gradient force, the Coriolis force, and the centrifugal force. For mesoscale eddies, the nonlinear term induced by the local curvature of streamlines is non-negligible. This study compares the statistical and dynamical parameters of mesoscale eddies under geostrophic and cyclogeostrophic

balances by examining five energetic North Pacific regions: the Aleutian Islands, Kuroshio Extension, South China Sea, California Coastal Current, and Hawaiian Islands. The comparison shows that cyclogeostrophic EKE is lower than geostrophic EKE for cyclonic eddies, whereas it is higher for anticyclonic eddies, particularly in energetic, low-latitude regions. The total number of eddies detected under the cyclogeostrophic balance is 35.65% lower than under the geostrophic balance. However, the frequency distributions of eddy radii in both frameworks show a right-skewed normal distribution. Detection under the cyclogeostrophic balance tends to eddies with larger radii and shorter lifespans. The velocity difference between the two balances for eddies increases with decreasing latitude. Similarly, case studies show that anticyclonic eddies exhibit more intense evolution under streamline curvature effects and are further prone to dissipation in low-latitude seas.

● There are a number of places throughout the paper that could benefit by further explanation. Some examples, 'eddy generation enhanced due to upwelling' (line 297), and 'AE influenced by curvature dissipate more readily' (line 607). Are there any process based studies that show these to be the case?

Response 4: Thank you for your comments.

(Line 297) To enhance the clarity of the findings, we have rewritten this sentence in the manuscript. (L294-296)
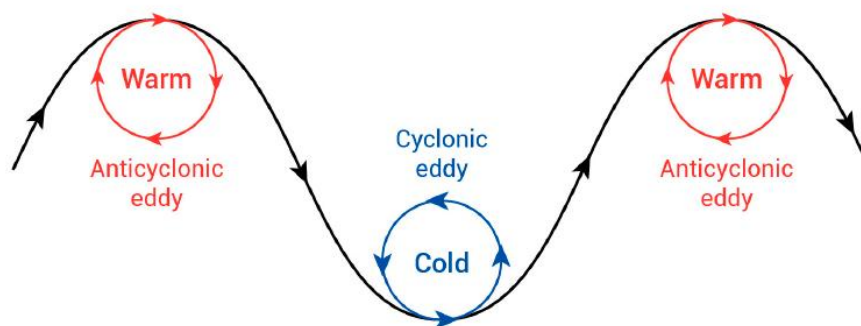
(Line 607) Regarding the five case studies, we have evaluated their necessity and streamline the discussion to focus on the most critical findings. Based on the statistical findings and the significance of streamline curvature, we have selected three regions — the Kuroshio Extension (KE), the South China Sea (SCS), and the Hawaiian Islands (HI)—for detailed case studies. (L563-633)

Furthermore, the description of some results has been rewritten to enhance accuracy.

● It is interesting that the Kuroshio Extension has the largest eddy radii (Fig 5), could there be a reason for this?

Response 5: Thank you for your comments. Using satellite altimetry data, Ji et al., (2018) revealed two main eddy generation mechanisms in the KE region . Apart from barotropic instability, baroclinic processes leading to the meandering path of the KE, which generates eddies with large spatial scales and long lifetimes, dominate the second mechanism.

● The inclusion of the case studies is to try and draw some physical understanding from the results? Maybe this needs to be clear.

Response 6: Thank you for your comments. We have re-writern the inclusion.

● At the end of the Introduction section, you could outline your paper e.g. 'In section X we will discuss the results, and in section Y …'. This will solve my above point.

Response 7: Thank you for your comments. We have add this part in the

Introduction. (L96-101)

The structure of this paper is as follows: Section 2 presents the methods and data employed in the study.In Section 3, we examine the statistical characteristics of kinematic parameters, the differences in dynamical parameters of mesoscale eddies under cyclogeostrophic and geostrophic balance, as well as the contrasting dynamical processes of individual eddies between the two balances, are summarized in Section 4.

● Stegner and Dritschel (2000) [A Numerical Investigation of the Stability of Isolated Shallow Water Vortices] looked at the stability of ACE and CE in cyclogeostrophic balance; maybe this paper will help to add further support and locate more citations.

Response 8: Thank you for your suggestions, we have reviewed the references you provided and integrated them into our research framework. (L628-633)

While Stegner and Dritschel (2000) noted that centrifugal force in shallow-water models stabilizes anticyclones but destabilizes cyclones, Shakespeare (2016) demonstrated that anticyclones sharpen more rapidly than cyclones under identical background strain. In a complementary finding, Buckingham et al. (2021) diagnostically showed that streamline curvature and the Rossby number together limit anticyclonic vortex intensity. Consequently, for altimeter-derived surface eddies, the action of centrifugal force leads to more pronounced differences in anticyclonic structures.

● I somewhat understand the inclusion of strain rate and enstrophy, but feel it should probably be omitted. In 2D turbulence, dissipation is proportional to enstrophy, and so you could get some understanding from this. The strain rate similarly suggests dissipation but in 3D turbulence, which the 0.25 degree altimeter is never going to capture. Have there been studies that have looked at turbulence using satellite altimeter data?

