Dear Editor and Reviewers

We are very pleased to have your comments concerning our manuscript entitled "Statistical analysis of dynamic behavior of continental shelf wave motions in the northern South China Sea" (egusphere-2023-1274). Thank the editor and reviewers for taking time out of your busy schedule to review our paper and provide constructive comments on it.

We have read and dealt with all the comments carefully. The revised manuscript with all comments highlighted with blue fronts has been uploaded, and point-to-point responses to the reviewer's comments are present following.

Response to Comments of Reviewer 1 （Blue font in the manuscript）

[Comment 1] According to Wang and Mooers (1976) as well as Brink (1991) and Huthnance (1995), the CSW and ATW referred in this manuscript should be more specified as Kelvin wave and topographic Rossby wave, respectively.

Wang, D., and C. N. K. Mooers, 1976: Coastal-trapped waves in a continuously stratified ocean. J. Phys. Oceanogr., 6, 853-863.

Brink, K. H., 1991: Coastal-trapped waves and wind-driven currents over the continental shelf. Annu. Rev. Fluid Mech., 23, 389-412.

Huthnance, J. M., 1995: Circulation, exchange and water masses at the ocean margin: the role of physical processes at the shelf edge. Prog. Oceanogr., 35, 353-431.

Response: We sincerely thank the reviewer for careful reading. Though all these waves are a kind of topographic wave, we would prefer using arrested topographic wave (ATW) and continental shelf wave (CSW) in this study. The reason is as follow.

(1) We think that the definition of topographic Rossby wave (TRW) covers a wider range than that of ATW. ATW is used to describe a mean wind-driven flow trapped within a coastal zone (Csanady, 1978; Wu, 2021). The mean longshore pressure gradient sustains mean flow opposing the mean wind in this linear theory ($\partial/\partial t = 0$). However, temporal derivative term ($\partial/\partial t$) in the dynamic equations for topographic Rossby wave (TRW) is balanced by other terms, i.e., f term and pressure gradient term (Hughes, 2019; Quan et al., 2021). Chen et al., (2022) pointed out that the period of TRW in the East China Sea is ~30 d. Quan et al., (2021) pointed out that the period of TRW in the abyssal South China Sea is less than 60 d. Therefore, the period of TRW is a key point. If the period of TRW is too long (~300 d in this study), then, the temporal derivative term is negligible. In this situation, it is better to use "ATW".

Moreover, this comment is very important to us. We have added some sentences and reference to make it clearly.

Line 95: The mean circulation in a coastal zone of variable depth may be modeled by linear equations (Wu, 2021).

Line 538: Wu (2021) used a nondimensional parameter (Pe_β) to describe the influence of open ocean forcing on shelf circulation, which is determined by the ratio of long-wave-limit planetary to TRW speeds. In this study, Pe_β <1, which indicates shelf currents decayed rapidly toward the coast.

(2) Firstly, Wang et al. (1976) classified the sub-inertial waves on the coastal shelf into several types as shown in Resp_Table 1. Kelvin wave should be considered as a kind of wave propagating with a flat bottom. In this study, we use a sloping bottom (Table 1 in the manuscript), not a flat one. Secondly, the phase speed of Kelvin wave should be $\sqrt{gH}$, which is faster than that of CSW

