



EGUsphere, author comment AC2  
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## Reply on RC2

Arachaporn Anutaliya

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Author comment on "Surface circulation in the Gulf of Thailand from remotely sensed observations: seasonal and interannual timescales" by Arachaporn Anutaliya, EGU sphere, <https://doi.org/10.5194/egusphere-2022-495-AC2>, 2022

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The paper introduces a discussion about the GoT surface circulation using remotely sensed data. The impacts of monsoon wind as well as those of ENSO and IOD on GoT surface circulation are discussed. Complex EOF and correlation analyses were used to investigate the drivers of surface circulation patterns. Seasonally, Complex EOF showed that about 28% of changes in surface circulation were attributed to the monsoon wind reversal. On interannual timescales, ENSO and IOD have spatially varying impacts on surface circulation with ENSO influence being more pronounced in the GoT interior whereas the GoT western boundary responds more to IOD conditions as evidenced by correlation analysis.

The paper is fairly well written. It introduces an important topic that can benefit a larger community to understand the impacts of climate on surface circulation and the extension to biogeochemical processes. However, there are a number of improvements that can help build a stronger case.

- The significance of the study should be emphasised. Besides the use of field observations and numerical modelling to study the surface circulation of GoT, previous studies also used remotely sensed data but findings did not converge. So, what makes the application of remotely sensed data in this study relevant. Also, most of the remotely sensed data used in this study were available from the 90s but the analysis only focused on the period starting from 2014. Why?
  - This study improves the understanding on the dynamics associated with the GoT circulation that has not been well-studied. It shows the role of wind on modifying both geostrophic and ageostrophic current. In addition, the study provides the variability of the circulation at the interannual timescale. The author tried to emphasize the significance of this study better in abstract, results, and conclusion sections.
  - Thanks to the reviewer for the helpful suggestion, discussions of the interaction between GoT circulation and (1) the upper GoT and (2) the SCS are also added to the manuscripts.
  - The reviewer is correct that most of the datasets are available since the 90s but under a time constrain of the provided grant, the author can only analyze these few years. The author picked 2014 to 2019 as the studied period because it includes a few major interannual events, such as the 2015/2016 El Nino, the 2016 negative IOD, 2017/2018 La Nina, and the 2019 positive IOD.

- In addition to datasets section, please also add a methods section. Most of the statistical analysis used were neither thoroughly explained nor proper references were provided. This is a weakness of the current manuscript. Complex correlation, rms correlation, etc. are not common correlation analysis methods and should be well introduced with proper citation prior to their use. Without such information it is difficult for the reader to make an easy interpretation of results presented. As for the datasets, please include the data source URLs in the datasets section and explanation about the ENSO and IOD data, and their provenance.
- The author thanks the reviewer for the suggestion. The methodology section is added to describe the complex empirical orthogonal function.
  - Complex correlation is introduced, and reference for the calculation is provided.
  - The ENSO and IOD indices are added in the dataset section. The data sources are provided in the data availability section.
- OSCAR and ADT data with spatial resolution of 27–37 km were used to discuss surface circulation patterns in the uGoT. This is a small ( $\sim 100$  km horizontally) and shallow area (Figure 1). The author recognises the limitations (L340) but still places a lot of emphasis on the variability of OSCAR current data in the uGoT (e.g., L120, L135, L184, etc.). I would recommend introducing the L340 text earlier and limit the discussion of uGoT surface circulation based on OSCAR data. Please note that the circulation patterns in the uGoT have been discussed using local wind data derived from meteorological stations as a way to overcome the limitations of coarse resolution remotely sensed wind data (Buranapratheprat et al., 2006).
  - The author thanks the reviewer for the suggestion. Discussion regarding the uGoT circulation, particularly that derived from the OSCAR products, has been limited and the author introduced the limitation regarding the observations over the uGoT in the dataset section (L87) and again at the beginning of the results (Circulation in the Gulf of Thailand) section (L146).
  - The introduction has been updated and the reference has been added.
- The sequence of some figures should be revised to make the flow easier. Complex EOF (Figure 3) can be understood with easy after Figure 4 is introduced, and after the method has also been introduced. Similarly, the correlation maps in Figure 8 are better after Figure 9 is introduced which will be in line with the text in L250.
  - The author used the CEOF to understand the dominant pattern associated with circulation over the GoT. As a result of the CEOF analysis, the most distinct circulation pattern associates with the seasonal monsoon winds, thus, the monthly circulation is examined in detail. Therefore, the author believes that the original figure sequence provides the more coherent story.
  - The methodology is added immediately after the dataset section.
  - Similarly, the author used the correlation map to understand which regions are heavily impact by each climate mode. Then, the regions with high impact, i.e., that along the western boundary and that in the GoT interior with 2 sub-regions, are further analyzed to understand how low-frequency variability over these regions change with the climate modes. The author believes that presenting figure 9 before showing figure 8 would cause confusions to the readers.