They are probably heavily constrained by resolution. An alternative could be to include the wind stress curl and Ekman pumping, but you then need a wind stress data product… you could look at spatial changes in EKE?

Response 9: We sincerely appreciate the reviewer's comments, which are both insightful and highly constructive. **The strain rate** indeed plays a significant role in turbulent dissipation. Similar to vorticity, strain rate characterizes the kinematic state of an eddy (Yang et al., 2020). By combining surface drifters, satellite altimetry and satellite ocean-color data, Zhang et al., (2019) detect that when the strain rate of mesoscale surface geostrophic flow is strong, it favors a higher ageostrophic kinetic energy level and an increase in surface chlorophyll concentration. The strain-induced frontal processes are characterized by a surface chlorophyll increase and secondary ageostrophic upwelling along the light side of the oceanic density front.
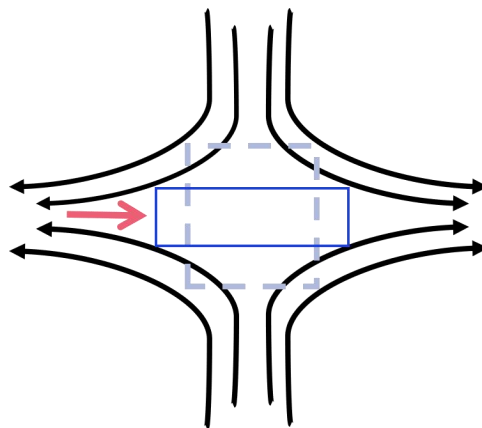
The geostrophic strain rate S_g is computed by the surface geostrophic velocity anomaly (u_g, v_g) from the altimeter data:

$$S_g = \sqrt[2]{\left(\frac{\partial u_g}{\partial x} - \frac{\partial v_g}{\partial y}\right)^2 + \left(\frac{\partial v_g}{\partial x} + \frac{\partial u_g}{\partial y}\right)^2}$$

This formula has been included in the manuscript, along with a corresponding explanation. (L140-144)

Mesoscale deformation flow, often referred to as the geostrophic strain field, has been found to effectively enhance mesoscale frontal structures, regulate the development of ageostrophic disturbances in submesoscale

fronts, and play a significant role in controlling nutrient upwelling and enhancing marine primary productivity. Regions with the strongest strain rates correspond to areas of high eddy kinetic energy. Strain rate characterizes the deformation of the flow field, manifesting as stretching in one direction and compression in the perpendicular direction, continuously stretching and contracting in horizontal space, thereby disrupting the geostrophic balance of the flow. Consequently, areas with strong strain rates often induce frontal processes (McWilliams, 2016; Zhang et al., 2019).

Schematic of surface flow strain rate. Red vector arrows indicate the flow direction, black solid lines with arrows denote streamfunction contours, blue dashed lines represent the boundaries of fluid parcels before deformation, and blue solid lines show the boundaries after deformation.

References :

Yang, X., Xu, G., Liu, Y., Sun, W., Xia, C., and Dong, C.: Multi-source data analysis of mesoscale eddies and their effects on surface chlorophyll in the Bay of Bengal, Remote Sens., 12, 3485, https://doi.org/10.3390/rs12213485, 2020.

Zhang, Z., Qiu, B., Klein, P., and Travis, S.: The influence of geostrophic strain on oceanic ageostrophic motion and surface chlorophyll, Nat. Commun., 10, 2838, https://doi.org/10.1038/s41467-019-10883-w, 2019.

McWilliams, J. C. (2006). Fundamentals of geophysical fluid dynamics. Cambridge University Press.

● The results are often quite long winded, could they be broken up and focus given to the most significant finding?

Response 10: We appreciate the reviewer's valuable feedback. To improve clarity, we have revised the results section by dividing it into clearer subsections, streamlining the text, and emphasizing the key outcomes more prominently.

● Could other eddy census studies be discussed further e.g. Chelton et al (2011), Chen et al (2019) 10.1029/2019JC014983

Response 11: Thank you for your suggestion. We have reviewed the references you provided and integrated them into our research framework. (L592, L638, L666)

● How do you think your results would differ if you chose an alternative eddy detection algorithm? Would eddy radii change? Just something to think about.

Response 12: Thank you for this relevant question. We agree that the choice of eddy detection algorithm can influence statistical results, including total numbers and radius distributions of eddies. As shown in You et al. (2021), the GOMEAD dataset (used eddy detection algorithm presented in this study) contains 8% fewer eddies than META (dataset uses an SLA based automatic eddy detection algorithm). This discrepancy stems from their methodological differences: GOMEAD tends to underestimate eddy counts and lifespans near islands and filters out

eddies with small radii, while META may merge two eddies into one due to tracking jumps and misses eddies when sea level anomaly (SLA) signals are weak.

We focus on the differences between the cyclogestrophic corrected dataset and the original altimetry dataset, and have supplemented the discussion accordingly in the manuscript. (L266-267)

Specific comments

- Line 22-23: eddy kinetic energy and Eddy Kinetic Energy - decide what to use.