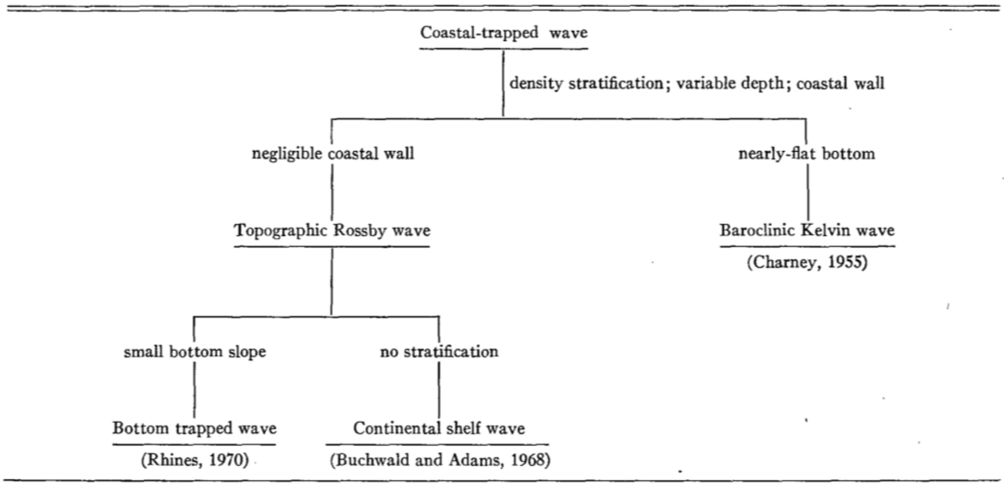
(Huthnance, 1995). The sea level variation should contain these waves together. However, the phase speed of signals extracted from tidal gauge data is about 10 m s^{-1}, much less than 30 m s^{-1} (H=100 m for $\sqrt{gH}$) in this study. Base on above reasons, we think it is better to use CSW.

As you are concerned, there are several points that need to be addressed. We have changed the description of CSW in the manuscript.

Line 36: Continental shelf wave (CSW) is a type of topographic Rossby wave (TRW) trapped in the continental shelf with amplitudes ranging from several tens' centimeters to more than one meter.

Line 51: CSWs could be taken as barotropic motion in a homogeneous coastal area. While in a stratified ocean, it could be classified into coastal trapped wave. If the bottom boundary is flat, it propagates as a Kelvin wave. Overall, they are resulting from conserving potential vorticity over the shelf (Chen et al., 2022; Quan et al., 2021; Wang and Mooers, 1976).

Resp_Table 1. The classification of coastally trapped waves. (Cited from Wang et al., 1976)



References:

Chen, J., Zhu, X.-H., Zheng, H., Nakamura, H., Zhao, R., Wang, M., et al., 2022: Observation of topographic Rossby waves triggered by Kuroshio path meander in the East China Sea. J. Geophys. Res., 127, e2022JC018667.

Csanady, G. T., 1978: The Arrested Topographic Wave. J. Phys. Oceanogr., 8, 47–62.

Hughes, C.W., Fukumori, I., Griffies, S.M. et al., 2019: Sea level and the role of coastal trapped waves in mediating the influence of the open ocean on the coast. Surv. Geophys., 40, 1467-1492.

Huthnance, J. M., 1995: Circulation, exchange and water masses at the ocean margin: the role of physical processes at the shelf edge. Prog. Oceanogr., 35, 353-431.

Quan, Q., Z. Cai, G. Jin, and Z. Liu, 2021: Topographic Rossby waves in the abyssal South China Sea. J. Phys. Oceanogr., 51, 1795-1812.

Wang, D., and C. N. K. Mooers, 1976: Coastal-trapped waves in a continuously stratified ocean. J. Phys. Oceanogr., 6, 853-863.

Wu, H., 2021: Beta-plane arrested topographic wave as a linkage of open ocean forcing and mean shelf circulation. J. Phys. Oceanogr., 51, 879–893.

[Comment 2] The description of wavelet analysis in section 2.5 is not necessary because it is a method widely used in different studies.

Response: We agree with the comment and delete section 2.5.

[Comment 3] By the way, it should be better to describe the theory of CSWs in section 2 rather than in section 4.

Response: We have restructured the sections. Section 2 describes the observed data. Section 3 presents theory of CSWs and ATWs. Section 4 presents the characteristics of the signals derived from the tide-gauge data and along-track SLA. Section 5 discusses the CSWs detected from tide-gauge data and the cross-shelf structure of sea level over the continental shelf.

[Comment 4] The EOF analysis may be a better tool to reveal the principal modes in Figs. 3 and 8.

