Anonymous Referee #3

Referee comment on "Air-sea heat flux during warming season determines the interannual variation of bottom cold water mass in a semi-enclosed bay" by Junying Zhu et al., Ocean Sci. Discuss., https://doi.org/10.5194/os-2021-96-RC3, 2021

General comments

In this study, the determining factors of the intensity of cold bottom pools in shelf seas and bays are studied. The major study site is a semi-enclosed bay in Japan, but also generalisations to comparable bay are made. The major conclusion is that the strength of the cool pool sometimes depends on the previous winter SST (other studies) or on the air sea buoyancy flux during the warming season (this study). While these results are potentially interesting, I think that their value is limited here, since the methods used are not state of the art. The quantification of the cold pool strength depends on a highly site-specific empirical measure, rather than on energy considerations.

Furthermore, the applied numerical model uses climatological forcing rather than realistic forcing. With this, a comparison between model results and field observations is not possible and interannual variability, a major focus of this study, cannot be assessed. For these reasons, I recommend to reject the manuscript at this stage and motivate resubmission of a manuscript that uses state-of-the-art methods.

Thanks for your careful reading and comments. Following your comments, we have finished a comprehensive revision on the original manuscript. Below is a point-to-point response.

In this study, we demonstrated the interannual variation of INCWM and explored its influencing factor using observation and numerical model. For the bottom cold water in Seto Inland Sea (Japan), this paper is the first time to report its interannual variation, therefore, we focused on its interannual variation and preliminarily analyzed influencing processes.

As you said, the quantification of the cold pool strength depends on a highly site-specific empirical measure. The prefectural fishery research centers carried out regular hydrographic observations at monthly intervals in the Seto Inland Sea (stations are shown in Fig. 1). Yu et al. (2016) studied the location change of front around INCWM using the data from Station 1 to Station 7 (Fig. 1 here). They also showed the temperature difference between the surface layer (0 m) and bottom layer (the deepest sampling depth at each station) in the climatology data from April to September (Fig. 2 here). As Fig. 2 (below)shown, INCWM occurs from May to September and locates at the central area of Iyo-Nada. The temperature difference between surface and bottom reaches its maximum in July. The transection (Sta.1 to Sta. 7 in Fig. 1) we used in the study just across the middle of INCWM. Therefore, the measurements of water temperature along the transect from Sta. 1 to Sta. 7 are supposed to be suitable to explore its cold pool strength and interannual variation. In our model, the location of INCWM (Fig.3 in the revised manuscript) is consistent with observation.

In the development of cold pool when water volume changes from mixed water to thermocline, heat transport process is the key to maintain INCWM and influence its strength. Therefore, based on the results of observation, we considered the energy change when analyzing the influencing factor of

INCWM strength. In the discussion part, we compare the different BCWMs in different coastal seas from the viewpoint of energy. We thought that highly site-specific empirical measure and energy considerations are complementary. The discussion about energy helps us to understand BCWMs variation with limited observation. Of course, more site-specific empirical measure is indispensable for a deeper understanding of BCWMs.

In terms of numerical model, we actually use climatological forcing in numerical model rather than realistic forcing. The primary aim of using numerical model is to study the response of INCWM to atmospheric changes by sensitivity experiments. Under the circumstances, a climatological model is applicable. Therefore, we ran model using climatological forcing and validated model using climatology observation data. This is our first work to study the interannual variation of INCWM, and in the future work, we will apply realistic forcing to drive model for intensive study on interannual variation of BCWMs in the Seto Inland Sea.

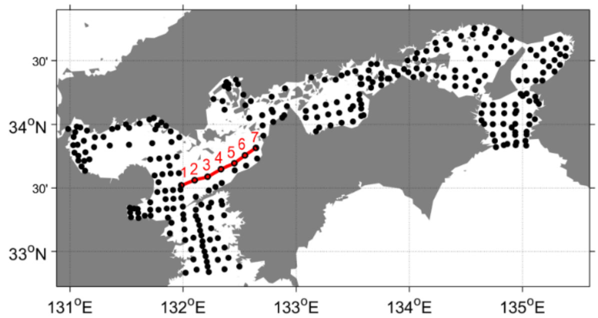

Fig. 1 All observation sites in Seto Inland Sea. Sta. 1-7 is used to study INCWM in our study.