Response 13: Thank you for your comment. We have noted it and confirm that "eddy kinetic energy" is used in our manuscript. We have carefully checked and revised the terminology for consistency.

- Line 24: 'Eddies predominantly …' this isn't new.

Response 14: Thank you for your comments. We have re-written the abstract. (L11-25)

The curvature of streamlines plays a significant dynamical and structural role in meandering currents. At scales comparable to the deformation radius, the motion of eddies is governed by a balance between the pressure gradient force, the Coriolis force, and the centrifugal force. For mesoscale eddies, the nonlinear term induced by the local curvature of streamlines is non-negligible. This study compares the statistical and dynamical parameters of mesoscale eddies under geostrophic and cyclogeostrophic balances by examining five energetic North Pacific regions: the Aleutian Islands, Kuroshio Extension, South China Sea, California Coastal Current, and Hawaiian Islands. The comparison shows that cyclogeostrophic EKE is lower than geostrophic EKE for cyclonic eddies, whereas it is higher for anticyclonic eddies, particularly in energetic, low-latitude regions. The total number of eddies detected under the cyclogeostrophic balance is 35.65% lower than under the geostrophic balance. However, the frequency distributions of eddy radii in both frameworks show a right-skewed normal distribution. Detection under the cyclogeostrophic balance tends to eddies with larger radii and shorter lifespans. The velocity difference between the two balances for eddies increases with decreasing latitude.

Similarly, case studies show that anticyclonic eddies exhibit more intense evolution under streamline curvature effects and are further prone to dissipation in low-latitude seas.

● Line 27: 'Vorticity is more stable' - the eddy is more stable by virtue of a smaller Rossby number?

Response 15: Thank you for your comments. In order to present the research outcomes more clearly, we have re-written the abstract. (L11-25)

● Line 31-32: Where do you look at eddy-eddy and eddy-current interactions?

Response 16: Thank you for your comments. In order to present the research outcomes more clearly, we have re-written the abstract. (L11-25)

● Line 50: space between 'kilometers(Chelton'.

Response 17: Thanks for your careful checks. We are sorry for our carelessness. Based on your comments, We have added spaces. (L41)

● Line 76: 'where leeward… shows significant periods…' do you cycles/variability?

Response 18: Thank you for your question. We have re-writern this part. (L65-69)

The Hawaiian Islands region is recognized as an area of frequent eddy occurrence (Calil et al., 2008). Using available datasets of sea surface height, sea surface temperature, and surface wind stress, Yoshida et al. (2011) further investigated the interannual-to-decadal variability of eddies within the Hawaiian Lee Countercurrent (HLCC) band.

● Line 108: source for satellite data?

Response 19: Thank you for your review. We have reorganized this part. (L104-114) The data download URL has been included in the manuscript. (L699-701)

- Line 112: put 'data are accessible …' in data availability, and cite in text.

Response 20: Thank you for your suggestions. We have revised the relevant sections according to your suggestions.(L104-114)

The data download URL has been included in the manuscript. (L699-701)

- Line 121: what is the velocity fluctuation? Spatial, temporal - 5,10 days?

Response 21: Thank you for your question. The relevant explanations have been added to the manuscript. (L132-137)

The eddy kinetic energy (EKE) is computed at each point in space and time as::

$$EKE = \frac{1}{2} \times \left[(u')^2 + (v')^2 \right] \tag{6}$$

where u' and v' are the surface velocity anomalies of zonal and meridional currents. The geostrophic eddy kinetic energy is obtained by the current components computed from the sea surface height anomalies (SSHA) of AVISO/DUCAS. For each component, the calculations are as follows:

$$u' = -\frac{g}{f} \left(\frac{\partial h'}{\partial y} \right) \tag{7}$$

$$v' = \frac{g}{f} \left(\frac{\partial h'}{\partial x} \right) \tag{8}$$

where h' is the SSHA. The cyclogeostrophic eddy kinetic energy is obtained by the cyclogeostrophic surface currents.

- Line 123: 'percentage difference…' between geos and cylco?

Response 22: Thank you for your question. We have reorganized this part. (L138-146)

The normalized difference between climatic mean geostrophic EKE and cyclogeostrophic EKE is given by:

$$a_{EKE} = \frac{\overline{EKE_i} - \overline{EKE_g}}{\overline{EKE_g}} = \frac{\sum_{i=1}^{n} \frac{1}{2}\left(\left(u_i'\right)^2 + \left(v_i'\right)^2\right) - \sum_{i=1}^{n} \frac{1}{2}\left(\left(u_g'\right)^2 + \left(v_g'\right)^2\right)}{\sum_{i=1}^{n} \frac{1}{2}\left(\left(u_g'\right)^2 + \left(v_g'\right)^2\right)} \times 100\% \tag{9}$$

where EKE_i denotes the EKE of the cyclogeostrophic surface currents, EKE_g represents the EKE of the geostrophic surface currents. u_i', v_i' are the zonal and meridional velocity anomalies of the cyclogeostrophic surface currents, respectively, while u_g' and v_g' denote the corresponding velocity anomalies of the geostrophic surface currents.

● Eq 5 is the dynamical Rossby number.