Response: Thanks for your valuable comment. We have added the EOF analysis into the manuscript. Line 469: To further reveal the variations in the along-track SLA in track 12 on the shelf, the empirical orthogonal function (EOF) analysis results are shown in Fig. 9 (EOF analysis for data along other tracks is similar, not shown here). The first four EOF modes of the along-track SLA explain 96.8% of the total variance. Mode 1 explains the seasonal variance of SSH (red curve in Figs. 6o-u). The seasonal cycle could be characterized clearly from Fig. 9b, with peaks in October and troughs in May. Mode 2 and Mode 3 are similar to the cross-shelf structure as shown in Fig. 3a, which explains 25.1% of the total variance. Mode 3 is influenced by the background of SSH in the open sea side. The amplitude is 0.3-0.4 m, which is comparable to the outlier data as shown in Table 2. Mode 4 is similar to the cross-shelf structure of mode-2 CSW as shown in Fig. 3b, which only explains 2.8% of the total variance. The EOF analysis indicates that CSW could explain <30% of the total variance of SSH in the study area, which is comparable to the IQR in boxplot of along-track SLA (Fig. 8).

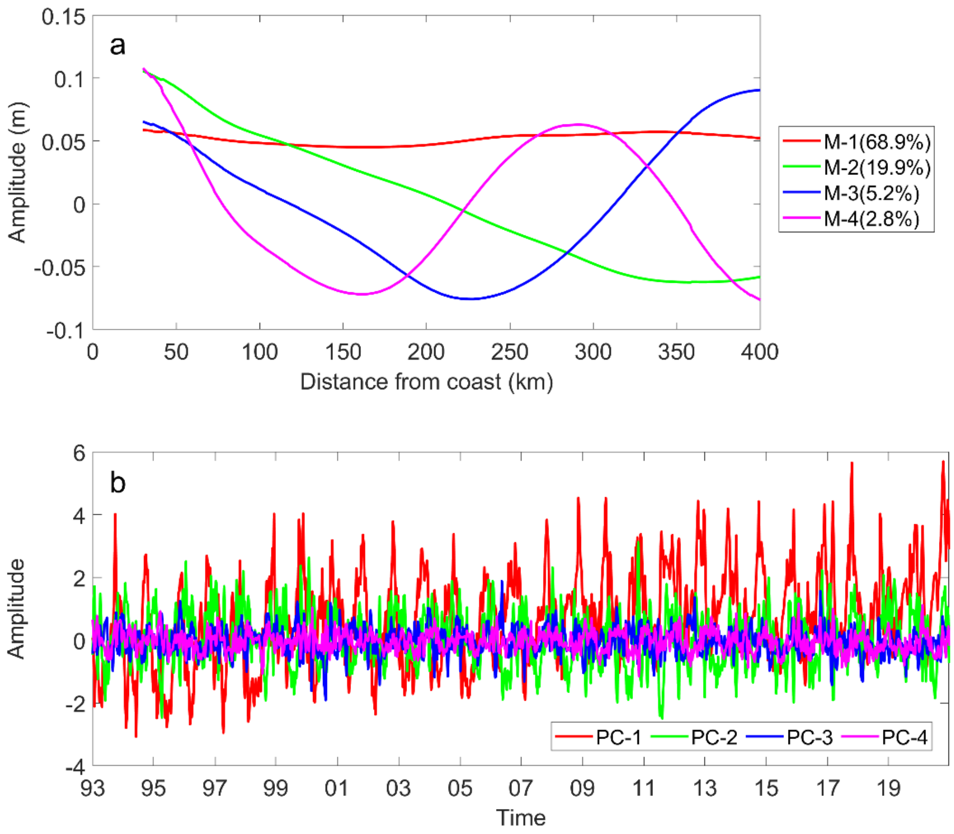


Fig. 9. The first four EOFs for along-track SLA on the shelf for tracks 12. Cross-shelf amplitude (a) and time series (b) of the first four EOFs. The variance explained by each mode is labeled in (a).

[Comment 5] The boundary conditions should be given in sections 4.1.1 and 4.1.2.

Response: We think this is an excellent suggestion. We have added boundary conditions to the sections 3.1.1 and 3.1.2 (restructured manuscript following comment 3).

Line 202: which is subject to the following boundary conditions: $\phi(0) = a$, and $\phi(l) = A$. a and A should be arbitrary. We could take a as the amplitude of oscillation in sea level from the tidal gauge station.