## Details

L30: please revise the text for clarity. Numerical simulations were done for uGoT but the spatially uniform wind does not represent that of GoT?

- The original text pointed out that the study by Yanagi and Takao (1998) indicates that

the wind field over the entire GoT (including the uGoT), and thus the use of uniform wind field over the uGoT could yield inaccurate results. The author understands that the original text might provide a misleading detail, and thanks the reviewer for pointing it out. Thus, the text has been updated.

L38: "The study suggests an overall cyclonic circulation..." Which study?

- The author refers to the study by Saramul (2017) which is based on the high spatial-resolution coastal radar mentioned in the previous sentence. The text has been updated to clarify this point.

L55: better open a new paragraph.

- The text has been updated.

L77: It is helpful to add the locations of the high frequency radar system in Figure 1.

- Figure 1 has been updated to include locations of the high frequency coastal radar stations.

L80: please explain how this comparison was done. How the spatial and temporal resolution differences were addressed? As admitted in L340 the OSCAR data may contain large error there. How to distinguish between the two, large difference or large error?

- The monthly mean data as provided by Saramul et al. (2017) is calculated from the OSCAR products for the comparison; the text has been updated to clarify this point. As of the author's understanding, it is not possible to pinpoint whether the difference is truly a difference or an error. However, given the process associated with estimating the OSCAR products, the derived current along coastal areas could contain high error and a validation is necessary. As there has been no validation of OSCAR products against an observation over the GoT, the comparison to an observation which is the high frequency coastal radar is needed. The results show that the OSCAR products is quite reliable over the GoT, particularly to the south of the uGoT.

L90: 20 km is below the ADT spatial resolution. How to know this is not noisy data?

- The reviewer is correct, noisy data can contribute to a lower correlation coefficient. However, it is difficult to specify which factor contributes to the low correlation at the specific location. The author has updated the text to address this issue.

L99-100: references for A and wind stress curl estimation?

- The estimations of A and wind stress curl are added.

L115: why use complex EOF? Does it improve the results over the classical EOF. What (additional) information is gained from the use of complex EOF? Again, these issues can be addressed by a proper methods section.

- In many studies, complex EOF is applied when the dataset being considered is in vector form. The statement is included in the methodology section added to this manuscript.

L120: much of this discussion should be removed from the text. 6 grid points are too rough to have a meaningful discussion. Any derived parameter will even include less grid pixels which further limits the interpretations.

- The author thanks the reviewer for the suggestion. The discussion has been removed.

L125: briefly explain the reader how to look at the results of complex EOF. For classical EOF the mode often indicates temporal variability when multiplied by the amplitude. What is the relationship between Figure 3a-c?

- A brief explanation regarding how to interpret the results of complex EOF is included at the end of the added methodology section. The CEOF mode (Figure 3a) describes the dominant pattern that accounts for 28% of the total variance of the velocity anomaly over the GoT. Generally, the pattern that is rotate according to the phase of the PC (Figure 3C; positive clockwise), i.e., the pattern displayed in Figure 3a is observed when the phase of PC is zero and the reverse is observed when the phase is  $\pm\pi$ . The pattern is present with a great intensity when the magnitude of the PC (Figure 3b) is high.

L151: reference(s) for the correlation coefficient from non-parametric method?

- The reference is added to the manuscript.

L165: what is rms correlation? reference(s)?

- The text refers to root-mean-square of the correlation coefficient. Rms stands for root-mean-square as defined earlier. To compute the rms, a square root of the mean of the squared quantity of interest (correlation coefficient over the interested area in the GoT in this case), i.e.  $\sqrt{\text{mean}(R^2)}$ . The rms calculation is commonly used in similar way as calculating average; hence the reference is not necessary. Using the rms instead of the average emphasizes the importance of the variance being explained.

L171: what is total current? Most of these details should be addressed by a proper methods section.

- The author understands the confusion since the original text does not clearly address the different type of currents. A statement has been added in the datasets section to clarify this point.

L224: what is the difference between this correlation coefficient and the other so far introduced?

- The correlation here is calculated between the wind stress curl and sea surface height data, while the previous correlations (subsection 4.1.2 Geostrophic and ageostrophic component) indicate how (1) the geostrophic current and the total current covary (Figure 6a, b) and (2) the ageostrophic current and the wind-driven Ekman current (Figure 6c, d).

L227: "...much of the correlation is attributed..."

- The accordant change has been implemented.

L232: "Still, the result suggests the importance of coastal trapped Kelvin waves..." add reference(s) as this is speculative?

- Coastal trapped Kelvin waves are known to travel equatorward along the western boundary of the basin and poleward along the eastern boundary based on the wave equation. Therefore, the statement regarding the Kelvin wave traveling direction is not speculative. Still, the author agree that an addition of references could be beneficial particularly to readers who are not familiar with the wave.