Response 23: Thank you for your comment. We have modified Equation 5 to clarify its meaning. (L153-154)

The relative vorticity, which quantifies the rotational characteristics of an eddy, can be expressed as follows:

$$\zeta = \frac{\partial v'}{\partial x} - \frac{\partial u'}{\partial y} \tag{12}$$

● Line 166: 'andSCS'

Response 24: Thank for your careful checks. We are sorry for our carelessness. Based on your comments, we have restored the spaces in the text. (L196)

● Line 180: 'This study compares…' say this earlier?

Response 25: Thank you for this helpful suggestion. We have re-writtern this part. (L214)

● Line 183: 'Satellite altimetry overestimates…' using geostrophic assumption?

Response 26: Thank you for your sugesstion. We have revised this part.

Geostrophic EKE derived from altimetry overestimates actual EKE in cyclonic eddies and underestimates it in anticyclonic eddies.
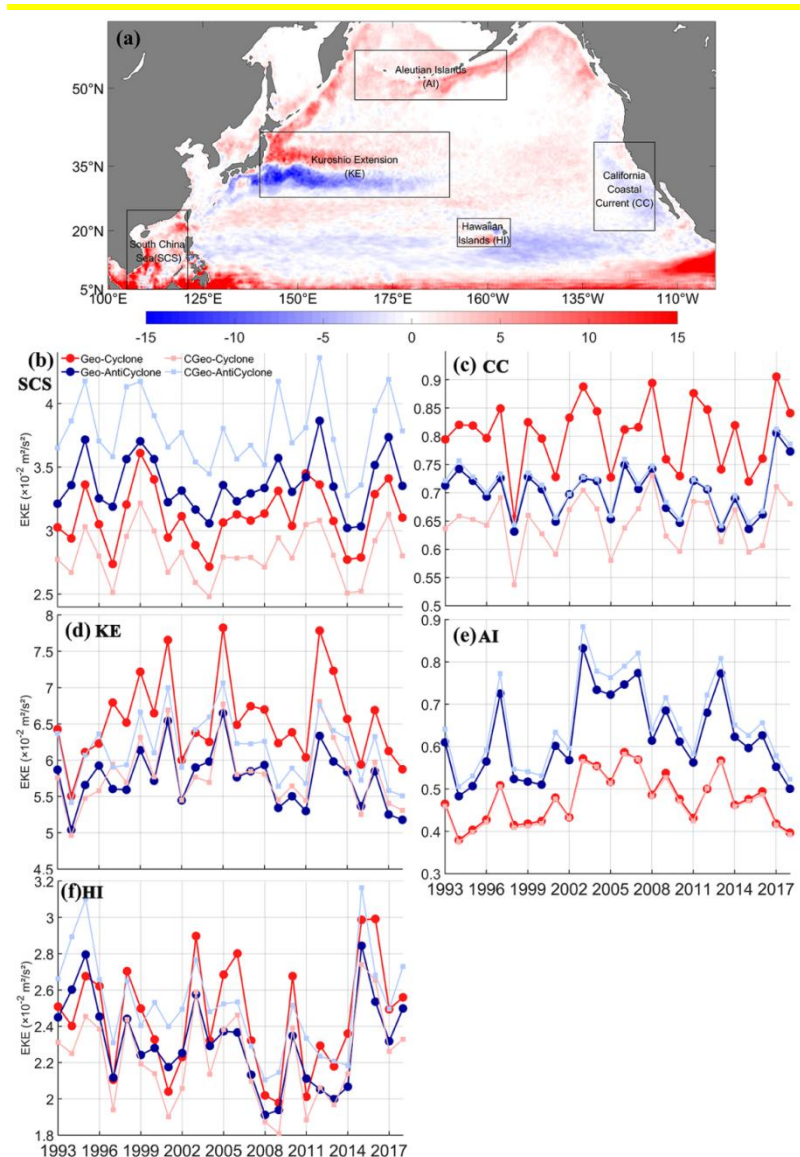
● Line 190: 'Spatially, the difference…' could be reworded to clarify cyclo is more positive than geos over the domain?

Response 27: Thank you for your comment. We have taken your comments seriously and have made the required additional explanations in the revised version. (L219-220)

indicating that the cyclogeostrophic current estimates exceed the geostrophic ones over most of the region

● Figure 1: Label each figure panel with the region (save reader from scanning caption and back to panels), remove legends from all but panel b.

Response 28： Thank you for the suggestion. We have re-plotted Figure1.

- Figure 2: Agulhas Insurgence?

Response 29： Thank you for your reminder. We sincerely thank the reviewer for careful reading. As suggested by the reviewer, we have corrected the 'Agulhas Insurgence' into 'AI'. The abbreviation 'AI' is used here primarily because Figure 1 already employs 'Aleutian Islands (AI)'.