Line 214: which is subject to the following boundary conditions: $\phi(x \to l) = A$, and $\phi(\infty) = 0$.

[Comment 6] Fig. 4 could be omitted because it is not helpful for the analysis and there are also few descriptions about it in the manuscript.

Response: We sincerely thank the reviewer for careful reading. Fig. 4 present the phase speed of CSWs. The first zero-crossing point on the right hand of each curve points out the phase speed of mode-1 CSW. The second zero-crossing points out the phase speed of mode-2 CSW. The value of these zero-point expressed as dispersion relationship curve of CSW in Fig. 7. Therefore, Fig. 4 is very important. Thank you again for your positive comments and valuable suggestion to improve the quality of our manuscript. We have added relevant contents and revised the Fig. 4.

Line 223: The solution of phase speed for CSWs is shown as Fig. 2. The zero-crossing points for each curve present the phase speed of CSWs. The first zero-crossing point on the right hand of each curve points out the phase speed of mode-1 CSW, e.g., c = 7.6 m s-1 for track 190.

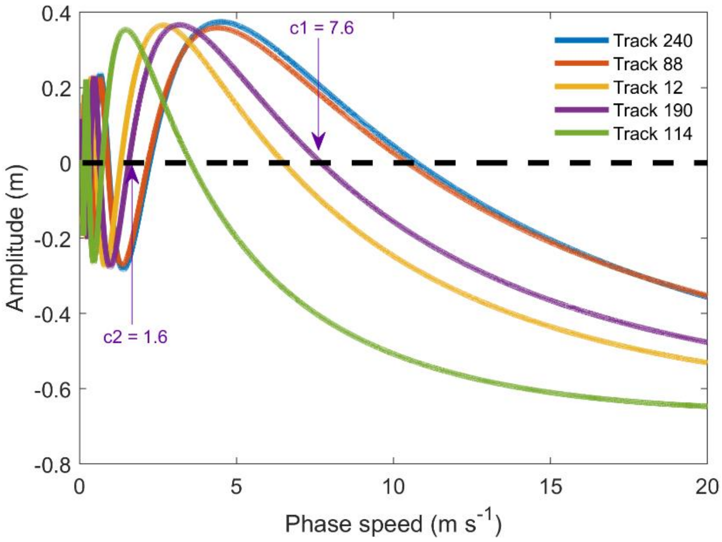


Fig. 4. Solution of phase speed for CSWs from Eq. (20). The zero-crossing values represent the phase speed of CSWs for different modes. Colorful curves are amplitude of zero-order of the first kind Bessel function in different modes for the idealized depth profile of tracks 12, 88, 114, 190, and 240, respectively. Arrows point out the phase speed of mode-1 (7.6 m s^{-1}) and mode-2 (1.6 m s^{-1}) CSWs along track 190.

Line 382: Black and green curves in (c) represent the dispersion relation (from Fig. 2) for the topographic profiles along tracks 12 and 190.

[Comment 7] Since the authors have realized that the discrepancies in Fig. 7 may be owing to the wind forcing and baroclinicity, they had better include these effects in Eq. 6 and show the relevant dispersion curve for comparison.

Response: We feel great thanks for your professional review work on our article. As you are concerned, we should consider these effects in Eq. 6. It is a big challenge for future work.

(1) wind forcing. The wind curve is ignored as the uniform along-shelf wind stress in this study. If we consider the wind stress curve, Eq. 6 should be a nonhomogeneous Bessel differential equation. Lin et al., (2005) present a fractional-calculus approach to the solutions of the classical Bessel differential equation of general order (Eq. 2.7 in Lin et al., 2005). The solution is an e-exponential form which is similar with the waveform we derived from theory and observation. Moreover, the expression from Lin et al., (2005) is very cumbersome. It is worth a detailed discussion in future.