L239: add the description (and/or sources) of the sea surface temperature and the Niño 3.4 box in the text.

- Descriptions for Niño 3.4 and DMI are added at the end of the datasets section and the corresponding sources are added to the data availability statement.

L245: as mentioned above, the discussion in this paragraph suggested that the sequence of Figure 8 and 9 is reversed.

- The author used the correlation map to understand which regions are heavily impact by each climate mode. Then, the regions with high impact, i.e., that along the western boundary and that in the GoT interior with 2 sub-regions, are further analyzed to understand how low-frequency variability over these regions change with the climate modes. The author believes that the original figure sequence provides the more coherent story. Reversing the order of figure 8 and 9 could confuse the reader regarding the region selected to compare with each climate mode.

L250: "...correlations between low-frequency Niño3.4 and selected forcings...". What parameter is the forcing, Niño3.4 or ADT, etc.?

- The forcings are ADT, zonal wind stress, and wind stress curl. The author investigated the impact of these forcings on the low-frequency variability of the uGoT circulation.

L300: "...but might relate to the winter warm pool" where?

- The author thanks the reviewer for pointing out the missing detail. The accordant change has been made.

L310: the last sentence is long, break it into smaller parts.

- The accordant change has been made.

Please consider revising the style of figure captions. I think starting with the label followed by the explanation is a commonly used caption style and is easy to read. E.g., Figure 1: Map of the Gulf of Thailand. (a) Triangles indicate the locations of tide gauges: FP denotes Fort Phrachula Chomklao station, KL denotes Ko Lak station, and KM denotes Ko Mattaphon station. (b) Shows the location of the Gulf of Thailand. Colour contours in (a) and (b) represent bathymetry. The black contour in (a) represents the zero-depth level.

- The author thanks the reviewer for the suggestion. The author tried the suggested caption style but cannot successfully change all of them without creating awkward sentences. Therefore, the author kindly asks the reviewer to allow leaving the caption format as is.

Figure 3. I could not locate boxes in Figure 2.

- The boxes are missing from the original figure; the figure is corrected.

Figure 5. Please use the positive half of the (b) Figure colour palette. On (a) blue corresponds to extreme positive but on (b) the same blue is extreme negative. This can be very confusing.

- The author has changed the color contour to avoid the mentioned confusion.

Figure 6. Same as in Figure 5. Add zero contours in (b) and (d).

- The author has changed the color contour and the zero contours are added in (b) and (d).

Figure 7. sea surface height (black) just needs to be mentioned once. How can a negative wind stress curl have both negative and positive values? I think the point here is that the displayed data was multiplied by (-1) to be in phase with the other parameter? Winds act on a much larger scale, so I am not clear about the point of the correlation between the green cross and triangle.

- The figure caption has been updated accordingly.
- The figure has been updated to plot wind stress curl on the second (right) y-axis with the reversed y-axis.
- In many scenarios, winds act on large scale, such as the seasonal current reversal that responds to the monsoon wind as being discussed in this manuscript and change in the warm water volume in the western equatorial Pacific due to the westerly wind bursts related to the development of ENSO events (e.g. Chen et al., 2016). However, winds do not necessarily have large-scale impact on the ocean current, for example, upwelling response to the local alongshore wind. This process is both local and small-scale. Dynamics, particularly those associated with planetary waves, associated with the ocean circulation are also sometimes remote and small-scale, for example, the effect of wind stress curl in the western Pacific can propagate in forms of Rossby waves and modify sea level in the Solomon Sea (Anutaliya et al., 2019). The effect of remotely-force waves on sea level or thermocline variation is commonly found (e.g. Dickinson, 1968; Sprintall et al., 2000; Delman et al., 2016). The author understands that impacts of planetary waves on circulation in the GoT has not been hitherto studied and could be unfamiliar to the reader. Therefore, the author has updated the text to provide some literacy regarding the topic.
- Anutaliya, A., Send, U., Sprintall, J., McClean, J. L., Lankhorst, M., & Koelling, J. (2019). Mooring and seafloor pressure end point measurements at the southern entrance of the Solomon Sea: Subseasonal to interannual flow variability. *Journal of Geophysical Research: Oceans*, 124, 5085– 5104. <https://doi.org/10.1029/2019JC015157>
- Chen, S., Wu, R., Chen, W., Yu, B. and Cao, X. (2016), Genesis of westerly wind bursts over the equatorial western Pacific during the onset of the strong 2015–2016 El Niño. *Atmos. Sci. Lett.*, 17: 384-391. <https://doi.org/10.1002/asl.669>
- Dickinson, R. E. (1968). Planetary Rossby Waves Propagating Vertically Through Weak Westerly Wind Wave Guides, *Journal of Atmospheric Sciences*, 25(6), 984-1002.

Figure 8. Non-significant correlation could be masked?

- The figure has been updated accordingly.