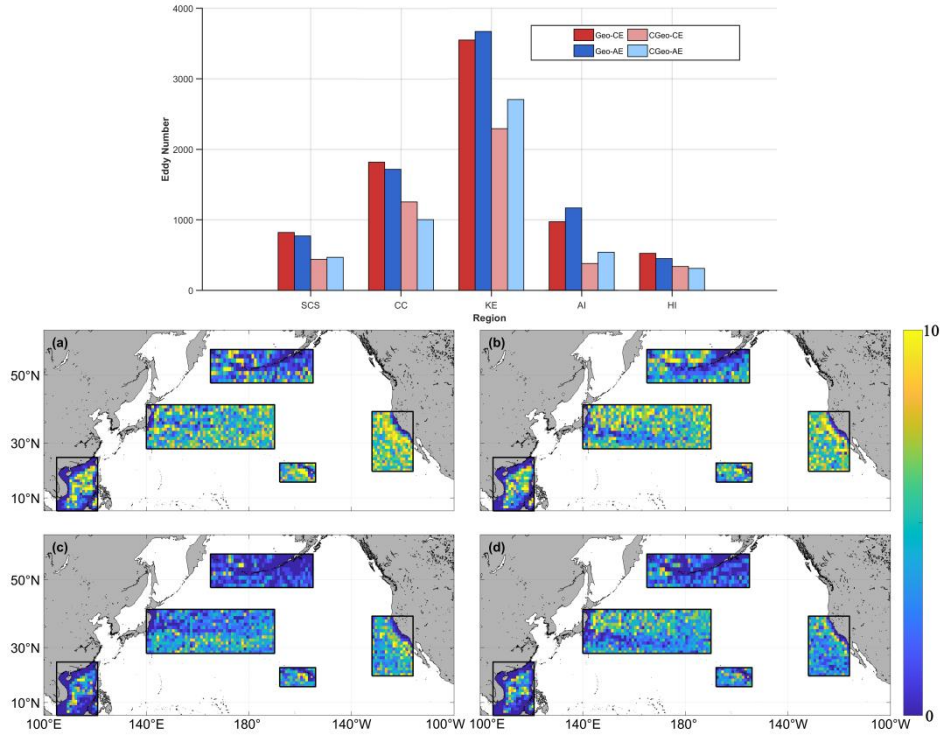- Figure 2: Why are there differences across regions?

Response 30： Thank you for your comments. The variations in eddy

kinetic energy (EKE) evolution across regions in Figure 2 are rooted in the distinct dynamical regimes and generation mechanisms specific to each area. The rate of energy gain, peak intensity, and decay rate of an eddy are all primarily controlled by the physical process that formed it and the environmental conditions it experiences.

We have revised this paragraph to better emphasize the main points. (L250-267)

- Figure 3: Regions are quite small, can these be made bigger?

Response 31: Thank you for your suggestion. Figure 3 primarily compares the total number of eddy detections, while the regional map illustrates their spatial differences. To enhance the clarity of the figure, we have changed the colormap and adjusted the numerical range of the colorbar.

● Line 360: Any studies showing why these eddies are larger? Can you cite any.

Response 32: Thank you for your question. We have added relevant references in the manuscript. (L362)

Such as:

The study by Dong et al. (2007) demonstrates that in deep-water island wakes, the horizontal scale of eddies is controlled by the Burger number $Bu = \left(R_d / D \right)^2$, where D is the island diameter and R_d is the baroclinic deformation radius. For large islands such as Hawaii, $D \gg R_d (i.e., Bu \ll 1)$ In this regime: The eddy size is set by the larger baroclinic deformation radius R_d , not the island scale. Baroclinic instability becomes the dominant generation mechanism, preferentially producing vortices of scale $\sim R_d$. Thus, the low-Bu environment created by Hawaii's large

topography inherently favors the formation of mesoscale eddies with relatively larger radii.

Reference:

Dong, C., McWilliams, J. C., and Shchepetkin, A. F.: Island Wakes in Deep Water, J. Phys. Oceanogr., 37, 862–891, https://doi.org/10.1175/JPO3047.1, 2007.

Jia, Y., Calil, P. H. R., Chassignet, E. J., Metzger, E. J., Potemra, J. T., Richards, K. J., and Wallcraft, A. J.: Generation of mesoscale eddies in the lee of the Hawaiian Islands, J. Geophys. Res., 116, C11009, https://doi.org/10.1029/2011JC007305, 2011.

Yoshida, S., Qiu, B., and Hacker, P.: Wind-generated eddy characteristics in the lee of the island of Hawaii, J. Geophys. Res., 115, C03019, https://doi.org/10.1029/2009JC005417, 2010.

- Figure 9 and 10: Less eddies generated and less dissipated in cyclo. All regions are fairly similar, can the results be compressed into one figure, side by side with generation and dissipation? Feel free to change or not, just a suggestion. Could any other figures be condensed? Show total and then most significant finding?