(2) baroclinicity. In the northern SCS, the water on the shelf in winter is almost uniformly mixed under a strong monsoon. The quantity of CSW events in winter is larger than that in summer as shown in Fig. 2. It means that these sub-inertial processes should be barotropic ones, i.e., CSW. In addition, Wang and Mooers (1976) presented sea level of coastal trapped wave in cross-shelf direction (Fig. 6 in Wang and Mooers, 1976). Sea level of mode-1 wave changes little in the cross-shelf direction. Moreover, it is suitable to study these baroclinic sub-inertial processes, i.e., coastal trapped wave by using current data in whole layer. In the next work, we will analyze the baroclinic sub-inertial processes by using three moorings deployed on the continental shelf of the SCS.

We will focus on these effects in the next work. We have added shortcoming of this article in the Summary.

Line 524: However, owing to the neglective wind stress and baroclinicity, higher modes of waves are not discussed in this paper. Observations from moorings and numerical models will be used in our future studies to obtain the characteristics of baroclinic coastal trapped waves.

References:

Lin, Shy-Der, Ling, Wei-Chich, Nishimoto, Katsuyuki, Srivastava, H. M. 2005: A simple fractional-calculus approach to the solutions of the Bessel differential equation of general order and some of its applications. Computers & Mathematics with Applications, 19(9): 1487-1498.

Wang, D., and C. N. K. Mooers, 1976: Coastal-trapped waves in a continuously stratified ocean. J. Phys. Oceanogr., 6, 853-863.

[Comment 8] The results shown in Fig. 9 suggest that the assumption at L260-264 is not proper for the reality.

Response: We agree with this comment. In fact, τ_0 is variable in the space, and τ_s^x is existent. However, the simplified wind stress is helpful to solve equation. If $\frac{\partial}{\partial x}\left(\frac{\tau_s^y}{f\rho}\right)$ is considered, it is hard to derive an analytical solution. The solution of a nonhomogeneous Bessel differential equation is a form of triple integral type. Numerical model is a powerful tool to resolve the actual situation.

The main difference between monthly climatological mean of along-track SLA and along-shelf sea surface wind stress in Fig. 9 is out of sync. The maximum value of monthly mean sea surface wind stress occurs in November and December. However, the maximum value of monthly along-track SLA occurs in October. The character is consistent with previous work. Ding et al., (2020) used a Finite Volume Community Ocean Model (FVCOM) to investigate the seasonality of coastal circulation in the north SCS. He found that southwestward current in fall and winter dominates the north SCS shelf. The transport is 1.93 Sv in autumn, while it is 1.73 Sv in winter. Using geostrophic current retrieval from along-track satellite altimeter data on the shelf of the north SCS, it found that the along-shelf current is strongest in October at approximately 0.17 m s^{-1} (Li et al., 2023).

Therefore, we think the main reason causing the difference should be the along-shelf current. The along-shelf current involves with ATW, which causes a difference between monthly climatological mean of along-track SLA and along-shelf sea surface wind stress as shown in Fig. 9. We have added explanation into the manuscript.

Line 508: In addition, one can also see a characteristic of out of sync between seasonal mean of along-track SLA and wind. The maximum of mean sea surface wind stress occurs in November and December. While, that of monthly along-track SLA occurs in October. Ding et al. (2020) investigated the seasonality of coastal circulation in the north SCS using a numerical model. The result indicates that the maximum of water transport is 1.93 Sv occurred in autumn. Li et al. (2023a) found the along-shelf current is strongest in October at approximately 0.17 m s-1. The along-shelf current involves with ATW, which is the reason why there is a difference between monthly climatological mean of along-track SLA and sea surface wind stress as shown in Figs. 10e-h.

References:

Ding, Y., Yao, Z., Zhou, L. et al. 2020: Numerical modeling of the seasonal circulation in the coastal ocean of the Northern South China Sea. Front. Earth Sci. 14, 90–109.

Li, J., Li, M., Wang, C., Zheng, Q., Xu, Y., Zhang, T., and Xie, L. 2023: Multiple mechanisms for chlorophyll a concentration variations in coastal upwelling regions: a case study east of Hainan Island in the South China Sea, Ocean Sci., 19, 469–484.

[Comment 9] L336: it should be (24).

Response: Thank you for your reminder. The typo is revised.