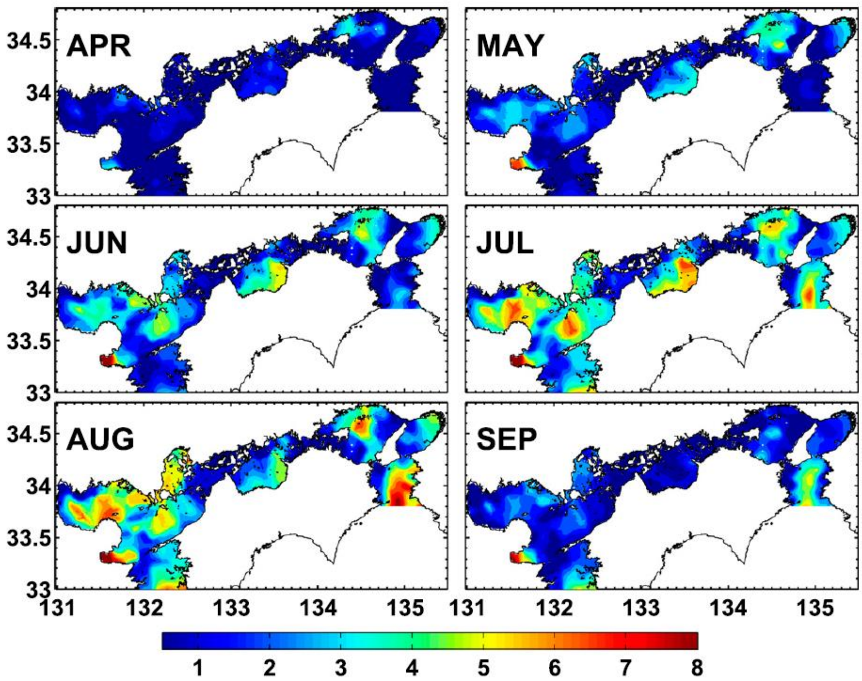

Fig. 2 Temperature difference between the surface layer (0 m) and bottom layer (the deepest sampling depth at each station) in the climatology data from April to September, obtained as averages of

data collected in the same months between 1971 to 2000. (from Yu et al., 2016)

Note: We collected the observation data from 1971 to 2015. However, the observation of Sta. 4 (around the central area of INCWM) starts from 1994, so we analyzed the interannual variation of INCWM from 1994 rather than 1971.

Specific comments

32-34: What defines a BCWM to be strong or weak? The temperature of it will certainly increase during spring and summer, such you probably define strength thought some temperature differences? Please specify.

Thanks for your suggestions. We have already considered to define BCWM intensity using temperature difference between spring and summer. However, this definition ignores the retention of water temperature in winter and only considers the temperature change from spring to summer. it is not suitable to define the NCWM intensity. Since BCWM steadily occurs almost every year, its performance characteristics, such as temperature and area, changes every year, are appropriate indicators to indicate its intensity. Therefore, we used the characteristics of water temperature and area of INCWM to define its intensity.

37: better "… and the Middle Atlantic Bight Cold …"

Thank and changed as your suggestion.

40: Isn't it more simply and more directly the winter temperatures of the vertically well mixed shelf sea waters and then probably also the summer SST that determine the strength of the BCWM? In addition to the heat fluxes, also laterally advective exchanges could set the temperatures. This is basically what you argue in lines 41-43.

Thanks for your comment. In lines 41-43, we just presented the result of Chen and Curchitser (2020) about the Middle Atlantic Bight Cold Pool whose interannual variation is related to the previous winter temperature and abnormal warming/cooling due to oceanic advection (including vertical and horizontal advection). In the paper, they also concluded that the winter (mid-January to March) temperature anomaly was the primary factor in determining the interannual variability of temperature anomaly near bottom cold pool region during the stratified seasons by a long-term numerical simulation. We did not emphasize the influence of laterally advective exchanges.

We are sorry that the improper expression caused your misunderstanding, we changed the sentence as "*Chen and Curchitser (2020) suggested that its temperature interannual variations during stratified seasons were controlled by both the previous winter temperature and abnormal warming/cooling due to total oceanic advection, and the winter (mid-January to March) temperature anomaly was the primary factor in determining the interannual variability of temperature anomaly near bottom cold pool region during the stratified seasons*." in lines 45-49 in the revised manuscript.

In terms of the factors determine the strength of the INCWM in this study, we calculated the correlation coefficients between the average temperature of the INCWM in July and the water temperatures at all the depths of each station from 1994 to 2015 for each month (from previous December to July). As shown in Fig. 5 in the revised manuscript, the water temperature of INCWM in July is not significantly related to winter well-mixed water temperatures and so is the summer SST. So, we could not use them to determine the strength of the INCWM. This also demonstrated the difference in control factors between INCWM and other bottom cold water masses (the Yellow Sea Cold Water Mass and the Middle Atlantic Bight Cold Pool).

74: make sure that you avoid double brackets ")(".

Thank and we have rewritten the sentence to avoid double brackets in the first paragraph in Section 2.1.