Response 33： Thank you for your sugession. Figures 9 and 10 have been combined into a single figure, and the associated text has been revised accordingly. (L415-431)
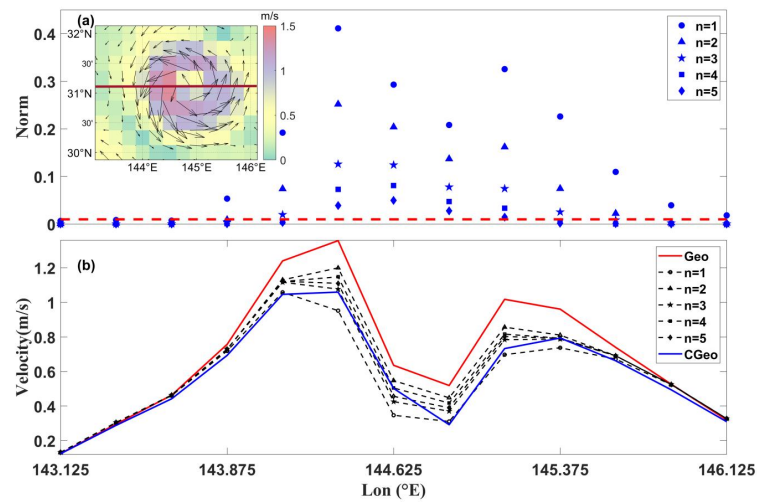
Furthermore, Figures 15 and 16 have been combined into a single figure.

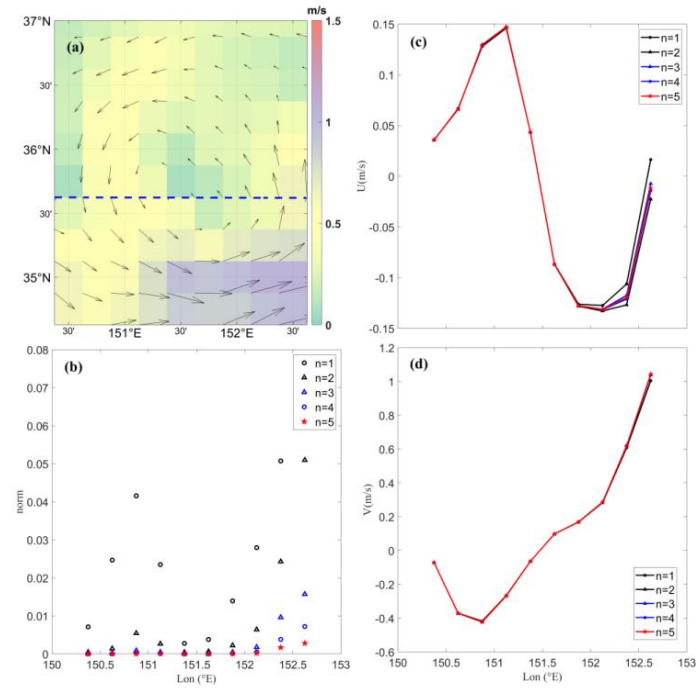- Line 468: Why are there less eddies generated and dissipated under cyclo balance?

Response 34： Thank you for your review. Regarding the observation you mentioned that "the number of eddies generated and dissipated under cyclogeostrophic (CGEO) balance is lower than under geostrophic (GEO) balance,"this can be explained as follows: Under the geostrophic

assumption, the velocity field of eddies is derived solely from the balance between the pressure gradient and the Coriolis force, neglecting centrifugal force. In contrast, under cyclogeostrophic balance, centrifugal force is incorporated into the equilibrium equations. This modifies the velocity distribution, boundary shape, and intensity of eddies, causing some eddies to no longer satisfy vortex detection criteria. As a result, fewer eddies are detected under CGEO than under GEO. Additionally, CGEO correction may enhance the dynamic stability of eddies, prolong their lifespans, and make them more resistant to dissipation.
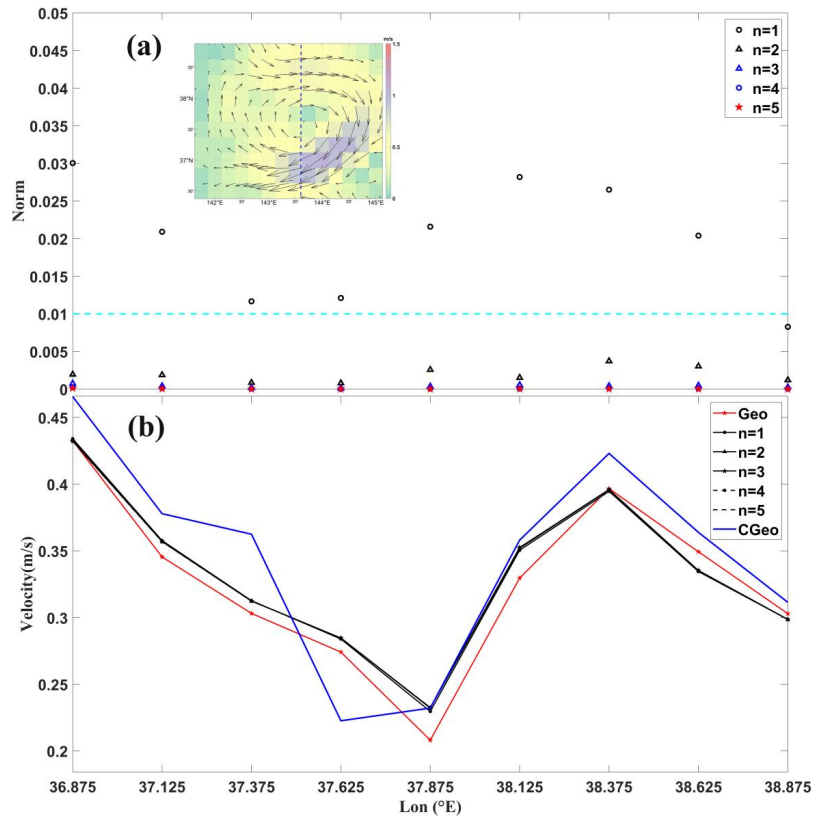
Here, we present several examples to illustrate the process of **Cyclogeostrophic correction:**

Correction of the eddy produced by shedding from the Kuroshio Large Meander.

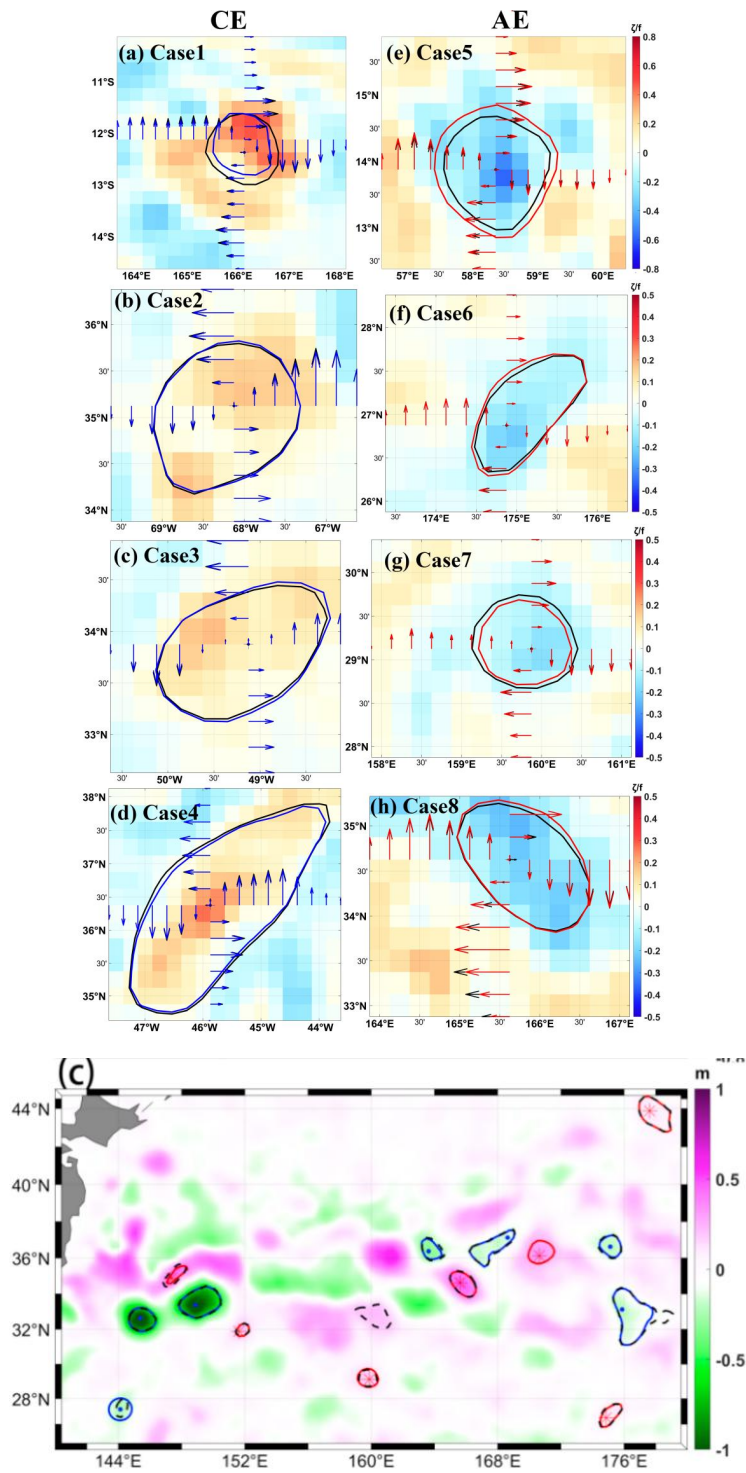The cyclogeostrophic correction process for shear-generated eddies.

The cyclogeostrophic correction process for eddies generated due to the combined effects of topography and the Kuroshio.

It is observed from the cases above that differential cyclogeostrophic correction at points of varying streamline curvature results in changes to

an eddy's shape and boundaries.

A comparison of eddy boundaries before (GEO) and after (CGEO) correction:

Reference：
Cao, Y., Dong, C., Stegner, A., Bethel, B. J., Li, C., Dong, J., ... & Yang, J. (2023).

Global sea surface cyclogeostrophic currents derived from satellite altimetry data. Journal of Geophysical Research: Oceans, 128(1), e2022JC019357.

Cao, Y., Dong, C., Qiu, Z., Bethel, B. J., Shi, H., Lü, H., & Cheng, Y. (2022). Corrections of mesoscale eddies and kuroshio extension surface velocities derived from satellite altimeters. Remote Sensing, 15(1), 184.