94-96: This measure certainly depends on the position of the transect relative to the cold water pool. Therefore, it is not a suitable measure. Also temperature itself is not a good measure, because it is too site-specific. Temperatures differences between surface and bottom need to be involved. A better measure would for example be the thermal contribution of the potential energy anomaly, integrated over an entire bay. Or you could use the thermal contribution to the Available Potential Energy (APE) of the bay. This can easily be calculated by means of a numerical model. Measurements can be used to reconstruct this as well, when some assumptions about the geometry of the cold pool are made. The measure could be converted into a mixing time scale by division by the kinetic energy supply through tides and wind (plus/minus surface buoyancy flux contributions).

Thanks for your comments. As mentioned before, the measure in this study across the central area of INCWM. Although there is only a vertical transection, it is the best measured data for analyzing the long-term variation of INCWM at present. We add description about the seasonal temperature difference between surface and bottom in the revised manuscript (Fig. 3).

This is the first time to explore the interannual variation of INCWM using long-term regular observation data. In this study, we focus on showing the interannual variation of INCWM and preliminary discuss its influence factor. As you said, more stations and observed hydrological parameters are needed to clarify detail dynamic mechanism controlling interannual variation of INCWM. On the basis of this work, we plan to perform more detailed observations and model simulations in the future to deeply study the dynamic mechanism, your suggestions give us many helps.

96: With the two indices you probably mean the transect area and the temperature.

The two indices are the averaged water temperature inside the INCWM and the area of INCWM along the observational transect. For better reading, we changed the sentence as "the intensity of the INCWM was defined by two indices, i.e., the spatially averaged water temperature inside the INCWM and the area of INCWM along the observational transect.". And move the description from Section 2.1 to Section 3.1.

100: This measure is highly empirical and not physically based, see above.

Kindly, the prefectural fishery research centers carried out regular hydrographic observations at monthly intervals in the Seto Inland Sea (stations are shown in Fig. 1) to monitor hydrological conditions and fishery resources. The stations are designed based on both physical oceanography and fishery distribution. High primary production and abundant fishery resources usually occurs where the cold water mass locates in many coastal seas (Yoon et al., 2000; Narváez et al., 2015; Abe et al., 2015; Coakley et al., 2016). As shown in Fig. 1 and Fig. 2 in the revised manuscript, the long-term observation transection (from Sta. 1 to Sta. 7) across the interior of INCWM and could present the temporal and spatial variation of INCWM well. The observation data is the best field survey data we can find to analyze the variation of INCWM although it just shows the vertical structure of INCWM.

References:

Abe K, Tsujino M, Nakagawa N, et al. Characteristic of Si: P: N ratio in bottom water in central Suo-Nada, western Seto Inland Sea. Journal of oceanography, 2015, 71(1): 53-63.

Coakley S J, Miles T, Kohut J, et al. Interannual variability and trends in the Middle Atlantic Bight cold pool//OCEANS 2016 MTS/IEEE Monterey. IEEE, 2016: 1-6.

Narváez D A, Munroe D M, Hofmann E E, et al. Long-term dynamics in Atlantic surfclam (Spisula solidissima) populations: the role of bottom water temperature. Journal of Marine Systems, 2015, 141: 136-148.

Yoon W D, Cho S H, Lim D, et al. Spatial distribution of Euphausia pacifica (Euphausiacea: crustacea) in the Yellow Sea. Journal of Plankton Research, 2000, 22(5): 939-949.

115-117: The model is forced by some kind of climatological wind, which leads to underestimation of the wind-energy input and mixing. The method for calculating the surface buoyancy flux is not mentioned. Since the wind is climatological, the reviewer can assume that also the buoyancy fluxes are idealised. Also, no information is given about open boundary conditions and riverine freshwater forcing. For an investigations like this one, is would be state of the art to apply a model with realistic forcing. Some information on the surface buoyancy forcing is given in lines 146-151, and it seems indeed that this forcing is climatological as well.

The following sections include some interesting discussions, but since the study is based on a highly site-specific empirical measure for the size of the cold pool and the numerical model is highly idealised, I propose that the authors do first improve their methods according to the above suggestions and then repeat the study.

Thank for your comment.

We actually use climatological forcing in numerical model rather than realistic forcing. The detailed model configurations have added in the first paragraph in Section 2.2.