- Line 486: Fig 11b and d should be Fig 12?

Response 35: Thank you for your reminder. We have corrected it. Following the manuscript revisions, the figure order has been adjusted accordingly.

- Figure 12: More of a uniform dissipation of geos eddies in KE region but not in cyclo, why?

Response 36: Thank you for your question. In the cyclogeostrophic balance, the inclusion of centrifugal force means that the velocity field is determined by the equilibrium among the pressure gradient force, the Coriolis force, and the centrifugal force. This significantly alters the dynamic characteristics of eddies: anticyclonic eddies are notably strengthened, making them more resistant to dissipation, extending their lifespans, and thereby reducing their dissipation rates (Shakespeare, 2016). Cyclonic eddies, on the other hand, are weakened and may be stretched or broken down more quickly.

Meanwhile, in the Kuroshio Extension (KE) region, the eddy distribution is inherently polarized: the northern part is dominated by anticyclonic eddies, while the southern part is predominantly cyclonic (Itoh and Yasuda, 2010). Therefore, compared to the geostrophic (GEO) balance, the dissipation under CGEO appears non-uniform.

Reference:

Shakespeare, C. J.: Curved density fronts: Cyclogeostrophic adjustment and frontogenesis, J. Phys. Oceanogr., 46, 3193–3207, https://doi.org/10.1175/JPO-D-16-0137.1, 2016.

Itoh, S., and Yasuda, I.: Characteristics of mesoscale eddies in the Kuroshio–Oyashio Extension region detected from the distribution of the sea surface height anomaly, J. Phys. Oceanogr., 40, 1018–1034, https://doi.org/10.1175/2009JPO4265.1, 2010.

● Figure 13: Label left column CE and right column ACE? Seems the biggest fluctuations are in SCS, any idea why?

Response 37: Thank you for your suggestion. We have updated the figure reference from Figure 13 to Figure 12 in the manuscript. We have added explanations and cited relevant literature. (L483-487)

To clarify, in **Figure 12**, the **rows** correspond to the eddy types: the **first row** (panels a, b) represents **CEs**, and the **second row** (panels c, d) represents **AEs**. The columns represent the velocity components: the **left column** (panels a, c) shows **zonal speed**, and the **right column** (panels b, d) shows **meridional speed**.

The most significant speed fluctuations in the South China Sea (SCS) as shown in **Figure 12** can be attributed to a combination of the following factors:

A. Complex Topography and Current Interactions: The SCS features complex underwater topography, including islands, seamounts, and continental slopes, which disturb flow patterns and enhance spatial variability in eddy velocities.

B. Strong Background Shear and Eddy Activity: Influenced by monsoons and Kuroshio intrusions, the SCS exhibits strong background

current shear. Frequent eddy generation and eddy–current interactions further amplify velocity fluctuations.

C. Low-Latitude Coriolis Effect: Located at low latitudes, the SCS has a small Coriolis parameter, making nonlinear effects (e.g., centrifugal forces) more significant. This leads to more pronounced velocity differences after cyclogeostrophic (CGEO) correction.

These factors collectively explain why the SCS shows the largest speed variability among all studied regions.

● Figure 15: Could be consistent with labelling? E.g. KE region is sometimes presented first, but here it is in panel d. Why are there such differences, even in geos and cyclo, this is where other literature could come in use.

Response 38： Thank you for your guidance. To ensure consistency, we have standardized the order of regions across all figures in the manuscript. In the manuscript, the figures that have been revised are: Fig. 2, Fig. 3, Fig. 4, Fig. 8, Fig. 9, Fig. 12, Fig. 13 and Fig. 14.

● Figure 16: You could almost say the vorticity and strain are inversely related?

Response 39: Thank you for your suggestion. We agree with your perspective. In fluid dynamics, vorticity (describing local rotation) and strain rate (describing local stretching/shearing) collectively form the velocity gradient tensor, providing a complete kinematic description of a

fluid parcel's motion. From an energy perspective, they jointly partition the kinetic energy of turbulence or disturbances. Under certain conditions, an increase in one quantity may occur at the expense of the other.

Figures 15 and 16 have been combined into a single figure, and the associated text has been revised accordingly.

● Line 580: Change name of discussion? Do you need to include all five case studies here?

Response 40: Thank you for these suggestions.

The original discussion has been integrated with the results and placed within Section 3.6 ("Case Studies").

Regarding the five case studies, we have evaluated their necessity and streamline the discussion to focus on the most critical findings. Based on the statistical findings and the significance of streamline curvature, we have selected three regions－the Kuroshio Extension (KE), the South China Sea (SCS), and the Hawaiian Islands (HI)－for detailed case studies.

● Line 732: Could additional sources and references be included here to tie up your findings? What are the implications, bigger picture, takeaway for the reader?

Response 41: Thank you for your guidance, we have added relevant references based on your suggestion and cited them appropriately.We agree that explicitly stating the broader implications strengthens the

- Line 780: Where do you discuss eddy-eddy interactions and how do you define this?