"*Four major tidal constituents (M2, S2, O1 and K1) at the open boundary were considered and the daily river discharges averaged over 24 years (1993–2016) from the Ministry of Land, Infrastructure and Transport were used in the model. Multi-year averaged daily surface fluxes of momentum, heat and fresh water was used to drive model (Zhu et al., 2019). The daily wind stress was based on hourly averaged results of wind stress, which was calculated by wind velocity from the Grid Point Value of Meso-Scale Model (GPV-MSM) (http:// database.rish.kyoto-u.ac.jp/arch/jmadata/data/gpv/) during 2007–2016 provided by the Japan Meteorological Agency with the resolution of 1/16°×1/20°, adopting the drag coefficient of Large and Pond (1981). The daily shortwave radiation was based on the newly released of Japanese Ocean Flux Data Sets with Use of Remote Sensing Observation (J-OFURO3) (https://j-ofuro.scc.u-tokai.ac.jp/) with a resolution of 1/4°×1/4° and averaged during 2002 to 2013. The daily longwave, sensible heat flux and latent heat flux were calculated and averaged by adopting bulk formula (Gill, 1982) using hourly air temperature, sea surface temperature, relative humidity, cloud cover, and wind velocity from the GPV-MSM (2007–2016). Daily evaporation was obtained by calculating the latent heat flux. The daily precipitation was provided by the GPV-MSM and averaged hourly from 2007 to 2016*"
The seasonal variation is shown in below figure.

The information in lines 146-151 in the old manuscript is about the dataset JRA55 which has been removed in the new manuscript.

Kindly, we first demonstrated the interannual variation of INCWM and explored its influencing factor in the study using long-term observation and a numerical model.

We are the first time to explore the interannual variation of INCWM and its influence factors. Model driving by climatological forcing could capture the evolution of INCWM and it can be competent to discuss the response of INCWM to air-sea heat flux changes by sensitivity numerical experiments. Based on this work, we plan to conduct a continuous run with realist forcing to detailly explore dynamic mechanism controlling the interannual variation of INCWM. We show the shortcoming of the work and future plans in the last paragraph in Section 5.

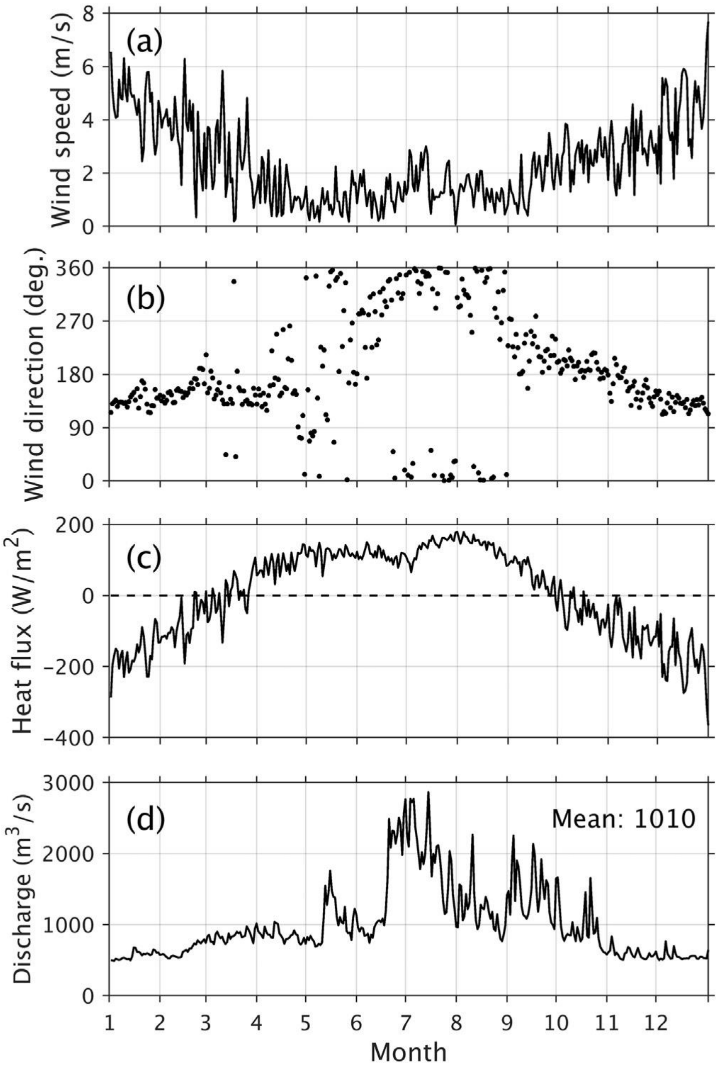

Fig. 3. Daily variations in multi-year averaged (a) wind speed, (b) wind direction, (c) air-sea heat flux, and (d) river discharges used in case Control. The wind direction in (b) is clockwise and the direction of southerly wind is 0. Positive values in (c) indicate that the ocean gains heat, while negative values indicate the opposite situation. (from Zhu et al., 2019)